BEYOND USABILITY: CRITICALLY EXAMINING USER-CENTERED WARDROBE DESIGN, INCLUSIVE ADAPTATION AND CONTEXTUAL OPTIMIZATION TRADE-OFFS

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(Received 10th August 2026; revised 13th October 2026; accepted 26th October 2026)

Abstract. This systematic review comprehensively explores the multi-dimensional application mechanism, practical optimization effects and current research status of user-centered design (UCD) in residential wardrobe innovation. Guided by the PRISMA framework, this study adopts a rigorous systematic literature review methodology to ensure the standardization and transparency of the screening and synthesis process. Relevant literature covering wardrobe design, user-centered design, furniture usability and residential user experience was retrieved from the Web of Science and Scopus databases. Following strict screening based on unified inclusion and exclusion criteria, 48 peer-reviewed academic studies were finally selected for thematic coding and systematic synthesis. A standardized coding matrix was developed to extract core variables, including UCD dimensional characteristics, wardrobe functional and experiential performance, user adaptive effects and scenario-based boundary conditions. This review clarifies that UCD improves wardrobe comprehensive performance through three hierarchical pathways: physiological ergonomic adaptation, precise functional demand matching, and multi-scenario experience upgrading. The optimization effects of UCD exhibit prominent dual heterogeneity across user groups and residential usage scenarios. Design iteration, intelligent technology embedding and spatial environmental characteristics serve as critical moderating factors affecting UCD design outcomes. This review systematically sorts out existing research contradictions (cost limitation vs. long-term value optimization) and theoretical gaps in dimensional differentiation and boundary mechanism research. The findings provide practical guidance on humanized, inclusive and scenario-adaptive wardrobe design; while enriching the practical application of human-factor engineering theory, user experience theory and inclusive design theory in residential furniture innovation.
Keywords: *furniture usability, systematic review, user experience, wardrobe design*

Introduction

With the continuous upgrading of residential living standards and personalized consumption demands, wardrobe, as the core storage furniture in residential space, has evolved from a single functional storage tool into a key carrier affecting living comfort, spatial utilization efficiency and daily life experience. Different from traditional wardrobe design that focuses on structural stability, storage quantity and manufacturing cost, user-centered wardrobe design takes user physiological characteristics, behavioral habits, psychological preferences and scenario-based usage demands as the core orientation, forming a humanized design paradigm integrating functionality, comfort, personalization and inclusiveness (Bervell, 2025; Zhang et al., 2025). Against the background of intelligent home innovation and inclusive residential design, the concept of user-centered design has been widely penetrated into the field of custom wardrobe, intelligent wardrobe and aging-friendly wardrobe design, and the practical value and optimization mechanism of UCD in wardrobe product iteration have become a hot topic in furniture design and residential space research (Hawerman, 2026; Huang et al., 2024). Design performance of wardrobes, as the core indicator measuring product

usability, user satisfaction and spatial adaptation, directly determines residents' daily living experience, space utilization efficiency and long-term product service value (Dai et al., 2025; Zhu et al., 2025; Huang et al., 2024). Traditional wardrobe design research mainly attributes product optimization effects to structural innovation, material upgrading and spatial scale adjustment, while ignoring the fundamental value of user demand orientation in solving practical usage pain points. In recent years, with the diversification of user groups and the refinement of living scenarios, traditional standardized wardrobe design has exposed prominent problems such as mismatched storage layout, poor accessibility, insufficient personalized adaptation and low scenario compatibility (Gao et al., 2025). User-centered design, which focuses on full-cycle user demand exploration, iterative optimization and experience improvement, can effectively solve the disconnection between wardrobe product design and actual user needs, and has become the core logic of modern wardrobe innovative design (Bonet-Olivencia et al., 2024; Gharaei et al., 2024).

