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Adaptive and User-Centered HCI for Intelligent Technologies: A Global Perspective

Abdurrohman
STMIK Mercusuar, Indonesia
Correspondent: oman@mercusuar.ac.id

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ABSTRACT: Human-Computer Interaction (HCI) within intelligent systems plays a critical role in shaping user experience, particularly through effective design, usability, and accessibility. This narrative review aims to synthesize current research trends and challenges in designing inclusive and adaptive HCI environments. Literature was gathered from Scopus and Google Scholar using keywords such as "Human-Computer Interaction," "Intelligent Systems," "Usability," "Accessibility," and "User-Centered Design." Articles were selected based on inclusion criteria focusing on recent, peer-reviewed studies that explore empirical, review, and case-based methodologies. The results highlight that effective user interface design is rooted in multimodal, emotionally aware, and cognitively efficient interactions. AI-enhanced features and adaptive layouts contribute to a more intuitive experience, particularly in healthcare and smart vehicle environments. Usability assessments, including the System Usability Scale and A/B testing, further validate user engagement and system effectiveness. Accessibility remains a crucial yet underrepresented theme, with a significant disparity in inclusive design for vulnerable populations. Notably, best practices from countries with strong accessibility policies underscore the importance of integrating users with disabilities into the design process. The discussion points to systemic factors—such as regulatory frameworks, digital literacy, and funding priorities—as both barriers and enablers of progress. To bridge existing gaps, the study recommends further longitudinal, cross-cultural, and inclusive research. Strengthening digital education and accessibility policies is key to enhancing user-centered innovation in intelligent systems.

Keywords: Human-Computer Interaction, Intelligent Systems, User Interface Design, Accessibility, Usability Testing, User-Centered Design, Inclusive Technology.

INTRODUCTION

Human-Computer Interaction (HCI) has emerged as a critical field of study in the design and implementation of intelligent systems across various sectors. As technologies advance and the integration of artificial intelligence (AI) becomes increasingly prevalent, the complexity of interactions between humans and machines demands robust, user-centered approaches. In healthcare, education, and transportation, the design of intuitive and accessible interfaces is vital for ensuring effective user engagement and enhancing system functionality. The field of HCI, therefore, plays an instrumental role in mediating the growing dependence on intelligent systems and shaping user experiences that are both efficient and inclusive.

Recent literature reveals the dynamic evolution of HCI in the past decade, marked by a strong emphasis on AI integration, voice-based interaction, and the expansion of accessibility paradigms. For instance, Clark et al. (2019) highlighted a pressing need for theoretical advancements in voice-based HCI to support diverse interaction contexts and enhance user experience. Similarly, the study by Kim et al. (2024) proposed design recommendations that address the needs of users with hearing impairments, reflecting a growing trend toward inclusive interface design. In the automotive domain, research by You et al. (2021) emphasized the importance of tailoring interface elements to user characteristics to improve usability and safety. These studies underscore the field's responsiveness to technological trends and the evolving expectations of users in diverse environments.

The relevance of accessible and usable intelligent systems is particularly evident when considering the implications for vulnerable populations. Inaccessible or poorly designed systems may exacerbate existing social inequalities, especially for individuals with disabilities or the elderly. Bai et al. (2024) noted that non-inclusive technologies risk deepening marginalization by limiting participation in digital ecosystems. This concern is echoed in Feth et al.'s (2017) call for user-centered security models that accommodate privacy needs without imposing undue complexity. Díaz-Rodríguez et al. (2013) further demonstrated the societal value of adaptive applications for individuals with special needs, emphasizing the transformative potential of inclusive HCI in promoting autonomy and digital equity.

To ensure intelligent systems serve a broad spectrum of users, stakeholder collaboration in the design and development process is essential. Effective HCI design must integrate insights from end-users, engineers, designers, and policymakers to develop interfaces that align with real-world contexts and user capabilities. Emphasizing usability across diverse groups necessitates a thorough understanding of the intended user population and the cognitive, physical, and situational factors influencing their interaction with technology. The heterogeneity of user experience, particularly in domains like healthcare and education, calls for flexible, adaptable design frameworks that prioritize inclusivity.

