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Integrating user perceptions of socio-emotional aspects in wheelchair design: A pilot study using Kansei Engineering

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ABSTRACT

Introduction: Comfort in wheelchair use is influenced not only by ergonomic factors but also by socio-emotional aspects that shape the user's experience. This study aims to explore how socio-emotional factors can be integrated into the representational aspects of wheelchairs.
Methods: 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.
Results: 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, with 8.61% for manual and 10.44% for powered models, as key to enhancing socio-emotional aspects.
Conclusions: 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.

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; Product et al., 2007). Emotional design thus explores the feelings products evoke through sensory interactions (Desmet, 2012). However, these emotions are often unconscious and challenging to articulate (Grimsaeth et al., 2010; Dorneles et al., 2023; Zhang

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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 (Costa et al., 2010; Mallin and Carvalho, 2015). 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 and 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 (Blach Rossen et al., 2012; Papadimitriou, 2008). 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.

While technological advancements, such as smart wheelchairs and integrated intelligent systems increased user acceptance and perceived usefulness (Barbosa et al., 2018; Tavares et al., 2016), research shows that aesthetics play a crucial role in the adoption or rejection of such devices (dos Santos et al., 2022). Earlier studies also found that new wheelchair designs have a more positive emotional impact on children than conventional models (Desmet and 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. In this context, WUs exhibit stronger emotional responses to various wheelchair models than non-users, who generally evaluate wheelchairs more negatively (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 et al., 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 (Rasoulivalajoozi et al., 2025). 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 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 (Lokman et al., 2017; Ismail et al., 2014), no studies have specifically used the KE method to address and polish the socio-emotional aspects of wheelchairs.

The remaining sections of the paper is organized as follows: Section 2 presents an overview of the KE method and details the steps for establishing the KE framework in wheelchair development. Section 3 reports the results and findings from each step of KE. Section 4 discusses the results, offers recommendations for industrial designers, addresses research limitations, and suggests future directions. Finally, Section 5 concludes the paper.

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 Fig. 1. 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.

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

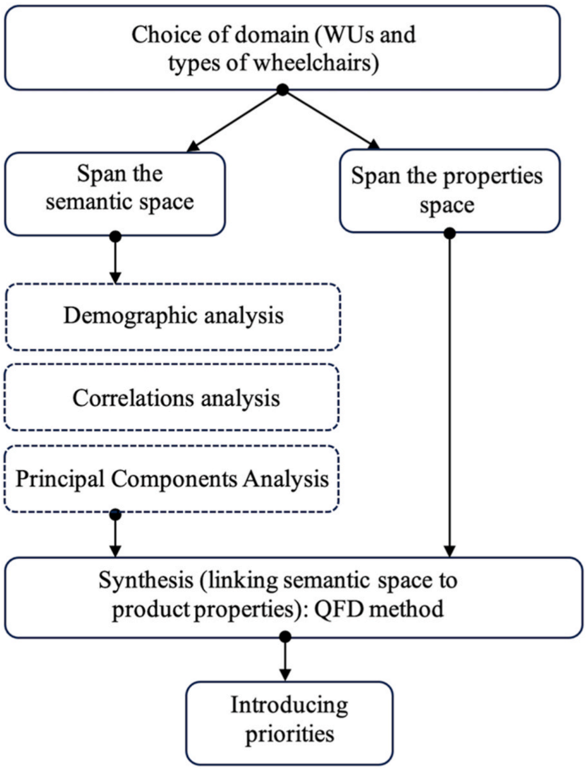

Fig. 1. The procedure of KE Type 1.