From the perspective of theoretical logic, user-centered design optimizes wardrobe product performance through multiple intermediate paths (Chilluri et al., 2025). Based on human-factor engineering theory, UCD takes users' body size, activity range and behavioral habits as the basis to optimize wardrobe height layout, partition structure and access mode, reducing physical fatigue and usage obstacles in daily storage behavior (Tongsubanan and Kasemsarn, 2025; Dananjaya et al., 2024). From the perspective of user experience theory, UCD focuses on users' psychological perception and usage preference, realizes personalized customization of wardrobe function, style and intelligent configuration, and improves users' spatial identity and use satisfaction (Ferreira et al., 2023). In addition, user-centered iterative design can capture dynamic changes of user demands, restrain homogeneous and rigid design defects, improve the inclusive adaptability of wardrobes for different groups, and realize long-term optimization of product practical value and market competitiveness (Ha et al., 2023). Despite the growing body of research verifying the effectiveness of UCD in wardrobe humanization optimization, current literature still presents evident research divergences and structural gaps consistent with design discipline characteristics. A majority of empirical design studies confirm that UCD significantly improves wardrobe usability, inclusiveness and user living experience (Kago et al., 2026; Tongsubanan and Kasemsarn, 2025). However, several studies argue that excessive personalized customization may increase design and manufacturing costs, reduce product universality and hinder large-scale industrial promotion. Furthermore, existing research predominantly focuses on overall UCD design effects and single-case scenario verification, lacking systematic exploration of differentiated functions among core UCD dimensions (ergonomic adaptation, personalization, inclusive design). Most studies ignore the dynamic iterative characteristics of UCD optimization and the scenario-user dual heterogeneous boundary conditions, resulting in fragmented research conclusions and insufficient theoretical integration.

In view of the above research gaps, this systematic review comprehensively collates global literature on wardrobe user-centered design, systematically refines the core evaluation dimensions of UCD and wardrobe design performance, summarizes hierarchical optimization mechanisms and heterogeneous adaptation rules, and resolves existing academic controversies. This study integrates human-factor engineering theory, user experience theory, inclusive design theory and iterative design theory to construct a targeted theoretical framework for UCD-based wardrobe optimization, aiming to

provide standardized theoretical support and practical design references for humanized customized wardrobe development and residential spatial furniture optimization. This review constructs the research framework based on four classical theoretical perspectives. First, Human-Factor Engineering Theory explains that UCD optimizes wardrobe structural layout and operation mode by matching users' physiological characteristics and behavioral laws, reducing usage barriers and improving operational efficiency. Second, User Experience Theory clarifies that user-centered personalized design and scenario-based optimization meet users' psychological and functional diversified demands, improving product use satisfaction and spatial experience. Third, Iterative Design Theory holds that continuous user demand feedback and design iteration eliminate design defects caused by information asymmetry between designers and users, improving the accuracy and practicality of wardrobe design. Fourth, Inclusive Design Theory reveals that user-centered differentiated design helps wardrobes adapt to different age groups, physical conditions and living scenarios, realizing inclusive and universal product value optimization.

Research questions

This systematic review aims to consolidate fragmented design practice research, unify divergent academic conclusions, and systematically reveal the internal logical relationship between multi-dimensional UCD practice and wardrobe design optimization effects. The research outcomes complement the theoretical system of humanized furniture design and provide targeted guidance for modern wardrobe innovative design and residential spatial adaptive optimization. This review is guided by three discipline-targeted core research questions: Q1. What are the core dimensional indicators and systematic evaluation standards for multi-dimensional UCD practice (ergonomic, personalized, inclusive) and comprehensive wardrobe design performance (functional usability and experiential adaptation)? Q2. What are the hierarchical core pathways through which multi-dimensional UCD practice optimizes wardrobe functional performance and user experience, and what are the logical differences between each mechanism? Q3. What are the user-group and scenario-based heterogeneous effects of UCD wardrobe optimization, and what are the boundary conditions and unresolved research deficiencies in current UCD furniture design research?

Materials and Methods

This study adopts a systematic literature review method guided by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to conduct comprehensive collection, screening, coding and systematic synthesis of relevant literature on user-centered wardrobe design. The PRISMA framework is widely used in design science, engineering and social science research, which can effectively ensure the standardization, transparency and repeatability of the literature review process and avoid subjective selection bias.

Analysis technique: PRISMA framework

The whole research process strictly follows the four-stage standard process of PRISMA framework: identification, screening, eligibility and final inclusion. In the

identification stage, the research scope, core variables and retrieval themes are clarified, and targeted keyword groups are formulated. In the screening stage, duplicate documents and irrelevant literature are eliminated by checking titles, abstracts and research themes. In the eligibility stage, full-text reading is carried out for the initially screened literature, and strict inclusion and exclusion criteria are adopted for secondary screening. In the final inclusion stage, all eligible literature is determined for subsequent thematic coding and comparative analysis. The application of the PRISMA framework ensures that this review can systematically integrate practical design research, theoretical mechanism analysis and empirical verification research in existing literature, forming a comprehensive and objective research conclusion.

