SOCIO-EMOTIONAL EXPERIENCES OF MOBILITY-IMPAIRED INDIVIDUALS

Introducing Design Principles in Wheelchair Development

A Ph.D. Thesis in the Individualized Program
(INDI)

Presented in Partial Fulfilment of the Requirements
for the Degree of Doctor of Philosophy (Individualized Program in Fine Arts) at
Concordia University
Montreal, Quebec, Canada

July 2025

CONCORDIA UNIVERSITY
School of Graduate Studies

This is to certify that the thesis prepared

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Entitled: **Socio-Emotional Experiences of Mobility-Impaired Individuals: Introducing Design Principles in Wheelchair Development**

and submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY (Individualized Program in Fine Arts)

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ABSTRACT

Socio-Emotional Experiences of Mobility-Impaired Individuals: Introducing Design Principles in Wheelchair Development

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Among the challenges individuals with mobility issues, such as wheelchair users, face—physical accessibility, being one—their socio-emotional needs, which are latent and shaped by interconnected underlying factors, have been less explored and addressed. These factors collectively influence the socio-emotional experience of wheelchair users. Existing research typically examines these needs from a single disciplinary perspective, such as sociology, psychology, or engineering, with a focus on urban navigation. However, studies rarely integrate the social and psychosocial needs of wheelchair users into the engineering and design process, whether for the environmental needs or the wheelchair design itself.

To address this gap, this thesis aims to introduce socio-emotional design principles through an interdisciplinary approach. Achieving socio-emotional design principles require a holistic perspective that incorporates descriptive semantic concepts, as well as environmental, cultural, socio-psychological, and aesthetic dimensions, to ensure the design meets users' socio-emotional needs, promotes inclusivity, and fosters positive social perceptions.

Based on the research's overarching objectives, this manuscript is organized into five chapters and ten sections. After elaborating on the problem statement and providing a general framework for understanding the wheelchair users' experience, this research initially introduces the interdisciplinary theoretical framework, consisting of three axes and two grounding layers, to ensure a comprehensive approach to wheelchair users. Then it explores and tracks the socio-emotional dynamics of wheelchair users, highlighting the relevant factors that influence their interactions and the impact of these factors on their experiences. Third, the research explores how wheelchair design influences users' socio-emotional interactions, focusing on two key layers: the external human-machine interface for safety and communication, addressing practical needs, and the socio-emotional aspects of design, supporting psychological well-being. Finally, regarding the review and empirical studies introduce ten socio-emotional design principles, along with one consideration, under the proposed interdisciplinary framework. Additionally, design concepts are introduced to demonstrate how these principles can be applied in practice. Overall, this research advances disability studies by advocating inclusive strategies to improve the social experiences of individuals with mobility challenges. It also establishes a framework for designing advanced mobility aids, contributing to the fields of engineering and industrial design.

ACKNOWLEDGEMENTS

As I reflect on the path that brought me here, I am filled with immense gratitude. This journey, shaped by both challenges and triumphs, would not have been possible without the love, support, and guidance of those around me. To all who have walked with me, this acknowledgment is for you.

First and foremost, my deepest gratitude flows to my parents, Gholamreza Rasoulivalajoozi and Soghra Mosaddegh, and to my entire family, whose unwavering love and support have been the bedrock of my journey. Through every challenge—across the long road from Iran to the Netherlands, and then to Canada—you have been my strength and my refuge. In every dark moment, you reminded me that I am never alone, and your light has never ceased to shine, guiding me forward. I am honored to share this accomplishment with you, for it is as much yours as it is mine.

I would like to express my sincere gratitude to my primary supervisors, Dr. Carmela Cucuzzella and Dr. Linda Dyer. Dr. Cucuzzella, your trust in me to embark on this PhD journey was a gift I will forever cherish. Dr. Dyer, your steady support, especially in the most challenging of times, has been a constant source of strength, helping me persevere when I could not see the way forward. Your guidance has been invaluable, and I will always remember your kindness. I am equally grateful to Dr. Tsz-Ho Kwok, a member of my co-supervisory committee, whose wisdom, insight, and unwavering support have broadened my perspectives and enriched my research. Dr. Kwak, your patience, counsel, and infectious enthusiasm have made this journey unforgettable. The lessons I have learned from you will continue to guide me throughout my career, and I will carry them with me always.

To my dear friends, Dr. Ghada Touir and Mr. Morteza Farhoudi, my sincere thanks for your invaluable feedback and unwavering support. Dr. Touir, you have been a constant source of kindness, always ready to help without hesitation. Morteza, you stood by my side through every step, listening with patience and offering companionship, making this journey far less lonely than it might have been. I am also deeply grateful for the generous support provided by Ideas-Be (Concordia University Research Chair in Integrated Design, Ecology and Sustainability for the Built Environment), Concordia University, the Individualized Program, and LEAP (Laboratoire d'Étude de l'Architecture Potentielle). Without their assistance, this work would not have been possible.

Lastly, I extend my gratitude to my dear friends—Armaghan Nejatian Ahadi, Morteza Hazbei, and Mohammad Abdalreza Zadeh—whose support and friendship have been invaluable. Thank you for being steadfast companions in this academic journey. And to Darlene Dubiel, your consistent support and assistance have been a quiet but powerful force throughout my time in the program, for which I am deeply thankful.

Dedication

To my parents and all my family members,
Your unwavering love, sacrifice, and support have been the bedrock of my journey. Thank you for instilling in me the values of perseverance, curiosity, and compassion. This achievement is as much yours as it is mine. Your belief in me has been a constant source of strength, and I am forever grateful for everything you have done.
With all my love and gratitude.

Mohsen Rasoulivalajoozi

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STATEMENT OF CONTRIBUTION

This thesis includes material that I (Mohsen Rasoulivalajoozi, the thesis author) have either written or co-written. The Introduction and Conclusion chapters (Ch. I and V) were exclusively authored by me, with guidance from my thesis advisors, Dr. Carmela Cucuzzella and Dr. Linda Dyer. These chapters were not intended for publication. The remainder of the thesis consists of three chapters (II, III, and IV) based on eight manuscripts that were written with the intention of being published, including:

I am the first and corresponding author on all the manuscripts—five have been published, and one is currently under review. It's worth noting that this thesis does not include some papers published during my PhD. However, the following list highlights contributions from my PhD coursework, which provided foundational knowledge for this thesis.

Cucuzzella, C., **Rasoulivalajoozi, M.** & Farzamfar, G. (2024). Spatial experience of cancer inpatients in the oncology wards: A qualitative study in visual design aspects. European Journal of Oncology Nursing, 102552. https://doi.org/10.1016/j.ejon.2024.102552

Rasoulivalajoozi, M., Rasouli, M., Cucuzzella, C. & Kwok, T. H. (2023). Prevalence of musculoskeletal disorders and postural analysis of beekeepers. International Journal of Industrial Ergonomics, 98, 103504. https://doi.org/10.1016/j.ergon.2023.103504

Rasoulivalajoozi, M. & Touir, G. (2023). Spinal fusion surgery for high-risk patients: A review of hospitals information. Social Determinants of Health, 9, 1–12. https://doi.org/10.22037/sdh.v9i1.39958

In all the manuscripts included in this thesis, I (Mohsen Rasoulivalajoozi) played a central role as the lead author, first author (or co-first author), and corresponding author. This indicates that I was primarily responsible for designing the study, conducting the literature review, developing the theoretical and methodological frameworks, collecting and analyzing data, and drafting, submitting, and revising the manuscripts.

Throughout the research process, my committee members, whether they were co-authors or not, provided valuable guidance and feedback, including on manuscript drafts. Other co-authors contributed to the manuscripts in varying capacities.

Declaration of Generative AI and AI-assisted technologies in the writing process:
Declaration of Generative AI and AI-assisted technologies in the writing process: During the preparation of this thesis, the author used ChatGPT OpenAI to improve the writing. After using these tools, the author reviewed and edited the content as needed and took full responsibility for the content of the published thesis.

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List of Acronyms: The following acronyms are used throughout this thesis.

WUs: Wheelchair Users
MAs: Mobility Aids
PWs: Powered Wheelchairs
MWs: Manual Wheelchairs
CMW: Conventional Manual Wheelchair
CMW: Conventional Manual Wheelchair
CPW: Conventional Powered Wheelchair
AMW: Advanced Manual Wheelchair
APW: Advanced Powered Wheelchair
AHP: Analytic Hierarchy Process
DPs: Design Principles
SEDPs: Socio-Emotional Design Principles
eHMI: External Human-Machine Interface
DAE: Dynamics of Affective Experience
KE: Kansei Engineering
PCA: Principal Components Analysis
WDCs: Wheelchair Design Characteristics

Glossary

Mobility aids: Devices that assist with movement, like wheelchairs or walkers.
Design Principle: Key guidelines used in product creation for aesthetic value, functionality and usability.
Socio-emotional experiences: Emotional and social responses influenced by interactions and surroundings.
Kansei Engineering: A method linking emotions to product design to improve user experience.
Wheelchair Design Characteristic: Aesthetic and stylish features of a wheelchair that impact users and peoples' perceptions.
Principal Components Analysis: A method for reducing data complexity by identifying key variables.
Positive feedback loop: A process where an outcome amplifies its cause.
Dynamics of Affective Experience: The changing patterns of emotional responses over time in a given context.
Semantic turn: The semantic turn signifies a shift in design from focusing on function to emphasizing the meaning artifacts hold for those impacted by them.

In this dissertation, the term **wheelchair users** are occasionally abbreviated as **WUs** solely for the purpose of improving readability and reducing repetition. This abbreviation is used with full respect for individuals who use wheelchairs and is intended to enhance clarity in distinguishing between wheelchair users and non-wheelchair users. The use of this abbreviation does not intend to depersonalize or diminish the importance of the individuals to whom it refers.

I

Introduction

Motivation & Problem Statement

1 Introduction

Wheelchairs are designed to enhance the independence, safety, and mobility of users with mobility impairments; yet sometimes their function can be influenced by users' specific view and interpretation, leading to different interactions with the wheelchair (Figure 1). It showed a man carrying his mobility-impaired mother on his back while using a wheelchair to transport her handbag (Observed by the author in the context of Iran). This is an example of a patient's unintended behavior, that raises some questions: Is there a hidden message behind using the wheelchair in this situation? Why did the man choose the risky option of carrying his mother, either knowingly or unknowingly? Many instances of such unintended behavior occur but are never reported; only the consequences are observed (Fekadu et al., 2020; Nie et al., 2024).

Figure 1. Illustration depicting a scenario in which a reluctance to use the wheelchair for patient transport was observed. © Image by Author.

In the context of using mobility aids (MAs), wheelchair users (WUs) may encounter a variety of challenges, including issues related to accessibility, user-wheelchair interactions, services, and social interactions (Ripat et al., 2018; DiGiovine et al., 2000, 2000). These challenges, in turn, influence users' perceptions and emotional reactions to these prescribed MAs, potentially leading to adverse outcomes that impact their rehabilitation (Kreutz & Taylor, 2002), emotional and social aspects in the short and long term (Barlew et al., 2013; Edberg & Persson, 2011; V. de S. P. Costa et al., 2010). In other words, this can create a detrimental positive feedback loop, where increasing social isolation, and negative self-perception and recovery amplify each other.

In this context, while product adaptability to users' physical needs significantly shapes their experiences (Soewardi & Afgani, 2019; Teodiano Freire Bastos et al., 2017), initial perceptions and attitudes toward MAs may stem from broader societal biases and stereotypes associated with disabilities (Barker et al., 2004; Ripat et al., 2018; V. de S. P. Costa et al., 2010). Social attitudes influence perceptions of the human body (Alleva et al., 2019; Ben-Tovim & Walker, 1995; Matin, 2021; K. White, 2002), reflecting broader cultural discourses (Airhihenbuwa & Phd, 1995; Ibeneme et al., 2017). This is particularly significant for MAs, which are always visible in public and become integral to users' personal and social identity (Blach Rossen et al., 2012; Rogers & Musselwhite, 2023). In some studies, indicated that long-term WUs often view their wheelchair as an extension of their body (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010). Therefore, when they use such devices in their social life, the wheelchair, as an extension of their body, shapes an aspect of their social representation. In other words, although such devices were created for WUs' mobility, their effect is beyond their physical mobility, affecting their social experiences. Here, if these aids are designed solely to address movement limitations, the concept of the WUs' body and identity as merely a mechanism for movement is reduced and reproduced.

In a social context, the interpretation of the body extends beyond just biomechanical movement. Lack of addressing social and representational aspects can reinforce the concept of body as a biomechanical organ, and perpetuate the common stereotypes about disability, such as a lack of independence and second-class citizenship. Here, as Mokdad et al. emphasized (Mokdad et al., 2018), we need to ask who should be responsible for answering the user's social experience: the designers of MAs, social attitudes toward the disabled, or both. Sociologically, abilities and disabilities are often framed in biomechanical terms related to social functionality (K. White, 2002), with MAs perceived as symbols of disability. This stigmatization can discourage users from continued use. On the other side, designers exacerbate this notion by using forms and symbols that portray the body as a disrupted mechanical function. However, they also have the opportunity to mitigate social perceptions of MAs and disability by identifying related design principles (DPs) that reduce disability-related metaphors associated with these aids. Achieving this requires a collective effort, and identifying these principles cannot be addressed solely within the field of design. It necessitates an interdisciplinary approach that integrates knowledge from sociology, design, and psychology to effectively tackle the complexities of the issue.

1.1 Design Thinking as an Interdisciplinary Approach

Due to the broad, interdisciplinary, or transdisciplinary nature of design science, this approach can readily incorporate insights from other fields to address the research problem. To this end, design thinking (Cross, 2011; Tromp et al., 2011), combined with the fields such as the sociology of health and disability and psychology, can shape an interdisciplinary approach to address the socio-emotional needs of WUs.

Design thinking is based on abductive reasoning (Cross, 2011), seeking to understand hidden signs and codes behind a challenge and provide solutions (Campos, 2011; Kapitan, 1992). This approach focuses on human-centerd thinking, collaborating with the target users to empathize, understand perspectives, define problems clearly, and generate creative ideas (Ku & Lupton, 2020). By applying such abductive reasoning, we can identify gaps in addressing WUs' social needs and help prevent unintended behaviors arising from negative socio-emotional experiences. Accordingly, the empirical question is: can these often-overlooked design opportunities in MAs serve as an untapped source for shaping positive socio-emotional perceptions and behaviors in daily life? By employing design thinking and decoding social metaphors, a set of DPs can shape the external representation of assistive devices, influencing societal perceptions of individuals with mobility disabilities and making a positive semantic turn in this context.

Fu. et al. (2016), define a principle as "*a fundamental rule or law, derived inductively from extensive experience and/or empirical evidence, which provides design process guidance to increase the likelihood of reaching a successful solution*." They emphasize that DPs are essential for describing and characterizing both the design and its associated processes. The DPs act as a middle ground between generalizable, replicable scientific approaches and practical experiences encountered in practice. Because DPs require interpretation, they are not as easily falsifiable as scientific laws (Bell et al., 2004).

On the other side, to enhance the effectiveness of DPs, and highlight an interdisciplinary lens, it is essential to identify and address the socio-emotional latent needs of WUs. Latent needs are unmet needs that WUs may not explicitly recognize, or express and which current products or services do not address (Raviselvam et al., 2019). For example, WUs might experience various negative emotions in their daily social lives, which they may overlook due to familiarity. These socio-emotional experiences shape their self-perceptions and social attitudes (Kleef & Côté, 2022). Specifically, socio-emotional experiences encompass individuals' interactions with and responses to their social environment, including emotions, relationships, and self-awareness (Mänty et al., 2020). These experiences influence how WUs perceive themselves and others, affecting their social interactions and emotional well-being (van Kleef & Lange, 2020). Therefore, to enhance social experiences and mitigate the stigma surrounding wheelchairs, a set of socio-emotional design principles (SEDPs) is required. The SEDPs will influence the meaning and interpretation of MAs in social contexts, which can, in turn, affect users' perceptions, behaviors, emotional well-being, and overall social identity. Such SEDP can be applied to wheelchairs' interfaces.

1.2 Scope and Focus of Thesis

This study aims to examine the design requirements for an efficient, social interface of wheelchairs, that can contribute to a pleasant social experience, free of negative stereotypes around disability. Indeed, we need to explore the challenges WUs face in their social and environmental contexts to identify how design interventions can enhance their social interactions and communication. Therefore, the focus is on the human factors, and DPs that are attributed to the wheelchair's body and structure, as opposed to solely addressing technical challenges. While many factors such as service design can be considered in the design intervention process, this thesis focuses on the social experience of users in time of using wheelchairs. This study centers on manual (MWs) and powered wheelchairs (PWs) as primary icons of mobility disability, affecting the social experience of users' bodies. Some sections of the thesis examine wheelchairs alongside other MAs to gain a broader understanding of users' social experiences with disability and societal perceptions.

Identifying SEDPs in the design of the wheelchair's external representation and its impact on the user's social experience is our highest priority. This issue is one of the critical arguments against external Human-Machine Interfaces (eHMI), where the social aspect and the need to address gaps in social interaction are neglected (de Winter & Dodou, 2022). Nevertheless, as eHMI in wheelchairs is crucial for communication and safety, it's important to evaluate it through human factors. Therefore, this aspect is also considered in a part of this thesis to outline the desired direction for integrating user interfaces with SEDPs. Beyond the mentioned features, environmental accessibility and spatial experience also enhance the perception of inclusivity in the WU's view, affecting Wu's experiences. Therefore, environmental factors are also considered in some sections of this thesis to understand WUs'' social experiences. On the other hand, the socio-emotional dimensions of WUs' experiences are central to this study, as social contexts directly shape perceptions of dignity, agency, and acceptance. These insights form the foundation for a holistic wheelchair design approach that is emotionally attuned and socially empowering. While addressed in a dedicated section, socio-emotional factors also inform the interpretation of findings throughout the thesis, guiding the development of SEDPs and influencing key design decisions. This research is based on three key assumptions:

a) Designing the external surface of a wheelchair can affect users' emotional perceptions and others' perspectives on disability.
b) SEDPs are not a universal solution for all wheelchair manufacturers, but they can be incorporated into designs within the constraints of engineering and production limitations.
c) The SEDPs are developed through research grounded in the social context of wheelchair use—positioning the wheelchair as one of the most recognizable and socially significant symbols of disability—and may be extendable to the design of other MAs.

1.3 Wheelchair User's Situation in a Public Setting: Finding the Variables

Achieving a negative-stereotype-free experience for WUs requires consideration of the related dynamic factors. In this study, the intended behaviors and WUs' social perception experiences—aimed at being free from negative stereotypes—are treated as dependent variables. The appearance and design of wheelchairs act as independent variables, while the SEDPs applied to wheelchair design are considered as the mediator variables. The primary aim of this study is to introduce such SEDPs as the mediator variables. Since social context (i.e., how bystanders perceive and treat the wheelchair) and environmental factors (e.g., barriers that create movement challenges) cannot be easily controlled, they are considered intervening variables. These factors and the challenges they create in wheelchair use accentuate the distinct abilities of WUs, perpetuating negative perceptions of disparity and affecting both their self-perception and how non-disabled bystanders view them. Figure 2 illustrates the variables involved in WUs' situations in a public setting.

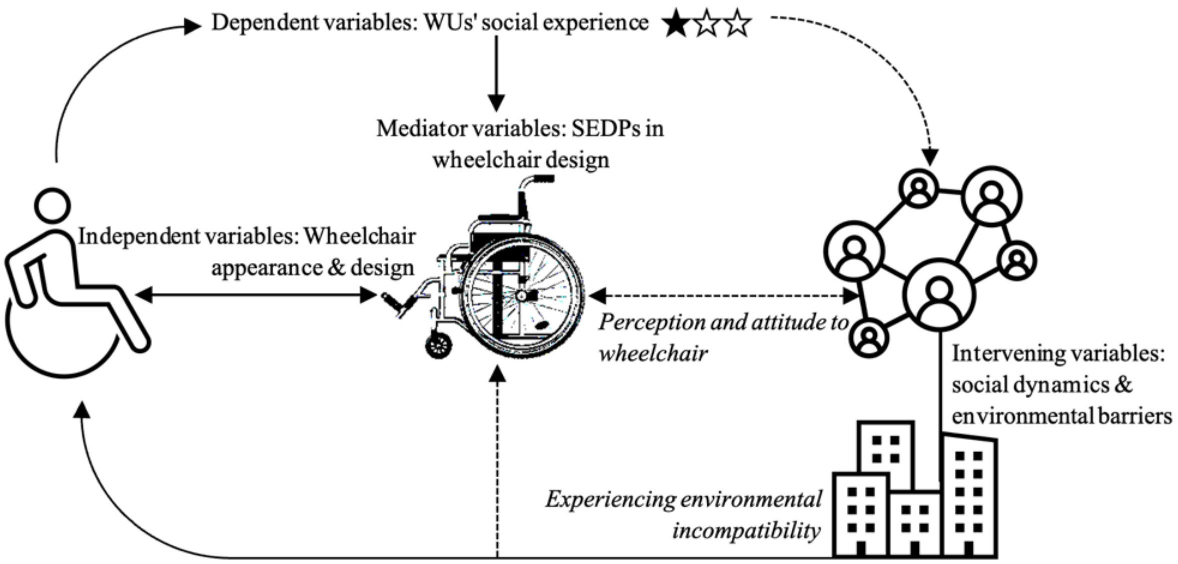

Figure 2. Variables affecting the social perception and experience of WUs. © Image by Author.

1.4 Research Aim and Questions

This thesis aims to introduce a set of SEDPs for wheelchair interfaces to mitigate negative stereotypes associated with mobility disabilities and align with the voices of WUs. Using these SEDPs, the semantic perception of wheelchairs can be redefined and redesigned, not only empowering users against social stigma but also shifting social perceptions towards greater acceptance and inclusivity. Accordingly, this study focuses on three principal objectives:

1. Defining a theoretical framework to track the reproduction of social perceptions in using MAs and identifying the domain of interventions to ensure a comfortable experience;
2. Understanding the key socio-emotional factors in interaction dynamics;
3. Discovering the visual design preferences in external communication of wheelchairs. To systematically address the objectives, a step-by-step approach is adopted.

Regarding the aim and objectives, the research questions are organized into main sections and subsections as shown in Table 1.

Table 1. Research questions.

	#	Research questions	Ch. #
Main question	**Q1**	Which SEDPs on wheelchair design contribute to the experience for WUs?	V
Sub-questions	**Q2**	How are current social perceptions of MAs shaped, and what design insights can create a more comfortable user experience?	II
	Q3	What factors influence the socio-emotional dynamics in the interactions of WUs, and how do they exert this impact?	III
	Q4	What are the users' preferred factors in wheelchair design to address the social interactions of WUs?	IV

1.5 Contributions

The four contributions of this study are:

- This study introduces an interdisciplinary theoretical framework for developing advanced mobility aids, offering not only design principles but also guidance for health policymakers and experts in disability studies to propose effective interventions that improve social engagement and overall satisfaction.
- By exploring the prerequisites socio-emotional factors in preferences of WUs, engineering, and industrial design researchers contribute to the development of wheelchairs that advance and shape both the functional communication and socio-emotional perception of wheelchair design.
- Exploring the expectations of WUs provide valuable insights for experts in design for care, helping them identify key patterns in users' social interactions with assistive devices and, consequently, create more user-friendly MAs.
- Comparing the findings with the existing literature on health behaviors contributes to developing a theoretical framework that identifies common patterns in responses and interactions. This, in turn, contributes to the body of knowledge on the sociological aspects of disability, where the influence of ableism is critically examined and challenged.
- The findings contribute to physiotherapy by establishing protocols for prescribing MAs to first-time clients. These protocols assist physiotherapists in understanding client reactions and encouraging acceptance and continued use of the device.

2 Literature Review

Given the study's interdisciplinary nature, reviewing WUs' experiences involves multiple fields. This includes environmental and engineering factors, external communications like eHMIs, emotional aspects of design and examining social perceptions and stereotypes.

2.1 Environmental and Engineering Factors in Developing WUs' Experiences

The existing literature often highlights studies focused on environmental accessibility aspects (Basiri, 2021; Hossen Sajib, 2022; Widehammar, Lidström, et al., 2019). In particular, research highlights the importance of wheelchair accessibility as a key determinant of independence, social participation, and overall inclusion in society (Sahoo & Choudhury, 2023). Additionally, previous studies highlight the importance of creating inclusive, sustainable urban transport infrastructure, implementing policies for older adults and people with disabilities, and promoting behavioural changes to improve safety and social inclusion (Jahangir et al., 2024).

In addition to environmental factors, advancements in engineering have significantly impacted WUs' interactions and rehabilitation (Ferretti et al., 2024), focusing primarily on operational aspects. For instance, motorized models such as the "TopChair," capable of climbing stairs (Heinrich, 2016), exemplify this advancement. Innovations in materials have also led to sports and recreation wheelchairs, and improved user experiences (Cooper & De Luigi, 2014). With advancements in computer programming, smart wheelchairs now incorporate various control methods such as eye-blink or eye-gaze tracking speech-based control, muscle activity control, head movement, hybrid control options, and obstacle detection (Nudra Bajantika Pradivta et al., 2019; Purwanto et al., 2009). Additionally, robotic wheelchairs utilize technologies like head or face movements commands (electrodes—electrooculographic signal (EOG)—or video oculographic (VOG) signal), blowing and sucking commands, and brain waves commands (electroencephalographic (EEG) signals) (Swee et al., 2016). Broadly, these developments fall into three categories of "smart wheelchairs," aimed at surpassing conventional limitations, "autonomous wheelchairs" offering control alternatives for individuals with limited hand control, and "robotic wheelchairs" programmed for user transport between predetermined locations (Teodiano Freire Bastos et al., 2017). Such developments are mostly investigated by the human computer interaction (HCI) community, focusing on various input devices (e.g. joysticks, head arrays), and user-centered control systems (Anwer et al., 2020; Carlson & del R. Millan, 2013; Carrington et al., 2014; Mónica Faria et al., 2013) to improve usability and users' interactional experience.

2.2 eHMIs for Improving the Environmental Safety and Communication

Studies have also explored WUs' interactions with their environment, focusing on the enhancing safety and intent communication through development of eHMI for wheelchairs. To this end, Bingqing Zhang's developed design implications, emphasizing three primary pillars: "Empathy, embodiment, and social acceptance," "Situational awareness and adaptability," and "Selective information management (B. Zhang et al., 2022). In this regard, an on-ground projection-based shared eHMI for wheelchairs with automated driving system (ADS) technology enhances motion clarity and makes the vehicle's path more understandable for users and pedestrians (X. Zhang et al., 2024). Nevertheless, they reported that WUs still feel their wheelchair attracts unwanted attention, and addressing their social needs remains a challenge.

Despite their benefits, eHMIs are criticized for solely relying on implicit communication, lacking standardization, and neglecting social aspects, which leaves gaps in social interaction (de Winter & Dodou, 2022). In addition, such developments in the operational aspects and interface may not always align with users," emotional needs and not be considered in design. For instance, an initial evaluation of existing AI-augmented wheelchairs highlighted a lack of emphasis on the aesthetic functions of mobility devices (Ito et al., 2020). Therefore, while eHMI provide safety and intent communication of WUs, it is needed to address the argument against eHMI, addressing the social interaction void that needs to be filled. It is crucial to identify which SEDPs integrated into the body of the wheelchair can impact both the user's experience and social perception.

2.3 Design for Emotions

Wheelchairs were primarily designed for physical disability. Nevertheless their overall beauty and appearance have always been important to users (Kent, 2021; Desmet & Dijkhuis, 2003). A review of wheelchairs over history reveals that aesthetics have consistently evolved, reflecting the prevailing fashion trends of each era (C. Slawson, 2019). In Figure 3, three ninth-century wheelchair styles are depicted, suggesting their differences from modern designs.

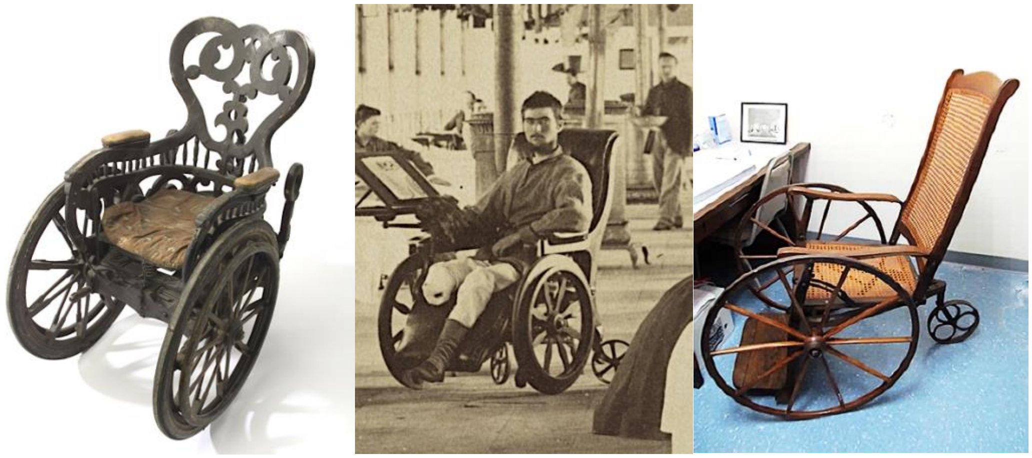

Figure 3. Three wheelchair designs throughout history.

European, c.1850-1890 (Left) (Science Museum, 2019); Patient in wheelchair, Carver Hospital (Maybe Armory Square Hospital) 1865 Courtesy of the Library of Congress (Middle) (C. Slawson, 2019); Wheelchair from the late 1860s. Courtesy of the NMCWM, Frederick, MD (Right) (Courtesy of the National Museum of Civil War Medicine, Frederick, Maryland-C. Slawson, 2019).

While various approaches to aesthetics exist in product design (Soleimani & Hossein Halimi, 2012), most wheelchairs on the market follow the "Form Follows Function" concept (Riggs, 2022) rather than addressing users' emotional needs. The previous studies recommended the aesthetic opportunities to enhance the appearance attractiveness of wheelchairs (Carneiro et al., 2017, 2018) affecting the perception of wheelchairs and emotional responses. A recent study examined how aligning PWs design with the emotional needs of elderly users affects their experience. Ultimately key emotional needs and influencing factors were emphasized and identified (A. Li et al., 2024). It is demonstrated that the design and appearance of a wheelchair evoke pairs of adjectives such as ugly/pretty, humble/sophisticated, antiquated/modern, introverted/sociable, and repulsive/attractive, among others. This suggests that a wheelchair's aesthetics function as a language that shapes attitudes. Interestingly, women tended to evaluate these aspects more negatively compared to men in the study (Lanutti et al., 2015), suggesting that aesthetic impressions may vary by gender.

Studies also suggested that assistive devices featuring modern aesthetics, free of negative symbolism, are more positively accepted by users compared to those with traditional aesthetics (C. Slawson, 2019; Ito et al., 2020; Soleimani & Hossein Halimi, 2012). Therefore, as studies emphasized (Lanutti et al., 2015; Dos Santos et al., 2022), considering aesthetics and user perceptions of wheelchair design is crucial for enhancing the acceptance and integration of users as active citizens within their communities Nevertheless, to date, there have been limited studies introducing SEDPs based on WUs' social experiences and the resulting emotions.

2.4 Social Perceptions and Stereotypes

Users' perceptions of wheelchairs are continually shaped by social stereotypes and interactions (Barlew et al., 2013; Edberg & Persson, 2011; V. de S. P. Costa et al., 2010). People often claim not to hold assumptions about individuals with disabilities socially (Lenney & Sercombe, 2002), however, despite increased awareness of the social needs of individuals with mobility disabilities, a recent study revealed that WUs continue to face societal stigma, correlating with higher levels of depression and feelings of pity, and discomfort (A. Li et al., 2024). In one of the examples, it was revealed that there is a higher level of social stigma associated with the product in the UK compared to Pakistan (Asghar et al., 2020). These studies draw our attention to how cultural attitudes, racial biases, and systemic class inequalities shape public perceptions and emotional responses toward WUs. The intersection of race, class, and culture plays a critical role in shaping perceptions, disparities, and accessibility across global contexts (Lindsay et al., 2022). Although, perceptions of social identity are also strongly influenced by personal beliefs, affecting WUs (Galli et al., 2015), other factors, such as mobility level, employment status, personal well-being, level of low-income (Fredericks et al., 2024; Pasin & Karatekin, 2024) were key determinants of social participation for people with disabilities. Other factors that reduce social participation include being female, unemployed, and having mobility limitations (Pasin & Karatekin, 2024).

WUs expressed that they experienced feeling humiliation, frustration, and loss in their interactions (Barlew et al., 2013). Studies showed that WUs considered the wheelchair as an extension section of their body (Blach Rossen et al., 2012) and it is considered a symbol of disability and incapacity (Papadimitriou, 2008; V. de S. P. Costa et al., 2010). Particularly women, frequently experience negative emotions such as hatred, disgust, contempt, disappointment, anger, and regret (Mokdad et al., 2018). Therefore, WUs, due to the continued use of wheelchairs as an icon of disability, are deeply affected by social interpretations of wheelchairs. Establishing SEDPs can play a role in reshaping and redefining the meaning associated with wheelchairs, reshaping these perceptions. To the best of our knowledge, no study has explored reflecting WUs' socio-emotional aspects in wheelchair design. Although there is growing interest in the social dimension of WUs, research on incorporating social aspects into wheelchair development remains relatively new, and the research community has yet to establish clear methods for translating these social concepts into design improvements. To address this, it is essential to review and explore the relationships between key concepts of interaction design, design for behavior, user experiences, and wheelchair comfort, as outlined in the next section.

3 **Theoretical Framework: The Key Concepts**

This section considers the various aspects of user-wheelchair interactions and justifies the necessity and implementation of various aspects of an interdisciplinary approach to providing SEDPs. To this end, Key concepts crucial for understanding WUs' perceptions and experiences—including interaction design, design for behavior, wheelchair experiences, and design for comfort—are presented. The interconnections among these concepts are also demonstrated.

3.1 Interaction Design in Wheelchair Developments

The interaction design's primary objective is to develop products that facilitate and support users in achieving their objectives most effectively (Sharp et al., 2019). This interdisciplinary approach also considers users' needs, limitations, and contexts, enabling designers to tailor the output to specific user demands (Sharp et al., 2019; Siang, 2020). Interaction design and users experience (UX) design have significant overlap; while interaction design focuses on the interaction between the user and the product, UX design encompasses more, including user research, creating personas, and conducting testing to shape the overall product experience (Siang, 2020). Generally, interaction design falls under the broader category of UX design and focuses on shaping the interaction between users and products (Desmet & Hekkert, 2007).

In fact, interaction with a product is the first step in encountering a product. Siang introduces five dimensions of interaction design (Siang, 2020): 1) Words: providing clear, meaningful information, 2) Visual Elements: graphics and typography complementing the text, 3) Physical Objects or Space: the physical aspect users interact with, 4) Time: the duration of engagement, and 5) Behavior: how users operate the product. Behavior also considers how the preceding dimensions shape the product's interactions, involving user and product reactions, such as emotional responses or feedback.

In this thesis, interaction aspects refer to elements involved when users engage with their wheelchairs, from initial use to long-term. Therefore, reviewing the first four dimensions that influence user behavior, with a focus on identifying psychological feedback related to design, is essential for shaping user-wheelchair interactions.

3.2 Role of Design in Shaping WUs' Behaviors

Herbert Simon states that design involves shaping courses of action to transition existing situations into preferred ones (Simon, 1996) and it is not limited to physical attributes but extends to the deliberate intention of influencing user behaviors. This idea aligns with Redström's argument (Redström, 2006) that all design inherently aims to impact user behavior by embedding socially constructed "scripts" within artifacts (Akrich, 1992). For instance, positioning a chair at a workstation is a subtle way of encouraging a user to "follow the script" and take a seat (Lockton et al., 2010). However, alignment between designers' intentions and actual user behavior is not always seamless since products are used within various contexts influenced by various users' intentions (e.g., emergent behaviors, intuitive responses, and experiences) (Blackler et al., 2010; Chamorro-Koc et al., 2009). Here, Stanton and Baber (Stanton & Baber, 1998) emphasize the reciprocal relationship between consumer behavior and products, noting that "*consumer behavior is shaped by products as much as products are shaped by consumer behavior*." This concept aligns with the notion of behavior-steering design, which originated from a sociological context (Verbeek & Slob, 2006). A common aspect in these interdisciplinary discussions is the strategic nature of design, which explicitly aims to elicit specific user behaviors, highlighting the designer's intent (Lockton et al., 2008b).

The Design with Intent method aims to bridge this gap by offering practical design interventions to influence various behaviors and providing examples of solutions from other contexts (Lockton et al., 2010). It defines "Design with Intent" (DwI) as "design explicitly intended to influence or achieve specific user behaviors" (Lockton et al., 2008a). But, if users engage with the product in an unintended or incorrect way, it can pose risks. For example, in fields like security or health and safety, adherence to intended behavior is essential (Cairns, 2013), and in safety-critical systems like medical monitors, the cost of failure is unacceptable. Similarly, as illustrated by the user-wheelchair interaction in the initial anecdote, unintended behaviors—such as improper interaction between a user and a wheelchair—may pose long-term risks.

In wheelchair development, it is essential to minimize the risk of unwanted or incorrect behaviors and align them with the wheelchair's primary goal, enhancing user mobility. Such principles typically affect users after the initial interaction phase. In this thesis, the behavior of WUs is examined through a visual lens, which integrates concepts from product semantics, semiotics, ecological psychology, and Gestalt psychology in wheelchair design. This lens is one of the six introduced by Lockton et al. in the *Design with Intent Method*, which can influence user behavior (Lockton et al., 2010).

3.3 Wheelchair Experience

The interactions play a crucial role in shaping the overall experience of using a wheelchair, impacting outcomes, and evoking emotional responses (Schifferstein & Hekkert, 2007). The experience not only emerges from the interactions but also accompanies and directs it, impacting the interaction's outcome and evoking emotional responses. Therefore, product experience extends beyond physical interactions to include passive perception, memory, thought, and anticipation. To examine wheelchair experiences, a comprehensive approach is essential considering all aspects influencing users' interactions, comfort, and expectations. To this end, Schifferstein and Hekkert's human-product experience framework, widely used in industrial design, offers valuable insights (Schifferstein & Hekkert, 2007). This framework encompasses subjective interactions with products—wheelchair—, including physical and non-physical designs, while excluding art. It also highlights the psychological effects of human-product interaction, such as sensory stimulation, attached meanings, and emotions. The three primary components of this framework are Aesthetic Response, Operational Understanding, and Expressive and Symbolic Meaning. Combining these three aspects shapes the emotional evaluation of user's experience (Desmet & Hekkert, 2007; Hekkert & Leder, 2008). *Aesthetic Response:* Characterized by feelings of (dis) pleasure based on sensory perception; for example, the wheelchair may look futuristic and beautiful, feel pleasurable, or sound nice to employ it in daily routine. *Operational Understanding*: Involves how people understand the operation of a product and what actions it affords. In wheelchair design, this primarily addresses expected functions. *Expressive and Symbolic Meaning:* Pertains to the meanings attributed to the product, including expressive, semantic, symbolic, or other connotative meanings. When artifacts are placed in a specific environment and context, they take on identifiable roles and meanings (Krippendorff & Butter, 2008). As further details on wheelchair experiences are required, this topic will be explored in greater depth within the next Ch. II, Section 3 of this thesis.

3.4 Comfortable Wheelchair Experience

The experiences of using a product (e.g., a wheelchair) create a comfortable or discomforting perception, affecting the user's expectations, and subsequently impact their next interaction with the product. The concept of comfort does not have a universally agreed-upon definition (Vink & De looze, 2008). Nevertheless, existing literature on comfort generally aligns on three key points: 1) comfort is a subjective construct that varies individually, 2) it is influenced by factors of different natures (physical, physiological, and psychological), and 3) comfort is a response to the environment (Vink & De looze, 2008; de Looze et al., 2003).

While engineering solutions may alleviate discomfort, they do not necessarily guarantee comfort for users. A lack of comfort can disrupt the flow of use and diminish users' willingness to continue using the product. Achieving optimal comfort for products like wheelchairs demands a meticulous approach, which involves examining the social, environmental, and physical layers that dynamically shape the experiences of WUs. Developing an initial understanding of how the interplay between discomfort—driven by engineering factors—and comfort—shaped by socio-emotional factors—impacts WUs' feedback is essential. This interplay likely evolves through users' experiences with wheelchairs, subsequently influencing their future interactions with mobility aids. Accordingly, we have dedicated the Section 3 in Ch., III to exploring the connections among these layers.

Based on the issues discussed on experience, interaction, and behavioral aspects, it appears there is a cyclical relationship between interaction, behavior, experience, and comfort (Figure 4). Applying SEDPs in wheelchair design can significantly enhance the social experience of WUs within this cycle.

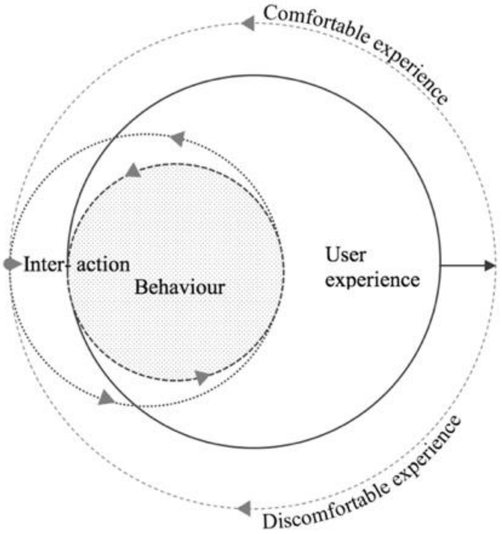

Figure 4. The cyclical interconnection between the concepts of behavior, interaction, and experience in the design process. © Image by Author.

4 Research Methodology

This section reviews the main aspects of the methodology, including strategies and approaches, as well as data collection and analysis.

4.1 Research Strategies

Design Strategy: In design strategy literature, handfuls of progressive design thinking frameworks have been introduced for selecting strategic design options (P. Jones, 2013). Richard Buchanan presented four positions designers use to create integrated design strategies for various design targets: “Symbolic and visual communications,” “Artifacts and material objects,” “Activities and organized services,” and “Complex systems and environments” (Buchanan, 1992). Garry VanPatter and Elizabeth Pastor also introduced four design geography, Designs 1.0 to 4.0, representing the evolution of design practice, research, and education to manage increasing complexity (P. H. Jones & VanPatter, 2009). These four stages represent design processes for different contexts are:

1. Traditional craft design process: this includes traditional design practice or design as making led by a designer with ingenuity and experience (e.g., consumer and institutional products, brands and identities, patient literature).
2. Industrial and interactive products design: design for value creation, including service design, holistic product innovation, multichannel, and user experience, or design as integrating.
3. Organizational level, transformation design (complex, bounded by business or strategy): design for transforming work practices, strategies, business system design, and organizational structures.
4. Social transformation (complex, unbounded): design for transforming social systems, social innovation Multistakeholder networks, health policies, and communities (P. H. Jones & VanPatter, 2009). Unique skills and methods are applicable in each domain, transferable upward but not downward as problem complexity increases from Designs 1.0 to 4.0 (P. Jones, 2013; P. H. Jones & VanPatter, 2009).

As this study aims to alter perceptions of wheelchairs as symbols of mobility disability, SEDPs focus on the tangible aspects of WUs’ experiences, categorized in domain 2.0. Focusing on these aspects (2.0.) is an initial step toward achieving organizational and social transformation (3.0 and 4.0). To this end, a bottom-up approach was adopted in this research. It means we need to identify experiential challenges, particularly the social aspects, and explore metaphors that shape WUs’ perceptions. Then we can identify which tangible elements can reproduce these metaphors to influence such perceptions. Subsequently, I introduce SEDPs as interventions that align with social metaphors and address feasibility aspects.

4.2 Research Approach

Given that this interdisciplinary study spans multiple disciplines, a mix of qualitative and quantitative methods has been employed. Qualitative methods were used to explore social dynamics in WUs' experiences, while quantitative methods were applied to evaluate WUs' emotional responses and translate these into tangible interventions. Combining qualitative and quantitative methods enhances the reliability and validity of research findings by cross-verifying results from multiple data sources, ensuring that conclusions are robust and well supported. This approach addresses both the "how" and "what" aspects of research questions. Mixed methods also provide flexibility, allowing for adaptation to new findings throughout the study, which is particularly valuable in complex, interdisciplinary research.

4.3 Data Collection: Considerations

Methodologies designed for research with WUs should help bridge the inevitable discrepancies between researchers and users (Råheim et al., 2016). Methodologies are designed to ensure that both researchers' observations and interpretations are balanced with WUs expressions of their ideas, opinions, and experiences. This balance helps achieve "dialogic symmetry," which leads to a more accurate and comprehensive understanding of WUs' experiences (Shaw et al., 2024). To achieve this, we require recognizing WUs' preferred forms of communication, acknowledging their diverse capabilities, and respecting their priorities, which may differ from those of researchers and designers (Canadian Transportation Agency, 2020; Flamm, 2023). Chapters requiring a qualitative research approach involve methods like interviews, co-design, observations, and creative workshops with WUs (Han et al., 2024; Ku & Lupton, 2020; Shaw et al., 2024). For chapters utilizing a quantitative approach, data is collected through questionnaires and surveys.

Given that WUs are often considered vulnerable groups, it is important to consider their participation with high ethical sensitivity. To this end, while carefully addressing ethical concerns, survey methods and focus group discussions with both WUs and non-WUs are applied. In some conditions, not all techniques may be suitable for capturing the voices of WUs. Therefore, alternative methods or mediators are needed to effectively capture the WUs' extended socio-emotional experiences. For instance, physiotherapists, as mediators, who have long-term involvement in the rehabilitation processes of MAs users are recruited as participants for in-depth interviews. Their close connection and holistic view in understanding the WUs' challenges provide objective and valuable insights into users' perceptions across various aspects, facilitating a discussion on how different MA designs impact users' inclusivity.

4.4 Data Analyses

Based on the research methods of each study, the appropriate analysis method is adopted. For qualitative research methods, the thematic analysis is used. In contrast, for quantitative research methods, a range of statistical tests such as Wilcoxon, Chi-square, correlation, and Principal Components Analysis are applied. The thematic analysis illustrates the main themes as a result of qualitative studies, while the statistical tests present the significant relations and differences between relevant variables. In addition, relevant theoretical frameworks are adopted for each study included in every chapter, to interpret the results.

4.5 Ethical Considerations

In this study, ethical considerations are prioritized, even if this necessitates omitting certain aspects of the study and acknowledging the resulting limitations and impacts on the analysis. In all chapters and sections involving human participation in the research process, ethical approval was obtained from Concordia's Research Ethics Committee.

5 Limitations and Future Studies

Like all studies, this research faces constraints that may affect its validity, generalizability, or interpretation. Future studies are expected to address these limitations.

Prototyping: This project does not aim to create the “ideal” wheelchair but seeks insights into design aspects that influence behavior and enhance social experiences, contributing to ideal future designs. Thus, apart from the eHMI section, no prototypes were presented. Creating a prototype wheelchair and testing it in real-life settings, based on these DPs, will require extensive investigations in future studies—whether longitudinal or cross-sectional. Therefore, due to time and resource constraints, creating physical prototypes from conceptual designs is not feasible. Future studies will involve gathering feedback from WUs to refine and develop the interdisciplinary framework.

Collaborating with design teams: The results of this study have not yet been applied by different design teams for developing wheelchairs. Future studies could focus on collaborating with various design teams to examine how they use the SEDPs in their design procedure, assessing their output and critical perspectives.

Assessing SEDPs in various sociocultural contexts: Given the challenges of recruiting WUs and ensuring their active participation across a range of studies, this research incorporates diverse social contexts where WUs can share their insights or complete questionnaires in both empirical and experimental investigations. Accordingly, participants were recruited from Iran and Canada. Since different cultures and social contexts may treat disability differently, future studies can assess the wheelchairs designed based on SEDPs in diverse sociocultural contexts.

New technologies: Although as part of this study, I introduce an eHMI for wheelchairs, it is applicable only with current PWs, and manual wheelchairs (MWs) are excluded. This study does not consider the newer, more expensive wheelchairs with automated driving system (ADS). Thus, future research can investigate how integrating SEDPs with ADS or artificial intelligence technologies.

6 Thesis Outline and Timetable

Ch. I: Introduction and Motivations: This chapter outlines the context and research problem. It covers the thesis scope and focus, presents the research questions, reviews the literature, and discusses theoretical aspects. Additionally, it provides the research outlines for the thesis, as shown in (Figure 5).

Ch. II: Interdisciplinary Theoretical Framework: This chapter presents the interdisciplinary theoretical foundation's foundation, exploring the sociological perspective of mobility disability and analyzing how their comfortable experiences can be classified. This framework aims to illustrate the intricate relationship between the social aspects influencing users and the design factors contributing to their comfort. This framework serves as the foundation for analyzing and refining SEDPs in wheelchair development and user interactions. Accordingly, we outline three studies in Ch. II, each addressing key aspects of the research.

Section 1: Domains of WUs' Socio-Emotional Experiences: This study presents a scoping review to map out a range of socioemotional experiences in using wheelchairs. Synthesizing the findings, in both qualitative and quantitative studies, will highlight the domains most frequently reported in the literature regarding WUs' social experiences. It will also identify areas that have received less attention. The findings will inform where design interventions can be introduced to improve the social experiences of MA users.

Section 2. Representation of Mobility Disability Stereotypes: This section adopts Foucault's "Archaeology of Knowledge" and postmodernist perspectives to explore how medical knowledge shapes dominant social perceptions and interpretations of mobility disabilities. I examine how the representations and notions of mobility disability reproduce in society and among MA users. The findings reveal discrepancies between clients' and medical professionals' perspectives, including physiotherapists, within the current health discourse. Accordingly, strategies are proposed to bridge these gaps and to advance an approach that challenges dominant interpretations of mobility disability.

Section 3. Comfort Aspects in Wheelchair Design: This section introduces a framework for categorizing WUs' discomfort and comfort experiences. The framework defines discomfort and comfort across three main layers. The analysis highlights the interplay between socio-psychological factors, user emotions, and wheelchair design, as well as the impact of the physical environment, wheelchair properties, and user limitations. Additionally, I discuss how advanced technology affects comfort and the associated challenges.

Summary & Discussion (Answer to Q2): Upon completion of these studies, we provide a summary and highlight the interconnections between these aspects, which contribute to shaping the interdisciplinary framework of this thesis. This framework answers Research Question 2 (Q2) and not only guides the subsequent stages of our research but also provides a lens for interpreting the results of our empirical findings, ultimately advancing the development of SEDPs.

Ch. III: Understanding the Socio-Emotional Dynamics: This chapter aims to show how WUs perceive themselves within social dynamics and examine how the dynamics of their affective experiences change over time as they use wheelchairs. Pedestrians' perceptions, social empathy, and interactions with WUs will also be examined.

Section 1. Perceived Inclusivity in Using MAs: This section aims to explore perceived inclusivity in MAs usage and identifies gaps in users' needs, applying it as a guideline to improve inclusivity. In this study, the four themes identified which provide a guideline for enhancing inclusivity in practice. Each theme provides implications to improve accessibility and enhance the perception of inclusivity.

Section 2. Dynamics of Affective Experiences in Using Wheelchair: This study aims to track the dynamics of affective experiences (DAE) of WUs during rehabilitation and recommend how to manage these dynamics. In this study I identify a total of three themes and additionally, two diagrams illustrating the dynamics of the affective experience of WUs and its influencing factors during rehabilitation is provided.

Section 3. Empathy and Interaction with Wheelchair Users in Society: This section presents the results of a study that aims to investigate the role of the WUs' body gestures and wheelchair design characteristics in pedestrians' willingness to empathize and interact. This study specifically examines the aesthetic and symbolic aspects of wheelchairs and their role in social communication. Additionally, it compares the impact of wheelchair design characteristics across two distinct gestures. Finally, the principal components that can instigate the willingness to empathize and interact are discovered and prioritized.

Summary & Discussion (Answer to Q3): Upon completion of these studies, we will provide a comprehensive summary and highlight the key aspects of our findings. This analysis will allow us to address Research Question 3 (Q3), providing insights into Socio-Emotional Dynamics in WUs' interactions.

Ch. IV: External Communication via Wheelchair Interfaces: While Ch. III explores the contextual and socially supportive aspects identified as impactful, Ch. IV focuses on the representational and aesthetic qualities of wheelchairs as critical mediators. This chapter examines two key aspects of WUs' communication: (1) eHMI considerations from a human factor perspective, with an emphasis on practical communication in urban settings, and (2) how socio-emotional considerations can be integrated into tangible design elements on the wheelchair's exterior and interface using the Kansei Engineering method.

Section 1. eHMI Requirements for Wheelchair: This section introduces a design framework for practical communication for WUs via an appropriate eHMI, viewed as a prerequisite from a human factor's perspective. It outlines key eHMI appearance considerations and practical communication factors before addressing socio-emotional aspects.

Section 2. Integrating Socio-Emotional Factors in Wheelchairs: This pilot study builds on previous insights to link socio-emotional needs with engineering elements, focusing on design considerations crucial for social polishing wheelchair interface. It centers around the question: What is the key socio-emotional design priorities for wheelchairs? To address this, I introduce a Kansei Engineering (KE) (Nagashima, 2012), model for developing a wheelchair interface for external communication.

Summary & Discussion (Answer to Q4): Upon completing the two studies, we will discuss the key findings from both and demonstrate how specific aspects of wheelchair appearances, both practical and aesthetic, can benefit WUs. The integration of insights from these studies will provide a comprehensive answer to the fourth research question of this thesis: What are the preferred factors in wheelchair design that can enhance the social interactions of WUs?

Ch. V: Discussion and Conclusion: This chapter reviews and analyzes findings from empirical studies using the interdisciplinary framework from Ch. II, exploring potential SEDPs to improve WUs' experiences. The conclusion summarizes research contributions, limitations and suggests directions for future studies. Figure 5 illustrates the outline of all chapters and studies presented in this thesis.

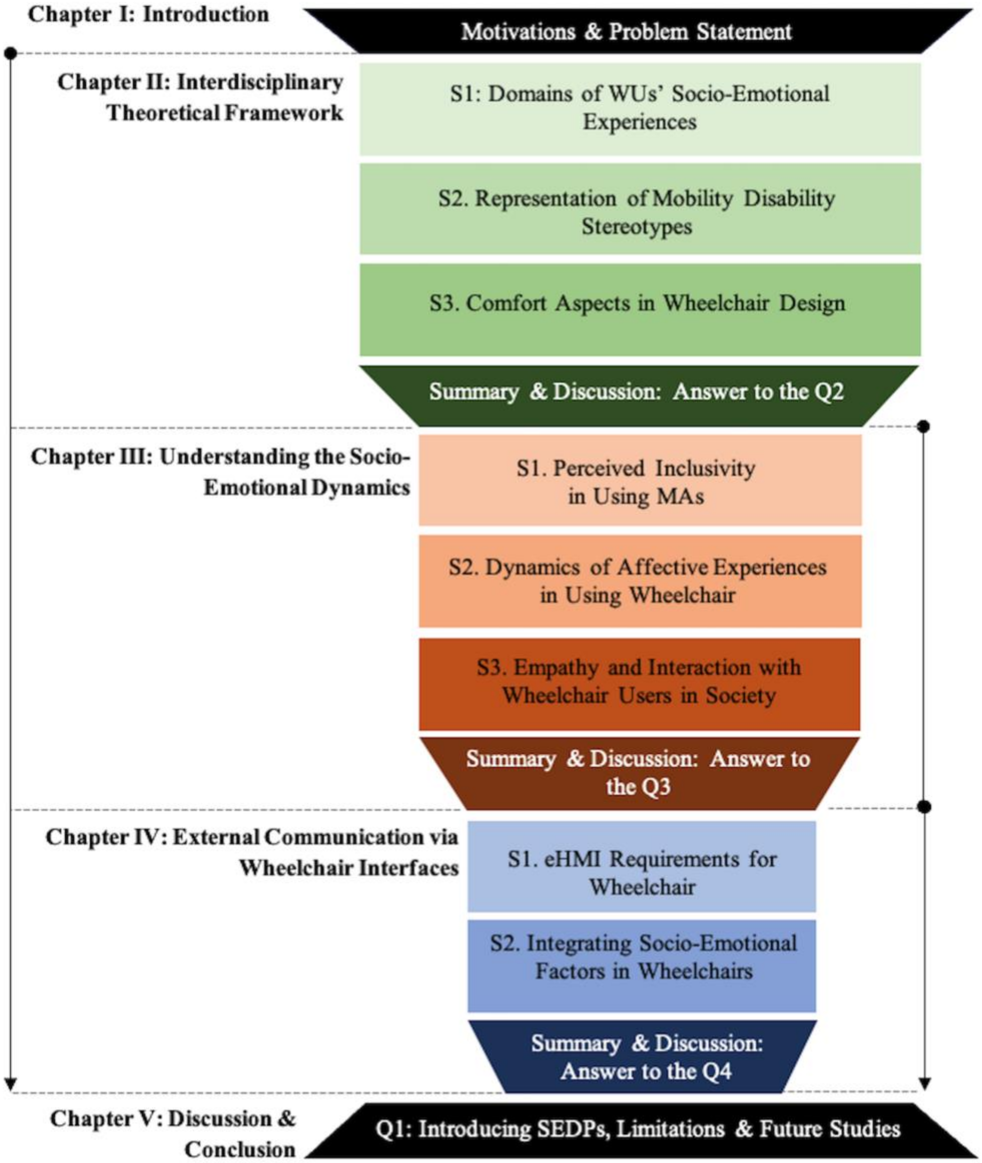

Figure 5. Thesis outline. © Image by Author.

Based on the overall framework of the thesis and its objectives, fundamental knowledge was reviewed through courses in design for care, sociology of health, and design theories during the initial phase. By the end of the first year (2020-21), the supervisor confirmed the first draft of the study's purpose, and the research on spatial experiences was initiated, leading to the publishing of one paper in the area of patients and spatial experiences.

In the second year, to address engineering considerations, a course on advanced technologies in medical engineering was completed. This resulted in two published papers on ergonomic studies and one published paper presenting a critical review of hospital services for surgery.

In the third year, efforts were concentrated on completing ongoing studies. Also, following the study's objectives, an interdisciplinary theoretical framework was developed, including scoping reviews on design interventions, the social representation of disability, and defining comfort in wheelchair use.

In the fourth year, the comprehensive exam was passed, and new research was initiated, focusing primarily on Ch. III and IV, which explore socio-emotional aspects through empirical studies. The research timetable is outlined in Appendix A.

7 Researcher Positionality

The author of this thesis, as a researcher with a background in design studies and human factors, and with academic engagement in areas of sociology of health, medical anthropology, and disability advocacy during the PhD period, approaches this research with a strong ethical commitment to enhancing the quality of life for individuals with impairments. Originally from Iran and having lived in Europe (primarily the Netherlands) and now in Canada, I bring a perspective shaped by diverse academic and cultural contexts. I am mindful that these varied cultural influences may have shaped my perspectives and interpretations throughout the study.

My previous research, including my master's thesis, also focused on the design of assistive technologies. This doctoral research builds on that foundation, seeking to address unresolved challenges and to further explore the socio-emotional dimensions of wheelchair users' experiences. While I do not have a physical impairment myself, I am conscious of how this position may influence my understanding. Throughout the research process, I made a deliberate effort to reflect critically on my role and to validate my interpretations through direct consultation with wheelchair users and physiotherapists.

II

Interdisciplinary Theoretical Framework

Domains of WUs' Socio-Emotional Experiences

This section is based on the following manuscript (published edition).

Rasoulivalajoozi, M., Cucuzzella, C., & Farhoudi, M. (2025). Domains of wheelchair users' socio-emotional experiences: Design insights from a scoping review. *Disability and Health Journal*, 101829. https://doi.org/10.1016/j.dhjo.2025.101829

The *Disability and Health Journal*, published by Elsevier, is a multidisciplinary journal dedicated to original research that advances knowledge in disability and health.

Abstract: Physical accessibility is not the only concern for wheelchair users (WUs); they also face barriers to social presence, such as challenges in social engagement and negative stereotypes. Identifying key domains in the literature that impact their social and emotional experiences is essential to addressing these issues. This scoping review sought to explore the key domains of WUs' socio-emotional experiences, as a foundation for providing design-oriented insights to enhance their social presence. To achieve this, a literature search was conducted using the Web of Science, PubMed, Scopus, and PsycINFO databases, along with a manual search of three relevant journals. Articles in English, based on original empirical studies that focused on the socio-emotional experiences of adult WUs (>18), were included. Of the 48 articles included, most were from Canada (n=11), Sweden (n=9), the U.S. (n=7), and the U.K. (n=6), with limited studies from other countries. Among the six domains explored, Independence & Autonomy (26%) was the most frequently reported, while Self-identity & Body Image (9%) and Social Stigma & Discrimination (5%) were the least. Three interconnected themes emerged to guide design insights: Theme I – Foundations: Autonomy & Control, Theme II – Connections: Social Participation & Support, and Theme III – Reflection: Self- & Social-Identity. While independence and agency are key concerns, little research has focused on perceptual issues like self- and social identity, often highlighted in the media. This area can be refined by recognizing the crucial role of design in aesthetically shaping WUs' social representation in public settings.

Keywords: Socio-emotional experience; Wheelchair users, Self-perception; Social participation; Design insights.

1 Introduction

While confronting physical obstacles such as inaccessible settings,(Desai et al., 2023; Harris et al., 2015) unequal access to healthcare (Chen et al., 2024), and inadequate transportation options (Unsworth et al., 2017), wheelchair users (WUs) also deal with considerable social difficulties. These social experiences often range from feelings of being treated as second-class citizens (Meikle, 2016), and facing discrimination (Human Rights Watch Council, 2018), to experiencing loneliness and social isolation.(Babik & Gardner, 2021; Gómez-Zúñiga et al., 2023) In turn, this can trigger emotional distress, damage self-perception (Barlew et al., 2013; Edberg & Persson, 2011; V. de S. P. Costa et al., 2010), and further intensify social isolation (Barker et al., 2004; Emerson et al., 2021). In this context, the interplay between social isolation and emotional distress creates a detrimental positive feedback loop, where emotional challenges deepen isolation, which in turn exacerbates emotional difficulties (Lidwell et al., 2010), affecting their quality of life (QoL). Breaking this cycle requires collective efforts from disability experts in both policy and practice. However, it is essential to first gain a clear understanding of the range of socio-emotional difficulties experienced by WUs. By mapping these domains, this understanding enables experts to develop effective interventions. While interventions can range from broad policy reforms to targeted design innovations, this study focuses on the latter, discussing design-oriented recommendations that directly impact the social presence—defined as the extent to which individuals are seen, acknowledged, and engaged in social settings, shaping their inclusion (Oh et al., 2018)—and experiences of WUs. This approach uncovers underlying challenges and reveals hidden insights, enabling the development of creative and effective solutions (Ku & Lupton, 2020).

In this study, we aim to map out the range of explored domains in WUs’ socio-emotional experiences and accordingly discuss the design insights. Specifically, it seeks to answer the research question: What are the most frequently explored domains of WUs' socio-emotional experiences? To achieve this, we conduct a scoping review of scholarly studies that focus on the experiences of WUs as outlined above. We then discuss the design insights to assist designers and disability researchers. It is worth emphasizing that the research question focuses on the frequency of exploration of socio-emotional domains within the literature, rather than the actual prevalence of these experiences among wheelchair users. While a higher volume of publications may indicate greater scholarly attention, it does not necessarily reflect the commonality or frequency of these experiences in the lived reality of WUs.

This study aligns with the rights enshrined in the United Nations Convention on the Rights of Persons with Disabilities (CRPD), highlighted at the 17th Session of the Conference of States Parties (COSP17) in June 2024 in New York (United Nation News, 2024). The CRPD emphasizes inclusivity, ensuring that individuals with disabilities have their dignity respected, their voices heard, and are actively involved in decisions affecting their lives, advocating for rights such as freedom of expression, education, healthcare, and employment. The contributions of this study are as follows:

- Mapping the socio-emotional experiences provides a comprehensive overview of existing research, identifying the scope and range of evidence available.
- The findings also enable researchers in disability studies and design for care to find the gaps in developing relevant recommendations for addressing the challenges associated with socio-emotional experience in using mobility aids (MAs).

2 Methods

2.1 Scoping Review Guideline

A scoping review was conducted by an interdisciplinary research team (disability studies, sustainability studies, and inclusive design) in the area of social inclusion. This review follows the Joanna Briggs Institute (JBI) methodology for the scoping methods and adheres to the Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (C. Tricco et al., 2018). Protocol registration was done in Open Science Framework (Rasoulivalajoozi et al., 2024). This study is a review article; it does not require approval from the Institute Review Board (IRB). We performed a scoping review using a scientific methodology.

2.2 Information Sources and Search Strategy

For data gathering, we used four search engines, Web of Science, PubMed, Scopus, and PsycINFO with every possible keyword to consider population (adults), intervention (consistent users of wheelchairs), and outputs (social and psychological experience of using wheelchairs). These databases were selected for their accessibility, thematic relevance, and coverage of international publications. We limited our search to publications from 2000 onward to capture advancements in best care practices for WUs over the past two decades. Search strategies were reviewed on February 1, 2023, and updated on May 28, 2024. Given the frequency of relevant qualitative study publications, we hand-searched the following three journals for relevant articles up to May 2024: (1) Disability and Rehabilitation, (2) Assistive Technology, and (3) Scandinavian Journal of Occupational Therapy. Using Boolean logic, the key concepts and terms were combined with "OR," "AND," and "NOT" to ensure comprehensive results, including all relevant subheadings (T. Chan, 2023). See Appendix B for the detailed search strategy. Search terms were developed through thesauri-based expansion within each academic database, input from the expert panel. To prevent every potential bias, a librarian at Concordia University, an expert in the field of health and medicine, monitored our protocols of search strategies and continuously checked the steps. The final studies were selected in two phases: title and abstract screening, followed by full-text review, conducted independently by two of the authors (M.R. and M.F.). Disagreements were resolved through discussion.

2.3 Eligibility Criteria

In this study, we specifically investigated the experiences of individuals with lower extremity dysfunction who were undergoing treatment with wheelchair, whether manual or powered.

Inclusion criteria

- *Population*: Focused on WUs, to capture evidence about social and psychological experiences.
- *Age Group*: Studies that focus on adult (>18) WUs.
- *Geographical Scope*: Studies from all countries.

- *Publication Date*: Studies published within a specific timeframe of 2000-2024.
- *Study Design*: Qualitative and quantitative studies as well as mixed-methods research.
- *Context*: Studies should consider socio-emotional experiences in everyday life, QoL, and social and psychological well-being within various contexts, such as public spaces, or social interactions.
- *Peer-Reviewed*: Only peer-reviewed articles to ensure the quality and credibility of the research.
- *Language*: Full-text articles published in English

Exclusion criteria

- *Theoretical Papers:* Papers focused solely on theoretical frameworks without empirical data on socio-emotional experiences.
- *Measure Testing*: Studies that focus only on testing or developing new measures or instruments.
- *Historical Reviews*: Reviews that focus on historical perspectives or developments rather than current socio-emotional experiences of WUs.
- *Patents*: Technical descriptions of wheelchairs.
- *Editorials/Commentaries*: Opinion pieces, editorials, and commentaries that do not provide original research data or empirical evidence.
- *Lectures/Speeches*: Content from lectures, speeches, and other non-peer-reviewed presentations.
- *Abstracts/Bibliographies/ Review Papers/Book Reviews*: Abstracts, bibliographies, and book or paper reviews that do not present full research studies or detailed findings.
- *Context:* Studies focusing *training programs, financial issues, accessibility in specific environment (e.g., tennis or basketball court), engineering development, design developments,* and communication technologies *(ICTs)* not related to general experiences of or WUs.
- *Service Providers*: Research focused on service providers' experiences rather than those of Wus.
- *Parents, friends, family and caregivers' experiences*: Studies focusing on the experiences of parents or caregivers rather than the WUs themselves.
- *Ambulatory Products*: Studies related to walkers, canes, scooters, and crutches.
- *In-Vitro Research*: Laboratory-based in-vitro research that does not involve WUs' socio-emotional experiences.
- *Clinical Trials*: Clinical trials focused on surgical or medical interventions.

2.4 Study Selection

Study selection was conducted in three main phases: First, the titles and abstracts of the citations were independently screened for relevance to the inclusion criteria by the authors. Second, authors combined possibly relevant citations and included discrepancies in the full-text review. Finally, during a group discussion, we reviewed and retrieved the potential eligible full-text articles and reached a consensus on disagreements or ambiguities. Search results were uploaded into Zotero for reference management, where duplicates were removed both automatically and manually. The remaining titles and abstracts were exported to Microsoft Excel, organized alphabetically, and screened for eligibility by M.R., C.C., and M.F.

2.5 Critical Appraisal

Initially, the authors ensured all socio-emotional aspects of WUs were considered, even if not the primary focus, providing a comprehensive and transparent synthesis of findings. Then, the McGill University Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018) was employed to evaluate the methodological quality of the articles. This validated and reliable tool (Hong et al., 2019; Souto et al., 2015) is suitable for assessing qualitative, quantitative, and mixed-method studies. Accordingly, all three authors independently screened a random sample of articles (See Appendix C), with only 5% disagreement, resolved through discussion. This triangulated review process ensured accuracy and reliability in the quality analysis of the included studies.

2.6 Data Extraction and Analysis

In alignment with scoping review methodology, key information was gathered from the included publications using an organized data extraction framework (Levac et al., 2010), which was divided into two following sections: (1) General publication details (including the authors' name, year of publication), and descriptive information (country, study methods, type of wheelchair, and sample size); and (2) Categories of explored domains, in which the socio-emotional experiences were identified. To systematically determine the socio-emotional domains, we first extracted all mentions of socio-emotional aspects from each study, recording them without predefined categories to ensure an open and comprehensive assessment. Next, we conducted an inductive thematic analysis, grouping similar socio-emotional aspects into preliminary categories. This process was carried out independently by each author, followed by joint discussions to refine and consolidate the themes. The final categorization was based on two main criteria: (1) the frequency and emphasis of each socio-emotional aspect across multiple studies. For instance, if a study discussed accessibility and its socio-emotional impact, the authors identified which socio-emotional domains were most emphasized and explored; and (2) the relevance of each aspect to the lived experiences of WUs in relation to mobility aids. This structured approach not only allows for the identification of patterns and gaps in the existing literature on socio-emotional experiences but also highlights areas where design recommendations could be most beneficial.

In the results, the table of studies is categorized and presented based on the design approaches: qualitative, quantitative, and mixed methods. This enables us to systematically compare the different methodologies, understand their contributions to the research on MA users' socio-emotional experiences, and identify which approaches have been most commonly applied.

3 Results

3.1 Describing the Literature

Following the removal of duplicates, 271 citations were identified from electronic database searches and three relevant journals. A total of 135 full-text articles were retrieved, of which 48 were included (Figure 6). These studies were classified as qualitative (n=31), quantitative (n=13), and mixed methods (n=4). Among the total participants (n=1293), the majority were involved in qualitative studies (n=466), with the remainder participating in quantitative studies (n=663) and mixed methods studies (n=164). In addition, most of the studies included PWs (n=31), while MWs were less frequently involved (n=20). In a few studies, the type of wheelchair was unclear (n=5). Mobility scooters (MS) were also type of mobility aids alongside wheelchairs in some studies (n=6). Tables 2, 3 and 4 present a general summary of the data extraction. According to the findings, the majority of studies on the socio-emotional experiences of WUs were conducted in Canada (n=11), followed by Sweden (n=9), the U.S. (n=7) and U.K. (n=6). Other countries conducted more limited investigations including Denmark, Brazil, and China (all n=2), and Italy, Norway, Spain, Ghana, Turkey, Netherlands, Kenya, and Germany (all n=1). In only one case, the country and context of study were not mentioned (Figure 7).

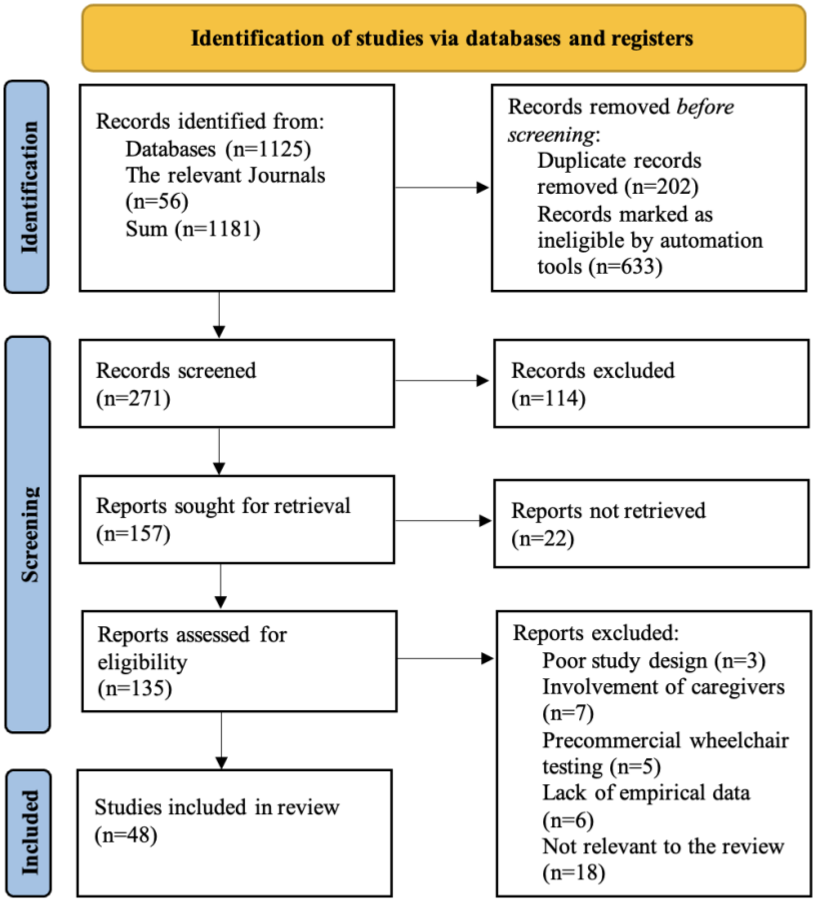

Figure 6. PRISMA flow chart of the selection of included articles.