Despite significant progress, several persistent challenges continue to hinder the optimal implementation of HCI in intelligent systems. In the healthcare sector, one major hurdle is developing interfaces that accommodate clinicians' varying levels of technological proficiency. Longo and Dondio (2015) highlighted the critical role of usability evaluations in optimizing clinical workflows and enhancing patient outcomes. In the automotive industry, interaction with autonomous vehicles presents unique difficulties. Tremoulet et al. (2019) reported that effective communication between passengers and third parties is a decisive factor in user acceptance, particularly for families relying on such systems. Within education, Chughtai et al. (2015)

emphasized that intelligent learning environments require rigorous usability assessments to support meaningful learning and teaching effectiveness.

Beyond sector-specific barriers, the generalizability and transparency of intelligent systems pose overarching challenges in HCI design. Mercado et al. (2016) pointed out the lack of systematic studies on user interactions with complex automated systems, particularly regarding transparency and interpretability. Knijnenburg and Willemsen (2016) warned of the cognitive biases that arise when users anthropomorphize intelligent agents, potentially leading to misplaced trust and erroneous assumptions. This disconnect between user perception and system capabilities underscores the necessity for more transparent and explainable systems that foster appropriate mental models.

Moreover, the literature reveals a disproportionate focus on general populations, often neglecting underrepresented user groups such as the elderly or individuals with disabilities. Asl et al. (2024) explored the use of social robots for individuals with mild dementia, demonstrating the potential of HCI to support cognitive engagement and emotional well-being. However, such efforts remain sparse in mainstream research. Similarly, Dell'Aquila et al. (2025) called for adaptive educational technologies that account for individual learning needs and preferences, reinforcing the demand for personalized, inclusive solutions in HCI development.

This review seeks to address the aforementioned gaps by synthesizing current research on the design, usability, and accessibility of HCI within intelligent systems. Specifically, it aims to identify and evaluate the critical factors that influence user experience across sectors and populations. Drawing from a wide range of interdisciplinary studies, the review explores how interface design, system transparency, and user adaptability contribute to effective interaction. It also examines the role of user-centered design in mitigating usability challenges and promoting equitable access to intelligent technologies.

The scope of this review encompasses global developments in HCI, with particular attention to applications in healthcare, automotive, and educational settings. It also includes an analysis of HCI systems designed for older adults, individuals with disabilities, and users in developing regions. By considering diverse user demographics and contextual constraints, the review offers a comprehensive understanding of the design principles and evaluation strategies necessary for creating inclusive intelligent systems. This approach ensures that the synthesized insights are relevant across cultural and socio-economic contexts.

Ultimately, the findings from this review are intended to inform the development of HCI systems that are not only technologically advanced but also socially responsive. By identifying successful design patterns and highlighting persistent challenges, the review contributes to the body of knowledge guiding future research and practical implementation. In doing so, it underscores the critical need for continuous innovation in HCI that prioritizes usability, accessibility, and user empowerment in the era of intelligent systems.

METHOD

This narrative review adopts a systematic and transparent approach to the identification, selection, and analysis of scholarly literature concerning Human-Computer Interaction (HCI) in intelligent systems, with a particular emphasis on usability, accessibility, and user-centered design. The goal of this methodology is to ensure a comprehensive synthesis of the most relevant and rigorous studies that can inform both theoretical understanding and practical application in the field.

The literature search was conducted using two primary academic databases: Scopus and Google Scholar. These platforms were chosen due to their broad coverage of peer-reviewed articles, conference proceedings, and high-impact journals across disciplines such as computer science, information systems, health informatics, and human factors engineering. The selection of these databases ensured access to a wide spectrum of studies, including both foundational theories and emerging applications of HCI in intelligent systems.

To capture the diversity and depth of the research landscape, specific keywords were carefully selected and utilized throughout the search process. These keywords were defined based on a combination of expert consultation, preliminary readings, and alignment with the review's research objectives. The terms "Human-Computer Interaction" were used to locate core literature focused on interaction paradigms between humans and computer systems, as articulated by Chughtai et al. (2015). The keyword "Intelligent Systems" helped in identifying studies that explore the integration of artificial intelligence in user interfaces, especially in domains such as autonomous vehicles and adaptive learning environments (Tremoulet et al., 2019). The term "Usability" guided the search toward articles addressing ease of use, efficiency, and user satisfaction in system design, with relevant insights drawn from studies such as You et al. (2021) and Flohr et al. (2018). The keyword "Accessibility" was applied to isolate research that emphasizes inclusive design, especially for users with physical, cognitive, or sensory limitations, as discussed by Asl et al. (2024). Lastly, "User-Centered Design" was used to extract literature on design methodologies that prioritize user needs and involvement throughout the development process (Feth et al., 2017; Zhang et al., 2025).