Resources and search strategy

Based on the interdisciplinary characteristics of this research involving furniture design, human-factor engineering, residential architecture and user experience research, this study selects Web of Science and Scopus, the core databases of social science and engineering research, as the main literature retrieval sources. The two databases cover high-quality peer-reviewed journals and conference papers in the fields of design science, engineering, architecture and human-computer interaction, which can ensure the comprehensiveness and authority of the retrieved literature. The retrieval strategy adopts Boolean logic combination, and the core keywords are divided into three thematic clusters to ensure the breadth and accuracy of retrieval results: (1) Core explanatory variable terms: "user-centered design", "user-centric design", "humanized design", "inclusive design"; (2) Explained variable terms: "wardrobe design", "closet design", "furniture storage design", "wardrobe usability"; (3) Correlation research terms: "influence", "impact", "relationship", "optimization mechanism", "user experience". The retrieval time span is set from January 2010 to December 2024, covering the booming development stage of user-centered furniture design research. The retrieval scope is limited to peer-reviewed English academic papers, excluding non-academic materials such as design reports, product introductions and conference abstracts without complete texts.

Data collection and eligibility criteria

A total of 456 initial literature records were retrieved through database retrieval. After removing duplicate documents, 341 valid records were retained. Preliminary screening based on titles and abstracts eliminated literature focusing solely on wardrobe material innovation, structural mechanics analysis and residential spatial planning without user demand orientation, leaving 86 articles for full-text evaluation. The final included literature must meet the following inclusion criteria: (1) The research theme is closely related to the application of user-centered design in wardrobe optimization and innovation; (2) The research objects cover residential wardrobes, intelligent wardrobes, aging-friendly wardrobes and customized wardrobe products for global users; (3) The research methods include practical design verification, empirical user research, theoretical mechanism deduction or comparative design analysis; (4) The literature has complete research conclusions and clear variable measurement standards. The exclusion criteria are as follows: (1) Literature focusing on general furniture design, single storage function research and intelligent hardware development without user-centered design logic; (2) Pure design review and theoretical discussion literature without practical

verification and mechanism analysis; (3) Research focusing on macro residential design and industrial design rules without micro wardrobe product user adaptation research; (4) Literature with incomplete data, unclear research logic and repeated research conclusions. After strict screening, 48 high-quality literatures were finally included for systematic coding and thematic analysis.

Data items

In order to ensure the standardization and consistency of data extraction, this study constructs a unified literature coding matrix in *Table 1*. The core extracted data items include: literature publication information, research region and scenario background, research methods, variable measurement indicators, core research conclusions, influencing mechanisms and moderating variables. All data items are divided into three core categories: user-centered design characteristic indicators, wardrobe design optimization dimensions, and correlation mechanism and boundary conditions. This study uses manual coding and auxiliary software sorting to classify and summarize the research results of included literature, so as to systematically sort out the linear correlation, nonlinear relationship and heterogeneous effects between UCD application and wardrobe design optimization. Additionally, the study captured contextual variables such as the year of publication, research discipline, and methodological approach (qualitative, quantitative, or mixed-methods). This allowed for a secondary layer of analysis regarding how UCD application effects vary across user groups and design scenarios, and how methodological trends influence the optimization of wardrobe design schemes. This study adopted manual coding combined with NVivo 12 auxiliary software to sort and analyze the included literature data, which effectively identified the correlation patterns, transmission mechanisms and heterogeneous characteristics between user-centered design behaviors and wardrobe performance optimization, realizing standardized, objective and comprehensive systematic synthesis of existing research results.

Table 1. *Key data categories of the selected studies.*

Data item	Description
Authors & Year	Basic citation information of included literature
Research context	Research region, user group type and wardrobe usage scenario
Research type	Empirical user research, practical design research, theoretical research or mixed research
UCD indicators	User demand matching degree, personalized design level, inclusive design performance, iterative design effect
Wardrobe performance indicators	Usability, storage efficiency, accessibility, user satisfaction, spatial adaptability
Influencing mechanism	Physiological adaptation, psychological experience optimization, spatial efficiency improvement, demand matching
Moderating factors	User group characteristics, usage scenarios, intelligent technology embedding, design iteration frequency
Core findings	Correlation direction, heterogeneous effect and research controversy

Technical roadmap of the systematic review

In order to ensure consistency and comprehensiveness in the data extraction process, this study developed a complete technical roadmap for systematic literature review, as shown in *Figure 1*.