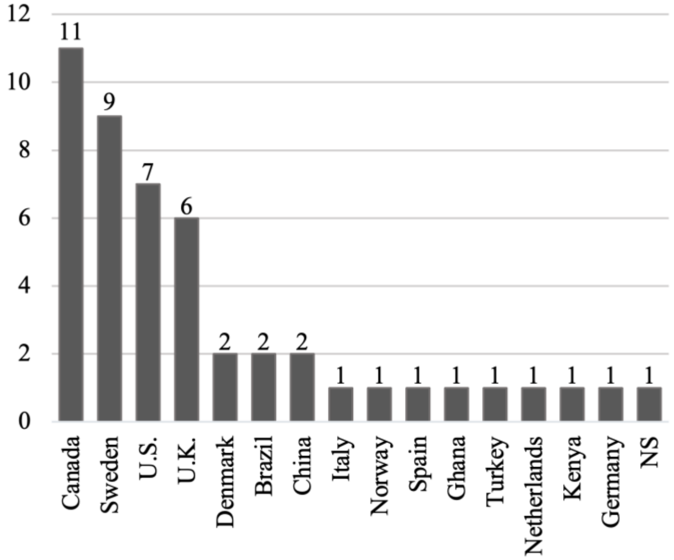

Figure 7. Distribution of studies by country.

Table 2. The list of studies with qualitative methods, and the explored domains of socio-emotional experiences of WUs.

General publication details and descriptive information				**Categories of explored domains**					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(Abu–Sadat, 2023)	Ghana	MW	2				✓		
(Barbareschi et al., 2021)	Kenya	NS	54	✓					
(Barker et al., 2004)	Canada	MW, PW, MSc	10			✓	✓	✓	✓
(Barker et al., 2006)	Canada	MW, PW, MSc	10			✓	✓		✓
(Barlew et al., 2013)	U.S.	NS	6	✓	✓			✓	
(Blach Rossen et al., 2012)	Denmark	PW	9		✓	✓	✓		
(Böttger et al., 2022)	Germany	PW	5		✓	✓	✓		✓
(C. Pettersson et al., 2014)	Sweden	PW, MSc	16				✓		✓
(V. de S. P. Costa et al., 2010)	Brazil	NS	10		✓		✓	✓	✓
(Edberg & Persson, 2011)	Sweden	NS	11			✓	✓		✓
(S. Evans et al., 2007)	U.K.	PW	17			✓	✓	✓	✓
(R. Evans, 2000)	U.K.	PW	8				✓	✓	✓
(Fortin-Bédard et al., 2022)	Canada	MW	14			✓	✓	✓	
(Frank et al., 2010)	U.K.	PW	64			✓	✓	✓	✓
(Henje et al., 2021)	Sweden	PW	13			✓			
(Hjelle & Vik, 2011)	Norway	NS	6			✓	✓		✓
(Korotchenko & Hurd Clarke, 2014)	Canada	PW, MSc,	29			✓	✓		✓
(Kristiansen, 2018)	Sweden	PW	5	✓		✓	✓		✓
(Labbé et al., 2018)	Canada	PW	19		✓	✓			✓

General publication details and descriptive information				Categories of explored domains					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(Lindström et al., 2022)	Sweden	PW	15	✓	✓	✓	✓	✓	✓
(Mattie et al., 2019)	Canada	MW	8			✓	✓	✓	✓
(Giacobbi et al., 2010)	U.S.	PW	20			✓	✓	✓	✓
(Pfeiffer et al., 2024)	U.S.	MW	6			✓	✓		
(Qiao et al., 2024)	China	MW	24		✓			✓	
(Reid et al., 2003)	Canada	MW, PW, MSc	11			✓	✓		✓
(Rogers & Musselwhite, 2023)	U.K.	PW, MW	11		✓	✓	✓	✓	✓
(Rousseau-Harrison et al., 2012)	Canada	MW, PW	10			✓	✓	✓	
(Rushton et al., 2014)	Canada	PW	12			✓	✓		
(Stenberg et al., 2016)	Sweden	PW	15	✓	✓		✓	✓	✓
(Torkia et al., 2014)	Canada	PW	12				✓		✓
(Widehammar, Lidström Holmqvist, et al., 2019)	Sweden	PW	14	✓		✓			✓

*Mobility aids: MW=Manual wheelchair; PW=Powered wheelchair; MSc=Motorized Scooter; NS=Not specified.

Table 3. The list of studies with quantitative methods, and the explored domains of socio-emotional experiences of WUs.

General publication details and descriptive information				Categories of explored domains					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(Brandt et al., 2004)	Denmark	PW	111			✓	✓		✓
(S. C. Chan & Chan, 2007)	China	MW	31			✓	✓		
(A. Davies et al., 2009)	U.K.	PW	51			✓	✓		

General publication details and descriptive information				Categories of explored domains					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(de Groot et al., 2011)	Netherlands	MW	109				✓		✓
(Greenhalgh et al., 2021)	U.S.	MW	24		✓			✓	✓
(I. Pettersson et al., 2010)	Sweden	MW	32		✓		✓	✓	✓
(Lanutti et al., 2015)	Brazil	MW	10		✓	✓		✓	
(Meyers et al., 2002)	U.S.	MW	28			✓	✓		✓
(Mortenson et al., 2022)	NS**	MW, PW, MSc	105			✓		✓	✓
(Örücü Atar et al., 2024)	Turkey	Stand PW	20		✓		✓	✓	
(I. Pettersson et al., 2009)	Sweden	PW	32			✓	✓		✓
(Pousada García et al., 2015)	Spain	MW/PW	60	✓		✓	✓	✓	✓
(A. L. Ward et al., 2015)	U.S.	PW	50			✓	✓	✓	✓

*Mobility aids: MW=Manual wheelchair; PW=Powered wheelchair; MSc=Motorized Scooter, **NS=Not specified.

Table 4. The list of studies with mixed methods, and the explored domains of socio-emotional experiences of WUs.

General publication details and descriptive information				Categories of explored domains					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(Garber et al., 2002)	U.S.	MW/PW	49			✓	✓	✓	✓
(May & Rugg, 2010)	U.K.	PW	20				✓	✓	✓
(Rudman et al., 2006)	Canada	MW	16		✓	✓	✓		

General publication details and descriptive information				Categories of explored domains					
Author, year	Country	Type of MA*	Sample size	Social stigma & discrimination	Self-identity & body image	Social integration & support	Independence & autonomy	Emotional well-being	Perception of control & agency
(Salatino et al., 2016)	Italy	PW	79				✓	✓	✓

*Mobility aids: MW=Manual wheelchair; PW=Powered wheelchair.

3.2 Domains of Socio-Emotional Experiences

In line with the aim of study, six domains of socio-emotional experiences were explored in the literature: social stigma & discrimination, self-identity & body image, social integration & support, independence & autonomy, emotional well-being, and perception of control and agency (Figure 8). Following are the descriptions of each domain:

- *Social stigma & discrimination*: This factor addresses the external negative attitudes and biases that WUs face from society, leading to feelings of exclusion or being judged based on their MAs rather than their abilities.
- *Self-perception & identity*: This relates to how WUs see themselves and how their identity might be influenced by their use of a MAs. It encompasses personal reflections on dignity, self-worth, and how they perceive their place in society.
- *Social integration & support*: This refers to the extent to which WUs feel included in social settings, despite any physical limitations. It also encompasses the support networks available to them—family, friends, and community resources—that foster connection and belonging.
- *Independence & autonomy*: This aspect emphasizes the user's ability to perform daily activities and make decisions without relying heavily on others. It's about the freedom to navigate their environment and live life on their own terms.
- *Emotional well-being*: This includes the overall mental and emotional health of WUs, which can be impacted by their experiences of using a MA, such as feelings of depression, anxiety, or contentment.
- *Perception of control & agency*: This reflects WUs' socio-emotional experience of feeling empowered and in control of their lives, shaping their confidence, autonomy, and self-determination.

To present the categories, we aimed to highlight distinct aspects of WUs' experiences. For instance, while *independence & autonomy* and *perception of control & agency* may appear similar, former focuses on the practical ability to perform tasks, whereas latter relates to the emotional experience and self-perception associated with that independence.

3.3 Prevalence of the Six Explored Socio-Emotional Domains

The investigation revealed that *independence & autonomy* (n=39, 26%) was the most explored and reported domain, indicating a strong focus on the importance of self-reliance and personal freedom for WUs (Figure 8). *Social integration & support*, and *perception of control & agency* (both n=33, 22%) ranked second, and *emotional well-being* (n=24, 16%) ranked third, showing a significant concern for social connectivity and the psychological effects of mobility on well-being. The lowest rates of reports of socio-emotional experiences were related to *self-identity & body image* (n=14, 9%) and *social stigma & discrimination* (n=7, 5%). This indicates that these domains, while crucial, may receive less attention or are underreported in comparison to other socio-emotional domains.

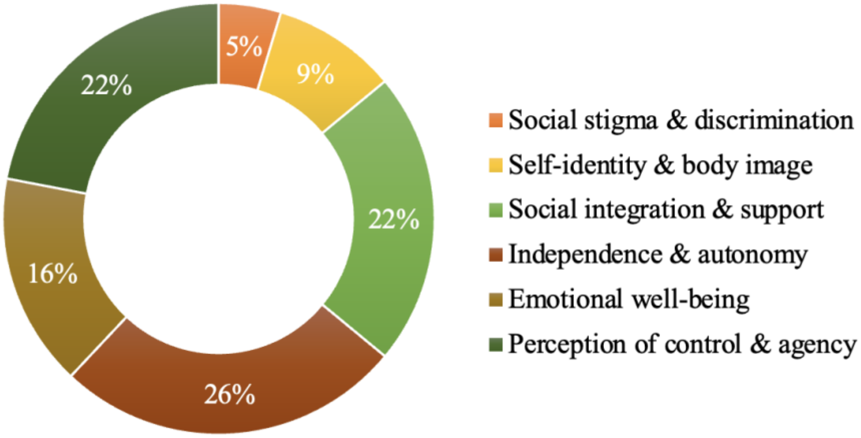

Figure 8. The percentages of the explored domains of socio-emotional experiences.

Each of these domains is shown in the classification of qualitative, quantitative and mixed methods studies in Figure 9. The diagram shows the most explored domain across all methods is *independence & autonomy*, with qualitative studies (n=25), quantitative (n=10), and mixed methods (n=4). The domain of *perception of control & agency* follows closely, with qualitative studies (n=21), quantitative (n=9), and mixed methods (n=3). *Social integration & support* also ranks highly, especially with qualitative studies (n=22) but fewer quantitative (n=9) and mixed methods (n=2). In contrast, self-identity & body image and social stigma & discrimination are the least explored areas. Self-identity & body image includes qualitative studies (n=9), quantitative (n=4), and mixed methods (n=1), while social stigma & discrimination has qualitative studies (n=6), quantitative (n=1), and no mixed methods (n=0). Emotional well-being falls between these extremes, with qualitative studies (n=14), quantitative (n=7), and mixed methods (n=3).

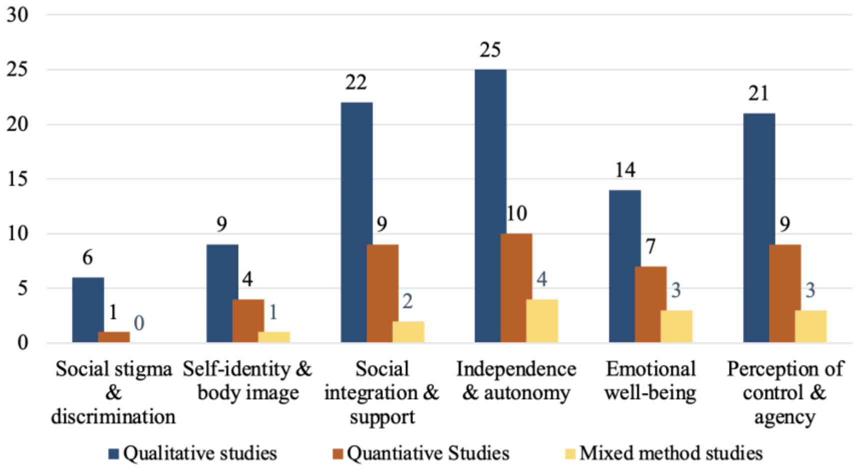

Figure 9. The number of the explored domains of socio-emotional experiences based on the categories of study methods.

3.4 Introducing Themes

In this section, the authors categorize the explored domains into three interconnected themes, reflecting a hierarchical progression of WUs' needs. These range from functional requirements like control and autonomy to more abstract needs such as social identity (Figure 10).

Themes I: Foundations: Autonomy & Control: This theme, which links the two domains of *independence & autonomy* and *perception of control & agency*, is more extensively explored in the literature (48%), nearly half of the total, and surpasses the exploration of the other four domains combined (52%). *Independence & autonomy* emphasizes personal freedom and self-reliance, highlighting how WUs' ability to engage in social spaces and form relationships is affected by their lack of independence. The perception of control and agency pertains to the extent to which WUs feel they can influence their social and physical environments, emphasizing the psychological and emotional dimensions of self-determination. This is reflected in the reviewed studies, which highlight how a strong sense of agency fosters empowerment, enabling individuals to engage in social interactions with greater confidence and autonomy (Hjelle & Vik, 2011; Labbé et al., 2018; Kristiansen, 2018; Mattie et al., 2019). A selection of quotes from the included studies is provided below:

> *"Findings also imply that participation means being autonomous and making decisions about one's own life …"*(Hjelle & Vik, 2011).
> *"'It's my legs' emphasized how powered wheelchairs are a form of mobility that not only enables users to take part in activities, but also impacts their identities, past and present"*(Labbé et al., 2018).
> *"Overall, the review showed that wheelchair factors and accessibility the most frequently reported factors associated with participation,…"*(Kristiansen, 2018).

Given their frequent discussion in the literature, these domains appear to be central to WUs' socio-emotional experiences and may facilitate greater social participation and inclusion.

Theme II: Connections: Social Participation & Support: This theme, centered on *social integration and support*, accounts for almost one fifth (22%) of the included studies and represents key steps toward active societal participation. It highlights the importance of social connections and support systems, such as networks of family, friends, and organizations. Social integration refers to WUs' ability to engage in community activities, while support addresses the assistance provided. This theme emphasizes the importance of social participation and accessible support in reducing isolation and fostering a sense of belonging, enabling WUs to affirm their self and social identity (Kristiansen, 2018; I. Pettersson et al., 2010; Pousada García et al., 2015; Lanutti et al., 2015; Rogers & Musselwhite, 2023). This mediating role of social participation and support is reflected in the following sample quotes:

> "*However, the electric wheelchair users were constantly confronted with stigma, because of the status of the disabled in society, which, sometimes isolated the users and negatively affected their self-concepts and identity …"*(Kristiansen, 2018).

> *"… identity is formed of interactions between internal conceptions of self and the presentation and experience"*(Rogers & Musselwhite, 2023).

Theme III: Reflection: Self- & Social-Identity: This theme, which combines *social stigma & discrimination* (5%) with *self-identity & body image* (9%), is less frequently reported in the literature (14%). It illustrates how societal attitudes shape both how WUs are externally perceived and how they internally view themselves. *Social stigma & discrimination* refer to the negative biases and marginalization WUs face, impacting their interactions and inclusion in public spaces. *Self-identity & body image* explore how WUs internalize these external perceptions and how mobility devices influence their self-image, with wheelchairs often becoming extensions of their identity (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010). Media and societal representations (R. Evans, 2000; S. Evans et al., 2007), whether positive or negative, play a key role in shaping this self-perception (I. Pettersson et al., 2010; Rushton et al., 2014; Widehammar, Lidström Holmqvist, et al., 2019; Greenhalgh et al., 2021; Rogers & Musselwhite, 2023). Together, these categories reveal the complex interplay between societal views and personal identity, crucial for understanding WUs' socio-emotional experiences. Regarding the emerging themes, Figure 10 illustrates the identified themes and their interconnections.

Although not explicitly included in the three themes, emotional well-being is closely connected to all of them. Autonomy and control foster a sense of self-worth and agency, which are critical to emotional health. Social integration and support systems help combat isolation, promoting inclusion and belonging. Additionally, societal perceptions and self-identity shape emotional responses, as negative stigmas can erode self-esteem while positive representations boost confidence. Emotional well-being, therefore, is not an isolated domain but rather a dynamic outcome influenced by the combined effects of autonomy, social connection, and identity.

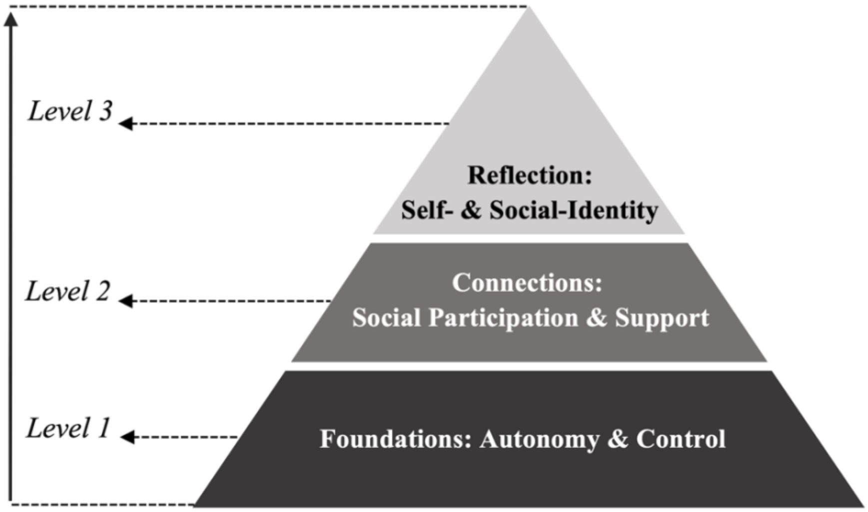

Figure 10. The hierarchical progression of WUs' needs. © Image by Author.

4 Discussion

The aim of this scoping review was to map the domains of socio-emotional experiences of WUs. Out of 48 studies reviewed, 31 were qualitative, often small-scale trials, with more than half involving fewer than 15 participants. The remaining studies were conducted with 13 quantitative and four mixed methods.

4.1 Global Disparities in WUs' Socio-Emotional Research

Figure 7 illustrates countries such as Canada, Sweden, the United States, and the United Kingdom have conducted substantial research on WUs' experiences, surpassing other nations. These countries have a strong tradition of disability rights advocacy, supported by progressive policies and legal frameworks like the Americans with Disabilities Act (ADA) in the U.S. (Americans with Disabilities Act, 2020), the Disability Discrimination Act in the U.K. (GOV UK, 2010), and comprehensive legislation in Canada and Sweden (Accessible Canada Act, 2019). They emphasize inclusivity, viewing disability as a socio-political issue connected to human rights (Lawson & Beckett, 2021). These policies and views collectively contribute to their leadership in disability research, reflecting a broader commitment to creating equitable, inclusive societies. Reports reveal that in developed nations, about 1% of people (10 million) still need wheelchairs, demonstrating that their essential right to mobility and participation in society is still not fully addressed. On the other side, in developing nations, this need rises to 2% (121.8 million people) (Markets, 2021). Alarmingly, less than 10% of individuals in developing regions have access to wheelchairs, underscoring that their fundamental right to mobility, as a first step, remains largely unmet (Wheelchair Foundation, 2023). This highlights the need for research to amplify WUs' voices on the global scientific platform. For example, a report highlights widespread discrimination against people with disabilities in Iran, leading to confinement at home due to a lack of independence (Human Rights Watch Council, 2018; Rasoulivalajoozi et al., 2025b). Therefore, there is a significant gap in the scientific literature regarding systematic observations of WUs' socio-emotional experiences, especially in developing countries. While gray literature continues to emphasize accessibility (BBC news, 2022; Candiago, 2024; Sadeghzadeh, 2015)، there remains a critical gap in understanding the socio-emotional experiences of WUs, especially in developing regions.

4.2 Reviewing the Explored Domains

Independence & autonomy, along with *perception of control & agency*, were the most frequently studied domains, whereas *social stigma & discrimination* and *self-perception & body image* received less attention. This discrepancy likely arises from a research focus on mobility and functional independence aligned with rehabilitative goals, overshadowing important socio-emotional aspects like stigma and self-identity. As the studies indicate that individuals with disabilities seek not merely to escape an identity defined by limitation and dependence, but to cultivate an identity characterized by self-fulfillment (Galer, 2012). It is logical that those still struggling with independence have their efforts toward self-fulfillment less reflected in studies.

The challenge of measuring internalized stigma and body image, coupled with societal discomfort discussing these issues, contributes to their underrepresentation in literature. Despite media coverage of self-perception, social stigma, and discrimination issues (BBC news, 2022; Human Rights Watch Council, 2018; Sadeghzadeh, 2015), these perceptual concerns remain largely neglected in academic studies. Addressing these gaps is essential for a comprehensive understanding of WUs' socio-emotional experiences.

The domain of *social integration & support* may be influenced by various factors such as accessibility, social attitudes, and available support systems (Hästbacka et al., 2016). However, achieving *independence & autonomy* can facilitate social integration by providing individuals with greater control over their mobility, thereby cultivate more opportunities for social interaction (Kristiansen, 2018; I. Pettersson et al., 2010; Pousada García et al., 2015; Lanutti et al., 2015; Rogers & Musselwhite, 2023). In line with this, studies, including systematic reviews, have similarly found that higher levels of social support are associated with enhanced mobility, independence, productivity, and participation in social activities (Fortin-Bédard et al., 2022; McCOLL & Friedland, 1995; Müller et al., 2012; Pollard & Kennedy, 2007). Accordingly, these areas are frequently reported close together. This suggests that while *independence & autonomy* remain primary concerns in WUs' experiences, *social integration & support* also become crucial once independence is attained (Government of Canada, 2021). Previous studies have confirmed that autonomy and social engagement together contribute to the unified goal of enhancing a person’s QoL (McClure & Leah, 2021). Users first prioritize autonomy for navigating social spaces, but once achieved, they shift focus to social engagement and support networks.

In *emotional well-being*, WUs may experience a range of feelings, from satisfaction (Domingues et al., 2019) to humiliation, frustration, loss, and humility (Barlew et al., 2013). These emotions arise from various influences, such as the enhanced independence and social participation provided by powered wheelchairs, which increase satisfaction and positive emotions (Domingues et al., 2019). However, these experiences are also linked to self-identity factors (Barbareschi et al., 2021). Therefore, emotional well-being likely results from a complex interplay of factors, highlighting the need for future studies to systematically explore the relationship between emotions and these domains.

4.3 Design Insights Based on the Themes

To address the *Foundations: Autonomy & Control,* optimizing devices and environments is essential for enabling WUs to feel independent and engage equally in social interactions. This involves both city infrastructure and transportation planning, as well as integrating advanced features into wheelchair development. Technical experts can play a crucial role in addressing potential discomforts. These efforts can be expanded to help ensure that, WUs feel no discrepancies between themselves and others. For example, aligning accessible seating with regular seating on buses can promote a sense of normalcy. Additionally, while ensuring environmental optimizations (e.g., obstacle-free buildings, ramps, and handrails), it is important to consider WUs' safety and communication—key elements of control—within social contexts through advancements like external Human Machine Interfaces (eHMIs) (X. Zhang et al., 2024). These technical interventions collectively enhance WUs' sense of autonomy and control.

While autonomy and control create the foundation for WUs to engage in social life, targeted policies and interventions are necessary to ensure their participation is fully supported. To enhance social integration and support, collaboration among social service providers, urban planners, and designers could help create environments that foster natural social integration (Cucuzzella et al., 2024). This can include designing public spaces, such as parks, plazas, and cafes, where the layout invites interaction, such as accessible seating arrangements interspersed with general seating, rather than isolating accessible seating to the periphery. Social programs that pair WUs with non-disabled peers in collaborative or recreational activities (Smith et al., 2016) can help break down barriers and reduce social stigmas (Damsté et al., 2024). Another impactful intervention is creating inclusive workplaces where employers actively support WUs through mentorship programs and adaptive work environments (Strauser et al., 2024). These interventions aim not only to reduce physical barriers but to cultivate a society where WUs feel fully integrated and supported in their everyday interactions.

However, social participation for WUs, is often accompanied by challenges, particularly in navigating societal assumptions and biases. While many people claim not to hold prejudices against individuals with disabilities, research shows that WUs continue to face significant stigma, leading to feelings of isolation, discomfort, and depression (Saia et al., 2024). This is central to the theme of Reflection: Self- & Social-Identity, where societal perceptions and stereotypes heavily influence how WUs view themselves and are viewed by others (Barlew et al., 2013; V. de S. P. Costa et al., 2010; Edberg & Persson, 2011). A key factor in shaping these perceptions is the wheelchair itself, often seen as a symbol of disability. Designing MAs purely for function, without considering their social and aesthetic impact, can perpetuate stereotypes (Rasoulivalajoozi & Farhoudi, 2025b). Integrating elements of emotional appeal, such as inspiration and empowerment into design can transform both user (Desmet & Dijkhuis, 2003) and societal perceptions. Studies show that modern, innovative designs elicit positive emotional responses from users (Rasoulivalajoozi & Farhoudi, 2025b; Faraji & Valajoozi, 2014; Carneiro et al., 2018), and the public (P. Costa et al., 2012). Shifting from traditional designs that emphasize limitation to those conveying activity, confidence, and individuality helps reshape society's view of WUs. Additionally, diverse visual representations of WUs in public spaces—depicting active, diverse individuals across age, gender, and ethnicity—can challenge stereotypes and promote inclusivity (Bühler, 2022). Ultimately, these interventions support WUs in not only escaping an identity confined by limitation and dependence, but in cultivating one rooted in self-fulfillment and empowerment.

4.4 Limitations and Future Studies

Since the literature search was conducted, additional studies may have been published that could have been included. Nevertheless, the current review provides a broad overview of the literature, spanning over 23 years of research. While this study focused on the themes emerging from WUs' socio-emotional experiences and the design insights based on those themes, future research could also consider the policy and practical implications, thereby helping to bridge the gap between theory and tangible improvements in the QoL for WUs. In terms of policy, it is needed for inclusivity-oriented interventions and standards that address the socio-emotional needs of WUs (Rasoulivalajoozi et al., 2025b), ensuring that interventions promote autonomy, agency, and social participation. In practice, designers and healthcare professionals could consider perceptual factors, such as self-identity and social identity, to enhance WUs' visibility and public interaction. Specifically, this research calls for further exploration of how design aesthetics influence social perception and interaction.

5 Conclusion

This paper presents a scoping literature review on social-emotional experiences of WUs, highlighting that *independence & autonomy*, *perception of control & agency,* and *social integration & support* are the most frequently reported domains. In contrast, *self-identity & body image*, and *social stigma & discrimination* are the least reported. These categories in turn can impact WUs' *emotional well-being*. Based on these findings, three themes of *Foundations: Autonomy & Control, social integration & support*, and *Reflection: Self- & Social-Identity are* introduced, suggesting areas where design insights could enhance WUs' socio-emotional experiences and QoL.

Representation of Mobility Disability Stereotypes

This section is based on the following manuscript (under review).

Rasoulivalajoozi, M.; Cucuzzella, C.; Farhoudi, M. Dyer, L. (2025). Intersecting Perceptions: A Foucauldian Study of Mobility Disability Representations in Clinical Encounters from Physiotherapists' Perspectives. *Humanities & Social Sciences Communications.*

Humanities & Social Sciences Communications, published by Springer Nature, is a fully open-access journal featuring peer-reviewed research across the humanities, behavioral, and social sciences.

Abstract: While patient-doctor interactions have been extensively studied, how interactions during rehabilitation influence individuals' self-concept—particularly through the subtle reproduction of disability-related stereotypes—has received less attention. This subtle mechanism is often shaped by representations of disability framed through a biomedical or mechanistic lens (e.g., the body as a machine), which can reinforce negative assumptions and dominant discourses about clients with mobility disability. This study seeks to examine the interactional dynamics between clients and the combined entity of healthcare professionals and medical systems, emphasizing representations that contribute to the construction of clients' experiences and self-concepts during rehabilitation. Using representation theories and Foucauldian medical discourse as our framework, we conducted in-depth interviews with 12 experienced physiotherapists, acting as intermediaries between clients and other healthcare professionals and systems. The transcripts were analyzed through a six-phased inductive thematic analysis framework. In the results, three themes were identified: (I) The Complex Medical System, But Reliable Physiotherapy Clinic; (II) A Knowledge-Language Differential in Healthcare Professionals-Clients Talks; and (III) Iconic Representations: Practical Use vs. Perceived Stigma. Each theme was supported by relevant quotes. While dominant stereotypes surrounding disability persist across the rehabilitation steps, physiotherapists' inclusive approaches were differentiated in themes I and II. However, healthcare professionals involved in rehabilitation, including physiotherapists, still reproduce the perception of the body as a machine. The themes identified are not limited to interactions within rehabilitation settings but also extend into wider public discourse, influencing societal perceptions of mobility impairments. Future research should prioritize co-produced approaches that center lived experiences to challenge dominant representations and promote inclusive rehabilitation.

Keywords: Mobility disability; Foucauldian medical discourse; Post-Modernism; Representation theory; Inclusive approach.

1 Introduction

People often claim not to hold assumptions about individuals with disabilities (Lenney & Sercombe, 2002), yet studies and reports show that wheelchair users continue to face societal stigma, correlating with higher levels of depression, pity, and discomfort (Human Rights Watch

Council, 2018; Saia et al., 2024). As negative social stereotypes still exist in social dynamics, even in developed societies that emphasize equity (Asghar et al., 2020), this raises important questions: How and where do such perceptions originate and perpetuate? Are they shaped by individuals with disabilities themselves, or do they primarily arise from societal discourse? Who holds significant influence in shaping these narratives? For instance, do healthcare professionals and systems, as the medical interpreters of health and concept of ability, contribute to shaping their clients' perceptions?

While a range of known factors such as social beliefs (Galli et al., 2015), employment status, personal well-being, and income levels (Fredericks et al., 2024; Pasin & Karatekin, 2024) influence an individual's self-perception of a disability, healthcare professionals are typically the first to inform clients of their mobility-related impairments. Medical experts diagnose and label disabilities objectively, expecting clients to follow prescribed treatments. Thus, aside from the previous perceptions of disability, clients begin to understand and define their role as a disabled person for the first time during the rehabilitation process and interaction with healthcare professionals. This moment of identity negotiation is critically examined by Papadimitriou, who emphasizes how rehabilitation encounters reshape clients' embodied self-understandings (Papadimitriou, 2008). In this context, healthcare professionals may adopt one of two viewpoints: the "human view" or the *medical gaze*. Oliver Sacks, as discussed in Toombs (1990), highlights that the *human view*—which emphasizes the individual patient— uncovers insights beyond clinical data, while the *medical gaze* focuses on the illness itself. These contrasting approaches not only influence doctor-patient relationships (Nielsen-Bohlman et al., 2004), but also have implications for broader public perceptions toward health in both personal and public spheres (Toombs, 1990). These perceptions shape and influence sociomedical discourses on health, as reflected through communication, language, and actions (Showstack et al., 2019; Federici, 2022). For instance, the naming and characterization of disabilities often mirror how doctors articulate these concepts. This naming function reflects what Phelan and Gibson identify as a normative process in rehabilitation discourse, wherein deviation from bodily norms is subtly reinforced through language (Gibson & Teachman, 2012; Phelan et al., 2014).

On a broader level, these perceptions affect representations in indirect interactions, social media, graphics, and public portrayals of assistive devices, which act as implicit forms of language conveying dominant discourses on disability (Krippendorff, 2006; Soleimani & Hossein Halimi, 2012). Such discourses may exacerbate perceptional disparities between patients and healthcare professionals, emphasizing distinct ontological perspectives on disability. For instance, for people who require mobility aids (MAs), wheelchair design—anchored in a rehabilitation-focused biomechanical perspective and often symbolizing disability—may clash with clients' humanistic views, rooted in unique social identities. Notably, Carol Thomas's (1999) social relational model offers a useful lens for understanding how these symbolic representations—such as those embedded in mobility aid design—intersect with societal power structures and exclusionary practices. This disconnect can influence societal perceptions of clients' physicality and movements in ways that differ from their self-perceptions (Barbareschi et al., 2021), potentially shaping a new self-representation that may lead to psychological effects such as isolation, depression, reluctance to use aids in public, and feelings of exclusion (Barker et al., 2004; Mortenson et al., 2022). Therefore, beyond the client-doctor relationship during the rehabilitation process, it is essential to mitigate the medical objective view and promote the humanistic perspective in both direct and indirect representations.

This study, which is part of a larger project tracking the experiences of mobility aid (MA) users, specifically aim to explore physiotherapists' perspectives regarding encounters between clients with mobility impairments and relevant sectors of the rehabilitation process, including clinics, hospitals, orthopedic services, radiology departments, etc. It examines how these interactions influence clients' perceptions and contribute to the representation and reproduction of disability stereotypes during the rehabilitation process. This understanding helps identify and challenge stigma, enabling designs and policies that promote empowerment and social inclusion. Then, we explore the distinct perceptions between individuals with impairment affecting mobility and healthcare professionals during rehabilitation. To this end, we specifically ask: What themes illustrate the various representations surrounding the dominant discourse of mobility disability during the rehabilitation process? And accordingly, how do clients with mobility impairment perceive the body, and disability differently than healthcare professionals? This study employs representation theories, and a post-modernist approach to health, particularly Foucault's medical discourse analysis, to explore themes and interpretations. Representation theory provides insight into doctor-patient interactions and differing perspectives (Street Jr., 2003), focusing on how health-related perceptions shape behaviors and decisions (S. E. Ward et al., 2007). Rooted in French philosophy, Foucault's approach examines the politics of knowledge and power, particularly in medicine (Ristić et al., 2021), uncovering how interactions reproduce distinct ontological views. In this study, we conducted in-depth interviews with physiotherapists, whose extensive client interactions and understanding of healthcare professionals make them ideal intermediaries in rehabilitation (World Physiotherapy, 2019). Their insights, based on experiences with diverse mobility impairments, capture valuable perspectives that may be less accessible through interviews with clients, a vulnerable group. The study's contributions are summarized as follows:

- By exploring the differing perspectives of clients with impairments affecting mobility and healthcare professionals, experts in disability studies and health managers can develop policies and practices to help healthcare professionals adopt new interaction and communication protocols.
- This study contributes to the efforts of relevant experts, such as healthcare administrators, educators, and disability advocates, in developing guidelines to shape socially representative disability-related imagery.

2 Literature Review

The academic literature has extensively explored the representations of disability in media and their significant influence on societal attitudes, emphasizing how social representations impact the lives of disabled individuals (Umar et al., 2024). Reports show that media portrays disabilities through three archetypes: the Victim, seen as a helpless object of pity; the Hero, who overcomes challenges; and the Villain, exemplified by characters like pirates with missing limbs (Media Smart, 2024). Research indicates that these representations are often inadequate, inaccurate, and predominantly negative, resulting in detrimental societal treatment of people with disabilities (Ocran, 2019). For instance, a study reveals that Indonesian mass media frequently portrays individuals with disabilities using passive syntactic structures (e.g., “are given help,” “receive care”) and ableist language, which collectively reinforce stereotypes of dependency and a lack of agency, thereby perpetuating ableism (Priyanti, 2018). To this end, the need for greater reassessment of strategies to combat negative attitudes toward disabled individuals is also emphasized (Derbyshire et al., 2023).

While a comparison of news media representations from 1998 to 2008 suggests a positive shift toward acknowledging the complexity of disabled identities (Devotta et al., 2013), recent research on stigma indicates that MA users frequently face public discrimination, contributing to increased depression and feelings of invisibility (Saia et al., 2024). Furthermore, numerous studies have focused on the general patient-physician relationship to address these disparities (Bensing & Dronkers, 1992; Haskard Zolnierek & DiMatteo, 2009; Roter et al., 1997; Suarez-Almazor, 2004), particularly within Western medicine, where the relationship between patients and the healthcare system has often been subject to criticism (Matin, 2021; K. White, 2002). Building on this critique, a growing body of work in Critical Rehabilitation Studies (CRS) has emerged, challenging traditional clinical understandings of disability by foregrounding its socio-political (Papadimitriou, 2008), embodied, and relational dimensions (Mosleh et al., 2019; Teachman et al., 2020). This perspective encourages rethinking foundational assumptions in rehabilitation and promotes more reflexive and inclusive practices (Teachman et al., 2020). Recent contributions also point to the role of professional discourse in shaping patient experience and power asymmetries during care. For example, Barradell and Scholten (2024) highlight how physiotherapy continues to reflect biomedical priorities that may conflict with patients' lived realities, reinforcing the need for critical engagement with disciplinary language and assumptions. Similarly, a recent Critical Disability Studies–informed study found that ableism persists across individual, group, and systemic levels in academic and healthcare settings, emphasizing the need for inclusive practices to confront embedded biases and enhance accessibility (Feldner et al., 2022). However, to the best of our knowledge, no studies have explored the representation and reproduction of stereotypes during rehabilitation in the orthopedic sector of healthcare, particularly in non-Western healthcare contexts. In such sociocultural contexts, holistic approaches that integrate cultural beliefs with clinical practices influence the prevailing medical discourse (Alkhaibari et al., 2023; Matin, 2021). Additionally, societal attitudes toward mobility impairments play a significant role in shaping the power imbalance between clients and healthcare professionals (K. White, 2002), influencing their (self)perceptions within clinical contexts. Our review highlights that disability representation has been widely studied in areas such as media, the workplace, and public interactions. However, no studies have examined how these representations serve as the foundation for perceptions formed during the rehabilitation process, where clients first become aware of their impairment affecting mobility.

3 Theoretical Framework

This study adopts representation theory, post-modernist views of the body, and Foucauldian discourse analysis to explore how perception of disability is constructed and reproduced in rehabilitation process. These frameworks align with our goal of examining how medical and healthcare spaces, institutional power, and professional interactions shape clients' self-concepts and experiences, reinforcing or challenging dominant disability narratives.

3.1 Representation Theory in Healthcare

Representation refers to the process by which individuals construct their understanding of the world through language, symbols, images, and cultural narratives (Barthes, 1978; Derrida et al., 2016). These representations shape perceptions, attitudes, and behaviors, influencing how people interpret and engage with their environment (Bandura, 1977). In the context of health, extensive research has explored how illness is represented, highlighting key cognitive dimensions such as identity, cause, consequences, and control over an illness across cultures (Keller, 1993; Kleinman et al., 1978; Lau et al., 1989).

In healthcare, representation plays a critical role in shaping doctor-patient interactions and perceptions of health and illness. When doctors and patients communicate, their exchanges go beyond clinical concerns and influence how both parties perceive illness and disability. In the rehabilitation context, the discourse of mobility disability is a network of interconnected ideas, attitudes, and experiences that shape the discourse and identities of both patients and healthcare professionals (Arribas-Ayllon & Walkerdine, 2008). For example, a wheelchair is more than a device — it carries assumptions about dependence that shape how professionals treat clients (e.g., focusing on physical fixes) and how clients see themselves.

From a discourse theory perspective, representation is not neutral. Power dynamics heavily influence how disability is portrayed and understood, both in healthcare interactions and beyond (Hall et al., 2013). In doctor-patient relationships, these power dynamics shape how patients see themselves and their abilities. The entry of power into the semantic circle of representation involves understanding how different groups, conditions, or signs affect perceptions and meanings through power dynamics (K. White, 2002). Representation, thus, can be inherently linked with the dynamic of differences, especially concerning the semantic perception disparities between healthcare professionals and patients (Moradi, 2018). Difference, in this context, is not merely an attribute but a mechanism for creating meaning, constantly constructed and reproduced under the influence of power dynamics (Foucault, 2008). Post-structuralists follow this discussion by arguing that categories like culture, identity, society, and ethnicity are not fixed but are constructed and constantly evolving through discourse shaped by power dynamics (Schrift, 2018; Williams, 2005). In this study, we explore how semantic differences and power dynamics in rehabilitation settings influence clients' perceptions.

3.2 Post-Modernism and Body Interpretation

Modernism emphasizes objective knowledge, scientific progress, and medical intervention in disease treatment, while post-modernism challenges the notion of a universal understanding of the human body (Higgs & Scambler, 1998). In the postmodern era, health is redefined beyond the absence of disease, seen instead as a dynamic, individual experience (Schrift, 2018; Williams, 2005). This shift prioritizes understanding how social and cultural perceptions shape health over merely controlling disease. Critics of modernist medical discourse, such as Michel Foucault and Jacques Derrida, argue against this rigid framework, instead emphasizing the subjective nature of the human body as a collection of individual experiences and interpretations (Schrift, 2018; K. White, 2002). Also, Michael Bury's arguments about the transition from modernity to post-modernity highlight key processes such as *objectification*, *rationalization*, and *subjectification*, which show how medical concerns shift from disease to subjective health considerations (Bury, 1986).

- *Objectification* involves the gradual distancing of medical knowledge from everyday understanding, consolidating it under the authority of experts and institutional control within hospitals and medical systems. Such a process narrows the diversity of illness experiences, reducing them to standardized medical observations and classifications.
- *Rationalization* entails the adoption of a calculating attitude across various aspects of life (Lyon, 1994), extending modern medicine's influence into everyday routines through scientific methods and statistical techniques (Higgs & Scambler, 1998). This emphasis on professional expertise leads to the reflexive integration of health principles into daily life, shaping behaviours and language around health and hygiene.
- *Subjectification*, as discussed by Foucault, introduces new forms of power and control, where individuals, particularly patients, are situated within medical discourses and institutions (Higgs & Scambler, 1998).

In the healthcare context, therapeutic language and institutions shape perceptions of disease and life, impacting self-perception and behaviour (Matin, 2021). Medical language and behaviours exert control over individuals' minds, reinforcing the authoritative role of doctors in shaping health narratives (Higgs & Scambler, 1998). *Subjectification* is pivotal in our study, as clients undergoing rehabilitation are consistently influenced by medical language and interpretations, enforcing the *subjectification* on clients. Post-structuralism challenges fixed meanings in language and culture, emphasizing their construction through language, power, and social context (Fox, 2016; Haghighat, 2007). Language, carrying meaning, power, and knowledge, can amplify an unequal doctor-patient dynamic. Doctors use scientific language, while patients may lack linguistic agency. Michael Bury (1986) presents the main aspects of discourse in health sociology, focusing on *Agency*, *Knowledge*, and *Power*. In this view, the *Agency* emphasizes reducing human agency (e.g., doctors) in discourse systems, treating all subjects, including medicine, as open to discussion (Schrift, 2018). *Knowledge*, according to Foucault in *The Birth of the Clinic* (1994), arises from doctor-patient interactions and hospital structures and is shaped by the healthcare profession's authority in determining truth. Here, post-modernists consider both general knowledge and specialized knowledge to be the products of techniques originating from various cultural backgrounds (Higgs & Scambler, 1998). Power shifted from foundational authority to disciplinary control under pastoral supervision (K. White, 2002), manifested through therapeutic oversight, self-regulation and surveillance, normalization practices, and individualized monitoring within welfare institutions. In the welfare sector (e.g., healthcare) this shift wields significant influence over discourse, shaping both perceptions and experiences (Schrift, 2018).

3.3 Foucauldian Medical Discourse

Foucault examined how bodies are positioned in society as subjects of social control through medical institutions. He described the power dynamics of the medical gaze and its influence on knowledge and social relations (C. A. White, 2004), arguing that knowledge and power are intertwined through discourse, which allows authority figures and social actors to exercise power. Each discourse shapes its own "truth," defining valid knowledge through exclusionary practices (Foucault, 2008), with *power* embedded in social relations rather than possessed by individuals or groups (Foucault, 1994). Furthermore, Foucault contends that discourses exist as various practices that "systematically form the object of which they speak," shaping individuals' actions, thoughts, and behaviours (1972, p. 49). Foucault argued that power relations are embedded within social institutions and that the *gaze* is one way in which power is exerted and maintained (K. White, 2002; Schrift, 2018). He believed the *gaze* permeated various aspects of society, such as medicine, criminal justice, and education, demonstrating how institutions and individuals wield power through observation and surveillance. He illustrates this with an interrogation room where the accused, unable to see the observers behind a glass wall, becomes the object of their scrutiny. In this dynamic, the unseen viewers hold complete control (Foucault, 1995).

In *The Birth of the Clinic* (1994), Foucault examines the medical gaze's role in diagnosis, reinforcing physicians' authority and power over patients. *Gaze* transcends mere observation; it denotes a scrutinizing, surveillant *gaze and* ultimately dominates by transforming perception into a disciplinary mechanism that constructs and regulates knowledge (Flynn, Thomas R, 1993). *Gaze* is important in trying to see the unthinkable matter in human seeing and to open the ways of seeing to the unseen matter (Rajchman, 1988). Doctors employ the power and knowledge to investigate the patient's body and see their body as a subject.

In Foucauldian medical discourse, another significant concept is *biopower***,** which refers to how political power governs populations through public health, demographics, and the regulation of life. The clinic plays a pivotal role in this biopolitical system, expanding healthcare from treating individual illnesses to managing broader "techniques of health" (Foucault, 2010, pp. 1978–1979) that shape both individual patients and the broader population's health and well-being (Ristić et al., 2021). Physicians assumed *medico-administrative* roles that addressed socio-economic factors, alongside *politico-medical* roles prescribing not only treatments for disease but also remedies for societal behaviour to promote a healthier image (Foucault & Rabinow, 1997, pp. 1954–1988; Ristić et al., 2021). In *The Politics of Health in the Eighteenth Century*, Foucault describes how medicine rose within these emerging regulatory systems and power structures (Foucault & Rabinow, 1997; K. White, 2002). Foucault elucidates the concept of *biopower* as follows:

> "*By this I mean a number of phenomena that seem to me quite significant, namely the set of mechanisms through which the basic biological features of the human species became the object of a political strategy, of a general strategy of power, or, in other words, how starting from the eighteenth century, modern western societies took on board the fundamental biological fact that human beings are a species*" (Foucault, 2007, p. 78; Ristić et al., 2021).

In the following section, we used the post-modernism perspective, with a specific focus on representation theory, and Foucauldian medical discourse, to analyse the perception disparities between healthcare professionals, clinics, and clients with impairments. Our aim here is to illustrate the key representational elements through which disparities are reproduced.

4 Material and Methods

4.1 Establishment of the Study Procedure

The authors initially aimed to explore key concepts that reflect how physiotherapists perceive the perspectives of both healthcare professionals and clients with mobility impairments. A shared understanding among all authors regarding representation theory and Foucault's conceptual framework was established. Representations and their associated meanings are trackable in the experiences of physiotherapists, who regularly engage with patients and navigate their process healthcare system (Chartered Society Of Physiotherapy, 2022). Physiotherapists were selected as participants for both practical and ethical reasons, as direct access to clients undergoing active rehabilitation was limited by institutional protocols. Clients with mobility impairments at this stage are considered a vulnerable population who may find it difficult to discuss topics beyond their immediate care needs. However, physiotherapists, as close observers of these experiences, can signal common perceptions and make these visible for analysis. Notably, clients' post-care experiences differ phenomenologically from their lived experiences during rehabilitation (Toombs, 1990). Therefore, we do not claim to represent clients lived experiences directly. Rather, our focus is on how disability is represented and constructed within rehabilitation discourses, and how these constructions may influence clients' perceptions. Physiotherapists, through their close relationships with clients and holistic understanding of the rehabilitation process, can provide meaningful insights into clients' perceptions and experiences. Furthermore, physiotherapists' interactions with a broad range of individuals with mobility impairments—many of whom may not be accessible for direct interviews—made them the most suitable participants for this study. Accordingly, the study conducted semi-structured in-depth interviews with physiotherapists, adhering to the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist commonly used in qualitative studies involving interviews (Tong et al., 2007).

Ethical approval was obtained from the Concordia University Human Research Ethics Committee (Certification Number: 30016116). Participants were informed about the study objectives and gave their written consent. They had the option to withdraw from the study at any point.

4.2 Development of Interview Guidelines and Questions

The questions and guidelines for this study were developed as part of larger research focusing on individuals who use MAs, nine questions were intended for this specific study. To develop the interview guide, two members of the research team conducted a literature review to identify key aspects of the interview questions that could highlight representations and reproductions of disparities and dominant discourses surrounding mobility disability within the framework of Foucauldian medical discourse. To ensure contextual relevance and methodological rigor, we consulted a practicing physiotherapist during the early refinement of the interview questions. Building on this and informed by pre-interview insights, an interdisciplinary panel reviewed and revised the interview protocol. This panel included the study authors—experts in human factors, health sociology, sustainability, inclusive design, qualitative research, and cognitive biases—along with a physiotherapist and a medical anthropology expert.

While the broader interview protocol included several components addressing a wide range of rehabilitation-related themes, the present manuscript draws exclusively on a focused subset of questions aligned with the specific aims of this study. These include participants' perceptions of client-provider interaction, disciplinary language, and the social positioning of individuals who use MAs. Then, for interpretation, the answers to questions related to this study were reviewed (Figure 11), serving as the basis for the current analysis. The key semi-structured interview questions, provided in English, can be found in Appendix D. To uphold the research's validity and rigor, we engaged a physiotherapist for preliminary refinement of questions in the interview. Also, based on pre-interview insights, an interdisciplinary panel, including the authors and two external members—a physiotherapist and an expert in medical anthropology—refined the interview guidelines and questions.

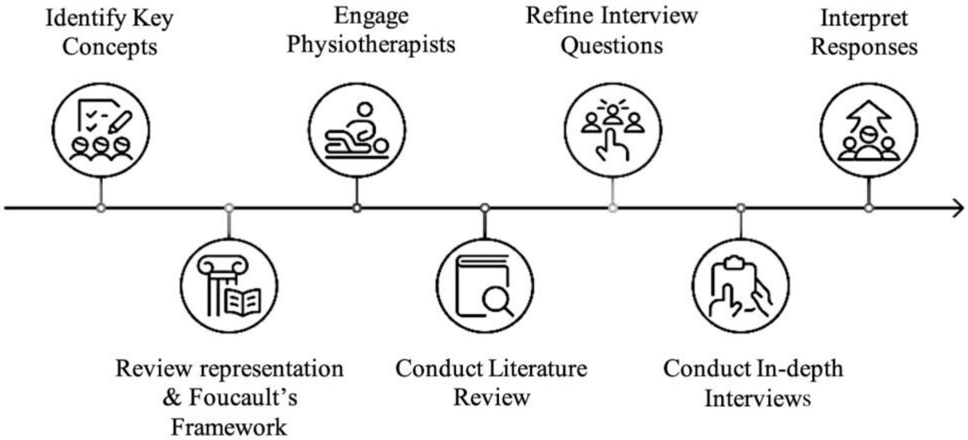

Figure 11. Research process. © Image by Author.

4.3 Recruitment

Experienced participants were recruited based on the following inclusion criteria: (1) registered physiotherapist qualification, (2) over 5 years of experience in private practice or hospital physiotherapy wards, and (3) willingness to provide informed consent and participate voluntarily. Exclusion criteria included simultaneous participation in studies focused on medical, clinical, or medical engineering topics, as these emphasize physical interactions and could overshadow the humanistic aspects explored in the interview. Using a combination of purposive and snowball sampling, 12 physiotherapists, with extensive experience (more than 5 years) working with physical disability patients, agreed to participate in the interview. The interviewers did not have any prior familiarity with the participants. Participant's interview characteristics are provided in Table 5.

Table 5. Background of participants and interview timing (*N*=12).

Participant (P) #	**Years of experience**	**Interview time (Min)**	**Working experiences and profession category**
P1	26	~58/120	Private clinic; Hospital; National Medical Committee of the Olympics
P2	25	~40/85	Private clinic; Welfare organization
P3	15	~22/50	Healthcare center
P4	7	~20/45	Home visiting
P5	13	~38/85	Private clinic
P6	25	~19/45	Private clinic; State welfare organization
P7	18	~33/65	National Medical Committee of the Olympics; Private clinic
P8	19	~30/30	Hospital
P9	21	~30/80	Healthcare center
P10	17	~23/60	Hospital
P11	23	~25/75	Healthcare center
P12	25	~23/60	Private clinic
-	Sum=234; Average=19.5	Sum ≈ 361/840	-

4.4 Data Collection

The interview times and locations were arranged with participants a day in advance, and detailed interviews were then conducted in Persian between March 2022 and February 2023 in private clinics and hospital physiotherapy wards in Kordkoy and Tehran, Iran. Before recording, the purpose and content of the study were briefly explained to the participants. Upon signing consent and confidentiality forms, interviews were digitally recorded, transcribed, and anonymized. All interviews were conducted by the first author, which allowed for a consistent approach in the administration of questions, tone, and interaction with participants. The interviews followed a structured guide a broader study, though this manuscript draws on a specific thematic subset focused on participants' views on disciplinary language, professional roles, and power dynamics in MA provision. The flexible structure enabled interviewer to adjust prompts based on participant responses, supporting deeper exploration of complex perceptual themes.

For the portion of the interview relevant to this study, ~19–58 minutes were specifically dedicated to exploring the selected humanistic themes. While this represents a subset of the overall interview duration—of ~50-90 minutes, the interactions were characterized by high participant engagement and substantial detail, demonstrating remarkable depth despite the shorter timeframe (Irvine, 2011). Factors such as participant expertise, clear alignment of interview questions with study objectives, and focused discussions facilitated efficient data collection, enabling us to achieve thematic saturation within this period. Prior research confirms that interview length alone is not the sole determinant of the depth or quality of data; participant engagement levels, richness of information provided, and relevance to the study's aims (Gilbbons, 2023; Kvale, 2004) collectively influence the efficacy and meaningfulness of in-depth interviews, even when conducted within comparatively shorter duration (Guest et al., 2006). The first was extended to ~58/120 minutes as a pilot and exploratory session that helped refine the interview approach and streamline subsequent sessions, resulting in greater consistency as reflected in Table 5.

A serene environment was upheld to ensure participants' ease and comfort. Participants were provided a flexible time to discuss and reflect on their insights. Interviews continued until reaching saturation**,** which occurred at the 12th interview, when repetitive responses indicated that key ideas had been sufficiently captured.

4.5 Data Analysis

Within 48 hours after the interviews, the audio recordings were carefully transcribed into written text. To enhance the credibility of the analysis, the transcriptions were reviewed with participants to verify the accuracy of their ideas and responses. The interviews were translated from Persian into English and anonymously reviewed by two authors. To ensure translation accuracy, two native Persian-speaking authors, deeply familiar with the culture and metaphors, collaborated closely with a native English-speaking author throughout the translation process. Following transcription and initial verification, the interview data were analyzed using Braun and Clarke's six-phase inductive and reflective thematic analysis framework (Braun & Clarke, 2012). This method involves sequential steps, including familiarization with the data, developing preliminary codes, identifying themes, reviewing themes, defining and naming themes, and producing a report (Braun & Clarke, 2006). The transcripts were entered into Nvivo 12 software for data coding, and an initial codebook was created. Two coders independently performed parallel coding, followed by discussions to resolve any discrepancies in their coding decisions. The codebook was iteratively refined throughout the analysis process to ensure comprehensive coverage of the data and consistency in coding. This iterative refinement helped maintain analytical rigor and allowed emerging themes to be accurately captured. They then met regularly to discuss and resolve discrepancies, achieving consensus on the coding scheme. Following this, the authors applied both semantic (explicit) and latent (underlying) interpretation strategies to synthesize codes into broader subthemes and overarching themes (Braun & Clarke, 2022). This process involved collating, sorting, and examining repetitions, similarities, differences, and gaps in the coded excerpts. Finally, relevant quotes were chosen, and the themes were reported in alignment with our research question (see Appendix E for an overview of the coding and theme development). Importantly, this thematic analysis was situated within a critical-interpretive framework, allowing us to examine not only participants' explicit experiences but also the underlying discourses shaping those narratives (Braun & and Clarke, 2019). We chose this method for its flexibility (Braun & Clarke, 2006), supporting descriptive insights alongside post-structural interpretation. As such, the themes were not treated as purely objective categories, but as meaning-laden constructs that reflect power relations and institutional discourses relevant to our research question (Byrne, 2022).

5 Results

Authors initially established and agreed upon 76 codes that clustered into 8 groups. Subsequently, after further discussion, two researchers identified seven themes and five sub-themes, which were later refined and consolidated into the following three themes: (I) The complex medical system, but reliable physiotherapy clinic, (II) A knowledge-language differential in healthcare professionals-clients talks, and (III) Iconic representations: practical use vs. perceived stigma.

5.1 Theme I. The Complex Medical System, But Reliable Physiotherapy Clinic

Based on this theme, physiotherapists expressed that they found there is a significant opportunity in the role of a physiotherapist to empathize with clients who sometimes share their own stories.

P2: "Sympathy, or understanding pain, is just as present in the minds of physiotherapists as it is for surgeons. However, the short interactions with orthopedics or surgeons don't allow them [orthopedics] to express this sympathy. In contrast, for us physiotherapists, who have more time with patients, this connection naturally develops."

Additionally, physiotherapists highlighted the intricate nature of the medical process from the perspective of clients, acknowledging its complexities and potential challenges.

P1: "Clients often view health organizations [excluding physiotherapy clinics] as the first group to blame, perceiving them as ineffective in providing adequate services."
P1: "They often ask, Are the doctors being honest? They have many doubts about their future health in this treatment system."

Despite this complexity, physiotherapy stood out as a beacon of trustworthiness and stability within the context of healthcare for clients. Physiotherapy clinics emphasized the importance of fostering trust and rapport with their clients, serving as pillars of support within the overwhelming maze of healthcare services.

P3: "Clients are always eager to talk if they feel the opportunity is there [clinics ...They share their own personal stories if they feel comfortable with us."

P6: "*Clients are very open to the treatment process and engage with us at the physiotherapy clinics, often saying, 'I will follow your recommendations.'…They [clients] express that our [physiotherapists] approach suits them better".*

Physiotherapists emphasize that some clients are professional assessors of clinics and usually try several clinics in the rehabilitation steps. Clients strive to validate and congregate their clinic selection through communication with other clients, both within and outside the clinic. This dialog constitutes a significant portion of daily patient interactions.

P9: "Clients comment on the clinic website or talk in private conversations, and there's one thing they often say: they congratulate each other on choosing the clinic."
P5: They are saying, 'I made a good choice picking this clinic, and so you [other clients] were also successful.' They focus more on psychological and behavioral aspects of the clinic, and physiotherapists than on treatment itself."

This theme indicates that in the realm of healthcare, physiotherapy stands out as a reliable and consistent refuge. It diverges from the conventional stereotypes associated with medical clinics, presenting itself as a reliable companion for clients on their path to rehabilitation.

5.2 Theme II. A Knowledge-Language Differential in Healthcare Professionals-Clients Talks

This theme highlights the knowledge-language disparities between involved healthcare professionals and clients, a concept central to Foucauldian medical discourse. Healthcare professionals, excluding physiotherapist, often possess extensive technical knowledge of medical terminology, treatment protocols, and rehabilitation strategies. In contrast, clients may lack familiarity with this specialized language and instead rely on their personal experiences, sensations, and vernacular to articulate their needs and concerns, potentially leading to challenges in achieving mutual understanding.

P1: "Typically, our conversations with colleagues involve technical language distinct from that used with our patients…".

P10: "The technical terminologies are primarily used when discussing treatment procedures. In contrast, clients often express their pains and symptoms using plain language."

P9: "While all doctors or physiotherapists may use a common medical term, the client's interpretation of it might differ, which can mislead the patient."

It reveals a stark contrast between the two parties, but healthcare professionals' way of communication is often perceived as more dominant and authoritative. Here clients are those groups who typically attempt to familiarize themselves with and use the medical term in direct communication with physiotherapists or even in social conversation.

P1: "Initially, clients often take pride in using medical terms in daily conversations, but their expressions reveal their limited knowledge and experience."

Conversely, when physiotherapists adopt a more empathetic and inclusive approach, actively listening to and validating the lived experiences and perspectives of their clients, the disparity in knowledge-language begins to dissolve, enabling a more equitable and collaborative exchange of information.

P4: "We encourage them to describe their pain using their feelings rather than technical terms. We advise, 'Please avoid phrases like 'my ligament is this' or 'my ligament is that' as they are often mispronounced."

P1: "I ask them to speak simply, using their native language. For instance, if someone is Kurdish, Lor, or from the Northern region, even if his Farsi-speaking partner wants to speak, I say let them speak."

5.3 Theme III. Icons Representations: Practical Use vs. Perceived Stigma

This theme of stark contrast in perception highlights the complexity of the relationship between clients and healthcare professionals regarding the interpretation of medical devices and their implications for self-image and identity. In this theme, icons representing ability or disability are interpreted differently. Healthcare professionals, including physiotherapists, assess orthopedic products functionally and technologically, focusing on their effectiveness for mobility and rehabilitation. Whereas, clients often perceive these products as stigmatized symbols of disability, associating them with limitations and societal views of incapacity, often linking them to concepts like "destiny" or "fate".

P3: "We [healthcare professionals and physiotherapists] view disability through the lens of technological advancements, focusing primarily on physical recovery, while disabled individuals see it in relation to aging, weakening, and the need for assistive devices in daily life."

P2: "They sigh. They believe that this [mobility impairment] is a form of retribution and punishment for their past actions…."

Clients experience mobility limitations and a loss of social roles as a result of their reliance on assistive products. In addition, the protocols prescribed by healthcare professionals, emphasized by the use of assistive products, reinforce a deviation from the clients' sense of ability.

P2: "Some orthotics may not suit certain clothing, creating an unflattering look or highlighting the illness, marking 'I am a patient' in society."

P6: "Clients imply that their prescribed assistive devices reflect their miserable circumstances..."

In this context, clients value physiotherapists' efforts but often express frustration, noting that healthcare professionals, including physiotherapists, cannot fully grasp the depth of their disability-related struggles since they have not experienced them firsthand. In response, physiotherapists often group clients with similar mobility levels during rehabilitation sessions, creating a sense of solidarity among those facing comparable challenges and reducing disparities.

P11: "Healthcare professionals view themselves as a caregiver, separate from the disability experience. Even a physiotherapist cannot fully understand their clients, as knowledge does not equate to lived experience…."

P6: "Clients often say; You've seen disability more than others, but you are not disabled."

Clients' negative emotions extend beyond clinics and are intensified in social and environmental contexts. Every instance of environmental inaccessibility reinforces their perception of disability. Consequently, in social settings, clients with mobility issues feel a lack of societal respect for their needs as equal citizens. This perception may arise from a dominant discourse that promotes only idealized bodies in the media. Comparing their bodies to those of able-bodied individuals, and even to their past selves, exacerbates their sense of inadequacy.

P8: "...In an unsuitable environment, mobility devices can be perceived as an insult [for clients], leading to feelings of shame and helplessness, like the sense of fear and shame after falling downstairs."

P2: "They compare themselves to the images of bodies that the media and their financiers decide and promote unhealthy bodies.... They feel they are far from the ideal body shape [advertised in media]."

P7: "Usually, many patients often stay in the past, leading to depression. This [depression] in all exaggerated and ironic form reaches the point where they [clients] say that when I was young, I was a judo player or when I was young, I was a basketball player..."

In this context, physiotherapists argue that the media not only misrepresents the ideal body but also showcases unrealistic body shapes. Here, feelings of inadequacy stemming from limited environmental accessibility are shaped not just by medical discourse but also by industries that leverage medicine's perceived authority.

P1: "The media cooperate with industries and the economy and often advertise something that is not good for the health of the body."

MAs, along with their connotations, also shape public attitudes and stereotypes. Participants noted that MAs, like wheelchairs or canes, carry symbolic meanings beyond functionality, often embodying societal stereotypes and stigma in clients' and people's views. This issue is not a concern of healthcare professionals. Clients with impairments affecting mobility may experience feelings of marginalization or stigma when using MAs, as these reminders of perceived differences and limitations can evoke emotional reactions such as anger and depression.

P5: "When using such products (MAs) in social situations, they [clients] feel that people treat them with pity... They [clients] feel shy and frustrated in public and therefore hesitate to use them [MAs] in public."

Under such negative social perceptions and stigmatization, clients may resist acknowledging MAs. However, their perceptions can vary depending on factors such as personal background, social context, and the cause of their disability. To address such social representations, participants often highlighted that the design and appearance of MAs, along with technological enhancements, can enhance the credibility of assistive products and positively influence user acceptance.

P1: "*Being socially perceived as a hero is different from being a fugitive or accused. Being [socially] accepted as someone whose fingers were cut off [according to religious law] for theft and someone whose finger is injured like Hans Brinker [Refers to Mary Mapes Dodge's novel about a boy who saves Amsterdam by plugging a dike leak with his finger] is very different."*

P12: "The beauty of assistive products can influence MA users' preference by 30-40%, which is significant for us [physiotherapists].

During coding, we highlighted the intersection of perceptions on disability between clients and healthcare professionals, rooted in their distinct ontological views, and categorized these under each thematic group (Table 6).

Table 6. Physiotherapists' reflection of ontological differences between clients and healthcare professionals.

Themes	**Individuals with mobility issues (Clients)**	**Medical professionals**
The Complex Medical System, But Reliable Physiotherapy Clinic	- The clinic involved the authority of medicine, but physiotherapy is different. - A place for reminding the pains, mostly socially. - Experiencing the first step of dysfunctionality. - Passive role in the clinic space, but not perceived for physiotherapy clinic. - Social support required (physiotherapy clinic provide it).	- Clinic is a place for recovery. - A place for improving the clients' anatomy. - Beginning the first phase of recovery. - Active role in the clinic space. - Medical considerations is the priority.
A Knowledge-Language Differential in Healthcare Professionals-Clients Talks.	- Experiencing disability in daily activities. - Social identity is under the effect of medical language. - Passive and receptive of med-knowledge. - Experience the lived time of disability. - Feeling pain and discomfort in the X region of the body and decreasing social interactions. - Using plain language in the description of pain.	- A biomechanical disruption. - Representation of the body as a biomechanism is the highest priority. - Active role in using *power-knowledge*. - Measuring the recovery with objective time. - Losing the muscle skeleton ability at X regions of the body. - Authority on medical terms.
Iconic Representations: Practical Use vs. Perceived Stigma	- Using the MA* for handling the daily activities. - MA are icons of dysfunctionality. - Using MA labels clients as a movement-disabled person. - Interpretation of the clients' body and MA in social context as a second-class citizen - Passive receiver of prescription.	- Using the MA to arrive at the standard of walking. - MA is anatomical functionally. - Using MA represents clients' needs in mobility. - Interpretation of white coat of doctors as an owner of specialized knowledge. - Active writer of prescription.

* MA = Mobility Aids

6 Discussion

In this study, our objective was to decipher the representational scenarios wherein clients' perceptions of mobility-related disability stereotypes are reproduced during the rehabilitation process. Applying representation theories and a post-modernist perspective, particularly Foucauldian medical discourse, we analyzed interviews, identifying three themes. The interpretation of these themes shows how initial interactions with the medical system and its professionals reproduce disability stereotypes and shape clients' perceptions within a medical discourse that contrasts with their more humanistic perspectives.

Theme I highlights the complexity of rehabilitation steps and the role of medical clinics, which becomes more evident when clients evaluate clinics in or beyond the clinical setting. However, this issue is less prominent for physiotherapy clinics, where extended sessions during rehabilitation provide clients with opportunities to share perceptions of their bodies and abilities. These interactions are often perceived as fostering empathy and patient-centered care [72]. Yet, such perceptions need also be understood within institutional discourses that shape how clients engage, express progress, and navigate recovery. Rather than standing outside biomedical authority, physiotherapy settings may reconfigure it through more participatory forms. While participants perceived themselves and their fellow physiotherapists as offering more intimate engagement opportunities compared to other healthcare professionals, this perception may reflect professional self-positioning rather than a distinct structural difference. Physiotherapy professional identity is fluid, shaped through negotiation within professional communities and influenced by workplace and institutional structures (Hammond et al., 2016). Compared to other healthcare professionals, physiotherapists often engage in longer-term interactions, allowing for a relational approach that clients interpret as supportive. The client-centered approach in these clinics enables clients to navigate the medical process more freely, reducing bureaucratic barriers and feelings of subjectification. Participants think that clients see these clinics as supportive when physiotherapists' authority is less dominant, aligning with studies showing a recent shift in medical authority toward patient-centered care (Stivers & Timmermans, 2020). These observations also resonate with debates in disability studies: the paradox of improving function while valuing disability as diversity. The ICF[1] model offers a way to navigate this tension by framing disability at the intersection of individual ability and social context (Roush & Sharby, 2011).

Physiotherapists perceived that, although clients often see physiotherapy clinics as more personalized than public welfare institutions, this individualized model reflects broader socio-political values emphasizing self-management and individual responsibility. In line with previous studies, they noted that their clients appreciate empathy and genuine concern (Steenbruggen et al., 2022), which fosters mutual trust (Cucuzzella et al., 2024); however this trust may also be shaped by professional norms that define the "ideal" patient as active, motivated, and emotionally

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[1] The International Classification of Functioning, Disability, and Health (ICF) is a framework developed by the World Health Organization (WHO) to understand and describe health and health-related states.

engaged.

According to Foucauldian medical discourse, clinics operate within biopolitical frameworks that regulate bodies and populations (Ristić et al., 2021)**.** Previous studies have shown that physiotherapists' narratives often reflect and reproduce dominant discourses in rehabilitation, highlighting tensions between biomedical frameworks and clients' lived experiences, as noted by Barradell and Scholten (2024). However, in this study, physiotherapists described their clinics as enacting these frameworks differently—placing greater emphasis on empowerment, engagement, self-management, and rehabilitation rather than on disciplinary control (Diener, 2021). This distinguishes their approach from the more regulatory focus typical of other healthcare professions or welfare policies. This contrast mirrors cultural critiques, such as the film *Patch Adams* (Shadyac, 1998)**,** which challenges doctor-centric approaches and emphasizes patient engagement. We contend that strengthening autonomy and active participation reduces the dominance of clinical authority discourses. Additionally, the interior design of physiotherapy clinics reinforces this perception. Unlike traditional medical spaces featuring complex devices and instructive pictograms, physiotherapy clinics often resemble gyms with visible rehabilitation equipment. Recent studies suggest that the concealment of medical devices can alleviate fear, enhance trust, and improve patients' mental well-being (Cucuzzella et al., 2024).

Theme II highlights the knowledge and language gaps between clients and healthcare professionals. Despite healthcare providers recognizing the value of plain language, doctors often use terms that patients struggle to understand, up to seventy times per encounter (LeBlanc et al., 2014; Pitt & Hendrickson, 2020). This may result from varying medical knowledge, language proficiency (Dahm, 2012), and communication skills in routine clinical interactions (Kenny et al., 2010). In addition, time constraints and management challenges in hospitals and orthopedic clinics may limit client interaction, hindering physician-patient communication (O'Reilly et al., 2022; Rasoulivalajoozi & Touir, 2023). In rushed examinations, doctors often prioritize efficiency, using jargon and abbreviations that can confuse patients and discourage them from asking further questions (Tariq & Sharma, 2024). Conversely, some studies suggest that advising doctors to avoid or clarify jargon may be ineffective (Dahm, 2012), highlighting the need for further investigation into its role. Nevertheless, our interviews showed that physiotherapists demonstrate empathy and inclusivity by avoiding medical terms, positively impacting client integration (Rasoulivalajoozi et al., 2025b). These discrepancies in using jargon, learned through medical training (Johnsson et al., 2018; Luke, 2003) and plain language by clients, not only create communication barriers (Dahm, 2012) but can also reinforce a power imbalance, leading clients to perceive themselves as lower in hierarchy than doctors. Hence, as shown in Theme II, clients may feel pressured to learn medical terminology to communicate effectively, reinforcing healthcare professionals' authority and their own passive role. This dynamic mirrors Foucault's concept of *power-knowledge*, where power operates through knowledge systems, shaping social hierarchies (Foucault, 2008; K. White, 2002). In this context, while physiotherapists often appear more accessible, we interpret their narratives not as direct evidence of relational truth, but as discursive positions shaped by their institutional alignment with biomedicine (Dalboni et al., 2023). From a Foucauldian perspective, these speaking positions reproduce certain normative assumptions while also negotiating space for more inclusive representations of disability.

Theme III illustrates how disability icons, like wheelchairs, are perceived differently by healthcare professionals and users, shaping their views within and outside clinical settings. While healthcare practitioners, including physiotherapists, focus on functionality and technological advancements to aid mobility, users often perceive these icons through the lens of broader social discourse, sometimes associating them with weakness and incapacity (Papadimitriou, 2008). This contrast is further emphasized by the appearance of two sides: healthcare professionals, in formal attire and stethoscopes, symbolize authority and observation (Luke, 2003), while MA used by clients serve as symbols of disability, reinforcing stereotypes and potentially making clients feel they belong to a lower-ability class, widening the perceived gap (Nimmon & Stenfors-Hayes, 2016; Rasoulivalajoozi et al., 2025a). These symbols act as tangible reminders of physical limitations, impacting clients' psychological experiences (Taleporos & McCabe, 2002), and reinforcing disability stereotypes. This also reflects a deeper issue: physiotherapy's 'body-as-machine' focus limits attention to social and psychological dimensions of disability (Nicholls, 2019).