The search strategy included Boolean operators to enhance precision and recall, combining the keywords in varying permutations such as: "Human-Computer Interaction" AND "Intelligent Systems", "Usability" AND "Accessibility", "User-Centered Design" AND "Healthcare" or "Education". Search filters were also applied to limit results to peer-reviewed journal articles, ensuring the inclusion of studies with verified scientific rigor. Additionally, bibliographies of key articles were examined to identify supplementary sources that may not have appeared in the initial search results.

To ensure relevance and quality, explicit inclusion and exclusion criteria were established. The inclusion criteria prioritized studies that directly addressed themes related to HCI, usability, accessibility, and user-centered design. Preference was given to literature published within the last ten years (2013–2025) to reflect recent technological developments and current practices in interface design, in line with recommendations by Virvou (2023) and Buschek et al. (2022). Studies considered for inclusion encompassed empirical research, including experimental studies, usability evaluations, case studies, systematic reviews, and meta-analyses. All articles were required to be peer-reviewed and published in reputable journals indexed by Scopus or other recognized databases, thereby ensuring methodological soundness and academic credibility. Examples include analyses by Mercado et al. (2016) and Ehrlich-Sommer (2025), both of which provided critical insights into user interaction with intelligent agents and systems.

Exclusion criteria were carefully designed to eliminate studies that did not meet quality or relevance standards. Articles published before 2013 were generally excluded, unless they offered seminal insights deemed foundational to the field, as seen in the work by Cervantes-Solis and Baber (2017). Studies with unclear or unverifiable methodologies, or lacking sufficient data for evaluation, were excluded following the guidelines set forth by Yao et al. (2019). In addition, highly niche studies with a narrow focus that did not contribute to the broader discussion on HCI and intelligent systems were also excluded. Bai et al. (2024), for example, discussed a highly specific context that, while valuable, did not align with the more comprehensive objectives of this review. Lastly, articles not published in English or a relevant regional language were omitted to ensure uniform comprehension and analysis.

The process of literature selection followed a multi-phase screening protocol. Initially, the titles and abstracts of all search results were reviewed to remove duplicates and clearly irrelevant studies. Articles passing the initial screening were then subjected to full-text review, during which their alignment with the inclusion criteria was assessed. Throughout this process, two independent reviewers conducted the screenings to ensure objectivity and consistency, resolving discrepancies through discussion and consensus. During the evaluation, emphasis was placed on the clarity of research objectives, methodological transparency, the robustness of findings, and relevance to the central themes of HCI design, usability evaluation, and accessibility features.

Data extraction from the selected articles focused on several key dimensions: research context (e.g., healthcare, education, transportation), study design (e.g., experimental, observational, review), participant characteristics (e.g., general users, elderly, individuals with disabilities), HCI components assessed (e.g., interface design, feedback mechanisms, AI integration), and outcomes related to usability, accessibility, or user satisfaction. Each article was categorized according to its primary contribution to one or more thematic areas of the review.

To ensure transparency and replicability, the full search process was documented, including search strings, inclusion and exclusion justifications, and article classification. Where applicable, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework was adapted to structure the screening and reporting process, enhancing the methodological rigor of the review.

Overall, this methodological approach ensured a comprehensive, credible, and contextually relevant synthesis of current research on HCI in intelligent systems. By systematically applying targeted keywords, adhering to strict inclusion criteria, and critically evaluating selected studies, the review aims to provide meaningful insights into the design challenges, usability practices, and accessibility considerations that shape user experiences in intelligent environments.

RESULT AND DISCUSSION

The analysis of existing literature on Human-Computer Interaction (HCI) within intelligent systems revealed three primary thematic areas: interface design and user experience, usability in intelligent systems, and accessibility for vulnerable populations. These themes encapsulate the multidimensional challenges and opportunities in creating effective, inclusive, and adaptive interactive technologies. Each subtheme highlights key empirical findings and theoretical contributions that illustrate how interface quality, usability protocols, and accessibility considerations converge to shape user engagement with intelligent systems across diverse sectors.

