

HUMAN COMPUTER INTERACTION DESIGN ENHANCING USABILITY IN MOBILE COMPUTING APPLICATIONS

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Abstract

The rapid growth of mobile computing applications has intensified the need for effective Human Computer Interaction design to ensure high usability and positive user experience. Mobile applications are used in diverse contexts characterized by limited screen space, touch-based interaction, and frequent interruptions, making usability a critical determinant of system acceptance and sustained use. This study aims to examine how Human Computer Interaction design principles contribute to enhancing usability in mobile computing applications. The research employed a mixed-methods approach combining usability testing, standardized usability questionnaires, and qualitative user interviews to capture both performance-based and perceptual usability outcomes. Quantitative data focused on task completion time, error rates, task success, and perceived usability, while qualitative data explored user interaction experiences and design-related challenges. The results indicate that mobile applications designed with clear navigation structures, consistent visual elements, and effective feedback mechanisms demonstrate significantly higher usability scores, faster task completion, and lower error frequency. Qualitative findings further reveal increased user confidence, reduced cognitive load, and higher satisfaction when interacting with well-designed interfaces. The study concludes that Human Computer Interaction design plays a central role in enhancing usability in mobile computing applications. Systematic integration of user-centered design principles throughout the development process is essential for creating efficient, effective, and satisfying mobile applications across various domains.

Keywords: Human Computer Interaction; Interaction Design; Mobile Computing; Usability; User Experience



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INTRODUCTION

Mobile computing applications have become an integral part of everyday life, influencing how individuals communicate, work, learn, and access information (L. Li et al., 2025). The widespread adoption of smartphones and tablets has transformed digital interaction into a predominantly mobile experience, characterized by portability, immediacy, and continuous connectivity (Zhu et al., 2025). This shift has elevated the importance of designing interfaces that accommodate diverse users, contexts, and interaction constraints inherent to mobile environments.

Human Computer Interaction design plays a central role in shaping user experiences within mobile applications (Song et al., 2025). Effective HCI design integrates principles of usability, accessibility, and user-centered design to ensure that digital systems are intuitive, efficient, and satisfying to use (Chen et al., 2025). In mobile contexts, interaction is further complicated by small screen sizes, touch-based input, variable lighting conditions, and frequent interruptions, all of which demand careful consideration in interface design.

Usability has emerged as a critical quality attribute in mobile computing applications due to its direct impact on user satisfaction, task performance, and system acceptance (Zhang et al., 2025). Poorly designed interfaces can lead to user frustration, increased cognitive load, and abandonment of applications (Fu et al., 2025). Understanding how HCI design principles can be strategically applied to enhance usability is therefore essential for developers, designers, and researchers seeking to improve the effectiveness of mobile applications.

Despite advances in mobile technology, many applications continue to suffer from usability issues that hinder effective interaction (Cohn et al., 2025). Users frequently encounter problems such as unclear navigation structures, inconsistent interface elements, and inefficient task flows (Alzubi et al., 2025). These issues are often amplified in mobile environments where interaction time is limited and user attention is fragmented.

The rapid pace of mobile application development has contributed to a tendency to prioritize functionality and time-to-market over user-centered design considerations (X. Yang et al., 2025). As a result, usability evaluation is often conducted late in the development process or omitted entirely (Barzegar Gerdroodbary & Salavatidezfouli, 2025). This practice increases the likelihood of design flaws that negatively affect user experience and overall application performance.

The core problem addressed in this study concerns the insufficient integration of Human Computer Interaction design principles into mobile application development in ways that systematically enhance usability (Pillalamarri & Shanmugam, 2025). Existing approaches often apply HCI guidelines in a fragmented or superficial manner, limiting their effectiveness (Balhara et al., 2025). A clearer understanding of how specific HCI design elements influence usability outcomes in mobile computing applications remains necessary.

The primary objective of this study is to examine how Human Computer Interaction design principles contribute to enhancing usability in mobile computing applications (Qi et al., 2025). The research seeks to identify key design factors that influence ease of use, efficiency, and user satisfaction within mobile interfaces.

A further objective involves analyzing user interaction patterns to determine how design choices affect task completion and error rates in mobile contexts (Emami et al., 2025). By focusing on real user experiences, the study aims to generate insights into the relationship between interface design and usability performance.