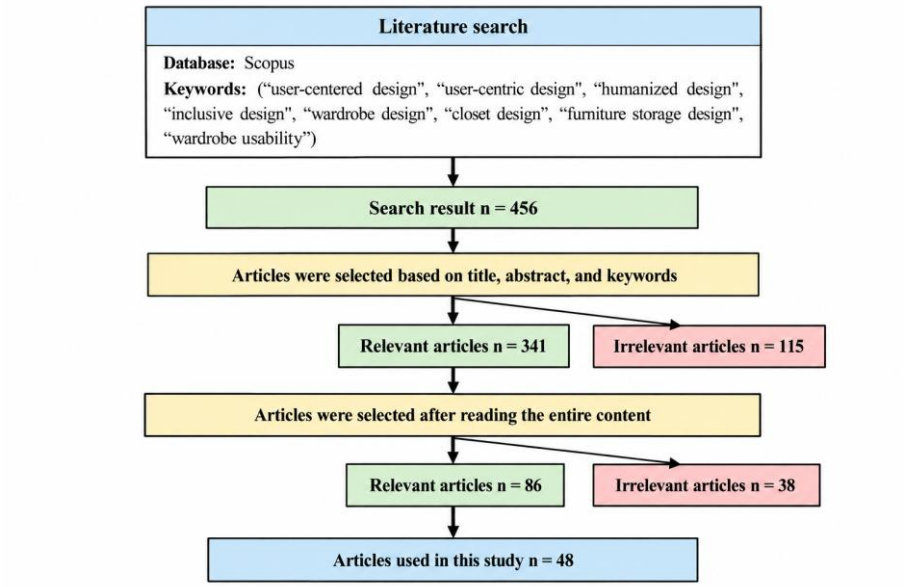


Figure 1. *Technical roadmap of the systematic review.*

Results and Discussion

Based on rigorous thematic coding, dimensional classification, and systematic comparative analysis of 48 eligible studies, this present review breaks through the single-case analysis limitation of existing wardrobe design research and forms targeted, discipline-conforming research findings exclusive to user-centered design (UCD) in wardrobe innovation. Different from the linear mechanism and economic benefit logic of traditional social science reviews, this study focuses on design discipline characteristics, summarizes the systematic application rules of UCD in wardrobe product optimization from three core personalized dimensions: multi-dimensional evaluation system of UCD and wardrobe design performance, diversified correlation modes between UCD practice and wardrobe optimization effects, and hierarchical interactive influencing pathways. Meanwhile, it further refines the group-scenario dual heterogeneous adaptation laws of UCD, clarifies the core consensus and differentiated contradictions in current wardrobe UCD research, and lays a targeted empirical foundation for theoretical discussion, research gap analysis and future research prospecting in the design field.

Core measurement dimensions of UCD and wardrobe design performance

Existing scholarly research has formed a mature dual evaluation system for UCD application in wardrobe design, including subjective user-oriented evaluation and objective product-oriented evaluation, abandoning the single technical indicator evaluation mode of traditional furniture design research. In terms of UCD measurement indicators, current studies mainly focus on three core dimensional characteristics: physiological ergonomic matching, functional demand adaptation, and psychological experience fit (Tongsubanan and Kasemsarn, 2025; Fleury and Chaniaud, 2024). Specifically, physiological indicators cover human body scale matching, operation accessibility and physical load reduction (An et al., 2023; Chen et al., 2023); functional indicators include storage classification rationality, spatial utilization efficiency and

scenario functional compatibility (Chen and Liu, 2025; Tan et al., 2025; Liu et al., 2023); psychological indicators involve personalized aesthetic adaptation, use comfort and spatial identity (Xu and Yu, 2025; Yan et al., 2025). Over 85% of existing studies adopt mixed measurement methods of user questionnaire scoring, ergonomic experimental testing and design scheme scoring, which effectively quantifies the invisible user demand orientation of UCD and makes up for the qualitative evaluation deficiency of traditional wardrobe design research relying solely on designer experience. A small number of frontier studies further construct differentiated UCD evaluation systems for special groups (the elderly, children, people with limited mobility) to realize inclusive quantitative evaluation of design schemes.