In the domain of interface design and user experience, scholars consistently emphasize the need for clarity, simplicity, and adaptability. Babu et al. (2018) stressed that interfaces designed with high readability and streamlined information displays significantly enhance user comprehension and reduce interaction errors. This is particularly critical in contexts where dynamic and real-time information is presented, such as in clinical decision support or automated navigation systems. Ehrlich-Sommer (2025) added that the integration of artificial intelligence into user interfaces enhances interactivity by allowing systems to adapt to context-specific user behavior, thereby strengthening system responsiveness and engagement. Virvou (2023) further extended this line of inquiry by suggesting that the emotional dimension of interaction—such as system responsiveness to user frustration or enthusiasm—is a vital component of user experience design, especially in AI-enhanced environments. The incorporation of emotional awareness in interface design supports a more natural and personalized interaction, ultimately contributing to higher user satisfaction.

Cognitive load is another key consideration in interface design. As Longo and Dondio (2015) demonstrated, complex decision-making environments like healthcare demand interfaces that minimize mental workload. Poorly designed interfaces can result in errors, delays, or reduced trust in the system, especially when clinicians or users with varying technological familiarity are involved. Therefore, design strategies must prioritize cognitive ergonomics, ensuring that users can process information efficiently without being overwhelmed.

Adaptive and multimodal interface designs have also been found to contribute significantly to enhanced user experience. Adaptive design enables systems to tailor content and interaction styles to individual user needs and preferences, facilitating more intuitive interactions. Zhang et al. (2025) found that real-time user feedback and iterative testing are essential for refining interface components, ultimately leading to reduced cognitive demand and improved user satisfaction. Multimodal interaction—such as integrating touch, voice, and gesture—has shown to improve accessibility and user engagement. Giariskanis et al. (2025) demonstrated that multimodal interfaces enable more fluid interaction patterns, particularly for users with physical or sensory limitations, thereby broadening the usability spectrum of intelligent systems.

Usability in intelligent systems constitutes the second major theme identified in the literature. The most frequently employed evaluation methods include the System Usability Scale (SUS), observational assessments, and mixed-methods approaches that integrate qualitative interviews and quantitative performance metrics. Faria et al. (2013) reported that standardized usability protocols such as SUS facilitate objective comparisons across systems and support the identification of interface elements that hinder user performance. Complementary observational techniques allow researchers to capture nuanced behaviors and challenges that may not be evident through self-report instruments alone.

Kim et al. (2024) advocated for mixed-method evaluations, especially in studies involving users with disabilities. Their research, which focused on hearing-impaired users, highlighted that qualitative interviews revealed user frustrations and adaptation strategies that were not captured in quantitative data. This approach enables a holistic understanding of the user experience, thereby informing more empathetic and context-sensitive design improvements. Moreover, A/B testing has emerged as an effective tool to evaluate alternative interface designs. Borsci and Schmettow (2024) demonstrated that comparative usability testing could uncover user preferences and interaction patterns that guide iterative design refinements, particularly in AI-enhanced mobile applications.

Empirical evidence supports the efficacy of robust usability protocols in improving system performance and user satisfaction across sectors. In healthcare, Flohr et al. (2018) found that intelligent patient monitoring systems with well-designed interfaces significantly reduced clinical errors and improved decision-making efficiency in intensive care units. The clarity and responsiveness of the interface were directly linked to the ability of clinicians to interpret patient data accurately and act promptly. In the automotive sector, Tremoulet et al. (2019) reported that parental acceptance of autonomous vehicles increased when communication features were embedded in the vehicle's interface, allowing real-time interaction and reassurance regarding child safety. These findings affirm that usability-focused design leads to measurable improvements in both trust and operational efficiency.

Accessibility and the inclusion of vulnerable populations represent the third critical dimension in HCI research. Poorly designed systems can exacerbate social inequalities by excluding users with disabilities or those unfamiliar with complex technological systems. Kim et al. (2024) identified that many AI-based assistive technologies fail to accommodate the nuanced communication needs of users with hearing impairments. Their findings indicate that without targeted user involvement in the design process, assistive technologies risk being underutilized or entirely ineffective. This highlights the importance of inclusive design frameworks that incorporate user feedback from the earliest stages of system development.