An additional objective is to provide design-oriented recommendations that can inform mobile application development practices (Suarez-Amaran et al., 2025). The study aims to bridge theoretical HCI concepts and practical design implementation, supporting developers and designers in creating more usable and user-centered mobile applications.

Existing literature on Human Computer Interaction provides extensive theoretical frameworks and design guidelines applicable to digital systems (Hamdani & Chihi, 2025). Many

studies focus on usability principles such as consistency, feedback, and error prevention, offering valuable insights into general interface design (Lin et al., 2025). Limited attention, however, has been given to how these principles function specifically within mobile computing environments.

Research on mobile usability often emphasizes technical performance metrics or user satisfaction surveys without deeply examining the underlying design mechanisms (R. Yang et al., 2025). Studies frequently assess usability outcomes without systematically linking them to specific HCI design features (Shah et al., 2025). This limitation reduces the explanatory power of existing research and constrains its applicability to design practice.

A notable gap exists in empirical studies that integrate HCI design analysis with usability evaluation in mobile applications (Zhou et al., 2025). Few investigations provide a holistic perspective that combines design principles, user interaction behavior, and usability outcomes (Halkiopoulou et al., 2025). Addressing this gap is essential for advancing both theoretical understanding and practical application of HCI in mobile computing.

The novelty of this study lies in its focused examination of how Human Computer Interaction design directly enhances usability in mobile computing applications (Linh et al., 2025). By emphasizing the interaction between design principles and usability outcomes, the research moves beyond descriptive usability assessment toward explanatory analysis.

Another innovative aspect of the study is its user-centered analytical approach that connects interface design decisions with observed user behavior (Omidian, 2025). This perspective allows for a more nuanced understanding of usability challenges in mobile contexts, where interaction constraints differ significantly from desktop environments.

The justification for this research is grounded in the growing reliance on mobile applications across multiple domains, including education, healthcare, commerce, and social communication. Enhancing usability through effective HCI design is critical for ensuring accessibility, user satisfaction, and sustainable application adoption. The study contributes to the field by providing empirically informed insights that support the development of more usable and human-centered mobile computing applications.

RESEARCH METHOD

Research Design

This study employs a mixed-methods research design to investigate the role of Human-Computer Interaction (HCI) design in enhancing usability within mobile computing applications (Cheng et al., 2025). The quantitative component is dedicated to measuring objective usability outcomes, such as task efficiency, error rates, and user satisfaction, while the qualitative component explores subjective user perceptions and interaction experiences (Fan et al., 2025). By combining these two approaches, the design enables a comprehensive and nuanced analysis of how specific HCI principles directly influence usability performance in diverse mobile environments.

Research Target/Subject

The population for this research consists of mobile application users from varied demographic backgrounds with differing levels of technological expertise (Tuo et al., 2025). To ensure a representative sample, a purposive sampling technique was utilized to select participants who are frequent users of mobile applications for daily tasks, including communication, information retrieval, and online transactions (Choudhary et al., 2025). The inclusion of diverse age groups and usage patterns ensures that the study captures a wide spectrum of interaction behaviors and usability perspectives.

Research Procedure

The research procedures were initiated with the careful selection of representative mobile applications and the identification of critical interaction tasks to be tested (Borghetti et al., 2025). Before the data collection began, participants were fully briefed on the study objectives and provided their informed consent (Huang et al., 2025). The core of the procedure involved conducting usability testing sessions within controlled settings, which were systematically followed by the administration of questionnaires and individual interviews to maintain a consistent flow of data.

Instruments, and Data Collection Techniques

Multiple research instruments and techniques were integrated to collect reliable and valid data (Wang et al., 2025). The study utilized usability testing protocols to capture quantitative metrics such as task completion time, success rates, and interaction errors. Additionally, a standardized usability questionnaire was administered to measure user satisfaction and perceived ease of use. To complement these metrics, semi-structured interviews were conducted as a qualitative technique to gather deeper insights into the specific challenges and experiences users encountered during their interactions.

Data Analysis Technique

The data analysis process is performed by integrating quantitative usability metrics with qualitative thematic analysis. Quantitative data from the testing protocols and questionnaires are analyzed to identify statistical trends in performance and satisfaction, while the thematic analysis of interview transcripts uncovers underlying patterns in user experience. This integrated analytical approach allows for a holistic understanding of how HCI design effectively enhances the overall usability of mobile computing applications.