This representation extends beyond the clinic into the public sphere, emerging in environmental accessibility and the symbolic perception of MA within society. For instance, each environmental inaccessibility encountered by clients can serve as a reminder of disability, reproducing stereotypes about disability (Rasoulivalajoozi et al., 2025b; Vennavally-Rao, 2022). Consistent with prior research, our findings demonstrate how individuals in such unequal situations experience frustration, anger, and feelings of marginalization (Barlew et al., 2013). These feelings may intensify as clients unconsciously compare their current bodies to their past selves and societal beauty standards promoted by the media (Aparicio-Martinez et al., 2019; Jiotsa et al., 2021). Furthermore, unlike other medical accessories, MA are designed for use and independence in public settings rather than in the internal space of the clinic, influencing public judgment, perceptions, and social identities (Barlew et al., 2013; F. Chan et al., 2009). Therefore, the symbolic representation of assistive products, such as wheelchairs, functions as a language in social contexts (Soleimani & Hossein Halimi, 2012). The design and aesthetic appeal of these assistive products can help mitigate negative stereotypes surrounding disability (Rasoulivalajoozi & Farhoudi, 2025b, 2025a; Dos Santos et al., 2022). Conventional MA designs, shaped by a mechanistic view of the body and collaborations between medical engineers and professionals, prioritize functionality over aesthetics (Faraji & Valajoozi, 2014). However, this could change with a redesign of the wheelchair's symbolic appearance to emphasize personal expression and social identity (Desmet & Hekkert, 2007; Krippendorff, 2006). For instance, in the X-Men movie series, Professor Charles Xavier's wheelchair transforms him from a disabled individual into an empowered superhero (Annalee, 2017). His wheelchair symbolizes strength, agency, and empowerment rather than disability, illustrating how design can challenge prevailing stereotypes and become integral to identity**.** While wheelchair designs have evolved, they still follow the modernist principle of 'form follows function,' or "functionalism" (Craven, 2019). This lack of social polish reflects a mechanistic approach, prioritizing biomechanical and machinery aspects over social considerations. The human-machine perspective on the body, exemplified in series like Inspector Gadget (Chalopin et al., 1983), offers a critical view of the body as a machine (Eveleth, 2018). The wheel stands out as a symbol of this mechanistic perspective in MA like wheelchairs, prominently featured in pictograms for user identification (Dawood, 2018). We believe that industrial symbols, such as the wheel, perpetuate a mechanistic view of the body in these products. Therefore, we recommend that future design studies aim to counter the dominance of purely biomechanical representations of MA by developing them to include emotional, symbolic, and socially situated dimensions, which may help challenge stigma and promote more holistic engagement.

7 Conclusion

Under the representation and post-modernism framework particularly the Foucauldian medical discourse, we decoded the representations, wherein differential ontological views regarding the body and disability between healthcare professionals, and clients are reproduced. The identified representations are categorized into three themes. We showed that representation in the rehabilitation steps still reproduces stereotypes and interpretations of disability, despite themes I and II highlighting some exemptions for physiotherapy clinics and physiotherapists’ approach in their communication. Indeed, within the context of Foucauldian medical discourse, although physiotherapists are part of the medical system, their approach does not fully align with the dominant discourse of medicine. Physiotherapists and their clinics adopt an inclusive approach aimed at mitigating the dominant discourse surrounding disability, allowing them to intentionally prioritize empathy and inclusivity throughout the long-term rehabilitation process. However, within all healthcare professionals engaged in the rehabilitation process, including physiotherapy, the perception of the body and the concept of disability persistently reproduce the notion of the body as a machine, identified by iconic representations (e.g., MAs). These understandings illustrate how the concept of disability is constructed and reproduced through initial interactions within the medical system, and how this framing limits clients’ sense of empowerment and hinders social inclusion. This contrasts with the client's perspective, which predominantly interprets the body and disability through the lens of social aspects. This doesn't imply that clinical recovery isn't essential to them, but it also highlights their social needs—not fully considered by healthcare professionals. All themes discussed can extend to public discourse, reinforcing the perceptions of negative stereotypes of disability. Following physiotherapists' inclusive approach (Themes I and II), we suggest promoting inclusivity across all forms of interaction, services and assistive product design to help alleviate negative stereotypes in movement disability discourse. Finally, the Foucauldian medical discourse provided a framework for identifying and tracking how representations of imbalances, inequities, and stereotypes surrounding disability are perpetuated.

7.1 Limitations and Future Studies

In this study, our access to clients' perspectives during rehabilitation was limited due to ethical considerations. Our findings need to be read in light of the epistemic asymmetry inherent in clinicians speaking about, rather than with, clients (Freeman, 2015; Wardrope & and Stewart, 2025). As emphasized in critical disability studies, the absence of lived voices risks reinforcing the silencing of disabled individuals (Yoshida & and Shanouda, 2015). Future research should establish ethical protocols to investigate clients' thoughts more comprehensively. While physiotherapists provide valuable insights through their close interactions with MA users, future research should also incorporate the lived experiences of these users, along with perspectives from other stakeholders, to support a more holistic understanding and inform user-centered design and policy. Although physiotherapists appeared to approach certain aspects of modern medicine differently in the two themes, this may reflect their tendency to present their profession in a favorable light during interviews. Nevertheless, we attempted to analyze the data through both semantic and latent dimensions. We recommend that future studies compare the interviews of all healthcare professionals involved in the rehabilitation process. Additionally, investigating medical discourses on disability within social contexts—beyond clinical settings and rehabilitation periods—could provide valuable insights. For example, future research could use the WHO’s ICF (2002) framework to integrate medical, social, personal, and environmental factors, better capturing MA users’ experiences and promoting an enablement-focused perspective. Exploring representations in real-life scenarios and on social media platforms would enhance our understanding of how stereotypes related to discourse of mobility disabilities are perpetuated.

Chapter II: Interdisciplinary Theoretical Framework. Section 3.

Comfort Aspects in Wheelchair Design

This section is based on a review of previous studies (unpublished edition).

Exploring Comfortability Aspects in Designing Wheelchairs: Presenting a Conceptual Framework.

Abstract: This study aims to find a conceptual framework for understanding the aspects of improving the comfortability of wheelchairs by design interventions. This research is grounded in the argumentative approach and discourse presented in the relevant literature. Accordingly, we initially reviewed the manual and power wheelchair experience, using a product experience framework, drawing insights from existing literature, in which the operational, aesthetic, and symbolic aspects were discussed. Subsequently, a conceptual framework was presented, distinguishing discomfort (physical) and comfort aspects (emotional and expectation-related) across three layers: users, wheelchairs as products, and contextual factors, encompassing both the physical environment and sociopsychological aspects. We described that, while discomfort aspects are prioritized over comfort, the absence of comfort (psychological factors) in wheelchairs can influence their meaning and perception, potentially causing interruptions in continuous use and questioning their fundamental functionality. We showed the dynamic relationship between the sociopsychological context, users' emotions and expectations, and wheelchairs, aiming to enhance comfort aspects. Similarly, the connections between the physical environmental context, wheelchair properties, and the physical processes and limitations of users were presented. We also discussed two controversial considerations of employing advanced technology in wheelchairs: patients' perceptions of others' responses and the duality between independence and social support, which influence both discomfort and comfort aspects. Additionally, we highlighted challenges in improving comfort that can be addressed. In conclusion, we highlighted the limitations and potential areas for future research and emphasized that a comprehensive design intervention should consider both aspects of discomfort and comfort to enhance the comfortable experience of a wheelchair.

Keywords: Comfortability, Design framework, Wheelchair, Discomfort, Product Experience

1 Introduction

Mobility aid (MA) users experience various challenges including physical interaction with the MA, such as repairs, inflexible movement within public spaces, and environmental obstacles encountered in public areas (e.g., uneven ground) (Widehammar, Lidström, et al., 2019) to psychological issues (Barker et al., 2006), such as the social stigma associated with using MAs or difficulties in managing daily tasks (Kapsalis et al., 2022). Considering these aspects is crucial for improving the overall experience and comfort of MA users, leading to greater acceptance and consistent use of their prescribed wheelchairs. In this regard, for developing the comfortable use and experience of wheelchairs, engineering, and ergonomic principles are often prioritized as a crucial role in enhancing the user-product interaction experience (Herrera-Saray et al., 2013), leading to users' comfort during short or long usage (Carneiro et al., 2017, 2018). For example, studies show that the ride comfort of ultralight wheelchairs is often perceived as more comfortable and ergonomically superior compared to lightweight ones (DiGiovine et al., 2000). In this context, rehabilitation engineering and assistive technology have contributed significantly to developing various assistive technologies catering to the physical needs of individuals with disabilities (Szeto, 2005). However, developing comfort is not only limited considering physical factors; the discomfort experienced by wheelchair users (WUs) also involves emotions and public feedback (e.g., humiliation, embarrassment, pain, and undue anxiety) (Barlew et al., 2013), often manifested through the wheelchair serving as a symbol of their disability in social interactions (A. Davies & Christie, 2017). Here, designers, utilizing an interdisciplinary approach, can go beyond integrating engineering aspects by also understanding users' emotions and addressing their socio-emotional needs. This holistic perspective enables the optimization of WUs' social presence and representation. Furthermore, interventions within the environment can account for architectural accessibility while considering social behaviors in various contexts, ultimately reducing negative judgments and fostering inclusion. Therefoe, by incorporating these interconnected aspects in the design-oriented interventions (Vink & De looze, 2008), and shaping a comprehensive conceptual framework, future interventions can move beyond addressing mere physical comfort to fostering a sense of dignity, confidence, and acceptance among WUs.

By taking a comprehensive approach, relevant experts, (e.g., designers and those involved in disability studies) can reshape public perception toward the wheelchair and improve the overall experience of WUs. To achieve this, a comprehensive and contextual understanding of the influential factors on physical and emotional comfort for MA users is necessary. By identifying these factors, we can determine relevant missions and design considerations that should be taken into account. Accordingly, this review aims to argue and explore the concept of comfortability aspects for WUs and emphasizes the design-oriented missions. Accordingly, we present a conceptual framework and approaches to developing user-wheelchair comfortability. This conceptual framework serves as a useful vision for developing design principles that organize comfortability considerations for WUs. We also describe some controversial aspects of using technologies in wheelchairs that might be challenging to develop physical and emotional comfortability. The contributions of this study are as follows:

- Moreover, health managers and physiotherapists can gain insight into clients' wheelchair experiences to understand how physical and socio-emotional factors impact their satisfaction, usability, and overall quality of life. Such insights can guide the development of more personalized rehabilitation plans, improve patient counseling, and inform policy decisions to create a more inclusive environment for WUs.

- The findings and the offered conceptual framework can be employed for identifying accurate design criteria for physical and emotional ergonomic considerations.

This review is grounded in the argumentative approach and discourse presented in the relevant literature. Accordingly, we initially present an examination of the properties and significance of wheelchairs in the domain of assistive technology. Then, we elucidate how the concept of product experience in industrial design aids our comprehension of the WUs' experience which is the primary step toward comfortability. Subsequently, in the fourth section, we discuss the key elements of comfort in design and describe our conceptual comfortability framework in wheelchair design in detail. We also discuss the technological considerations limitations and future research. Ultimately, after reviewing the limitations and potential of future studies, we conclude our study by summarizing the key elements.

2 Wheelchair Profile and Advancements

Assistive technology devices (ATD) encompass products, services, or devices aiding individuals with reduced abilities, including disabilities. ATDs aim to enhance their quality of life, reduce dependence on others, and promote social inclusion and well-being (Szeto, 2005). ATDs utilize a variety of advanced technological facilities based on patients' support requirements. Particularly, the user interface is a key feature, leading to convenience, reliability, safety, comfort, and functionality for the user's (WHO-Asssitive, 2024).

2.1 Categories and Main Features

Assistive devices can be categorized into three main types: (i) mobility devices like wheelchairs and walkers, (ii) devices for assistive learning, and (iii) manipulative devices such as prosthetic devices (Teodiano Freire Bastos et al., 2017). In this study, we focused on Mobility devices, specifically wheelchairs. Presently, wheelchairs can be categorized into four main types. The first is the commonly used *manual wheelchair*, which can be propelled by the user or assisted by a caregiver. The second type is the *motorized wheelchair* powered by batteries. The third type is *mobility scooters*, suitable for reasonably able individuals. Lastly, there are sport-specific wheelchairs, which provide increased manoeuvrability and speed for athletes (Teodiano Freire Bastos et al., 2017). As we focused on the wheelchair, the general character and physical features of manual and powered wheelchairs are presented here: Manual wheelchair typically features a metallic tubing body with a cushioned seat and four wheels. It is ideal for individuals with limited upper limb strength or lower limb issues (Hasnan, 2018), offering benefits such as low cost, easy availability, a lightweight design, and a sturdy frame. Manual wheelchair Weight is between 13 to 20 kg with dimensions approximately 610 to 760 mm wide and 1100 to 1500 mm long, carrying up to 113 kg or sometimes 160 to 200 kg (Teodiano Freire Bastos et al., 2017).

2.2 Powered Wheelchairs

Powered wheelchairs rely on power electronics systems for improved stability, including additional wheels and a low center of gravity to support the heavy batteries and motors. The powered wheelchair specifications are as follows: Material and feature: steel, aluminum, or carbon-fibber-based frames come, equipped with adaptive cushioning, sensor-based navigation, emergency calling features, and user-friendly controllers. Weight: between 36 to 70 kg, chassis size: about 1040 mm (long) and 530 mm(wide), power motor: ranging from 100 to 320 W (at 24 V), allowing for driving distances exceeding 30 km (Teodiano Freire Bastos et al., 2017). To use motorized wheelchairs, individuals require adequate upper limb control and strength (knadmin, 2017) to operate the joystick and visual capability to navigate around people, obstacles, and hazards (Sandoval-Bringas et al., 2022). However, these wheelchairs may not be suitable for areas with inadequate wheelchair infrastructure or poorly designed pathways. Motorized wheelchairs offer a means of social inclusion, enabling people with disabilities to enjoy lifestyles similar to others. However, these benefits are predominantly available in relatively wealthy societies and planned cities (Teodiano Freire Bastos et al., 2017).

3 A Conceptual Framework Toward Wheelchair Experience

To gain a comprehensive understanding of the wheelchair experience, we utilize Schifferstein and Hekkert's human-product interaction conceptual framework. This framework offers a broad perspective on the wheelchair experience. This framework encompasses subjective experiences during interactions with products, including utilitarian physical or non-physical designs, but excluding art. It involves the awareness of psychological effects, such as sensory stimulation, attached meanings, and emotions, resulting from the human-product interaction. A product experience, known as "Erfahrung," that is the result of interaction between user and product, extends beyond physical actions and encompasses various forms of interaction, including passive perception, remembering, thinking, and even anticipation of using the product (e.g., anticipating using your new stereo) (Desmet & Hekkert, 2007). Such interactions can be sensorial or cognitive and play a significant role in shaping the overall experience. The experience itself not only results from the interaction but also accompanies and guides it, influencing the interaction's outcome and eliciting emotional responses (e.g., it can either facilitate or hinder the achievement of goals, leading to a range of emotional responses). The three main components of a product experience are identified as an understanding of product operation and actions (usability function), aesthetic response, and attribution of meaning (semantic/symbolic) (Figure 12). Usability is about understanding how to use a product, the aesthetic response relates to sensory perception, such as the visual appeal, tactile sensations, or pleasant sounds of the product, and the attribution of meaning associated with the significance of the product for users. These components collectively shape the overall product experience (Schifferstein & Hekkert, 2007).

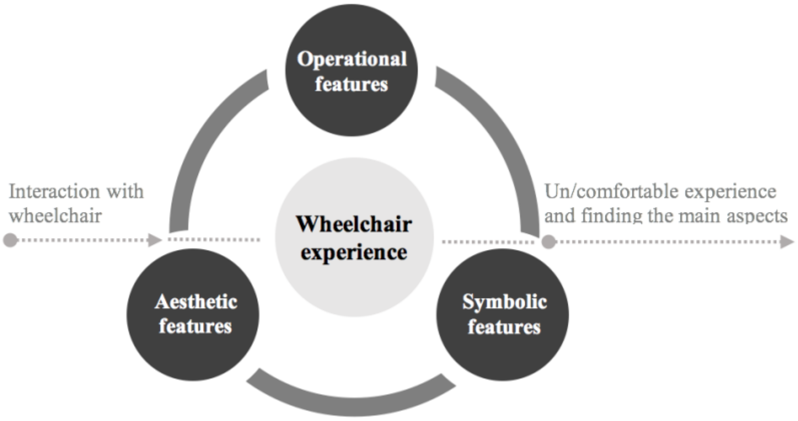

Figure 12. Three main effective features of the wheelchair experience.
Drawing from the conceptual framework of the product experience (Adapted from Schifferstein & Hekkert, 2007).

3.1 A Review of Operational Features

In the realm of assistive products, wheelchairs have undergone significant technological advancements. In recent decades, these advancements have led to the development of battery-powered wheelchairs with motors (Edlich et al., 2004), such as the "TopChair," which can even climb stairs (Heinrich, 2016). Additionally, improved materials have facilitated the creation of sports and recreation wheelchairs, used in events like the Paralympic Games (Cooper & De Luigi, 2014).

These wheelchair advancements have benefited diverse groups of individuals, ranging from those with upper limb strength and control but who cannot walk, to quadriplegics requiring substantial assistance to control the wheelchair. Others who benefit include individuals using wheelchairs for sports, outdoor activities, daily life, and the elderly facing mobility challenges. Consequently, various types of wheelchairs are tailored to cater to individuals with disabilities and limitations. These advancements include *smart wheelchairs* designed to overcome traditional limitations, *autonomous wheelchairs* with control options for those with limited hand control, and *robotic wheelchairs* programmed to transport users between predefined locations (Teodiano Freire Bastos et al., 2017). In this regard, command signals generated by different parts of the human body to control mechanical systems, are employed to enhance user control: For instance, *smart wheelchairs* can be controlled using methods such as Eye-Blink or Eye-Gaze Tracking (Purwanto et al., 2009) (myoelectric signals—EMG) (Nudra Bajantika Pradivta et al., 2019), Speech-Based control, Muscle Activity control, Head Movement, Hybrid Control Options, and Obstacle Detection. On the other hand, *robotic wheelchairs* employ technologies like Head or Face Movements Commands (electrodes—electrooculographic signal, EOG—or through a video camera—video oculographic signal, VOG), Blowing and Sucking Commands, and Brain Waves Commands (electroencephalographic signals—EEG) (Swee et al., 2016). In addition, the person controlling these devices must intentionally generate signals, and the human-computer interaction (HCI) should process these signals reliably and instantly to execute commands that align with the user's intentions. Depending on the individual's condition, different interfaces, such as touch screens or head pointers, may be effective for those with early-stage neuropathy like amyotrophic lateral sclerosis (ALS)[2], but alternative interfaces may be necessary for patients with spinal cord injuries (SCI) (Teodiano Freire Bastos et al., 2017).

3.2 A Review of Aesthetic Features

Aesthetics, rooted in the Greek word "aesthesis," refers to understanding through sensory perception. Much of the aesthetics research focuses on determining aesthetic preference by identifying visual properties of objects, such as intensity, size, and color, however, according to Hekkert and Leder, these properties can be broadly classified into three classes: psychophysical, organizational, and meaningful properties. The psychophysical properties of objects include their formal qualities, such as intensity, size, and color (hue, saturation, and brightness), which are quantifiable attributes. In line with gestalt laws (Behrens, 1998) that consider the aesthetics aspects, the organizational properties involve human tendencies to group elements based on color, pattern, and shape (similarity principle) or to consider unifying properties such as balance, proportion, symmetry, complexity, and variety (Hekkert & Leder, 2008). The meaningful properties in product aesthetics also involve attributing perceived meaning to characteristics such as novelty, strangeness, originality, or outdatedness. These properties are categorized into familiarity and prototyping, originality, novelty, innovativeness, and product expression and association (e.g., feminine, easy to use, etc.).The aesthetic effects of certain properties are also highly dependent on context and social relationships (Hekkert & Leder, 2008). Findings from studies often indicate a universal agreement in aesthetic pleasure that can be applied to products. Lidwell et al show the 125 principles of design in which at least 28 principles consider the ways to enhance the appeal of objects (Lidwell et al., 2010).

In wheelchair design, while these devices are primarily developed for addressing physical disability, the overall aesthetics and appearance are equally crucial for users. Historical analysis shows that the aesthetics of wheelchairs have evolved alongside the prevailing fashion trends of each era (C. Slawson, 2019). Recent findings indicate that while designing wheelchairs that are often associated with societal stigma and seen as symbols of disability presents challenges (Barbareschi et al., 2021) , there are opportunities to address this issue by incorporating an aesthetic framework to improve their visual appeal (Carneiro et al., 2017). Studies suggest that users better accept assistive devices with modern, stigma-free aesthetics compared to those with traditional designs (Carneiro et al., 2015; Walsh & Petrie, 2016; Carneiro et al., 2018). However, an initial assessment of AI-augmented wheelchairs highlights a lack of focus on their aesthetic functions (Ito et al., 2020). Therefore, considering aesthetics and users' perception is vital in wheelchair design, as it can foster greater acceptance and enable users to be seen as active, integrated citizens within their communities (Lanutti et al., 2015).

3.3 A Review of Symbolic Features

Once artifacts are placed in a specific environment and context, they assume identifiable roles. In

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[2] ALS is a nervous system disease that specifically affects nerve cells in the brain and spinal cord, leading to a loss of muscle control (Mayoclinic, 2023).

contrast with natural sciences, it is crucial for designers, to perceive the connections between products and their context of use either environmental, social, or cultural.

In the realm of assistive products, a study that aimed to highlight the societal perception of communicative content (semantic/meaning) of an Assistive Technology product, it is revealed a higher level of social stigma associated with the Assistive Technology product in the UK (United Kingdom) compared to Pakistan (Asghar et al., 2020). Socially, people often claim not to have assumptions about individuals with disabilities (Lenney & Sercombe, 2002), but explicit reports from WUs and implicit psychophysiological measures suggest a clear sense of discomfort in the presence of disabled individuals (Guglielmi, 1999). According to Schifferstein and Hekkert, a range of factors, including skills, concerns, sensitivity, and structural properties of products, contribute to our perception of products. However, the ultimate meaning of products is derived from our interactions with people. Research shows that people's perception of individuals with disabilities results in their different treatment toward this group (Lindsay & Yantzi, 2014).

When we sensorially experience products like wheelchairs, they provide cues on their usage and reveal their function. In other words, through these interactions with people, we can determine the behavior facilitated by a product and identify its primary or secondary functions (Schifferstein & Hekkert, 2007).

The meaning linked with wheelchairs can vary among different stakeholders, including WUs, manufacturers, public transit, and families of WUs. Figure 13 shows how the meanings of artifacts originate from direct stakeholders' conceptions and interactively affect the contextualization of the artifacts (Krippendorff & Butter, 2008). Therefore, the importance of meanings lies in whose perspectives or interpretations we consider, (Krippendorff & Butter, 2008), certainly, WUs are of the highest priority. It has been shown that perceptions of social identity are dynamic and influenced by personal beliefs that can profoundly affect WUs (Galli et al., 2015). In human-product interaction, these meanings are enacted, tested for their capabilities, and adjusted to align with desired objectives.

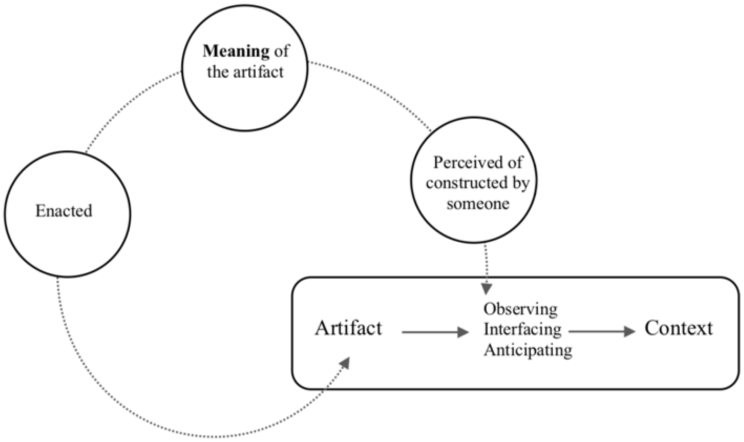

Figure 13. The circle of relationship between artifact and context.
(Adapted from Krippendorff & Butter, 2008).

Combining these aforementioned aspects shapes the emotional evaluation of users (Desmet & Hekkert, 2007; Hekkert & Leder, 2008). According to these reviews, we try to organize and use these three aspects in our conceptual framework of comfortability to improve the comfortable experience for WUs.

4 Key Elements of Comfort in Design

The concept of comfort lacks a universal definition (Vink & De looze, 2008). Webster's dictionary describes comfort as a state of relief, encouragement, and enjoyment. Slater (1985) describes it as a state of physiological, psychological, and physical harmony between an individual and their environment (Slater, 1985). According to de Looze, et al, the literature on comfort generally agrees on three points: (1) comfort is a subjective construct that varies individually, (2) comfort is influenced by factors of different natures (physical, physiological, psychological), and (3) comfort is a response to the environment (de Looze et al., 2003; Vink & De looze, 2008).

In addition, many authors differentiate between comfort and discomfort, highlighting that the absence of discomfort does not necessarily equate to comfort. Comfort is experienced when there is a greater level of satisfaction expected (L. Zhang et al., 1996). Discomfort is grounded in physical processes (L. Zhang et al., 1996); physical aspects (pain, fatigue, Stiffness, etc.), while emotional experiences are more closely linked to comfort (e.g., comfort can be linked to the factors such as feeling well-being and beauty aspect of a chair, including Luxury, Safe Refreshment Well-being) (Vink & De looze, 2008). Therefore, we initially need to categorize the discomfort and comfort aspects of a wheelchair as well.

In the quest to optimize product comfort, a distinct and nuanced approach is necessary for each type of product. Nevertheless, in instances where products share substantial commonalities, a similar approach can be employed (Vink & De looze, 2008). In this regard, as the most visible aspect of a wheelchair is the seating posture of the user, it would be comparable to a regular seat product comfort feature. Hence, we can use the fundamental principles of comfort for chair design as a starting point and then discuss other aspects that are specifically relevant to wheelchairs. De Looze et al. (2003) proposed a model for the comfortability of seating that explains the impact of different factors. In De Looze's model, discomfort and comfort for seating were considered on three levels Human, Product, and Context (de Looze et al., 2003). And for fluent applying this model, Armstrong considered four items of '*exposure*', '*dose*', '*response*', and '*capacity*' as the main issues in discomfort. *Exposure* means the external factors that may disrupt an individual's internal state, the so-called "dose". These disturbances can trigger various mechanical, biochemical, or physiological "responses" based on the individual's physical "capacity" (Armstrong et al., 1993).

4.1 Conceptual Comfortability Framework in Wheelchair Design

In this section, we fully describe our proposed framework to enhance the overall comfortability of the wheelchair experience. The framework consists of three fundamental layers: the human factor, the wheelchair itself, and the contextual elements. Regarding De Looze's model, the components of our framework are also subdivided into two categories discomfort and comfort aspects (Figure 14). Our justifications for this classification and subcategories are presented as follows.

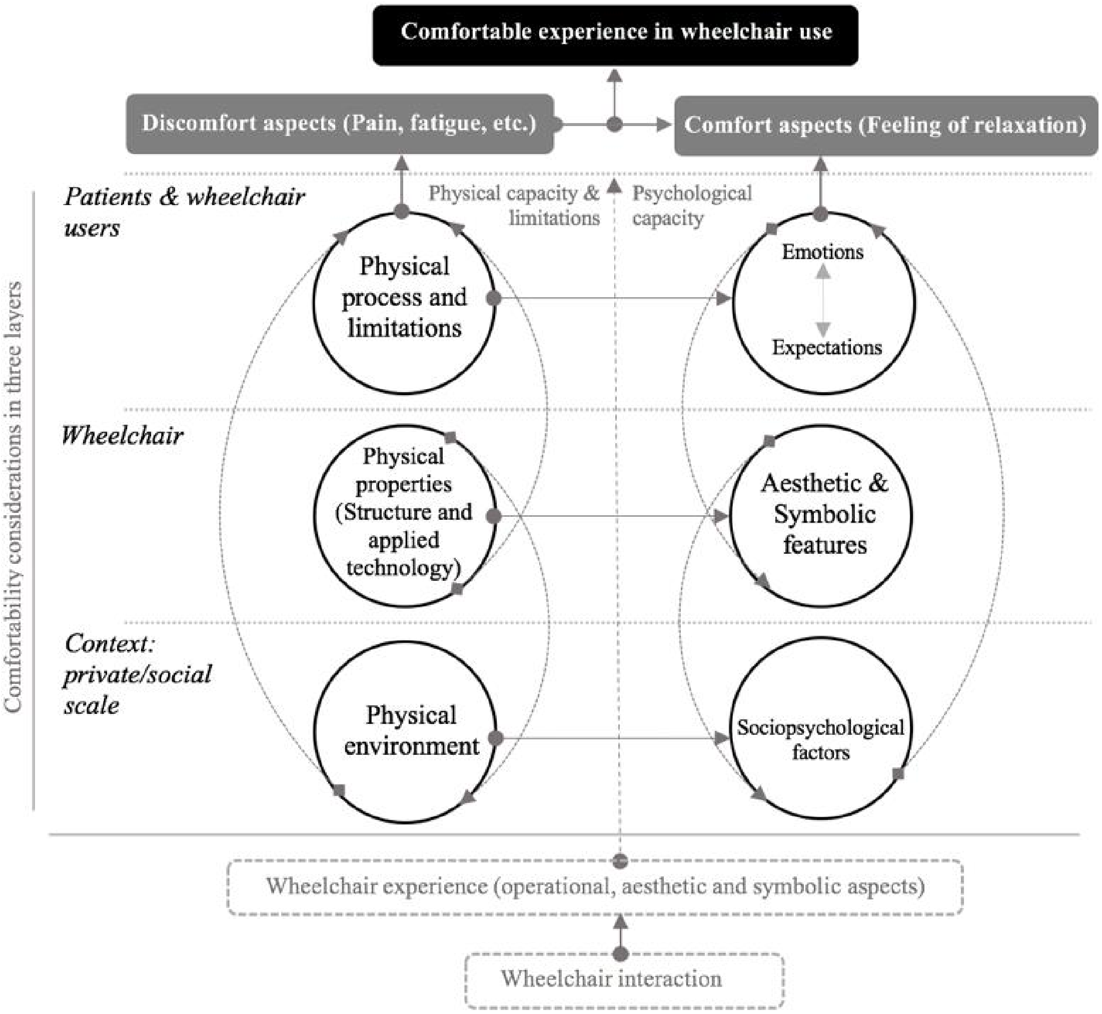

Figure 14. A Conceptual Framework for developing comfortability in the process of wheelchair design. © Image by Author.

Context and environmental layer: Regarding wheelchairs, the physical characteristics of the environment (e.g., private or public) play a significant role in WUs' comfortability (Meyers et al., 2002). For instance, a poor person-environment fit can compromise independence (Steinfeld & Danford, 1996) and may expose WUs to difficult movement situations external physical feedback may generate extra forces and pressure from the wheelchair on the body and joint angles (Rankin et al., 2012). This feedback can lead to internal effects (dose) such as muscle activation, internal force, intra-discal pressure, and changes in skin and body temperature, triggering biomechanical responses (Roman-Liu, 2013). Thus, the lack of compatibility between the physical features of the wheelchair and the environment leads to discomfort and the perception of physical discomfort in the environment might be established through the sensing of such pressure and biomechanical factors. Therefore, physical challenges in the environment can be recognized as discomfort since those physical aspects disrupt the basic expectations of WUs. Also, improper physical environmental conditions can impact both the emotional evaluation and social interaction of users because WUs and those around them notice the WUs' exclusion, and they are reminded of society's limitations regarding disabilities. Accordingly, WUs may be exposed to unpleasant social interactions (e.g., underestimated or lack of mental ability). Such patterns of external feedback in the social context, either direct (e.g., lack of proper interaction from colleagues) or indirect (e.g., sense of presence in an exclusive space or lack of ramp) can also remind their disability and lack of competency. This leads to negative emotions such as depression, isolation, anxiety, and changes in their expectations and state of mind, triggering negative emotional responses (Schröppel et al., 2021). Therefore, these environmental and contextual factors, which are indirectly and dynamically associated with the wheelchair and the user's reflection, are vital to understanding the wheelchair's meaning to the user and arriving at a more positive experience. The pleasant perception of the environment, either indoors or outdoors, can be improved by several strategies including an inclusive design approach and optimizing the spatial experience of WUs. According to the supportive theory of Ulrich, three principles of (1) having a sense of control, (2) access to social support, and (3) positive distraction can positively impact patients' state of mind in the environment if designers incorporate them into the user's spatial experience (Ulrich, 1991). For example, to enhance the indoor environmental design and patients' spatial experience, interventions can range from the structural layout to considerations like window size and color. Accordingly, the sociopsychological issues can be classified in the comfort level, which needs to be addressed after the discomfort of physical environmental challenges.

Product layer: According to our review in section 3, we found that various technologies can enhance movement control and independence for WUs. Such advanced technologies enhance users' mobility and adaptability in various environments, enabling them to overcome environmental obstacles. For instance, ergonomic wheelchairs improve users' compatibility, are easier to use, easier to repair, and easier to move (Soewardi & Afgani, 2019), minimizing the risk of upper limb injuries (Giner-Pascual et al., 2011) or a novel design of Stair-climbing wheelchairs enables access to paths that lack ramps (Prajapat et al., 2020). Nonetheless, there are still occasions when the substantial technology integrated into wheelchairs could disrupt the user's ability to move and maneuver in the internal spaces and restrict their activities within that environment. As an illustration, in Figure 15, the bulky size of the powered wheelchair prevents the user from opening the door. Consequently, she opts to utilize a metal rod to push the door instead.


[redacted]

Figure 15. The bulky size of the powered wheelchair prevents the users from accessing the handle of the door. © Image by Author.

Apart from the physical aspects, the wheelchair experience goes beyond mere usability; which includes aesthetics and symbolic aspects. Understanding the aesthetics and symbolic aspects is critical, especially when we know WUs experience this MA product in public spaces. Accordingly, while technological factors are crucial for the physical movement of the user, aesthetic aspects related to the wheelchair should not be overlooked, leading to significantly influencing the overall evaluation by the user. The aesthetic considerations and style of a wheelchair, in addition to its physical features (i.e., using advanced technologies), can evoke better emotions in users and may enhance their positive emotional response to the product (Hekkert & Leder, 2008). Beauty can initially attract users, but a well-designed operational experience is crucial for retaining their attention in the long term as well. Therefore, we classify the advanced technologies, and aesthetic developments in the discomfort and comfort groups respectively. In this regard, to employ aesthetic principles effectively, considering the interests and perceptions of users is primarily essential, even when universal principles of aesthetics are used (Hekkert & Leder, 2008).

For considering the physical appearance, we can discrete the internal and external aspects of a wheelchair. Many of the commonly used wheelchairs available lack external covers and are primarily designed based on frame structures, which represent wheelchairs as consisting of structural elements (i.e., struts, frames, welded or screwed connections, etc). According to Lidwell and colleagues, the form of products can be categorized into three formats: *mass structure* (e.g., dams, and adobe walls), *frame structures* (e.g., bicycles, and skeletons), and *shell structure* (e.g., bottles, airplane fuselages, and domes) (Lidwell et al., 2010). Similar to its interpretation in architecture, a shell structure in product design refers to the outermost layer or framework of a product that encloses, protects, and often enhances the aesthetic form of its internal components (P. Sharma, 2023; Lidwell et al., 2010). Shell structures are designed to be strong and lightweight, efficiently distributing loads while often serving as the visual and tactile interface (Farshad, 1992). In this regard, adding the feature of a *shell structure*[3] (e.g., covering the wheel or motor of a wheelchair), to the frame structure of a wheelchair, can offer an opportunity to socially polish the

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[3] Shell structures are thin, covered plate constructions that envelop a volume, supporting loads without the need for an internal frame or solid mass material.

external appearance of a wheelchair (Koleini Mamaghani & Farhoudi, 2018). Figure 16 shows a wheelchair with the typical frame structure. This external cover can act as a language of the product (Hernández et al., 2018) and may affect the WUs' interaction and the people around them, the so-called expectation effect (Lidwell et al., 2010), and potentially mitigate the stigma of the wheelchair and disability.

We posit that designing and social polishing the external part of a wheelchair with aesthetics in mind positively impacts the wheelchair's symbolic meanings in a dynamic social context. In other words, there is a reciprocal relationship between the wheelchair's aesthetic consideration and its context, showing how aesthetics influence perceptions, the symbolic meaning of the wheelchair, and interactions with the wheelchair in real-world settings (Interaction Design Foundation, 2023).

Figure 16. Sample of most common type of wheelchairs.
(Left: powered wheelchair, Image by Jon Tyson on Unsplash, and Right: manual wheelchair, Free license image on Freepik).

Human (User) layer: WUs are the central part of a human-product experience, and their needs should be the top priority—among all stakeholders. Therefore, we placed WUs in a place where all considerations concentrate on the users's comfortability. In this regard, we initially need to consider both the physical and psychological capacity of WUs as each user has unique physical characteristics or limitations in both areas. Accordingly, biomechanical features and physical processes of wheelchairs can address discomfort, while emotions and expectations of users fall into the category of comfort.

Both categories of discomfort and comfort at the human level are influenced by the two bottom levels of the wheelchair and context. Alongside an ergonomics approach to address discomfort during wheelchair usage, designers should consider methods that address users' emotional needs and capacity. For this purpose, the Human-Cantered Design (HCD) approach can play a remarkable role in creating—conceptually, linguistically, materially—and utilizing artifacts (Krippendorff & Butter, 2008). This approach is particularly important in the context of WUs, as it considers the enhancement of their physical and emotional comfort simultaneously. According to Krippendorff, K., the concept of the HCD approach is supported by four pillars: *Second-order understanding*; *meanings*; *networks of stakeholders*; and *interfaces* (Krippendorff & Butter, 2008) (Schifferstein & Hekkert, 2007). Accordingly, the design of a wheelchair can be considered via these pillars as well.

- *Second-order understanding* notes that designers need to grasp the perspective of WUs who interact with their design by understanding how they perceive MAs within their own context. Therefore, users' voices should be carefully listened to.
- *Meaning* is understanding of MA users construct their worlds and distinguish wheelchairs based on personal significance, not only in physical terms but how they contribute to communication. Therefore, it is important to see how WUs perceive and engage with our designs.
- *Networks of stakeholders* note that designers must recognize stakeholders, both supporters, and opponents, and embrace their active involvement in the design process. They should view themselves as an active participant within stakeholder networks. e.g., the family of WUs or their colleagues at work can be part of the process.
- *Interface* considers dual or interactive descriptions, relating to the conceptions enacted and monitored by humans and how artifacts support or deny their intended meaning to users. The interface encompasses *recognition* (i.e., wheelchairs are categorized based on what they could afford users to do or prevent us from experiencing), *exploration,* which is identified as a concept of "ready at hand" in Heidegger's school of thought (Chillón, 2017) (i.e., we search for ways to handle a wheelchair), and *reliance* stages, also known as “ready to hand” in the philosophy of Heidegger (Chillón, 2017) (i.e., we can interact with a wheelchair and proceed naturally, and flawlessly). The ultimate goal of HCD is to achieve reliance, where the significance of something no longer requires conscious reflection. (Schifferstein & Hekkert, 2007).

The relationship between users and wheelchairs goes beyond mere recognition and exploration, and over time, it develops into a state of reliance. However, the reliance can be influenced by contextual factors such as negative feedback or lack of usability, and environmental conditions, potentially prompting users to shift back into exploration or recognition. Thus, the meaning of wheelchairs for users can change the shifting of phases. Accordingly, it is crucial for designers to not only consider recognition, exploration, and reliance steps but also to understand the contextual factors during the reliance phase, that may disrupt wheelchair use and trigger negative emotions.

According to Krippendorff, there are methodological differences in understanding meanings when exploring the users (Krippendorff & Butter, 2008). These differences include *observing* how users or stakeholders interact with wheelchairs based on designer-intended meanings, *interfacing* with wheelchairs and participating in the contexts of use and *anticipating* contexts through narratives that attribute meaning to artifacts (refer to Figure 13). For instance, hearing stories related to wheelchairs shapes the meaning attributed to wheelchairs and potential users' expectations, influencing their attitudes and experiences.

In our proposed framework, discomfort is prioritized over comfort factors. Helander and Zhang posit that when users still perceive discomfort, the importance of comfort factors is reduced by the presence of discomfort factors (Helander & Zhang, 1997). Consequently, discomfort tends to overshadow comfort when discomfort factors are present in wheelchairs. If patients perceive a lack of functional benefits from the wheelchair, they disregard the aesthetic aspects of its appearance. Of course, this happens if the patients have no choice except to use a wheelchair. Therefore, descriptors of functionality are placed in higher priority in determining comfort when using a wheelchair, (physical aspects), while descriptors of appearance assume a secondary role (non-physical aspects). However, the absence of aesthetics in wheelchairs can potentially affect their meaning and perception, leading to interruptions in continuous use and questioning of the fundamental functionality of the wheelchair.

4.2 Technological Considerations in Discomfort and Comfort of Wheelchairs

While acknowledging the potential of technological progress to enhance user satisfaction, provide facilities for mobility (Cowan et al., 2012), and drive performance and desired behaviors (Fogg, 2002; Rawat, 2020), it is essential to adopt a discerning approach in its application and thoroughly evaluate the relevant contexts and scenarios. Therefore, to employ advanced technologies in addressing discomfort in designing a wheelchair, some considerations should be taken into account:

Despite the advancements in technology that have addressed various discomforts and provided a sense of control over body movement (Kumar et al., 2021), similar to the feeling of control in space, it is crucial to consider implementing such technologies in wheelchair design. For instance, although mechatronics technology tackles issues related to movement discomfort, and provides more maneuverability and independence in Electric-powered wheelchairs (EPWs) (R. Evans, 2000; Meng et al., 2015), the size of these mechanisms draws attention from others to the user's body and the wheelchair's appearance (Figure 17). This can lead people to perceive technologically advanced WUs as those who have a more severe disorder compared to manual WUs, thereby diminishing positive distractions. In other words, the emotional comfort of individuals is strongly influenced by the attention they receive from people who view them with heightened scrutiny. Patients' perceptions of others' responses to displays of pain and suffering are among the significant factors considered when employing the West Haven-Yale Multidimensional Pain Inventory instrument (WHYMPI/MPI) (Kerns et al., 1985). WHYMPI/MPI is a concise, reliable, and comprehensive tool for chronic pain assessment, divided into three parts. The second part focuses on patients' perceptions of others' responses to their pain, based on cognitive-behavioral theory.

Figure 17. The bulky size of the wheelchair takes up a big space and attracts the most attention. © Image by Author.

The use of assistive technologies can provide physical independence (Steinfeld & Danford, 1996) and social participation to WUs (Smith et al., 2016). However, it may also affect feelings of social support and social isolation among WUs (Emerson et al., 2021), as other people may perceive the technology embedded in the wheelchair as a means of super support for the users. In other words, technologies could help physical independence as part of addressing discomfort, however, the meaning of the need for social support, as a part of comfort, can be reduced. Therefore, we assume that while WUs attain physical independence through embedded technology, they receive diminished social support, since others may think such high-tech wheelchairs provide them the most independence. This relationship requires further exploration. Further, we hypothesized that this effect would be greater for WUs who live alone because this population may have fewer opportunities for human support.

4.3 Addressing the Challenges in Improving the Comfortability

The considerations mentioned above are essential in comfort design. However, translating these aspects into actual design poses challenges. Therefore, it is necessary to explore potential solutions to address these challenges and improve comfortability in wheelchair design.

The complexity associated with comfort highlights the importance of conducting group user tests at various stages of product design. While a MA like a wheelchair should be studied at the group level, certain individual needs such as physical and ergonomic adjustments can be customized. Involving end-users in the design process is crucial since they possess a deep experience with wheelchair use in a long time. This involvement is a key aspect of participatory ergonomics, which focuses on adapting the environment to the human by engaging relevant stakeholders such as end-users, designers, experts, and representatives involved in the buying and use of the end-product (Burgess-Limerick, 2018).

Participatory ergonomics can employ both subjective methods (e.g., questionnaires, interviews, observations, participant observation) and objective methods (ergonomic metric factors). Subjective methods alone can suffice in determining whether comfort is experienced since it is a subjective phenomenon. However, if the results are to be used for wheelchair redesign, incorporating subjective and objective methods becomes useful. For instance, the application of Kansei Engineering in wheelchair design can bridge qualitative emotions to physical aspects, facilitating a more comprehensive understanding of the comfort (Schütte et al., 2004).

5 Conclusion

According to our discussion, it is found that enhancing the comfort experience of a wheelchair is not solely focused on physical factors like addressing discomfort. Social and contextual factors also play a vital role in WUs' comfort. Thereby, we primarily explored the experience of wheelchair properties in the product experience framework that is mostly employed in industrial design. We reviewed the operational interaction and the aesthetical, and symbolic meaning of the wheelchair. We showed that alongside operational advancements, the potential of improving wheelchair aesthetics and symbolism should be highlighted. Also, we cannot overlook the aesthetic context, that is reciprocally linked to the meaning of wheelchairs, in design interventions aimed at improving comfort. Considering these contextual and semantic factors during the initial phase of using a wheelchair can significantly impact users' expectations and emotional comfort, either preventing them from or persuading them to frequent and necessary usage. In this regard, three layers of human (top), wheelchair (middle), and context (bottom) were fully discussed within two categories of discomfort—addressing physical challenges—and comfort—sociopsychological considerations. Each of the key determinants of operational, aesthetic interactions, and symbolic meanings were discussed in our proposed framework of wheelchair comfortability. In addition, the review of wheelchair technologies indicates that most engineering advancements have addressed discomfort factors, leading to increased user controllability. However, the investigation of social and psychological aspects of wheelchair use still remains limited. Although the wheelchair symbol significantly impacts the user's identity, unlike other vehicles, wheelchairs lack a "shell structure," and are limited mostly to "frame structure". This area presents the untapped potential for improving comfort alongside the technologies employed for addressing discomfort.

We discussed that disregarding comfort factors at the product and context levels can disrupt the wheelchair usage process for users as well, in both the short (beginning phase of using a wheelchair prescribed by a physiotherapist) and long term (after some months). While discomfort factors consider the user's physical interaction with the wheelchair during use, comfort factors have a more significant influence on the user's long-term perception and satisfaction with the wheelchair.

5.1 Limitations and Further Research

Peter Vink's research on comfort and design (Vink & De looze, 2008), highlights the importance of distinguishing between short-term and long-term comfort. Since short-term and prolonged use may yield different comfort experiences, evaluating both is crucial in designing wheelchairs for optimal comfort in future studies. A second aspect to consider is the subjective nature of comfort. Each individual has their own perception and opinion regarding the comfort experience of a using wheelchair, making it challenging to design a product that satisfies everyone. This subjectivity complicates the construction of comfort because it is uncertain how each person will respond to a product. For instance, some individuals may perceive their disability as a punishment for their sins, resulting in viewing a wheelchair as a public disgrace rather than a therapeutic means of rehabilitation (Vink & De looze, 2008). In our review, we posited that there is a stronger association between objective measures and discomfort than comfort, as discomfort directly relates to factors like physical exposure, dose, or response, allowing for measurable criteria. As evidence, studies have shown that reducing pressure points alleviates sitting discomfort and supports effective rehabilitation [73]. Goossens et al. (2005) identified a clear link between increased pressure and perceived discomfort [74]. Similarly, research highlights differences in ride comfort and ergonomics across lightweight and ultralight wheelchair designs [75]. Therefore, while physical discomfort, such as fatigue or pain, can be detected through bodily pressure points (Xu & Huang, 2020), socio-psychological factors—such as aesthetic and symbolic aspects of comfort—often remain obscured by feelings of shyness or fear of social judgment. Future projects could incorporate models like Kansei Engineering (Schütte et al., 2004) or Quality Function Deployment (QFD) (Kiran, 2017). to address these factors. Thus, further research is suggested to explore and integrate socio-psychological dimensions of comfort into product design.

Chapter II. Summary and Discussion

This section is based on a review and discussion of the three studies in Ch. II, for answering the question 2 (Q2).

1 Introduction

In Ch. II, we first reviewed the social experiences of wheelchair users (WUs), identifying areas that are underexplored and aspects requiring greater attention (Section 1). Based on these insights, we outlined the domain of design interventions that could enhance their socioemotional experiences. Additionally, we examined WUs' interactions with medical systems throughout the rehabilitation journey, discussing how initial perceptions of disability and understanding of assistive devices are formed and how these concepts are reproduced (Section 2). Finally, by exploring the layers and categories of comfort and discomfort in using MAs, we demonstrated how these aspects are interconnected and how they collectively shape WUs' experiences (Section 3). As all three studies broadly address the socioemotional experiences and perceptions of WUs, synthesizing their findings and connecting their outputs and overlaps provides a foundation for addressing Question 2. To achieve this, in addition to reviewing all three studies from Sections 1, 2, and 3, we discuss how the themes of the studies presented in Sections 1 and 2 connected the emotion and expectations of WUs, as well as the sociopsychological contexts surrounding the perception of MAs. These two aspects were defined within the comfort group in the study presented in Section 3, with the aesthetic and symbolic features of wheelchairs acting as mediators between them. As discussed, these aspects are interconnected, continuously shaping and reinforcing one another. By elucidating these connections (Figure 18), we can respond to the Question: **How are current social perceptions of mobility aids (MAs) shaped, and what design insights can create a more comfortable user experience?** and accordingly, we shape an Interdisciplinary Theoretical Framework for taking the next steps for arriving at SEDPs.

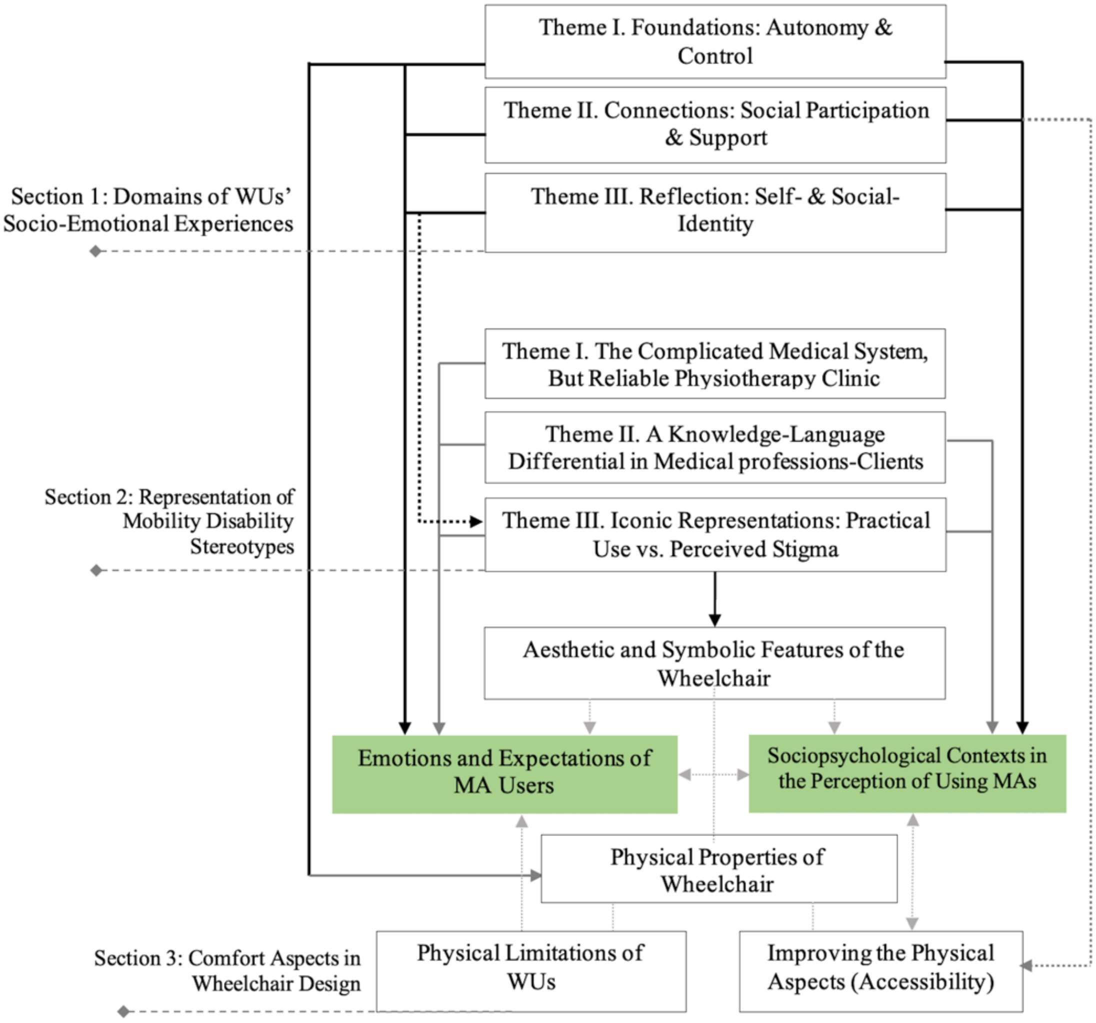

Figure 18. Interconnections between the outputs of three studies in Ch. II: Impact on WUs' emotions, expectations, and socio-psychological contexts. © Image by Author.

The first study shows that among the six domains explored in the socio-emotional experiences of WUs, Independence & Autonomy (26%) were the most frequently reported, while Self-Identity & Body Image (9%) and Social Stigma & Discrimination (5%) were the least reported. Three interconnected themes emerged to guide design insights: Theme I – Foundations: Autonomy & Control, Theme II – Connections: Social Participation & Support, and Theme III – Reflection: Self- & Social-Identity.

Theme I: Foundations: Autonomy & Control can affect WUs' emotional expectations by fostering independence and self-efficacy, boosting confidence, and reducing dependency. This theme also affects the sociopsychological perception of MAs by emphasizing the wheelchair's role in empowering users to independently manage their needs and actively engage in society. However, if the wheelchair conveys traditional notions of disability and social stigma, it can adversely impact broader social perceptions. *Theme II. Connections: Social Participation & Support* also influence both aspects, using the interventions (e.g., encouraging social programs, services, and inclusive environment and service, etc.) as it emphasizes the importance of fostering interactions and social inclusion. It can impact WUs' emotional expectations by creating opportunities for meaningful engagement, reducing isolation, and enhancing feelings of belonging. Simultaneously, it affects sociopsychological contexts by normalizing the presence of WUs in public settings, thereby fostering social acceptance and a culture of inclusivity. Here, as discussed in Section 3, improving physical accessibility serves as a foundational step in facilitating these connections, enabling WUs to engage more in social activities and enhancing the role of social participation in their overall experience.

The study in Ch. II, Section 1 highlighted that while independence and social support are critical, limited research has explored perceptual issues like representational aspects and self- and social identity. Accordingly, *Theme III: Reflection: Self- & Social-Identity* plays a crucial role in shaping both emotional expectations and sociopsychological contexts. Self- and social identity are shaped by social representation, which influences public perceptions of individuals with disabilities. As we discussed, when mobility assistive devices are designed with a fresh, innovative aesthetic, they can challenge stereotypes and positively affect users' self and social identity. Thoughtful design can mitigate negative stereotypes, foster dignity, and even convey a sense of heroic value. For example, as discussed in the study Section 2, iconic elements that reinforce the mechanistic view prevalent in medical discourse should be reconsidered. Wheels—the industry's most symbolic component—are physically attached to WUs' bodies, while users often perceive their wheelchairs as extensions of themselves. Accordingly, when the design of wheelchairs continues to emphasize industrial icons, it potentially can reinforce the notion of the body as a machine, perpetuating a biomechanical perspective. To counteract industrial symbolism, designers should prioritize deindustrialized visuals that highlight the user's individuality and dignity. This aligns with the second study's recommendation to reduce biomechanical symbols in the social representation of wheelchairs. Simultaneously, such efforts to reshape reflections to enhance self- and social identity have a significant impact on sociopsychological contexts. These efforts challenge traditional stereotypes, promote a more positive narrative about mobility disabilities, and encourage society to adopt a more inclusive and nuanced understanding of disability.

Finally, since WUs' aesthetic preferences may vary by context, involving them in the design process is crucial. This ensures their voices and needs are prioritized, leading to more inclusive and representative designs. Additionally, enhancing perceived inclusivity by considering factors such as environmental context, cost, and other relevant aspects—discussed in the next chapter—can influence socio-emotional experiences in daily life.

1.1 Representation of Mobility Disability Stereotypes

The scoping review in Section 1 was expanded in Section 2 through a qualitative study exploring how initial perceptions of mobility disability are shaped by clients' interactions with medical systems. The findings identified three themes influencing WUs' expectations and the socio-psychological contexts of using MAs. For example, *Theme I: The Complicated Medical System,* *But Reliable Physiotherapy Clinic* revealed that clients often find the medical system complex, yet they view physiotherapy clinics as reliable sources of support due to long-term relationships. These fosters trust and emotional reassurance, mitigating the perceived complexities of rehabilitation. As a result, the trust established within physiotherapy clinics helps moderate WUs' negative perceptions of disability, reframing it as more manageable and empowering.

Theme II: Knowledge-Language Differential in Medical Professionals-Clients Talks also influences both aspects. Unlike other medical professionals, physiotherapists use more inclusive language, reducing the knowledge-language gap. Emotionally, language gaps between medical professionals and clients can lead to feelings of exclusion and a diminished sense of control over their rehabilitation. When clients struggle to understand medical terminology, which often expresses the objective signs and symptoms of "disease," they may perceive the rehabilitation process as complicated. Such unfamiliarity can lead them to adopt an "illness" role, reflecting the psychosocial perception of disease. As a result, their behavior and expectations may shift, positioning them passively in feeling illness rather than actively participating in their treatment. These dynamic shapes clients' expectations and affects their use of prescribed MAs, leading to hesitation or skepticism based on preconceptions formed during interactions with medical professionals. In contrast, the inclusive approach of physiotherapists helps clients feel less impacted by the medicalized view of disability.

Finally, *Theme III: Iconic Representations: Practical Use vs. Perceived Stigma* highlights how medical professions involved in rehabilitation, including physiotherapy, often promote a mechanistic view of the body, treating it as a machine. In terms of design, wheelchairs act as a visual language that can either reflect or challenge societal perceptions of disability. For instance, when design representations are rooted in the biomechanical view, they risk reinforcing reductive narratives of the body as merely mechanical, perpetuating stereotypes surrounding mobility disabilities. To this end, while the practical design and functionality of wheelchairs mostly highlight the body-machine connection, their aesthetic and symbolic representation can either reinforce or challenge the stigma associated with disability. Thus, as in Section 1, addressing stereotypes through aesthetic revisions and a deindustrialized visual identity can reshape preconceptions and narratives surrounding the stigma of MAs, aligning them more closely with the socio-emotional perceptions of clients rather than the biomechanical views dominant in medical discourse. Thoughtful design can promote the narrative of WUs as active social participants, influencing how both they and others perceive MAs in daily life, countering traditional stigmas.

1.2 Comfort Aspects in Wheelchair Design

The findings in Section 3 highlight that while addressing discomfort is always prioritized, there is also a need to consider comfort, not only in terms of physical ergonomics but also psychological aspects. The absence of comfort can lead to negative perceptions of MAs, influencing continuous use and raising questions about their fundamental functionality. Designers should focus on creating wheelchairs that not only support physical health and ergonomic aspects but also enhance the psychological well-being of users by promoting a sense of identity and dignity. The third study showed that there is a dynamic relationship between the sociopsychological context, user emotions, and wheelchair functionality. Therefore, improving inclusivity and refining aesthetic representations should first be based on considering these aspects within social contexts and values. Additionally, the physical and emotional capacities and expectations of WUs are critical components in the prescription of any new MA. While these factors may vary among different individuals with a range of disabilities and personal characteristics, research across different groups of WUs can reveal common themes and shared needs. For example, the physical limitations of individuals with spinal cord injuries may differ from those with cerebral palsy, leading to distinct technological requirements for wheelchairs. Similarly, the emotional capacities and expectations of younger users may differ from those of older adults. However, by researching diverse groups, common properties may emerge that contribute to the acceptance of a prescribed MA by the target group.

According to our review, while physical limitations, emotional capacities, and expectations should serve as foundational elements along with another aspect of an interdisciplinary theoretical framework, the broader social context and values must surround and underpin these factors. This ensures a more holistic approach that addresses both individual needs and societal perspectives. Understanding these relationships can guide the design of MAs that are more attuned to the emotional needs of WUs, fostering a sense of belonging and acceptance in social settings. Also, the study in Section 3 raises critical considerations regarding the integration of advanced technology in wheelchair. The study raises also critical considerations regarding the integration of advanced technology in MAs. While addressing the physical discomforts of WUs is essential, designers must carefully consider how to introduce technological advancements without negatively affecting users' socio-emotional experiences. For instance, it is important to avoid drawing undue attention to the wheelchair.

2 Introducing an Interdisciplinary Theoretical Framework

According to these dynamics of the interconnections between the output of three studies in Ch. II, we can identify and propose three axes along with two foundational layers, that form the foundation of our interdisciplinary framework for enhancing and shaping WUs' socioemotional experiences. There are no specific priorities assigned to the axes in terms of their impact on WUs' experiences. However, since our primary aim was to organize the design principles from a human factor's perspective for wheelchair design, followed by surrounding aspects related to technology, as well as the physical and social environment, we have structured the axes of our theoretical framework as follows (Figure 19).

Axis I. Moderating Disability Stereotypes through Aesthetic and Deindustrialized Visual Identity
Axis II. Prioritizing Technology for Physical Comfort over Pretentious Design Representation.

Axis III. Empowering Inclusivity Beyond Accessibility (Environment, Visual Symbols, Product, Language)
Layer I: Physical Limitations (i.e., capacities), and Emotional Capacities & Expectations
Layer II: Context & Social Values

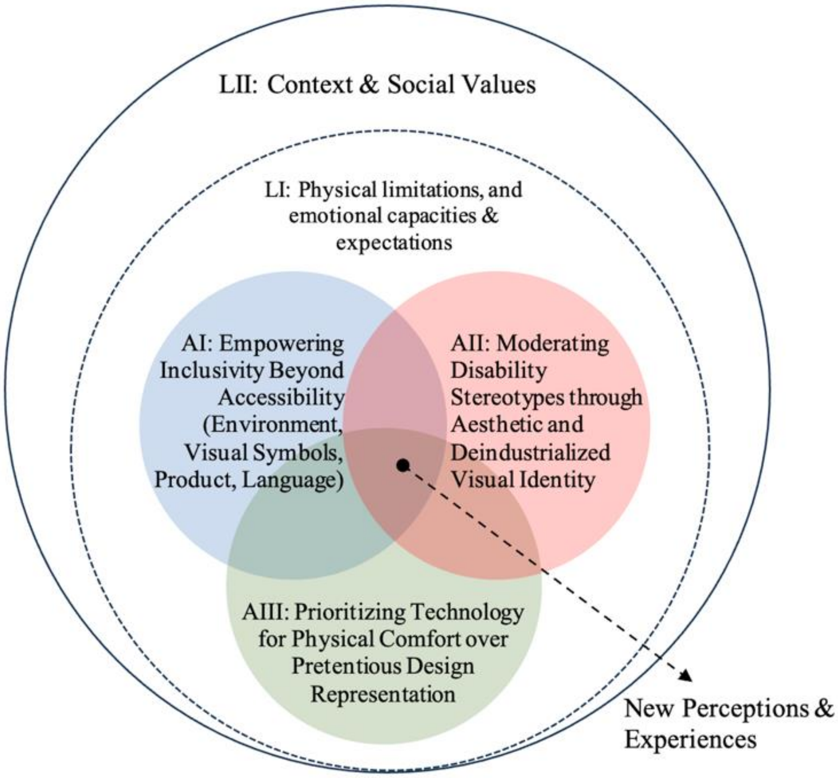

Figure 19. Interdisciplinary theoretical framework of addressing the socioemotional experiences of WUs. © Image by Author.

This interdisciplinary theoretical framework not only serves as a guide for experts in disability studies, design, and architecture to enhance WUs' socioemotional experiences but also provides a lens for interpreting these experiences. Furthermore, this framework serves as a guide for further exploring each aspect of WUs' social experiences that are presented in the next chapters. For example, the next section will examine the social dynamics between WUs and their environment—both physical and social—by focusing on perceptions of inclusivity and interactions with prescribed wheelchairs during rehabilitation. We will also explore public perceptions of WUs based on different design characteristics of wheelchairs.

III

Understanding the Socio-Emotional Dynamics

Perceived Inclusivity in Using Mobility Aids

This section is based on the following manuscript (published edition).

Rasoulivalajoozi, M., Cucuzzella, C., & Farhoudi, M. (2025). Perceived Inclusivity in Mobility Aids Use: A Qualitative Study in Iran. *Disabilities*, 5(1), Article 1. https://doi.org/10.3390/disabilities5010015

Disabilities is an international, peer-reviewed, open access journal on the physical, biopsychosocial, and environmental aspects of disability, published quarterly online by MDPI.

Abstract: Despite inclusive design focusing on improving environmental accessibility for mobility aid (MA) users, it often fails to ensure true inclusivity due to mismatches between interventions and user perceptions. Therefore, understanding MA users' perceptions of inclusivity is essential for advancing disability studies and design, as it highlights key interventions for more effective practices. This study aims to explore perceived inclusivity in MAs' usage and identifies gaps in users' needs, classifying their needs and offering recommendations to meet them. First, the DARE-Inclusive Design Framework was used to develop interview guidelines and interpret results. Next, using a qualitative descriptive research, semi-structured in-depth interviews were conducted with 12 experienced physiotherapists in Iran. Finally, an inductive thematic analysis was applied to identify and present the emerging themes. Four themes were identified: 1. Perceived Financial Value: Assessing Worth, 2. Objective Enhancements: Optimizing Environments and MAs, 3. Subjective Enhancements: Trustworthiness, Support, and Hope, and 4. Contextual Factors: Interpretations and Representations. The four interconnected themes provide guidelines for inclusivity-oriented interventions, emphasizing financial assessment, high-tech integration, and aesthetic and symbolic considerations in MA design. Physiotherapists can also mediate emotional responses and enhance inclusion during rehabilitation. Additionally, social context and disability etiology impact users' acceptance and use of MAs.

Keywords: Mobility aids; Social inclusion; Physiotherapy; Inclusive design; User experiences

1 Introduction

Users of mobility aids (MAs) (wheelchairs, walkers, orthosis, etc.) often experience various physical and social challenges in their daily lives, including incompatible environments (Desai et al., 2023; Harris et al., 2015), the uneven distribution of accessibility to health services (Chen et al., 2024), public transport (Unsworth et al., 2017), and limited involvement in social interactions and activities (Barker et al., 2006; Herrera-Saray et al., 2013; Oishi et al., 2010; J. Kim et al., 2024). Such challenges can potentially stimulate the perceived differences between MA users and individuals without mobility issues. This sense of separation, sometimes accompanied by negative feedback in their social experiences, triggers emotional reactions and may negatively impact their self-perception (Barlew et al., 2013; V. de S. P. Costa et al., 2010; Edberg & Persson, 2011). This, in turn, leads to further social isolation (Barker et al., 2004; Emerson et al., 2021) and can create a positive feedback loop (Lidwell et al., 2010) where increasing isolation and negative self-perception amplify each other. This loop may intensify negative responses regarding their environment, perpetuating a cycle of social and emotional challenges (Barlew et al., 2013; Rousseau-Harrison et al., 2012).

In response to MA users' challenges, the inclusive design approach tries to consider the aspects of equity, aging, disability, and technology-related skills to eliminate barriers—in the environment and interactions with MAs—among individuals with diverse capabilities (Newell, 2003; Yaldiz et al., 2023). Using this approach enables designers to positively influence and shape users' experience in using MAs (Heylighen et al., 2017; Schifferstein & Hekkert, 2007). However, achieving true inclusivity cannot be limited to merely ensuring environmental accessibility and the effectiveness of MAs (Patrick & Hollenbeck, 2021). It is also essential to find out how MA users perceive, appraise, and experience inclusivity in practice. For instance, negative stereotypes toward disability in social interactions can influence MA users' perceptions of disability (Grue, 2016; Human Right Watch, 2018; Barbareschi et al., 2021). Additionally, if the design of a wheelchair—both its appearance and operational aspects—does not align with the users' needs and preferences, users may still feel excluded. Therefore, other factors beyond accessibility can influence and shape their perceived inclusivity (PI) (Sahoo & Choudhury, 2023). To this end, it is essential to explore whether MA users genuinely perceive the inclusivity-oriented interventions or if these efforts are seen as focusing solely on physical accessibility (Perangin-Angin et al., 2023).

In this regard, UNICEF suggests the "5 A & Q" principles, which aim to consider the needs of users requiring assistive devices. These principles include availability, accessibility, affordability, adaptability, acceptability, and quality (Physiopedia, 2024; UNICEF, WHO., 2018). Previous studies have primarily focused on addressing the needs of individuals with mobility disabilities by implementing environmental adjustments (Basiri, 2021; Hossen Sajib, 2022; Widehammar, Lidström, et al., 2019), facilitating MA users' navigation (Basiri, 2020), and optimizing ergonomics (Widehammar, Lidström, et al., 2019). One of the few case studies in Iran evaluated the accessibility of library buildings and equipment. The results showed that accessibility was not rated as 'good' either by disabled users or architects (Bodaghi & Zainab, 2013). These studies highlight the importance of wheelchair accessibility as a key determinant of independence, social participation, and overall inclusion in society (Sahoo & Choudhury, 2023).

Besides wheelchair accessibility, the perception of disability symbols affects attitudes toward inclusivity. The ambiguous design of the International Symbol of Access creates confusion among individuals with various impairments (Vice et al., 2020). By primarily representing mobility impairment, it inadvertently contributes to a sense of exclusivity for those with other types of impairments. Furthermore, a lack of inclusivity is still perceived even in hospitality and customer services, where personalized support and accessibility are of great importance. Reports in Iran show that negative stereotypes and discrimination, even among state social workers and medical workers, impede people with disabilities from accessing essential services (Human Right Watch, 2018). Also, while wheelchair tourists are eager to travel, existing barriers make them more selective about natural destinations, indicating that true inclusivity requires a cultural shift (Perangin-Angin et al., 2023).

In this context, while studies have emphasized the importance of understanding inclusivity across various aspects, including physical, psychological, and social considerations (Holmes & Maeda, 2020; Patrick & Hollenbeck, 2021), no study to date has holistically examined MA users' PI and its classifications. Filling this gap provides valuable insights for enhancing MAs, environments, and related services, resulting from inclusivity-oriented interventions that are both relevant and effective. It also contributes to creating targeted policies and social programs that meet MA users' socioemotional needs (Turk & Mitra, 2023), promoting inclusivity and support, thereby reducing stigma and enhancing social engagement. In this study, we aim to bridge this gap of knowledge by exploring the interconnected layers, including emotional, social, and design aspects. We focus specifically on identifying the challenges users face when interacting with their MAs or engaging in social interactions in public and private settings. Additionally, due to the limited research on inclusivity in Iran and the underrepresentation of voices from Iranian MA users in global studies, we chose this setting for our study. To this end, we aim to answer the following questions: What key themes represent the perceived mismatches among those with movement disabilities who use MAs? How can inclusivity-oriented interventions alleviate perceptions of exclusion? By addressing these questions, this study contributes to the multifaceted understanding of PI, aiding disability studies in creating a framework for co-design practices and policies that extend beyond accessibility.

This study also aligns with the aims of the Convention on the Rights of Persons with Disabilities (CRPD), adopted in December 2006, which advocates for an inclusive society, ensuring accessibility, equity, and non-discrimination (United Nations, 2007). The CRPD requires countries to implement policies that protect the rights of persons with disabilities, eliminate discrimination, and promote awareness of their capabilities, ensuring their right to live independently, access transportation, public facilities, and education, and benefit equally from healthcare and social protection. Our focus on inclusivity beyond accessibility can contribute to these goals by exploring their perceptions of inclusivity and providing opportunities to address unmet needs.

2 Materials and Methods

2.1 Establishment of the Study Procedure

Given that the phenomena of inclusivity and its properties are interconnected and subjective, a qualitative descriptive research is adopted, which enables us to assess the tacit and taken-for-granted understanding of PI (Tracy, 2013). To this end, the authors initially clarified key concepts in inclusive design, highlighting its differences from design for accessibility, design for all, and universal design (Nussbaumer, 2011). Then, to examine and classify the experiences of MA users, we employed the DARE-Inclusive Design Framework (Patrick & Hollenbeck, 2021). In line with our research objectives, a number of experienced physiotherapists were selected for the in-depth interviews (IDIs) (Jamshed, 2014; Longhurst, 2009). Subsequently, themes and subthemes were identified, analyzed, and classified according to the DARE framework (Figure 20).

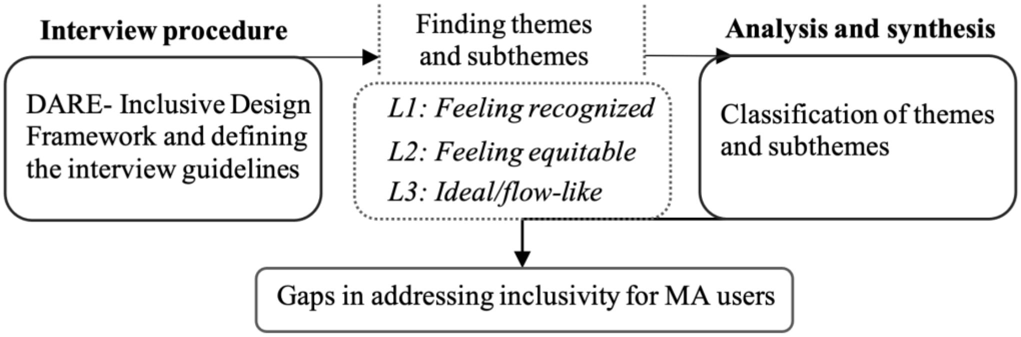

Figure 20. Procedure of Research Design. © Image by Author.