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 Cirrus Plus EC) and the 'Excel 2000 Series Wheelchair' by Medline 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, 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, 2014). We identified the visual features of wheelchairs that shape WDCs by applying the Criticism of Interface Aesthetics (CIA) concept (Bertelsen and Pold, 2004), traditionally used in HCI, to understand wheelchair visual perception. The first CIA step, Stylistic References, widely applied in graphics, industrial design, and architecture (Faraji and Valajoozi; Rasouli Valajoozi and Zangi, 2016; Cucuzzella et al., 2024), 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. The study was conducted over three months in Canada and Iran. To mitigate cultural differences and ensure consistency, the concept of each KW was carefully translated into Persian by native scholars. 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 ($<.05$) 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 et al., 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[1] (Brace et al., 2007). Eigenvalues greater than .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, 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 (Schütte et al., 2004; Ginting et al., 2020). 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 I 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 II). TI values are calculated as follows, where TI_j represents the technical importance of the *j*th requirement; R_{ij} is the relationship strength between the ith 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 1) that capture the socio-emotional

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

Table 1
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
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 2
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		

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 2).

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 Fig. 2 for details). This suggests that while aesthetics is prioritized over symbolism by most participants, both factors are important to WUs (see Fig. 3).

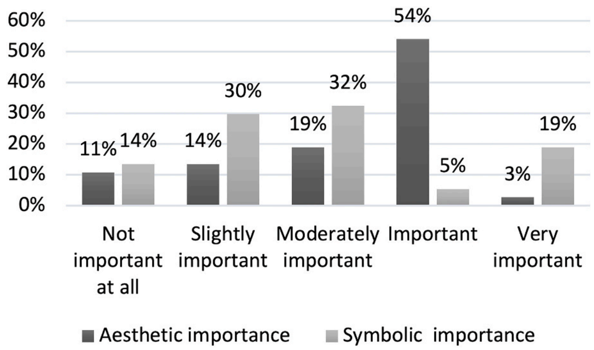

Fig. 2. The distribution of Aesthetic and Symbolic importance among WUs.

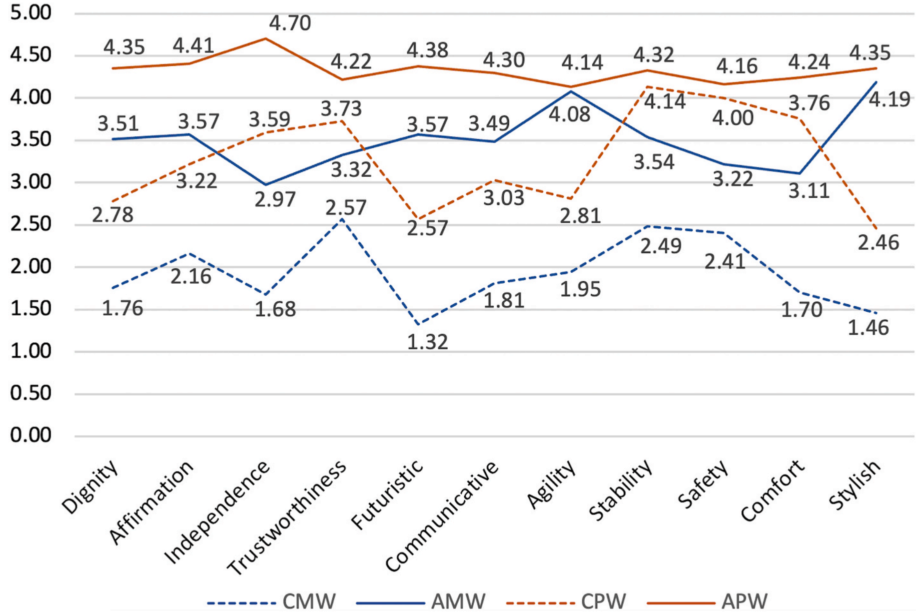

Fig. 3. Scorelines of four WDCs based on the KWs.

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 3). 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.

The investigation examined the relationship between age and gender with the aesthetic and symbolic aspects of wheelchairs, yielding several key findings (Table 4). 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 3
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)	.042	.213 (1)	.893	.042
Gender	0.187[b] (1)	.666	.670 (1)	.071	.666
Aesthetics importance	10.458[c] (4)	.033	.236 (1)	.532	.236
Symbolic importance	18.060[d] (4)	.001	.002 (1)	.699	.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.