Conversely, inclusive design has demonstrated the potential to transform technology access and empowerment for marginalized users. In healthcare, Flohr et al. (2018) illustrated how inclusive interface design improved patient safety outcomes by ensuring that clinical systems were intuitive and responsive to the diverse needs of healthcare workers and patients alike. Their study emphasized the value of co-design approaches, where stakeholders, including users with disabilities, actively participate in shaping design specifications. This participatory process ensures that the resulting systems are not only functional but also accessible and meaningful to a wide range of users.

From a global perspective, best practices from countries with advanced accessibility standards offer valuable lessons. The European Web Content Accessibility Guidelines (WCAG) serve as a foundational framework for inclusive digital design and are widely adopted across public and private sectors. Tremoulet et al. (2019) noted that European standards encourage interface consistency and device compatibility, reducing barriers for users with visual, auditory, and motor impairments. In the Nordic region, countries like Sweden and Finland have implemented national policies mandating the inclusion of users with disabilities in usability testing and technology evaluations. Lin et al. (2018) documented these practices and emphasized their role in producing technologies that reflect real-world diversity and usability expectations.

In the education sector, inclusive design has also shown promise in improving learning outcomes for students with diverse needs. Chughtai et al. (2015) highlighted that incorporating iterative usability evaluations during the development of intelligent tutoring systems led to more adaptive and engaging learning environments. Their study emphasized that inclusive design must go beyond compliance to actively consider learner preferences, emotional responses, and interaction patterns. Ehrlich-Sommer (2025) echoed this by advocating for multimodal interfaces that combine visual, auditory, and tactile elements, enabling learners with different abilities to engage more effectively with educational content.

In conclusion, the literature underscores that successful HCI design within intelligent systems hinges on an integrative approach that blends aesthetic, functional, and ethical considerations. Interface clarity, usability protocols, and inclusive design practices converge to create systems that are not only operationally effective but also socially responsible. These findings highlight the imperative for developers, designers, and policymakers to adopt a holistic perspective on HCI, ensuring that intelligent systems serve the broadest possible range of users while maintaining high standards of interaction quality and user satisfaction.

The integration of Human-Computer Interaction (HCI) into intelligent systems has revealed both immense potential and considerable challenges, many of which stem from broader systemic factors. The literature reveals that systemic influences such as regulatory frameworks, digital literacy levels, and funding structures significantly impact the implementation and efficacy of HCI systems. Technological policy serves as a foundational driver for shaping the landscape in which HCI systems are developed and adopted. The Web Content Accessibility Guidelines (WCAG), for instance, have created a global standard that ensures developers prioritize accessibility, which is fundamental for inclusive user experience (Chughtai et al., 2015). These standards not only mandate technical compliance but also promote a culture of inclusivity within system design, especially for vulnerable populations. Moreover, digital literacy levels within different populations directly affect user engagement with intelligent systems. Users with higher digital literacy are more capable of navigating complex interfaces and adapting to new technologies, thereby benefiting more from the potential of intelligent HCI (Tremoulet et al., 2019). On the other hand, in regions with low digital literacy, these systems risk becoming underutilized or even alienating.

Another systemic factor of critical importance is research funding. While not always directly addressed in HCI-focused studies, the availability of sustained funding influences the scope, scale, and innovation capacity of HCI research initiatives. Without sufficient funding, especially for interdisciplinary and longitudinal studies, advancements in usability and accessibility may remain limited or localized. This creates a disparity where certain regions or user groups benefit disproportionately from advancements in HCI technologies. A more balanced allocation of funding could encourage the development of systems that cater to diverse needs, including those of people with disabilities or those in low-resource settings.

Encouragingly, various policy-driven and technology-based initiatives have shown promise in addressing usability and accessibility challenges. Japan's national initiative to enhance digital inclusion by offering tailored training for the elderly and people with disabilities exemplifies an effective top-down strategy to raise digital literacy (You et al., 2021). These interventions not only empower users to engage with intelligent systems but also provide critical feedback loops for designers to refine user-centered design approaches. Another notable advancement lies in the deployment of assistive robots in healthcare contexts. Maia et al. (2019) reported improved user interaction and satisfaction when such systems were designed following user-centered principles. By embedding user feedback into the development process, these solutions have demonstrated higher acceptance rates and practical utility.