2.2 DARE-Inclusive Design Framework

This framework, outlined by Patrick and Hollenbeck, categorizes overarching barriers in inclusive design into three levels: physical, social, and attitudinal (Patrick & Hollenbeck, 2021). The DARE framework proposes that (a: Design) design signals a degree of social inclusion or exclusion, (b: Appraisal) users take note of these cues and evaluate the design based on its inclusivity, (c: Response) emotions are triggered by a mismatch between the individual (or aspects of their identity) and the design, and finally, (d: Experience) these emotions shape consumers' perceptions and overall experiences. The three levels of DARE are as follows:

Level 1 (L1) focuses on accessibility and is linked to industry regulations. L1 follows market-driven reform policies and neoliberalism principles, which suggest that market forces can self-regulate. Designs under L1 aim to meet the minimum standards to remove barriers.

Level 2 (L2) emphasizes increased engagement and positive emotions, promoting equitable access and fair relationships guided by social justice principles. Rooted in social justice, L2 seeks to validate users' experiences through empathy and understanding how products impact their everyday lives.

At Level 3 (L3), a minimal mismatch between users and design is ideal. L3 focuses on empowered success through positive design, emphasizing human flourishing and the complete inclusion of all individuals (Pohlmeyer, 2017). Users experience a state of flow, enjoying profound immersion in tasks with a harmonious interaction between themselves and the environment, enabling fluid and creative interaction with their physical and social environment (Patrick & Hollenbeck, 2021).

This framework allows us to comprehensively consider three levels of inclusivity, and the mismatches between users and their MAs, environment, and social context (Patrick & Hollenbeck, 2021). According to DARE, we categorize themes into three levels and explain how design optimization of environments and MAs influences the initial appraisal, prompts a response, and shapes the perception and experience of MA users.

2.3. Development of Interview Guidelines and Questions

For the initial draft of the interview guide, research team members reviewed the literature and highlighted the key relevant aspects of the DARE framework (Patrick & Hollenbeck, 2021). The authors discussed potential exclusion areas, such as engineering and ergonomics, which prioritize physical interactions. We integrated these considerations with insights from previous research. For study validity and rigor, a physiotherapist and an inclusive designer were invited to assemble a panel of design experts to refine the interview guidelines and questions further. Their insights and corrections were used only to refine the interview questions and were not incorporated into the final dataset. Following unanimous agreement among authors, the final interview guide was approved, outlining the sequence and content of questions under the established guidelines. In English, some of the key semi-structured interview questions were as follows:

(1) Broad questions (e.g., experiences, definition of disability, etc.).
(2) What are your thoughts on the adjustment of environments and MAs for clients' needs? And how might they be improved?
(3) How do clients perceive their bodies and disability? How do they compare their body before and after their disability challenge begun?
(4) How do clients see their MAs and the environment? Are there any mismatches between their expectations and the existing situation?
(5) How can technology influence the client's decision to accept or refuse a prescribed MA?
(6) How do clients feel about social activities and participation? How do culture and social context affect their perceptions?
(7) How do clients deal with potential social challenges? And what do they do to improve their social participation?

2.3 Recruitment and Study Population

We considered physiotherapists as the participants due to their prolonged involvement in the rehabilitation processes (Chartered Society Of Physiotherapy, 2022). This approach is ethically appropriate because MA users are considered a vulnerable group, and they may find it difficult to discuss their personal and emotional aspects with researchers they are meeting for the first time. Their close connection and holistic view of MA users' challenges offer valuable insights into users' perceptions, enabling a discussion of how different inclusivity-oriented interventions impact PI. Accordingly, the inclusion criteria were as follows: (1) qualification as a registered physiotherapist, (2) having work experience of over 5 years in either the private sector or hospital physiotherapy wards, and (3) willingness to participate voluntarily. Participants were excluded if they were involved in concurrent studies on the engineering and ergonomics of MA development that were focused on direct user–wheelchair interaction and could influence responses regarding inclusivity in using wheelchair. Employing a mix of purposive and snowball sampling, 12 physiotherapists with extensive experience in treating MA users agreed to participate in the interviews. Considering this study's objective to explore themes with an expected moderate-to-high prevalence (e.g., above 40%), a sample size of 12 participants is deemed sufficient for comprehensive coverage. This estimation is grounded in the required sample size to account for theme prevalence within the population, ensuring a 90% likelihood of observing the target number of occurrences (Fugard & Potts, 2015). The interviewers had no prior acquaintance with the participants. Table 7 outlines the characteristics of the participants.

Table 7. Background of participants and interview timing (*N*=12).

Years of experiences	**Interview time (Min)**	**Working experiences and profession category**
*S=234, **A=18.14 (min-max: 8-25)	S=840, A=70 (min-max: 50-90)	Private clinic (N=4), healthcare center (N=2), home visiting (N=1), state welfare organization (N=2) hospital (N=3), national medical committee of the Olympics (N=2).

*S: Sum, **A: Average

2.4 Data Collection

The primary interviewer coordinated the time and location of the interviews with the participants a day in advance. Subsequently, detailed interviews, lasting 50–90 min, took place between March 2022 and February 2023 in the participants' private clinics and public hospitals (physiotherapy wards) in the cities of Kordkoy and Tehran, Iran. After obtaining written consent and the participants signed confidentiality forms, the interviews were digitally recorded using audio recorders and then transcribed and anonymized. The interviews followed a semi-structured IDIs outline, adjusted as necessary based on the participants' responses. The IDIs included both general and specific questions about how individuals perceive inclusivity when using MAs. A calm environment was maintained to ensure that the participants felt at ease responding to the questions. The participants were given adequate time for their responses, and discussions continued until data saturation was reached. This study followed the Consolidated Criteria for Reporting Qualitative Research checklists (COREQ) (Tong et al., 2007).

2.5 Data Analysis

Within 48 h post-interview, audio recordings were meticulously transcribed into text. All interviews, conducted in Persian, were translated into English and anonymously reviewed by two authors. Two of the authors specialized in disability studies and inclusivity, with a particular focus on the concepts and ideas within this field. As native Persian speakers, they were highly familiar with Persian metaphors and semantics, with extensive experience conducting IDIs and thematic analysis in similar qualitative research. Following transcription and initial verification, a structured analysis of the interview data was carried out using Braun and Clark's six-phased inductive thematic analysis framework (Braun & Clarke, 2012). This methodological approach involves sequential stages, including data familiarization, generation of preliminary codes, thematic identification, theme review, defining and naming the themes, and producing a report (Braun & Clarke, 2006). Transcripts were inputted into the Nvivo 12 software for coding the data, and the initial codebook was drafted. To enhance the credibility of the data analysis, the transcriptions were reviewed with the participants to confirm the accuracy of their ideas and the responses. Two coders independently conducted parallel coding, followed by discussions to reconcile any differences in the coding decisions. After coding was complete, the authors employed semantic and latent data interpretation strategies to identify broader themes (Braun & Clarke, 2022). This involved collating, sorting, and searching for repetitions, similarities, differences, and missing information within the coded excerpts. Finally, the relevant quotes were selected and the findings were reported in accordance with our research question. In this study, “clients” reflects the participants’ language, so “clients,” “MA users,” and “users” are used interchangeably.

2.6 Ethics

Ethical approval was granted by Concordia University’s Ethical Review of Human Subject Research policy (Certification Number: 30016116). The participants were briefed on the study objectives, provided their written consent, and had the option to withdraw at any time.

3 Results

The authors initially established and agreed upon 72 codes that were clustered into 10 groups. In the next step, six themes and nine subthemes were identified, which were later refined to four themes and six subthemes through discussion. As this study represents the perspectives of MA users in Iran, more quotes are provided to illustrate their PI. After refining and reviewing the codes and themes, PI among MA users is reflected in four main themes:

(1) Perceived Financial Value: Assessing Worth.
(2) Objective Enhancements: Optimizing Environments and MAs (technological and ergonomics optimization in MAs; enhancement of accessibility in private and public settings).
(3) Subjective Enhancements: Trustworthiness, Support, and Hope (fear and shyness in the usage of MAs in public settings; desire for empathy from family and physiotherapists).
(4) Contextual Factors: Interpretations and Representations (causes of disability and inclusivity perceptions; lack of aesthetic polish in MA design).

3.1 Theme I: Perceived Financial Value: Assessing Worth

This theme primarily addresses the significance of valuing MAs. Participants noted that while standard MAs are generally not expensive, some users think that their quality does not justify the cost (Table 8; Q1, 2, and 3). Particularly, those clients desiring a high-quality wheelchair or customized orthosis find them unaffordable, thus settling for basic models lacking specialized features (Table 8; Q4). In this situation, MA users feel nobody understands their situation (Table 8; Q5). MA users here perceive exclusivity as a denial of their fundamental right to movement, exacerbated by the necessity to pay extra for their basic rights (Table 8; Q6). Three highly experienced participants noted that the economic context can influence the behavior of both MA users (Table 8; Q4) and producers as well. They highlighted that many companies prioritize financial gains over quality when producing MAs (Table 8; Q7). Alternatively, if users cannot afford commercially available MAs, they may opt to create their own solutions for mobility (e.g., handmade walkers or crutches) (Table 8; Q8).

Table 8. Participants supporting quotes on the Theme I.

Quote (Q) #	Perceived Financial Value: Assessing Worth.
Q1	*Most assistive devices are affordable…However, if an orthosis were to be individually prepared by an orthotist during rehabilitation, it will certainly be more expensive for clients than mass-produced ones.*
Q2	*…The economic factor is important in prescribing a solution [suggesting an MA]…. It should not impose a financial burden on the individual…. A suitable price of MAs greatly influences the decision to accept or reject the product.*
Q3	*The complaint was that the price we paid did not correspond to the period of use... I [user] paid a fee, but after a month of use, it is not washable, nor are the parts replaceable. This is a common complaint.*
Q4	*...It is not fair for clients to endure fatigue or face potential tragedies just for not affording an orthosis…. Eventually, they have no choice but to accept the basic and inexpensive models of MAs.*
Q5	*In developing societies where there is economic fluctuation, the clients often say: You've never been in my shoes to understand the financial strain it puts on me….*
Q6	*…It is difficult to pay for something that you didn't need to pay for before [mobility]. They [clients] often compare their current situation to their past.*
Q7	*Producers' recommendations for user-friendliness are often related to their profit motives rather than focusing on research on users, development, and improving clients' health….*
Q8	*In a society like Afghanistan [A neighbouring country of Iran], or impoverished cities within Iran, despite a weak economy and poverty, people sometimes address their needs with minimal resources, such as wooden handmade canes, which are locally crafted.*

3.2 Theme II: Objective Enhancements: Optimizing Environments and MAs

This theme involves objective and tangible elements, which means that addressing these factors through engineering and technical considerations would impact their PI. Participants cited specific challenges where environmental adjustments, such as ramps or elevators, were lacking, thereby hindering accessibility (Table 9; Q9). This situation often led to feelings of anger and being overlooked and excluded in terms of ease of movement and maneuverability (Table 9; Q10, Q11). Moreover, participants highlighted the need for improved ergonomic quality in assistive products, as this would enhance comfort and reduce mismatches. This involves using higher quality materials, like softer pads for wheelchair seating, and incorporating relevant anthropometric data in product design to improve compatibility and comfort (Table 9; Q12–Q15). Ensuring the long-term functionality of the MAs was also highlighted, as participants reported instances of users expressing functional dissatisfaction. This situation often stemmed from mismatches in using the aids within indoor and outdoor spaces due to restricted movement, as well as discomfort from prolonged seating on the pad of the wheelchair or pressure on crutches (Table 9; Q16 and Q17). Participants also emphasized the significance of integrating new technologies into the design of MAs, which fosters acceptance and ongoing use of prescribed MAs (Table 9; Q18). Alongside the usability, the aesthetic of such mobility devices was highlighted which can affect the acceptance of MAs, especially for youth (Table 9; Q18–Q20).

Table 9. Participants supporting quotes on Theme II.

Quote (Q) #	Objective Enhancements: Optimizing Environments and MAs
Q9	*The whole city can be a ground for constant complaints from disabled individuals…. Despite employing fanciest architectural style, like the fancy stairs, the slope is so steep that the wheelchair may overturn.*
Q10	*…Being mindful of the environment for people with disabilities shows respect for their needs.... When users [MA users] see this effort, it boosts their self-confidence. But in places where nothing is set up for disabilities, everything seems to treat them (MA users) like a burden, leading to feelings of shame and helplessness that are seen on their faces.*
Q11	*Their [clients] reaction is anger and finally yield and ask for help…. Our [physiotherapists] approach is moderating dissatisfaction or justifying shortcomings.*
Q12	*In terms of anthropometry, there is limited variation in the sizing of these products [MAs] within our country [Iran]. Sizes are typically limited to small, medium, and large….*
Q13	*Ergonomics and environmental adaptation are important…. However, equipment from other countries may not always be suitable for the new environment [Iran].*
Q14	*It is very important to use a material that reduces the weight of the MAs.*
Q15	*One of the factors is the lightness of the material…. The material used must be lightweight yet strong enough to carry the muscles and skeleton of the body.*
Q16	*We need to have some devices [MAs] that show a sense of trust and functionality for a long time. …The feeling of relying on such device gives [to MA users] a peace of mind.*
Q17	*Sometimes the users complain about the long-time seating and lack of suitable structure of conventional wheelchairs with a sturdy material.…To reduce pressure, they add sponge foam padding.* *They complain so much that some refuse to use the product. They insist, asking if there's another way [for recovery].*
Q18	*Technology can have a significant impact, ranging from 20% to 40%. Especially for those who resist using MA [wheelchair].*
Q19	*The beauty of assistive products can influence MA users' preference by 30-40%, which is significant for us [physiotherapists]. This is especially true for children and young people, where appearance matters a lot.*
Q20	*Embellishments can motivate them to accept continued use over time. It may also affect their social interpretation…In my opinion, the best colors are vibrant and warm colors. There should be color variations and users' subconscious should like the color. The design of the work and clinic space should motivate people and do not remind them of their troubles. …We have to bring something into the clients' eyes that has a good effect on the patient's emotions. …The sense of touch is very important, for example, the roughness of the seat, and the coldness of the material should be taken into considerations.*

3.3 Theme III: Subjective Enhancements: Trustworthiness, Support, and Hope

This theme involves the subjective and intangible elements, where MA users subconsciously and emotionally evaluate their environment and prescribed MAs. For instance, the trustworthiness factor encompasses aspects where users are dubious about the benefits, functionality, and even medical efficacy of MAs (Table 10; Q21). MA users may hesitate to fully rely on these aids due to concerns about stability and the probability of falling (Table 10; Q22). This uncertainty is highlighted, particularly when individuals fear the embarrassment of falling in public settings, leading to feelings of shame (Table 10; Q23). The participants stated that users perceive MAs as mere accessories rather than essential tools, further complicating their trust in these devices (Table 10; Q24). The participants noted that users typically adhere to physiotherapist instructions but may feel hopeless if they observe no progress in therapy sessions. In this situation, they seek continuous support from their families and physiotherapists as a reliable source of support and hope (Table 10; Q25, 26). The participants also conveyed MA users' concerns about burdening their families, evoking feelings of guilt (Table 10; Q27). MA users sometimes feel they are not contributing to their community, which leads to disappointment about their future health prospects. (Table 10; Q28). Consequently, users may distance themselves from their physiotherapists or families, despite their persistent requests for progress updates on their recovery (Table 10; Q29). According to this theme, the perception of exclusion is reflected in their emotions and internal dialog, shaping their overall perspective on disability.

Table 10. Participants supporting quotes on Theme III.

Quote (Q) #	Subjective Aspects: Trustworthiness, Support, and Hope
Q21	*Sometimes they are unsure if relying on these devices will provide adequate support for movement. For example, they ask, "Is this device robust enough to carry me?*
Q22	*...It [lack of trust to MAs] is rooted in their self-confidence. ...Timid individuals often try to hunch over and walk slowly and take great care. It is rooted in fear and anxiety. ...Mental and psychological factors are very effective [in perception of the disability].*
Q23	*In an unsuitable environment, MAs can be perceived as an insult [for users], leading to feelings of shame and helplessness, like the sense of fear and shame after falling downstairs*
Q24	*Once they are disappointed, they state it [MAs] is useless and consider it as a burden. That is why they may consider the MAs as an excessive gadget….*
Q25	*They are very open and receptive to the treatment process and respond: I will use whatever assistive device [MAs] you [physiotherapist] recommend. ...They continuously check their progress of rehabilitation. ...A trusting relationship with their doctor enhances clients' levels of hope. Sometimes clients trust their physiotherapists even more than their religious assumptions.*
Q26	*Sometimes clients get nervous and depressed…they are upset with their own families and do not like to get help from them. They say: don't bother me. If the depression is severe and persistent, the patient may even contemplate suicide…. Without hope, they gradually face challenges and may engage in risky behaviors.*

Quote (Q) #	Subjective Aspects: Trustworthiness, Support, and Hope
Q27	*Sometimes clients feel they have become a burden on their family. ...For example, I have a client who feels embarrassed and ashamed when his wife and family bring him to physiotherapy.*
Q28	*Regarding social participation, they feel shy and don't want to use assistive devices in public.*
Q29	*Depression is a significant social challenge for them [clients]... If they believe they won't recover or regain a normal life, it leads to feelings of despair. ...When clients seem to have lost hope, they may refuse to cooperate with their physiotherapist.*

3.4 Theme IV: Contextual Factors: Interpretations and Representations

This theme explores the symbolic significance and representation of MAs and users' bodies in public spaces. Within this theme, the social context and the cause of disability, influence how disability is perceived and depicted in society at large (Table 11; Q30, 31). For instance, mobility disability from war injuries, like those from the Holy Defense (The Iran-Iraq War was referred to as the "Imposed War" and the "Holy Defense" in Iran due to its perception as a defensive struggle against aggression (UChicago Library, 2024) in Iran, is often seen as heroic. In contrast, disability resulting from theft-related incidents is frequently stigmatized and accompanied by guilt. (Table 11; Q32). Generally, users may resist using MAs due to stigma (Table11; Q33). Dissatisfaction grows when they recognize the devices' limitations in functionality for health and mobility (Table 10; Q24). In response, physiotherapists play a pivotal role in promoting continued use by emphasizing the MAs' potential to enhance movement function (Table 9; Q11, Table 11; Q34). In social context, individuals with disabilities often face negative treatment, comments, and social pressures in public environments (Table 9; Q10, Table 10; Q23). Culturally, there is a tendency to underestimate individuals with physical disabilities (Table 11; Q35). Using MAs is often seen as a sign of failing to manage daily routines, which can label users as disabled. This perception exacerbates social pressure, especially when faced with public spatial challenges and accessibility issues, such as in public transport systems (Table 10; Q23). Under this social context, individuals experience fatigue and disinterest in social interactions (Table 11; Q36). According to this theme, the PI stems from their appraisal of social presumptions, and the symbolic representation of disability, affecting their social interactions. In this regard, aesthetic consideration of MAs can remarkably affect their social symbolic representations (Table 9; Q20).

Table 11. Participants supporting quotes on Theme IV.

Quote (Q) #	Contextual Factors: Interpretations and Representations
Q30	*They sigh. They believe that this [mobility disability] is a form of retribution and punishment for their past actions….*
Q31	*...Social, accessibility, and work environment issues, along with cultural differences, appearance [MAs] and clothing styles can affect the fit and perception of MAs, potentially exacerbating the patient's [clients] condition and reproducing the meaning of "I am a patient."... This interpretation [being dis/abled] may differ between rural*

Quote (Q) #	Contextual Factors: Interpretations and Representations
	areas, where disability is more associated with negative stereotypes, and the larger urban society.
Q32	*Being socially perceived as a hero is different from being a fugitive or accused. Being [socially] accepted as someone whose fingers were cut off [according to religious law] for theft and someone whose finger is injured like Hans Brinker [Refers to Mary Mapes Dodge's novel about a boy who saves Amsterdam by plugging a dike leak with his finger] is very different.* *...For instance, someone disabled due to an unsafe car or road often blames society and views themselves as a victim. …Owning a crutch or wheelchair from wartime, even if it's no longer necessary, serves as a heroic symbol for the individual–embodying qualities of courage, selflessness, and determination….*
Q33	*Products [MAs] should be designed to confer prestige rather than limitations….*
Q34	*…They [Clients] believe they're alone in their illness, unaware that others require assistance too…However, we can encourage them to persevere by offering support and empathy.*
Q35	*[User] are most reluctant to use these devices due to societal negative attitudes and pity….*
Q36	*…The decline in individual independence, especially in social and financial areas, significantly affects clients' likelihood to use MAs.*

4 Discussion

This study aimed to explore perceived inclusivity in the use of MAs, identify gaps in users' needs by uncovering relevant themes, categorize these gaps, and provide recommendations to address them. Accordingly, each theme is interpreted in this section, with its scope and connections to other themes or subthemes discussed. Additionally, three levels of the DARE framework outline each theme's position. These four interconnected themes can serve as a guideline to enhance PI among MA users.

Theme 1 discusses the financial constraints related to the MAs, limiting access to basic assistive devices. This may prompt physiotherapists to seek alternatives or delay rehabilitation, potentially worsening the clients' (patients) condition (Colizzi et al., 2020; Rasoulivalajoozi & Touir, 2023). Consequently, more expensive treatments, like surgery, may be needed (Boden et al., 2020). Financial limitations can even lead individuals to opt for second-hand MAs, which often lack proper anthropometric fit. This aligns with previous studies, which highlight the importance of understanding the economic landscape when providing wheelchairs (Gowran et al., 2021). This issue is exacerbated in the economic context of Iran, where inflation has significantly increased the prices of assistive devices, including imported ones, causing wheelchair prices to at least triple (EtemadOnline, 2024). This concern extends globally, as international reports indicate that only 5–35% of the 80 million individuals worldwide in need of a wheelchair have access to one, mainly due to high costs that vary by country (WHO-Asssitive, 2024). This issue is aligned with concerns raised by critics regarding commercialism in modern medicine (Matin, 2021; K. White, 2002).

While interviews imply that conventional MAs are affordable (Table 8; Q1), from an inclusivity standpoint, the issue is not solely cost-related; it is about perceived dissatisfaction with the fundamental right of mobility. Users perceive MAs for mobility as an added financial burden, not just a cost issue. Thus, dissatisfaction arises not from the cost but from having to pay for a right. This gap between their mobility rights and the financial hurdle in accessing MAs is perceived as inadequate inclusivity. Additionally, for those seeking advanced powered wheelchairs with features like stair climbing, costs can be higher, further enhancing feelings of exclusion. These costs can reduce individuals' access to proper MAs and the opportunities to engage in social activities (Skempes et al., 2022). This highlights a gap in the first level of inclusivity according to the DARE framework, where MA users are still unsatisfied with the insufficiency of market-driven policies and efforts by the government and industry to meet their needs (Patrick & Hollenbeck, 2021). To this end, advocating increased governmental support for MA users and related services is recommended (Bodaghi & Zainab, 2013), aligning with recent proposals such as the Rehabilitation Policy Action Framework in Europe (Skempes et al., 2022). This framework outlines 48 options across six domains to translate political aspirations into actionable outcomes. This framework highlights reallocating healthcare funds for expanded rehabilitation resources, enhancing PI in theme 1.

Theme 2 shows that users objectively evaluate the design features of MAs and environmental accessibility, continuously thinking of optimization suggestions. According to the DARE framework's L1, users are aware of the efforts to include their needs but often notice mismatches between their needs and the design of MAs (Patrick & Hollenbeck, 2021). To this end, in cases of minor mismatches, they often try to find alternative solutions (e.g., using a padding to relieve pressure). But if mismatches escalate, this may lead to negative reactions and discontinued MA use, feeling that their mobility needs cannot be met by MAs. According to previous studies, conventional wheelchairs inadequately address users' needs both at home and in public spaces (Kapsalis et al., 2022). Also, the lack of anthropometric and ergonomic adjustments causes discomfort (Faraji & Valajoozi, 2014), affecting inclusivity (Mohebbi et al., 2023). In our study, participants also emphasized enhancing technology usability in MAs as a symbol of advancement. In other words, beyond enhancing usability, this aspect highlights the positive impact of technology on users' psychological and social needs, as noted in previous studies (Domingues et al., 2019). However, in one of the recent studies, MA users noted that assistive technologies could simultaneously attract stigma from others (Barbareschi et al., 2021). Therefore, we must examine which features, either technological or appearance, of these MAs can evoke positive emotions and reduce stigma. The same pattern of dissatisfaction can occur in public environments or transportation when MA users experience disruptions to their routines.

Elevated levels of environmental mismatch can contribute to negative stereotypes and condescending emotional responses (Soetemans & Jackson, 2021) and even affect their social participation (Desai et al., 2023; Sadeghzadeh, 2015). Disabled individuals, like all users, have the right to be considered in building and function planning (Bodaghi & Zainab, 2013). To this end, Europe's Design for All (DfA) and Singapore's Barrier-Free Accessibility (BFA) program suggested promoting a social model of disability (BCA, 2019; EIDD, 2004; Vice et al., 2020). These initiatives advocate for barrier-free design in products, services, and environments to accommodate all abilities and socioeconomic situations. According to DARE, theme 2 initially addresses MA users' tangible needs, corresponding to accessibility (L1). However, neglecting these needs may lead to impacting MA users psychologically, extending to L2 (Patrick & Hollenbeck, 2021).

Theme 3 emphasizes the trustworthiness of MAs and space of usage, which may lead to caution and uncertainty for MA users in unfamiliar public settings. To overcome this hesitation, clients seek continuous confirmation of MA reliability, relying on physiotherapists' opinions and empathy to address mismatches between their internal needs and their environment. This affects MA users' feeling of having support and promotes their positive mental state (Andrade & Devlin, 2015). This aligns with previous studies highlighting the significance of trust in patient care (Wade, 2020), which can also enhance treatment effectiveness (Goold, 2002). Physiotherapists, in their role as trusted practitioners, can serve as catalysts in shaping users' perceptions and persuading the acceptance of MAs. In addition, all design aspects of products and environments should promote a sense of trustworthiness for MA users, fostering their psychological comfort (Cucuzzella et al., 2024). Research on trust in healthcare is expanding, encompassing empirical and conceptual investigations (Douglass & Calnan, 2016; Cucuzzella et al., 2024), as well as studies on communication (Sousa-Duarte et al., 2020) and service (Rasoulivalajoozi & Touir, 2023) in healthcare settings.

Emphasizing trustworthiness in MA design is also important, as it directly influences users throughout rehabilitation and affects their perception of the prescribed MA. If MAs are perceived as structurally fragile, users may hesitate to use them due to a lack of trust. Consequently, establishing trust, both from physiotherapists and within the environment, can alleviate doubts regarding disability. Accordingly, theme 3 highlights the importance of validating users' experiences across MAs—products, environment, and social support domains by empathizing with them (Patrick & Hollenbeck, 2021)—emphasizing the significance of enhancing interventions at L2 in DARE.

Theme 4 reveals how sociocultural context and disability etiology shape users' perceptions of MA inclusivity. This aligns with prior research, which shows that social contexts influence how MAs are interpreted (Grue, 2016; Barbareschi et al., 2021). However, since PI is considered a dynamic process (Holmes & Maeda, 2020), we expect perceptions and emotional responses to MAs to change over time for users (Mokdad et al., 2018).

On the other hand, people's awareness of the etiology of disability within a social context can also influence the perception of disability and its representation with MAs in public settings. For instance, in war-related contexts, MA symbolizes heroism, with users embodying societal values, while, in theft incidents, those MAs can carry stigma and guilt, leading users to hide their disability or avoid using MAs. While prior studies have discussed the societal role (V. de S. P. Costa et al., 2010; Grue, 2016; Jutai & Day, 2002), none have specifically addressed the etiology of disability, affecting the perceptions of and reactions toward MAs. In this context, regardless of how users of MAs perceive themselves (i.e., heroes or stigmatized), bystanders unaware of MA users' backstories may still view MAs through the lens of the prevailing discourse on disability (Shinohara & Wobbrock, 2016). For a bystander, the appearance of MAs is the only factor that serves as a primary medium for conveying stereotypes associated with mobility disability. Hence, MAs' aesthetics are a key factor that works as a language of the product (Hernández et al., 2018), influencing the symbolic meaning of disability, evoking emotions in MA users, and impacting bystanders' impressions (Norman, 2004; Shi et al., 2021). This creates a reciprocal relationship between the aesthetics of MAs and the social context, influencing both symbolic perceptions and real-world interactions (Interaction Design Foundation, 2023). We recommend incorporating elements of social refinement into the design of MAs by prioritizing power and agility concepts. This helps prevent the reinforcing positive feedback loop, where growing isolation and negative self-perception feed into each other. For instance, emphasizing external surfaces in wheelchairs with a futuristic style offers an opportunity to prioritize aesthetics over the traditional form-follows-function approach commonly seen in MAs (Schifferstein & Hekkert, 2007). We posit that addressing the symbolic and aesthetic aspects of MAs can indirectly but strongly influence users' PI, as evidenced by prior research (Dos Santos et al., 2022). Future studies should explore how to translate emotional aspects into physical attributes of MAs.

At L2 of the DARE framework, we empathize with users' social experiences and understand how MAs' appearance affects their interactions. By avoiding negative representations, we can foster enjoyment, enabling users to engage with their environment freely, without encountering negative perceptions (L3) (Patrick & Hollenbeck, 2021). Hence, theme 4 aligns with the interventions of L2 and L3 in the DARE framework.

4.1 Limitations and Future Studies

Ethical constraints prevented us from interviewing individuals with disabilities during their recovery process. While our study focused on the experiences of physiotherapists, their perspectives may not fully reflect MA users' inner dialogs. Thus, future studies should involve both physiotherapists and active MA users for data collection. In this study, our access was limited to tracking PI in MA use over time. Consequently, we suggest conducting longitudinal studies in future research to track PI at each stage of rehabilitation. This study lacks practical inclusive design recommendations. Future research in design fields should focus on translating themes into actionable design interventions and soliciting patient feedback to refine these approaches. Additionally, a systematic review could compare our findings with the existing literature, contributing to the development of an inclusive design toolkit for specialists in disability and design for care.

5 Conclusion

In this study, we identified four interconnected themes as a guideline for improving PI: (1) Perceived Financial Value: Assessing Worth, (2) Objective Enhancements: Optimizing

Environments and MAs, (3) Subjective Enhancements: Trustworthiness, Support, and Hope, and (4) Contextual Factors: Interpretations and Representations. These intertwined themes influence one another and ultimately shape PI. The findings revealed that while the cost of MAs may not be a significant concern, users perceive it as exclusionary when they must pay for something considered to be a basic right for all. This aspect has been relatively overlooked in the existing literature. Also, applying high-tech elements in MAs, beyond enhancing usability, can evoke positive emotions and relieve negative reactions like frustration, guilt, sadness, and shame. Theme 3 showed that fostering trustworthiness for MA users in physiotherapist interactions, the environment, and the design of MAs greatly enhances PI. We also justified how the context and cause of disability can indirectly influence users' perception, utilization, and perpetuation of MAs. To this end, the aesthetic and symbolic representation of MAs in public spaces can influence the perception of social inclusion, a novel factor that has been emphasized less.

In terms of the DARE framework's inclusivity levels, theme 1 revealed a gap in addressing accessibility, focusing on L1. Theme 2 addressed L1, but neglecting tangible aspects may extend a gap in L2. Theme 3 highlighted trustworthiness and social support as catalysts, in enhancing PI, emphasizing the importance of interventions within L2. Furthermore, theme 4 showed interventions in L2 and L3, where MA users' enjoyment is promoted by an empathetic understanding of their social experiences and avoidance of negative representations. In summary, our findings revealed substantial gaps across all three levels, with interconnected factors dynamically influencing PI. This shows that the DARE framework effectively justified and classified MA users' PI. We suggest that future studies incorporate the themes identified in this study into empirical research and offer feedback to optimize inclusivity for individuals using MAs.

Dynamics of Affective Experiences in Using Wheelchair

This section is based on the following manuscript (published edition).

Rasoulivalajoozi, M.; Cucuzzella, C.; Farhoudi, M. (2025). The Dynamics of Affective Experiences with Wheelchair Use During Rehabilitation: A Qualitative Study Through Physiotherapists' Perspectives. *Journal of Acta Psychologica, 256*, 105022. https://doi.org/10.1016/j.actpsy.2025.105022

Acta Psychologica, published by Elsevier, is a peer-reviewed, open-access journal covering all fields of psychology.

Abstract: The interaction between users and mobility aids, including emotional attachment and functional expectations, influences their perceptions and decisions on acceptance and continued use during rehabilitation. Tracking interactions during rehabilitation helps identify key intervention points, leading to effective therapeutic relationships and user-centered mobility aid designs. This study aims to track the dynamics of affective experiences (DAE) of wheelchair users (WUs) during a planned rehabilitation timeframe and recommend how to manage these dynamics. To this end, initially, the product experience framework was applied for the development of interview guidelines and analysis. Next, adopting a qualitative approach, semi-structured, in-depth interviews with 12 experienced physiotherapists were conducted in Iran. Transcripts were then analyzed using a thematic analysis framework to identify themes. A total of three themes have been identified which include: 1) Coping in Using the Wheelchair, 2) Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal, and 3) Approaching Recovery: Challenges in Over-reliance. Additionally, two diagrams illustrating the dynamics of the affective experience of WUs and its influencing factors during rehabilitation have been provided. This study shows that the affective experience of WUs is not static and changes through various stages of rehabilitation. This dynamic is influenced by factors of emotional and functional importance, both of which often grow after initial resistance but follow varied patterns. However, emotional attachment can sometimes lead to over-reliance even after recovery, posing challenges in the rehabilitation. Physiotherapists can help balance this attachment, influencing users' affective experiences with their wheelchairs.

Keywords: wheelchair experience; affective experience; emotional attachment; rehabilitation; physiotherapy

1 Introduction

User-product experience is influenced by major components including the aesthetic response, operation and attributed meanings, as well as users' personal goals and aspirations, leading to emotional responses (Rasoulivalajoozi & Farhoudi, 2025b; Schifferstein & Hekkert, 2007). Similarly, individuals with mobility disabilities experiences with their mobility aids (MAs), such as wheelchairs, is influenced by meaningful situational and contextual factors (Rasoulivalajoozi et al., 2025a). Potential wheelchair users (WUs) are often aware that the assistive devices they intend to buy can carry negative stereotypes, setting them apart from individuals without a disability (Cahill & Eggleston, 1995). In other words, WUs' perceptions are influenced by social context, interactions, cultural factors, and even language (Grue, 2016; Matin, 2021). Such negative stereotypes about MAs can affect users' perceptions and decisions to use them. Given that these MAs are constantly connected to the users' bodies and may be considered an extension or part of their bodies (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010). Therefore, perceptions toward their wheelchair represent emotional understanding of their body that play a role in the social participation (V. de S. P. Costa et al., 2010; Rasoulivalajoozi & Farhoudi, 2025b). A study indicates that WUs, especially females, generally had negative emotional responses such as hate, disgust, contempt, disappointment, anger, and regret (Mokdad et al., 2018). Thus, users' perceptions of MAs are continuously influenced by social stereotypes and interactions (Barlew et al., 2013; V. de S. P. Costa et al., 2010; Edberg & Persson, 2011), leading to perceived pity, depression (Saia et al., 2024), and reduced social interaction (Rasoulivalajoozi et al., 2025a).

As Mokdad et al. emphasized, we need to ask who is responsible for these results: the designers of MAs, social attitudes towards the disabled, or both. Although changing the perceptions and negative emotional responses towards wheelchairs requires a collective effort (Mokdad et al., 2018), we need to first find out how such perceptions in user-wheelchair interactions are shaped and may fluctuate over the rehabilitation. Without understanding and tracking the dynamics of perceptions end emotional responses throughout rehabilitation, we cannot develop effective interventions to enhance the acceptance and consistent use of wheelchairs. Emotions are typically intense, specific, and short-lived, however, they collectively can form broader affective experiences, such as overall mood trends and general outlook on recovery (e.g., optimism or pessimism during rehabilitation) (Pňaček(ová), 2022). Therefore, to track perceptions of wheelchairs throughout a planned rehabilitation timeframe we need to prioritize the Dynamics of Affective Experiences (DAE) over the fluctuation of emotions. DAE, likely cannot be static and are changed (Bettiga & Lamberti, 2018; Yoon et al., 2020), at each stage of the rehabilitation from purchasing to the end of usage.

Tracking the DAE in using wheelchair during the rehabilitation timeframe helps in developing training programs aimed at improving effective therapeutic relationships for physiotherapists. It enhances physiotherapists' understanding of users' adherence to or rejection of wheelchairs or other types of MAs, thereby improving rehabilitation outcomes and user satisfaction. Furthermore, this exploration could emphasize the importance of affective attachment with wheelchairs to promote user-centered design in MAs. This calls for identifying design criteria and interventions influencing users' responses (Carneiro et al., 2017), providing positive perceptions, and encouraging continued use. Socially, this tracking reveals how users' perceptions of disability change under the influence of social discourse on disability throughout the timeframe of rehabilitation. This helps to provide policies and practices to mitigate the stigma and social disengagement.

In this regard, previous studies have predominantly focused on the interaction between individuals with mobility disabilities and their assistive devices, including wheelchairs, from various perspectives. These perspectives include improving environmental factors (Hossen Sajib, 2022; Widehammar, Lidström, et al., 2019), ergonomic optimizations (Widehammar, Lidström, et al., 2019), engineering aspects (Teodiano Freire Bastos et al., 2017), and health status, collectively enhancing WUs' experience. One study found that patients with more severe impairments rated their wheelchair less positively than those with less impairment, indicating a positive correlation between health status and attitudes toward the wheelchair (Antler et al., 1969). Previous research has also highlighted the emotional design of wheelchairs (Carneiro et al., 2017; Mokdad et al., 2018; Desmet & Dijkhuis, 2003) and their role in social participation (Rousseau-Harrison et al., 2012; Sapey et al., 2005; Brandt et al., 2004). Socially, wheelchairs have been shown to significantly impact social involvement (Carneiro et al., 2018). One study demonstrated a difference in understandings of prescribers and WUs, highlighting that users place greater importance on emotion and appearance (Mortenson & Miller, 2008). This finding emphasizes the unique perceptions among WUs that need to be investigated and tracked in more depth. To the best of our knowledge, this study is the first to monitor the DAE in using wheelchair throughout the rehabilitation, addressing a significant gap in existing research.

While some individuals may require MAs for their entire life, others may only need wheelchairs temporarily. This study aims to explore the phases of wheelchair usage and the associated perceptions during a planned rehabilitation timeframe, drawing on the in-depth experiences of physiotherapists who participated in the interviews. We particularly focus on identifying the interaction challenges that WUs face in both public and private settings, which shape their affective experience in using their wheelchairs. In alignment with the study's goal, we specifically address the following questions: What key themes represent the different phases of DAE in using wheelchair throughout rehabilitation, and how do these dynamics emerge and transform? The contributions are summarized as follows:

- Tracking WUs' affective experience over a timeframe contributes to disability studies and physiotherapy for developing protocols in phases of prescribing MAs and monitoring the rehabilitation.
- Health design thinking experts can introduce relevant design interventions in services and assistive products to enhance inclusivity, considering the dynamics of perceptions throughout the rehabilitation.

2 Method

2.1 Establishment of the Study Procedure

As the depth of information and socio-economic and cultural factors are important for understanding the complex emotions and social interactions associated with MAs, a qualitative approach — specifically, a thematic analysis within an interpretivist paradigm — were taken to capture a wide range of perspectives (Özcan et al., 2021). Thematic analysis was chosen for its ability to identify, analyze, and report patterns within qualitative data, providing a rich and detailed understanding of participants' perspectives. This approach is characterized by flexibility (Busetto et al., 2020), making it beneficial for tracking the DAE of WUs. Such dynamic can be explored through interviews with physiotherapists, due to their close, long-term relationships with people with mobility disabilities (Chartered Society Of Physiotherapy, 2022). Additionally, physiotherapists generate valuable insights from their interactions with a diverse range of individuals with varying mobility disabilities, insights that may not be easily captured in interviews with vulnerable WUs. Therefore, physiotherapists were the most appropriate participants for this study. Other studies have also adopted this approach, relying on healthcare providers to represent the needs and experiences of target groups and patients (Coombs et al., 2022; Jack et al., 2018; Cucuzzella et al., 2024). We initially used the *product experience framework* to interpret WUs' experiences over time (Desmet & Hekkert, 2007). Subsequently, we employed in-depth interviews (IDIs), aligned with our research objectives (Jamshed, 2014; Longhurst, 2009). Following the identification of the themes, we defined the Level of Dependence Index (LDI), a conceptual construct representing the dependence of users on MAs throughout the rehabilitation process. The LDI captures a continuum from 'resistance'—reflecting reluctance or emotional struggle in adopting MAs—to 'reliance,' indicating acceptance and integration of MAs into daily life. As a qualitative construct, the LDI was suggested through a thematic analysis. Accordingly, we presented the DAE diagram**.** This diagram illustrates the transformation of affective experiences throughout a planned rehabilitation timeframe. Finally, we justify the emergence of this dynamics.

2.2 A Framework for Understanding Users' Experience of Wheelchairs

In this study, we adopted the widely used *product experience framework* introduced by Hekkert and Desmet (Desmet & Hekkert, 2007) to explore DAE in using wheelchair over time. This framework encompasses three layers of *aesthetic pleasure* (i.e., the degree to which all our senses are gratified), *meaning attribution* (i.e., the meanings we attach to the product), and *emotional response* (i.e., the feelings and emotions that are elicited through the product's usage). According to this framework, emotions are evoked through interactions with products when users appraise the products as beneficial or harmful to their concerns, linking sensory appeal and interpreted meanings to emotional outcomes. The *designing emotions* model (Desmet, 2002) was also taken to explore the emotional aspect of the wheelchair-user interaction. This model includes three components of *appraisal*, *concern*, and *product*. Users first assess a product's utility (appraisal), determine if it meets their emotional needs (concern), and if the product holds significance, it elicits a positive emotional response. The model emphasizes that while the connection between a product's appearance and emotions is not straightforward, emotions can be measured and designed for, contributing to a deeper understanding of product-user interactions.

In our study, adapted from these frameworks, individuals with mobility disabilities are considered as users and wheelchairs as products. It should be noted, the term "clients" is used as it reflects the participants' language, and therefore, "clients," "WUs" and "users" are used interchangeably. Aesthetic perception and evaluation represent the sensory pleasure during interaction with a wheelchair, and meaning attribution relates to users' interpretations of a wheelchair. The emotional response denotes the feelings and emotions evoked in users by a wheelchair. For WUs, these emotional responses can shape the DAE in using wheelchair, as the devices not only fulfil their functional needs but also resonate with their personal goals and aspirations, fostering a lasting attachment.

2.3 Development of Interview Guidelines and Questions

Research team members initially conducted the relevant literature review and highlighted the key relevant aspects of the product experience framework (Desmet & Hekkert, 2007). The authors excluded the areas of engineering aspects and ergonomics, which focus more on physical interactions. To ensure study validity and rigor, we formed an expert panel consisting of the authors and two external members—a physiotherapist and an inclusive designer—both with extensive experience working with mobility disabilities. The expert panel acknowledged that contextual elements, such as cultural factors, personal beliefs, and social considerations, influence each phase. Accordingly, while participants may define ableism and perceive disability through a medical model that frames it as an undesirable individual deficit, the questions and results aim to capture the social and psychological aspects of disability (Johnston & Bonetti, 2001). Then, this panel facilitated the drafting of the IDI guidelines and questions. Finally, after unanimous agreement among authors, the final interview guide, detailing the sequence and content of questions, was approved. In English, some samples of the key questions were:

1) How do clients feel and react when they are prescribed an MA for the first time?
2) What factors influence clients to adopt or hinder their use of wheelchairs in daily routines? How do these factors shape their expectations of wheelchairs?
3) How do clients perceive their wheelchairs and their environment? Are there any compatibility issues? How soon after using wheelchairs do they report any compatibility issues with their environment?
4) How do clients perceive high-tech wheelchairs? Does this perception affect their decision to accept or refuse a prescribed wheelchair?
5) How do clients feel after using MAs for several months? Which contextual factors (e.g., culture, society) most influence perceptions of disability and representation of wheelchairs?
6) Do clients become aware of their rehabilitation progress and how they eventually discontinue using prescribed MAs?
7) What factors encourage or discourage users from continuing to use wheelchairs? How do they compare their body before and after experiencing a disability challenge?

2.4 Participants

In this study, experienced physiotherapists were selected as participants for the IDIs. Their prolonged relationships with WUs and continuous monitoring during the rehabilitation process distinguish them from other caregivers, such as orthopedists and radiologists, who typically have shorter interactions with clients during medical visits. These physiotherapists were selected based on their extensive, direct engagement with WUs, which provides a unique perspective on the long-term affective experiences of these individuals. The inclusion criteria for participants were: 1) being registered as a physiotherapist in the Islamic Republic of Iran Medical Council (IRIMC), 2) a minimum of 5 years of experience in either the private sector or hospital physiotherapy wards, and 3) voluntary participation. Exclusion criteria included concurrent participation in studies related to the engineering and ergonomics of MAs development. As these studies primarily optimize direct user-wheelchair interactions, they may influence participants' responses, which should reflect the long-term affective experiences of WUs. A combination of purposive and snowball sampling techniques was used to recruit participants. Initially, physiotherapists with the required qualifications were approached through professional networks and clinics. These physiotherapists then referred colleagues who also met the criteria, thus expanding the participant pool. A total of 12 physiotherapists, all of whom were treating clients with physical disabilities, agreed to participate in the interviews. Given the study's aim to address themes with an anticipated moderate to high prevalence (e.g., over 40%), a sample size of 12 is expected to provide adequate coverage. This calculation is based on the sample size needed, considering theme prevalence in the population and aiming for a 90% probability of observing the desired number of instances (Fugard & Potts, 2015). The participants were not acquainted with the interviewers prior to the study, ensuring that the interviews remained unbiased. Table 12 provides further details on participant characteristics, including their professional background and the settings in which they treat WUs.

Table 12. Background of participants and interview timing (*N*=12).

Participant (P) #	**Years of experience**	**Interview time (Min)**	**Working experiences and profession category**
P1	26	120	Private clinic, hospital & national medical committee of the Olympics
P2	25	85	Private clinic, welfare organization
P3	15	50	
P4	7	45	Home visiting
P5	13	85	Private clinic
P6	25	45	Private clinic, state welfare organization
P7	18	65	National medical committee of the Olympics, Private clinic
P8	19	70	Hospital
P9	21	80	Healthcare center
P10	17	60	Hospital
P11	23	75	Healthcare center
P12	25	60	Private clinic
-	Sum=234, Mean=19.5	Sum=840, Mean=70	-

2.5 Data Collection

Participants received an email before the interviews with an informational leaflet and invitation letter. The primary interviewer scheduled interview times and locations with participants one day in advance. Following this, interviews, lasting between 50 to 90 minutes, were conducted from March 2022 to February 2023 in participants’ private clinics and public hospitals (physiotherapy wards) located in Kordkoy and Tehran, Iran. Upon obtaining written consent and signed confidentiality forms, interviews were recorded digitally with participants’ consent, then transcribed, and anonymized. The interviews followed a semi-structured IDIs outline (Longhurst, 2009), allowing for open-ended responses while ensuring consistency across sessions. This format enabled participants to elaborate on their experiences while providing researchers with the flexibility to probe deeper into relevant themes.

The IDIs included targeted inquiries into clients’ interactions with MAs at various stages of their rehabilitation. A comfortable environment was maintained to facilitate answering questions. Participants were given enough time to contemplate their perspectives and discussions persisted until data saturation was achieved. The study adhered to the Consolidated Criteria for Reporting Qualitative Research (COREQ) checklist (Tong et al., 2007). Physiotherapists primarily shared experiences of adult WUs (>18 years) who required a wheelchair for a defined period due to conditions such as temporary spinal cord injuries, post-surgical recovery, or severe fractures (e.g., hip, pelvic, or lower limb). They did not differentiate between gender differences. Their insights were based on the rehabilitation experiences of approximately 410-500 users of diverse MAs, closely monitoring their recovery progress. This number was derived from participant-reported data provided to the research team.

2.6 Data Analysis

Audio recordings were transcribed within 48 hours after each interview. Originally conducted in Persian, the interviews were translated into English and then anonymously reviewed and archived by two authors. To ensure translation accuracy, two authors—both native Persian speakers familiar with the culture and metaphors—collaborated with a native English-speaking author. After transcription and initial verification, the interview data were systematically analyzed using Braun and Clarke’s inductive thematic analysis framework (Braun & Clarke, 2012). This approach involves six phases: familiarizing with the data, generating initial codes, identifying themes, reviewing themes, defining and naming themes, and producing a final report (Braun & Clarke, 2006). To ensure the rigor and credibility of the analysis, the transcriptions were reviewed with participants to verify the accuracy of their ideas. Transcripts were entered into Nvivo 12 for coding and sorting, and an initial codebook was created. The codebook was iteratively refined throughout the analysis process to ensure comprehensive coverage of the data and consistency in coding. This iterative refinement helped maintain analytical rigor and allowed emerging themes to be accurately captured. Two independent coders analyzed the transcribed interviews separately. Inter-coder reliability was assessed through regular discussions and consensus meetings, where coders compared their findings and discussed discrepancies. Authors applied both semantic and latent data interpretation strategies to identify broader themes (Braun & Clarke, 2022). This involved organizing, sorting, and examining coded excerpts for repetitions, similarities, differences, and gaps. Then, the codebook was refined through consensus to minimize subjective bias and ensure consistency in theme development.

Ultimately, the relevant quotes were selected, and findings were reported in alignment with our research question. The research team held weekly meetings during coding and analysis to discuss progress and agree on data interpretation. Reflexivity was maintained throughout the process, with researchers acknowledging their potential biases and actively reflecting on how these might influence data interpretation.

2.7 Ethics

The Human Research Ethics Committee approved the study (Certification Number: 30016116). Participants were informed about the study's objectives, gave written consent, and were allowed to withdraw at any time.

3 Results

The authors initially agreed on 44 codes, grouped into 6 clusters. These were then refined into four themes and two sub-themes, and further discussion consolidated them into three main themes. These themes represent the physiotherapists' perspective on WUs' interactions with their devices throughout the different stages of a planned rehabilitation process:

(1) Coping in Using the Wheelchair
(2) Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal
(3) Approaching Recovery: Challenges in Over-reliance

3.1 Theme I: Coping in Using the Wheelchair

This theme addresses the challenges, presumptions, and expectations potential users face when starting to use the wheelchair. It primarily involves negative presumptions about self-disability and living with an MA daily. Subsequently, addressing the mobility issue, and integrating devices into daily routines for upholding independence and quality of life are secondary issues when clients think about a wheelchair (Table 13; Q1). Clients are often shocked when realizing they must use a wheelchair in daily life, both privately and publicly (Table 13; Q2). They often show a resistant reaction to using wheelchairs, even after purchasing the prescribed devices. They may even prefer to deny their disability or ask physiotherapists for an alternative rehabilitation method (Table 13; Q3 Users are not yet faced with physical environmental obstacles but are primarily confronted with negative stereotypes about mobility disabilities, with wheelchairs serving as iconic representations of these stereotypes in their mindsets (Table 13; Q2 and Q4). During this period, individuals often react with anger or depression, comparing their current disabled state to their past abilities (Table 13; Q5). They may blame themselves for mistakes leading to mobility issues or attribute their condition to fate rather than realistic factors (Table 13; Q6). Here, clients' defensive approach to using MAs prevents them from thinking about desired functionality or aesthetics—it is not a priority for them (Table 13; Q7).

Table 13. Participants supporting quotes on Theme I.

Quote (Q) #	Coping in Using the Wheelchair
Q1	*Once they[clients] find they need to use it, notions around the disability will be reminded…. They ask how people see them from now on.* *…They [clients] also consistently think about possible challenges that might be faced. And how all of these can be handled.*
Q2	*The first reaction is shock. They [clients] do not believe that they need to use a wheelchair from now on….*
Q3	*They [clients] tend to ignore using a wheelchair or a cane, even after buying a wheelchair…. We [physiotherapist] need to persuade them that they must use it, otherwise, it may lead to a risky situation or delay the recovery….* *Their primary concern is when will I get rid of this product [MAs or any kind of wheelchair] …. The first and most urgent question is how many days I [clients] should wear it (the brace). Is it possible to reduce this time with another activity? Is there any alternative option, instead of using a wheelchair?*
Q4	*They think that their wheelchair or cane reveals their disability and affects their friends, family, and themselves' perception. How others see me [as a patient] is very important….*
Q5	*Their reaction is initially anger and finally yield…. They occasionally experience feelings of depression and even contemplate suicide.* *…Individuals may become depressed or react with anger…. It can depend on support from their environment, family, peers, and the encouragement or coercion they face regarding assistive device usage.* *Clients feel that they recently had all kinds of well-being routines (exercise, rest, makeup), but now this issue has become a disability.*
Q6	*They sigh. They believe that this [mobility disability] is a form of retribution and punishment for their past actions….*
Q7	*At first, they [clients]do not consider the quality or design style of wheelchairs…. Their primary concerns revolve around their mindset regarding disability and the challenges of mobility disability, that considerably influence their state of mind….*

3.2 Theme II: Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal

In this phase, clients reluctantly accept the wheelchair, fearing delays or risks to their rehabilitation without it (Table 14; Q8). They confront physical environmental obstacles for the first time, realizing the challenges of navigating mobility in environments while facing society's negative perceptions of WUs (Table 14; Q9). However, despite accepting the prescribed wheelchair, clients view them solely as functional devices, serving their practical purpose for mobility and nothing beyond that (Table 14; Q10). Over time, WUs become accustomed to their devices and focus more on tackling their physical and interactional challenges, rather than dwelling on initial presumptions

(Table 14; Q11). Clients view physiotherapists as sources of knowledge who can provide encouragement and support to continue using MAs (Table 14; Q12). Here, the emphasis on the functionality and aesthetic of the wheelchair becomes also heightened, since both influence the user's mobility and self-perception and society's reactions. For instance, powered wheelchairs are often preferred over manual ones due to their advanced technology for ease of mobility and futuristic appearance (Table 14; Q13). However, the cultural context, social values and the cause of disability can also significantly affect the user's perception and emotion and continued use of the wheelchair in public. Mobility disabilities from war injuries, such as during the Holy Defense[4] in Iran, are seen as heroic, while those from incidents like theft are associated with stigma and guilt (Table 14; Q14).

Table 14. Participants supporting quotes on Theme II.

Quote (Q) #	Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal
Q8	*Finally, after resisting, they [clients] accept because they see that their health is in danger…. Their reaction is initially anger and finally yield.*
Q9	*In an environment where nothing is suitable for disabilities and all tools and equipment convey disability as an insult, feelings of shame and helplessness are greatly amplified and perpetuated for the users….* *…Clients easily explore such meanings and share their experiences at this stage with us [physiotherapist].* *Unfortunately, in our country mobility disability is seen as a stigma, which causes patients [users] to feel shy and embarrassed….*
Q10	*Clients think it [wheelchair] is temporary, so they consider it just for their functionality….* *They may consider it [MA] as an extra load and gadget on their body, which is just applicable to mobility.*
Q11	*It can be said that we observe a phenomenon of adaptability with the wheelchair or prescribed MA….There is a period when clients finally accept the products, yet still experience social and cultural challenges…. This stage may persist until full recovery is achieved.* *If you design the environment in such a way that all tools and accessories are considered for a disabled person, what is being expressed here is respect for disability. The disabled person will also understand this, and the given respect will make the acceptance of disability easier for them….*
Q12	*…However, we can encourage them to persist and continue to use it by offering support and empathy.*

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[4] The Iran-Iraq War was referred to as the "Imposed War" and the "Holy Defense" in Iran due to its perception as a defensive struggle against aggression (UChicago Library, 2024).

Quote (Q) #	Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal
	They are very open and receptive to the treatment process and respond with, "I will use whatever you say", when it is recommended….
Q13	*…Products [MAs] should be designed to confer prestige rather than limitations. Therefore, they should depart from traditional norms and meanings, embracing advanced features instead.* *Technology can have a significant impact, ranging from 20% to 40%. Especially for those who resist using MA [wheelchair].* *The beauty of assistive products can influence client's preference by 30-40%, which is significant. This is especially true for children and young people, where appearance matters a lot.*
Q14	*…Social, accessibility, and work environment issues, align with cultural differences, appearance [MAs] and clothing styles can affect the fit and perception of MAs, potentially exacerbating the patient's condition and reproducing the meaning of "I am a patient." ….* *Owning a crutch or wheelchair from wartime, even if it's no longer necessary, serves as a heroic symbol for the individual – embodying qualities of courage, selflessness, and determination….*

3.3 Theme III: Approaching Recovery: Challenges in Over-reliance

During this stage, clients frequently seek updates on the time of recovery from physiotherapists. They strive to mentally prepare themselves to achieve full recovery and abandon the use of the wheelchair. However, their reactions are two-fold: eagerness and happiness on one hand, and fear of leaving MAs on the other (Table 15; Q15). In this context, some clients may prefer to continue using wheelchairs, even after achieving full recovery (Table 15; Q16). Users have become emotionally and mentally attached to their wheelchairs, viewing them as a primary source of support. In other words, users sometimes prefer to continue using their wheelchairs with their limited functionality for daily activities, even after recovery (Table 15; Q17). Here, physiotherapists play an important role in persuading clients to discontinue use, reducing their reliance and emotional attachment to their wheelchairs (Table 15; Q18).

Table 15. Participants supporting quotes on Theme III.

Quote (Q) #	Approaching Recovery: Challenges in Over-reliance
Q15	*As patients [clients] approach the end of rehabilitation, we observe a duality in their emotions…. Some [MA users] are excited, while others show fear and sadness.* *…They [clients] may become dependent and stubborn, accustomed to its presence, and still doubting their recovery.*
Q16	*Becoming accustomed to improper walking or malposition results in an awkward posture. However, the patient [client] grows used to it and even develops a kind of addiction to it.*

Quote (Q) #	Approaching Recovery: Challenges in Over-reliance
	Sometimes, a client subconsciously may continue using the wheelchair out of despair, even if they have recovered….
Q17	*…Despite any attachment to the wheelchair, the patient [clients] must be encouraged to transition away from it. Sometimes I [physiotherapists] see that women impose the disease on their partner.* *Actually, if they seek more emotional support, they may intentionally prolong the use of this device [MA]….*
Q18	*Now a person gets so used to that device that it becomes difficult to let go and move on without them.… We must now insist that it [leaving MA] is no longer dangerous.* *…It [continuous use of the MA] causes weakness. It causes an incorrect posture….* *Only a skilled psychologist can convince them [clients] to discontinue its use....*

3.4 Mapping the DAE and Its Influencing Factors

In the presented themes, it is impossible to pinpoint the exact duration of each phase due to the unique nature of individual's mobility issues and context. However, based on the introduced LDI, we can roughly illustrate the DAE in user-wheelchair interaction throughout a planned rehabilitation timeframe (Figure 21). This figure is developed from thematic patterns in the interviews, illustrating the affective experiences of WUs described by physiotherapists. The vertical axis ranges from "Resistance" at the bottom to "Reliance" at the top, while the horizontal axis tracks progression over time. As DAE diagram shows, initially, clients enter a "Strict resistance" period, characterized by a refusal to accept the wheelchair due to contextual and emotional barriers. Over time, they reach a "Yielding point," where resistance is at its lowest, indicating the beginning of acceptance. Following this, users enter a "Receptive period," becoming more accustomed to integrating wheelchairs into daily routines and recognizing their practical benefits. Eventually, users become accustomed to wheelchairs but still do not view their usage as completely normal (i.e., "Accustomed to, yet still not considered normal"), achieving a sense of stability in acceptance without full satisfaction. As adaptation continues, users feel more connected to the wheelchair, and their reliance increases (i.e., "Risk of over-reliance on wheelchair"). Despite being "Fully recovered" and having the potential to abandon the use of MAs, they may still risk over-reliance on the wheelchair out of habit or perceived convenience, even after regaining mobility. While the overall pattern of the DAE remains consistent, the duration and intensity of each phase may vary among clients. These variations are influenced by social and contextual factors that indirectly impact their experiences.

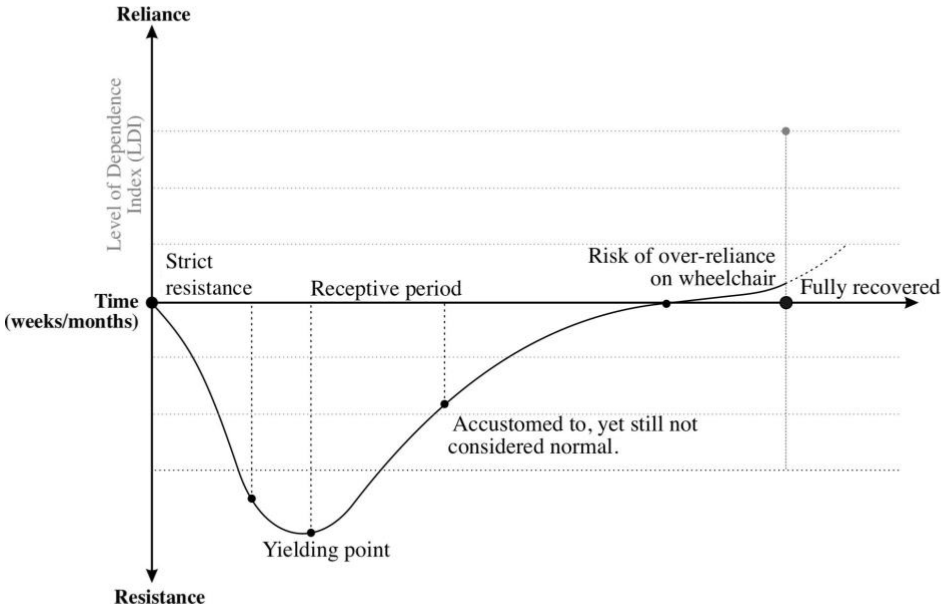

Figure 21. Dynamics of Affective Experience (DAE) in user-wheelchair interaction during rehabilitation. © Image by Author.

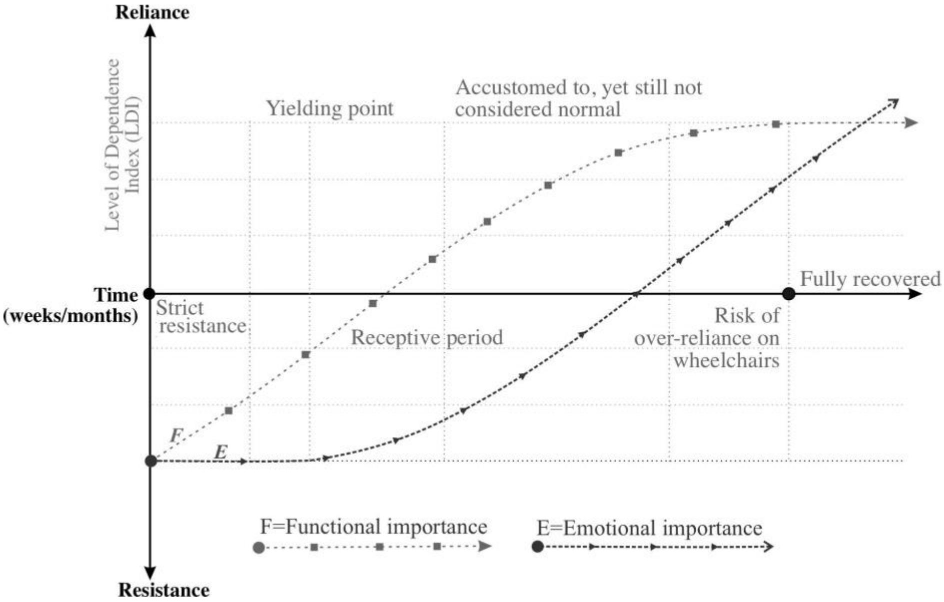

Figure 22. The flow of emotional and functional importance in alignment with the phases of the DAE in using wheelchair. © Image by Author.

In further exploring the emergence of DAE, as illustrated in the Figure 21, two primary factors were identified in themes: Emotional importance (E) and Functional importance (F). Figure 22 visualizes the progression of functional (line F) and emotional (line E) importance, as repeatedly noted in our qualitative data. This figure illustrates the flow of these factors in alignment with the phases of the DAE. The left-to-right progression captures users' shifts from "Strict Resistance" in the early stages to eventual "Full recovery" at the far right. Both lines begin at relatively low levels (i.e., "Strict resistance") and increase as individuals become more involved with their MAs, displaying similar upward trajectories but with key distinctions in timing and nuance. Initially, functional importance grows as users acknowledge the practical benefits of the wheelchair (i.e., “Receptive period”), while emotional importance increases from the “Yielding point” steadily, as users seek to experience MAs in their social context. Functional importance stabilizes as recovery nears (i.e., “Fully recovered”), maintaining a consistent level. In contrast, emotional importance continues to rise even as recovery approaches. While we refrain from making broad generalizations about the DAE diagram presented (Figures 21 and 22), recognizing that it may vary across different contexts and personal attitudes, it nonetheless represents a general pattern observed in our study, supported by the theoretical framework and relevant justifications. Both diagrams were reviewed and validated by the participating physiotherapists.

4 Discussion

In this section, each theme is interpreted, and their scope and connections with other themes are discussed. By justifying the identified themes, we can understand and track the user-wheelchair experience illustrated in the DAE diagrams. Additionally, we discuss how changes in emotional and functional importance shape the DAE. The provided themes and accompanying diagrams represent this study’s unique contribution, addressing a gap in the literature concerning client DAE in using MAs.

Themes indicate that the DAE with prescribed wheelchairs change over time, as emotional and functional priorities vary throughout the rehabilitation (Figure 22). The DAE can also vary depending on cultural contexts, personal beliefs about disability, and health status, all of which can influence the length of each phase. Research shows that attitudes toward wheelchairs vary with time and health status, suggesting that a disabled person’s attitude may be shaped by how they perceive the duration of their disability (temporary vs. permanent) (Antler et al., 1969). While previous studies on user-product interaction have highlighted changes in user experiences over the life cycle of products usage (Yoon et al., 2020) and provided models for assessing these experiences (Kujala et al., 2011), no studies have specifically tracked the experiences of WUs throughout rehabilitation. The DAE is particularly pronounced among WUs compared to users of other artifacts, as they constantly fluctuate between the duality of emotional and functional aspects. WUs hold negative presumptions and emotion about disability and using a wheelchair (Darling, 2019; Iezzoni et al., 2000), while simultaneously expecting mobility, physical comfort, independence, support, and functionality to meet their needs. The intensity of each factor justifies the flow of DAE.

During the initial phase, users encounter resistance stemming from negative stereotypes about disability, leading many individuals with significant mobility challenges to not identify themselves as disabled (Iezzoni et al., 2000). This perception persists until they come to accept the wheelchair (Mortenson & Miller, 2008). According to Desmet’s Basic model of *designing emotions* (Desmet, 2002) users first, appraise the wheelchair’s usefulness and value it based on its ability to meet their emotional needs. If the wheelchair (product) is seen as significant, a positive emotional response emerges (Mokdad et al., 2018). Based on Theme 1, users likely do not value the wheelchair emotionally, and the attributed meaning reinforces negative disability stereotypes. Previous studies also highlighted the impact of traditional notions about disability (Barbareschi et al., 2021) and the stigma associated with wheelchair (Saia et al., 2024; Barbareschi et al., 2020). Accordingly, users show resistance to using wheelchairs or any MAs, due to perceived low emotional and functional significance. Particularly, the expected functionality of the prescribed MA is overshadowed by users' negative presumptions (attributed meaning) about wheelchairs (Desmet & Hekkert, 2007). Previous research has also confirmed that the initiation of wheelchair use can be psychologically distressing (Aho et al., 2018). However, as WUs acknowledge the practical benefits of the wheelchair, its functional importance increases, with emotional importance still taking a secondary role. This functional importance paving the way to the yielding point. In this context, healthcare professionals can play a key role during both the introduction and ongoing use of wheelchair (Aho et al., 2018; Rasoulivalajoozi et al., 2025b).

Users finally accept the wheelchair reluctantly, as refusal could result in declining mobility. During this phase, the functional importance continues to rise, while emotional importance begins to increase. As they enter the receptive period, users gradually become accustomed to the prescribed wheelchair, incorporating it into their daily lives. Consequently, functional importance plays a key role and is anticipated to increase steadily. Similarly, with the integration of the wheelchair —the *product*—into their social lives and mediated by its aesthetics and positive attributed meaning, emotional importance also grows as expected (Desmet, 2002; Desmet & Hekkert, 2007; Faraji & Valajoozi, 2014). During the adjustment period, users employ wheelchairs but may not yet see their usage as completely normal. While the resistance stage is marked by reluctance, interaction becomes central during the adjustment phase. Accordingly, in this stage, any mismatch between users' expectations and the wheelchair's appearance and functionality can lead to emotional responses such as anger and frustration, potentially discouraging continued use (Barlew et al., 2013; Rousseau-Harrison et al., 2012).

Here both the emotional and functional importance are expected to continue growing. This step continues until full recovery, where the physiotherapist advises stopping wheelchair use. As they approach the recovery point, the functional importance may stabilize since they have already improved their skills with the wheelchair in resolving mobility challenges. However, since users' social presence depends on their use of a wheelchair (Rasoulivalajoozi et al., 2025a), its emotional importance may continue to grow, potentially leading to over-reliance. This over-reliance may pose risks to rehabilitation and reduce motivation for physical activity when users eventually need to discontinue using the wheelchair. In addition, it can lead to several negative consequences, such as muscle atrophy, poor posture, and pressure sores (Requejo et al., 2015; Stephens & Bartley, 2018) due to insufficient physical activity. It also increases the risk of secondary issues, including barriers to social interactions and psychological impacts like feelings of loss, anxiety, or depression (Johnston & Bonetti, 2001; Rousseau-Harrison et al., 2011; Saia et al., 2024). For instance, over-reliance on the wheelchair can act as a barrier to social interactions, as WUs may avoid situations that require them to challenge their dependence or face stigma from others. Moreover, when users are encouraged or required to discontinue its use, they may experience a sense of losing a part of their identity or independence.

Studies show that some WUs, after long usage, consider the wheelchair an extension of their body (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010a). Consequently, their emotions regarding the wheelchair are closely tied to their feelings about their own body, therefore losing the wheelchair can feel like losing a part of themselves. This over-reliance can also stem from the sense of safety and security the wheelchair provides, especially in unfamiliar environments or when facing physical limitations. Additionally, the wheelchair may become a symbol of autonomy for users who might otherwise feel vulnerable in social settings, further deepening their attachment. These potential reasons align with previous research suggesting that wheelchairs can provide reassurance or stability, and may become intertwined with users' identity or sense of self (Darling, 2019). In such cases, the intermediary role of a third party, such as a physiotherapist, can impact the users' emotional attachment toward the prescribed wheelchair (Aho et al., 2018). They can facilitate a gradual transition from each phase of wheelchair use, setting clear rehabilitation milestones, and providing emotional support. In other words, physiotherapists can act as catalysts in balancing the emotional attachment between users and wheelchairs, influencing users' decisions regarding wheelchair use; overall, shaping a DAE characterized by active acquisition during the resistance period and active discontinuation as WUs approach recovery. This necessitates ongoing connections between physiotherapists and clients within a client-centered framework (Mortenson & Miller, 2008; Rasoulivalajoozi & Touir, 2023). Additionally, support from family and friends is helpful (Rasoulivalajoozi et al., 2025a; Cucuzzella et al., 2024), and empathetic conversations along with efforts to build inclusivity can further alleviate the emotional burden associated with the loss of wheelchair use. Research shows that understanding the experiences of people with disabilities and engaging in empathetic conversations can improve attitudes and enhance inclusivity (Matera et al., 2021; Rasoulivalajoozi et al., 2025b).

In terms of *product experience framework*, as users approach recovery, they still apprise the wheelchair as beneficial and as a source of security. Even if they no longer need the wheelchair for mobility, they remain concerned about potential risks associated with not using it. Consequently, their emotional responses during interactions with the wheelchair remain strong, making it difficult for them to stop using wheelchair. This is supported by studies noting users may develop psychological dependence on their wheelchairs due to the sense of security and comfort they provide (Morris et al., 2022). Additionally, users may become accustomed to the attention and care they receive while using the wheelchair (Martire & Schulz, 2007), fulfilling emotional needs. Inadequate guidance or support during rehabilitation can also lead to habitual wheelchair use, which is challenging to change (Gardner et al., 2023). Therefore, *product experience* and *emotional design frameworks* could provide a lens for the justifying DAE of WUs during the three phases of resistance, acceptance, and the end of a planned rehabilitation timeframe.