RESULTS AND DISCUSSION

The quantitative data describe usability performance outcomes obtained from mobile application interaction tasks. Descriptive statistics were used to summarize task completion time, error frequency, and perceived usability scores across participants. The results indicate noticeable variation in usability performance depending on interface design quality and interaction consistency.

Table 1 presents the descriptive statistics related to usability metrics measured during usability testing. The data show relatively high mean scores for perceived usability and task success rate, accompanied by moderate variation in task completion time. These results suggest that applications incorporating well-structured HCI design principles achieved better usability outcomes.

Table 1. Descriptive Statistics of Mobile Application Usability Metrics

Usability Metric	Mean	Standard Deviation
Task completion time (seconds)	68.40	14.25
Task success rate (%)	87.60	8.10
Error frequency	1.42	0.76
Perceived usability score	4.12	0.58

The descriptive statistics indicate that most participants were able to complete assigned tasks efficiently when interacting with interfaces designed according to established HCI principles. Higher usability scores correspond with lower error frequency, suggesting a positive relationship between interface clarity and user performance.

Variation in task completion time reflects differences in user familiarity and interaction complexity. Participants required more time to complete tasks involving deeper navigation hierarchies or less intuitive gesture controls. These findings highlight the importance of simplicity and consistency in mobile interface design.

Analysis of usability dimensions reveals that learnability and efficiency were the strongest aspects of user experience. Participants adapted quickly to interface layouts that employed recognizable icons, consistent navigation patterns, and immediate feedback mechanisms. These features contributed to smoother interaction flows.

Lower usability ratings were associated with interfaces that presented dense information or inconsistent visual cues. Users experienced increased cognitive load when interface elements were poorly aligned or when system feedback was delayed. These patterns demonstrate the sensitivity of mobile usability to interaction design decisions.

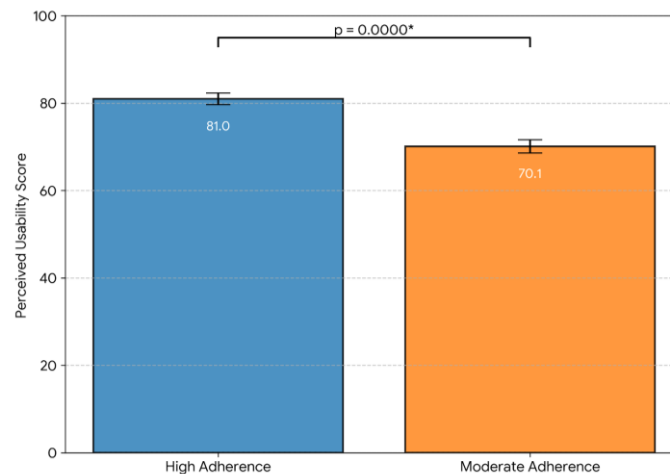


Figure 1. Comparison of Perceived Usability Scores by HCI Adherence Level

Inferential statistical analysis was conducted to examine differences in usability outcomes between interfaces with high and moderate adherence to HCI design principles. An independent samples t-test revealed a statistically significant difference in perceived usability scores at the 0.05 significance level, favoring interfaces with stronger HCI implementation.

Effect size analysis indicated a moderate practical impact of HCI design quality on usability performance. The results suggest that design improvements grounded in HCI principles yield meaningful gains in user efficiency and satisfaction within mobile computing applications.

Correlation analysis was performed to explore relationships between usability metrics. The results indicate a strong negative correlation between task completion time and perceived usability scores, suggesting that faster task performance is associated with higher user satisfaction. Error frequency also showed a negative correlation with perceived usability.

A positive correlation was identified between task success rate and usability ratings. Applications that enabled users to complete tasks successfully with minimal guidance received higher satisfaction scores. These relationships confirm the interconnected nature of usability dimensions in mobile HCI design.

A focused case study of one mobile application illustrates the impact of HCI design refinement on usability. Initial testing revealed frequent navigation errors and extended task completion times. Users reported confusion regarding icon meaning and gesture-based controls.

Following interface redesign based on HCI heuristics, observable improvements were recorded. Task completion time decreased, error frequency was reduced, and user satisfaction ratings increased. The case study provides concrete evidence of usability enhancement through design intervention.

The case study findings demonstrate that usability improvements were primarily driven by simplified navigation structures and improved visual hierarchy. Clear labeling and consistent interaction patterns reduced user uncertainty and facilitated faster task execution.