Table 4
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)	.008	.037 (1)	.839	.008
Age & Symbolic importance	107.040 [b] (72)	.005	.108 (1)	.850	.005
Gender & Aesthetic importance	12.428 [c] (4)	.014	.003 (1)	.580	.014
Gender & Symbolic importance	3.231 [d] (4)	.520	.538 (1)	.296	.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. Fig. 2 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.

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 5). 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.

Table 5
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 6
Rotated Component Matrix for both AMW (left) and APW (right).

Variables	Rotated Component Matrix[a]: AMW			Rotated Component Matrix[b]: APW		
	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
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.

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 = .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 6).

The Rotated Component Matrix in Table 6 presents the principal components for AMW and APW as follows:

AMW.

- C1: High loadings for Safety (.907), Stability (.714), and Futuristic (.677), with Trustworthiness, Affirmation, and Communicative contributing to lesser extent.
- C2: Significant loadings for Comfort (.820), Agility (.702), Communicative (.676), and Stylish (.675).
- C3: Dominated by Dignity (.879), with moderate contributions from Affirmation (.666) and Trustworthiness (.658), and lesser input from Independence.

APW.

- C1: Strong associations with Independence (.896), Futuristic (.892), Trustworthiness (.742), Communicative (.715), Comfort (.715), and Stylish (.660).
- C2: High loadings for Safety (.785) and Dignity (.763), with Trustworthiness contributing less significantly.
- C3: Dominated by Agility (.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 (Fig. 4), with the rationale for these names provided in the discussion section.

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 (see Appendix I for details). 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 (Fig. 5).

The initial QFD analysis results, shown in Fig. 5, 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.