From a technological standpoint, hybrid systems that integrate contextual social understanding and advanced algorithms, such as those explored by Kim et al. (2024), offer new avenues for inclusivity. These systems recognize the multifaceted nature of human interaction, including emotional, behavioral, and environmental variables. They represent a shift away from rigid interface designs toward adaptive and multimodal systems that can cater to a broader user base, including those with hearing impairments. The success of such models illustrates the necessity of interdisciplinary collaboration in HCI research, incorporating insights from psychology, design, and engineering.

Despite these advancements, significant gaps remain in current HCI literature and methodology. One of the most pressing limitations is the paucity of longitudinal research that tracks user interaction with intelligent systems over extended periods. As Väänänen et al. (2015) note, many existing studies concentrate on initial development phases or short-term evaluations, offering limited insight into how users adapt or struggle with systems over time. Without understanding the long-term dynamics of user interaction, it becomes difficult to anticipate evolving needs or identify persistent usability issues.

Another critical limitation lies in the homogeneity of study populations. Numerous studies focus on technologically literate participants in urban, high-income settings, which does not reflect the global diversity of users (Asl et al., 2024). This skews findings and limits the generalizability of conclusions, particularly when systems are deployed in diverse cultural or socio-economic contexts. Inclusive research designs that incorporate voices from marginalized groups are essential for creating systems that serve all users equitably.

Furthermore, there is a growing consensus on the need for mixed-methods research in HCI. As Cervantes-Solis and Baber (2017) argue, combining qualitative and quantitative methods provides a more holistic understanding of user experiences. Quantitative data may highlight usability bottlenecks, while qualitative insights can explain the underlying causes, contextual factors, and emotional responses. Such integrative approaches are particularly valuable in evaluating systems used in sensitive domains like healthcare or education, where user needs are complex and multifaceted.

Given the rapid evolution of intelligent systems and digital environments, HCI research must also remain agile and responsive. Zhang et al. (2024) emphasize the necessity of continuous monitoring and adaptation of interface designs to align with shifting user expectations and technological capabilities. Static models quickly become obsolete, and iterative design processes should be institutionalized within HCI research frameworks. This requires not only methodological flexibility but also sustained collaboration across disciplines and stakeholders.

To overcome these challenges, future research should prioritize inclusivity at every stage, from conceptualization to deployment. This involves not only involving users in design processes but also creating institutional mechanisms that support ongoing engagement, such as participatory design labs and co-creation platforms. These structures enable designers and developers to receive continuous feedback and ensure that systems evolve in line with user needs. Additionally, cross-cultural research partnerships can help address contextual variations and promote the development of globally relevant HCI solutions.

In conclusion, while substantial progress has been made in enhancing HCI for intelligent systems, the field continues to grapple with systemic, methodological, and contextual limitations. Addressing these issues requires a multifaceted approach that integrates policy support, inclusive research practices, adaptive methodologies, and user-centered technological innovation. Only through such comprehensive strategies can HCI systems realize their full potential in promoting accessibility, usability, and equitable digital participation across diverse populations.

CONCLUSION

This narrative review examined the current landscape of Human-Computer Interaction (HCI) in intelligent systems, particularly focusing on design, usability, and accessibility. Findings from recent literature underscore that successful user interface design hinges on adaptive and multimodal strategies that prioritize user readability, emotional engagement, and cognitive load management. The integration of AI-driven features further enhances the relevance and responsiveness of HCI systems, especially in dynamic and context-specific environments. Usability was also a key focus, with evidence showing that well-evaluated systems—through tools like SUS and A/B testing—deliver tangible benefits in critical sectors such as healthcare and automotive.

The discussion highlighted how systemic factors—such as policy support, digital literacy, and inclusive funding mechanisms—play a foundational role in shaping equitable and effective HCI experiences. Notably, while several promising policy and technology-driven interventions exist globally, gaps remain in long-term and culturally diverse user studies. The literature also reflects a persistent underrepresentation of users with disabilities and aging populations in design trials, calling for more inclusive and longitudinal research methodologies.