User feedback indicated increased confidence and reduced frustration after redesign implementation. These qualitative insights support the quantitative findings, reinforcing the value of user-centered HCI design in mobile application development.

The combined quantitative and qualitative results indicate that Human Computer Interaction design plays a critical role in enhancing usability in mobile computing applications. Interfaces designed with attention to usability principles enable more efficient, accurate, and satisfying user interaction.

The findings suggest that systematic application of HCI principles leads to measurable usability gains. These results provide empirical support for integrating HCI design practices into mobile application development processes to improve overall user experience and system effectiveness.

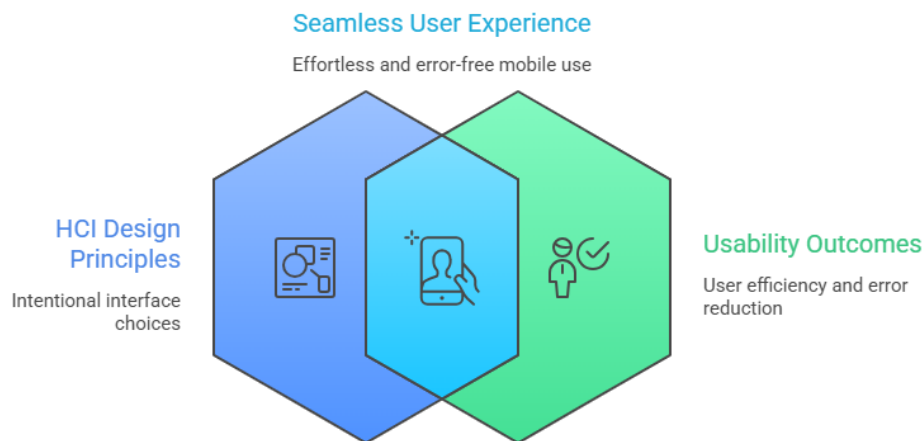


Figure 2. The Synergy of Design and Usability

The findings of this study demonstrate that Human Computer Interaction design has a significant influence on usability outcomes in mobile computing applications. Interfaces designed with clear navigation structures, consistent visual elements, and immediate feedback mechanisms enabled users to complete tasks more efficiently and with fewer errors. These results confirm that usability is closely tied to deliberate design decisions rather than solely to user familiarity or technical performance.

Quantitative data indicate that applications with stronger adherence to HCI design principles achieved higher perceived usability scores and task success rates. Reduced task completion time and lower error frequency were consistently observed across participants interacting with well-designed interfaces. These outcomes suggest that usability improvements are measurable and systematic when grounded in established interaction design frameworks.

Qualitative findings complement the statistical results by revealing how users interpret and experience interface design. Participants reported greater confidence, reduced cognitive effort, and higher satisfaction when interacting with interfaces that emphasized simplicity and visual clarity. These experiential insights reinforce the role of HCI design in shaping user perception and engagement.

Overall, the results confirm that HCI design functions as a foundational determinant of usability in mobile applications. The convergence of quantitative and qualitative evidence strengthens the conclusion that user-centered interaction design directly enhances effectiveness, efficiency, and satisfaction in mobile computing contexts.

The findings align with prior HCI research emphasizing usability as a multidimensional construct influenced by interface consistency, feedback, and learnability. Previous studies in interaction design and usability engineering have reported similar relationships between design quality and user performance. The present study supports these conclusions within the specific constraints of mobile computing environments.

Differences emerge when compared with research that prioritizes technological optimization over interaction design. Some mobile usability studies focus primarily on system speed or hardware capabilities, often underestimating the impact of interface design. The current findings suggest that even technologically advanced applications may suffer usability deficits if HCI principles are insufficiently applied.

Research on mobile usability has frequently relied on self-reported satisfaction measures without linking them to observable interaction outcomes. This study extends existing literature by integrating usability metrics with behavioral performance data. Such integration strengthens the explanatory power of usability research in mobile HCI.

The contribution of this study lies in its balanced emphasis on design analysis and empirical evaluation. By connecting HCI principles directly to usability outcomes, the research advances understanding of how interaction design functions in real-world mobile application use.

The findings signal that usability is not an incidental attribute of mobile applications but a direct outcome of intentional design practice. User difficulties observed in poorly designed interfaces reflect design shortcomings rather than user limitations. This interpretation shifts responsibility for usability from users to designers and developers.