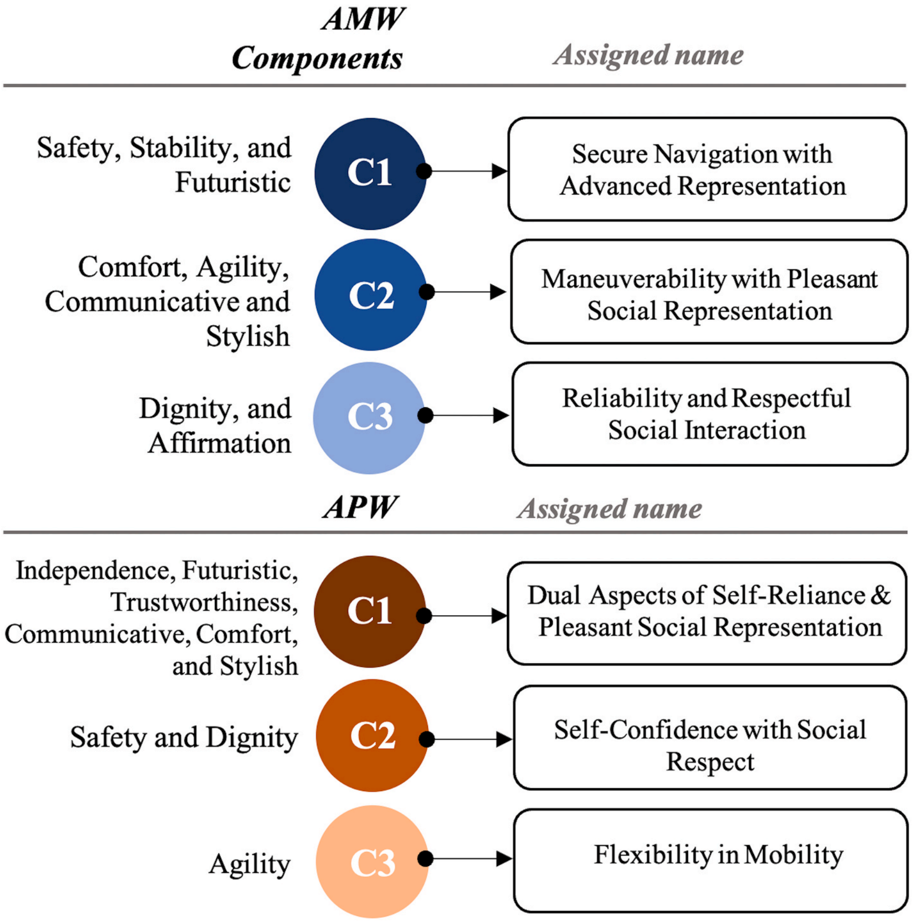

Fig. 4. The assigned name for each principal components in each category of AMW and APW.

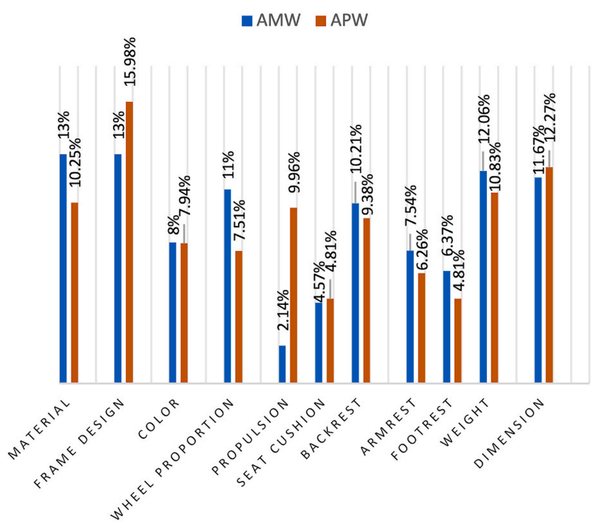

Fig. 5. Technical importance of each technical properties.