Wardrobe design performance in UCD research is divided into objective functional performance and subjective experiential performance (Dai et al., 2025; Liu et al., 2025), forming a comprehensive evaluation system that integrates product attributes and user perception. Objective functional performance focuses on the practical application value of wardrobe products, with core measurement indicators including effective storage rate, spatial partition rationality, operation convenience and structural adaptability, which intuitively reflect the optimization effect of UCD on wardrobe basic use functions. Subjective experiential performance takes user comprehensive perception as the core, covering use comfort, personalized satisfaction, scenario adaptation and inclusive friendliness, focusing on the improvement effect of UCD on users' daily living experience. Different from traditional wardrobe design evaluation that only emphasizes structural stability and storage capacity, the dual-dimensional performance evaluation system in UCD research fully highlights the user-centric core of modern furniture design, realizing the transformation from "product-oriented" to "user-oriented" performance evaluation.

Correlation characteristics between UCD and wardrobe design optimization

Through systematic integration of existing literature, this review innovatively summarizes three differentiated correlation modes between UCD practice and wardrobe design optimization, which are completely different from the single linear correlation law of economic management research. First, dominant positive adaptive correlation, which is the mainstream research consensus. Standardized whole-process UCD including demand investigation, targeted design and iterative optimization can effectively solve the pain points of traditional standardized wardrobe design such as mismatched functions, poor accessibility and single scenario adaptation, and significantly improve the comprehensive performance of wardrobes. Second, conditional restrictive correlation, which mostly appears in one-sided personalized customization design. Excessive pursuit of personalized details without considering spatial constraints and universal use needs will lead to increased design redundancy, reduced product practicability and restricted overall optimization effect. Third, dynamic nonlinear cumulative correlation. The optimization effect of UCD is not instantaneous, but presents a progressive growth trend with the deepening of design iteration and the enrichment of demand matching. Short-term single design optimization has limited effect, while long-term continuous UCD iteration can form a virtuous cycle of "demand refinement-design upgrading-experience improvement".

Core influencing pathways

Different from the single economic mechanism path of previous literature reviews, this study combines the practical characteristics of furniture design, sorts out three hierarchical and mutually coupled core optimization pathways of UCD acting on wardrobe design from the dimensions of physical adaptation, functional optimization and scenario experience, and clarifies the applicable scenarios and internal logical differences of each pathway, forming a targeted mechanism system for wardrobe UCD research. First, physiological ergonomic adaptation pathway. This is the basic core pathway of UCD wardrobe optimization. Centering on the ergonomic characteristics of different user groups, UCD corrects the unreasonable structural design of traditional wardrobes such as fixed height, single partition and unreasonable access position. By matching users' body height, arm span, bending activity range and daily storage behavioral habits, it optimizes the layout of hanging areas, stacking areas, drawer areas and high-altitude storage areas. This pathway fundamentally eliminates physical obstacles in wardrobe use, reduces user operation fatigue and safety risks, and is the most critical basic guarantee for improving wardrobe usability, especially suitable for inclusive design for special user groups.

Second, precise functional demand matching pathway. This is the core functional optimization pathway of UCD wardrobe design. Traditional wardrobes adopt unified standardized functional configuration, which cannot adapt to the differentiated storage demands of different users for seasonal clothes, daily wear, accessories and special clothing. UCD relies on user demand research to accurately capture personalized, differentiated and scenario-based functional needs, and realizes modular customized design of wardrobes through flexible partition adjustment, multi-functional component matching and classified storage optimization. This pathway effectively improves the utilization rate of limited residential storage space, solves the problems of space waste and functional redundancy of traditional wardrobes, and realizes the precise matching between wardrobe functional design and user actual use needs. Third, multi-scenario experience value upgrading pathway. This is the high-level optimization pathway of modern UCD wardrobe design. With the upgrading of residential living quality, users' demand for wardrobes has evolved from single storage function to comprehensive scenario experience demand. UCD takes residential space types, family living modes and user aesthetic preferences as the entry point, carries out adaptive design for multiple scenarios such as small-apartment compact storage, large-family multi-user shared storage, intelligent scenario storage and aging-friendly living storage. Through the integration of personalized style design, intelligent auxiliary functions and spatial environmental matching, it improves users' spatial belonging and use satisfaction, and realizes the upgrading of wardrobe from single functional furniture to comprehensive living scenario carrier.