The understanding of DAE presented in this study highlights the complexity of emotional attachment to wheelchairs in the rehabilitation process. Rather than assuming that fostering attachment universally enhances rehabilitation, it is important to recognize that its impact is highly phase- and context-dependent. On the one hand, in the early stages of rehabilitation, a positive emotional bond with a wheelchair can serve as a powerful enabler, enhancing autonomy, confidence, and self-efficacy. These factors not only enhance engagement in rehabilitation but also contribute to long-term physical and emotional well-being by reinforcing users' sense of agency and control over their mobility. On the other hand, emotional attachment can take a counterproductive form, particularly when it encourages an overreliance on the wheelchair at the expense of mobility progression. In such cases, attachment may inadvertently diminish motivation for continued physical improvement, reinforcing a cycle of dependence that restricts participation in both rehabilitative efforts and broader social and physical activities. This perspective highlights the need for individualized rehabilitation strategies that balance the benefits of emotional attachment with the imperative of sustained mobility development, ensuring that attachment functions as a facilitator rather than a barrier to long-term well-being. However, for a precise understanding of the underlying factors, we recommend further justification through theories related to the patient's psychology, as well as the necessity of longitudinal studies.

5 Conclusion

The study shows the DAE in using wheelchair during a planned rehabilitation timeframe. To this end, we identified three themes: (I) Coping in Using the Wheelchair, (II) Reluctant Acceptance of the Wheelchair: Adjusting to the New Normal, and (III) Approaching Recovery: Challenges in Over-reliance. Based on these themes, we presented the DAE diagram illustrating the stages of users' interaction with wheelchairs, each stage depicting unique perceptions based on the LDI (resistance-reliance) during rehabilitation. The duration of each stage varies depending on each case's therapeutic issues and context. Initially, clients experience shock and resistance toward using a wheelchair due to perceived low emotional and functional importance. Over time, both factors increase in parallel, with functional importance growing first, followed by the rise of emotional importance starting from the yielding point. Ultimately, as WUs approach full recovery, functional importance may stabilize, while emotional attachment continues to grow. This can potentially pose risks to mobility and rehabilitation due to the risk of over-reliance. In this context, physiotherapists can facilitate a balanced emotional attachment between users and wheelchairs, shaping a DAE marked by active adoption during resistance and active cessation as users approach recovery.

5.1 Limitations and Future Studies

This study focused on experienced physiotherapists as participants in the interview sessions, but their perspectives may not fully capture WUs' affective experience. Given the WUs undergoing rehabilitation are considered vulnerable participants, ethical constraints and the approved protocols prevented us from interviewing individuals with disabilities during this phase. However, future studies should include both physiotherapists and active WUs. We also recommend that future research conduct longitudinal studies. This approach will provide more detailed insights by continually monitoring the DAE in wheelchair use and its influencing factors of emotional and functional importance. This study lacks policy and design practice recommendations. Future research should apply these themes to develop effective interventions, particularly in training programs for physiotherapists and defining design criteria for enhancing environments and MAs. Finally, a literature review comparing our findings with existing research on user-product interaction can help develop a behavioral design framework for healthcare design specialists focused on MAs.

Chapter III: Understanding the Socio-Emotional Dynamics. Section 3.

Empathy and Interaction with Wheelchair Users in Society

This section is based on the following manuscript (under publication).

Rasoulivalajoozi, M. (2025). Pedestrians’ Social Empathy and Interaction with Wheelchair Users: The Impact of User Gestures and Mobility Aid Design in a Pilot Study. *International Journal of Industrial Ergonomics*. https://doi.org/10.1016/j.ergon.2025.103793

The *International Journal of Industrial Ergonomics*, published by Elsevier, is a peer-reviewed, open-access journal covering industrial and occupational ergonomics, design, human performance, and productivity.

Abstract: Wheelchair users (WUs) experience various accessibility challenges in public spaces, which may lead them to seek assistance from pedestrians in difficult situations. In this context, understanding the factors influencing pedestrians' empathy and interaction with WUs facilitates their social interactions in challenging urban situations. This study examines how WUs’ body gestures and wheelchair design characteristics (WDCs) impact pedestrian perception and interaction. A pilot cross-sectional study was conducted with 52 participants in two phases: (1) a questionnaire assessing willingness to engage with WUs exhibiting independent or help-seeking gestures, and (2) evaluating four wheelchair types—from conventional to advanced—using key semantic descriptors of appearance and social perception. Findings revealed no significant relationship between age, gender, and willingness to interact across the two gesture conditions ($p>0.05$), except for a significant association between age and willingness to interact with users of advanced powered wheelchairs in the help-seeking gesture condition ($p=0.027$). Also, pedestrians' willingness to interact was significantly higher when WUs exhibited help-seeking gestures compared to independence gestures ($p<0.001$). WDCs influenced pedestrian perceptions more strongly when WUs displayed independence (86.3%) than help-seeking gestures (50%). Moreover, analysis of semantic evaluations revealed distinct perceptual dimensions for advanced manual and powered wheelchairs, with three principal components identified for each, offering valuable insights for developing wheelchairs with greater social polish. This study highlights that both WDC and user gestures significantly affect pedestrian interaction, with the masking effect of help gestures on WDCs being a key finding. Additionally, advanced WDCs signify WUs' independence, helping reduce negative social stereotypes among pedestrians.

Keywords: Wheelchair design; Pedestrian behavior; Social interactions; Social empathy; Interaction design.

1 Introduction

When wheelchair users (WUs) encounter obstacles such as crossing streets or navigating stairs, they probably face a choice: tackle the challenge alone, with potential risks, or seek assistance from nearby pedestrians. However, this is not a one-sided issue; bystanders also find themselves in a situation of deciding whether to interact. In this context, several factors can influence bystanders' willingness to interact with WUs, including the user's physical condition, sociopsychological (J. Kim et al., 2024) and cultural factors (D. Costa & Duarte, 2019), physical appearance (Jiotsa et al., 2021), personal traits (Bitman, 2022) like assertiveness, and situational aspects such as urgency and location. In addition, the implicit cues, like eye contact and gestures (Dey & Terken, 2017), alongside wheelchair design factors such as size, color, and design (Dey, Habibovic, Pfleging, et al., 2020; Sokolowski et al., 2021; Gan et al., 2021; Faraji & Valajoozi, 2014), may influence bystanders' perceptions of the WUs' need for interaction. For instance, while individuals using manual wheelchairs (MWs) and powered wheelchairs (PWs) may have similar assistance needs, PWs often convey ease of operation and greater independence, suggesting less need for help. In contrast, MWs, which depend on physical effort, may appear to require more assistance. These perceptions align with Attribution Theory (Davis et al., 2017; Weiner, 1986), which explains how observers infer others' capabilities and intentions based on visible cues—such as wheelchair type or user behavior. Influenced by wheelchair design characteristics (WDCs) and user gestures, such perceptions not only reinforce stereotypes about WUs (G. M. Davies, 2009; G. M. Davies & Patel, 2005; Dey et al., 2017) but also affect their sense of self and identity, as some users perceive their wheelchair as an extension of their body (Blach Rossen et al., 2012). In this context, a wheelchair's aesthetic and structural design can strongly shape how bystanders interpret a user's sociability, independence, and need for assistance. These impressions—often formed rapidly and unconsciously—can significantly influence pedestrians' willingness to engage with WUs. According to Social Identity Theory (Islam, 2014), visible assistive devices may signal group membership, reinforce social boundaries and potentially contributing to stigmatization or exclusion in public settings (Rasoulivalajoozi et al., 2025b). Thus, the wheelchair's aesthetic and design characteristics can shape how bystanders perceive users in terms of sociability (B. Zhang et al., 2024), independence, and need for assistance, ultimately influencing their willingness to interact.

These assumptions are vital for WUs to enhance social participation and ensure equal interactions, especially in urban settings where challenges may disrupt negotiation, empathy, and interaction. Building on this understanding, when developing the design of wheelchairs, either MW or PWs, a relevant question is whether their design characteristic affects social interactions. If it does, how can visual factors be designed to enhance social interactions between bystanders and WUs? Additionally, how the WUs' gestures and behaviors can influence interactions? Studies highlight that the external Human-Machine Interface (eHMI) enhances implicit communication in negotiable situations where WUs need to interact with their environment (X. Zhang et al., 2024; Holländer et al., 2021). However, they still draw unwanted attention to users, exacerbating social stigmas (X. Zhang et al., 2024). eHMIs still fail to fully bridge the social interaction gap and instigate social empathy aspects (Asha et al., 2021). Beyond technical interfaces, other studies have shown that incorporating emotional factors (e.g., inspiration and admiration) into wheelchair design and appearance can positively impact users (Desmet & Dijkhuis, 2003; Dzogbewu et al., 2025). Moreover, the affective experiences of WUs may fluctuate across different stages of use, with modern designs often eliciting more positive emotional responses than traditional ones (Carneiro et al., 2018), which may even influence their initial encounters with the wheelchair or, in some cases, lead to over-reliance (Rasoulivalajoozi et al., 2025c). This finding is supported by experimental research demonstrating that both users and non-users tend to respond favorably to new and innovative aesthetics (P. Costa et al., 2012). Recent research on the socio-emotional aspects of wheelchair design demonstrated that aesthetic and symbolic importance are significantly linked to social communication challenges. Using principal components extracted through Kansei Engineering, the study also highlighted adjustable frame design—applicable to both manual and powered models—as a key factor in enhancing socio-emotional outcomes (Rasoulivalajoozi & Farhoudi, 2025b). Such design considerations therefore can help mitigate social stigma, addressing social interaction challenges for both groups. However, with the exception of a few cases where aesthetics are significantly applied in wheelchair design (SCEWO, 2024; WHILL, 2024), a review of brands in the mobility aids industry shows that most wheelchair designs predominantly follow the *Form Follows Function* principle (Craven, 2019). These designs tend to focus on frame structures and often lack external covers, presenting wheelchairs as mere assemblies of structural elements like struts and connections (Lidwell et al., 2010). A narrow focus on design can reinforce negative emotions and stereotypes; for instance, a study showed that female WUs often reacted negatively to current wheelchair designs, experiencing hate, disgust, and regret (Mokdad et al., 2018), potentially affecting their interactions.

While mobility aid manufacturers primarily focus on integrating futuristic technologies into wheelchair design, the social and psychological dimensions of wheelchair aesthetics and user behavior—and their effects on social interaction—remain underexplored. There is limited understanding of how aesthetic design influences social empathy and interpersonal engagement. In other words, it remains uncertain whether radically different or conventional wheelchair designs will affect people's assumptions and perceptions in situations requiring social empathy and negotiation. This understanding contributes to managing the integration of new technologies into advanced wheelchair designs. To address this gap, this study aims to investigate how visual and behavioral cues—specifically, the wheelchair's appearance and design characteristics (manual vs. powered, conventional vs. advanced) and the user's gesture (independent vs. help-seeking)—influence pedestrians' perceptions, social empathy, and decision-making. Accordingly, this study seeks to answer two research questions: 1) What is the relative impact of the WUs' gesture, and WDCs, on pedestrian's decision to interact with the user? 2) Do these interactions differ for MW versus PWs? Additionally, the paper explores the priorities of variables in the WDC that shape the perceptions of pedestrians toward the wheelchairs. To examine these questions, a pilot experimental study was conducted in two phases. In Phase 1, non-WU participants immerse themselves in a scenario where a WU faces a challenge and indicate their willingness to interact. In Phase 2, participants evaluated four distinct wheelchair types using semantic descriptors related to social perception and appearance. By employing these steps, the following hypotheses were tested: H1: WUs’ body gestures influence bystanders’ inclination to interact, H2: Different WDCs affect pedestrians’ willingness to engage with WUs, and H3: WDCs are prioritized differently in shaping perception between MWs and PWs with varying design styles.

The present study aims to examine how the aesthetic design of MWs and PWs, as well as the behavior of WUs, stimulates and influences pedestrians' reactions. The contributions of this study include:

- This study offers industrial designers and disability experts’ insights into public perceptions of wheelchairs and their users. These insights can inform design principles aimed at reducing disability stereotypes and enhancing eHMIs for wheelchairs, focusing on key social challenges.
- The findings can be compared with existing literature through a review, contributing to the development of a theoretical framework for understanding common factors that shape social interactions between mobility aid users and society.

2 Material and Methods

2.1 Research design

In line with the study's aim, a cross-sectional pilot experimental investigation was conducted in two phases (Figure 23): In Phase 1, demographic data was collected first, followed by participants indicating their willingness to interact with WUs exhibiting two different body gestures presented through composite imagery. In both conditions, participants viewed four types of wheelchairs: a Conventionally Manual Wheelchair (CMW), an Advanced Manual Wheelchair (AMW), a Conventionally Powered Wheelchair (CPW), and an Advanced Powered Wheelchair (APW). While the clear differences in WDCs suggest that the appearance of a wheelchair may influence bystanders' responses, the variations observed in the two conditions featuring the same wheelchair underscore the significant impact of WUs' gestures on pedestrians. If a significant difference is found, it is necessary to determine which semantic words describe the wheelchairs. Accordingly, phase 2 investigates to highlight the key components representing the characteristics of the wheelchairs shown in Phase 1. This segment explores components within WDCs and their priorities that influence social empathy and interactions. The WDCs are graded by semantic words in the questionnaire.

Concerning experiment design, observing the influence of wheelchair design on pedestrians' willingness to interact requires a variety of models, from traditional to advanced electric ones. However, many advanced MWs exist only as concepts, making observation impractical. Therefore, composite imagery is a more feasible alternative for simulating diverse wheelchair designs.

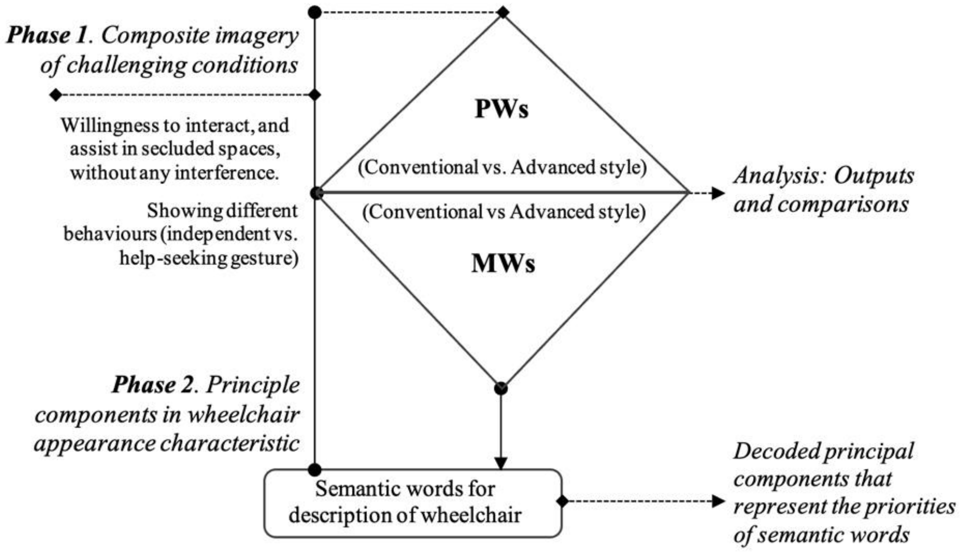

Figure 23. The phases of the procedure. © Image by Author.

The dependent variable is inclination towards social empathy and interaction, that assess based on pedestrians' attitudes and willingness to help. In this context, WUs' gestures are considered as the independent variable, while the WDCs (described using semantic words) and the wheelchair type (manual vs. powered/electric) are considered mediator variables that may influence the pedestrians' willingness to interact. Since WUs are shown in a constant context and environment, potential contextual variables were controlled (Figure 24).

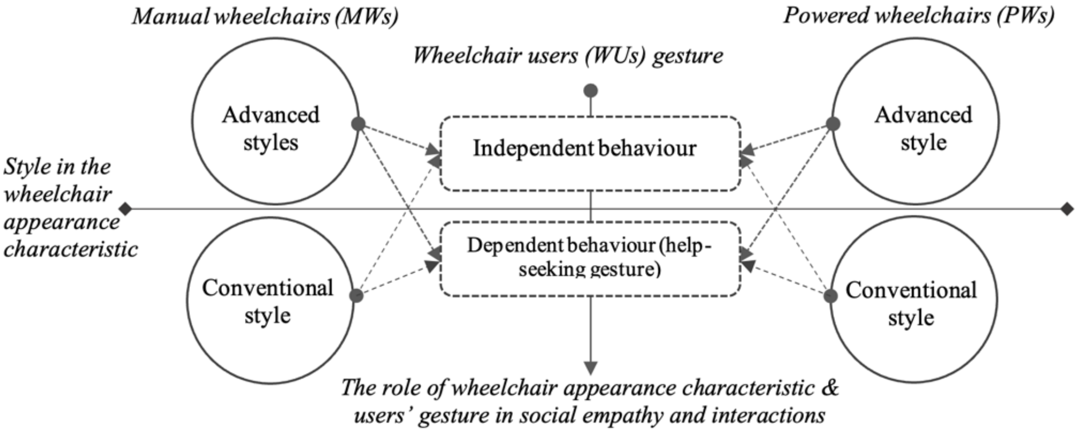

Figure 24. Variables in assessing social empathy and interactions based on wheelchair type and their design characteristic. © Image by Author.

2.2 Recruitment

Since the study aimed to explore pedestrian behavior and willingness to interact, specifically, non-WUs were considered as the target group. The inclusion criteria comprised: (1) the ability to read and respond to the questionnaire, (2) age above 18 years, and (3) willingness to provide informed consent and participate voluntarily. Exclusion criteria were concurrent participation in studies related to behavior and social interactions, as this could influence participants' intuition in their responses. Through a snowball sampling method, initially 65 participants agreed to take part in the survey. Ultimately, 52 participants completed the questionnaire (Age: mean =37.51, range=22 to 51, Std Error=1.35; Gender: 37% male and 63% female, Std Error=0.67).

2.3 Data Collection and Procedure

Initially, after participants consented and signed confidentiality forms, verbal explanations were provided in person to immerse them in the conditions required for their responses. Questionnaire data were collected between June and July 2024. If additional time was needed, participants had up to five days to complete the questionnaire, respond to questions, or request further clarifications. The experiment in both phases was primarily conducted online, with participants completing the survey via a secure digital platform (Google Forms), and the author was available to explain the procedure and provide assistance at the outset and throughout the virtual sessions. In six cases, data were collected during in-person sessions facilitated by the author, who used the same survey content, images, instructions, and procedures as in the online format to ensure consistency and comparability across both data collection methods. All responses were collected in English in Montreal, Canada.

Phase 1: In the composite imagery, the WU is shown facing a challenging situation involving an acute ramp, where the need for assistance is ambiguous. The scenes were presented from a pedestrian's perspective, positioned along the side of a neutral, empty street rather than a crosswalk. To create these synthetic images, original photographic elements of a WUs and a background were combined using Adobe Photoshop. The user's figure was carefully extracted from photographs using masking and layering techniques and digitally placed into the standardized street environments. The backgrounds were selected and edited to be neutral and free of visual distractions such as signage, crosswalks, or other pedestrians, ensuring the focus remained on WDCs and user gestures. To ensure consistency, all images featured a standardized background free of distractions such as signage or other pedestrians, allowing the focus to remain on wheelchair design and user gesture. WUs wore identical grayscale clothing, displayed neutral facial expressions, and were rendered in grayscale to minimize visual bias. Each image was meticulously composed to balance realism with experimental control, isolating the effects of wheelchair design and gesture while reducing extraneous visual cues.

Across these conditions, the wheelchair samples varied systematically in design characteristics to reflect different categories of wheelchair design. Specifically, two of the wheelchairs were selected to represent conventional models, characterized by standard frame structures, visible mechanical components, and minimal aesthetic characteristics. The other two were categorized as advanced designs, which exhibited features such as integrated technology, unconventional forms, or enhanced ergonomic structures. These visual and structural differences in WDCs were drawn from real-world examples and classified based on commonly accepted distinctions in design and assistive technology literature.

Each wheelchair model was presented with two distinct user gestures: an independent gesture (hands on wheels, forward-facing) and a help-seeking gesture (one arm raised, head turned with eye contact): Condition 1, demonstrating independent gesture and behavior, and Condition 2, making eye contact and help-seeking gestures. Such body gestures indicated the level of tendency of WUs towards interaction. One example of composite imagery along with an analysis of the environment and scales is presented in Figure 25. Then, participants, acting as pedestrians, rated their willingness to offer help and engage in social empathy and interaction with WUs on a 5-point scale, where 5 indicates the highest willingness and 1 indicates no interest in interaction. Although the pedestrian's inclination to interact was assessed using composite imagery of a challenging scenario rather than direct observation, extra explanations from a first-person perspective were provided to help participants feel immersed in a real scenario.

Figure 25. A composite imagery of a challenging scenario. © Image by Author.
This image is including the main horizontal lines of pedestrians and WUs, as well as the improper slope of the acute ramp and walking path. The composite imagery was colored, and the users' faces were not obscured in the questionnaires.

Phase 2: Participants were shown the same four wheelchair images used in Phase 1, each selected to represent distinct variations in WDCs. These WDCs were categorized based on key features—such as structural innovation, embedded technology, and form complexity—that commonly differentiate "conventional" from "advanced" designs in clinical and commercial settings. The advanced designs were represented by:

- WHILL Model C2 PW – known for its compact, minimalistic style, front omni-wheels, and integrated smart control system (WHILL, 2024).
- Gear-Adjustable MW (You Seong Kim's concept design) – notable for its ergonomic customization, gear-driven propulsion, and futuristic aesthetic (McNulty-Kowal, 2020).

Conventional designs were represented by:

- Cirrus Plus EC Folding PW (Drive Medical) – a standard powered type with traditional frame and joystick (Drive Medical, 2024).

- Excel 2000 Series MW (Medline) – a basic manual type with standard cross-brace folding frame (Medline, 2024).

All images were presented in black and white to eliminate color bias and encourage participants to evaluate the structural and form-based characteristics without influence from aesthetic preferences unrelated to form. The distinction between advanced and conventional categories was informed by industrial classification standards and design literature, which emphasize the presence of novel functional or visual elements in defining advanced mobility aids.

Participants rated each wheelchair on a 1-5 scale for various aspects associated with the descriptive semantic terms, as detailed in Table 16. Each word is presented via word pairs with scores where 1 represents the lowest intensity of the descriptive terms and 5 represents the highest. These words remain consistent across all wheelchairs. In this study, the refined set of semantic descriptors was developed through a mixed-method approach involving literature review, expert validation, and aesthetic analysis. Initially, we extracted candidate terms from scientific literature and magazines related to wheelchair design, focusing on both functional and socio-emotional attributes (e.g., stylish, trustworthy, futuristic, friendly). This was complemented by an aesthetic evaluation based on the Criticism of Interface Aesthetics (CIA) framework (Bertelsen & Pold, 2004), which, though traditionally applied in Human-Computer Interaction (HCI), offers valuable insights into the visual perception of design artifacts such as wheelchairs. The first CIA component—stylistic references—was particularly instrumental, offering analytical dimensions such as form style, simplicity, proportion, symmetry, complexity, novelty, strangeness, and associative relevance. This approach, widely used in graphic, industrial (Rasouli Valajoozi & Zangi, 2016; Faraji & Valajoozi, 2014), and architectural design (Coyne, 2001; Bertelsen & Pold, 2004), was employed to ensure that selected terms captured aesthetic resonance and social symbolism. Subsequently, an affinity analysis was conducted to consolidate and cluster the descriptors. This validation step ensured the final word list was both conceptually sound and relevant to real-world perceptions of wheelchair design. The resulting nine semantic terms were used consistently across all evaluations and served as the input for the PCA analysis (Asana, 2024). Using semantic words is a key aspect of Kansei Engineering (KE), which translates users' emotional responses and preferences into tangible product design attributes (Nagashima, 2012; Rasoulivalajoozi & Farhoudi, 2025b).

Table 16. The set of semantic words in description of wheelchairs design characteristic.

Semantic words	Explanation	Spectrum of word pairs
Friendliness	Feeling welcome to interact with product, positive experience, enjoyable	Unapproachable/ Friendly
Dignity	Self-respect, Honor	Stigmatized/Valued
Control	Maneuverable, Responsive, Adjustable, Precise	Non-responsive/ Responsive
Stylish	Elegant, Sleek, Chic, Clean	Plain/ Stylish
Independence	Autonomy, Self-sufficiency, Freedom	Dependent/Independent
Agility	Versatile, speedy Flexible	Inflexible/Agile
Futuristic	High-tech, Innovative	Outdated/Futuristic

Semantic words	Explanation	Spectrum of word pairs
Affirmation	Social validation	Rejected/Accepted
Trustworthiness	Reliability, Integrity	Unreliable/Trustworthy

2.4 Data Analysis

Initially, Kolmogorov-Smirnov (K-S) and Shapiro-Wilk test was used to assess the normality of the distribution, guiding the selection of appropriate parametric or non-parametric tests (Brace et al., 2007). The low p-value (<0.05) indicates deviation from normality, suggesting the use of non-parametric tests. Accordingly, the Chi-square test was used to examine the relationship between demographic variables (age, gender) and willingness to interact with WUs in each condition. In a Chi-square test, the small p-value (<0.05) indicate a significant association, and a higher p-value suggest the relationship may be due to chance (*Chi-Squared Goodness of Fit Tests with Applications*, 2013). The SPSS software version 29 was used to conduct all tests in this study.

Phase 1: Following descriptive statistics exploring the means and weight for each condition with different wheelchairs, the Wilcoxon test was applied to analyze significant differences between various wheelchairs in the two conditions (independent gesture and help-seeking gesture). This non-parametric test was chosen because the same participants evaluated multiple conditions, resulting in paired and dependent observations. As such, the Wilcoxon test was more appropriate than alternative tests (e.g., the Mann-Whitney U test), which are designed for comparing independent samples. This test was also used to compare differences between the four wheelchairs used in each condition, as well as between each specific wheelchair across the two conditions. A small p-value (p<0.05) indicates a significant difference; a high p-value (p>0.05) suggests no substantial difference (Brace et al., 2007). Given the assumption that WDCs and WUs' gestures impacts pedestrians' interaction, it was hypothesized that these effects would occur in a specific direction. Therefore, a 1-tailed test was used by halving the 2-tailed p-values obtained from the software, with significant differences reported accordingly.

Phase 2: First a descriptive analysis applied to explore the means and weight of each semantic words as the variables. Then, to determine which order of semantic words could describe—the high-rated—wheelchairs, the Principal Component Analysis (PCA) was conducted on semantic words as the variables, identifying and grouping those with similar interpretations. The PCA is a statistical method used to condense a dataset, consisting of numerous cases and variables, into its fundamental factors known as principal components (Bartholomew, 2010). For this, the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests were initially checked to assess data suitability (Brace et al., 2007). A KMO value close to 1 indicates suitability for factor analysis, and Bartlett's Test of Sphericity tests whether the correlation matrix is significantly different from an identity matrix[5]. A significant result (p<0.05) indicates that the correlations are strong enough for meaningful factor analysis (Bartlett, 1951). Additionally, since PCA in this study was applied for exploratory purposes and pattern identification, and given that strong factor loadings (0.7 and above) were

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[5] An identity correlation matrix indicates that the variables are unrelated, making them unsuitable for factor analysis.

observed, the sample size of 52 participants was sufficient for the analysis (Brace et al., 2007).

Eigenvalues greater than 0.8 were considered for PCA due to their ability to explain a substantial amount of variance in the data and captures more information from the dataset. In PCA, Varimax rotation was applied to simplify and clarify the component matrix. The Rotated Component Matrix then shows the loadings of variables on the rotated components. The rotation enhances interpretability by maximizing the variance of squared loadings for each component, making it easier to identify variables with high loadings on specific components.

2.5 Ethics

Ethical approval was obtained from the Human Research Ethics Committee (Certification Number: 30020136).

3 Results

The K-S and Shapiro-Wilk tests ($p<0.05$) indicated non-normality, necessitating the use of non-parametric analysis. The Chi-square test revealed no significant relationships between age, gender, and the participants willingness to interact in two conditions ($p>0.05$), except for a significant relationship between age and willingness to interact with users of the APW in Condition 2 (help-seeking gesture), χ^2 (96, N = 52) = 124.38, p = 0.027 (Table 17). This suggests that as age increases, individuals are more willing to interact and offer help to users of APW, compared to other types. Also, to complement the Chi-square test, the corresponding Cramér's V value of 0.773 indicates a strong association between age and willingness to interact with APW users in this context. A Cramér's V value above 0.50 is considered a large effect size (Gignac & Szodorai, 2016). This suggests that older participants were substantially more likely to respond positively to help-seeking gestures from APW users compared to younger participants.

Table 17. Pearson Chi-Square test (left) and Cramer's V test (right) showing the significant and strong relationship between age and interacting with APW in the help-seeking gesture condition.

	Value	**df**	**Asymptotic Significance (2-sided)**		**Value**	**Approximate Significance**
Pearson Chi-Square	124.378^a	96	.027	Cramer's V	.773	.027
N of Valid Cases	52		.027	N of Valid Cases	52	

a. 125 cells (100.0%) have expected count less than 5. The minimum expected count is .04.

3.1 Phase 1: Differences Between Two Conditions: Independence Gesture Vs. Help-Seeking Gesture

The descriptive analysis of the mean (m) value of willingness to interact and offer help under two conditions—independent and help-seeking gesture—reveals that participants are more willing to interact in the help-seeking gesture condition compared to independence gesture. The Wilcoxon test indicates significant differences between the two conditions across all WDCs, with the following results: CMW (Z=3.426, p<0.001, r = 0.48), AMW (Z=4.298, p<0.001, r=0.60), CPW (Z=5.266, p<0.001, r=0.73), and APW (Z=4.695, p<0.001, r=0.65). These values reflect a consistently strong effect of the help-seeking gesture on enhancing social empathy and interaction (see Figure 4). To quantify the magnitude of these effects, we calculated the **effect size (r)** using the formula $r = \frac{Z}{\sqrt{N}}$, where Z is the standardized test statistic and N is the number of observations. According to Cohen's (1988) benchmarks for interpreting r, an effect size of approximately 0.10 is considered small, 0.30 is medium, and 0.50 or greater represents a large effect (Gignac & Szodorai, 2016). As shown above, all results demonstrate medium to large effect sizes, suggesting that the help-seeking gesture significantly influences pedestrian willingness to socially engage with wheelchair users.

The scoreline of help-seeking gesture reflects a strong effect of the help-seeking gesture, on social empathy and interactions (Figure 26). The results shows that difference is more pronounced when using PWs, with the notable change in CPW, which increased from (m=3.21) with the independence gesture, to (m=4.5) with help-seeking gesture. The CMW shows the smallest difference between conditions (m=3.65 vs. m=4.28), indicating a more consistent social response regardless of the body gesture. In the help-seeking gesture, CPW has the highest willingness mean (m=4.5), whereas APW in the independent gesture has the lowest (m=2.82), indicating a reduced inclination for offering help and interaction when the user of an APW does not seek help. The Figure 4 illustrates that participants were less willing to interact under independent gesture with PWs (CPW: m=3.21; APW: m=2.28), whereas the mean willingness was higher for MWs (CMW: m=3.65; AMW: m=3.5). In contrast, under the help-seeking gesture, willingness to interact was similar for advanced characteristic of wheelchairs (AMW and APW, m=4.21), but the mean value was increased with conventional characteristics in both MW and PW (CMW: m=4.28; CPW: m=4.5). The data highlights the remarkable impact of WUs' gestures on social empathy and interactions. Therefore, Wilcoxon test and descriptive analysis confirm the study's H1.

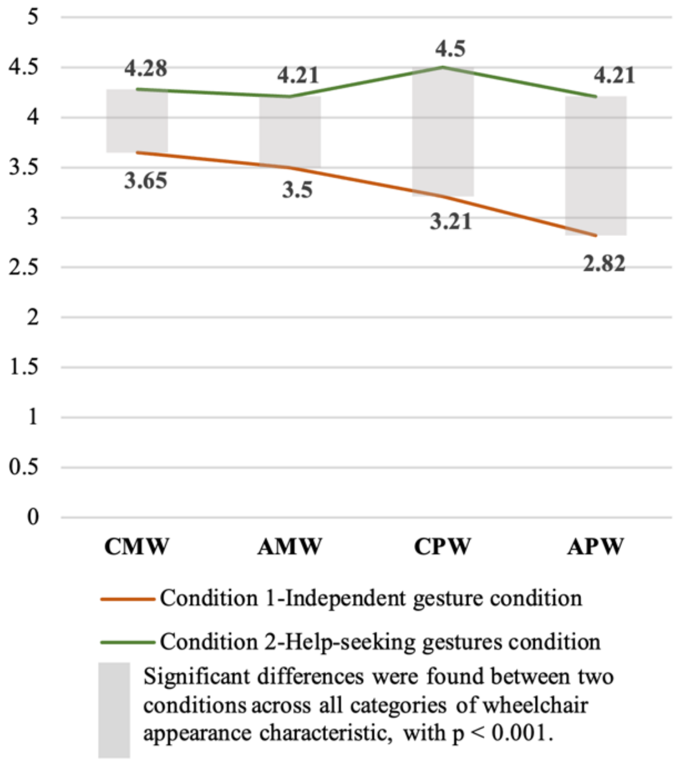

Figure 26. Mean value of willingness to interact in two conditions using wheelchairs with four different design characteristics.

3.2 Phase 1: Differences between WDCs

For H2, the Wilcoxon test indicated significant differences between most wheelchair styles under the independent gesture, except for CMW and AMW (p>0.05) (Figure 27). Significant differences were found between CMW & CPW ((Z=-2.275, p=0.011, r=0.32), CMW & APW (Z=-2.954, p=0.001, r=0.41), AMW & CPW (Z =-1.746, p=0.040, r=0.24), AMW & APW (Z=-2.820, p=0.002, r=0.39), and CPW & APW (Z=-2.492, p=0.006, r=0.35). These effect sizes indicate small to moderate differences in perceived social empathy among the wheelchair styles under the independent gesture condition**.** Conversely, under the help-seeking gesture, no significant differences were observed in half of the comparisons (p>0.05); however, significant differences were found between CPW & CMW (Z=1.844, p=0.032, r=0.26), AMW & CPW (Z=2.563, p=0.005, r=0.36), and CPW & APW (Z=-2.261, p=0.012, r=0.3), also reflecting small to medium effect sizes.

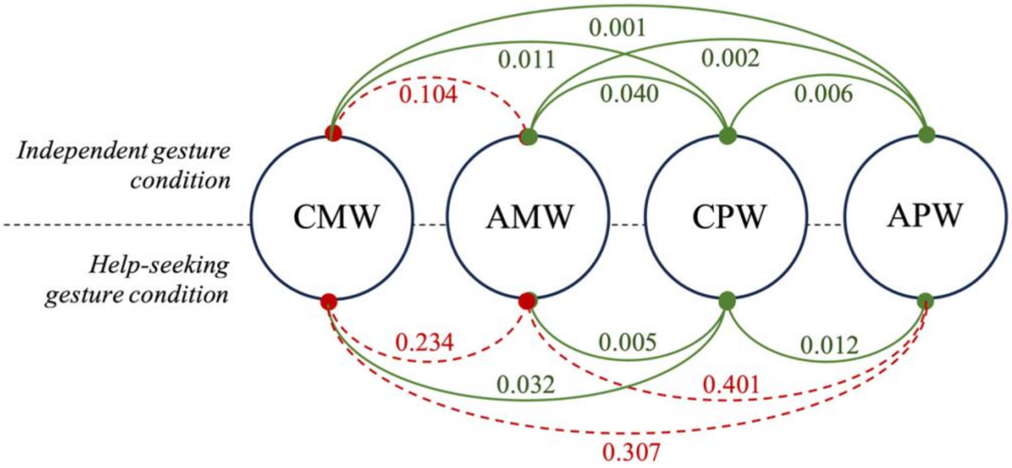

Figure 27. Differences in willingness to interact with various WDCs under two different conditions. Condition 1: Independent gesture and Condition 2: Help-seeking conditions. The solid green lines represent significant differences ($p<0.05$), the dotted red lines mean no significant differences ($p>0.05$). © Image by Author.

According to Figure 5, among the 12 possible comparisons across the two conditions, eight cases (66.66%) showed significant differences between WDCs, while only four cases (33.33%) were not significant. Notably, five of the significant differences in both conditions (41.6%) occurred in the independence gesture, whereas only three (25%) were found in the help-seeking gesture. The number of significant differences between WDCs in condition 1 was greater (86.3%) than in condition 2 (50%). This suggests that when using a wheelchair with an independent gesture, its design characteristics play a more pronounced role in differentiating pedestrians' interactions. In contrast, with the help-seeking gesture, the user's gesture overshadows the influence of wheelchair design. The Wilcoxon test and descriptive analysis confirm the study's H2, concerning the influences of WDCs on pedestrian willingness to interact with WUs.

3.3 Phase 2: Descriptive Scorelines of WDCs

A descriptive analysis compares various WDCs across four types: CMW, AMW, CPW, and APW, based on the semantic words (Figure 6). The comparisons show that the APW consistently scores highest across multiple variables, except in Trustworthiness, where it slightly trails CPW (m=3.9 vs. 3.98). The highest scores for APW are in Futuristic (m=4.51) and Stylish (m=4.34), indicating its perception as modern and advanced. The lowest score for APW is in Independence (m=3.67), and it holds a middle-ground position in Affirmation, Agility, Control, Friendliness, and Dignity (m=3.84 to 4.23). The AMW follows a similar pattern to APW but with lower scores, peaking in Futuristic (m=4.03) and Stylish (m=3.9). Its lowest scores are in Affirmation (m=3.19), Trustworthiness (m=2.63), and Independence (m=2.92), with middle-ground scores in Control, Dignity, Friendliness, and Agility (m=3.13 to 3.5).

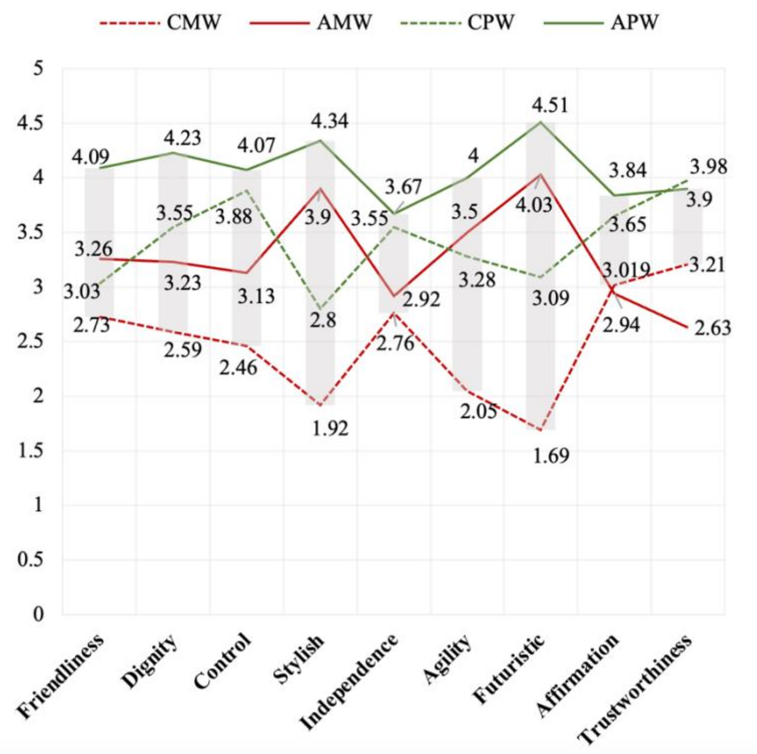

Figure 28. The scorelines for four WDCs based on semantic words.

The CPW scores highest in Trustworthiness (m=3.98) and Control (m=3.88). Its lowest scores are in Stylish (m=2.8), Friendliness (m=3.03), and Futuristic (3.09). Agility, Affirmation, Dignity, and Independence, fall in a middle-ground position (m=3.28 to 3.65). The CMW follows a similar pattern to CPW but with lower scores, except in Friendliness (m=2.73) and Dignity (m=2.59). The CMW scores lowest in most categories, particularly Stylish (m=1.92) and Futuristic (m=1.69), indicating it is perceived as the most old-fashioned compared to other types. Its highest score is in Affirmation (m=3.19), slightly above AMW (m=3.019 vs. 2.94), and in Independence (m=2.76), though both are still lower than other wheelchair types. For Agility, Control, Dignity, and Friendliness, CMW maintains a middle-ground position (m=2.05 to 2.73).

The scorelines for CPW and AMW are positioned between two other ones, indicating that WDCs of these two types are less accepted than APW but more accepted than CMW. Overall, the results in this section show that the scorelines for advanced style in both PW and MW tend to follow a similar pattern, albeit at different levels. Those conventional styles also exhibit a similar pattern with varying score levels. The results also show that the PWs' scorelines are nearly symmetric along a horizontal axis. Variables such as Control, Independence, Affirmation, and Trustworthiness became closer, whereas Friendliness, Dignity, Stylishness, Agility, and Futuristic characteristics grew more distant. The same pattern of symmetry is observed between MWs, with minor differences. Independence and Affirmation scores moved closer, but in other variables, they diverged, particularly in Stylishness and Futuristic qualities, where the gap widened significantly. In both categories of PWs and MWs, Affirmation scores are higher in the conventional style compared to the advanced one, marking the only instance where a variable in the conventional format surpasses its advanced counterpart. The distinct patterns observed between the group of PWs and MWs suggest that the principal components for representing their social characteristics differ. Therefore, since advanced designs such as AMW and APW have higher scores than conventional types, these are prioritized for presenting the PCA results.

3.4 Phase 2: Principal Components in WDCs

Initially, the KMO analysis reveals values for AMW (0.852) and APW (0.845), indicating that the data is well-suited for factor analysis. Additionally, Bartlett's Test of Sphericity shows that the correlations between variables are sufficiently strong to justify the use of factor analysis, PCA test, in both categories ($p<0.001$).

According to the PCA, Table 18 show the total variance explained by the components for AMW and APW. On the left side of this table, the initial Eigenvalues indicate the total variance explained by each component before extraction and rotation. This section includes both the percentage of variance for each component and the cumulative percentage of variance. In the middle part, the Extraction Sums of Squared Loadings reflect the variance explained by each component after extraction, which should match the percentages of the initial eigenvalues in this case. On the right side, the Rotation Sums of Squared Loadings show the variance explained by each component after rotation, facilitating the interpretation of the factors. For selecting principal components, a variance above one is commonly chosen; however, with the test adjusted using an Eigenvalue threshold of 0.8, the results indicate that components with Eigenvalues above 0.8 are present in both categories of wheelchairs. Although component 3 (C3) is not as strong as the first two components, it was also included to capture additional variability and to track more subtle distinctions within the data. Therefore, the first three components (APW: C1=4.767, C2=1.135, C3=0.882 and AMW: C1=4.632, C2=1.135, C3=0.843) each with an explained variance above 0.8, were selected. The more details of all components are shown also in Figure 29 which are Scree Plots of PCA. The cumulative variance explained by the first three components is 75.37% for APW and 73.45% for AMW, indicating these components capture a substantial portion of the dataset's variability. In PCA, the percentage of explained variance serves as an effect size measure, highlighting the strength of each component in representing the data structure. This supports the relevance of these components for understanding underlying patterns.

Table 18. Total variance explained for AMW (above) and APW (below).

AMW	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component (C)	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
C1	4.632	51.464	51.464	4.632	51.464	51.464	2.938	32.648	32.648
C2	1.135	12.616	64.080	1.135	12.616	64.080	2.087	23.192	55.840
C3	.843	9.372	73.452	.843	9.372	73.452	1.585	17.611	73.452
C4	.627	6.963	80.414						
C5	.590	6.558	86.973						
C6	.370	4.114	91.087						
C7	.304	3.374	94.461						
C8	.284	3.156	97.616						
C9	.215	2.384	100.000						
APW									
C1	4.767	52.962	52.962	4.767	52.962	52.962	2.764	30.711	30.711
C2	1.135	12.612	65.575	1.135	12.612	65.575	2.076	23.072	53.783
C3	.882	9.804	75.378	.882	9.804	75.378	1.944	21.595	75.378
C4	.728	8.083	83.462						
C5	.426	4.737	88.199						
C6	.383	4.256	92.455						
C7	.282	3.131	95.586						
C8	.228	2.535	98.121						
C9	.169	1.879	100.000						

Extraction Method: Principal Component Analysis.

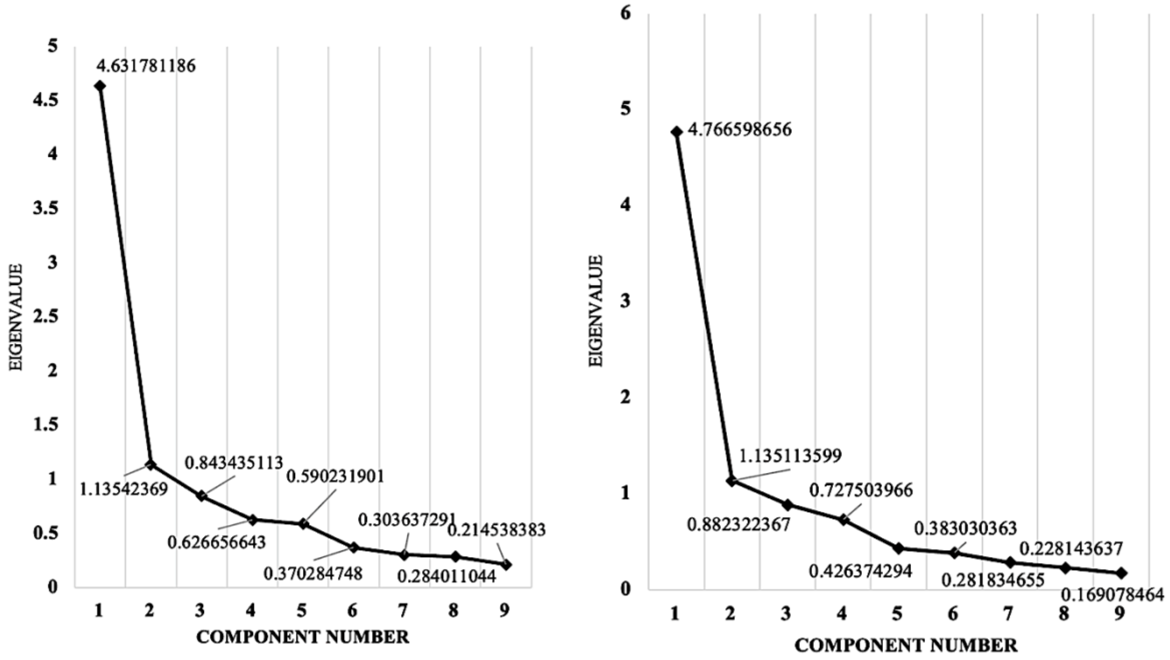

Figure 29. The Scree plot of PCA analysis on both AMW (left), and APW (right).

To identify which semantic words have the highest loadings, the Rotated Component Matrix (for both AMW and APW) displays the loadings of each semantic attribute on the identified components (Table 19). Additionally, the Component Plot in Rotated Space visually represents these findings (Figure 30). In the plot, variables positioned closely together indicate a strong loading on the same principal component.

Table 19. Rotated Component Matrix for both AMW and APW.

AMW- Rotated Component Matrix[a]				**APW- Rotated Component Matrix[b]**			
	Component				Components		
	C1	C2	C3		C1	C2	C3
Agility	**.819**			Friendliness	**.891**		
Futuristic	**.801**			Dignity	**.839**		
Stylish	**.795**			Stylish	**.712**		.476
Control	.610	.532		Affirmation		**.881**	
Trustworthiness	.587	.460	.362	Trustworthiness	.397	.665	.341
Independence		**.904**		Control	.629	.641	
Affirmation		.659	.326	Independence			**.811**
Friendliness			**.946**	Agility	.390	.370	.659
Dignity	.442	.491	.564	Futuristic		.422	.649

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[A]

a. Rotation converged in 4 iterations.
b. Rotation converged in 5 iterations.

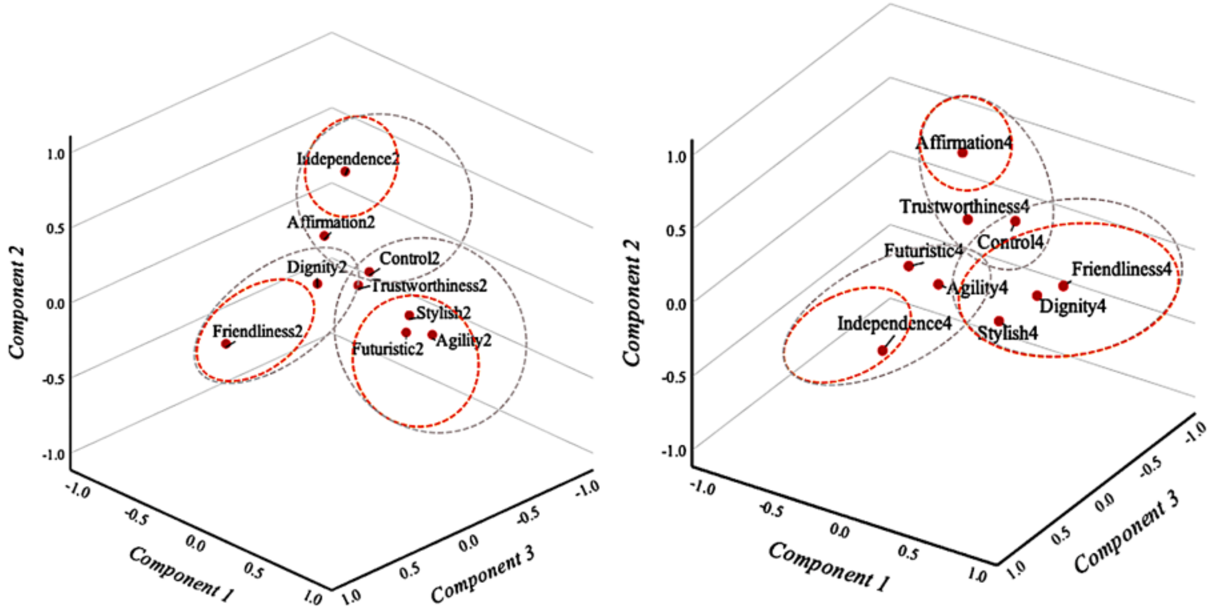

Figure 30. Component Plot in Rotated Space. Left: AMW, right: APW.
The dotted line indicates a group of semantic words (variables) that are more related to each other.

To enhance understanding of the social cognitive structures underlying participants' evaluations, the first three principal components were interpreted based on their factor loadings for each wheelchair category (APW and AMW). These components reveal distinct latent patterns in how participants semantically relate different characteristics. According to the Rotated Component Matrix in Table 19, and visualized in Figure 30, the principal components for APW and AMW are described as follows:

AMW:

C1 is shaped by Agility (0.819), Futuristic (0.801), and Stylishness (0.795), indicating a performance-style dimension. In this group, cognitive emphasis is placed on movement and appearance, suggesting that form and dynamic function are tightly coupled in perception. Control and Trustworthiness also contribute but to a lesser extent.

C2 is led by Independence (0.904), with lesser contributions from Affirmation and Control. This dimension suggests a self-determination axis, where users interpret the manual device through the lens of autonomy and personal agency.

C3 is primarily defined by Friendliness (0.946) and, to a lesser extent, Dignity. This reflects a socio-relational dimension, where the design's approachability and perceived respectfulness cluster together in users' cognitive schema.

APW:

C1 is primarily defined by Friendliness (0.891), Dignity (0.839), and Stylishness (0.712). This cluster suggests a relational-aesthetic dimension, where social warmth and perceived elegance co-occur. This implies that for APW designs, users cognitively associate friendly appearance with a sense of dignity and style, reflecting an integrated social-emotional appeal.

C2 is led by Affirmation (0.881), with Trustworthiness and Control also contributing but less significantly. This component can be seen as a social validation dimension, suggesting that the perception of being affirmed or socially accepted is interlinked with perceived reliability and control over the device.

C3 is dominated by Independence (0.811), with Agility and Futuristic contributing to a lesser extent. This reflects an autonomy-functionality dimension, where independence is cognitively linked to motion capability and advanced features, indicating how participants associate freedom with technological competence.

These interpretations show that PCA not only reduces dimensionality but also reveals distinct social meaning structures that participants apply in their evaluation of wheelchair characteristics. The findings from the PCA and descriptive analysis support the study's H3, which proposes that WDCs are prioritized differently across wheelchair types—manual and powered—with varying design styles. For each principal component in both APW and AMW categories, a corresponding label was assigned (see Figure 31). The rationale behind these naming conventions is elaborated in the discussion section.

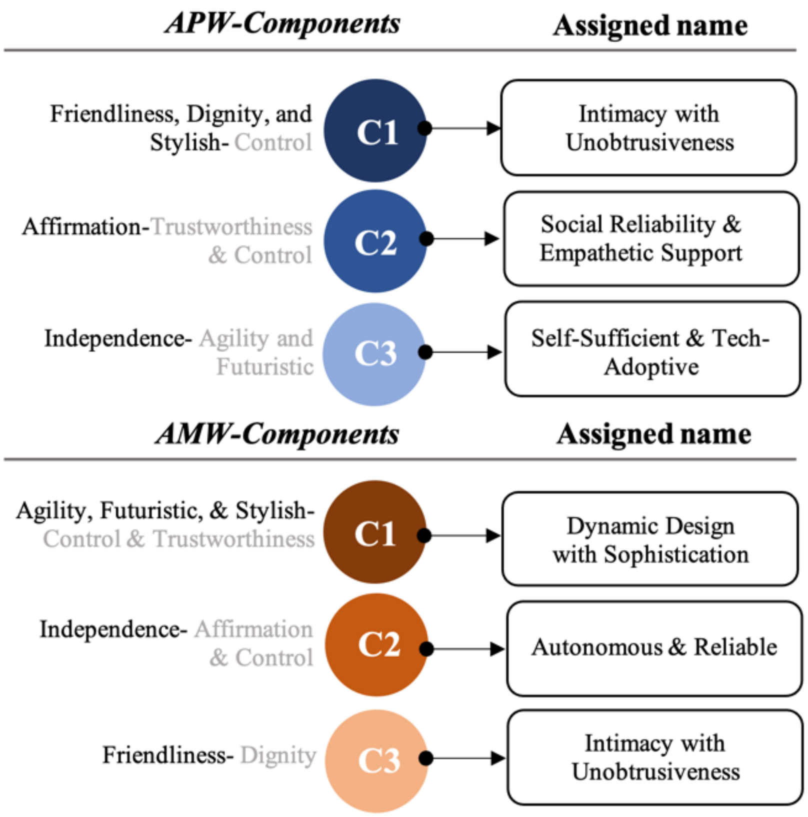

Figure 31. The components for each category of APW and AMW with the assigned names. © Image by Author.

4 Discussion

In this study, the effect of WUs' gestures and WDCs on pedestrians' empathy and willingness to interact was reviewed, revealing that both factors play a significant role. Then, the principal components were determined to establish the order of variables related to WDCs. Initially, the results indicated that as age increases, there is a corresponding increase in the willingness to interact with APWs during help-seeking gestures. This may be due to the fact that as individuals age, they often develop greater empathy or experience with disability (Baig et al., 2022; Guariglia et al., 2023; N. Sharma et al., 2021), leading to a higher likelihood of engaging with WUs. However, due to limited data, this relationship should be interpreted cautiously as a trend rather than a definitive finding. Previous research also indicates that young people, regardless of gender, still hold negative attitudes toward physically disabled individuals, underscoring the need for greater destigmatization (N. Sharma et al., 2021). Additionally, the appealing design of APWs may evoke more emotional responses from pedestrians, as individuals are often attracted to the aesthetics of products (Shi et al., 2021). Further investigation is suggested to explore the relationship between age, WDCs, and empathy.

4.1 Willingness to Interact Based on Body Gesture and WDCs

The results show that while both WUs' gestures and WDCs play a crucial role in pedestrians' willingness to interact, the help-seeking gesture often overshadows WDCs. This likely occurs as a direct help-seeking gesture naturally prompts a more immediate and empathetic response from pedestrians, who prioritize the user's request for assistance over the decision to offer help and interaction based on WDCs. As a result, wheelchair design and appearance become secondary considerations when a clear request for help is expressed, highlighting the strong impact of WUs' gestures and eye contact in social interactions. However, gestures for seeking interaction can vary, impacting pedestrians differently, as they are highly individual and influenced by factors like motor abilities, strength, and fatigue (Bilius et al., 2023). Therefore, it is worth identifying different gesture categories and evaluating their impact on interactions in future studies.

When WUs adopt an independent gesture, WDCs become crucial (83.3%) and, act as the means of communication and "first language" for initiating interactions (Krippendorff & Butter, 1984). Previous studies have confirmed that both WUs and non-users respond positively to innovative and distinct aesthetics (P. Costa et al., 2012), which can evoke more favorable emotional reactions compared to traditional wheelchair designs (Carneiro et al., 2018). This highlights the importance of non-verbal cues and design characteristic in facilitating positive and effective social engagement for WUs (Ebrahimi et al., 2016; Rasoulivalajoozi et al., 2025a). The result showed that, in the help-seeking gesture, willingness to interact is highest for CPW (4.5), likely due to their familiarity and more common use, leading to greater pedestrian support. Compared to CMW (4.28), CPW may convey greater mobility challenges for its users in the same help-seeking gesture, resulting in more attention being directed toward CPWs. Conversely, in the independence gesture, willingness to interact decreases for PWs (CPW=3.21, APW=2.82) compared to MWs (CMW=3.65, AMW=3.5). This is likely because PWs, which suggest self-sufficiency due to their propulsion, inspire pedestrians to assume help is unnecessary. In contrast, MWs, perceived as requiring manual effort, may stimulate more willingness to interact. However, an alternative explanation may be that APWs, due to their highly technical and machine-like appearance, create a sense of psychological distance and reduce perceived approachability (Ham et al., 2012; Rasoulivalajoozi & Farhoudi, 2025a). This suggests that lower willingness to interact with APWs may stem not only from assumptions about user independence but also from the social signaling of the design itself. Overall, while the findings demonstrate how WDCs and WUs' gestures and behaviors influence social empathy and interaction, future research could further investigate how perceived autonomy and perceived distance interact to shape bystander responses.

4.2 Scorelines of Semantic Words, and PCA Results

The results in the descriptive analysis of semantic words as variables in WDCs show that the scoreline patterns for conventional and advanced styles differ, indicating that each style evokes distinct perceptions among pedestrians, regardless of whether the wheelchair is electric or manual. However, despite the general similarities within the group of conventional and advanced styles, some scores differences of variables create varying priorities, as shown in the PCA results for APW and AMW. The results also show a symmetric scoreline pattern in PWs and MWs, in which some variables related to social representation—such as Stylish, Futuristic, Friendliness, and

Dignity—are more highlighted in pedestrians' view in the advanced styles category. This may stem from the assumption that these wheelchairs are sufficiently independent, making their social representation aspects more prominent in pedestrians' perceptions. This can explain why the willingness to interact with the APW is lower than with the CPW in the independent gesture. The PCA results confirm this as well, showing that C1 of APW includes the highest loadings of Friendliness, Dignity, and Stylish. Friendliness suggests intimacy through personal connection, while Dignity and Stylish contribute to unobtrusiveness by ensuring a respectful and aesthetically pleasing design, without drawing unnecessary attention. Accordingly, the name of *Intimacy with Unobtrusiveness* was assigned to the C1 describing APW. This order differs for AMW, where only Stylish—shared with APW—is included in C1 with the highest loadings, alongside Agility and Futuristic. This suggests that AMW's perceptions are slightly different from APWs, with an initial impression of being dynamic and incorporating modern, cutting-edge technology. Agility implies dynamic by reflecting the wheelchair's adaptability, and Futuristic suggests cutting-edge technology and innovative materials. Stylish denotes modern, visually appealing elements that align with current trends. The combination of these elements implies a sophisticated, high-tech style that is both refined and visually appealing. Accordingly, the name of *Dynamic Design with Sophistication* was assigned to the C1 describing AMW.

In C2 of APW, the social-related variable Affirmation—meaning social validation and acceptance—still shows a high loading in the Rotated Component Matrix for APW. This underscores that social aspects still remain a top priority in the advanced style of PWs. Affirmation implies social reliability and empathetic support, indicating that this design is not only perceived as societal approval but also conveys trustworthiness. As a result, *Social Reliability & Empathetic Support* was assigned to C2 to describe APW. Conversely, Independence had the highest loading in C2 of AMW, perceived as implying an autonomous and self-directed nature in its use. The practical sense of maneuverability, likely due to the angled large side wheels similar to those used in athletic wheelchairs, is highlighted in C2 of AMW. This suggests reliability in maneuverability. Accordingly, the name *Autonomous & Reliable* was assigned to the C2 describing AMW.

In C3 of APW, Independence has the highest loading, accompanied by lower loadings of Agility and Futuristic, similar to the combination of C1 and C2 in AMW. After recognizing the social aspect, being autonomous is highlighted in pedestrians' view. Independence implies autonomy, with agility ensuring responsiveness, meanwhile the futuristic design incorporates technology that enhances the user's capability. Accordingly, the name *Self-Sufficient & Tech-Adoptive* was assigned to C3 describing APW. In contrast to APW, where Friendliness and Dignity are placed in C1, for AMW these variables are positioned in C3, the last principal component. This suggests that after perceiving the AMW as a maneuverable device, pedestrians recognize social representational aspects like Friendliness, with a lower loading of Dignity. Similar to C1 of APW, *Intimacy with Unobtrusiveness* is proposed as a descriptor.

5 Conclusion

This study aimed to evaluate participants' willingness to engage with WUs by scoring their social empathy and interaction in scenarios where users faced the risk of falling or toppling while navigating an acute ramp. The impact of both body gestures and WDCs were assessed, followed by the use of semantic words to describe and interpret the wheelchairs. The initial analysis showed that as age increases, the willingness to empathize and interact also increases, likely due to greater experience or empathy with disability. The results also showed that while both body gestures and WDCs significantly influence pedestrians' willingness to empathize and interact, the help-seeking gesture has a stronger effect, overshadowing WDCs. In the independence gesture condition, WDCs are the main means of communication, acting as the language for initiating interactions. Also, in the independent gestures, PWs are perceived as more self-sufficient, leading to lower willingness from pedestrians for social empathy and interaction compared to MWs. However, it is important to distinguish between pedestrians' perception and the actual needs of users: the lower interaction scores observed for APW (e.g., $m = 2.82$) may not accurately reflect user independence, but rather indicate a misjudgment of user vulnerability by bystanders. This highlights the potential risk of over-attributing self-sufficiency based on design appearance alone, especially in contexts involving physical danger. The analysis of key features and interpretations of WDCs revealed that advanced styles of both PW and MW scored higher based on semantic words. Among the scorelines, APW ranked highest, in contrast CMW ranked lowest. Since advanced wheelchair styles scored higher than conventional ones, PCA identified three principal components for both APW and AMW based on semantic word loadings. Each component was named accordingly, illustrating perceptions of these wheelchairs in pedestrians' view. These components provide valuable insight for designers aiming to develop wheelchairs with enhanced social polish. Future design efforts may benefit from incorporating clearer visual cues that help distinguish perceived independence from actual user needs in risky situations. The findings have important practical implications for industrial and human factors design by demonstrating how WDCs and user gestures influence social interactions. Designers can leverage these insights to create assistive technologies that not only enhance user autonomy and functionality but also foster positive social perceptions and interactions. Moreover, understanding these social-cognitive dimensions can support broader initiatives to reduce stigma and promote greater acceptance of mobility device users.

5.1 Limitation and Future Studies

This study evaluated interaction conditions only through composite imagery due to limited access to advanced styles of the MW and PW. Although participants were immersed in scenarios with additional explanations, the results may differ from real-life interactions. To strengthen ecological validity, future research should incorporate real-world validation methods, such as eye-tracking and systematic field observations in everyday environments (e.g., bus stops or busy sidewalks). This would help capture how real-world distractions, noise, and time pressure affect bystanders' interactions with wheelchair users. While this study focused on only help-seeking and independent gestures, WUs may use different gestures shaped by their disabilities. Future research could explore these variations and their impact on interactions. The sample size of 52 participants was adequate for detecting key differences, as confirmed by PCA checks (KMO, Bartlett's Test, and strong factor loadings). Although no separate post-hoc power test was performed, these methodological checks support the sample's suitability for exploratory analysis. Nevertheless, a larger and more diverse sample, with formal power calculations, would strengthen statistical justification and improve generalizability. While snowball sampling was practical, it may introduce selection bias, as participants tend to recruit others with similar characteristics, potentially limiting sample representativeness. Moreover, the study was conducted in Canada, and the single cultural context (Montreal) may have influenced participants' perceptions and responses. Social attitudes towards disability, familiarity with assistive technologies, and norms around interaction can vary widely across cultural contexts. Thus, caution is advised when extrapolating findings to other populations, and future studies should examine cross-cultural variations to enhance applicability. Lastly, this study was limited to examining the nuances of semantic words related to wheelchairs. Therefore, future studies could introduce design principles that foster social engagement and uphold the independence of WUs

Chapter III. Summary & Discussion

This section is based on a review and discussion of the three studies in Ch. III, for answering the question 3 (Q3).

1 Introduction:

In Ch. III, these studies were designed in line with understanding the socio-emotional dynamics and answering the Question 3: **What factors influence the socio-emotional dynamics in the interactions of (wheelchair users) WUs, and how do they exert this impact?** To answer this question, we initially tried to explore perceived inclusivity, identifying themes that reveal how WUs experience exclusivity beyond mere lack of accessibility (Section 1). Based on these insights, we proposed interventions—ranging from design solutions to social programs and support systems—to address these challenges. By reviewing and highlighting the key findings from section 1, we gain a deeper understanding of WUs' experiences in their interactions with society, the environment, and their wheelchairs. These findings reveal the factors influencing the socio-emotional dynamics in the interactions of WUs. While this study primarily addresses the first part of the question (What), the second part (How) is explored in greater depth in the studies presented in Sections 2 and 3.

In Section 2, we further explore how the dynamic of affective experiences evolves over a planned rehabilitation period. We examined WUs' interaction journeys, from the initial wheelchair prescription to the recovery phase, highlighting how their dynamic affective experiences (DAE) are shaped by both emotional and functional significance.

Finally, as WUs are represented through the mediator of their wheelchairs, in Section 3, we investigate how pedestrians perceive and engage with WUs using an experimental study. This investigation was more focused specifically on the social aspects, examining how different wheelchair design styles and WUs' behavior influence pedestrian interactions. The study reveals how wheelchair design characteristic (WDCs) and user gestures can directly stimulate social empathy and willingness to engage.

1.1 Section 1. Perceived Inclusivity (PI) in Using MAs

The study in Section 1, aimed to explore perceived inclusivity (PI) in the use of mobility aids (MAs) and identify gaps in users' needs, classifying these needs and offering recommendations to address them. We identified four interconnected themes as a framework for improving PI:

Theme I) Perceived Financial Value: Assessing Worth
Theme I) Objective Enhancements: Optimizing Environments and MAs
Theme II) Subjective Enhancements: Trustworthiness, Support, and Hope
Theme IV) Contextual Factors: Interpretations and Representations

Theme I highlighted that, while the cost of MAs may not be a primary concern, users perceive it as exclusionary when they must pay for something considered a basic right. This underscores the importance of the fair accessibility of wheelchair costs in shaping WUs' perceptions and attitudes, revealing that socio-emotional well-being is linked to perceptions of fairness and access to their rights. Theme II emphasized that incorporating high-tech elements in MAs, beyond improving usability, can foster positive emotions and alleviate negative reactions such as exclusions, guilt, sadness, and shame. Enhancing the functionality and usability of MAs through advanced solutions not only improves performance but also generates positive feelings like relief and hope while reducing negative emotions. However, neglecting tangible physical design aspects could widen the gap, complicating socio-emotional experiences further. Theme III showed that fostering trustworthiness in interactions between MA users and physiotherapists, as well as in the environment and design of MAs, significantly enhances PI. Positive interactions with physiotherapists, supportive environments, and reliable MA designs help build trust and inclusivity. These subjective factors play a crucial role in socio-emotional resilience and the perception of belonging. Additionally, we examined how the context and cause of disability indirectly influence users' perceptions and use of MAs. The aesthetic and symbolic representation of MAs in public spaces plays a critical role in shaping perceptions of social inclusion, an underemphasized factor. The symbolic representation of MAs and their reception in public spaces significantly impact WUs' feelings of inclusion or exclusion. Addressing societal and cultural narratives surrounding disability and mobility is essential to fostering empathy and understanding. Figure 32 illustrates the themes, that served as the factors, influencing the socio-emotional interactions of WUs.

In summary, the findings revealed significant gaps in creating a genuine perception of inclusivity, with interconnected factors dynamically influencing PI. These gaps underscore the importance of addressing users' needs and how mismatches in these areas can adversely impact social interactions and feelings of inclusion.

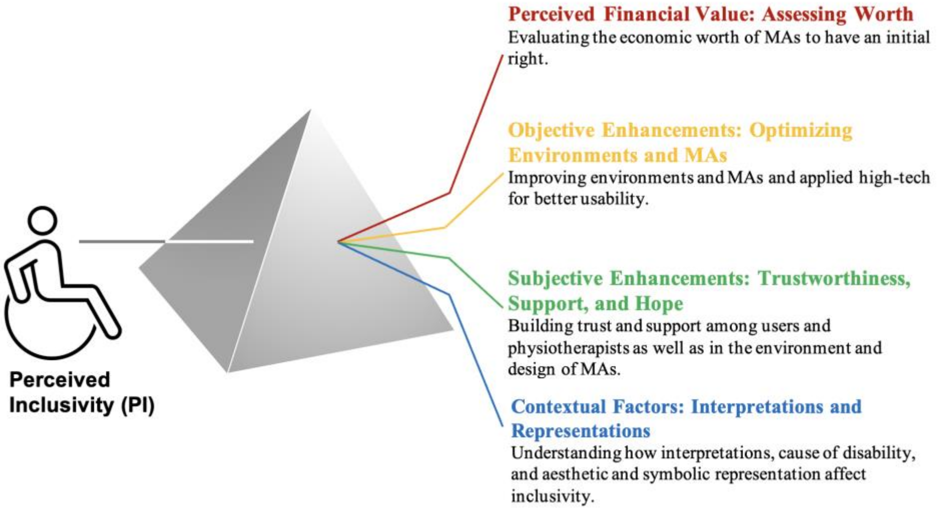

Figure 32. Themes identified in perceived inclusivity among WUs. © Image by Author.

Factors influencing the socio-emotional perceptions of WUs in social interactions.

1.2 Section 2. Dynamics of Affective Experiences in Using Wheelchair

After analyzing the factors shaping WUs' socio-emotional perceptions, represented by the four themes of perceived inclusivity, we tracked their experiences with prescribed wheelchairs during rehabilitation. This analysis highlights where and how various socio-emotional factors significantly influence WUs' perceptions; it responds to the second part of the Q2.

The key themes identified include: 1) Coping with Using the Wheelchair, 2) Reluctant Acceptance: Adjusting to the New Normal, and 3) Approaching Recovery: Challenges of Over-reliance. The themes reveal that WUs initially experience resistance and struggle to cope with using a wheelchair. Over time, they reluctantly accept it as they adjust to their new normal and move toward recovery. However, during recovery, they may encounter challenges related to over-reliance on the wheelchair. Accordingly, the findings demonstrate that the affective experience of WUs is dynamic, evolving through different stages of rehabilitation.

These dynamics are influenced by the emotional and functional significance perceived by WUs, which in turn are shaped by underlying assumptions and contextual factors. To this end, we illustrated how emotional and functional significance shapes the DAE of WUs during rehabilitation.

An important point is that while assumptions and stereotypes often heavily influence initial perceptions of WUs in the early stages, however, these perceptions are not static. This suggests that socio-emotional experiences can be significantly reshaped if factors influencing socio-emotional dynamics—such as those related to perceived inclusivity (discussed in Section 1)—are effectively optimized. Optimizing the influencing factors, and targeted interventions can first address the underlying emotional and functional significance from WUs' perspectives, which, in turn, can indirectly enhance and improve their overall socio-emotional experiences. Throughout the rehabilitation journey, physiotherapists, who are deemed as trusted for their expertise in medicine and ongoing connection with WUs, can play a crucial role in shaping their perceptions. As highlighted in Section 1, Theme III, physiotherapists are seen as a key source of trust and support, meaning they can significantly influence the socio-emotional experiences of WUs.

1.3 Section 3 Empathy and Interaction with Wheelchair Users in Society

As discussed in Ch. II Sections 1 and 2, and Section 1 of Ch. III, a significant aspect of WUs' social interactions occurs when they appear in public settings with their wheelchairs, which mediate their physical presence and distinguish them from other pedestrians. the representational aspects of wheelchairs, particularly their aesthetics and design characteristics, can influence perceptions of WUs and others, potentially shaping attitudes and interactions. To explore how these aesthetic and representational aspects impact people's attitudes toward WUs, and how such WDCs can evoke social empathy, we conducted experimental research. In this study, we also considered the WUs' gesture as one of the influential factors that may affect the pedestrian's reactions. The findings revealed that WDCs, along with users' body gestures, significantly influence social interactions. This study finds no significant relationships between gender, age, and interaction with WUs, except for a positive correlation between age and interaction with powered wheelchairs in help-seeking gestures. Moreover, pedestrians demonstrated a significantly higher willingness to interact when WUs displayed help-seeking gestures compared to independence gestures. WDCs were found to have a greater influence on pedestrians' perceptions during independence gestures than help-seeking gestures, indicating that the help-seeking gesture overshadows the impact of WDCs on social empathy and interaction. Advanced WDCs, however, emphasize WUs' independence and help mitigate negative social stereotypes held by pedestrians.

Furthermore, the semantic patterns of descriptive words differ between advanced and conventional wheelchairs. Three principal components were identified for each advanced format, both manual and powered, providing valuable insights for designing wheelchairs with enhanced social polish. For the APW, the first to third components reflecting pedestrians' perceptions are associated with the descriptive concepts of 1) *Intimacy with Unobtrusiveness*, 2) *Social Reliability & Empathetic Support*, and 3) *Self-Sufficient & Tech-Adoptive*. In contrast, for the AMW, pedestrians' perceptions align with the concepts of 1) *Dynamic Design with Sophistication*, 2) *Autonomous & Reliability*, and 3) *Intimacy with Unobtrusiveness*. These findings highlight differences in perceptions when advanced WDCs are applied to powered versus manual wheelchairs.