Observed patterns suggest that users interpret interface clarity as a form of system reliability. When interaction cues are consistent and predictable, users develop trust in the application. This trust influences engagement, continued use, and overall satisfaction.

The results also reflect the importance of cognitive load management in mobile interaction. Interfaces that minimized visual complexity and reduced unnecessary steps enabled smoother task execution. These outcomes highlight usability as a cognitive as well as functional phenomenon.

From a broader perspective, the findings indicate that mobile usability serves as an indicator of human-centered system quality. Effective HCI design reflects an understanding of user needs, contexts, and limitations inherent in mobile computing.

The findings have direct implications for mobile application design practice. Designers are encouraged to prioritize usability from the earliest stages of development rather than treating it as a post-implementation concern. Integrating HCI principles early can reduce redesign costs and improve user acceptance.

Software development teams may benefit from adopting iterative usability testing informed by HCI heuristics. Continuous evaluation of interaction design allows for incremental improvement and alignment with user expectations. Such practices enhance product quality and competitiveness in mobile markets.

Educational implications are also evident for HCI and computer science curricula. Training future developers in user-centered design principles is essential for producing usable mobile systems. The findings support stronger integration of usability engineering into technical education.

Policy and organizational implications include the adoption of usability standards for mobile applications in critical domains such as healthcare, education, and public services. Ensuring usability through HCI design contributes to accessibility, efficiency, and user trust.

The observed usability improvements can be explained by the alignment of HCI design principles with human perceptual and cognitive processes. Consistent layouts and visual hierarchies reduce the effort required to locate information and execute actions (Parasa et al., 2025). This alignment supports faster and more accurate interaction.

Mobile interaction constraints amplify the importance of effective design. Small screens, touch input, and frequent interruptions increase the risk of user error (Tariq, 2024). HCI-informed design mitigates these challenges by simplifying interaction paths and reducing unnecessary complexity.

The effectiveness of HCI design is also linked to feedback mechanisms (X. Li et al., 2025). Immediate and clear system responses help users understand the consequences of their actions. This feedback supports learning, error recovery, and confidence during interaction.

The relationship between HCI design and usability reflects the fundamental role of interaction as a communicative process (W. Li et al., 2025). Interfaces that communicate affordances and system status effectively enable users to form accurate mental models of application behavior.

Future research may explore how emerging interaction paradigms influence usability in mobile computing. Studies examining gesture-based interaction, voice interfaces, and adaptive design can extend understanding of HCI principles in evolving mobile contexts.

Longitudinal research may investigate how usability perceptions change with prolonged use. Understanding how users adapt to interface design over time can inform sustainable usability strategies. Such research can distinguish initial usability from long-term user experience.

Methodological expansion using eye-tracking, interaction logging, or physiological measures may provide deeper insight into user behavior. These approaches can uncover subtle usability issues not captured through self-report or task performance alone.

Practical innovation remains essential for advancing mobile usability. Continued collaboration between researchers, designers, and developers can refine HCI design frameworks responsive to real-world constraints. The findings of this study provide a foundation for ongoing improvement of usability in mobile computing applications.

CONCLUSION

The most significant finding of this study is that Human Computer Interaction design directly and measurably enhances usability in mobile computing applications. Interfaces that consistently applied HCI principles such as clarity of navigation, visual hierarchy, feedback, and interaction consistency enabled users to complete tasks more efficiently, with fewer errors and higher satisfaction. These findings demonstrate that usability improvements are primarily driven by design quality rather than by users' technical proficiency or familiarity with mobile devices.

The primary contribution of this research lies in its conceptual and methodological integration of HCI design principles with empirical usability evaluation. Conceptually, the study reinforces usability as an outcome of human-centered interaction design rather than a secondary system attribute. Methodologically, the combination of usability testing, standardized questionnaires, and qualitative user feedback provides a comprehensive framework for assessing how specific design elements influence mobile user performance and experience.

Several limitations should be acknowledged when interpreting the results. The study focused on a limited set of mobile applications and interaction tasks, which may restrict the generalizability of findings across different application domains and user populations. The short-term evaluation period also limits insight into long-term usability and user adaptation. Future research is encouraged to include longitudinal designs, broader application categories, and emerging interaction modalities to further examine the evolving relationship between HCI design and usability in mobile computing environments.