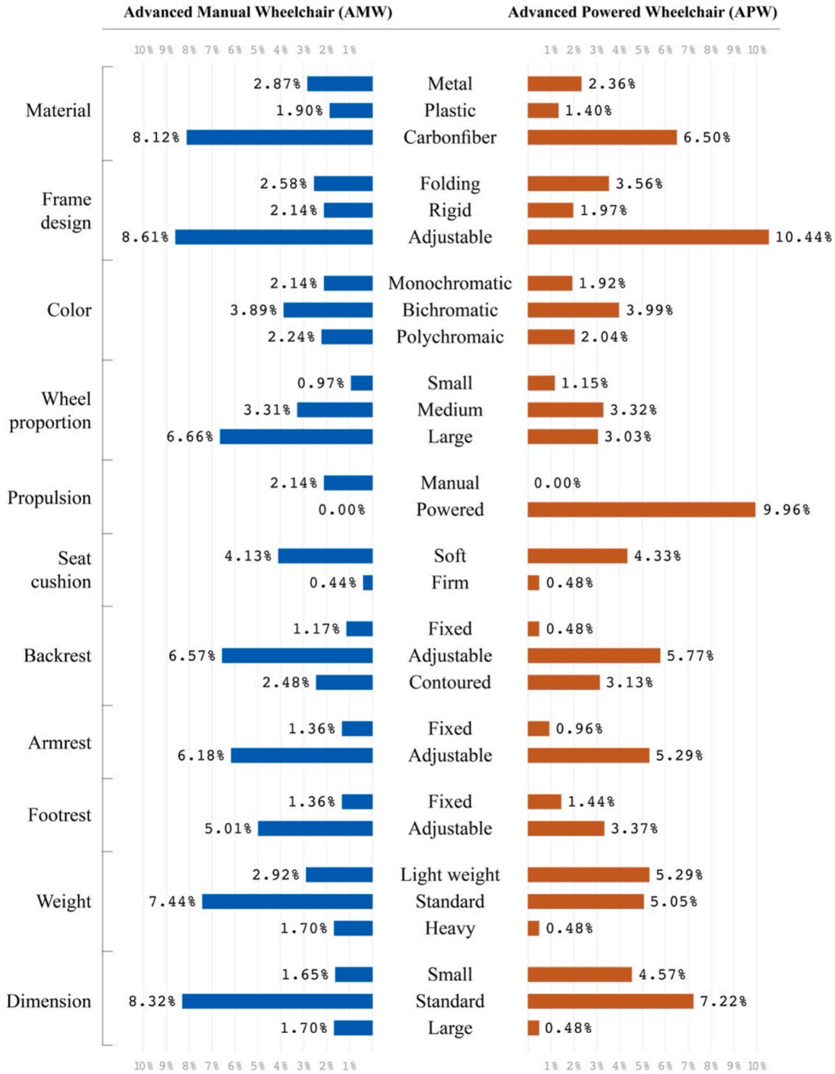

Fig. 6. Technical importance of each sub-categories of technical properties for considering the priorities in developing AMW and APW.

Fig. 6 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%).

In the concluding analysis of the results, we summarize the key lessons learned from the study. Table 7 highlights the main findings at each stage, aiding in the identification of the most prominent aspects for discussion.

Table 7
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.
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., 2020Wickenden et al., 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 (Weir, 2023; Donizzetti, 2019).

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 Ageing Society, 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 and 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.

4.3. 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 (Rasoulivalajoozi et al., 2025). Additionally, emotional 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. Furthermore, while the identified components and proposed technical requirements align with the WDCs in this study, future research could integrate these findings into advanced technologies, such as smart wheelchairs (Zhang et al., 2024), and intelligent systems designed to improve accessibility (Barbosa et al., 2018; Tavares et al., 2016). Capturing WUs' socio-emotional experiences in relation to these integrated designs would offer valuable insights into their perceptions.

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.

CRediT authorship contribution statement

Mohsen Rasoulivalajoozi: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Morteza Farhoudi:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Data curation.

Disclosure

The authors confirms that the abstract and full-text of this research has not been presented at any other journal, symposiums, conferences, or events.

The article's publication has been explicitly approved by the authors at the institution where the work was conducted. If accepted, the article will not be published elsewhere in the same form, in English or in any other language, including electronically, without the written consent of the copyright-holder.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT Open AI in order to improve the writing. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

The authors do not have permission to share data.

References

Medline Medline Excel 2000 Series wheelchairs Available online: https://www.medline.com/product/Medline-Excel-2000-Series-Wheelchairs/Z05-PF05425?question=wheelchair& (accessed on 27 August 2024).

Barbareschi, G., Carew, M.T., Johnson, E.A., Kopi, N., Holloway, C., 2021. "When they See a wheelchair, They've not even seen Me"—factors shaping the experience of disability stigma and discrimination in Kenya. Int. J. Environ. Res. Publ. Health 18, 4272. https://doi.org/10.3390/ijerph18084272.

Barbosa, J., Tavares, J., Cardoso, I., Alves, B., Martini, B., 2018. TrailCare: an Indoor and Outdoor context-Aware system to assist wheelchair users. Int. J. Hum. Comput. Stud. 116, 1–14. https://doi.org/10.1016/j.ijhcs.2018.04.001.

Barlew, L., Secrest, J., Guo, Z., Fell, N., Haban, G., 2013. The experience of being Grounded: a Phenomenological study of Living with a wheelchair. Rehabilitation Nursing Journal 38, 193. https://doi.org/10.1002/rnj.96.

Bartholomew, D.J., 2010. Principal components analysis. In: Peterson, P., Baker, E., McGaw, B. (Eds.), International Encyclopedia of Education, third ed. Elsevier, Oxford, pp. 374–377. ISBN 978-0-08-044894-7.

Bertelsen, O.W., Pold, S., 2004. Criticism as an approach to Interface aesthetics. In: Proceedings of the Proceedings of the Third Nordic Conference on Human-Computer Interaction. Association for Computing Machinery, New York, NY, USA, pp. 23–32.