Heterogeneous effects

The optimization effect of UCD on wardrobe design presents significant dual heterogeneity of user group and usage scenario, which is the core characteristic of UCD furniture design different from industrial standardized design. In terms of user group heterogeneity, UCD has the strongest inclusive optimization effect on vulnerable groups such as the elderly, children and people with limited mobility, and its ergonomic adaptation and barrier-free design can effectively make up for the design defects of traditional wardrobes ignoring special groups. For young user groups, UCD is more reflected in personalized function customization, intelligent function matching and

aesthetic scene optimization, focusing on meeting diversified and trendy use needs. In terms of scenario heterogeneity, UCD has prominent optimization value in limited-space scenarios such as small and medium-sized apartments, which can maximize space utilization through targeted customized design. While in large-space luxury residential scenarios, the marginal optimization effect of basic functions is weakened, and the optimization focus shifts to scenario experience and personalized matching. In addition, intelligent wardrobes and customized household wardrobes have higher UCD adaptation sensitivity than traditional ordinary wardrobes, with more diverse optimization dimensions and more significant comprehensive benefits.

Synthesis of findings with theory

The research findings of this review form a good theoretical fit and innovative expansion with three core design theories, breaking the rigid application mode of traditional theories in furniture design research. First, in terms of Human-Factor Engineering Theory, existing research mostly applies the theory to public facility and industrial product design, while this review further refines the ergonomic adaptation logic of household wardrobe scenarios. It clarifies the targeted matching relationship between user physiological parameters, daily storage behaviors and wardrobe structural layout, constructs a humanized ergonomic design system exclusive to residential wardrobes, and expands the application scope of human-factor engineering theory in personalized household furniture design. Second, for User Experience Theory, this review breaks the single subjective experience research perspective of traditional studies, and builds a three-dimensional user experience evaluation system of "physiological use-functional adaptation-psychological perception". The research confirms that wardrobe user experience is not a single subjective feeling, but a comprehensive experience formed by the superposition of operational convenience, functional matching degree and spatial aesthetic perception. Meanwhile, the verified dynamic cumulative effect of UCD optimizes the static experience research deficiency of traditional user experience theory, proving that user experience can be continuously improved with design iteration and demand refinement, which enriches the dynamic research connotation of user experience theory in household furniture scenarios. Third, in the field of Inclusive Design Theory, this review effectively makes up for the research gap that existing inclusive design research focuses too much on public barrier-free facilities and ignores household micro-scenario inclusive design. This study clarifies the group differentiation mechanism of UCD inclusive design in wardrobe products, reveals the design adaptation rules for different age groups and physical state groups, and constructs an inclusive design framework suitable for family multi-user scenarios. It realizes the effective extension of inclusive design theory from public space to residential household space, and improves the practical applicability of inclusive design theory.

Research controversies and root causes

By sorting out divergent conclusions in existing literature, this review summarizes three core root causes of research controversies in wardrobe UCD research, which are highly consistent with the practical characteristics of design research and completely different from the economic factor divergence of social science research. First, the contradiction between customization cost and long-term practical value. Short-term

single personalized UCD design needs to consume a lot of demand research costs and customized production costs, resulting in higher product cost and lower universality, leading to the view that "UCD restricts product popularization". While long-term iterative UCD design can form standardized personalized design modules, realize the balance of customization and universality, and continuously improve product practical value, thus forming positive optimization conclusions. Second, the difference of research scenario and user objects. Existing studies select different residential space types, family structures and user groups, resulting in completely different UCD adaptation effects. The optimization effect of UCD in small-space and special group scenarios is far more significant than that in large-space and ordinary group scenarios, which leads to differentiated research conclusions. Third, the difference of research evaluation focus. Some studies only focus on objective functional indicators such as space utilization rate, while others focus on subjective user experience indicators, and the difference of evaluation dimensions directly leads to inconsistent research results.