DECLARATION OF AI AND AI ASSISTED TECHNOLOGIES IN THE WRITING PROCESS

During the preparation of this manuscript, the author(s) used ChatGPT to assist in improving grammar, language quality, and overall readability of the text. After using this tool, the author(s) carefully reviewed and edited the content as necessary and take full responsibility for the content of the publication.

AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; In-vestigation.

Author 3: Data curation; Investigation.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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.

REFERENCES

- Alzubi, T. M., Alzubi, J. A., Singh, A., Alzubi, O. A., & Subramanian, M. (2025). A Multimodal Human-Computer Interaction for Smart Learning System. *International Journal of Human-Computer Interaction*, 41(3), 1718–1728. <https://doi.org/10.1080/10447318.2023.2206758>
- Balhara, S., Gupta, N., Alkhayat, A., Bharti, I., Malik, R. Q., Mahmood, S. N., & Abedi, F. (2025). A survey on deep reinforcement learning architectures, applications and emerging trends. *IET Communications*, 19(1), e12447. <https://doi.org/10.1049/cmu2.12447>
- Barzegar Gerdroodbary, M., & Salavatidezfouli, S. (2025). A predictive surrogate model based on linear and nonlinear solution manifold reduction in cardiovascular FSI: A comparative study. *Computers in Biology and Medicine*, 189, 109959. <https://doi.org/10.1016/j.compbiomed.2025.109959>
- Borghini, S., Ruo, A., Sabattini, L., Peruzzini, M., & Villani, V. (2025). Assessing operator stress in collaborative robotics: A multimodal approach. *Applied Ergonomics*, 123, 104418. <https://doi.org/10.1016/j.apergo.2024.104418>
- Chen, Y., Hao, Y., Feng, L., Meng, J., Yang, Z., Wu, H., Li, P., Zhu, Z., Zhao, B., & Wei, Q. (2025). A flexible multifunctional triboelectric nanogenerator based on bio-inspired nanocellulose/tannic acid@MXene-composited hydrogel for human healthcare. *International Journal of Biological Macromolecules*, 306, 141261. <https://doi.org/10.1016/j.ijbiomac.2025.141261>
- Cheng, A., Li, X., Li, D., Chen, Z., Cui, T., Tao, L.-Q., Jian, J., Xiao, H., Shao, W., Tang, Z., Li, Xinyue, Dong, Z., Liu, H., Yang, Y., & Ren, T.-L. (2025). An intelligent hybrid-fabric wristband system enabled by thermal encapsulation for ergonomic human-machine interaction. *Nature Communications*, 16(1), 591. <https://doi.org/10.1038/s41467-024-55649-1>
- Choudhary, S., Kaushik, N., Sivathanu, B., & Rana, N. P. (2025). Assessing Factors Influencing Customers' Adoption of AI-Based Voice Assistants. *Journal of Computer Information Systems*, 65(5), 592–609. <https://doi.org/10.1080/08874417.2024.2312858>
- Cohn, C., Snyder, C., Fonteles, J. H., T. S., A., Montenegro, J., & Biswas, G. (2025). A multimodal approach to support teacher, researcher and AI collaboration in STEM +C learning environments. *British Journal of Educational Technology*, 56(2), 595–620. <https://doi.org/10.1111/bjet.13518>