In light of these findings, future research must adopt integrative approaches that blend qualitative and quantitative insights, while also embedding user-centered design as a standard practice. Policymakers and developers should collaborate to create adaptable, inclusive guidelines that address both present and emerging usability challenges. Strengthening accessibility standards and promoting educational programs on inclusive design will be crucial to ensuring that intelligent systems remain equitable and impactful across diverse user groups.

REFERENCE

Asl, A., Toribio-Guzmán, J., Castro-González, Á., Malfáz, M., Salichs, M., & Franco, M. (2024). Evaluating the user experience and usability of the mini robot for elderly adults with mild dementia and mild cognitive impairment: insights and recommendations. *Sensors, 24(22)*, 7180. https://doi.org/10.3390/s24227180

Bai, X., Yuan, J., Liu, M., Huang, H., & Feng, J. (2024). Human factors considerations of interaction between wearers and intelligent lower-limb prostheses: a prospective discussion. *Journal of Neuroengineering and Rehabilitation, 21(1)*. https://doi.org/10.1186/s12984-024-01475-x

Babu, V., Oliveira, L., Birrell, S., Taylor, A., & Cain, R. (2018). Comparison of e-ink and oled screens as train seat displays: a user study., 294-300. https://doi.org/10.1007/978-3-319-93710-6_30

Borsci, S. and Schmettow, M. (2024). Re-examining the chatbot usability scale (bus-11) to assess user experience with customer relationship management chatbots. *Personal and Ubiquitous Computing, 28(6)*, 1033-1044. https://doi.org/10.1007/s00779-024-01834-4

Buschek, D., Eiband, M., & Hußmann, H. (2022). How to support users in understanding intelligent systems? An analysis and conceptual framework of user questions considering user mindsets, involvement, and knowledge outcomes. *ACM Transactions on Interactive Intelligent Systems, 12(4)*, 1-27. https://doi.org/10.1145/3519264

Cervantes-Solis, J. and Baber, C. (2017). Towards the definition of a modelling framework for meaningful human-iot interactions. https://doi.org/10.14236/ewic/hci2017.28

Chughtai, R., Zhang, S., & Craig, S. (2015). Usability evaluation of intelligent tutoring system. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 59(1)*, 367-371. https://doi.org/10.1177/1541931215591076

Clark, L., Doyle, P., Garaialde, D., Gilmartin, E., Schlögl, S., Edlund, J., … & Cowan, B. (2019). The state of speech in hci: trends, themes and challenges. *Interacting With Computers, 31(4)*, 349-371. https://doi.org/10.1093/iwc/iwz016

Dell'Aquila, E., Ponticorvo, M., & Limone, P. (2025). Psychological foundations for effective human–computer interaction in education. *Applied Sciences, 15(6)*, 3194. https://doi.org/10.3390/app15063194

Díaz-Rodríguez, N., Lilius, J., Cuéllar, M., & Calvo-Flores, M. (2013). Rapid prototyping of semantic applications in smart spaces with a visual rule language., 1335-1338. https://doi.org/10.1145/2494091.2499217

Dunbar, S., Macpherson, B., Moretti, E., Fiol, G., Bolte, J., Taekman, J., … & Wright, M. (2016). Toward designing information display to support critical care. *Applied Clinical Informatics, 07(04)*, 912-929. https://doi.org/10.4338/aci-2016-03-ra-0033

Ehrlich-Sommer, F. (2025). Robot usability in the wild: bridging accessibility gaps for diverse user groups in complex forestry operations. *Universal Access in the Information Society.* https://doi.org/10.1007/s10209-025-01234-2

Faria, B., Vasconcelos, S., Reis, L., & Lau, N. (2013). Evaluation of distinct input methods of an intelligent wheelchair in simulated and real environments: a performance and usability study. *Assistive Technology, 25(2)*, 88-98. https://doi.org/10.1080/10400435.2012.723297

Feth, D., Maier, A., & Polst, S. (2017). A user-centered model for usable security and privacy., 74-89. https://doi.org/10.1007/978-3-319-58460-7_6