This study reveals that while WUs' gestures and WDCs are key factors influencing and stimulating social empathy and interactions, it also highlights how and under which conditions these factors become more impactful.

IV

External Communication via Wheelchair Interfaces

Chapter IV. External Communication via Wheelchair Interfaces. Section 1.

eHMI Requirements for Wheelchair

This section is based on the following manuscript (published edition).

Rasoulivalajoozi, M., & Farhoudi, M. (2025a). Advancing eHMI for powered wheelchairs beyond safety and communication: A pilot study on enriching social interaction through a co-design approach. *Transportation Research Part F: Traffic Psychology and Behaviour*, *114*, 200–215. https://doi.org/10.1016/j.trf.2025.05.036

Transportation Research Part F: Traffic Psychology and Behaviour, published by Elsevier, focuses on the psychological and behavioral aspects of traffic and transport.

Abstract: Enhancing safety and communication while minimizing unwanted attention is key for wheelchair external Human-Machine Interfaces (eHMIs). This study aims to introduce an interface to enhance eHMIs for powered wheelchairs, improve external communication, and enhance positive social interactions in challenging urban situations. A co-design approach was adopted, centering wheelchair users (WUs) in a two-step methodology. First, data were collected through a qualitative survey to define criteria, which informed themes for focus group discussions. These themes guided the ideation process. Eighteen participants, including WUs and experts in cognitive psychology, physiotherapy, and design, were involved. Concepts developed in ideation sessions were analyzed using the Analytic Hierarchy Process. A prototype was then developed to be assessed by both WUs and pedestrians through a structured questionnaire. According to the analysis, four themes were identified: I. Streamlined Information in Interaction, II. User-Centric Safety Feedback, III. Harmonious and Minimalist Interaction Design, and IV. Effortless Integration and Production. Regarding these themes, a table with design suggestions and implications was introduced. Ultimately, five interface concepts were proposed, with Concept 2, ‘WheelSafe Illumina’ (41.3%), and Concept 1, ‘WheelGlow Assist’ (28.1%) emerging as top priorities, both featuring a shell structure. Concept 2 was developed for prototyping. The feedback from the experiences of both WUs and pedestrians indicate that the proposed eHMI may enhance perceived communication and safety without drawing negative attention. Integrating eHMI into a shell structure improves functional communication while also minimizing unwanted attention toward WUs—an often-overlooked issue in previous research that our co-design approach identified and effectively addressed.

Keywords: Powered wheelchair; eHMI; Interface design; Intent communication; Interaction design; Social acceptance.

1 Introduction

Operating a wheelchair in an urban setting is challenging due to complex interactions with drivers and pedestrians, making it difficult to navigate crowded sidewalks and intersections safely. Implementing external communication features on wheelchairs can help users move safely without communication barriers or ambiguity, especially in negotiable situations where clearly signaling their intent is crucial (Dey, Matviienko, et al., 2021). This would reduce their travel burden and enhance their independence in mobility (X. Zhang et al., 2024). User-device interfaces and external Human-Machine Interfaces (eHMIs) play a pivotal role in empowering wheelchair users (WUs) to control their wheelchairs, significantly affecting their communication with their surroundings (K. Kim et al., 2022; Bizier et al., 2016; Frank et al., 2010). Particularly, they facilitate indirect negotiation with pedestrians and car drivers.

Pedestrians can directly signal their intent to cross using eye contact and gestures with drivers (Dey, Matviienko, et al., 2021; Rasoulivalajoozi, 2025; Dey & Terken, 2017). However, WUs, particularly those with physical limitations, such as restricted head and neck mobility, can face challenges in employing basic non-verbal communication methods, such as eye contact (Henje et al., 2021). This approach may convey ambiguous signs, depending on the severity of their disabilities, leading to potential safety challenges. Likewise, those with speech impairments may struggle with verbal communication, impeding interaction with pedestrians for assistance. In discussions about eHMI, most systems rely on a single modality, potentially overlooking the requirements of individuals with sensory impairments, including vision or hearing impairments (Dey, Habibovic, Löcken, et al., 2020). In ideal situations, eHMIs for individuals with minimal mobility impairments are often installed on mobility scooters, modeled after conventional car headlights, taillights, and flashers. However, WUs with more significant mobility impairments navigate diverse settings, routes, and social interactions, requiring specialized eHMI features.

In negotiable situations, where WUs need to convey intentions, such as signaling turns or indicating right of way, their powered wheelchair (PW) can create misconceptions (Brandt et al., 2004). Bystanders may mistakenly believe these users do not require negotiation or assistance, often due to the assumption that advanced wheelchair technology makes them fully self-reliant. This challenge may be exacerbated by socio-psychological phenomena like the bystander effect (Latané & Darley, 1970), where individuals are less likely to offer help to WUs when others are present. To date, most solutions have implemented ground-light projection systems to address safety and communication needs. However, these systems have often led to negative social reactions (Dey, van Vastenhoven, et al., 2021; Jiang et al., 2022; B. J. Wang et al., 2018; X. Zhang et al., 2024), such as drawing unwanted attention to WUs (Lanutti et al., 2015; Barbareschi et al., 2021; V. de S. P. Costa et al., 2010)—that is, attracting excessive or inappropriate public focus that makes users feel self-conscious, stigmatized, or socially exposed. This phenomenon may work as a barrier to social acceptance and integration.

This multifaceted challenge demands both an interdisciplinary perspective and co-design to address communication dynamics in wheelchair use. An interdisciplinary approach integrates the psychological, social, and design aspects of eHMIs, while co-design incorporates WUs' voices and concerns, ensuring their preferences and motion intentions are effectively conveyed to drivers and pedestrians. In line with this, we aim to introduce considerations for eHMI in PWs and present an external interface prototype developed through a co-design process. In this study, while the interface should focus on enhancing intent communication, and safety, it is worthwhile to explore alternative non-projection eHMI to mitigate unwanted attention, improve social acceptance, and enhance positive interactions for WUs in dense urban environments. Accordingly, we seek to answer the research question: How can a wheelchair eHMI enhance intent communication and safety while improving social acceptance and reducing unwanted attention? Finally, we assess the effectiveness of our prototype using the evaluation models. This study offers the following contributions: 1) The proposed themes and considerations can serve as a framework for design experts in care to address the needs of various types of mobility aid users; 2) The proposed concepts enable engineers and human-computer interaction (HCI) experts to examine how social communication dynamics can be integrated with safety engineering considerations.

2 Literature Review

eHMIs, commonly used as communication aids in automated vehicles (AVs) and pedestrian interactions (Holländer et al., 2021), facilitate communication of the vehicle's status, and intentions (Lim & Kim, 2022). These interfaces address the communication gap arising from the absence of traditional cues like eye contact and gestures, leading to a more positive perception of AVs compared to conditions without eHMI (Faas et al., 2020). eHMIs, classified as physical, auditory, or visual (Dey, Habibovic, Löcken, et al., 2020; B. Zhang et al., 2022). Among these, external interaction screens, matrix lights, and projection interfaces are commonly used because of their versatile interactions with diverse road users (Jiang et al., 2022). Common visual communication modalities generally include emulating human driver cues (Eisma et al., 2020), as well as textual, graphical (Bazilinskyy et al., 2019), lighting, and projection interfaces (Dey, van Vastenhoven, et al., 2021; X. Zhang et al., 2024). These visual modalities can be designed and organized in specific ways, to provide mutual understanding between users and pedestrians. For instance, when eHMI signals match vehicle movements, drivers experience fewer crashes and pass faster than situations without eHMI (Rettenmaier et al., 2020). These findings indicate that eHMI facilitates effective communication, reduces uncertainty in intention estimation, and prevents accidents.

Although eHMIs are widely recognized for their value in AVs, their application in other modes of transportation, such as for cyclists and WUs, has been limited and has not been extensively studied in eHMI research (Dey, Habibovic, Löcken, et al., 2020; B. Zhang et al., 2022; de Winter & Dodou, 2022). In this context, similar to cyclists, WUs engage with AVs in dynamic situations, necessitating eHMIs visible from all sides (Vlakveld et al., 2020), as they may face safety and communication challenges, particularly at higher speeds. Concerning pedestrians, predicting their behavior is also challenging, due to its dynamic nature, lack of training, and occasional rule-breaking tendencies (Carmona et al., 2021). Therefore, here a well-designed eHMI can offer advantages such as complementing implicit communication, and potentially enhancing overall performance and increased comfort levels (Chang et al., 2017; Habibovic et al., 2018). In one case, it is found that explicitly conveying a wheelchair's movement intentions, using methods like ground-projected light paths or red arrows, significantly improved interaction smoothness and pedestrian cooperation (Watanabe et al., 2015). In another recent study introduced an on-ground light projection-based eHMI for wheelchairs using automated driving system (ADS) technology, which improved motion intention clarity and appeal (X. Zhang et al., 2024). However, critiques of ground-projected light persist. For example, participants noted that projections were insufficiently visible in bright light and expected better performance in low light or indoor environments. Concerns were also raised about projections' effectiveness on various terrains and their compatibility with existing accessibility infrastructure. Some users worried that on-ground projections might be difficult for passing vehicles to see, potentially leading to distraction, navigation challenges and unsafe situations caused by blind spots. The performance of wheelchairs in crowded areas and on challenging terrains, such as steps or uneven surfaces, was deemed crucial for safety and trust. There were concerns that constant focus on projections during autonomous driving could lead to overlooked environmental risks (X. Zhang et al., 2024). Considering these challenges in user experiences, it is worth exploring how alternative eHMI solutions can address these concerns.

2.1 eHMI: Social Perceptions

WUs sometimes view their wheelchairs as an extension of their body (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010), which can attract more negative attention if the technology is highly noticeable (Barbareschi et al., 2021). Their interactions with the outside world influence both their self-perception and how others perceive them, making it crucial to avoid drawing unwanted attention to their disability (V. de S. P. Costa et al., 2010; Barbareschi et al., 2020; Lanutti et al., 2015). While wheelchairs are vital empowering tools, they also serve as a visible sign of disability, attracting unnecessary attention and potentially leading to social stigma (Barbareschi et al., 2021). To avoid this issue, WUs often prefer visual over auditory communication in their daily interactions (Asha et al., 2021). An innovative design can provide a better user experience and reduce the association with stigma compared to a traditional wheelchair (Carneiro et al., 2017; Mokdad et al., 2018; Faraji & Valajoozi, 2014). In this regard, one study introduce an interface using laser projections and light displays on the street (Asha et al., 2021). The assessments showed that explicit interfaces could enhance interaction, but despite initial designs still lacked empathy and sensitivity, potentially drawing undue attention. Similarly, another study introduced on-ground projection light eHMIs with non-intrusive interaction methods. These included timed appearances, disappearing components, and customizable switches to minimize space use and attract attention only in emergencies (X. Zhang et al., 2024). Nevertheless, some participants reported that projections still drew undue attention. Additionally, auditory cues might cause stress due to excessive focus on the WUs. Despite the real-time interactivity and benefits of light projection eHMIs, which enhance trust and effectively convey users' emotions and intentions, they still attract more undue attention than traditional manual methods. To date, there is still a gap in exploring alternative eHMI solutions for wheelchairs that address social aspects and minimize unwanted attention.

2.2 eHMI: A Framework for Enhanced Interaction of WUs

The aforementioned challenges associated with eHMIs in road communication, safety, and social interaction can be tracked in three key arguments presented by Joost de Winter and Dimitra Dodou (de Winter & Dodou, 2022): 1) the dominance of implicit communication in pedestrian-Automative vehicle (AV) interaction and the absence of a clear social interaction void to be filled,

2) the existence of a diverse range of eHMI concepts lacking standardization and consensus, 3) the potential for negative effects like distraction, confusion, and overreliance. Therefore, it is initially required to adopt a comprehensive framework to mitigate these potential challenges. To this end, Bingqing Zhang et al. offered design implications in a co-design session involving WUs and designers for shared control interaction interfaces of wheelchairs (B. Zhang et al., 2022). These implications highlight three primary pillars in eHMI for wheelchair design: 'Empathy, embodiment, and social acceptance,' 'Situational awareness and adaptability,' and 'Selective information management.' We aim to integrate these aspects as the theoretical framework into our research process to develop an alternative eHMI that addresses the limitations identified in existing literature. Each pillar addresses key criteria for developing eHMIs and aligns with our research question. Specifically, 'Empathy, embodiment, and social acceptance' emphasizes the need for social acceptance and reducing unwanted attention, whereas 'Situational awareness and adaptability' and 'Selective information management' focus on enhancing intent communication and safety, as reflected in our research question.

3 Methodology

3.1 Research Design

In line with the study's objective and the engaging framework developed by Bingqing Zhang et al., (B. Zhang et al., 2022) we adopted a co-design approach to foster empathy toward WUs among the research and development team. For this we have taken four steps: *Step 1*: We initially conducted a qualitative survey for WUs to collect their primary concerns related to eHMI. *Step 2:* We held a set of focus group discussions that encouraged interactive dialogue about eHMI priorities among participants from diverse backgrounds, including cognitive psychology, physiotherapy, design, and WUs themselves. This group setting was intended to facilitate rich discussions and feedback, contributing to an interdisciplinary exploration. Focus group discussions are widely used in qualitative research to deeply explore social dynamics and communication perspectives (O.Nyumba et al., 2018). We followed the Consolidated Criteria for Reporting Qualitative Research (COREQ), a common checklist for studies involving focus groups (Tong et al., 2007). *Step 3:* Included ideation sessions where participants actively shared their desired external interface for wheelchairs, and evaluated the proposed interface concepts to select the highest-ranked one for prototyping. These sessions encouraged collaboration and allowed participants to illustrate ideas for improving eHMIs that aligns with user priorities. *Step 4:* After the prototype is created, a group of experienced WUs and pedestrians assessed it and shared their viewpoints, helping us identify deficits and positive aspects of the proposed eHMI (Figure 33). The study protocol was approved by the Human Research Ethics Committee, with certification number 30019494.

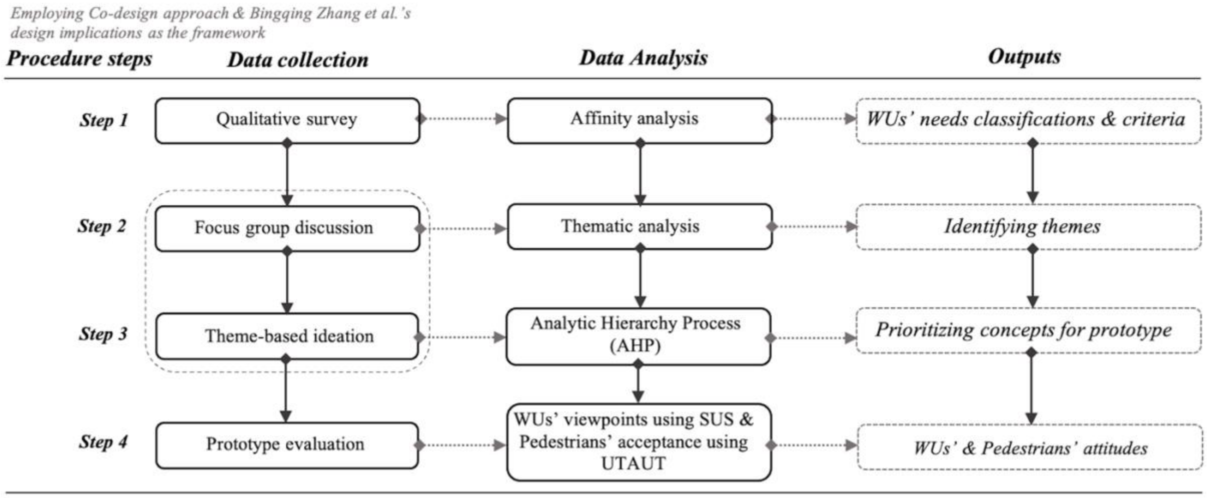

Figure 33. The research design and procedure. © Image by Author.

3.2 Participants

Inclusion criteria for all participants, including WUs, were: (1) aged 18 years or older; (2) willingness and ability to visually express design or interface-related ideas through hand-sketching or diagrammatic methods; (3) availability for in-person meetings; and (4) completion of a literature review provided by the authors on the challenges and user experiences related to mobility aids. The inclusion criteria for non-WUs were (5) being a registered Ph.D. or master's student, or a professional with expertise in cognitive psychology, physiotherapy, and design. Additional criteria for WUs included: (6) a minimum of three years of experience using a manual or powered wheelchair; and (7) regular engagement with diverse public and social environments (e.g., transit, public spaces). To ensure meaningful participation in design activities, (8) eligible WUs had no major cognitive, sensory, or upper-limb motor impairments affecting verbal or visual communication. The study excluded master's students and experts involved in parallel engineering studies on wheelchair development, as their focus on functional aspects might overshadow the communication and social factors among WUs, which are the primary focus of our study. Additionally, WUs who were undergoing medical visits were excluded to ensure that their health issues and mobility disability did not influence their participation, even for the qualitative survey. Potential participants were screened for eligibility and contacted.

3.3 Procedure

Step 1: Initially, responses to a qualitative survey were collected from 22 WUs (aged 32–55; mean age = 42; 10 males and 12 females). The main challenges they reported in urban settings were then grouped. At this stage, we did not suggest or emphasize any themes, as our intention was solely to use these concerns to inform the prompts for the subsequent focus group discussions.

Step 2: The focus group discussion began with a review of the qualitative survey responses and an examination of the general structure of PWs. To facilitate effective dialogue, we established clear guidelines for presenting prompts and encouraging discussion from diverse perspectives. The results of this section serve both as a reflective summary of insights from interdisciplinary discussions—presented as themes—and as a modular set of design considerations derived from these themes, adaptable to contextual and cultural needs. These considerations were shared with participants during the ideation sessions to guide and inspire clear, focused suggestions. In this step, 18 participants (aged 32–57; mean age = 39.25; 10 males and 8 females*),* including WUs with ≥5 years of wheelchair use experience, as well as experts attended the in-person focus group meetings (see Table 20).

Table 20. Background and characteristics of focus group discussion's participants (*N*=18).

Characteristic	**(n), (%), median (min–max)**	**# of exploratory sketches**
Age	39.25 (min-max: 32-57)	-
Profession area		Total of 85 pages:
Design	(n=6), 33%	35
Physiotherapy	(n=3), 16.6 %	10
Cognitive psychology	(n=3), 16.6 %	16
WUs	(n=6), 33%	24

Step 3: During the ideation sessions, we employed brainstorming and sketching techniques. These concepts primarily address three key states within the WUs' journey: 1) during yielding or when the wheelchair is at rest, 2), when the WUs initiates movement, and 3) when the WUs is cruising. For each wheelchair state, we considered scenarios to discuss potential solutions for safe and effective social communication. We also aimed to present possible solutions and design interventions for each scenario. Concepts also needed to be free of language or culture-specific elements, avoiding text or symbols tied to any culture. We prioritized the use of intuitive design elements and everyday metaphors to reduce cognitive load and enhance usability. By integrating familiar visual and interactive cues, the interface minimizes the need for users to learn a new system or symbolic 'language,' thereby supporting a more seamless and accessible user experience. Our designs were based on the most common PWs' models (All Star Wheelchair). Subsequently, the interface concepts were reviewed and evaluated collaboratively by both participants and researchers. This assessment was guided by the themes identified in Step 2, which served as the criteria for the Analytic Hierarchy Process (AHP) (Vaidya & Kumar, 2006**.** Based on the participants' ratings, the highest-ranked concept was selected for further refinement and prototyping. This structured evaluation ensured that concept selection was both transparent and scientifically justified. By applying the AHP, we systematically translated the identified qualitative themes into quantitative evaluation criteria**.** This integration enabled data-driven prioritization of concepts aligned with the study's thematic goals. Consequently, the final concept reflected a synthesis of participant insights and broader design considerations, supporting a user-centered and methodologically robust design outcome.

Step 4: Within two weeks following the concept selection, the highest-rated interface design was translated into a functional prototype. This initial prototype was integrated onto the wheelchairs of participating users to simulate realistic usage scenarios. The evaluation phase involved two participant groups: WUs and pedestrians. A total of 12 WUs (5 males, 7 females; aged 39–62*; mean age = 48;* 1 to 22 years of wheelchair experience) and 27 pedestrians (15 males, 12 females; aged 33–51*; mean age = 38.3*) took part in the experimental sessions. Participants interacted with the prototype under controlled yet contextually relevant conditions to assess its effectiveness in real-time communication and social interaction.

3.4 Data Collection

In this study, four sets of data were collected: (*Step 1*) qualitative surveys completed by WUs; (*Step 2*) focus group discussions; (*Step 3*) participant scores for concept evaluation; and (*Step 4*) feedback from WUs and pedestrians following the prototype assessment.

Step 1: The survey responses provide a data pool, that serves as the outline, used in focus groups discussion. The primary questions addressed in the qualitative survey were:

(1) Have you encountered difficulties in social communication while using a wheelchair? please describe.
(2) When faced with a challenging situation, do you typically seek assistance? If so, how do you communicate your request?
(3) How important are the appearance and symbolic meaning factors (for communication) once you are using a wheelchair?
(4) How does your wheelchair communicate with car drivers and pedestrians in navigating in the cities?
(5) How would you describe your ideal wheelchair to navigate in an urban setting?

Step 2: A total of six focus group discussions and ideation sessions were conducted over a three-week period in August and September 2024. These sessions alternated and were held in person at a university laboratory, which was prepared in advance by the first author after securing the necessary permissions. Efforts were made to create a welcoming and inclusive environment, minimizing external judgment and peer pressure to encourage participants to express their ideas freely. Each session lasted approximately two hours, resulting in a total of 12 hours for all six sessions. Each session involved six individuals: four participants (including two WUs and two domain experts in design, cognitive psychology, or physiotherapy) and two members of the research team who facilitated the discussions and actively directed the conversation. The authors reflected on the guiding questions for the discussions (see Appendix F for details).

During the focus group discussions, the first author guided the conversations according to the study's objectives, while the second author facilitated and organized the discussions, documenting key insights. The second author ensured that all important points were carefully recorded. When a point showed potential for further exploration, the first author encouraged deeper dialogue to foster richer and more focused exchanges among participants. The authors made a concerted effort to capture the interdisciplinary nature of the issues, consider counterarguments to dominant claims, and identify insights that aligned with the development of the eHMI and the study's overall aims. These structured yet flexible sessions provided rich interdisciplinary dialogue, grounded in participants’ lived experiences and professional insights. Multimodal insights were documented through audio recordings, field notes, and photographs, enabling a comprehensive understanding of participants’ cognitive processes, creative reasoning, and socio-emotional responses. The key themes emerging from the discussions were synthesized and used to inform participants' ideation processes, which were further developed into the final interface concepts.

Step 3: In the ideation sessions, the primary focus was on the ideation phase, where both verbal and visual contributions were recorded for analysis. Verbal data included participants' spoken reflections, critiques, and discussions around the design concepts, while visual data encompassed sketches, diagrams, and annotated ideas produced during the ideation activities. The emerging concepts were then discussed using the *Criticism of Interface Aesthetics* (CIA) framework (Bertelsen & Pold, 2004), which offers a structured approach to analyzing the aesthetics of human-computer interfaces. This model provides valuable insights into the visual perception of wheelchairs. Its first component—stylistic references—involves analyzing aesthetic influences in interface design and has broad applicability across disciplines such as graphic and industrial design (Faraji & Valajoozi, 2014; Rasouli Valajoozi & Zangi, 2016), architecture, and interior design (Bertelsen & Pold, 2004; Cucuzzella et al., 2024). Based on these discussions, the finalized ideas and concepts were rendered using 2D and 3D design software. To evaluate the concepts, 18 participants and two authors took part in a final session, during which they discussed each concept and reached a consensus. Based on these discussions, mean scores—reflecting participants’ average ratings—were determined and used as input for the AHP evaluation model (Vaidya & Kumar, 2006).

Step 4: Initially, the prototype was installed on users' wheelchairs, and participants were introduced to the eHMI components to help them understand the user interface. We then asked participants, including WUs and those in the role of pedestrians, to spend 5-10 minutes participating in our experiment. Accordingly, we designed an experiment for participants to share their viewpoints toward the prototype. In this experiment, we aimed to demonstrate and evaluate scenarios where WUs and pedestrians interact using the proposed eHMI. While testing was held in a residential complex's indoor parking lot rather than on actual streets, we aimed to provide participants with an immersive first-person experience using our wheelchair-mounted prototype. The evaluation procedure was conducted over several days and spanned a two-week period.

3.5 Data Analysis

The analysis consists of four sections: classification of survey responses, thematic analysis of discussions, evaluation and prioritization of concepts, and prototype assessment by both WUs and pedestrians.

Step 1. Analysis of survey responses: In this step, we have used the *affinity analysis* to organize number of ideas and responses (WUs: N=22) provided by qualitative survey. This method also helped participants (N=18) to organize a large number of ideas by grouping them into natural relationships (Asana, 2024). This method is used to generate, organize, and consolidate information related to a product, process, complex issue, or problem. After generating ideas, we categorized them based on their affinity or similarity.

Step 2. Analysis of discussion: We conducted a structured analysis of the discussion sessions based on Braun and Clark's six-phase inductive *thematic analysis* framework. This approach consists of sequential stages: data familiarization, generation of preliminary codes, thematic identification, theme review, defining and naming the themes, and producing a report (Braun & Clarke, 2012). Two independent coders initially analyzed the concepts separately. Inter-coder reliability was then established through regular discussions and consensus meetings, during which discrepancies were resolved and main insights and concepts (screening) were categorized (Kudrowitz et al., 2012) followed by the construction of preliminary themes. Both semantic and latent interpretation strategies were employed to identify broader themes (Braun & Clarke, 2022), involving the organization, comparison, and analysis of coded excerpts for repetitions, similarities, differences, and gaps. Themes were refined through critical discussion and consensus to reduce subjective bias and ensure consistency. Reflexivity was maintained throughout, with researchers acknowledging and reflecting on their potential biases during interpretation. Participants clarified their thoughts in group discussions and briefly described their ideas for validation.

Step 3. Concept evaluation: Following the ideation process, the finalized ideas and concepts were evaluated using the AHP, a structured decision-making method designed to prioritize and compare complex, multi-criteria options effectively (Vaidya & Kumar, 2006). In the AHP process, six steps were taken; including Step 1: Define the problem and Criteria, 2: Define Alternatives, 3: Establish priority amongst criteria and alternatives using pairwise comparison, 4: Checking consistency amongst the pairwise comparisons, 5: Evaluating relative weights from the pairwise comparisons and getting the calculated overall priorities for the alternatives, and 6: Performing Sensitivity Analysis (Spicelogic, n.d.). In the AHP, the Consistency Ratio (CR) ensures the consistency of pairwise comparisons. A CR below 0.1 (10%) is acceptable (Malczewski, 1999); if it exceeds this threshold, judgments are inconsistent and may need revision (Pourghasemi et al., 2012). In our model, the emerged themes—organized into groups during Step 1—served as the evaluation criteria, and the finalized design concepts were defined as the alternatives. For detailed calculations, please refer to Appendix G and H.

Step 4. Prototype assessment: After finalizing and refining the prototype, we focused on evaluating the attitudes of both WUs and pedestrians, the usability of the wheelchair equipped with the prototype, and its potential psychological impact. In this regard, the *viewpoints of WUs* and *pedestrians* were assessed as follows:

Viewpoints of WUs: In this part, WUs were asked to navigate an experimental route marked by white arrows on the ground, designed to simulate interactions with barriers and pedestrians (Figure 34). The route included two physical objects and two pedestrians as obstacles. The obstacles required the user to select specific options to indicate their state, whether risky or fine, showing the WUs' intentions to pedestrians. They also needed to perform tasks such as avoiding obstacles or turning. In interactions with pedestrians, WUs needed to communicate their intentions. We aimed to assess the WUs' behavior in responding to different negotiable situation that indirectly convey by eHMIs. To evaluate the experiment, we used the System Usability Scale (SUS) to assess the wheelchair's usability (Brooke, 1996). Immediately after the experiments, participants' attitudes towards the proposed eHMI interaction were measured using a modified questionnaire from Xiaochen Zhang et al. (X. Zhang et al., 2024). Participants rated nine statements using a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Further details are provided in Appendix J.

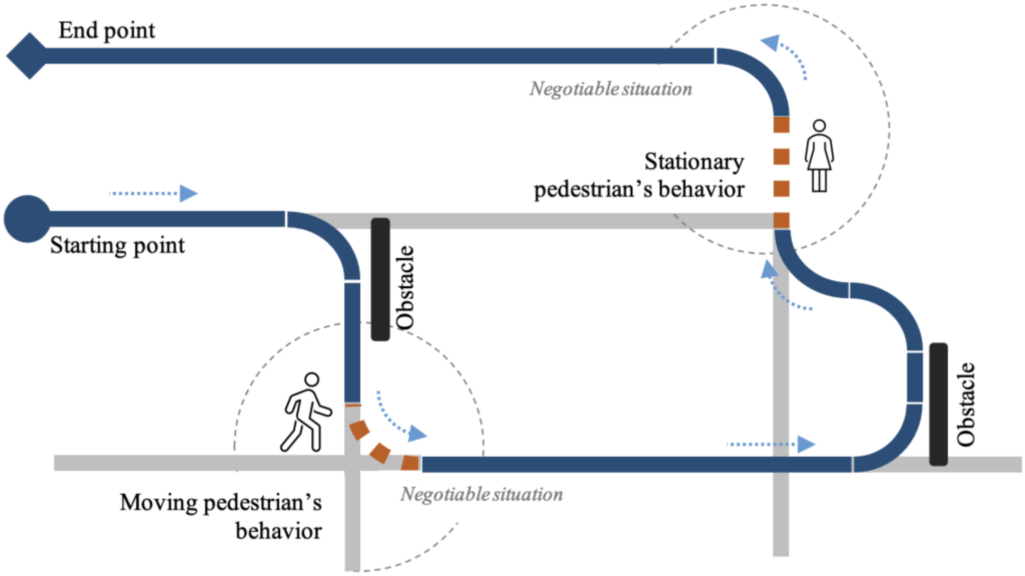

Figure 34. The experimental routes include WUs' behaviors and interactions with pedestrians. © Image by Author.

Viewpoints of pedestrians: We aim to assess pedestrian acceptance when interacting with a wheelchair equipped with our prototype. Participants role-playing pedestrians engaged from a first-person perspective, both stationary and moving. To measure pedestrian acceptance, we used a modified questionnaire based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model, which includes dimensions such as performance expectancy, effort expectancy, and intentions (Rahman et al., 2017). Relying on the questionnaire from Xiaochen Zhang et al. we assessed pedestrians' attitudes toward the wheelchair equipped with our eHMI prototype (X. Zhang et al., 2024) (see Appendix K for details).

4 Results

Using affinity analysis, four criteria were identified in the qualitative survey including, communication, safety, aesthetics and feasibility. Accordingly, communication and safety were considered as the primary criteria, and aesthetics, and feasibility were categorized as the secondary criteria. The notion of communication, which involves the transmission of verbal and non-verbal messages (Munodawafa, 2008), in this context, refers to developing a means to understand the situation and intentions of WUs from the perspective of pedestrians and drivers. In the context of user-product interaction, safety, defined as the absence of any undue threat to human life or health (*Report on International Consumer Product Safety Risk Assessment Practices*, 2016), refers to providing opportunities to improve the user-wheelchair interaction, mitigate risks, and ensure the security of WUs. Product design aesthetics involve understanding the complexity of visual and non-visual elements (Hekkert & Leder, 2008) and achieving a harmonious visual appeal using those principles (Faraji & Valajoozi, 2014). Feasibility means the evaluation of whether a proposed concept is legally and technically possible and economically justified (Simplilearn, 2012). Each of these criteria was used as a basis to identify the corresponding themes in group discussions. Through group discussions, 43 codes were extracted, and a single theme emerged for each category of criteria, ultimately identifying four distinct themes:

- *Streamlined Information in Interaction*;
- *User-Centric Safety Feedback*;
- *Harmonious and Minimalist Interaction Design*; and
- *Effortless Integration and Production*.

Then, design suggestions and implementations were provided for each theme, with their relevance to the wheelchair's three states—yielding/rest, initiating, and cruising—identified (Table 21). This table guided our ideation process throughout the study; however, not all suggestions were directly implemented in the final design concepts. Rather, the suggestions serve as a modular design consideration pool that others can adapt based on context-specific needs—such as varying regulations and interaction patterns in street and urban settings across different countries, community norms surrounding assistive devices, individual user preferences, and broader cultural and social factors. We propose that Table 21 can support future research and practice by offering a structured yet flexible set of design considerations. It can also act as a foundation for identifying which communicative features may benefit from standardization to ensure consistent and recognizable signaling across various wheelchair platforms and their integrated communication systems.

Table 21. Design suggestions and implementations and their relevance to the three states of the wheelchair.

Criteria: Themes	**Design suggestion**	**Implementation and considerations**	Yielding/ at rest	Initiating	Cruising
Communication: Theme I. Streamlined Information in Interaction	Bright, high-visibility LED indicators with universal icons (e.g., arrows, stop signs).	Large LED arrow indicates wheelchair direction	NA	•	◦
	Small screen display with brief messages or symbols.	Use red "STOP" or green "GO" symbols instead of lengthy text.	NA	◦	•
	Use widely recognized traffic symbols and colors.	Use caution symbols like a yellow triangle or a green pedestrian icon for safe crossing.	◦	•	•
	Coherent light patterns reflecting wheelchair status/actions.	Blink arrows sequentially to indicate turn preparation and execution.	NA	◦	•
	Display offering full context of wheelchair movements.	Use visual indicators and text (e.g., "Turning Left" with an arrow) along with real-time feedback (e.g., "Speed Reduced").	◦	•	•
Safety: Theme II. User-Centric Safety Feedback	Lock/confirm certain controls to prevent accidental use.	Add a "confirm" button and two-step activation for critical functions.	•	◦	•
	Position eHMI controls for easy, natural access.	Position controls on armrests, angled for natural hand placement.	NA	•	•
	Use large, distinct icons and labels.	Use symbols like a red “X” for stop, green “checkmark” for activation, and blue “gear” for settings with tactile/visual feedback.	NA	◦	•
	Create a simple, grouped control layout.	Cluster controls by function with distinct sizes and shapes for easy use.	NA	•	•
	Make the control panel height- and angle-adjustable	Include a sliding/pivoting mechanism to adjust the control panel's position.	NA	•	•
	Add backlighting for low-light visibility.	Implement adjustable LED backlighting for clear visibility in various lighting.	•	•	•

Criteria: Themes	**Design suggestion**	**Implementation and considerations**	Yielding/ at rest	Initiating	Cruising
	Proximity Warning Lights	Use LED lights that change color (green, yellow, red) based on obstacle proximity for navigation safety.	◦	•	•
	Real-Time Status Indicators	Display mode on the external interface with alerts for critical conditions.	NA	◦	•
Aesthetics: Theme III. Harmonious and Minimalist Interactions Design	Choose a functional, appealing and harmonic color palette.	Use a high contract color panel on eHMI for high visibility.	NA	NA	NA
	Add variety of textures for visual interest.	Combine soft-touch rubber handles with contrasting metal finish on eHMI for a modern look.	NA	NA	NA
	Use abstract, readable icons and text.	Design clean-line icons with sans-serif fonts, ensuring consistent spacing.	NA	◦	◦
	Ensure eHMI design matches the wheelchair.	Match eHMI shapes and finishes with the wheelchair’s design.	NA	NA	NA
	Keep symbols recognizable and clear.	Use minimalistic symbols with ample spacing for clarity.	NA	◦	•
Feasibility: Theme IV. Effortless Integration and Production	Design a tool-free, quick-connect eHMI.	Use snap-fit or quick-release components with a clear, visual guide for easy eHMI installation.	•	NA	NA
	Use lightweight, durable materials for comfort and maneuverability.	Use carbon fiber or high-strength aluminum for a lightweight, durable eHMI casing, and design compact internal components.	◦	•	•

During the ideation, participants mostly emphasized the absence of adequate external surfaces on PWs to accommodate eHMIs. Accordingly, they tried to add external surfaces as an opportunity to introduce a broader range of innovative and efficient eHMIs. This led to the generation of 85 pages of exploratory sketches, which were then organized into 12 primary themes (see Figure 35). Following this categorization, a screening process identified five key concepts. The presented concepts include 'WheelGlow Assist,' 'WheelSafe Illumina,' 'PathGuard Illumina,' 'Safeguard Sonic,' and 'Handle Illumina'. Following are the descriptions of these five concepts.

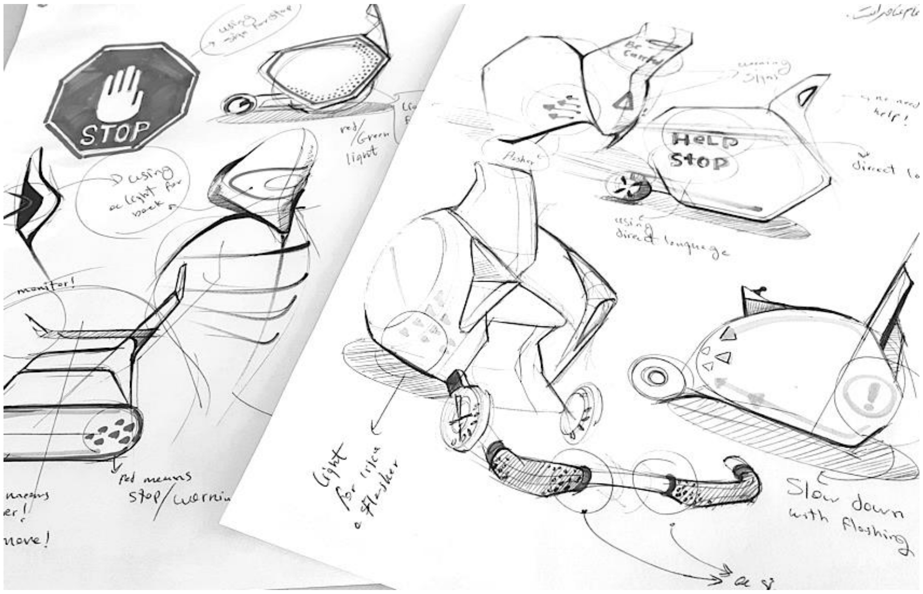

Figure 35. A sample of exploratory sketches. © Image by Author.

4.1 Concepts

In this section, five concepts are introduced along with their general features. Concept 2 is described in greater detail, as it was ultimately chosen by the participants.

Concept 1. WheelGlow Assist: Inspired by traditional traffic signals into the wheelchair's frame, integrating red for urgent need of assistance, yellow suggests uncertainty and invites help, and green lights signifies safe and unobstructed mobility. When turning, the light blinks red to signal direction. In emergencies, users can activate a flashing red light for help, while a circulating green light indicates comfortable movement. The animated green light stays on even when stationary, offering continuous feedback on the wheelchair's status and intentions (see Figure 36, Concept 1).

Concepts 2. WheelSafe Illumina: This concept uses arrow lights to convey the user's movement intentions. In normal mode, only the turn signals and blue front/back lights are illuminated, indicating no issues or need for assistance. In caution mode, a yellow stop signs light blinks (specifically visible to drivers), and simultaneously, a blue animated arrow moves from back to front. This indicates that while the user is managing their movement independently, caution is needed, and others should stay alert or help if necessary. In critical situations, a rapidly twinkling red light indicates the need for immediate assistance. In this mode, the hand and blue arrow lights are off, indicating the user is capable of handling their movement. Users manage all settings via a control panel on the armrest, aligned with the lights on the wheelchair. Effective day and night, this concept clearly communicates with pedestrians, drivers, and users, but selecting the correct light is crucial to avoid confusion. (see Figure 36, Concept 2).

Concept 3. PathGuard Illumina: A ground light projection, similar to eHMI, is used. A red light signals a need for assistance, while a twinkling yellow light indicates road crossing, with faster twinkling showing increased caution. A white light means no assistance is needed. Effective at night but less distinct in daylight, this cost-effective solution relies solely on floor light projection and can be used on various PWs, even without external surfaces. However, it is limited to conveying simple messages and may not support complex interactions (see Figure 36, Concept 3).

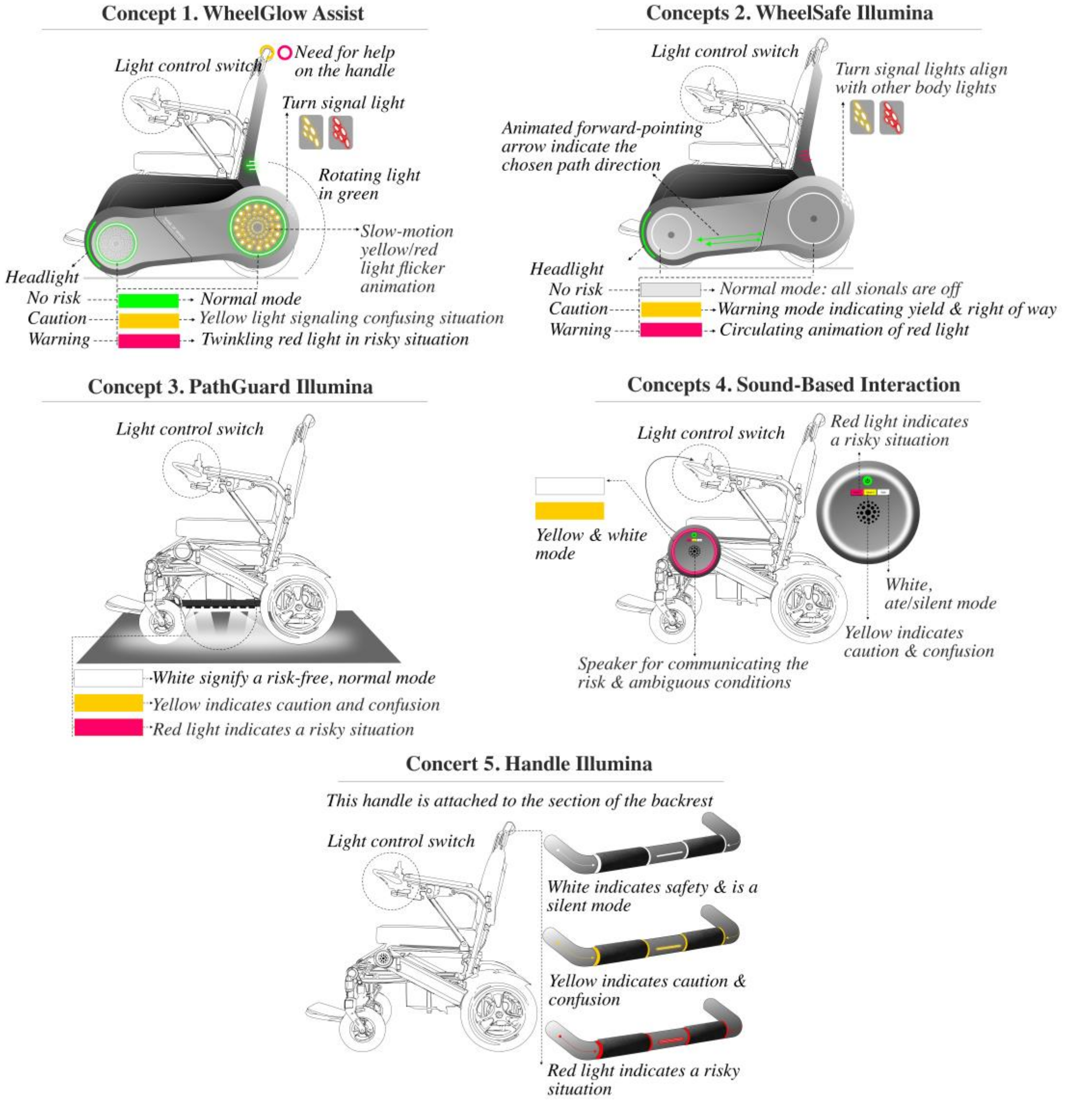

Figure 36. Five proposed concepts. © Image by Author.

Concept 4. Safeguard Sonic: This concept uses sound-based interactions, with three distinct sound effects. An affixed device emits a continuous alarm and flashing red light in emergencies. A specific sound alerts others to potential risk, while silence indicates safety with no need for assistance. Distinct alarms stand out in noisy areas, and the Doppler Effect enhances perception of direction and urgency (Isoardi, 2012) (see Figure 36, Concept 4).

Concept 5. Handle Illumina: Compatible with all wheelchair types, this back-handle accessory signals assistance with a twinkling red light for urgency, a rhythmic yellow light for caution, and a white light for nighttime visibility. However, rear-only visibility may limit communication with drivers from the side or front (see Figure 36, Concept 5).

4.2 Concept Evaluation

Using the AHP method for defining criteria, the weighted scores for the identified themes were distributed as follows: 56.4% for communication, 28.0% for safety, 9.9% for aesthetics, and 5.7% for feasibility, with a consistency ratio (CR) of 8.8% (see Table 22 and Appendix H & I). Results show that Concept 2: 'WheelSafe Illumina' ranked highest (41.3%), followed by Concept 1: 'WheelGlow Assist' (28.1%). These two concepts use external surfaces for better communication between WUs and their surroundings. Concept 3: 'PathGuard Illumina' ranked third (13.0%). Concepts 5: 'Handle Illumina' (5.7%) and 4: 'Safeguard Sonic' (11.8%) ranked lowest (see Figure 37). However, integrating these with top-ranked concepts could enhance multisensory communication, improving safety without drawing unnecessary attention or causing discomfort to users. Figure 38, A, illustrates a further development of Concept 2, and B, its prototype.

Table 22. AHP evaluation of five proposed concepts based on the weight of each criterion.

	Criteria: Themes			
Name of Concepts (C)	***Communication*: Theme I.** Streamlined Information in Interaction	***Safety*: Theme II.** User-Centric Safety Feedback	***Aesthetics*: Theme III.** Harmonious and Minimalist Interactions Design	***Feasibility*: Theme IV.** Effortless Integration and Production
C1. WheelGlow Assist	30.1%	25.9%	32.7%	15.8%
C2. WheelSafe Illumina	43.2%	44.1%	46.1%	15.8%
C3. PathGuard Illumina	11.9%	9.4%	12.3%	34.4%
C4. Safeguard Sonic	10.4%	16.6%	3.9%	9.6%
C5. Handle Illumina	4.4%	4.0%	5.0%	24.4%
Consistency Rate (CR)	4.7%	5.1%	8.4%	1.9%

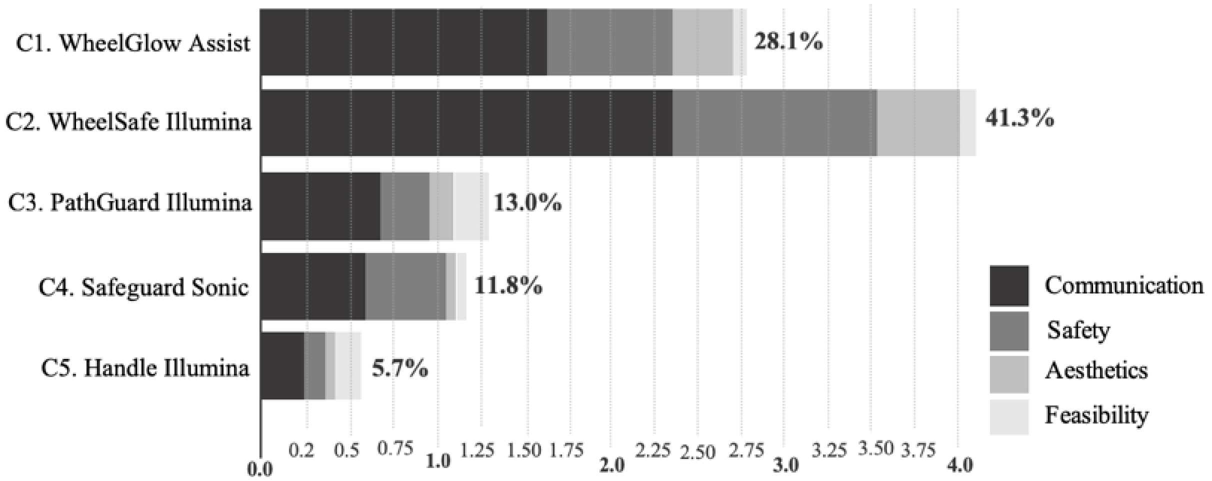

Figure 37. The final AHP evaluation of five proposed concepts.

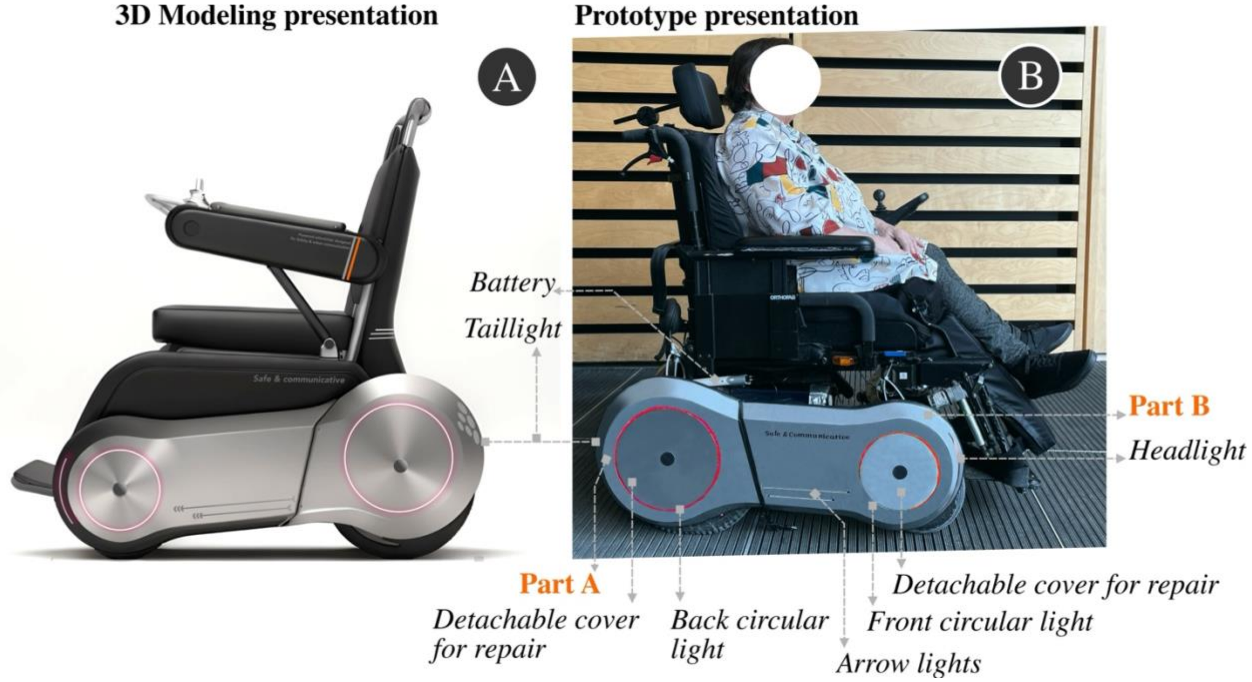

Figure 38. A: The final Concept 2: 3D modeling presentation of WheelSafe Illumina. B: Prototype presentation. © Image by Author.

After selecting Concept 2, WheelSafe Illumina, prototype development began. During this phase, we adjusted and optimized the concept based on feedback from the evaluation. Within two weeks, the initial prototype was implemented and ready for evaluation by both WUs (N=12; 5 males, 7 females; ages 39-62, mean=48.6 years; wheelchair experience: 1-22 years), and pedestrians (N=27; 15 males, 12 females, average age 41). The results of the WUs' attitude questionnaire, shown in Figure 39, indicate that most WUs participants had a positive view of the proposed eHMI for wheelchairs, demonstrating openness to accept and install on their wheelchairs. Participants expressed satisfaction and trust in the safe navigation (67%) and effective communication features of the proposed eHMI (75%). However, some participants indicated that they did not entirely rely on the eHMI (58%), occasionally preferring to use their body gestures. Participants also felt that the eHMI did not attract significant unwanted attention (59%), making them comfortable using it, though some remained somewhat concerned about such attention (41%). In contrast, when considering direct interaction with WheelSafe Illumina and potential risks associated with its use, participants expressed a willingness to use it in the future (75%), as indicated by responses to reverse Question 5. They largely viewed the proposed eHMI as a useful improvement over their current wheelchairs, appreciating the ease of control and the enjoyment it provided during use (67%). In the last two reverse questions, participants further confirmed their positive assessment by disagreeing with statements about inconsistency (75%) (Q8), and unnecessary complexity or loss of independence when attaching WheelSafe Illumina (84%) (Q9).

The pedestrian acceptance questionnaire results shown in Figure 40 indicate that most pedestrians had a positive attitude toward the proposed eHMI. Pedestrians believed that the WheelSafe Illumina could help pedestrians react more quickly to unsafe walking conditions while crossing the road (67%). Additionally, they expressed that interaction features on eHMI-equipped wheelchairs would lower the risk of an accident (78%). While participants found this interaction with the proposed eHMI easy to learn (59%), some still found it ambiguous to decode the signs (41%), showing a potential in providing a communicative property. However, in general interaction, participants had no hesitation to cross the road when the WheelSafe Illumina is attached to wheelchairs in operation (70%) (Q4) and felt comfortable crossing the road in front of eHMI-equipped wheelchairs (74%).

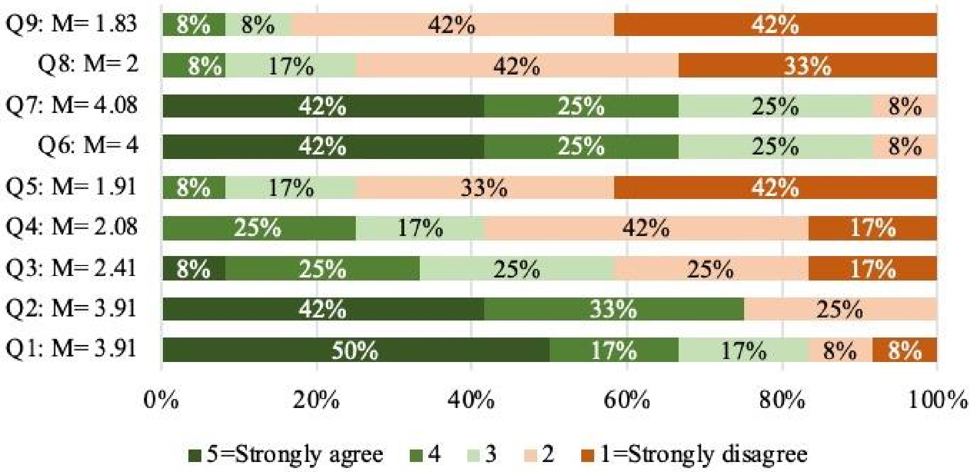

Figure 39. WU’s viewpoint on proposed eHMI: WheelSafe Illumina (*N*=12).
Q means Question number. (Q 3 is neutral and 4, 5, 8 and 9 are reversed questions.

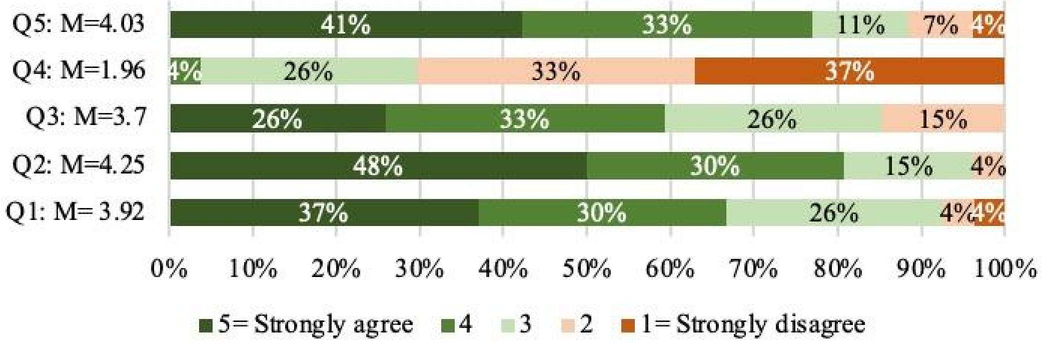

Figure 40. Pedestrians' acceptance of proposed eHMI: WheelSafe Illumina (*N*=27).

5 Discussion

5.1 Integrating Shell Structures to Improve Aesthetics and Social Acceptance

In this study, Concept 2 and Concept 1, prioritized highest, and utilizing external surfaces, introduce novel approaches to intent communication, whereas Concepts 3, 4, and 5 build upon existing possibilities. This aligns with previous research showing that external coverings can effectively convey a product's language (Hernández et al., 2018). It is worth noting that many wheelchairs lack external covers, emphasizing structural elements like struts, frames, and joints. According to Lidwell and et al., structures can be categorized into three formats: mass structures (e.g., dams and adobe walls), frame structures (e.g., bicycles and skeletons), and shell structures (e.g., bottles, airplane fuselages, and domes) (Lidwell et al., 2010). A shell structure is an outer layer that encloses and protects internal components while enhancing aesthetic form. It is designed to be strong yet lightweight, efficiently distributing loads and serving as the product's visual and tactile interface (Farshad, 1992; P. Sharma, 2023). In light of this, using a shell structure, such as covering the wheel or motor, enhanced the wheelchair's aesthetics and facilitated the integration of visual cues for better social acceptance and communication (Lanutti et al., 2015; Rasoulivalajoozi et al., 2025a). This is highlighted in themes I, III, and IV and their design suggestions, which create clear and concise designs that are functionally efficient. These designs are harmonious and easily integrated into existing systems and processes, allowing for ease of implementation.

Furthermore, in Concept 2 and 1 concealing the bulky mechanisms of the wheelchair may help counteract the stigma associated with its size—as emphasized in prior studies (Rasoulivalajoozi & Farhoudi, 2025b; Asha et al., 2021). For instance, Xiaochen Zhang et al.'s study highlighted this challenge, where the eHMI's ground illumination drew undue attention, increasing social discomfort for WUs (X. Zhang et al., 2024). Although the proposed eHMI in our study could mitigate unwanted attention, we believe the issue extends beyond the argument surrounding eHMI and involves the symbolic role of the wheelchair as an icon of disability (Mokdad et al., 2018; Barbareschi et al., 2021). This necessitates defining design principles that address the socio-emotional needs of WUs and applying them in wheelchair development (Rasoulivalajoozi et al., 2025a). Researchers can explore the role of aesthetic design criteria in shaping the external appearance of wheelchairs to enhance users' social empathy and communication, as addressed in Themes I and III.

5.2 Safety and Communication Aspects

This study emphasized the importance of transparent communication in the proposed eHMI, consistent with previous research demonstrating that transparency enhances trust, safety, and acceptance in driving systems (Detjen et al., 2021). The WheelSafe Illumina improves system transparency by adding dynamic visual cues to the wheelchair's shell, clearly conveying the WU's intent to drivers and pedestrians in negotiable situations. The prototype test revealed that although most WUs are satisfied with the proposed eHMI, its effectiveness in complex situations is limited. A portion of participants (58%) still occasionally prefer using body gestures rather than relying solely on the eHMI. This suggests a possible skepticism toward the eHMI's ability to accurately convey intended messages to drivers or pedestrians. As body language is more inclusive and typically used, they find body language and eye contact more effective in navigating these situations (Dey, 2020). In this context, the receivers of the message should be near WUs, therefore the distance between WUs and others, whether pedestrians or drivers, also plays a crucial role in conveying the intended message. Future studies could explore the role of body gestures and the impact of distance on communication between WUs and their environment.

In addition, maintaining a balance between accuracy and the number of visual cues on the shell structure is essential to prevent confusion. This is particularly true when considering potential audio cues, as Theme III highlights the need to minimize clutter and complexity. While the combination of visual and audio cues may offer benefits, previous research suggests caution regarding audio cues emitted from wheelchairs due to perceived stigmatization (Asha et al., 2021). Therefore, if audio cues are to be integrated, careful sound design is necessary. The combination of visual and haptic feedback design modalities shows promise for AV and PW interaction (Mahadevan et al., 2018; Colley et al., 2020; Asha et al., 2021). This is also emphasized in our study, in Theme II, User-Centric Safety Feedback, which prioritizes user safety in interactions with PWs. Although haptic feedback design was not incorporated into the prototype due to implementation constraints, future research could investigate its potential contribution to wheelchair design.

Additionally, our experiment found that pedestrian participants felt WheelSafe Illumina improved reaction times and reduced risk (67%). This aligns with research showing that pedestrian awareness of WUs' intentions leads to smoother movements compared to scenarios without communication (Morales et al., 2015). However, some participants (41%) found WheelSafe Illumina ambiguous when crossing roads, likely due to the simultaneous use of multiple dynamic visual elements. This lack of clarity and complexity may confuse pedestrians and cause them to miss the interaction, reducing user confidence. This issue can also likely stem from insufficient training time and a lack of standardization and consensus in eHMIs, as noted in arguments against eHMI (de Winter & Dodou, 2022). We hope that more consistent and inclusive visual elements for wheelchair eHMI will clarify these signs and improve effectiveness. Also, this can be improved by reducing the number of signs and optimizing visual priorities. While the bright primary color scheme was chosen to enhance sign visibility and ensure clarity, adding words and more visual elements on external surface could further reduce confusion among pedestrians and improve their ability to interpret intentions.

6 Conclusion

In this study, we collected data from WUs and engaged them, along with relevant experts, in focus group discussions and the design process. This led to the identification of key criteria and four themes. During co-design sessions, we applied design implications from Bingqing Zhang et al. outline the main aspects of eHMI for wheelchairs, aligning with our study's aims and addressing limitations in previous research. Following the evaluation of five concepts, Concept 2 (WheelSafe Illumina) was ranked highest and selected for prototyping. This concept aimed to enhance communication for both users and pedestrians, reduce the cognitive load of WUs, provide a more autonomous and personalized navigation experience, and mitigate unwanted attention and distractions caused by WUs' focus on the eHMI with light projection on the ground. The experiment evaluating WUs' viewpoints and pedestrian acceptance highlighted the appeal, safety, and communication of WheelSafe Illumina, but raised concerns about the consistent use of the eHMI. While WUs found the interface improved communication, and safety, and did not increase negative attention, some still preferred using body language for accuracy. Pedestrians felt that the interface enhanced their safe interaction with WUs, but some found the signs ambiguous, indicating a need for more training and universal communicative signs in developing eHMIs. Overall, although on-ground projection eHMI provides safety, assistance, and maintains users' attention on the route, our study found that integrating a shell structure with eHMI on the wheelchair also promotes a supportive attitude toward WUs. This approach, often overlooked in previous research, was effectively addressed through our co-design approach throughout the study. Notably, while eHMI with a shell structure and aesthetic considerations partially addresses WUs' socio-emotional needs, the issue extends beyond eHMI alone; a semantic turn and redesigning the wheelchair as an icon of disability with a socio-emotional polish could further enhance its social interaction.

6.1 Limitations and Future Studies

This study assessed WUs’ and pedestrians’ interactions in a simulated indoor parking environment to ensure safety and controlled testing during the prototype phase. While this setting provided insights into visibility, intuitiveness, and perceived social comfort, it did not capture the complexities of real urban contexts—such as interactions with drivers and unpredictable environmental factors. Future research should deploy WheelSafe Illumina in outdoor settings to evaluate its effectiveness across diverse traffic conditions and social scenarios, including driver behavior, mobility dynamics, and sensory distractions.

This study is limited by its reliance on subjective questionnaires to assess pedestrian-WU interactions, without incorporating objective behavioral data such as avoidance distance, decision-making time, motion capture, eye tracking, or WU operation error rates. While these measures could provide a more comprehensive understanding, they were beyond the scope of our study. Future research could integrate these objective metrics to further validate or challenge the findings and provide deeper insights into pedestrian-WU dynamics.

While the integration of a shell structure into wheelchair interfaces has been positively received in terms of aesthetics and perceived social acceptance, it is essential to consider additional dimensions that may influence feasibility and broader adoption. From a technical perspective, materials such as lightweight composites or thermoplastics could offer structural durability while preserving mobility performance. Given the potentials of mass production, the cost of this shell structure could be reduced, making it more affordable for users, and it can be optimized for attachment to various wheelchair models. On the other hand, functional constraints must be addressed. For example, a shell structure might limit customizability or hinder accessibility for users who require modular support systems or frequent maintenance access. Therefore, future iterations of this concept should undergo comprehensive user testing and cost-benefit analyses to carefully balance form, function, and inclusivity. Future studies should compare our eHMI with concepts introduced by Xiaochen Zhang et al. (X. Zhang et al., 2024) and explore integrating their features. While the social considerations were emphasized in the focus group discussions as well as the proposed eHMI (de Winter & Dodou, 2022), we were not able to eliminate the iconic role of the wheelchair as a symbol of disability (Rasoulivalajoozi et al., 2025b). The iconic role of the wheelchair requires further investigation in socio-emotional design studies.

Integrating Socio-Emotional Factors in Wheelchairs

This section is based on the following manuscript (published edition).

Rasoulivalajoozi, M., & Farhoudi, M. (2025b). Integrating user perceptions of socio-emotional aspects in wheelchair design: A pilot study using Kansei Engineering. *Journal of Transport & Health*, *42,* 102002. https://doi.org/10.1016/j.jth.2025.102002

The *Journal of Transport & Health* (JTH), published by Elsevier, focuses on research exploring the interactions between transport, health, and related policies.

Abstract: Comfort in wheelchair use is influenced not only by ergonomic factors but also by socio-emotional aspects that shape the user's experience. Accordingly, this study aims to explore how socio-emotional factors can be integrated into the representational aspects of wheelchairs. To achieve this, a cross-sectional study was conducted with 37 wheelchair users using Kansei Engineering methods. Participants provided data on semantic and product spaces through a questionnaire covering demographics, aesthetic importance, symbolic importance, and social communication challenges. They also rated four distinct wheelchairs using Kansei words (KWs). Then, Quality Function Deployment (QFD) linked users' insights to specific wheelchair properties. The results showed that, Aesthetic (76%) and Symbolic (56%) importance, as well as age, were significantly associated with social communication challenges (57%) ($p<0.05$). Age was significantly associated with both Aesthetic and Symbolic importance, while gender was only linked to Aesthetic importance ($p<0.05$). Descriptive analysis indicated that advanced manual and powered wheelchair designs scored higher than conventional ones. Accordingly, three key components were identified for both categories, with the highest loadings of KW in each. QFD results prioritized adjustable frame design, ranked highest at 8.61% for manual and 10.44% for powered models, as crucial to enhancing socio-emotional aspects. Beyond analyzing the dynamics of aesthetics, symbolism, and social challenges, this study uncovers users' perceptions of wheelchair design characteristics. It proposes principal components to guide designers and includes computational analysis to connect these insights with wheelchair properties, aspects often overlooked in assistive device literature. However, redesign effectiveness also hinges on understanding social factors like stereotypes, and wheelchair-related metaphors.

Keywords: Wheelchair design; Socio-emotional aspects; Kansei Engineering; Emotional design; Users experience.

1 Introduction

In new product development, the focus has shifted from a purely product-centered approach to one that is consumer-oriented, prioritizing users' psychological needs and emotional experiences as essential to achieving user satisfaction (Nagamachi, 2002; Schifferstein & Hekkert, 2007). Emotional design thus explores the feelings products evoke through sensory interactions (Desmet, 2012). However, these emotions are often unconscious and challenging to articulate (Dorneles et al., 2023; Grimsaeth et al., 2010; J. Zhang et al., 2020), posing a design obstacle. This challenge is particularly pronounced in assistive products, where mobility devices are traditionally viewed solely as functional tools for independence and mobility. Consequently, emotional considerations frequently become secondary. Yet, the emotional experience of these devices is shaped not only by individual factors but also by societal perceptions that often portray them as visible symbols of disability (Mallin & Carvalho, 2015; V. de S. P. Costa et al., 2010). Such perceptions can create negative social experiences, discouraging users from fully accepting and continuing to use assistive devices. Wheelchairs as visible symbols of disability are referred to in the article as 'symbolic importance'.

Research shows that wheelchair users (WUs) often experience emotions such as embarrassment (Cahill & Eggleston, 1994), humiliation, frustration, and loss (Barlew et al., 2013), and a sense of being treated as second-class citizens (Meikle, 2016). For some, wheelchairs become extensions of their bodies, affecting their sense of identity (Papadimitriou, 2008; Blach Rossen et al., 2012). These insights highlight the importance of addressing emotional factors in wheelchair design, as they shape both users' personal connections with their wheelchairs and societal perceptions of WUs.

Earlier studies found that new wheelchair designs have a more positive emotional impact on children than conventional models (Desmet & Dijkhuis, 2003). However, some parents expressed concern that overly modern or uncommon designs made their children stand out too much, evoking negative emotions. Carneiro et al. (2018) similarly found that modern, innovative wheelchair designs elicit more positive responses from both users and observers, reshaping perceptions despite the stigma often associated with assistive devices. Supporting this, research shows that aesthetics play a crucial role in the adoption or rejection of such devices (Dos Santos et al., 2022). In this context, WUs exhibit stronger emotional responses to various wheelchair models than non-users, who generally evaluate wheelchairs more negatively (P. Costa et al., 2012). Both groups respond positively to innovative aesthetics, though older adults and those with lower education levels tend to value these features less. While these studies emphasize the role of emotion in wheelchair design and highlight key developmental priorities, a gap remains in systematically measuring and translating the socio-emotional perceptions of WUs into specific product characteristics. Addressing this gap can reduce long-term healthcare costs by increasing users' engagement and willingness to consistently use their wheelchairs. Accordingly, this paper aims to translate favorable socio-emotional responses into actionable design requirements, shaping wheelchair design characteristics (WDCs) to enrich WUs' socio-emotional experiences. This work connects socio-emotional needs with wheelchair design, broadening the scope of user-centered design in assistive technologies, an aspect often overlooked in ergonomic and technical assessments. In addition, this study examines how aesthetic and symbolic importance is linked to social communication challenges, particularly across age and gender, offering new insights into how design elements affect social interaction and user experiences.

Accordingly, this study seeks to answer two questions: How can the socio-emotional perceptions of WUs be effectively translated into design features for both manual and powered wheelchairs? Which perceptions should be prioritized to best meet the socio-emotional needs of WUs? To explore these questions, we conducted a cross-sectional study using the Kansei Engineering (KE) method, which creates a mathematical link between consumers' needs and product characteristics, thereby streamlining design (Nagamachi, 2002; Nagashima, 2012). KE translates these emotional responses into design specifications, effectively converting consumer emotions into actionable design elements (Nagamachi, 1999). While widely applied across industries like automotive, appliances, construction, textiles, and packaging (Koleini Mamaghani et al., 2014; Lu et al., 2008), this methodology has not yet been applied to wheelchair development.

Aligned with the study's aims, we test two main hypotheses: H1) The social communication experiences of WUs are influenced by the wheelchair's perceived aesthetic and symbolic significance; and H2) Different WDCs elicit varying socio-emotional perceptions. This study seeks to identify key components that enhance the socio-emotional aspects of wheelchair design. Furthermore, it aligns with the United Nations Convention on the Rights of Persons with Disabilities (CRPD), as discussed at COSP17 in June 2024 in New York (United Nation News, 2024), by promoting principles of inclusivity, dignity, autonomy, community participation, and non-discrimination for individuals with disabilities. The contributions of this study include the following:

- While most relevant studies focus on improving physical comfort and usability, formulating emotional design criteria for wheelchair development provides ergonomists and industrial designers with essential insights to enhance user acceptance of assistive technologies. This broader perspective bridges a gap often overlooked in favor of purely technical evaluations.
- The findings introduce foundational considerations to advance design principles that integrate socio-emotional aspects, alongside insights from research on social stereotypes and cultural factors. Accordingly, they can be compared with existing literature through a systematic review, contributing to the development of a theoretical framework for emotional design specifically applicable to mobility aids.

1.1 Concept of Kansei Engineering (KE)

KE offers a model that links individuals' emotional responses to specific product properties (Hakim et al., 2024). The term 'Kansei,' originating from Japanese, refers to the psychological feelings and needs that emerge when a person interacts with a product in a given environment. KE captures an individual's subjective impression of a product by engaging all five senses—sight, hearing, touch, smell, taste—alongside cognition and balance. It encompasses aspects of sensitivity, aesthetics, emotions, and intuition. Various methods are used to measure Kansei, including verbal descriptions, physiological responses (e.g., heart rate, EMG, EEG), behaviors, and facial/body expressions. Verbal descriptions are the most commonly used, as they reflect elements of Kansei within an individual's mind; however, it is essential to recognize that words only partially capture Kansei. In most English-language studies, verbal descriptions remain the predominant measure.

Nagamachi outlined four key aspects of KE (Schütte et al., 2004): 1) understanding user sentiments related to ergonomics and product psychology, 2) identifying the product's personality, 3) establishing KE as an ergonomic tool, and 4) adapting design to social shifts and user preferences. Six general types of KE techniques are commonly applied, depending on research goals and scope: 1) Category Classification, 2) KE System, 3) Hybrid KE System, 4) KE Modeling, 5) Virtual KE, and 6) Collaborative KE Design (Schütte et al., 2004). While this method has been limitedly applied in developing assistive devices (Ismail et al., 2014; Lokman et al., 2017), no studies have specifically used the KE method to address and polish the socio-emotional aspects of wheelchairs.