Blach Rossen, C., Sørensen, B., Würtz Jochumsen, B., Wind, G., 2012. Everyday Life for users of electric wheelchairs – a Qualitative Interview study. Disabil. Rehabil. Assist. Technol. 7, 399–407. https://doi.org/10.3109/17483107.2012.665976.

Brace, N., Kemp, R., Snelgar, R., 2007. SPSS for Psychologists: A Guide to Data Analysis Using Spss for Windows, third ed. Palgrave Macmillan, Basingstoke. ISBN 978-1-4039-8787-7.

Cahill, S.E., Eggleston, R., 1994. Managing Emotions in Public: the Case of Wheelchair Users. https://doi.org/10.2307/2787157.

Carneiro, L., Rebelo, F., Noriega, P., 2018. Different wheelchairs designs influence emotional Reactions from users and non-users? In: Rebelo, F., Soares, M.M., Rebelo, F., Soares, M.M. (Eds.), Proceedings of the Advances in Ergonomics in Design, pp. 572–580. Cham.

Costa, V., de, S.P., Melo, M.R.A.C., Garanhani, M.L., Fujisawa, D.S., 2010. Social representations of the wheelchair for People with Spinal Cord Injury. Rev. Latino-Am. Enfermagem 18, 755–762. https://doi.org/10.1590/S0104-11692010000400014.

Costa, P., Figueredo, F.M. da S., C, 2012. Portugal function versus emotion in a wheelchair design. In: Advances in Usability Evaluation Part II. CRC Press. ISBN 978-0-429-09724-9.

Crolic, C., Zheng, Y., Hoegg, J., Alba, J.W., 2019. The influence of product aesthetics on consumer inference making. Journal of the Association for Consumer Research 4, 398–408. https://doi.org/10.1086/705033.

Cucuzzella, C., Rasoulivalajoozi, M., Farzamfar, G., 2024. Spatial experience of Cancer Inpatients in the Oncology Wards: a Qualitative study in visual design aspects. Eur. J. Oncol. Nurs. 70, 102552. https://doi.org/10.1016/j.ejon.2024.102552.

Desmet, P., 2012. Faces of product pleasure: 25 positive emotions in Human-product interactions. International Journal of Dsign 6.

Desmet, P., Dijkhuis, E., 2003. A wheelchair can Be Fun: a case of emotion-Driven design. In: Proceedings of the Proceedings of the 2003 International Conference on Designing Pleasurable Products and Interfaces. Association for Computing Machinery, New York, NY, USA, pp. 22–27.

Donizzetti, A.R., 2019. Ageism in an aging society: the role of knowledge, Anxiety about aging, and stereotypes in Young People and adults. Int J Environ Res Public Health 16, 1329. https://doi.org/10.3390/ijerph16081329.

Dorneles, S.O., Francisco, R., Barbosa, D.N.F., Barbosa, J.L.V., 2023. Context Awareness in recognition of affective states: a systematic Mapping of the literature. Int. J. Hum. Comput. Interact. 39, 1563–1581. https://doi.org/10.1080/10447318.2022.2062549.

dos Santos, A.D.P., Ferrari, A.L.M., Medola, F.O., Sandnes, F.E., 2022. Aesthetics and the perceived stigma of assistive technology for visual Impairment. Disabil. Rehabil. Assist. Technol. 17, 152–158. https://doi.org/10.1080/17483107.2020.1768308.

Drive Medical Cirrus Plus EC. *Folding Power Wheelchair, 18 Seat* [Shopping website]. Align Home Health Care. https://alignhomehealthcare.ca/product/cirrus-plus-ec-folding-power-wheelchair-18-seat/.

Faraji, A., Valajoozi, M.R.. Interactive Foot Orthosis (IFO) for People with Drop Foot. Available online: https://www.scientific.net/AMM.464.129. (Accessed 7 March 2021).

Ginting, R., Ishak, A., Malik, A.F., Satrio, M.R., 2020. Integration of Kansei engineering and quality function Deployment (QFD) for product development : a literature review. IOP Conf. Ser. Mater. Sci. Eng. 1003, 012020. https://doi.org/10.1088/1757-899X/1003/1/012020.