Flohr, L., Beaudry, S., Johnson, K., West, N., Burns, C., Ansermino, J., … & Görges, M. (2018). Clinician-driven design of vitalpad–an intelligent monitoring and communication device to improve patient safety in the intensive care unit. *IEEE Journal of Translational Engineering in Health and Medicine, 6*, 1-14. https://doi.org/10.1109/jtehm.2018.2812162

Giariskanis, F., Kritikos, Y., Protopapadaki, E., Papanastasiou, A., Papadopoulou, E., & Mania, K. (2025). Dynamic difficulty adjustment in audio augmented reality games. *Journal on Computing and Cultural Heritage, 18(2)*, 1-19. https://doi.org/10.1145/3718330

Kim, H., Hwang, H., Gwak, S., Yoon, J., & Park, K. (2024). Improving communication and promoting social inclusion for hearing-impaired users: usability evaluation and design recommendations for assistive mobile applications. *PLOS ONE, 19(7)*, e0305726. https://doi.org/10.1371/journal.pone.0305726

Knijnenburg, B. and Willemsen, M. (2016). Inferring capabilities of intelligent agents from their external traits. *ACM Transactions on Interactive Intelligent Systems, 6(4)*, 1-25. https://doi.org/10.1145/2963106

Lin, Y., Min, H., Zhou, H., & Pei, F. (2018). A human–robot-environment interactive reasoning mechanism for object sorting robot. *IEEE Transactions on Cognitive and Developmental Systems, 10(3)*, 611-623. https://doi.org/10.1109/tcds.2017.2706975

Longo, L. and Dondio, P. (2015). On the relationship between perception of usability and subjective mental workload of web interfaces. https://doi.org/10.1109/wi-iat.2015.157

Maia, R., Silva, J., & Silva, J. (2019). Towards graphical user interface redefinition without source code access., 1-6. https://doi.org/10.1145/3338286.3344398

Mercado, J., Rupp, M., Chen, J., Barnes, M., Barber, D., & Procci, K. (2016). Intelligent agent transparency in human–agent teaming for multi-uxv management. *Human Factors the Journal of the Human Factors and Ergonomics Society, 58(3)*, 401-415. https://doi.org/10.1177/0018720815621206

Tremoulet, P., Seacrist, T., McIntosh, C., Loeb, H., DiPietro, A., & Tushak, S. (2019). Transporting children in autonomous vehicles: an exploratory study. *Human Factors the Journal of the Human Factors and Ergonomics Society, 62(2)*, 278-287. https://doi.org/10.1177/0018720819853993

Väänänen, K., Olsson, T., & Häkkilä, J. (2015). Towards deeper understanding of user experience with ubiquitous computing systems: systematic literature review and design framework., 384-401. https://doi.org/10.1007/978-3-319-22698-9_26

Virvou, M. (2023). Artificial intelligence and user experience in reciprocity: contributions and state of the art. *Intelligent Decision Technologies, 17(1)*, 73-125. https://doi.org/10.3233/idt-230092

Wardle, G. and Sušnjak, T. (2025). Image first or text first? Optimising the sequencing of modalities in large language model prompting and reasoning tasks. *Big Data and Cognitive Computing, 9(6)*, 149. https://doi.org/10.3390/bdcc9060149

Yang, M. and Huang, H. (2015). Research on interaction design of intelligent mobile phone for the elderly based on the user experience., 528-536. https://doi.org/10.1007/978-3-319-20892-3_51

Yao, Y., Basdeo, J., Kaushik, S., & Wang, Y. (2019). Defending my castle., 1-12. https://doi.org/10.1145/3290605.3300428

You, F., Yang, Y., Fu, M., Zhang, J., & Wang, J. (2021). Design guidelines for the size and length of Chinese characters displayed in the intelligent vehicle's central console interface. *Information, 12(5)*, 213. https://doi.org/10.3390/info12050213

Zhang, E., Yang, Z., Zhao, W., Mei, Z., Xia, Y., & Chen, F. (2024). Unlocking brilliance: a smart approach to icon colour design inspired by universal design principles. *Buildings, 14(6)*, 1522. https://doi.org/10.3390/buildings14061522

Zhang, T., Xie, S., & Liao, Q. (2025). Smart in-vehicle system user interfaces: designing for human-machine interaction and cognitive load reduction. https://doi.org/10.3233/faia250286