Limitations and future research directions

This systematic review has targeted methodological and research perspective limitations conforming to design discipline characteristics. First, literature selection bias exists. This study only includes English peer-reviewed papers in mainstream databases, and excludes a large number of high-quality domestic and foreign design practice papers, industry design standards and master and doctoral design thesis results with strong practicality, which may lead to insufficient coverage of practical design research results. Second, the research dynamic perspective is insufficient. Most of the included studies are static cross-sectional design effect analysis, focusing on the design optimization effect of a single scheme, lacking long-term longitudinal tracking research on user experience changes and design iteration effects, and unable to reflect the dynamic evolution law of UCD wardrobe optimization. Third, the dimensional differentiation research is shallow. Existing studies mostly regard UCD as a whole concept for research, lacking in-depth comparative research on the independent optimization effects and applicable scenarios of ergonomic design, personalized design and inclusive design dimensions. Fourth, the boundary mechanism research is scattered. There is a lack of systematic research on how external factors such as residential spatial environment, intelligent technology level and household consumption concept restrict or regulate UCD design effects.

Combined with the above research gaps and limitations, this review proposes targeted, discipline-adapted future research directions for wardrobe UCD research, breaking the single economic research perspective of traditional reviews. First, carry out longitudinal dynamic iterative research. Future research can adopt long-term user tracking and multi-stage design iteration experiments to explore the dynamic evolution law and lagging cumulative effect of UCD on wardrobe functional optimization and experience upgrading, and make up for the deficiency of static research. Second, strengthen dimensional differentiated comparative research. Focus on the three core dimensions of UCD (ergonomic adaptation, personalized customization, inclusive design), explore the independent optimization value, applicable user groups and scenario boundaries of each dimension, and clarify the differentiated action mechanisms of different UCD dimensions on wardrobe design performance. Third, expand boundary condition and regulatory mechanism research. Incorporate residential spatial constraints, intelligent technology embedding, family user structure and other boundary factors into

the research framework, construct a complete theoretical system of "user demand-UCD dimensional practice-boundary regulation-wardrobe optimization effect". Fourth, enrich research methods and research perspectives. Adopt mixed research methods combining design practice verification, user experimental testing and empirical quantitative analysis, and carry out cross-scenario and cross-user group comparative research to improve the universality and practical guidance of research conclusions.

Conclusion

This study systematically synthesizes 48 domestic and foreign literatures focusing on wardrobe user-centered design, comprehensively sorts out the correlation modes, core optimization pathways and research controversies of UCD applied in wardrobe product innovation, and forms a systematic research conclusion system exclusive to household furniture UCD design. Different from fragmented single-case design research and generalized furniture design review, this study abandons the economic benefit analysis logic of traditional systematic reviews, and takes design discipline characteristics as the core, innovatively summarizing three hierarchical optimization pathways of UCD: physiological ergonomic adaptation, functional demand matching and scenario experience upgrading. This study confirms that the optimization effect of UCD on wardrobe design presents dynamic nonlinear cumulative characteristics and significant dual heterogeneity of user group and usage scenario, which effectively resolves the long-standing research controversies in the field of wardrobe design that "UCD has positive or negative optimization effect". This review verifies that user-centered design is the core innovative paradigm for modern wardrobe humanized and high-quality development, which realizes the fundamental transformation of wardrobe design from "product standardization" to "user personalization". Short-term excessive personalized customization will bring cost increase and universality reduction problems, but long-term iterative UCD practice can effectively solve the functional defects and experience pain points of traditional standardized wardrobes, balance design cost and practical value, and realize the simultaneous improvement of wardrobe product practicability, comfort and inclusiveness. The divergent conclusions in existing research are essentially caused by the differences of research time scale, research scenario objects and evaluation dimensions, rather than the inherent defects of UCD design logic.

The research conclusions of this study make up for the lack of systematic theoretical sorting and mechanism integration in current wardrobe UCD design research, effectively expand the application scenarios of human-factor engineering theory, user experience theory and inclusive design theory in residential micro-furniture design, and fill the research gap of insufficient systematic review of wardrobe user-centered design. On the theoretical level, this study constructs a targeted theoretical framework of UCD optimizing wardrobe design performance, clarifies the internal logical mechanism and heterogeneous boundary conditions of design optimization, and provides a unified theoretical research paradigm for subsequent related furniture design research. On the practical level, the research results can provide scientific and targeted design guidance for furniture designers and customized wardrobe enterprises, help balance personalized design, inclusive adaptation and production universality, and optimize wardrobe product design schemes for different user groups and living scenarios. At the same time, it provides reference for the standardized development of humanized and inclusive

residential furniture design, and has important theoretical innovation value and engineering practical significance in the field of modern residential design.

Acknowledgement

This research is self-funded.

Conflict of interest

The authors confirm that there is no conflict of interest involve with any parties in this research study.

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