Grimsaeth, K., Gangwar, M., Baggerud, B., Narain, R., 2010. Kansei engineering based emotional product design: an illustration by a Battery Drill Case-study. Kansei Engineering International Journal 9, 67–79. https://doi.org/10.5057/kei.9.67.

Hakim, A., Suhardi, B., Laksono, P.W., Ushada, M., 2024. Systematic review of Kansei engineering method developments in the design Field. J. Optimasi Sist. Ind. 23, 92–108. https://doi.org/10.25077/josi.v23.n1.p92-108.2024.

Ismail, M.N., Lokman, A.M., Sia Abdullah, N.A., 2014. Formulating Kansei concept of assistive device for People with physical disabilities. In: Proceedings of the 2014 3rd International Conference on User Science and Engineering (I-USEr), pp. 30–35.

Koleini Mamaghani, N., Rahimian, E., Mortezæ I, S.-R., 2014. Kansei Engineering Approach for Consumer's Perception of the Ketchup Sauce Bottle.

Lanutti, J.N.L., Medola, F.O., Gonçalves, D.D., da Silva, L.M., Nicholl, A.R.J., Paschoarelli, L.C., 2015. The significance of manual wheelchairs: a Comparative study on male and female users. Procedia Manuf. 3, 6079–6085. https://doi.org/10.1016/j.promfg.2015.07.752.

Lokman, A.M., Ismail, M.N., Abdullah, N.A.S., Omar, A.R., 2017. Kansei wheelchair design based on KJ method. Adv. Sci. Lett. 23, 4349–4353. https://doi.org/10.1166/asl.2017.8329.

Lu, H., Chen, Y., Wang, Y., 2008. Knowledge-based customers' Desirability Acquisition of Clothing. Proceedings of the 2008 Fourth International Conference on Natural Computation 7, 94–98.

Mallin, S.S.V., Carvalho, H.G., 2015. de Assistive Technology and User-Centered Design: Emotion as Element for Innovation. Procedia Manuf. 3, 5570–5578. https://doi.org/10.1016/j.promfg.2015.07.738.