2 Methods

2.1 Steps of KE

KE follows a systematic approach, including domain selection, development of emotional features, creation of product-related subsets, and synthesis (Soares, 2021). This study employed Type 1: Category Classification to establish socio-emotional design criteria for wheelchair development. The steps of this study are outlined in Figure 41. The procedure begins with selecting the domain and reviewing different types of wheelchairs, followed by the consideration of semantic and properties spaces. In the semantic space phase, demographic and related statistical analyses are conducted. Then, in the synthesis phase, the connection between the semantic and properties spaces is established using Quality Function Deployment (QFD) methods, and finally priorities are determined.

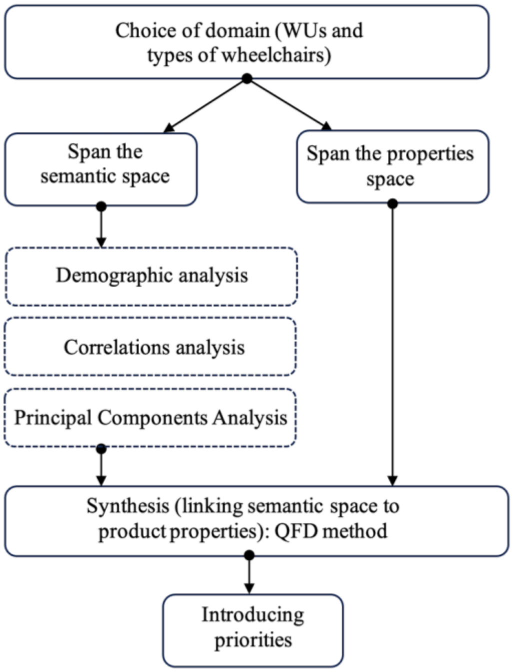

Figure 41. The procedure of KE Type 1. © Image by Author.

2.2 Choice of Domain

The initial stage identifies the product's domain and target group by analyzing market data, user demographics, behavior, and emotional needs. It also reviews conceptual and existing products, potential solutions, and unexplored concepts to comprehensively define the domain and select representative samples (Koleini Mamaghani et al., 2014; Soares, 2021). In this study, we focused on WUs who actively use wheelchairs, emphasizing their socio-emotional needs over ergonomic and technical aspects, which primarily address physical interactions. After reviewing existing wheelchair models, the advanced and conventional wheelchair designs were selected for their distinctive features, including enhanced aesthetics, functional adaptability, and technological integration. This selection was based on our analysis of products, and market trends, rather than manufacturers' advertising. Accordingly, we selected the 'WHILL Model C2 Power Wheelchair' (WHILL, 2024) and the 'Gear-Adjustable Manual Wheelchair' by You Seong Kim (McNulty-Kowal, 2020) as examples of advanced models, while the 'Cirrus Plus EC Folding PW' by Drive Medical (Drive Medical, 2024) and the 'Excel 2000 Series Wheelchair' by Medline (Medline, 2024) represented conventional models. These selections provide a clear contrast in WDCs, based on the assumption that wheelchair appearance may influence participants' responses.

2.3 Span the Semantic Spaces

The second stage involves three steps: collecting descriptive words for the domain, selecting those with the greatest impact on user perceptions, and choosing kansei words (KWs) aligned with strategic goals (Marco-Almagro et al., 2014). Words are gathered from sources such as literature, media, and user feedback, then categorized and refined to represent key terms. Accordingly, we collected a range of descriptive KWs relevant to WDCs, based on a review of academic papers (n=48) and grey literature (videos: n=6; news agencies: n=10; blog posts and virtual discussions) focused on wheelchair experiences. The selected KWs emphasize aspects influencing the socio-emotional responses of WUs.

2.4 Span the Properties Spaces

This stage entails gathering, categorizing, and selecting key product properties. A wide range of potential properties is collected and organized by importance, with the most significant chosen as representative of the product (Koleini Mamaghani et al., 2014; Marco-Almagro et al., 2014). We identified the visual features of wheelchairs that shape WDCs by applying the Criticism of Interface Aesthetics (CIA) concept (Bertelsen & Pold, 2004), traditionally used in HCI, to understand wheelchair visual perception. The first CIA step, Stylistic References, widely applied in graphic and industrial design (Faraji & Valajoozi, 2014; Rasouli Valajoozi & Zangi, 2016), offers aesthetic insights into wheelchairs, focusing on form, proportion, complexity, distinctiveness, and design relevance. To ensure usability in subsequent analyses, we minimized property variations by collecting all components of powered and manual wheelchairs, then selecting the most influential. Each element was analyzed and, if necessary, divided into secondary components. We then created new shapes by rearranging these elements and evaluated the final configurations, identifying the most influential wheelchair properties.

2.5 Analysis

This stage connects emotional and physical features by establishing relationships between them and identifying relevant product attributes for each KW or group. Data was gathered through a questionnaire administered via Qualtrics. Participants received a brief introduction to the project, instructions on completing the survey, and an explanation of the KE method. The questionnaire collected demographic data (age, gender), participants' challenging experiences in social communication (Yes/No), and their perspectives on the aesthetic and symbolic importance of wheelchair design, rated on a Likert scale from 1 ('not important at all') to 5 ('very important').

In the next section, the four selected wheelchairs were presented for evaluation, accompanied by high-quality 3D perspective images to clearly display the WDCs. Participants rated the wheelchairs using KW descriptors on a 1–5 scale and provided initial feedback on each sample. The collected data was organized in Excel and further analyzed using SPSS 29 (Statistical Package for Social Sciences) for advanced statistical computations. To mitigate potential cultural differences and ensure consistency, native scholars carefully translated the concept of each KW into Persian. This received ethical approval from the Human Research Ethics Committee (Certification Number: 30020132). The analysis followed three main steps:

Step 1: Descriptive statistics were used to report demographic data (age and gender) and the perceived aesthetic and symbolic importance of wheelchair design. Chi-square tests were then conducted to examine relationships between demographic factors, the perceived importance of aesthetics and symbolism, and the social communication challenges faced by WUs. This analysis aimed to assess whether aesthetics and symbolism, as represented by KWs, influence WUs' social communication, thus helping to confirm or reject H1. Additionally, the test evaluated whether age and gender affected perceptions of aesthetic and symbolic value in wheelchair design. In the Chi-square test, a small p-value ($p<0.05$) indicates a significant association, while a larger p-value suggests the observed relationship may be due to chance (Brace et al., 2007).

Step 2: Descriptive analysis was used to identify the most important KWs across different WDCs, determining which of the four wheelchairs, each with unique design features, should proceed to the next step—identifying key principles influencing WDC representation. Principal Component Analysis (PCA) was then applied for factor extraction, a method that reduces datasets with multiple variables into core factors, or principal components (Bartholomew, 2010). PCA groups related KWs and attributes into components, highlighting the emotional or sensory dimensions that most influence user preferences. This test addresses H2 by exploring different patterns and priorities in wheelchair perception. By identifying principal components, designers can optimize product features to align with these key dimensions. Data suitability was verified through the Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, with a KMO value near 1 indicating adequacy and Bartlett's Test of Sphericity ($p<0.05$) confirming that the correlation matrix significantly differs from an identity matrix[6] (Brace et al., 2007). Eigenvalues greater than 0.8 were used to capture substantial variance, and KWs with factor loadings above 0.600 were considered significant for principal components. PCA results, using varimax rotation, enhanced interpretability by maximizing variance and identifying variables with high loadings on specific components. Each component is marked with a 'C' in this study (e.g., C1 for the first component). In the next stage, the highest loadings from PCA will be linked to refined wheelchair properties from the properties space stage.

2.6 Synthesis

Designers often develop an intuitive sense of the relationship between user impressions and product traits through experience with target groups, yet this latent knowledge can be challenging to articulate and communicate (Schütte et al., 2004). To bridge this gap, Quality Function Deployment (QFD) was chosen over other methods, such as crosstab analysis and linear regression. QFD, particularly its House of Quality matrix, links customer needs to design metrics, making implicit knowledge more explicit and actionable (Ginting et al., 2020; Schütte et al., 2004). This matrix connects user needs to design specifications, translating their requirements into product design criteria (Soares, 2021). In our study, the QFD process follows these steps:

1) Customer Requirements (WHATs): Representing WUs' socio-emotional needs, derived from the voice of the customer. Principal components and corresponding KWs from the previous stage are incorporated here to reflect priority needs.
2) Technical Requirements (HOWs): The physical properties or design attributes that address WUs' needs. Wheelchair properties identified in the *properties space* stage are listed here.
3) Relationship Matrix: This matrix links customer requirements (WHATs) to technical requirements (HOWs), indicating relationship strength: 1=weak, 3=moderate, and 9=strong. The scoring was conducted by the authors and two external experts in ergonomics and physiotherapy through three group discussions, continuing until consensus was achieved.
4) Importance Weights: Each customer requirement is assigned a weight to reflect its importance. Weights were determined based on the loadings of each principal component, with C1 weighted at 5, C2 at 4, C3 at 3, and remaining components at 1.
5) Correlation Matrix: Located at the top of the House of Quality (HoQ), this matrix shows how product properties interact, indicating positive (+) or negative (−) correlations, or no relationship (0), thereby highlighting synergies or conflicts. (See Appendix L for details.)
6) Technical Importance (TI): The TI of each property is calculated using a weighted sum formula that combines relationship scores between customer needs and product properties with the importance weights of those needs (see Appendix M). TI values are calculated as follows, where TI_j represents the technical importance of the j^{th} requirement; R_{ij} is the

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[6] An identity correlation matrix indicates that the variables are unrelated, making them unsuitable for factor analysis.

relationship strength between the i^{th} customer need and the j^{th} requirement (1=weak, 3=moderate, 9=strong); W_i is the importance weight of the i^{th} customer need, typically derived from customer surveys or other research; and n is the total number of customer needs.

$$TI_j = \sum_{i=1}^{n} R_{ij} \times W_i$$

7) Priorities: Design priorities were established by calculating the TI percentage, where $Importance\ \%_j$ represents the importance percentage of the j^{th} technical requirement. TI_j is the technical importance of the j^{th} requirement (calculated from the weighted sum), TI_k represents the technical importance of the k^{th} requirement, and m is the total number of technical requirements.

$$Importance\ \%_j = \left(\frac{TI_j}{\sum_{k=1}^{m} TI_k}\right) \times 100$$

8) Target Values and Competitive Analysis: In QFD, target values establish technical goals, while competitive analysis benchmarks wheelchair performance against competitors to identify areas for improvement. These sections are beyond the scope of this study.

3 Results

3.1 Semantic and Properties Spaces

After selecting domains and wheelchair samples, we categorized the wheelchairs into four WDCs: Conventional Manual Wheelchair (CMW), Advanced Manual Wheelchair (AMW), Conventional Powered Wheelchair (CPW), and Advanced Powered Wheelchair (APW). These categories were consistently used throughout the study. For KW collection (Semantic Spaces), 138 words were initially nominated. After removing synonyms and similar terms, the list was refined to 52, which were then clustered into 18 groups. From each group, one representative word was selected, resulting in 11 Kansei candidates (Table 23) that capture the socio-emotional perception of WDCs. Brief explanations and descriptive word pairs were provided for each KW to ensure clarity for participants. For wheelchair properties, 18 properties with 38 features were initially identified; after refinement, this was reduced to 11 properties with 29 features (Table 24).

Table 23. KWs used in the study.

KWs	Explanation	Word pairs
Dignity	Self-respect, Honor	Valued/Stigmatized
Trustworthiness	Reliability, Integrity	Trustworthy/Unreliable
Independence	Autonomy, Self-sufficiency, Freedom	Independent/Dependent
Affirmation	Social validation	Accepted/Rejected
Stylish	Elegant, Sleek, Chic, Clean	Stylish/Plain
Stability	Balanced, Firm, Solid, Symmetric	Stable/Unstable

KWs	Explanation	Word pairs
Safety	Protective, Secure, Reliable	Safe/Risky
Comfort	Cozy, Soft, Soothing, Pleasant	Comfortable/Uncomfortable
Agility	Versatile, Flexible	Agile/Inflexible
Communicative	Expressive, Interactive, Engaging	Communicative/non-communicative
Futuristic	High-tech, Innovative	Futuristic/Outdated

Table 24. The wheelchair main properties.

Properties	Features	Properties	Features
Material	Charon fiber	Backrest	Contoured
	Plastic		Adjustable
	Metal		Fixed
Frame design	Adjustable	Armrest	Adjustable
	Rigid		Fixed
	Folding	Footrest	Adjustable
Color	Polychromatic		Fixed
	Biochromatic	Weight	Heavy
	Monochromatic		Standard
Wheel proportion	Large		Light weight
	Medium	Dimension	Large
	Small		Standard
Propulsion	Manual		Small
	Powered		
Seat cushion	Firm		
	Soft		

3.2 Questionnaire Results

Among those who agreed to participate, 41 individuals completed the survey. Four cases with unrelated or outlier data were removed, and eight responses were corrected with participant confirmation, resulting in 37 cases (Canada=16, Iran=21) included in the final analysis (age range: 32–89; gender: 11 males, 26 females; years of wheelchair use: 1–50).

Step 1: In the descriptive analysis, 57% of participants reported challenges in social communication, while 43% did not, indicating that over half faced such difficulties. Regarding aesthetic and symbolic importance (rated moderately to very important), 76% of participants valued aesthetics, and 56% valued symbolism (see Figure 42 for details). This suggests that while aesthetics is prioritized over symbolism by most participants, both factors are important to WUs.

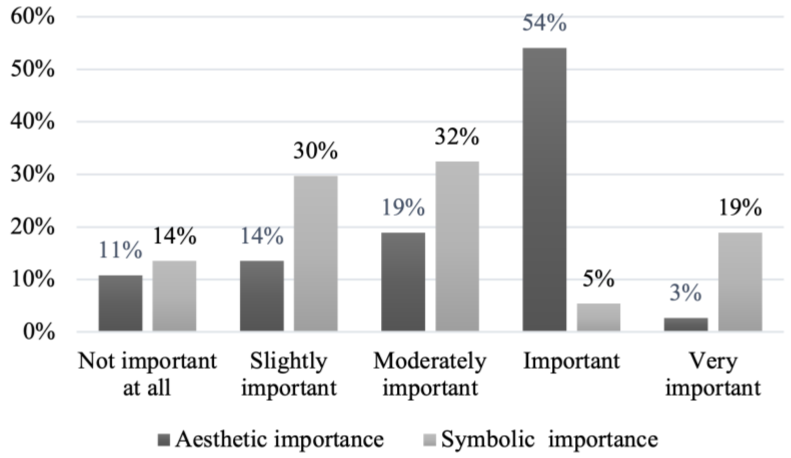

Figure 42. The distribution of Aesthetic and Symbolic importance among WUs.

In the inferential analysis, the Chi-square test revealed a significant association between social communication challenges and age (p=0.042); however, this relationship is non-linear, as communication challenges vary across age groups in a non-linear pattern. No significant relationship was found between gender and communication challenges (p>0.05), indicating that males and females experience similar levels of social communication difficulties. A significant association was also found between social communication challenges and both aesthetic (p=0.033) and symbolic importance (p=0.001) in wheelchair design (Table 25). The Linear-by-Linear Association (p=0.002) indicates that participants facing greater communication challenges place higher importance on the symbolic aspects of wheelchair design. While a significant association exists between communication challenges and aesthetic importance, this relationship is also non-linear (p>0.05). This suggests that WUs' communication challenges may partly stem from social representation, as reflected in wheelchair appearance, though the relationship is complex. In all significant associations, Cramer's V test confirmed the strength of these relationships, supporting H1—that the aesthetic and symbolic aspects of wheelchair design influence WUs' social communication.

Table 25. The Chi-square and Cramer's V result, showing the relationship between social communication challenges with Age, Gender, Aesthetic and Symbolic importance (*N*=37).

	Chi-square			**Cramer's V**	
	Value (df)	Sig (2-sided)	Linear-by-Linear Association (df)	Value	Sig (2-sided)
Age	29.530[a] (18)	0.042	0.213 (1)	0.893	0.042
Gender	0.187[b] (1)	0.666	0.670 (1)	0.071	0.666
Aesthetics importance	10.458[c] (4)	0.033	0.236 (1)	0.532	0.236
Symbolic importance	18.060[d] (4)	0.001	0.002 (1)	0.699	0.001

a. 38 cells (100.0%) have expected count less than 5. The minimum expected count is .43. b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.62. c. 8 cells (80.0%) have expected count less than 5. The minimum expected count is .43. b. 7 cells (70.0%) have expected count less than 5. d. 7 cells (70.0%) have expected count less than 5. The minimum expected count is .86.

The investigation examined the relationship between age and gender with the aesthetic and symbolic aspects of wheelchairs, yielding several key findings (Table 26). A significant association exists between age and aesthetic importance (p=0.008), with a positive linear relationship (p=0.037), suggesting that perceptions of aesthetic importance change predictably with age. Additionally, while age is significantly associated with symbolic aspects (p=0.005), the lack of a linear trend (p>0.05) indicates diverse prioritization of symbolic importance across age groups. Gender is also significantly associated with aesthetic importance (p=0.014); females exhibited a broader range of aesthetic importance ratings than males (p=0.003). This points to gender-related differences in aesthetic preferences, which could inform the design process. Cramer's V test confirms the strength of these significant relationships. No significant association was found between gender and symbolic importance (p>0.05), suggesting that both genders share similar views on the symbolic meaning of wheelchairs.

Table 26. Chi-square test showing the relationship between demographic data (age and gender), and Aesthetic and symbolic importance of wheelchair design (*N*=37).

	Chi-square			**Cramer's V**	
	Value (df)	Sig (2-sided)	Linear-by-Linear Association (df)	Value	Sig (2-sided)
Age & Aesthetic importance	104.085 [a] (72)	0.008	0.037 (1)	0.839	0.008
Age & Symbolic importance	107.040 [b] (72)	0.005	0.108 (1)	0.850	0.005
Gender & Aesthetic importance	12.428 [c] (4)	0.014	0.003 (1)	0.580	0.014
Gender & Symbolic importance	3.231 [d] (4)	0.520	0.538 (1)	0.296	0.520

a. 95 cells (100.0%) have expected count less than 5. The minimum expected count is .03. b. 95 cells (100.0%) have expected count less than 5. The minimum expected count is .05. c. 8 cells (80.0%) have expected count less than 5. The minimum expected count is .35. d. 8 cells (80.0%) have expected count less than 5. The minimum expected count is .70.

Step 2: In the second part of the questionnaire, descriptive KWs were used to assess perceptions of WDCs. Figure 43 shows that APW scores (Mean (m) of each KW) consistently rank highest across all KWs, with Independence (m=4.70) as the most preferred attribute overall. In contrast, CMW scores lowest in all KWs, with its highest rating in Trustworthiness (m=2.57). The AMW and CPW scores fall between these extremes, with both rated higher than CMW but lower than APW. In six categories—Dignity, Affirmation, Futuristic, Communicative, Agility, and Stylishness—AMW outperforms CPW, whereas in five others—Independence, Trustworthiness, Stability, Safety, and Comfort—CPW scores higher than AMW. In two categories of AMW and APW, Agility and Stylishness scores are relatively close (AMW: m=4.08 vs. APW: m=4.14 in Agility; AMW: m=4.19 vs. APW: m=4.35 in Stylishness). A notable observation is the near-symmetrical pattern of AMW and APW scores along a horizontal axis, suggesting that while advanced wheelchair designs differ in perceptions of factors like Independence and Comfort, they are similarly perceived in terms of Agility and Style. Conversely, the similar pattern between CMW and CPW, despite different levels, indicates that the wheelchair type—manual or powered—does not notably impact perceptions of conventional WDCs.

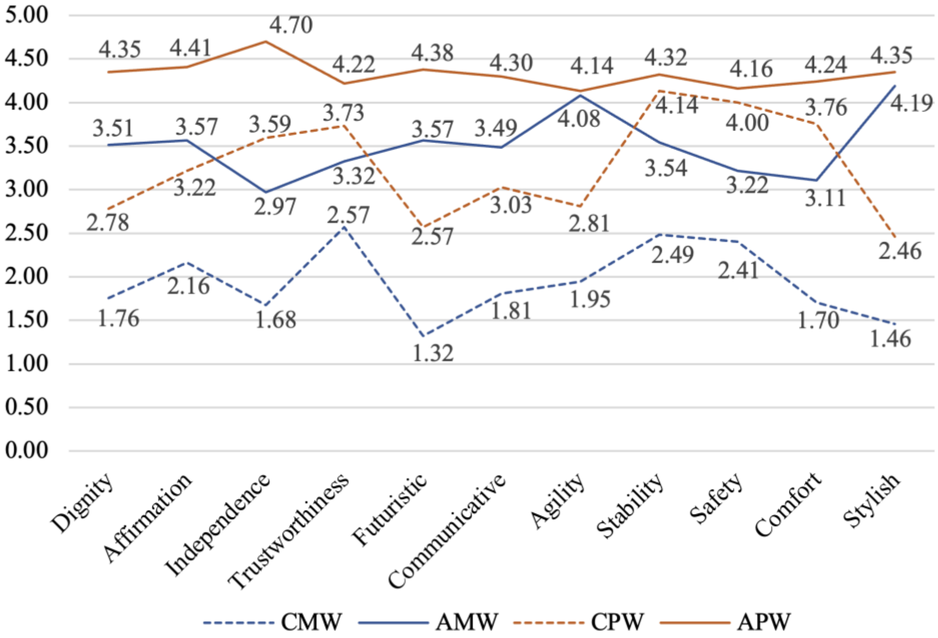

Figure 43. Scorelines of four WDCs based on the KWs.

Descriptive results show that AMW and APW received the highest scores within their respective manual and powered categories, leading to their selection for factor analysis to simplify the data and reveal connections between descriptive terms. KMO values of 0.827 for AMW and 0.744 for APW indicate suitability for PCA, and Bartlett's Test of Sphericity ($p<0.001$) confirms that variable correlations justify factor analysis in both categories. The PCA results display the total variance explained by the components for AMW and APW (Table 27). The left side shows initial Eigenvalues, with total variance, percentage of variance, and cumulative percentage before extraction and rotation. The middle section, 'Extraction Sums of Squared Loadings,' reflects variance explained after extraction, matching the initial Eigenvalue percentages. The right side, 'Rotation Sums of Squared Loadings,' shows variance after rotation, simplifying component interpretation.

Typically, principal components are selected with a variance above one; however, by adjusting the threshold to an Eigenvalue of 0.9, three components with Eigenvalues above 0.9 were identified for both AMW and APW. This adjustment captures more variability and highlights subtle distinctions. Accordingly, the first three components were selected—AMW: C1=5.839, C2=1.154, C3=1.035; APW: C1=5.706, C2=1.411, C3=0.917. The cumulative variance for AMW (72.98%) and APW (73.03%) shows that these three components account for a significant portion of dataset variability, making them crucial for analysis. To identify the KWs with the highest loadings, the Rotated Component Matrix displays each word attribute's loadings on the selected components for both AMW and APW (Table 28).

Table 27. Total variance explained for AMW (above) and APW (below).

Total Variance Explained-AMW

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	5.839	53.082	53.082	**5.839**	**53.082**	53.082	3.021	27.464	27.464
2	1.154	10.494	63.575	**1.154**	**10.494**	63.575	2.615	23.770	51.234
3	1.035	9.412	72.988	**1.035**	**9.412**	72.988	2.393	21.754	72.988
4	.740	6.723	79.710						
5	.569	5.175	84.885						
6	.488	4.441	89.326						
7	.365	3.319	92.645						
8	.315	2.863	95.508						
9	.200	1.819	97.327						
10	.165	1.499	98.825						
11	.129	1.175	100.000						
Total Variance Explained-APW									
1	5.706	51.869	51.869	**5.706**	**51.869**	51.869	4.026	36.598	36.598
2	1.411	12.826	64.695	**1.411**	**12.826**	64.695	2.140	19.455	56.054
3	.917	8.338	73.033	**.917**	**8.338**	73.033	1.868	16.979	73.033
4	.856	7.786	80.819						
5	.815	7.414	88.232						
6	.498	4.530	92.762						
7	.336	3.053	95.816						
8	.198	1.802	97.618						
9	.140	1.272	98.889						
10	.079	.717	99.607						
11	.043	.393	100.000						

Extraction Method: Principal Component Analysis.

Table 28. Rotated Component Matrix for both AMW (left) and APW (right).

Variables	AMW: Rotated Component Matrix[a]:			APW: Rotated Component Matrix[b]		
	C1	C2	C3	C1	C2	C3
Dignity	.024	.194	**.879**	-.156	**.763**	.248
Affirmation	.503	.177	**.666**	.151	.457	.403
Independence	.421	.376	.583	**.896**	.193	.084
Trustworthiness	.580	.085	**.658**	**.742**	.584	-.001
Futuristic	**.677**	.454	.144	**.892**	.140	.212
Communicative	.588	**.676**	.142	**.715**	-.020	.489
Agility	.293	**.702**	.006	.171	.192	**.783**
Stability	**.714**	.313	.289	.435	.492	.466

Variables	AMW: Rotated Component Matrix[a]:			APW: Rotated Component Matrix[b]		
	C1	C2	C3	C1	C2	C3
Safety	**.907**	.126	.178	.392	**.785**	.003
Comfort	.090	**.820**	.274	**.715**	.011	.433
Stylish	.147	**.675**	.418	**.660**	.235	.579

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 8 iterations. b. Rotation converged in 10 iterations.

The Rotated Component Matrix in Table 28 presents the principal components for AMW and APW as follows:

AMW:

- C1: High loadings for Safety (0.907), Stability (0.714), and Futuristic (0.677), with Trustworthiness, Affirmation, and Communicative contributing to lesser extent.
- C2: Significant loadings for Comfort (0.802), Agility (0.702), Communicative (0.676), and Stylish (0.675).
- C3: Dominated by Dignity (0.879), with moderate contributions from Affirmation (0.666) and Trustworthiness (0.658), and lesser input from Independence.

APW:

- C1: Strong associations with Independence (0.891), Futuristic (0.892), Trustworthiness (0.742), Communicative (0.715), Comfort (0.715), and Stylish (0.660).
- C2: High loadings for Safety (0.785) and Dignity (0.763), with Trustworthiness contributing less significantly.
- C3: Dominated by Agility (0.783), with a minor contribution from Stylish.

The PCA and descriptive analysis support H2, confirming that WDCs are prioritized differently across manual and powered wheelchairs with distinct design styles. Each component in the AMW and APW categories was named accordingly (Figure 44), with the rationale for these names provided in the discussion section.

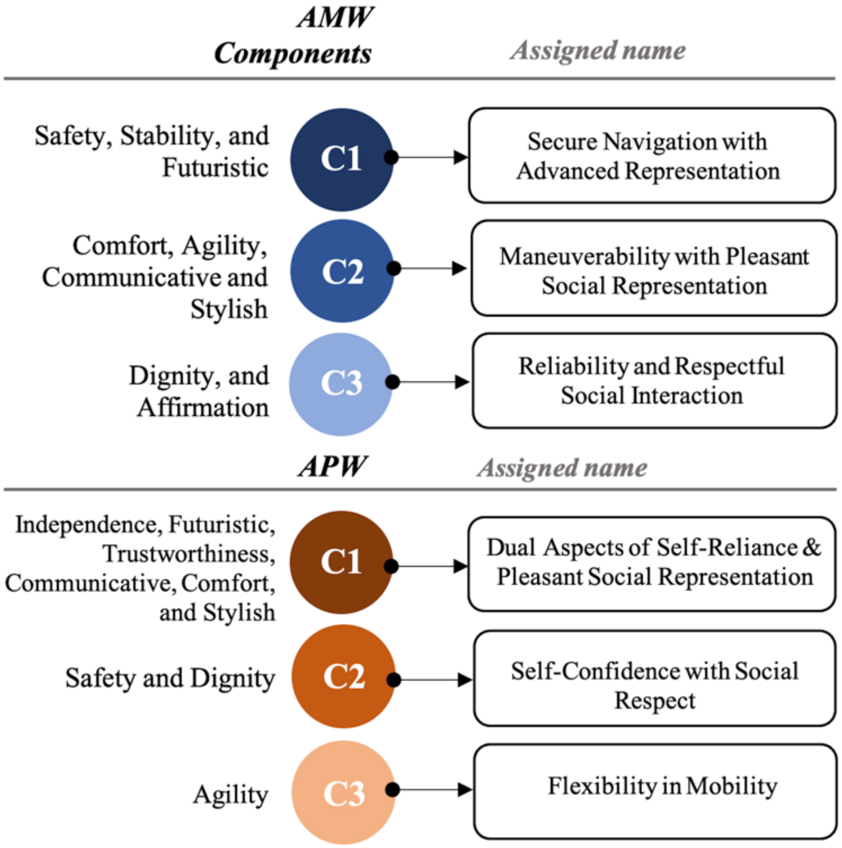

Figure 44. The assigned name for each principal components in each category of AMW and APW. © Image by Author.

3.3 Synthesis: Connecting the Semantic Space to Wheelchair Properties

Initially, wheelchair properties were entered into the Technical Requirements (HOWs) section at the top of the QFD table, and the Correlation Matrix was populated with positive (+), negative (−), and neutral (0) correlations. Next, KWs were added to the Customer Requirements (WHATs), with Importance Weights assigned based on their respective C levels. The Relationship Matrix was then developed, followed by calculating the technical importance of each property and its percentage (Figure 45).

The initial QFD analysis results, shown in Figure 46, highlight the relative importance of various wheelchair properties for both AMW and APW models in shaping WDC. While propulsion type (AMW=2.14%, APW=9.96%) and wheel proportion (AMW=11%, APW=7.51%) vary due to the manual or powered nature of each model, the importance of other features remains relatively similar, with differences not exceeding 2%. Frame design holds the highest importance for both AMW and APW, followed by material, dimensions, and weight—all exceeding 10%—indicating their crucial role in defining WDC. For AMW, wheel proportion and backrest also surpass 10%, reflecting their significance in manual wheelchair design. Seat cushions, footrests, and armrests have the lowest importance in both models, likely because they are more closely tied to physical ergonomics than socio-emotional design factors and may require experiential rather than visual assessment.

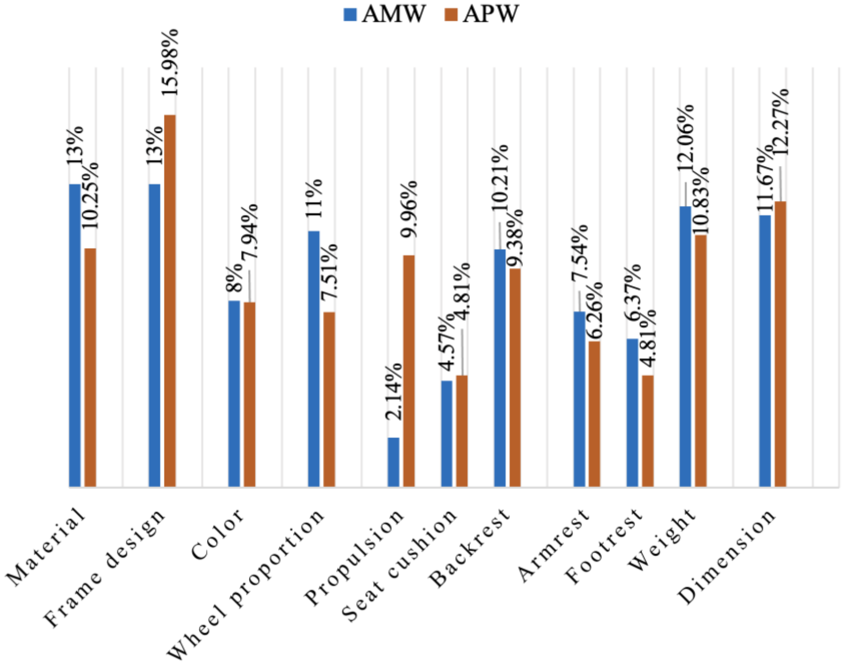

Figure 45. Technical importance of each technical properties.

Figure 46 illustrates the prioritization of wheelchair property sub-categories based on QFD results. While AMW and APW differ in their top three principal components, their technical requirements follow similar patterns, with notable exceptions in Dimensions, Weight, and Wheel Proportion. In APW, small dimensions rank second, while in AMW, they rank third. Standard weight is the top priority in AMW, whereas lightweight and standard weight are close competitors in APW. Additionally, AMW favors large wheels, while APW prioritizes medium-sized wheels. Notably, powered propulsion is more prominent in APW (9.96%) compared to AMW (2.14%), highlighting its role in enhancing the socio-emotional aspects of powered wheelchair design.

In both models, factors such as carbon fiber material, adjustable frame design, soft seat cushions, and adjustable backrests, armrests, and footrests follow similar priority patterns, especially among the top three priorities. For AMW, the top priorities include adjustable frame design (8.61%), standard dimensions (8.32%), carbon fiber material (8.12%), standard weight (7.44%), adjustable backrests (6.57%), large wheels (6.66%), and adjustable armrests (6.18%). For APW, adjustable frame design ranks highest (10.44%), followed by standard dimensions (7.22%), carbon fiber material (6.50%), adjustable backrests (5.77%), adjustable armrests (5.29%), and lightweight construction (5.29%).

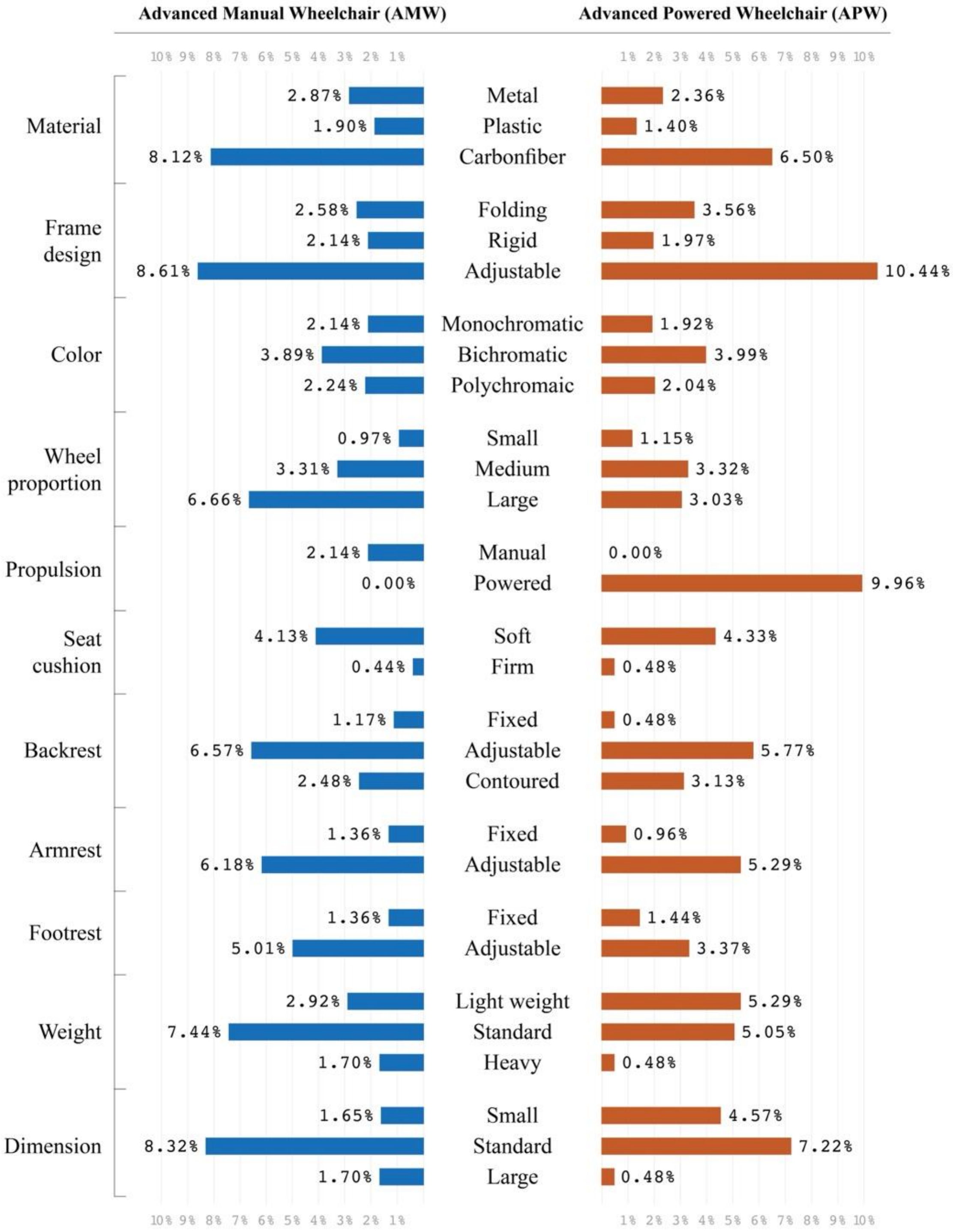

Figure 46. Technical importance of each sub-categories of technical properties for considering the priorities in developing AMW and APW. © Image by Author.

In the concluding analysis of the results, we summarize the key lessons learned from the study. Table 29 highlights the main findings at each stage, aiding in the identification of the most prominent aspects for discussion.

Table 29. Summary of the key lessons from the study.

Steps	Summary of lessons
Step 1: Descriptive and inferential analysis	• Most WUs experience social communication challenges. • Aesthetic and symbolic importance are significant factors for WUs. • Social communication challenges are significantly associated with age. • Social communication challenges are significantly associated with aesthetic and symbolic importance in wheelchair design. • Greater communication challenges increase the importance of symbolic wheelchair design. • Age is significantly associated with aesthetic importance, showing a positive linear relationship. • Gender significantly influences aesthetic importance, with females showing a broader range of ratings and males rating aesthetics higher overall. • Gender is significantly associated with aesthetic importance, with females showing a wider range of ratings than males. • No significant association was found between gender and symbolic importance, indicating both genders share similar views on wheelchair symbolism.
Step 2: Descriptive and PCA test	• In the descriptive words, APW scores rank highest, while CMW scores rank lowest across all KWs. • AMW and APW scorelines showed a near-symmetrical pattern, indicating that while perceptions of Independence and Comfort vary, Agility and Style are similarly perceived in both advanced wheelchair designs. • The similar Scorelines pattern between CMW and CPW suggests that wheelchair type (manual or powered) does not significantly affect perceptions of conventional WDCs. • Descriptive results show AMW and APW received the highest scores in their categories, leading to their selection for factor analysis, which identified key connections between descriptive terms. • The Rotated Component Matrix reveals the three main components for AMW and APW, highlighting the most influential factors.

Steps	Summary of lessons
Synthesis: QFD analysis	• QFD results show that while propulsion type and wheel proportion vary, the importance of other features is similar, with differences under 2%. • QFD results show frame design is most important for both AMW and APW, followed by material, dimensions, and weight, highlighting their role in WDC. • Seat cushions, footrests, and armrests rank lowest, as they focus on physical ergonomics and require experiential assessment. • AMW and APW differ in top three components, but their technical requirements align, except in dimensions, weight, and wheel proportion. • Powered propulsion is more prominent in APW, enhancing its socio-emotional design aspects. • AMW priorities: adjustable frame, standard dimensions, carbon fiber, standard weight, adjustable backrests, large wheels, and adjustable armrests. • APW priorities: adjustable frame, standard dimensions, carbon fiber, adjustable backrests, adjustable armrests (5.29%), and lightweight construction (5.29%).

4 Discussion

The study revealed that the majority of participants considered the aesthetic and symbolic aspects of wheelchairs important, with both factors significantly linked to WUs' experience of social communication challenges. This finding suggests that aesthetically pleasing and symbolically meaningful wheelchair designs can positively influence public perception and social acceptance, reducing stigma and fostering better interactions for WUs (McLaughlin et al., 2004). Consequently, WUs who view their mobility aids as lacking in these aspects may face increased social barriers and communication challenges. Previous studies confirm that assistive technology often serves as a marker of disability; while non-users see it as enabling, users note it can also attract stigma (Barbareschi et al., 2021). Stigmatizing beliefs stem from various personal and societal factors (Masanja et al., 2020; Wickenden et al., 2020, 2020), yet our study emphasizes the impact of WDCs on users' social communication challenges. Results also showed that age is associated with experiencing social communication challenges, though gender is not, possibly due to the increased communication difficulties that often accompany physical disability with age (Yorkston et al., 2010), a finding supported by the broad age range (32–89) of participants involved in this study. Other factors, such as ageism—discrimination against older individuals based on negative stereotypes—may also play a role in social communication challenges among older participants (Donizzetti, 2019; Weir, 2023).

Further analysis in this study found significant relationships between age, gender, and the perceived importance of aesthetics, possibly due to generational preferences and attitudes toward design aesthetics (Urbano et al., 2022). Although this study did not assess different functional or aesthetic styles, prior research cautions against the assumption that aesthetics must be sacrificed for function in designs for older adults (Office for Product Safety & Standards, 2021). Future studies should examine preferred design aesthetics more closely. Gender was significantly associated with aesthetic importance, with females showing a broader range of ratings compared to males, who consistently rated aesthetics higher. This aligns with previous studies, which also highlighted the concepts of masculine and feminine in the aesthetic design of wheelchairs (Lokman et al., 2017). This importance of aesthetic may reflect women's focus on visual appeal and non-functional forms, while men generally prefer geometric designs, affecting both groups' preferences for refined wheelchair aesthetics (Xue & Yen, 2007). Additionally, studies indicate greater brain activity in females than males when perceiving beauty (Sample, 2009). However, aesthetic considerations should be approached cautiously, as research suggests women may be less receptive to novel designs if aesthetics compromise stability.

No significant association was found between gender and the symbolic importance of wheelchairs, suggesting that both males and females hold similar views on their symbolic meaning. This may be attributed to the universal importance of symbolism in mobility aids, where personal identity and social acceptance transcend gender. However, this finding contrasts with studies showing that men generally have more positive perceptions of their wheelchairs' practical and symbolic functions than women (Lanutti et al., 2015). This discrepancy may stem from the diverse cultural contexts of our participant groups, potentially influencing gender's role in symbolic importance. Future research should further investigate these discrepancies.

4.1 The Preferred WDCs

In the analysis of WDCs, KWs were used to describe the four categories, with results showing that APW and AMW had the highest scores. While previous studies suggest that WUs' emotional responses vary based on factors such as emotion, disability type and intensity, and gender (Mokdad et al., 2018), this analysis demonstrates that WDCs prioritizing both aesthetics and functionality influence WUs' preferences. The near-symmetrical pattern between AMW and APW scores—along a hypothetical horizontal line—indicates that advanced WDCs differ in perceived value depending on the mode of operation. Specifically, notable differences appeared in Independence and Comfort, where scores diverged, while scores in Agility and Stylishness were closely aligned. This may be because Independence and Comfort are more affected by the mode (manual vs. powered), whereas Agility and Stylishness depend more on aesthetic design features common to both types. In contrast, the similar patterns between CMW and CPW, with parallel but lower scorelines, suggest that manual and powered conventional wheelchairs are perceived similarly, with CPW preferred for its enhanced comfort in propulsion. When aesthetic considerations are less prominent, functionality becomes the primary factor.

The preference for AMW over CPW, with higher scores in six KWs—especially in Agility—suggests that aesthetic aspects continue to impact WUs' perceptions, enhancing their appreciation for advanced features. This aligns with previous research indicating that aesthetics is not only important for WUs (Lanutti et al., 2015), but can influence users' judgments about functionality (Crolic et al., 2019).

PCA analysis identified three components for both AMW and APW, with the most influential KWs grouped by their highest loadings. These components highlight key socio-emotional factors in wheelchair design, each assigned a name to reflect broader design criteria, with justification provided.

In AMW, C1 groups Safety (implying user's assurance of protection), Stability (referring to consistent support and reliability during movement), and Futuristic (suggesting innovative design enhances user experience). Accordingly, this component is named 'Secure Navigation with Advanced Representation.' In C2, Comfort (conveying physical ease), Agility (emphasizes smooth navigation), Communicative (referring to effective social interaction), and Stylish (concerning aesthetic appeal in social settings) are highlighted, leading to the name 'Maneuverability with Pleasant Social Representation.' In C3, Dignity (implying recognition of worth and respect) and Affirmation (conveying validation and support fostering belonging) are emphasized, resulting in the name 'Reliability and Respectful Social Interaction.'

In APW, C1 includes Independence and Comfort (focusing on self-reliance and ease), Trustworthiness and Communication (emphasizing social acceptance and connection), and Futuristic and Stylish (highlighting the importance of societal representation). Accordingly, this component is named 'Dual Aspects of Self-Reliance and Pleasant Social Representation.' In C2, Safety (representing user's assurance of protection), Dignity (highlighting recognition of worth and respect), empowering users to feel valued and respected. With these in mind, the phrase 'Self-Confidence with Social Respect' is chosen for this component. In C3, Agility reflects smooth navigation, enabling quick adjustments, ease of movement in various environments. This component is named 'Flexibility in Mobility.'

Previous studies have suggested evaluating the final design to link psychological aspects with technical elements in four areas—sensational, physical, aesthetic, and operational (Ismail et al., 2014). However, they have not introduced principal components derived from statistical analysis (Lokman et al., 2017), which scale the prioritized factors with loadings and guide designers through interpreted names. This study assigns proper names to these components, contributing new knowledge to the literature on using KE in assistive devices.

4.2 Design Considerations on Wheelchair Properties

QFD analysis revealed that while AMW and APW share similar technical requirements, some aspects, such as dimensions, weight, and wheel proportion, require distinct considerations. The analysis identified frame design as the most critical factor for both AMW and APW in terms of socio-emotional perception. This is likely due to the adjustable frame's significant influence on both aesthetic appeal and functional comfort, making it central to users' emotional and practical experiences. However, adjustability should be supported by other key requirements: standard dimensions, carbon fiber material, and standard weight for AMW, or lightweight construction for APW. Additionally, large wheel proportions for AMW, medium for APW, biochromatic color schemes, and adjustable backrest, footrest, armrest, and soft seat cushions are recommended to meet functional and socio-emotional needs. These considerations lay the foundation for developing wheelchairs that effectively address socio-emotional aspects. The factors identified in this study can be incorporated through various design styles and structures. For example, an adjustable frame design or backrest can be approached from either a minimalist, modern, and futuristic aesthetic or a structuralist aesthetic. While both approaches address adjustability and other technical requirements, they may influence WUs' perceptions in distinct ways. Thus, new wheelchair development must also consider broader social factors, including cultural interpretations, metaphors, stereotypes, and the discourse surrounding disability.

5 Conclusion

This study highlights that social communication challenges among WUs are a significant aspect of wheelchair use, closely linked to representational qualities like aesthetics and symbolism. In refining the socio-emotional design of wheelchairs, especially regarding aesthetic and symbolic attributes, this study demonstrates that WUs perceive and prioritize different WDCs uniquely, showing a strong preference for advanced design features over conventional ones. The analysis of Kansei word arrangements revealed distinct principal components for both AMW and APW, providing valuable insights into the descriptive factors shaping WUs' perceptions. Each component was assigned a name reflecting key characteristics that align with WUs' desired wheelchair designs, directing designers to factor in socio-emotional considerations during development. Additionally, computational analysis linking these insights with wheelchair properties through QFD identified frame design as the most critical factor in addressing socio-emotional perceptions for both manual and powered wheelchairs, though it must align with other type-specific technical requirements. These findings offer valuable insights for designers and engineers, enhancing ergonomic and functional considerations in developing next-generation wheelchairs that leverage new technologies. Finally, while addressing these technical and design considerations is an essential step toward creating wheelchairs that better meet WUs' socio-emotional needs, it is equally vital to consider broader social factors. These include societal interpretations, wheelchair-related metaphors, prevailing stereotypes, and the discourse surrounding disability. Future studies should expand on these aspects, incorporating cultural and social dimensions alongside technical innovations, to ensure more inclusive and adaptive wheelchair designs.

5.1 Limitations and Future Studies

This study faced several limitations. First, while we addressed the socio-emotional needs of WUs, broader socio-cultural factors influencing participants' perceptions were not considered. Addressing this gap requires collaborative, interdisciplinary research to examine how these contextual factors shape the interpretation and perception of wheelchairs. Additionally, technical requirements were limited to objective criteria (e.g., adjustability, monochromatic or biochromatic color schemes), focusing on essential technical needs to enhance socio-emotional experiences. Further aesthetic elements (e.g., wider color spectrum and style options) could be explored, requiring broader designer collaboration, which was beyond this study's scope. Future research should address these limitations to deepen insights into optimizing WDCs for socio-emotional factors. Building on this study, future research could systematically identify common socio-emotional challenges faced by mobility aid users and develop a conceptual framework to improve their societal experiences.

Chapter IV. Summary & Discussion

This section is based on a review and discussion of the three studies in Ch. IV, for answering the question 4 (Q4).

1 Introduction

Ch. III explored the influential factors shaping the socio-emotional perceptions and interactions of wheelchair users (WUs). While several contextual and socially supportive aspects were identified as impactful, this chapter highlighted the representational and aesthetic qualities of wheelchairs as critical mediators. These representational and aesthetic qualities, supported in our introduced interdisciplinary theoretical framework in Ch. II, not only convey the physical abilities of their users but also influence their social interactions. Specifically, the findings from the third study (Ch. III, Section 3) demonstrated how WDCs can affect pedestrians' perceptions and stimulate social empathy and interactions with WUs. While several descriptive concepts were identified to capture how pedestrians perceive advanced WDCs as more acceptable and appreciated by users, these concepts were primarily limited to reflect the pedestrians' perspectives.

To fully address the socio-emotional needs of WUs that affect their interactions in public and urban social settings, it was also essential to recognize the preferred representational and aesthetic qualities from the standpoint of WUs. To this end, we conducted two studies. The first focused on identifying design characteristics of interfaces that enhance practical communication needs, particularly for safe navigation within the city through optimized eHMIs. The second explored which WDCs are most appreciated and the preferred descriptive concepts, providing a deeper understanding of WUs' preferences and needs in social interactions.

Integrating insights from these two studies helps address the fourth research question of this thesis: **What are the users' preferred factors in wheelchair design to enhance the social interactions of WUs?** Reviewing these studies that answer the fourth question of this thesis serves as the foundational prerequisites for the aesthetic and representational aspects of wheelchairs, aimed at improving and enriching the socio-emotional experiences of WUs and is the final step toward developing SEDPs, discussed in the next chapter.

1.1 Section 1: eHMI Requirements for Wheelchair

This study aimed to introduce an enhanced eHMI interface for powered wheelchairs to improve external communication, ensure safety, and foster positive social interactions in complex urban environments. The findings identified four key themes: (I) Streamlined Information in Interaction, (II) User-Centric Safety Feedback, (III) Harmonious and Minimalist Interaction Design, and (IV) Effortless Integration and Production. A corresponding of design suggestions and implications was developed, addressing the core design criteria of communication, safety, aesthetics, and feasibility.

These themes highlighted which and how visual factors could be applied to enhance wheelchair interfaces, acting as influential factors in improving the safety and social interactions of WUs.

Following brainstorming sessions, five interface concepts were proposed, with Concept 2: "WheelSafe Illumina" and Concept 1: "WheelGlow Assist" emerging as top priorities, both incorporating a shell structure. Concept 2 was then developed into a prototype and prepared for experimental testing by pedestrians and users. Results demonstrated that the proposed eHMI successfully enhances communication and safety without drawing undue attention, fostering a sense of security in pedestrians during interactions with WUs. This specifically highlighted that integrating a shell structure with the eHMI fosters a more supportive attitude toward WUs. Beyond enhancing safety and addressing the practical communication needs of WUs, this integration positively influences their emotional experience by reducing undue attention—an issue identified in previous studies. Furthermore, the proposed eHMI allows users to focus more on their path and surroundings, minimizing navigation-related distractions. This enables WUs to engage more effectively in eye contact and gesture-based interactions with pedestrians, as well as in negotiable situations, such as street crossings that require communication with drivers. In contrast, eHMIs relying on on-ground light projection face significant limitations. Such systems, as noted in prior studies, often lead to drawbacks including user distraction, confusion, and overreliance, which can undermine their intended functionality. By addressing these concerns, the newly introduced eHMI offers an alternative that better balances practical, emotional, and socio-interactional needs. This study specifically answers the research questions by revealing the preferred visual factors in wheelchair design for WUs, focusing on interface elements that enhance safety, communication, and emotional well-being, while also encouraging positive social interactions.

1.2 Section 2. Integrating Socio-Emotional Factors in Wheelchairs

In line with the aim of this chapter, this study applied Kansei Engineering to explore how socio-emotional factors can be integrated into the representational aspects of wheelchairs. Initially, the results revealed that both Aesthetic and Symbolic importance, along with age, were significantly associated with social communication challenges. Age was found to be significantly correlated with both Aesthetic and Symbolic importance, while gender was only linked to Aesthetic importance. These analyses highlighted the influence of Aesthetic and Symbolic factors on WUs' perceptions and priorities, which play a crucial role in their social communication.

Descriptive analysis based on semantic words also indicated that advanced manual and powered wheelchair designs received higher ratings than conventional ones. As a result, three key components were identified for each category, with the highest loadings of Kansei words (KW) in each. These components reflect WUs' perceptions of advanced and admired WDCs, which can be emphasized in future wheelchair designs to better meet their needs.

Accordingly, the principal components for the AMW were labeled as *C1: Secure Navigation with Advanced Representation, C2: Maneuverability with Pleasant Social Representation, and C3: Reliability and Respectful Social Interaction*. For the APW, the principal components were named:

C1: Dual Aspects of Self-Reliance & Pleasant Social Representation, *C2: Self-Confidence with Social Respect, and C3: Flexibility in Mobility.* These findings highlight the differences in WUs' perceptions when advanced WDCs are applied to powered versus manual wheelchairs. As a result, different priorities should be applied in developing WDCs for manual and powered models. The QFD results revealed that adjust frame design, ranked highest for both manual and powered models, is crucial for enhancing socio-emotional aspects. Other wheelchair properties were also identified, with specific priorities outlined for aligning with the preferred socio-emotional needs of WUs.

2 Conceptual Basis for Addressing Wheelchair External Communication

According to general insights from these two studies, while eHMIs and related considerations are essential for ensuring safe and effective navigation for WUs in urban environments, it is equally important to consider WUs' preferences when designing WDCs that impact their social interactions. As demonstrated in Ch. IV, Section 2, the findings indicated that aesthetic and symbolic aspects of design are significantly related to social communication challenges (Rasoulivalajoozi & Farhoudi, 2025b). Therefore, the development of eHMIs for wheelchair interfaces can be understood as the foundational layer in addressing discomfort, as discussed and highlighted in Ch. IV, Section 1, with a primary focus on safety and functional communication needs. Alongside this, the next step—a socio-emotional refinement—constitutes a critical complementary layer. Together, these two layers are essential for enhancing the overall socio-emotional experience of WUs. This aligns with the scoping review findings in Ch. I, Section 1, where *Autonomy and Control* was identified as a foundational theme for enhancing the socio-emotional experiences of WUs (Rasoulivalajoozi et al., 2025a). To this end, as long as the extracted themes reinforce core expectations and provide a sense of control, they serve as essential components of the framework. Similarly, ergonomic insights from Ch. I, Section 3, emphasize addressing physical and practical discomforts as a priority before targeting emotional well-being (de Looze et al., 2003). In line with this, the themes mainly focus on reducing discomfort by removing barriers to presence and mobility, thereby facilitating social participation in urban environments. Nevertheless, one might argue that the theme *Harmonious and Minimalist Interaction Design*, introduced in the section on developing eHMIs (Ch. IV, Section 1), also aligns with emotional comfort rather than foundational needs. However, its practical advantages—such as simplified controls and compact form—reduce cognitive load and enhance intuitive use, supporting safe and efficient navigation. Therefore, this aspect can also fit within the foundational layer of the framework. Likewise, other themes, extracted in Ch. IV, Section 1, emphasize practical aspects such as safety, effective communication, and the feasibility of external eHMI applications, which we also place in the foundational layer. It is also worth noting that, although not mechanically functional, the principal components (Cs) identified and labeled in Ch. IV, Section 2, play a crucial role in fostering user engagement (Rasoulivalajoozi & Farhoudi, 2025b). Without these perceptual layers, the core themes and considerations of eHMIs may fall short in motivating adoption. As mentioned in the section on dynamic affective experiences of WUs (Ch. III, Section

2), aesthetic and symbolic dimensions significantly influence users' perceptions, acceptance, and emotional connection to mobility aids (Rasoulivalajoozi et al., 2025c). That section showed that initial negative impressions can lead to strong emotional resistance and hinder long-term use. Thus, the principal components function as second-layer elements in our framework, with a circular influence: they shape users' first impressions and readiness to engage with foundational features. This feedback loop underscores the need to integrate perceptual considerations to support both adoption and long-term satisfaction. Accordingly, we introduced a diagram (Figure 47) illustrating these two main layers: the foundational layer addresses safety and practical communication—primarily fulfilled through eHMI—while the upper layer focuses on optimizing socio-emotional needs.

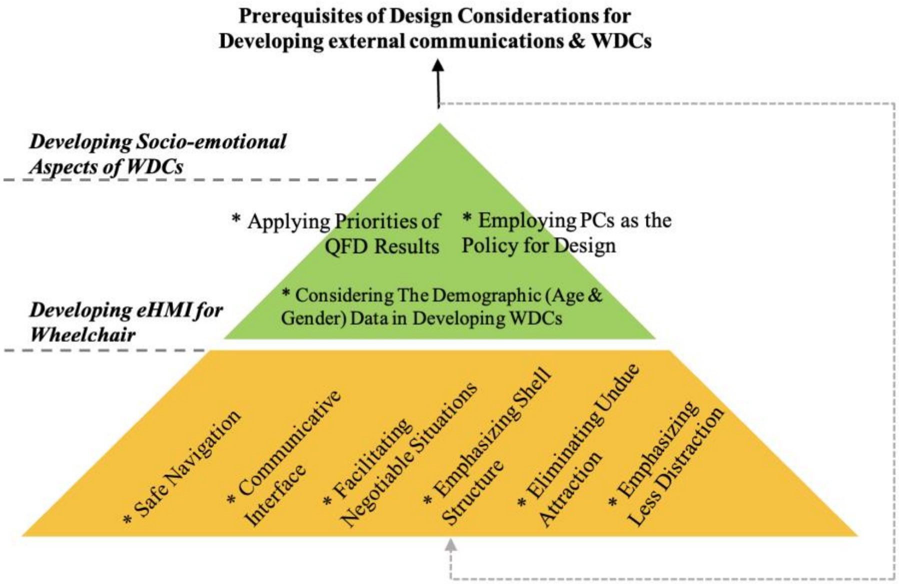

Figure 47. Two main layers prerequisites of design considerations for developing WDCs. © Image by Author.

While this summary of the two studies answers Research Question 4 (Q4), the identified preferred factors serve as prerequisites for achieving SEDPs. Achieving SEDPs requires a holistic approach that not only considers descriptive semantic concepts, but also integrates environmental, cultural, socio-psychological, and aesthetic dimensions, discussed earlier, to ensure the design meets users' socio-emotional needs while promoting inclusivity and fostering positive social perceptions.

Chapter

V

Chapter

Discussion and Conclusion

Chapter V. Discussion and Conclusion.

Introducing SEDPs, Limitations & Future Studies

This chapter first provides a summary of the insights and outline the key contributions gained from this thesis. Then, having already addressed the three sub-questions as a foundation for answering the main research question, we now (in this chapter) focus on responding to the primary research question (Q1). Additionally, we discuss design considerations and limitations and propose directions for future research.

The thesis tried to explore various aspects of the socio-emotional experiences of wheelchair users (WUs) and establish foundational principles and design strategies to facilitate meaningful social interactions for WUs in public settings. The findings are drawn from a combination of existing research, insights from mediators such as physiotherapists with extensive and close relationships with mobility-impaired clients, and empirical data collected through questionnaires and interactions with WUs. After elaborating on the research problem and outlining the framework of the thesis in the introduction (Ch. I), the study began with the development of an interdisciplinary theoretical framework (Ch. II). It then proceeded with an analysis of what and how key factors affecting WUs' social interactions (Ch. III) and then identified critical design factors of wheelchairs that reflect user preferences (Ch. IV).

1 Summary and Contributions

1.1 Ch. II: Systematization of Design Dimensions

The current design space for developing eHMI on wheelchair interfaces and applying SEDPs that enhance WUs' social experiences is highly complex, encompassing a multitude of variables at individual, feasibility, and contextual levels, each characterized by unique attributes.

The practical design requirements for facilitating WUs' interactions in social settings must account for diverse considerations, including cultural norms, society size, urban versus rural environments, production limitations, types of physical mobility challenges, and specific contextual factors.

Given the dynamic and evolving nature of these interactions, there was a pressing need for clarity and unambiguity to effectively address these multifaceted challenges and ensure meaningful and comprehensive design insights. This necessitated careful consideration of design principles (DPs) that encompass both the functional interface (safety, and communication) and socio-emotional dimensions, as well as other relevant physical environmental factors for comfort experiences.

To address this, we first conducted a conceptual analysis in Ch. I, focusing on the dimensions of interaction, behavior, experience, and comfort. We then conducted three studies that reflect the interdisciplinary nature of social perceptions of mobility aids (MAs). Based on these, we developed a theoretical framework that was based on revealing designers' roles in shaping social perceptions—resulting from a scoping review—exploring how disability and its stereotypes are represented and perceived by WUs, and examining how physical, environmental, social, and emotional factors contribute to WUs' comfort. Our framework included three axes, with no prioritization, and two foundational layers:

Axis I. Moderating Disability Stereotypes through Aesthetic and Deindustrialized Visual Identity

Axis II. Prioritizing Technology for Physical Comfort over Pretentious Design Representation.

Axis III. Empowering Inclusivity Beyond Accessibility (Environment, Visual Symbols, Product, Language)

Layer I: Physical Limitations (i.e., capacities), and Emotional Capacities & Expectations

Layer II: Context & Social Values

This interdisciplinary framework addresses the second research question of this thesis, contributing insights from disability studies, design, and architecture to enhance WUs' socio-emotional experiences. It also guided our exploration in subsequent chapters. This framework not only provides a systematic way to classify existing studies on the socio-emotional experiences of WUs to gain a comprehensive overview but also serves as a robust tool for guiding the exploration of future designs, DPs, and related concepts in a structured and actionable manner.

Specifically, while previous studies have addressed emotional and social aspects in isolation, our approach sought to elucidate the interconnection between these two main dimensions, exploring how they dynamically influence one another. Furthermore, we examined how human-centered design interventions can significantly contribute to shaping the WUs' perceptions.

1.2 Ch. III: Insights into WUs' Perceptions and Social Interactions

To address gaps in understanding socio-emotional dynamics, we conducted three studies, presented in three sections, exploring key aspects of these interactions. These studies aimed to answer Q3: What factors influence the socio-emotional dynamics in the interactions of WUs, and how do they exert this impact?

In the first section, we explored perceived inclusivity, identifying themes that show how WUs perceive inclusivity. Our findings revealed that WUs' perceptions of inclusivity extend beyond environmental accessibility, encompassing factors such as financial constraints, visual representational aspects, and contextual influences. This underscores the need for a comprehensive, collaborative approach among several experts including physiotherapists and designers to enhance WUs' socio-emotional experiences effectively. Four key themes were introduced as influential factors:

Theme I. Perceived Financial Value: Assessing Worth

Theme II. Objective Enhancements: Optimizing Environments and MAs

Theme III. Subjective Enhancements: Trustworthiness, Support, and Hope

Theme IV. Contextual Factors: Interpretations and Representations

While this study addresses the first section of question 3, "What", the "How" is explored in parts 2 and 3 as well.

In Section 2, we explored WUs' affective experiences of wheelchairs during planned rehabilitation, providing insights into the dynamic nature of these experiences and the emotional and functional significance that shapes the DAE. A key finding is that these affective experiences change through the rehabilitation stages, shaped by emotional significance—influenced by assumptions and context—and functional significance, challenging the notion of fixed perceptions or lack of attachment across stages. Early stages often present significant challenges, marked by resistance and coping struggles, however, the emotional attachment can sometimes result in post-recovery over-reliance, complicating rehabilitation. While design interventions to address the challenges of over-reliance remain unclear, we identified physiotherapists' pivotal role in managing WUs' affective experiences and fostering balanced attachment to their wheelchairs.

Ultimately, to address the knowledge gap in pedestrian interactions with WUs, Section 3 explored how pedestrians perceive and engage with WUs through an experimental study. This investigation focused on the social aspects, revealing how both wheelchair design characteristics (WDCs) and user gestures can stimulate social empathy and increase willingness to engage. In addition, while WDC played a lesser role in shaping perceptions during independence gestures, its influence diminished during help-seeking gestures, where the gesture itself overshadowed WDC in fostering social empathy. Additionally, age emerged as a factor affecting pedestrian interactions. This study challenges the initial emphasis on WDC alone, highlighting the critical role of WUs' behaviors and gestures in social interactions (Rasoulivalajoozi, 2025). Our finding also introduced the three key WDC components in advanced wheelchairs that reflect pedestrians' perceptions and, when highlighted in design, can enhance social empathy in help-related situations.

1.3 Ch. IV: Design Prerequisites; Cultivating a Positive Social Image of Wheelchairs

Finally, in Ch. IV, we tried to identify key WDC elements that influence the socio-emotional experiences of WUs in social contexts. This chapter aimed to answer Q4: **What are the users' preferred factors in wheelchair design to enhance the social interactions of WUs?** Specifically, we focused on recognizing WUs' preferred visual representational and aesthetic qualities in wheelchair appearance. To this end, we introduced a conceptual model based on two studies. We divided external communication into two aspects of eHMI: the first addresses discomforts in social settings, such as concerns around safety, communication, and the consideration of social aspects on the wheelchair interface; the second focuses on the upper layer, which involves the style and design factors of wheelchairs that enhance WUs' socio-emotional experiences.

In Section 1, we explored user preferences to identify design-related factors that enhance effective communication, safety, aesthetics, and feasibility in developing the eHMI for wheelchair interfaces. When evaluating WUs' expectations, the results indicated a positive reception of the design criteria implemented in the eHMI for wheelchairs. The study addressed gaps in eHMI design by showing that a holistic approach—encompassing aesthetic aspects—enhances WUs' social and hedonic experiences. The social benefits were found to be greater when using a shell structure, as opposed to more attention-grabbing alternatives like on-the-ground projections.

Furthermore, in Section 2, we demonstrated that socio-emotional factors are strongly linked to WDCs, with aesthetic and symbolic importance playing a significant role in addressing social communication challenges. Given that both advanced manual and powered wheelchair designs are highly valued by WUs, we identified three key components that reflect WUs' perceptions of advanced WDCs. These components can be emphasized in future designs to better align with their needs. Additionally, this study added new knowledge, in the scope of wheelchair design, by discovering the crucial physical properties of the wheelchair that enhance its socio-emotional impact.

This Ch. highlighted that while eHMIs are crucial for the safe navigation of WUs in urban settings, it is equally important to consider WUs' preferences in designing WDCs that impact their social interactions. The findings show that aesthetic and symbolic aspects are closely tied to social communication challenges. Therefore, eHMIs for wheelchair interfaces address the physical and practical communication needs of WUs, while socio-emotional polishing forms a complementary layer, both essential for enhancing WUs' hedonic experience.

2 Answering the Main Question (Q1)

Q1: Which SEDPs on wheelchair design contribute to the experience for WUs?

To answer the main question (Q1) of the study, we first recall the concept of DPs. As discussed in Ch. I, DPs are fundamental rules derived from extensive experience or empirical evidence that guide the design process to increase the likelihood of successful outcomes (Fu et al., 2016). They bridge generalizable scientific approaches and practical experiences (Bell et al., 2004). DPs, however, are not directly applicable through immediate practical instructions such as design considerations or implementations. Instead, they must be adapted to the specific styles, limitations, and potentials of each context. To address this and enhance the effectiveness of DPs, we employ the interdisciplinary theoretical framework introduced in Ch. II, that provided a comprehensive lens for enhancing the socio-emotional experiences of WUs. The foundation of our interdisciplinary framework is built on three key axes: *AI. Prioritizing Technology for Physical Comfort over Pretentious Design Representation*, *AII. Moderating Disability Stereotypes through Aesthetic and Deindustrialized Visual Identity; technological considerations*, *AIII. Empowering Inclusivity Beyond Accessibility* (Environment, Visual Symbols, Product, Language). These axes can guide the relevant DPs in addressing the latent needs of WUs, provided they are grounded in the foundational layers of Physical Limitations (i.e., capacities), *Emotional Capacities & Expectations* (Layer I) and *Context & Social Values* (Layer II). These axes not only guide our DPs to positively influence human factors, functional optimization, and aesthetic and symbolic value but also shape users' perceptions, behaviors, emotional well-being, and overall social identity, as well as the MAs' semantic perception in social contexts. To this end, the 10 SEDPs have been compiled based on the key study findings and are presented under the relevant axis of our interdisciplinary theoretical framework (Table 30). Design teams can apply these principles to provide practical design suggestions and considerations, based on the potential and limitations they encounter.

Table 30. Organization of SEDPs (*N*=10) and considerations (*N*=1) aligned with the interdisciplinary theoretical framework.

Layers		Axes of introduced interdisciplinary theoretical framework	SEDPs & Considerations
LII: Context & Social Values	LI: Physical Limitations (i.e., Capacities), and Emotional Capacities & Expectations	AI. Moderating Disability Stereotypes through Aesthetic and Deindustrialized Visual Identity	**DP**[*]**1.** *Deindustrialized Visual Identity* **DP2.** *Emphasizing the Set of WUs' Preferred Principal Components* **DP3.** *Emphasizing the Set of Pedestrians' Perceived Principal Components* **DP4.** *Emphasizing Trustworthiness and Agility in the Style of a Wheelchair*
		AII. Prioritizing Technology for Physical Comfort over Pretentious Design Representation	**DP5.** *Strengthening Emotional Engagement via User-Product Interfaces* **DP6.** *Minimizing Complexities Yet Integrating New Technologies* **DP7.** *Mitigating Undue Attraction*
		AIII. Empowering Inclusivity Beyond Accessibility	**DP8.** *Promoting Environment Inclusion by Minimizing Discrepancies* **DP9.** *Prioritizing the Inclusive Environment Over High-tech Wheelchair* **DP10.** *Empowering Inclusive Service Design and Social Program* **C**[**]**.** *Assistance of Physiotherapists in Shaping the Perceptions of Mobility Aids*

*DP=Design Principles; **C= Consideration.

2.1 AI. Moderating Disability Stereotypes through Aesthetic and Deindustrialized Visual Identity

DP 1. Deindustrialized Visual Identity: This principle emphasizes the elimination of visible signs and semantic meanings associated with industrial processes in the appearance of wheelchairs and other mobility aids. For instance, when the structure and frame of a wheelchair—such as exposed metal pipes, wires, or electrical connectors—are prominently visible, they evoke an unrefined and mechanical design approach. This contrasts with other objects like jewelry, which, despite their close contact with the body, convey aesthetics and beauty rather than industrial manufacturing processes.

By adopting a Deindustrialized Visual Identity, designers can shift focus away from biomechanical and industrial elements, highlighting a visual language that emphasizes users' social dignity and humanity. This principle aligns with findings from Ch. II, Section 1, which highlighted that aspects like Self-Identity & Body Image are often overlooked and also emphasized the effect of Aesthetic considerations on WUs' self- and social representation and identity (Rasoulivalajoozi & Farhoudi, 2025b). Additionally, the first theme of Section 2 in the same chapter underscores *Iconic Representations: Practical Use vs. Perceived Stigma*. By applying the *Deindustrialized Visual Identity* principle, designers can turn the semantic representation of wheelchairs, diminishing the perception of the body as a biomechanical machine. Although this approach may not entirely eliminate the perception of the wheelchair as an extension of the body, as noted in previous studies based on a biomechanical perspective, it can at least aesthetically refine this perception. By doing so, the connection between the wheelchair and the user can be moderated, highlighting a more socially polished and independent identity for WUs.

Reducing elements associated with the identity of wheelchairs, such as visible wheels, can shift the focus toward a more aesthetically pleasing shell structure. This design choice can effectively divert attention away from the wheels, particularly in manual wheelchairs. Consequently, users and onlookers may perceive the wheelchair less as a medical device and more as a stylish mobility and transportation solution. By promoting this approach, designers can not only create an external space for a wider range of effective and accurate eHMI but also enjoy greater flexibility in creating wheelchairs that cater to diverse styles and tastes. This approach aligns with the principle of "Deindustrialized Visual Identity," helping to minimize the mechanical aspects often associated with wheelchairs and encouraging a narrative centered on empowerment and capability.

DP2. Emphasizing the Set of WUs' Preferred Principal Components: This DP mostly arose from Ch. V, Section 2, where we could find the preference of WUs in the perception of advanced and admired wheelchairs (Rasoulivalajoozi & Farhoudi, 2025b). As highlighted in the summary and discussion of Ch. V, while eHMIs are essential for ensuring safe and effective navigation for WUs in urban settings, it is equally crucial to consider WUs' preferences when designing WDCs that influence their social interactions. The findings emphasize that aesthetic and symbolic aspects are closely linked to social communication challenges. Therefore, alongside eHMIs, the following components associated with underlying semantic words with high loadings play a crucial role in providing a socio-emotional polish, forming a vital complementary layer.

- AMW principal components: C1 - Secure Navigation with Advanced Representation, C2 - Maneuverability with Pleasant Social Representation, and C3 - Reliability and Respectful Social Interaction.
- APW principal components: C1 - Dual Aspects of Self-Reliance & Pleasant Social Representation, C2 - Self-Confidence with Social Respect, and C3 - Flexibility in Mobility.

In addition, while the QFD results emphasize the prioritized physical properties for social polish, we propose that designers' intuitive thinking can introduce a diverse array of forms and styles, further enriching and enhancing these descriptive principal components.

DP3. Emphasizing the Set of Pedestrians' Perceived Principal Components: Beyond the principal components, certain visual characteristics of wheelchairs from pedestrians' perspectives also merit attention. These features are closely linked to the symbolic and perceptual interpretation of wheelchairs, significantly influencing how people perceive WUs. Consequently, alongside the principal components outlined in the previous sections (DP5), the following components, derived from underlying semantic words with high loadings, play a vital role in shaping public perceptions of WUs. The required explanation was provided for each component in Ch. III, Section 3 (Rasoulivalajoozi, 2025).

- AMW principal components: C1- Dynamic Design with Sophistication, C2 - Autonomous & Reliability, and C3 - Intimacy with Unobtrusiveness
- APW principal components: C1- Intimacy with Unobtrusiveness, C2 - Social Reliability & Empathetic Support, and C3 - Self-Sufficient & Tech-Adoptive.

DP 4. Emphasizing Trustworthiness and Agility in the Style of a Wheelchair: While there are both similarities and differences in descriptive perceptions between WUs and pedestrians regarding the AMW and APW, further investigation is needed in future studies. However, certain shared aspects emerge that likely warrant greater attention at this stage. For example, trustworthiness in wheelchair design not only fosters user confidence but also shapes societal perceptions, portraying WUs as active, independent, and capable individuals. These factors formed the second component—*Social Reliability & Empathetic Support*—and were detailed in Ch. III, Section 3. A wheelchair that appears sturdy and reliable fosters a sense of security, encouraging users to engage in social activities without fear of malfunction or instability. This is essential for both physical safety and emotional confidence. Design elements that signal durability, such as reinforced structures, high-quality materials, and a solid base, enhance the perception of trustworthiness. For instance, using the bulky form at the bottom of a wheelchair compared to the seat and armrest implies a heaviness, perceived as more trustworthy. Agility-enhancing features, such as lightweight materials, responsive maneuverability, and forward-oriented designs like arrow shapes, improve wheelchair performance, empowering users to maintain their independence and mobility. A wheelchair that allows for quick and smooth movements supports spontaneous interactions and active participation in social settings, which is vital for fostering a sense of belonging and community. Incorporating features that enhance agility, such as adjust seating positions or ergonomic controls, allows users to adapt their wheelchairs to various activities and environments. Also, as shown in Ch. III, Section 3, when pedestrians observe a reliable advanced wheelchair, they may be more inclined to engage with the user, leading to increased social interactions.

2.2 AII. Prioritizing Technology for Physical Comfort Over Pretentious Design Representation

DP5. Strengthening Emotional Engagement via User-Product Interfaces: As discussed in Ch. I, II, and III, the use of technology plays a crucial role in encouraging WUs to accept and continue using their prescribed wheelchair. However, the physical interaction addressing their discomfort should not be disruptive or overwhelming, as this affects both their emotional and functional expectations, as discussed in Ch. III, Section 2. To achieve this, collaborative interaction mechanisms should be adopted, such as incorporating intuitive gesture controls and user-friendly features for more seamless user-wheelchair interaction. The new attached technical accessory should help the wheelchair convey clear functionality, and trust.

In some instances, adding playful and innovative elements—such as interactive or customizable features like ambient lighting or design components can enhance the joy of interaction. Additionally, incorporating transparent systems, with visible indicators for power status, brakes, and other critical functions, helps reassure users and provides them with a sense of control. Ultimately, as discussed in the section on eHMI, it is essential to ensure intuitive and efficient user interfaces for advanced controls. Including smart communication tools, such as speech and gesture recognition systems, can further facilitate and enhance the connection between the user and the wheelchair.

DP6. Minimizing Complexities Yet Integrating New Technologies: This principle emphasizes the need for wheelchair technologies to be user-friendly, ensuring that while WUs are open to adopting new technologies, their initial interactions are simple and intuitive. This approach helps prevent technophobia, which could discourage users from embracing these innovations. Avoiding of complexity is supported by law of Prägnanz in Dutch language, translates to "good figure" or "pithiness". It is a principle of Gestalt psychology that states people tend to interpret complex images in the simplest way possible (Lidwell et al., 2010). In addition, as highlighted in Ch. III, Section 1, simplifying initial interactions can facilitate Coping in Using the Wheelchair, fostering a sense of *Self-Sufficiency and Tech-Adaptiveness* as noted in Section 3 of the same chapter. Additionally, this principle aligns with the findings in Ch. II, Section 1, where *Independence & Autonomy* were identified as critical factors (Rasoulivalajoozi et al., 2025a). In Ch. IV, Section 2, *Flexibility in Mobility* was emphasized as a key consideration, linking closely to the concept of *Agility* without causing undue concern (Rasoulivalajoozi & Farhoudi, 2025b). This supports the development of Self-Confidence and Social Respect, ensuring that users feel both capable and respected in social contexts.

DP7. Mitigating Undue Attraction: This principle focuses on minimizing any unintended attention that may be drawn to the appearance of wheelchairs and mobility aids. Such attention can make WUs feel conspicuously different in their mobility, emphasizing their disability and potentially leading to feelings of embarrassment and discomfort. This is suggested to be applied to both the design of external Human-Machine Interfaces (eHMI) and the overall design style of wheelchairs.

For eHMI, this principle is supported by studies highlighting that undue attention is a common concern among WUs, affecting their social experiences while navigating urban environments (X. Zhang et al., 2024). Additionally, as explored in the QFD results of Ch. IV, Section 2 (Rasoulivalajoozi & Farhoudi, 2025b), such unwanted attention can be mitigated by avoiding bright primary colors (e.g., red, blue, yellow) and overly large or bulky wheelchair designs, which tend to draw more visual focus.

2.3 AIII. Empowering Inclusivity Beyond Accessibility

DP8. Promoting Environment Inclusion by Minimizing Discrepancies: This principle emphasizes that while environmental optimizations (e.g., obstacle-free buildings, ramps, and handrails) are essential (Zallio & Clarkson, 2021), they should not highlight the discrepancies between WUs and others in their ability to navigate. If these differences are emphasized, it can trigger reminders of mobility disabilities and evoke negative emotions. Instead, design should focus on equity, ensuring that all individuals are treated equally. For example, aligning accessible seating with regular seating on buses can promote a sense of normalcy. This inclusive approach can be applied to both city infrastructure and transportation planning, as well as in workplaces through mentorship programs and adaptive environments to actively support WUs (Strauser et al., 2024). A Canadian study found that WUs had a 50% lower chance of being invited for an interview, with a callback rate of 7.2% compared to 14.4% for non-disabled applicants (Bellemare et al., 2019; Bjørnshagen & Ugreninov, 2021). Addressing these aspects goes beyond considering the WUs' autonomy and control, fostering a sense of equity, and preventing feelings of discrimination and unfairness.

DP9. Prioritizing the Inclusive Environment Over High-tech Wheelchair: While fostering inclusivity for WUs is highly encouraged, the associated costs should not fall solely on them. Users should not feel that their disability imposes an extra financial burden exclusively on them. Instead, optimizing the environment should take precedence over embedding advanced technologies in wheelchair design. For example, prioritizing the installation of ramps or elevators in buildings specifically designed for wheelchair accessibility is more effective than relying on costly stair-climbing wheelchairs, which place the financial responsibility primarily on the users. This approach not only enhances inclusivity but also helps mitigate undue attention that might arise from using complex technology and bulky wheelchair designs, allowing users to feel more integrated into society.

DP10. Empowering inclusive service design and social program: This DP emphasize social services that ensure WUs feel supported and do not perceive paying for a wheelchair as a barrier to accessing their fundamental right to social participation, a right enjoyed by all. Nevertheless, the World Health Organization (WHO) estimated that 10% of people with disabilities, or 80 million individuals, still require a wheelchair for mobility. This number is expected to rise as the population ages and chronic health conditions become more common (WHO, 2024). WHO regards access to assistive mobility devices like wheelchairs as a human right, as they enable individuals to live independently, work, care for themselves and others, and perform daily tasks. In other side, social programs that pair WUs with non-disabled peers in collaborative or recreational activities (Smith et al., 2016) can help break down barriers and reduce social stigmas (Damsté et al., 2024). While not directly related to wheelchair design, these interventions can shape WUs' perceptions of their right to mobility and social presence. For example, the service design in transportation considering the inclusive approach (Santana et al., 2018) not only promotes equity and inclusion but also fosters positive social interactions and enhances emotional well-being (UK GOV, 2024).

Considerations: Assistance of Physiotherapists in Shaping the Perceptions of Mobility Aids: Optimizing WUs' perceptions is significantly influenced by physiotherapists, who have extended interactions with users and the agency within the medical discourse to shape the understanding of disability. In this thesis, it was found that physiotherapists' inclusive approaches in their clinics, including their efforts to minimize language and knowledge discrepancies with clients, were instrumental in positively influencing WUs' perceptions of their recovery process and shaping trust and interpretations of mobility aids. Physiotherapists' inclusive language plays a crucial role in shaping how wheelchairs are perceived in clients' view, especially during the initial stages when users first recognize the need for them. By presenting the wheelchair as a tool for transportation and independence rather than solely an orthopedic device, physiotherapists can help shift societal perceptions. Additionally, medical clinics—including physiotherapy and related orthopedic facilities—can enhance this inclusive narrative by incorporating images of advanced wheelchairs or empowering depictions of WUs into their interior design. This reinforces the idea of wheelchairs as modern, agile devices associated with social prestige rather than merely therapeutic aids. Furthermore, these positive images in clinical settings could also be incorporated into urban environmental graphics, showcasing WUs in active, dynamic postures rather than static ones (related to DP9). While this may not directly impact WUs' social experiences, such representations can influence their perceptions, thereby positively affecting their self-image and social interactions.

3 Wheelchair Design Concept Grounded in SEDPs

Regarding these SEDPs, we proposed design concepts aligned with DPs under the categories of AI and AII. After collecting 48 exploratory sketches (Figure 48), two concepts were selected and suggested for manual wheelchairs and one for a powered wheelchair (Figure 49). The aim was to highlight the importance of reimagining wheelchair design in a way that challenges traditional industrial aesthetics, focusing on user empowerment and social perception. By considering these factors, the design aimed to create a more inclusive, emotionally resonant experience for WUs, aligning with the principles of social presence and dignity.

Other key highlights included emphasizing the set of WUs' preferred principal components and considering the set of pedestrians perceived principal components. Additionally, highlighting trustworthiness and agility in wheelchair style, as outlined in DP4, was an important factor.

For eHMI development, we applied the principles outlined in *DP5, Strengthening Emotional Engagement via User-Product Interfaces*, as detailed in Ch. IV, Section 1. We employed a shell structure covering the wheels, minimizing complexities, and integrating new technologies. By using a shell design, attention is drawn away from the biomechanical representations and the typical frame structure of standard wheelchairs. This shift contributes to reducing stigmatizing mechanical aesthetics often associated with traditional wheelchairs.

Figure 48. Sketches for developing concepts of wheelchairs. © Image by Author.

Although these wheelchair concepts feature modern and futuristic styles that may still attract attention, we estimate this attention would be positive. Rather than stigmatizing the user, it is likely to evoke a sense of prestige, reflecting a progressive and empowering image of WUs. Additionally, this design considers WUs' feeling of independence by showing agility and weight while supporting their social image in public contexts. The lights integrated into the back and sides of the wheelchairs not only enhance safety and facilitate communication via the interface but also convey that WUs are active and using their wheelchair as a mode of transportation, rather than merely viewing it as a mobility aid for disability. For a more thorough evaluation, further analysis and discussions are needed after developing a prototype version of these concepts. WUs should use them in their daily routines and accordingly, we can assess how these designs impact their experiences.

Figure 49. Design concepts of wheelchair based on the SEDPs-AI and AII. © Image by Author.

4 Assessing the SEDPs

Finding a single method to assess SEDPs comprehensively is not feasible. However, experimental tests and longitudinal studies can be designed to evaluate individual SEDPs or selected combinations to determine their effectiveness. For instance, when encouraging designers to apply the DPs defined in *AI. Moderating Disability Stereotypes through Aesthetic*, the output—new WDCs with reduced emphasis on biomedical aspects—can be evaluated through Principal Component Analysis (PCA) (Brace et al., 2007; Hakim et al., 2024; Soares, 2021). This analysis typically leverages semantic descriptors rated by users on a Likert scale (1–5) to assess alignment with SEDPs. In the case of *AII. Prioritizing Technology for Physical Comfort over Pretentious Design Representation*, the assessment could focus on WU's satisfaction and acceptance. Questionnaires based on the Unified Theory of Acceptance and Use of Technology (UTAUT) model could be employed, covering dimensions such as performance expectancy, effort expectancy, and behavioral intentions (Rahman et al., 2017).

Additionally, longitudinal studies with qualitative approach could help observe and track WUs' perceptions and behaviour (Caruana et al., 2015; Tuthill et al., 2020) after implementing policies related to *AIII. Empowering Inclusivity Beyond Accessibility*. Comparisons can be made with individuals who have not benefited from such inclusive approaches. Similar to the study in Ch. III, Section 2 (Rasoulivalajoozi et al., 2025c), these perceptions could be gathered through interviews with physiotherapists or through other direct methods, such as observing WUs in public settings (Haynes, 2000), or tracking their social experiences using repeated questionnaires (C. R. G. Jones et al., 2024; Newcastle University, 2024) during wheelchair usage. Future studies could explore these evaluation methods, and feedback derived from such studies inform the refinement and further development of SEDPs.

5 Discussion

In this section, we look at various considerations in distilling the insights presented in the thesis and the implications of implementing SEDPs in the design of future wheelchairs.

5.1 Considerations for the Future High-tech Wheelchairs

In Ch. II, we explored an interdisciplinary framework for enhancing the socio-emotional experiences of WUs. While conventional manual and powered wheelchairs benefit from this framework and introduced SEDPs, the integration of wheelchairs equipped with emerging technologies, such as AI-powered and self-driving, may bring unforeseen shifts in public perceptions, concepts of ability, and modes of interaction.

We posit that while such technology primarily addresses physical limitations and discomforts, the domain of comfort—particularly the emotional aspects of WUs—remains largely untapped and the wheelchairs equipped with advanced technologies—not advanced design character— still continue to reflect existing traditional social perceptions (Saia et al., 2024). Consequently, we estimate that the socio-emotional aspects will still benefit from SEDPs informed by our interdisciplinary theoretical framework. For instance, AI-powered autonomous wheelchairs can recognize voice commands, gestures, facial expressions, lane navigation, and gaze in natural settings for individuals with mobility impairments. Technologies such as lane detection, enabled in real time using hardware, deep learning algorithms, and image manipulation, demonstrate significant advancements (B et al., 2024). However, the structural complex mechanisms of these systems may concurrently attract undue attention (V. de S. P. Costa et al., 2010; Barbareschi et al., 2020; Lanutti et al., 2015), which many WUs identify as a negative aspect of wheelchair design (Desmet & Dijkhuis, 2003). Therefore, while these technologies may affect societal expectations and introduce new challenges, design insights must evolve to ensure advanced wheelchairs achieve their intended social presence and integrate seamlessly into society.

Another challenge in implementing self-driving and AI-based technologies in wheelchairs is the inherent duality between independence and facilitation that these systems present. While these systems enhance navigation (Masud et al., 2024), social presence, and self-reliant by reducing overwhelm (Hou et al., 2024), they can potentially also undermine the user's sense of control, fostering feelings of passivity. Some studies have demonstrated that wheelchairs are often perceived as an extension of the user's body (Blach Rossen et al., 2012; V. de S. P. Costa et al., 2010); therefore, expecting one’s "body" to function autonomously, without direct control, can seem contradictory. To address this issue and maintain a sense of control and trust, it is essential to establish a clear link between user autonomy and technological facilitation by semi-autonomous control systems and shared control, ensuring that the user remains actively engaged in the decision-making and operational processes of the wheelchair (Carlson & Demiris, 2008; Y. Wang et al., 2021). In one case, a vision-based autonomous wheelchair was introduced, but calibrating the camera with the human eye without obstructing the user’s vision was a significant challenge (Masud et al., 2024). Future studies must address this issue to enhance usability while ensuring the system does not hinder users' ability to maintain eye contact in social settings.

5.2 Considerations for Key Insights

Socio-Cultural Attitudes Toward Implementing eHMI and SEDPs

A theme in discussions around designing accep eHMI is lack of standardization (de Winter & Dodou, 2022). Standardization is often cited as a critical challenge, as eHMI elements may evoke different interpretations and reactions across various cultural contexts. In Ch. IV, Section 1, we discussed the importance of carefully considering sound design for wheelchairs, particularly as it relates to external communication (Passero et al., 2024). In this context, the studies show that in some cultures, the honking of a car horn serves multiple functions—it can express gratitude, such as thanking another driver for yielding, or signal protest, like voicing frustration toward the behavior of cars or cyclists (Mahmood, 2021). Therefore, when designing warning honking features for eHMI, it should be carefully crafted to avoid evoking negative perceptions from others, including car drivers. Similarly, blinking yellow/red lights in the proposed wheelchair interface—side view— may be interpreted differently across cultures (Alhawiti et al., 2024), and such varying interpretations or potential negative reactions toward WUs can pose significant challenges. Not only might this compromise WUs' safety in critical situations, such as at intersections where negotiation with other transportation modes (e.g., vehicles or wheelchairs, bicycles) is necessary (Dey, Matviienko, et al., 2021; Y. Li et al., 2018; Löcken et al., 2019), but it can also affect their socio-emotional experience. Negative reactions to the warning visual signals or sound cues may lead WUs to feel their social presence is disrespected, reinforcing the sense of being treated as second-class citizens (BBC News, 2016; Meikle, 2016). Therefore, the lack of standardization and common understanding of eHMI and its varying cultural perceptions can potentially create substantial challenges. Without considering the target WUs' cultural context, the intended communication and user experience may be compromised.

Similarly, the socio-cultural attitude of the aesthetic of products varies significantly between regions (Reinecke & Gajos, 2014; Takagi et al., 2012). For instance, in North America, larger-scale products with bold (Deepti, 2023), visually striking designs are often regarded as a status symbol and a norm for aesthetics. However, in Japan, there is a cultural preference for simplicity and a design philosophy centered on minimalism and (Uniqe Japan, 2024) "form follows function (Riggs, 2022)" These differing aesthetic values significantly impact how a wheelchair design might be perceived, even if the introduced SEDPs are properly used. When a wheelchair with a shiny, elaborate, and exaggerated aesthetic is introduced into a culture that does not culturally value such designs, it may not only face rejection but could also evoke discomfort or reinforce stigma by drawing undue attention to the user (X. Zhang et al., 2024; Desmet & Dijkhuis, 2003). Conversely, in societies that appreciate bold and striking designs, such a style may be more readily accepted and celebrated. To ensure that wheelchair designs meet users' socio-emotional needs, it is essential for design teams to adopt an anthropological perspective (Singh et al., 2021). By investigating the aesthetic norms and cultural values of their target context, designers can create products that resonate with the users' environment and avoid unintended socio-emotional or cultural conflicts. Ultimately, a culturally adaptive approach can helps foster designs that empower WUs and enhance their experience in social contexts. In this regard, previous research has emphasized the scarcity of studies on the intersection of assistive technology (AT) and culture, highlighting the need for further exploration in this area (Ripat & Woodgate, 2011).

Age Considerations in Wheelchair Design Development

In Ch. III, Section 3 and Ch. IV, Section 2, age emerged as a key factor shaping perceptions of WDCs. In Ch. III, a positive correlation was identified between pedestrians' age and their willingness to interact with WUs using an advanced powered wheelchair while employing a help-seeking gesture. Similarly, Ch. IV highlighted that WUs' older age is significantly associated with the aesthetic and symbolic importance of wheelchairs. While evidence from prior studies shows that aesthetic preferences vary across age groups—children (Desmet & Dijkhuis, 2003), young adults, and older adults (Brandt et al., 2004; S. Evans et al., 2007)— however, our study highlights that the aesthetic significance of wheelchairs becomes increasingly important and even affects the older individual's perceptions, whether they are WUs or not.

Findings showed that assumptions about a person's competence, intellect, and overall disability experience are often influenced by the physical representation of their wheelchair (Saia et al., 2024). Studies also emphasize that while the international wheelchair symbol is widely recognized as an emblem of disability, many individuals with significant mobility impairments do not view themselves with this label of disability (Iezzoni et al., 2000), revealing a gap between personal self-representation and societal symbolism. Therefore, when the self-perceptions of older adult WUs—who often associate themselves with greater maturity and wisdom—are challenged by wheelchairs that reflect traditional notions of disability, a paradox may arise. This paradox may prompt older adults to more emphasize the aesthetic appearance of their wheelchairs as a means of bridging the gap between their self-image and societal image.

WUs still continue to face societal stigma, which is linked to higher levels of depression, perceived pity, discomfort, and invisibility (Saia et al., 2024). As a result, many WUs specifically, older adults, do not like to express their need for assistive devices (Jung & Ludden, 2019). However, the provision of appropriate aesthetic models for wheelchairs could help reduce these stigmatized perceptions by influencing behaviors and attitudes across different age groups. In support of this idea, prior research cautions against the assumption that aesthetics must be sacrificed for function in designs for older adults (Office for Product Safety & Standards, 2021). To this end, when designing wheelchairs with SEDPs, particularly those addressing visual representational aspects, it is essential to consider age-specific preferences. Such an approach can promote greater acceptance and inclusivity while meeting the practical and socio-emotional needs of users across various age groups.

Reports indicate that the growing population of older adults with mobility disabilities (Nie et al., 2024; United Nations, 2024), makes their social presence and interaction a critical area for attention. While previous research emphasizes physical barriers as obstacles to their social engagement and outdoor activities (Nie et al., 2024), future studies should investigate how the aesthetic and visual representational aspects of wheelchairs affect their willingness to participate in such activities.

5.3 Potential Negative Application of SEDPs

According to presumptions about wheelchair design, the new advanced wheelchair with a deindustrialized look may make it harder to recognize it as an assistive device, potentially reducing users' or bystanders' willingness to perceive its applicability in emergency situations. Nevertheless, we posit that these wheelchairs are primarily designed for use in social, daily routines and are unlikely to be used in emergency or hospital settings. Thus, the emphasis on a more aesthetically appealing design may be more relevant to the wheelchair's role in everyday interactions, where it helps foster social integration, rather than compromising its function in critical situations.

On the other hand, focusing excessively on the preferences of WUs as outlined in DP2 could make mass production more difficult or costly due to the need for extensive aesthetic refinement and detail. This, in turn, could exacerbate issues of accessibility and affordability, as many individuals with disabilities still lack access to basic, standard wheelchairs. In a similar vein, overemphasizing pedestrian perceptions (DP3) may prioritize appearance or social acceptance over WUs' functional needs, compromising comfort, safety, or usability. To address this potential bias, we suggest, as discussed in Ch. II, Section 3, prioritizing physical aspects that address discomforts first, and subsequently integrating these perceptions with DP2, which focuses on WUs' preferences and aesthetic considerations, as complementary factors.

Moreover, too much emphasis on agility and trustworthiness in design could result in misperceptions and trade-offs of stability or comfort, especially in the case of users with more significant mobility challenges. Some WUs might find these attributes irrelevant to their needs, particularly if they need special help from a family or hired assistants to handle their issues. At the same time, while minimizing complexity is often positive, attempting to integrate new technologies may introduce unanticipated technical challenges. Here, over-simplifying might also omit and hide beneficial features that more tech-savvy or need-specific WUs could rely on. Therefore, we suggest that a minimalistic approach should not come at the expense of sacrificing new technologies, and this process should be implemented carefully and thoughtfully. Finally, while creating inclusive services is crucial, overly emphasizing inclusivity may lead to compromises in the specific service design quality, causing users to feel as though they are being treated based on a generalized concept of "diversity" rather than having their personal needs met. As a result, this could lead to users feeling underserved or pigeonholed into predefined social programs.

Ultimately, addressing these potential challenges requires collaborative efforts between designers, WUs as the central stakeholders, producers, and anthropologists. Additionally, SEDPs should be considered holistically, in relation to and evaluated alongside other DPs, rather than selectively choosing only a few. This ensures a more balanced approach, reducing bias and minimizing the risk of compromising the results.

5.4 Limitations of the Setup of the Studies

Each of our research questions focused on specific aspects of the socio-emotional experiences of WUs. Accordingly, we designed the review, exploratory studies, and experiments to address the themes, factors, aspects, and variables we aimed to investigate. In all our studies, we assumed that WUs use wheelchairs in social settings and that certain negative stereotypes are already present in society. Building upon this assumption, we sought to better understand how these factors influence the interaction dynamics between WUs and pedestrians.

In the exploratory studies, while recruiting WUs contributed significantly to our study, ethical concerns prevented us from interviewing WUs who were undergoing rehabilitation. To address this limitation, we interviewed physiotherapists with extensive experience working with WUs throughout their rehabilitation journey, which provided a deep understanding of their socio-emotional experiences. For example, in one of the studies (Ch. III, Section 2) where we aimed to track interactions between users and wheelchairs, we were unable to directly monitor and observe WUs' feelings, as rehabilitation journeys vary significantly in duration. Additionally, such emotions are not always easily articulated or observable. As a result, we relied on the extensive experience of physiotherapists to extract semantic clues during our interviews, gaining insights into the socio-emotional aspects of these interactions through their professional perspectives. In two studies (Ch. IV) WUs who were not in rehabilitation but met the inclusion criteria, not only could share their perception toward different WDC through questionnaire, but also, we could engage them in the design process to capture their views and opinions.

While our empirical studies offered valuable insights regarding the research questions posed, further experimental research is necessary for more complex scenarios to gain a more nuanced understanding of interactions between WUs and pedestrians. To ensure a systematic approach, in the experimental studies (Ch. III, Section 3; Ch. IV, Section 2), we chose to start with comparatively simple scenarios to better understand the causal factors of the observed interactions. Introducing more complex scenarios, such as incorporating additional gestures or varying WDC, might have omitted or obscured the root causes of the effects we were trying to investigate. For example, in Ch. III, Section 3, if we had designed more complex scenarios involving various environmental elements combined with multiple gestures, it could have caused confusion, diverting pedestrians' attention and influencing their reactions to interactions with WUs. The insights gained from the simpler scenarios in this thesis can later be applied to more complex interactions, with more meticulous research considerations, to capture additional details.

In addition, in the experimental studies, while capturing interactions through observation was beneficial, it was not ideal, as one of the advanced wheelchairs was only in the concept design phase and therefore could not be observed in real-world use. Additionally, observing WUs in a public context presented challenges, as external factors—such as varying pedestrian behaviors, environmental conditions, and contextual influences—were difficult to control, potentially affecting the reliability and consistency of the observations. To address these limitations, future research could incorporate simulated or controlled environments where different WDC can be tested, allowing for more precise observations while minimizing confounding variables.

6 Research Gaps and Future Work

Research on addressing the social needs of WUs is progressing, yet many questions and areas remain unexplored. While some potential gaps and suggestions for future research are highlighted at the end of each section, this part provides an expanded review of additional gaps and opportunities for further investigation.

Firstly, despite progress in designing eHMI (enhanced Human-Machine Interfaces) for wheelchairs, gaps persist in identifying the most effective colors, text, animated lines, and imagery to address communicative challenges in complex, requiring implicit negotiation. These elements are crucial for enhancing safety, improving communication, and supporting WUs' socio-emotional satisfaction in public settings. In this regard, previous studies and established frameworks (B. Zhang et al., 2022; de Winter & Dodou, 2022), including our presented concepts in Ch. IV, Section 2, offer a foundation for eHMI development in wheelchairs. However, the intricate graphical aspects—such as the optimal selection of colors, types of lines, animated shapes, and light displays—are yet to be thoroughly explored. Addressing these gaps in future studies can pave the way for more effective and user-centered eHMI and wheelchair designs.

Furthermore, one of the important aspects is considering the needs of individuals with severe impairments in body control, requiring specific considerations in wheelchair design. Conditions such as Muscular Dystrophy, which causes progressive muscle weakness, and quadriplegia, leading to loss of function below the neck, necessitate tailored solutions like electric wheelchairs with special adjustments such as tilting, reclining, or standing functionalities to provide critical support. However, while these wheelchairs could benefit from eHMIs and SEDPs, some users' inability to rely on body gestures for direct communication presents challenges. As such, relying on body gestures can be challenging to perform, or even may confuse pedestrians and drivers attempting to interpret the user's intentions. Here, incorporating specialized gadgets alongside eHMIs tailored to users' physical needs becomes essential, although these functional adaptations can influence the wheelchair's visual representation. At present, mature, robust, and multi-modal eHMI and SEDPs that address the needs of this diverse user base are relatively lacking. To move forward, future research should focus on integrating eHMIs and SEDPs with the unique structural requirements of wheelchairs designed for users with specific needs, ensuring these technologies improve both functionality and aesthetic representational aspects.

Our study in Ch. III, Section 3, highlighted the importance of WUs' movement patterns and body language in implicit communication. Building on this, a potential research area is exploring more explicit communication through WUs' body language. While WUs' movement patterns and body language typically arise naturally from their situation or need for help, it would be valuable to examine additional gestures, identifying which types are most effective and how they vary across cultures. Our findings suggest that WUs' gestures (whether independent or help-seeking) play a more significant role in promoting social empathy than WDCs. Analyzing more complex body gestures could provide insights into optimizing wheelchair design and how various body gestures interact with WDCs.

In addition, the timing and distance of eHMI signals, applied on wheelchairs, in relation to pedestrian movement, vehicle speed, and traffic situations remain largely unexplored. A critical next step in eHMI design should be to define and evaluate these characteristics. While the field currently focuses on improving safety and communication, future research should also examine the impact of eHMIs on efficiency in different critical situations

Moreover, most research on eHMI for wheelchairs, including the one of studies in this thesis (Ch. IV, Section 2), has focused on how WUs can communicate their intentions to pedestrians or drivers. However, more work is needed to enable a complete information exchange—an interaction where pedestrians, drivers, self-driving cars, and cyclists can also communicate with WUs. For example, with the increasing presence of self-driving cars, it is crucial to explore the safety and communication challenges WUs face in interactions with these vehicles in critical situations. In scenarios involving human drivers, visual signals may be judged based on assumptions about their meaning or commonly understood body gestures of WUs by human drivers. However, in interactions with self-driving cars, WUs cannot be sure that their eHMI signals are properly received. Therefore, future research should also focus on enhancing two-way communication between WUs and self-driving cars, and if promising, develop a common language for this interaction.

The perception of SEDPs across different cultural contexts is an area worth exploring in future studies. As mentioned in this chapter, the design style or size of a wheelchair may be perceived differently depending on the culture. Therefore, it would be valuable for design teams to apply SEDPs within various cultural contexts.

In Ch. III, Section 2, we explored users' interactions and dynamic affective experiences in a planned rehabilitation process. In this regard, applying the introduced SEDPs, particularly those related to visual representational aspects, and collecting feedback from WUs in such a process would be valuable. In addition, comparing the perceptions of WUs using optimized wheelchairs with SEDPs during daily routines to those in rehabilitation would offer valuable insights into the effectiveness of SEDPs. This comparison would highlight how the SEDPs impact users in two different conditions, where their self-perception and views on ability or disability may vary.

In a related vein, as shown in Ch. IV, Section 2, increasing age was significantly linked to the aesthetic and symbolic importance of wheelchair design. This presents an opportunity to explore whether SEDPs should be customized for different age groups and which visual elements would be most appealing to each group. Tailoring these elements could help optimize the emotional experiences of WUs in different age groups. Furthermore, the effect of SEDPs—particularly the aesthetic representational aspects—can be expanded to older adults and children, with comparisons of their feedback and perceptions when using and experiencing wheelchairs.

Moreover, as mentioned in Ch. III, Section 1, the etiology and cause of a mobility disability can influence a user’s willingness or resistance to use a wheelchair. However, the impact of other grounding factors such as type of job or financial support, that shape social identity, in users' DAE remains underexplored. For instance, being a teacher who uses a wheelchair in school and the educational workplace may affect their social presence, power dynamic, and interactions in the workplace. One of the first academic studies examining the working lives of disabled teachers in England has called for "urgent change" after uncovering significant workplace discrimination and barriers to career progression (Harbuck, 2023). Therefore, a wheelchair designed aesthetic representational emphasize, based on SEDPs, could positively influence social perceptions, enhancing the dynamic of relationships with colleagues and students. Additionally, financial concerns, discussed in Ch. III, Section 1, as an extra burden for WUs, may vary depending on individual financial support. Consequently, future studies could explore whether perceptions of WUs from inclusivity vary based on the level of individuals' financial support.

Building on these socio-economic considerations, it is also important to acknowledge a key limitation of this study: its limited engagement with the intersecting dimensions of race, culture, and social class (Lindsay et al., 2022). These socio-cultural factors undoubtedly shape perceptions of self and disability, the lived experiences of assistive device users, and their interactions in public space. However, the scope of this research did not allow for a comprehensive intersectional analysis. Future studies should prioritize these intersections and consider issues of accessibility across diverse populations to inform more inclusive, equitable, and context-sensitive design practices—ultimately fostering greater public empathy toward WUs.

Overall, our research offers valuable insights into the behavior of WUs and their socio-emotional experiences, highlighting the potential of eHMIs and SEDPs to improve these experiences, enhancing their social interactions and presence. With the growing population of older adults requiring wheelchairs, their social presence and addressing social needs will become even more significant. While further work is needed to advance the knowledge in this area, this thesis lays a solid foundation for future research. In this regard, given that the needs of WUs cannot be addressed from a single disciplinary perspective, adopting an interdisciplinary and orchestrated approach was essential. To this end, ongoing collaboration between experts in disability studies, industrial design, medical anthropology, and sociology in health, environmental, and urban studies is essential in the future for developing effective solutions to enhance WUs' socio-emotional experiences as well. Through these multi-faceted insights, we can contribute to a more cohesive social future for WUs, where society recognizes and legitimizes their active role, moving beyond stereotypes about disability and minimizing the negative impacts on their socio-emotional well-being.

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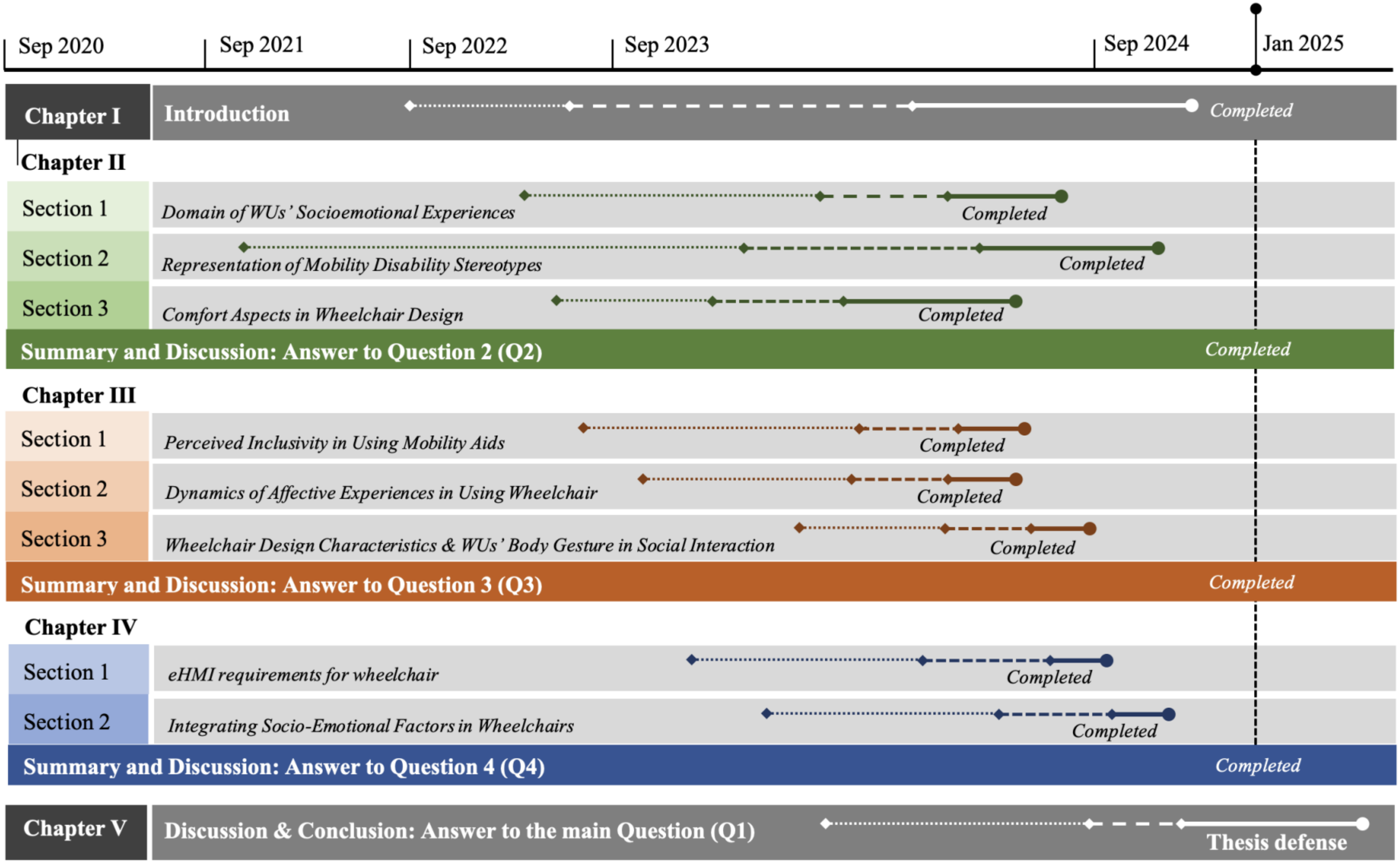
Appendix

Appendix A The outline of research timetable.



Appendix B Search strategies.

Web of Science
Wheelchair (Title) AND Experience OR psychological OR Social OR Wheelchair OR Social OR Emotion OR Independence OR Stigma OR Autonomy OR Discrimination OR Perception OR quality of life (Abstract) AND Wheelchair OR Scooter OR Mobility aid (Title) AND 2000-01-01/2024-05-30 (Publication Date) AND Experience OR Wheelchair OR Social OR Emotion OR Independence OR quality of life OR Stigma OR Autonomy OR Discrimination OR Perception (Author Keywords) NOT Children OR Service OR in-vitro OR Clinical OR Sport wheelchair OR quality of life (Abstract) NOT Children OR Service OR Sport OR Clinical OR Engineering OR Medical OR surgical OR Basketball OR Tennis OR Volleyball OR Training OR financial OR ambulatory OR walkers OR canes (Title) NOT Review OR Book Review OR Database Review OR Book OR Book Chapter OR Correction OR Editorial Material OR Discussion OR Film Review OR Poetry OR Bibliography OR Chronology OR Letter OR Record Review OR News Item OR Retraction OR Meeting Abstract OR Withdrawn Publication OR Art Exhibit Review OR Correction, Addition OR Item About an Individual (Document Type) NOT Wheelchair design OR Engineering development OR Service OR Children OR Service OR Sport OR Clinical OR Engineering OR Medical OR surgical OR Basketball OR Tennis OR Volleyball OR Training OR financial OR ambulatory OR walkers OR canes (Topic)

PubMed Search
((((("Wheelchair"[Title] AND (("Wheelchair"[Title/Abstract] AND "Device"[Title/Abstract] AND "Test"[Title/Abstract] AND "Experience"[Title/Abstract]) OR "psychological"[Title/Abstract] OR "Social"[Title/Abstract] OR "Wheelchair"[Title/Abstract] OR "Social"[Title/Abstract] OR "Emotion"[Title/Abstract] OR "Independence"[Title/Abstract] OR "Stigma"[Title/Abstract] OR "Autonomy"[Title/Abstract] OR "Discrimination"[Title/Abstract] OR "Perception"[Title/Abstract] OR "quality of life"[Title/Abstract])) NOT ("Review"[Publication Type] OR (("books"[MeSH Terms] OR "books"[All Fields] OR "Book"[All Fields]) AND "Review"[Publication Type]) OR (("database"[All Fields] OR "database s"[All Fields] OR "databased"[All Fields] OR "databases"[All Fields] OR "databasing"[All Fields]) AND "Review"[Publication Type]) OR (("motion pictures"[MeSH Terms] OR ("motion"[All Fields] AND "pictures"[All Fields]) OR "motion pictures"[All Fields] OR "film"[All Fields]) AND "Review"[Publication Type]) OR "Bibliography"[Publication Type] OR "Letter"[Publication Type] OR (("records"[All Fields] OR "recordability"[All Fields] OR "recordable"[All Fields] OR "recordables"[All Fields] OR "recorded"[All Fields] OR "recorder"[All Fields] OR "recorders"[All Fields] OR "recording"[All Fields] OR "recordings"[All Fields] OR "records"[MeSH Terms] OR "records"[All Fields] OR "record"[All Fields]) AND "Review"[Publication Type]) OR (("art"[MeSH Terms] OR "art"[All Fields]) AND ("exhibited"[All Fields] OR "exhibites"[All Fields] OR "exhibitions as topic"[MeSH Terms] OR ("exhibitions"[All Fields] AND "topic"[All Fields]) OR "exhibitions as topic"[All Fields] OR "exhibit"[All Fields] OR "exhibiting"[All Fields] OR "exhibits"[All Fields]) AND "Review"[Publication Type]))) NOT ("wheelchair design"[Title/Abstract] OR "engineering development"[Title/Abstract] OR "Service"[Title/Abstract] OR "Children"[Title/Abstract] OR "Service"[Title/Abstract] OR "Sport"[Title/Abstract] OR "Clinical"[Title/Abstract] OR "Engineering"[Title/Abstract] OR "Medical"[Title/Abstract] OR "surgical"[Title/Abstract] OR "Basketball"[Title/Abstract] OR "Tennis"[Title/Abstract] OR "Volleyball"[Title/Abstract] OR "Training"[Title/Abstract] OR "financial"[Title/Abstract] OR "ambulatory"[Title/Abstract] OR "walkers"[Title/Abstract] OR "canes"[Title/Abstract])) NOT ("Children"[Title/Abstract] OR "Service"[Title/Abstract] OR "Sport"[Title/Abstract] OR "Clinical"[Title/Abstract] OR "Engineering"[Title/Abstract] OR "Medical"[Title/Abstract] OR "surgical"[Title/Abstract] OR "Basketball"[Title/Abstract] OR "Tennis"[Title/Abstract] OR "Volleyball"[Title/Abstract] OR "Training"[Title/Abstract] OR "financial"[Title/Abstract] OR "ambulatory"[Title/Abstract] OR "walkers"[Title/Abstract] OR "canes"[Title/Abstract])) AND "English"[Language] AND 2000/01/01:2024/05/29[Date - Publication] AND "loattrfull text"[Filter] AND "loattrfull text"[Filter]) AND ((casereports[Filter] OR classicalarticle[Filter] OR congress[Filter] OR interactivetutorial[Filter] OR interview[Filter] OR introductoryjournalarticle[Filter] OR observationalstudy[Filter]) AND (fft[Filter]))

PsycINFO
Title: wheelchair *AND* **Abstract**: Wheelchair *AND* **Abstract**: Experience *OR* **Abstract**: Emotion *OR* **Abstract**: Psychology *OR* **Abstract**: Public *AND* **Keywords**: Wheelchairuser *OR* **Keywords**: Experience *OR* **Keywords**: Participation *OR* **Keywords**: Interaction *AND* **Peer-Reviewed Journals only** *AND* **Year**: 2000 *To* 2024

Scopus
TITLE (wheelchair AND NOT walker AND NOT cane AND NOT orthesis) AND TITLE-ABS (wheelchair OR experience OR social OR emotional OR theme) AND NOT TITLE-ABS (engineering AND NOT clinical AND NOT in-vitro AND NOT surgery AND NOT service AND NOT sports AND wheelchair AND NOT medical AND NOT surgical AND NOT basketball AND NOT tennis AND NOT volleyball AND NOT training AND NOT financial AND NOT ambulatory) AND PUBDATETXT (2000-2024) AND LANGUAGE (english) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (EXACTKEYWORD , "Wheelchairs") OR LIMIT-TO (EXACTKEYWORD , "Wheelchair") OR LIMIT-TO (EXACTKEYWORD , "Adult") OR LIMIT-TO (EXACTKEYWORD , "Spinal Cord Injury") OR LIMIT-TO (EXACTKEYWORD , "Disabled Persons") OR LIMIT-TO (EXACTKEYWORD , "Spinal Cord Injuries") OR LIMIT-TO (EXACTKEYWORD , "Physiology") OR LIMIT-TO (EXACTKEYWORD , "Wheelchair Users") OR LIMIT-TO (EXACTKEYWORD , "Electric Wheelchair") OR LIMIT-TO (EXACTKEYWORD , "Manual Wheelchair") OR LIMIT-TO (EXACTKEYWORD , "Young Adult") OR LIMIT-TO (EXACTKEYWORD , "Paraplegia") OR LIMIT-TO (EXACTKEYWORD , "Disability") OR LIMIT-TO (EXACTKEYWORD , "Assistive Technology") OR LIMIT-TO (EXACTKEYWORD , "Wheels") OR LIMIT-TO (EXACTKEYWORD , "Propulsion") OR LIMIT-TO (EXACTKEYWORD , "Wheelchair Propulsion") OR LIMIT-TO (EXACTKEYWORD , "Smart Wheelchairs") OR LIMIT-TO (EXACTKEYWORD , "Patient Rehabilitation") OR LIMIT-TO (EXACTKEYWORD , "Quality Of Life") OR LIMIT-TO (EXACTKEYWORD , "Powered Wheel Chairs") OR LIMIT-TO (EXACTKEYWORD , "Powered Wheelchair") OR LIMIT-TO (EXACTKEYWORD , "Activities Of Daily Living") OR LIMIT-TO (EXACTKEYWORD , "Daily Life Activity") OR LIMIT-TO (EXACTKEYWORD , "Wheelchair Control") OR LIMIT-TO (EXACTKEYWORD , "Physical Disability") OR LIMIT-TO (EXACTKEYWORD , "Physical Activity") OR LIMIT-TO (EXACTKEYWORD , "Disabled People") OR LIMIT-TO (EXACTKEYWORD , "Wheelchair User") OR LIMIT-TO (EXACTKEYWORD , "Sport") OR LIMIT-TO (EXACTKEYWORD , "Power Wheelchair") OR LIMIT-TO (EXACTKEYWORD , "People With Disabilities") OR LIMIT-TO (EXACTKEYWORD , "Accessibility") OR LIMIT-TO (EXACTKEYWORD , "Psychology") OR LIMIT-TO (EXACTKEYWORD , "Pilot Study") OR LIMIT-TO (EXACTKEYWORD , "Case Report") OR LIMIT-TO (EXACTKEYWORD , "Male") OR LIMIT-TO (EXACTKEYWORD , "Female") OR LIMIT-TO (EXACTKEYWORD , "Article") OR LIMIT-TO (EXACTKEYWORD , "Human") OR LIMIT-TO (EXACTKEYWORD , "Humans")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "HEAL") OR LIMIT-TO (SUBJAREA , "PSYC") OR LIMIT-TO (SUBJAREA , "MULT") OR LIMIT-TO (SUBJAREA , "ARTS") OR LIMIT-TO (SUBJAREA , "ENVI")) AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "p")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2000) OR LIMIT-TO (PUBYEAR , 2001) OR LIMIT-TO (PUBYEAR , 2002) OR LIMIT-TO (PUBYEAR , 2003) OR LIMIT-TO (PUBYEAR , 2004) OR LIMIT-TO (PUBYEAR , 2005) OR LIMIT-TO (PUBYEAR , 2006) OR LIMIT-TO (PUBYEAR , 2007) OR LIMIT-TO (PUBYEAR , 2008) OR LIMIT-TO (PUBYEAR , 2009) OR LIMIT-TO (PUBYEAR , 2010) OR LIMIT-TO (PUBYEAR , 2011) OR LIMIT-TO (PUBYEAR , 2012) OR LIMIT-TO (PUBYEAR , 2013) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2018) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024))

Appendix C Quality appraisal tool; Mixed Methods Appraisal Tool (MMAT).

			Screening questions		Qualitative					Quantitative					Mixed methods					
Article #	**Peer-reviewed Journal**	**Concerning socio-emotional experiences of WUs**	**S1**	**S2**	**1.1.**	**1.2.**	**1.3.**	**1.4.**	**1.5.**	**4.1.**	**4.2.**	**4.3.**	**4.4.**	**4.5.**	**5.1.**	**5.2.**	**5.3.**	**5.4.**	**5.5.**	**Eval.**
Abu–Sadat, 2023	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Barbareschi et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Barker et al., 2004	Y	Y	Y	Y	Y	Y	Y	C	Y											A
Barker et al., 2006	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Barlew et al., 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Blach Rossen et al., 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Böttger et al., 2022	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
C. Pettersson et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Costa et al., 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Edberg & Persson, 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Evans et al., 2007	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Evans, 2000	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Fortin-Bédard et al., 2022	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Frank et al., 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Henje et al., 2021	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Hjelle & Vik, 2011	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Korotchenko & Hurd Clarke, 2013	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Kristiansen, 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Labbé et al., 2018	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Lindström et al., 2022	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Mattie et al., 2020	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
P. R. J. Giacobbi et al., 2010	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Pfeiffer et al., 2024	Y	Y	Y	Y	Y	Y	Y	C	Y											A

			Screening questions		Qualitative					Quantitative					Mixed methods					
Qiao et al., 2024	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Reid et al., 2003	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Rogers & Musselwhite, 2023	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Rousseau-Harrison et al., 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Rushton et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Stenberg et al., 2016	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Torkia et al., 2014	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Widehammar et al., 2019	Y	Y	Y	Y	Y	Y	Y	Y	Y											A
Brandt et al., 2004	Y	Y	Y	Y						Y	Y	Y	Y	Y						A
Chan & Chan, 2007	Y	Y	Y	Y						Y	Y	Y	Y	Y						A
Davies et al., 2003	Y	Y	Y	Y						Y	Y	Y	C	Y						A
de Groot et al., 2010	Y	Y	Y	Y						Y	Y	Y	Y	Y						A
Greenhalgh et al., 2021	Y	Y	Y	Y						Y	Y	Y	N	Y						A
I. Pettersson et al., 2010	Y	Y	Y	Y						Y	Y	Y	Y	Y						A
Lanutti et al., 2015	Y	Y	Y	Y						C	Y	Y	C	Y						A
Meyers et al., 2002	Y	Y	Y	Y						C	Y	Y	C	Y						A
Mortenson et al., 2022	Y	Y	Y	Y						Y	Y	Y	Y	Y						A
Örücü Atar et al., 2024	Y	Y	Y	Y						C	Y	Y	C	Y						A
Pettersson et al., 2009	Y	Y	Y	Y						Y	Y	Y	C	Y						A
Pousada García et al., 2015	Y	Y	Y	Y						Y	Y	Y	C	Y						A
Ward et al., 2015	Y	Y	Y	Y						Y	Y	Y	C	Y						A
Garber et al., 2002	Y	Y	Y	Y											Y	Y	Y	C	Y	A
May & Rugg, 2010	Y	Y	Y	Y											Y	Y	Y	C	Y	A
Rudman et al., 2006	Y	Y	Y	Y											Y	Y	Y	C	Y	A
Salatino et al., 2016	Y	Y	Y	Y											Y	Y	Y	C	Y	A

Abbreviations: Y: Yes; N: No; C: Can’t tell; A: Approved.

Mixed Methods Appraisal Tool. McGill University.		Questions
Screening questions	S.1.	Are there clear research questions?
	S.2.	Do the collected data allow to address the research questions?
1. Qualitative	1.1.	Is the qualitative approach appropriate to answer the research question?
	1.2.	Are the qualitative data collection methods adequate to address the research question?
	1.3.	Are the findings adequately derived from the data?
	1.4.	Is the interpretation of results sufficiently substantiated by data?
	1.5.	Is there coherence between qualitative data sources, collection, analysis and interpretation?
2. Quantitative randomized controlled trials	2.1.	Is randomization appropriately performed?
	2.2.	Are the groups comparable at baseline?
	2.3.	Are there complete outcome data?
	2.4.	Are outcome assessors blinded to the intervention provided?
	2.5.	Did the participants adhere to the assigned intervention?
3. Quantitative nonrandomized	3.1.	Are the participants representative of the target population?
	3.2.	Are measurements appropriate regarding both the outcome and intervention (or exposure)?
	3.3.	Are there complete outcome data?
	3.4.	Are the confounders accounted for in the design and analysis?
	3.5.	During the study period, is the intervention administered (or exposure occurred) as intended?
4. Quantitative descriptive	4.1.	Is the sampling strategy relevant to address the research question?
	4.2.	Is the sample representative of the target population?
	4.3.	Are the measurements appropriate?
	4.4.	Is the risk of nonresponse bias low?
	4.5.	Is the statistical analysis appropriate to answer the research question?
5. Mixed methods	5.1.	Is there an adequate rationale for using a mixed methods design to address the research question?
	5.2.	Are the different components of the study effectively integrated to answer the research question?
	5.3.	Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
	5.4.	Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
	5.5.	Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

Appendix D The Overview of questions and guidelines**.**

Interview guide
Please tell me about your professional experience and responsibilities. Probes: Years of experience, institutional context, education, etc. Can you describe the process of your visit with a client who potentially should use the mobility aid products? How do the disabled persons feel about themselves in the cultural and social context? (Any challenges or uncomfortable etc.) How do they feel about social activities and participation? (Feeling shame, or excluded) tell us more, please! How do they deal with some potential social challenges and what do they can do to improve their social participation? When using mobility aid products, are clients able to adapt easily to their environment? For example, dissatisfaction or complaints regarding their connection with urban furniture. Tell us more, please! Would you like to use the assistive products (mobility aids) if you were in a walking disability condition? How might the design and beauty of assistive products (mobility aids) be improved? Color, shape, etc. How can the technology influence the client's decision to accept or refuse a prescribed mobility device?

Appendix E Summary of coding structure.

Raw Data (Example Quote)	**Initial Code**	**Code Group**	**Theme**
P2: "Sympathy, or understanding pain, is just as present in the minds of physiotherapists…"	Longer client interaction builds trust	Client-Clinic Trust	The Complex Medical System, But Reliable Physiotherapy Clinic
P1: "Clients often view health organizations… as the first group to blame…"	Blaming wider health system	System Distrust	The Complex Medical System, But Reliable Physiotherapy Clinic
P1: "Typically, our conversations with colleagues involve technical language…"	Professional vs. lay language	Knowledge-Language Gap	A Knowledge-Language Differential in Healthcare Professionals–Clients Talks
P3: "We view disability through the lens of technological advancements…"	Professional vs. social understanding of disability	Medical vs. Social Lens	Iconic Representations: Practical Use vs. Perceived Stigma
P8: "…In an unsuitable environment, mobility devices can be perceived as an insult…"	Devices cause shame	Stigma & Perception	Iconic Representations: Practical Use vs. Perceived Stigma
P1: "The media cooperate with industries…"	Media promotes unhealthy body standards	Media & Body Image	Iconic Representations: Practical Use vs. Perceived Stigma
P12: "The beauty of assistive products can influence…"	Aesthetics affect acceptance	Aesthetics & Product Acceptance	Iconic Representations: Practical Use vs. Perceived Stigma
P9: "Clients comment on the clinic website or talk in private conversations, and there's one thing they often say:	Peer validation & shared satisfaction	Peer Influence & Social Validation	The Complex Medical System, But Reliable Physiotherapy Clinic

Raw Data (Example Quote)	Initial Code	Code Group	Theme
they congratulate each other on choosing the clinic…”			

Appendix F Focus group prompts

Questions of qualitative survey	Questions guided the discussion
a) Have you encountered difficulties in social communication while using a wheelchair? please describe.	**** Empathy, Embodiment & Social Acceptance*** 1. In what ways do you feel your wheelchair affects how others perceive or interact with you in public? (Explores how design influences social identity, empathy, and inclusion.) 2. Do you think having personalized or expressive elements (e.g., color, tone, or symbols) in an eHMI would help you feel more comfortable or in control socially? (Engages the emotional and symbolic dimensions of interface design.)
b) When faced with a challenging situation, do you typically seek assistance? If so, how do you communicate your request?	***Empathy, Embodiment & Social Acceptance*** 3. Are there specific gestures, expressions, or subtle cues you use to communicate that you wish could be supported or enhanced by the wheelchair interface? (Connects embodiment and natural expression with technological mediation.) ***Selective Information Management*** 4. Would you want to control when and how your wheelchair communicates with others? In what situations would you prefer it to stay silent or discreet? (Explores the importance of privacy and contextual control over information flow.) 5. Can you imagine using different 'modes' or settings (e.g., private, help, social) on your wheelchair? How might these help you manage social interactions? (Introduces the idea of modular or user-defined interface behaviors.)
c) How important are the appearance and symbolic meaning factors (for communication) once you are using a wheelchair?	***Empathy, Embodiment & Social Acceptance*** 6. How would it feel if your wheelchair could visually or audibly express your needs or intentions to others—do you think this could reduce misunderstandings or discomfort? (Invites reflection on whether eHMI can enhance social communication and dignity.)
d) How does your wheelchair communicate with car drivers and pedestrians in navigating in the cities?	***Situational Awareness & Adaptability*** 7. What kinds of environments or situations make it hardest for others to understand your movements or intentions (e.g., in crowds, crossing streets, in clinics)? (Identifies contexts where enhanced eHMI feedback can improve mutual awareness.) 8. What types of alerts or signals (like direction, urgency, or assistance requests) would you want your wheelchair to give in different scenarios? (Focuses on adaptive output for navigating varied social and physical settings.) 9. How could eHMI features improve situational awareness for pedestrians during interactions with wheelchair users? (Highlights multi-user dynamics in different use contexts.)

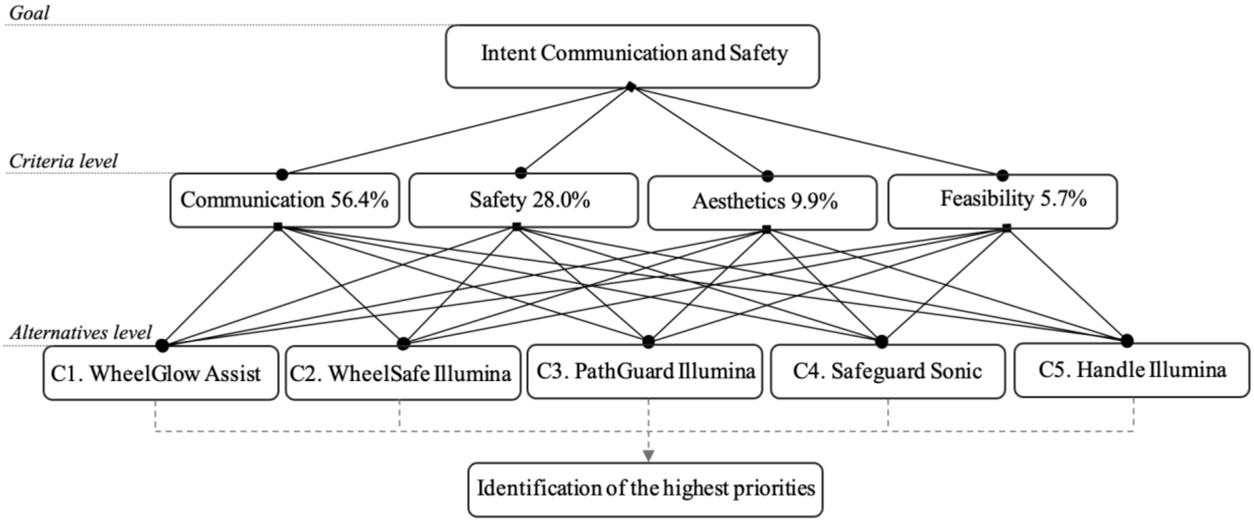
Questions of qualitative survey	Questions guided the discussion
	Selective Information Management 10. What information about you or your intentions do you think should be visible to others, and what should remain private? (Supports user agency in filtering and curating outward messages.)
e) How would you describe your ideal wheelchair to navigate in an urban setting?	Share exploratory concepts and sketches derived from the themes identified in the above responses

Appendix G Comparing the criteria in the AHP model.

Criteria	Communication	Safety	Aesthetics	Feasibility
Communication	1	3.00	6.00	7.00
Safety	0.33	1	5.00	4.00
Aesthetics	0.17	0.20	1	3.00
Feasibility	0.14	0.25	0.33	1

Consistency Ratio CR = 8.8%
Number of comparisons = 6
Principal eigen value = 4.241
Eigenvector solution: 6 iterations, delta = 6.8E-8

Appendix H The AHP model in three levels of Goals, Criteria, and Alternatives.



Appendix I Comparing the concepts based on the four criteria of communication, safety, aesthetics, and feasibility.

Communication	C 1	C 2	C 3	C 4	C 5
C1	1	0.50	4.00	3.00	6.00
C 2	2.00	1	5.00	3.00	7.00
C 3	0.25	0.20	1	2.00	3.00
C 4	0.33	0.33	0.50	1	3.00
C 5	0.17	0.14	0.33	0.33	1

Number of comparisons = 10
Consistency Ratio CR = 4.7%
Principal eigen value = 5.211
Eigenvector solution: 5 iterations, delta = 2.7E-8

Safety	C 1	C 2	C 3	C 4	C 5
C1	1	0.33	4.00	2.00	6.00
C 2	3.00	1	5.00	2.00	7.00
C 3	0.25	0.20	1	0.50	4.00
C 4	0.50	0.50	2.00	1	4.00
C 5	0.17	0.14	0.25	0.25	1

Consistency Ratio CR = 5.1%
Number of comparisons = 10
Principal eigen value = 5.228
Eigenvector solution: 5 iterations, delta = 9.8E-8

Aesthetics	C 1	C 2	C 3	C 4	C 5
1	1	0.50	5.00	6.00	7.00
2	2.00	1	6.00	7.00	7.00
3	0.20	0.17	1	5.00	4.00
4	0.17	0.14	0.20	1	0.50
5	0.14	0.14	0.25	2.00	1

Consistency Ratio CR = 8.4%
Number of comparisons = 10
Principal eigen value = 5.378
Eigenvector solution: 6 iterations, delta = 2.3E-8

Feasibility	C 1	C 2	C 3	C 4	C 5
C1	1	1.00	0.50	2.00	0.50
C 2	1.00	1	0.50	2.00	0.50
C 3	2.00	2.00	1	3.00	2.00
C 4	0.50	0.50	0.33	1	0.50
C 5	2.00	2.00	0.50	2.00	1

Consistency Ratio CR = 1.9%
Number of comparisons = 10
Principal eigen value = 5.088
Eigenvector solution: 4 iterations, delta = 1.3E-8

Appendix J Questionnaire for wheelchair users' point of view.

Question #	Questionnaire Question: Five-Point Likert Scale (1 = Strongly Disagree, 5 = Strongly Agree)
1	I trust that the WheelSafe Illumina can provide a safe navigation and communicate without any challenge.
2	I believe I can effectively communicate my intentions to nearby drivers and pedestrians, whether I want to pass or stop.
3	I would prefer to rely on my body gestures in challenging situations rather than depend on the Illumina set on my wheelchair.
4	I feel, using the WheelSafe Illumina attracts more attention than I would like, which makes me uncomfortable.
5	I would not use this WheelSafe Illumina in the future because the technology poses potential risks.
6	I think the WheelSafe Illumina is more useful than any other wheelchair I have used before, and I would enjoy riding it.
7	I can easily control the options of WheelSafe Illumina properties at any time.
8	I thought there was too much inconsistency in this WheelSafe Illumina system.
9	I found the system unnecessarily complex and need the support of a technical person to be able to use this WheelSafe Illumina system.

Appendix K Questionnaire for pedestrians' point of view.

Question #	Questionnaire Question: Five-Point Likert Scale (1 = Strongly Disagree, 5 = Strongly Agree)
1	I feel that an interaction features on Illumina -equipped wheelchairs would help me react more quickly to unsafe walking conditions while crossing the road.
2	I believe that an interaction feature on Illumina-equipped wheelchairs would lower my risk of an accident while crossing the road.
3	For me, learning to interact with an Illumina -equipped wheelchair while crossing the road is an easy task.
4	I find it challenging to cross the road when Illumina -equipped wheelchairs are in operation. (reverse score)
5	I can easily cross the road in front of Illumina -equipped wheelchairs.

Appendix L Correlation matrix in relationship of technical requirements.

Dimension	Large																													0
	Standard																												0	0
	Small																											0	0	0
Weight	Heavy																										0	-	-	-
	Standard																									0	0	+	+	0
	Light weight																								0	0	0	-	+	-
Footrest	Adjustable																							0	0	0	0	0	0	0
	Fixed																						0	0	0	0	0	0	0	0
Armrest	Adjustable																					0	0	0	0	0	0	0	0	0
	Fixed																				0	0	0	0	0	0	0	0	0	0
Backrest	Contoured																			0	0	0	0	0	0	0	0	0	0	0
	Adjustable																		0	0	0	0	0	0	0	0	0	0	0	0
	Fixed																	0	0	0	0	0	0	0	0	0	0	0	0	0
Seat cushion	Firm																0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Soft															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Propulsion	Powered														0	0	0	0	0	0	0	0	0	0	0	0	+	-	-	+	-
	Manual													0	0	0	0	0	0	0	0	0	0	0	+	0	-	-	+	-
Wheel proportion	Large												0	+	+	0	0	0	0	0	0	0	0	0	+	+	0	+	+	+
	Medium											0	0	0	+	0	0	0	0	0	0	0	0	0	+	+	-	0	0	-
	Small										0	0	0	-	0	0	0	0	0	0	0	0	0	0	-	-	-	0	-	-
Color	Polychromatic									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	-	-
	Biochromatic								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	+	+	+
	Monochromatic							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Frame design	Adjustable						0	0	0	0	+	+	0	+	+	+	0	0	+	+	0	+	0	+	+	+	0	+	+	+
	Rigid					0	0	0	0	0	-	0	-	-	0	0	-	0	+	+	-	+	-	+	0	-	-	0	0	-
	Folding				0	0	0	0	0	0	+	0	-	+	0	+	0	0	+	+	0	+	0	+	+	+	0	+	+	+
Material	Charon fiber			0	+	-	+	0	0	0	-	0	0	+	+	0	-	-	+	+	-	+	0	+	+	+	+	+	+	+
	Plastic		0	0	+	-	+	0	0	0	-	0	0	+	+	0	-	-	+	+	-	+	0	+	0	0	0	+	0	-
	Metal	0	0	0	-	-	+	0	0	0	-	-	-	-	0	0	-	-	+	0	-	+	0	+	-	-	-	0	-	-
		Metal	Plastic	Chabon Fiber	Folding	Rigid	Adjustable	Monochromatic	Biochromatic	Polychromatic	Small	Medium	Large	Manual	Powered	Soft	Firm	Fixed	Adjustable	Contoured	Fixed	Adjustable	Fixed	Adjustable	Light weight	Standard	Heavy	Small	Standard	Large
		Material			Frame design			Color			Wheel proportion			Propulsion		Seat cushion		Back rest			Arm rest		Footrest		Weight			Dimension		

Appendix M QFD calculation of technical importance (TI) using weighted sum of relationship scores and importance weights (Top: AMW, Bottom: APW).

AMW		Material			Frame design			Color			Wheel proportion			Propulsion		Seat cushion		Backrest			Armrest		Footrest		Weight			Dimension			
1: low 5: high Customer importance rating	Functional Requirements (How's) → Customer Requirements - (What's). Voice of Costumers (VOC) ↓	Metal	Plastic	Carbon Fiber	Folding	Rigid	Adjustable	Monochromatic	Bichromatic	Polychromatic	Small	Medium	Large	Manual	Powered	Soft	Firm	Fixed	Adjustable	Contoured	Fixed	Adjustable	Fixed	Adjustable	Light weight	Standard	Heavy	Small	Standard	Large	*Sum of the row*
5	PC1: Safety	3	1	3	0	1	3	1	1	3	1	3	9	3	0	3	1	1	3	1	3	9	3	9	1	9	3	1	9	3	*91*
5	PC1: Stable	3	1	1	1	3	3	1	1	0	1	3	9	1	0	3	0	3	9	3	1	3	1	3	0	3	3	0	9	3	*72*
5	PC1: Futuristic	1	1	9	3	1	9	1	3	1	0	1	1	0	0	0	0	0	3	3	0	3	0	3	3	9	1	1	9	1	*67*
4	PC2: Comfort	0	1	3	3	1	9	0	0	0	0	1	3	1	0	9	1	0	9	3	1	9	1	3	1	3	0	0	3	0	*65*
4	PC2: Agility	1	3	9	1	0	3	0	1	3	1	1	3	0	0	0	0	1	3	1	1	3	1	3	9	9	0	3	3	0	*63*
4	PC2: Communicative	0	0	3	1	1	3	1	3	1	0	0	0	1	0	0	0	0	3	0	0	1	0	1	0	0	0	3	3	0	*25*
4	PC2: Stylish	1	1	3	1	1	3	1	3	1	0	1	0	1	0	0	0	1	3	3	3	9	3	3	1	3	1	1	3	0	*51*
3	PC3: Dignity	1	0	3	1	1	3	3	3	0	1	3	1	1	0	3	1	1	3	1	1	3	1	3	1	3	1	1	3	0	*47*
3	PC3: Affirmation	1	0	3	0	0	1	3	3	1	1	3	1	1	0	0	0	0	1	0	0	1	0	1	0	0	0	1	3	0	*25*
3	PC3: Trustworthiness	3	1	3	1	1	3	1	3	1	0	1	3	1	0	3	1	1	3	3	1	3	1	1	0	9	1	0	3	1	*53*
1	PC4: Independence	0	1	3	3	1	9	0	0	0	0	0	3	3	0	1	0	0	3	1	1	3	1	3	1	3	0	3	9	1	*53*
	Technical importance score	59	39	167	53	44	177	44	80	46	20	68	137	44	0	85	9	24	135	51	28	127	28	103	60	153	35	34	171	35	*2056*
	Importance %	**2.87**	**1.90**	**8.12**	**2.58**	**2.14**	**8.61**	**2.14**	**3.89**	**2.24**	**0.97**	**3.31**	**6.66**	**2.14**	**0.00**	**4.13**	**0.44**	**1.17**	**6.57**	**2.48**	**1.36**	**6.18**	**1.36**	**5.01**	**2.92**	**7.44**	**1.70**	**1.65**	**8.32**	**1.70**	**100%**
	Priorities rank	13	20	3	14	17	1	17	10	16	27	11	5	17	29	9	28	26	6	15	24	7	24	8	12	4	21	23	2	21	

APW		Material			Frame design			Color			Wheel proportion			Propulsion		Seat cushion		Backrest			Armrest		Footrest		Weight			Dimension			
1: low 5: high Customer importance rating	Functional Requirements (How's) → Customer Requirements - (What's). Voice of Costumers (VOC) ↓	Metal	Plastic	Carbon Fiber	Folding	Rigid	Adjustable	Monochromatic	Bichromatic	Polychromatic	Small	Medium	Large	Manual	Powered	Soft	Firm	Fixed	Adjustable	Contoured	Fixed	Adjustable	Fixed	Adjustable	Light weight	Standard	Heavy	Small	Standard	Large	*Sum of the row*
5	PC1: Independence	0	0	0	3	1	9	0	0	0	0	0	1	0	9	1	0	0	3	1	1	3	1	3	9	3	0	9	3	0	*60*
5	PC1: Futuristic	1	1	9	3	1	9	1	3	1	0	1	1	0	3	0	0	0	3	3	0	3	0	3	9	3	0	3	9	1	*71*
5	PC1: Trustworthiness	3	1	3	1	1	3	1	3	1	1	3	3	0	9	3	1	1	3	3	1	3	1	1	0	9	1	0	3	1	*64*
5	PC1: Communicative	0	0	1	1	1	3	1	3	1	0	0	0	0	1	0	0	0	3	0	0	1	0	1	0	0	0	3	3	0	*23*
5	PC1: Comfort	0	0	0	3	1	9	0	0	0	0	1	3	0	9	9	1	0	9	3	1	9	1	3	3	3	0	3	9	0	*80*
5	PC1: Stylish	1	1	3	1	1	3	1	3	1	0	1	0	0	3	0	0	1	3	3	1	3	3	3	1	3	1	1	3	0	*45*
4	PC2: Safety	3	1	3	1	1	3	1	1	3	1	3	3	0	3	3	1	1	3	1	3	9	3	9	1	9	3	1	9	3	*86*
4	PC2: Dignity	1	0	3	1	1	3	3	3	0	1	3	1	0	3	3	1	1	3	1	1	3	1	3	1	3	1	3	3	0	*51*
3	PC3: Agility	1	3	9	1	0	3	0	1	3	3	3	1	0	3	0	0	1	3	1	1	3	1	3	9	9	0	9	3	0	*74*
1	PC4: Affirmation	1	0	3	0	0	1	3	3	1	1	3	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	3	0	*25*
1	PC4: Stable	3	1	1	3	3	3	1	1	0	1	3	3	0	3	1	0	3	9	3	1	3	1	3	0	9	9	0	9	3	*80*
	Technical importance score	49	29	135	74	41	217	40	83	42	24	69	63	0	207	90	10	10	120	65	20	110	30	70	110	105	10	95	150	10	*2078*
	Importance %	**2.36**	**1.40**	**6.50**	**3.56**	**1.97**	**10.44**	**1.92**	**3.99**	**2.02**	**1.15**	**3.32**	**3.03**	**0.00**	**9.96**	**4.33**	**0.48**	**0.48**	**5.77**	**3.13**	**0.96**	**5.29**	**1.44**	**3.37**	**5.29**	**5.05**	**0.48**	**4.57**	**7.22**	**0.48**	**100%**
	Priorities rank	17	22	4	12	19	1	20	11	18	23	14	16	29	2	10	25	25	5	15	24	6	21	13	6	8	25	9	3	25	