Marco-Almagro, L., 2014. S; Schü Tte, S. Development of an Affective Sensorial Analysis Method for the Food Industry.
Masanja, M.M., Imori, M.M., Kaudunde, I.J., 2020. Factors associated with negative attitudes towards Albinism and People with Albinism: a case of Households Living with persons with Albinism in lake Zone, Tanzania. Open J. Soc. Sci. 8, 523–537. https://doi.org/10.4236/jss.2020.84038.
McLaughlin, M.E., Bell, M.P., Stringer, D.Y., 2004. Stigma and acceptance of persons with disabilities: Understudied aspects of Workforce Diversity. Group Organ. Manag. 29, 302–333. https://doi.org/10.1177/1059601103257410.
Meikle, J., 2016. People with disabilities treated like second-class citizens, Says Watchdog. Guardian.
Mokdad, M., Mebarki, B., Bouabdellah, L., Mokdad, I., 2018. Emotional responses of the Disabled towards wheelchairs. In: Chung, W., Shin, C.S. (Eds.), Proceedings of the Advances in Affective and Pleasurable Design. Springer International Publishing, Cham, pp. 86–96.
Nagamachi, M., 1999. Kansei engineering and its Applications in automotive design. SAE Trans. 108, 2275–2282.
Nagamachi, M., 2002. Kansei engineering as a powerful consumer-oriented technology for product development. Appl. Ergon. 33, 289–294. https://doi.org/10.1016/S0003-6870(02)00019-4.
Nagashima, T., 2012. Introduction to Kansei engineering. In: Saeed, K., Nagashima, T. (Eds.), Biometrics and Kansei Engineering. Springer, New York, NY, pp. 173–176. ISBN 978-1-4614-5608-7.
Office for Product Safety & Standards Ageing Society, 2021. Product Design for Older People.
Papadimitriou, C.C., 2008. Pettersson. Disabil. Soc. 23, 691–704. https://doi.org/10.1080/09687590802469420.
Product, Experience, Schifferstein, H.N.J., Hekkert, P. (Eds.), 2007, first ed. Elsevier Science, San Diego, CA.
Rasouli Valajoozi, M., Zangi, N.O., 2016. A review on visual criteria of pure Milk packaging for parents and their children (case study: Tehran, Iran). Br. Food J. 118, 83–99. https://doi.org/10.1108/BFJ-12-2014-0425.
Rasoulivalajoozi, M., Cucuzzella, C., Farhoudi, M., 2025. Perceived inclusivity in mobility aids Use: a Qualitative study in Iran. Disabilities 5, 15. https://doi.org/10.3390/disabilities5010015.
Sample, I., 2009. Women appreciate beauty better than men, Says study. Guardian.
Schütte, S.T.W., Eklund, J., Axelsson, J.R.C., Nagamachi, M., 2004. Concepts, methods and tools in Kansei engineering. Theor. Issues Ergon. Sci. 5, 214–231. https://doi.org/10.1080/1463922021000049980.
Soares, M.M., 2021. Ergodesign Methodology for Product Design: A Human-Centered Approach. CRC Press, Boca Raton. ISBN 978-1-00-321479-3.
Tavares, J., Barbosa, J., Cardoso, I., Costa, C., Yamin, A., Real, R. Hefestos, 2016. An intelligent system applied to Ubiquitous accessibility. Univ Access Inf Soc 15, 589–607. https://doi.org/10.1007/s10209-015-0423-2.
United Nation News, 2024, June 8. Convention on the Rights of Persons with Disabilities: 5 fast facts. UN News [United Nations], UN. https://news.un.org/en/story/2024/06/1150836.
Urbano, I.C.V.P., Guerreiro, J.P.V., Nicolau, H.M.A.A., 2022. From Skeuomorphism to Flat design: age-related differences in performance and aesthetic perceptions. Behav. Inf. Technol. 41, 452–467. https://doi.org/10.1080/0144929X.2020.1814867.
Weir, K., 2023. American Psychological Association, p. 36.
WHILL, inc.. WHILL Model C2 Wheelchair: Portable Electric Power Chair | WHILL [Company]. https://whill.inc/us/whill-model-c2/.
Wickenden, M., Thompson, S., Mader, P., Brown, S., Rohwerder, B., 2020. Accelerating Disability Inclusive Formal Employment in Bangladesh, Kenya, Nigeria, and Uganda: what Are the Vital Ingredients? the Institute of Development Studies and partner organisations. ISBN 978-1-78118-624-4.
Xue, L., Yen, C.C., 2007. Towards female preferences in design – a Pilot study. International Journal of Dsign 1.
Yorkston, K.M., Bourgeois, M.S., Baylor, C.R., 2010. Communication and aging. Phys. Med. Rehabil. Clin 21, 309. https://doi.org/10.1016/j.pmr.2009.12.011.
Zhang, J., Yin, Z., Chen, P., Nichele, S., 2020. Emotion recognition using Multi-Modal data and Machine learning techniques: a Tutorial and review. Inf. Fusion 59, 103–126. https://doi.org/10.1016/j.inffus.2020.01.011.
Zhang, X., Song, Z., Huang, Q., Pan, Z., Li, W., Gong, R., Zhao, B.Shared eHMI., 2024. Bridging Human–Machine understanding in autonomous wheelchair navigation. Appl. Sci. 14, 463. https://doi.org/10.3390/app14010463.
McNulty-Kowal, S. (2020, October 9). *This gear-adjustable manual wheelchair's upgrade helps wheel you uphill with ease—Yanko Design* [Online magazine]. https://www.yankodesign.com/2020/10/09/this-gear-adjustable-manual-wheelchairs-upgrade-helps-you-wheel-you-uphill-with-ease/.