- Emami, M., Bayat, A., Tafazolli, R., & Quddus, A. (2025). A Survey on Haptics: Communication, Sensing and Feedback. *IEEE Communications Surveys & Tutorials*, 27(3), 2006–2050. <https://doi.org/10.1109/COMST.2024.3444051>
- Fan, K., Li, K., Wang, Z., Men, W., Wu, X., Cheng, J., & Zhang, J. (2025). An unprecedented strategy with electric double layer and adaptive ionic liquid in fully ionogel fiber-based TENG for enhanced output and dynamic stability. *Nano Energy*, 135, 110658. <https://doi.org/10.1016/j.nanoen.2025.110658>
- Fu, X., Mo, S., Buendia, A., Laurent, A. P., Shao, A., Alvarez-Torres, M. D. M., Yu, T., Tan, J., Su, J., Sagatelian, R., Ferrando, A. A., Ciccica, A., Lan, Y., Owens, D. M., Palomero, T., Xing, E. P., & Rabadan, R. (2025). A foundation model of transcription across human cell types. *Nature*, 637(8047), 965–973. <https://doi.org/10.1038/s41586-024-08391-z>
- Halkiopoulos, C., Gkintoni, E., Aroutzidis, A., & Antonopoulou, H. (2025). Advances in Neuroimaging and Deep Learning for Emotion Detection: A Systematic Review of Cognitive Neuroscience and Algorithmic Innovations. *Diagnostics*, 15(4), 456. <https://doi.org/10.3390/diagnostics15040456>
- Hamdani, R., & Chihi, I. (2025). Adaptive human-computer interaction for industry 5.0: A novel concept, with comprehensive review and empirical validation. *Computers in Industry*, 168, 104268. <https://doi.org/10.1016/j.compind.2025.104268>
- Huang, T., Gao, B., Li, M., Zhou, X., He, W., Yan, J., Luo, X., Lai, W., Li, J., Luo, S., Yue, Y., Ma, Y., & Gao, Y. (2025). Cathode-Free Aqueous Micro-battery for an All-in-One Wearable System with Ultralong Stability. *Advanced Energy Materials*, 15(4), 2402871. <https://doi.org/10.1002/aenm.202402871>
- Li, L., Xu, H., Li, Z., Zhong, B., Lou, Z., & Wang, L. (2025). 3D Heterogeneous Sensing System for Multimode Parallel Signal No-Spatiotemporal Misalignment Recognition. *Advanced Materials*, 37(6), 2414054. <https://doi.org/10.1002/adma.202414054>
- Li, W., Luo, F., Liu, Y., Zou, Y., Mo, L., He, Q., Lin, P., Xu, Q., Liu, A., Zhang, C., Cheng, J., Cheng, L., & Ji, L. (2025). Bioinspired Smart Triboelectric Soft Pneumatic Actuator-Enabled Hand Rehabilitation Robot. *Advanced Materials*, 37(9), 2419059. <https://doi.org/10.1002/adma.202419059>
- Li, X., Wang, Y., Tian, Y., Zhang, L., & Ma, J. (2025). Biomimetic multiscale structure with hierarchically entangled topologies of cellulose-based hydrogel sensors for human-computer interaction. *Carbohydrate Polymers*, 348, 122825. <https://doi.org/10.1016/j.carbpol.2024.122825>
- Lin, J., Chen, J., Yang, K., Roitberg, A., Li, Siyu, Li, Z., & Li, Shutao. (2025). AdaptiveClick: Click-Aware Transformer With Adaptive Focal Loss for Interactive Image Segmentation. *IEEE Transactions on Neural Networks and Learning Systems*, 36(3), 5759–5773. <https://doi.org/10.1109/TNNLS.2024.3378295>
- Linh, V. T. N., Han, S., Koh, E., Kim, S., Jung, H. S., & Koo, J. (2025). Advances in wearable electronics for monitoring human organs: Bridging external and internal health assessments. *Biomaterials*, 314, 122865. <https://doi.org/10.1016/j.biomaterials.2024.122865>
- Omidian, H. (2025). AI-powered breakthroughs in material science and biomedical polymers. *Journal of Bioactive and Compatible Polymers*, 40(2), 161–174. <https://doi.org/10.1177/08839115241308202>

- Parasa, S., Berzin, T., Leggett, C., Gross, S., Repici, A., Ahmad, O. F., Chiang, A., Coelho-Prabhu, N., Cohen, J., Dekker, E., Keswani, R. N., Kahn, C. E., Hassan, C., Petrick, N., Mountney, P., Ng, J., Riegler, M., Mori, Y., Saito, Y., ... Sharma, P. (2025). Consensus statements on the current landscape of artificial intelligence applications in endoscopy, addressing roadblocks, and advancing artificial intelligence in gastroenterology. *Gastrointestinal Endoscopy*, 101(1), 2-9.e1. <https://doi.org/10.1016/j.gie.2023.12.003>
- Pillalamarri, R., & Shanmugam, U. (2025). A review on EEG-based multimodal learning for emotion recognition. *Artificial Intelligence Review*, 58(5), 131. <https://doi.org/10.1007/s10462-025-11126-9>
- Qi, W., Xu, X., Qian, K., Schuller, B. W., Fortino, G., & Aliverti, A. (2025). A Review of AIoT-Based Human Activity Recognition: From Application to Technique. *IEEE Journal of Biomedical and Health Informatics*, 29(4), 2425–2438. <https://doi.org/10.1109/JBHI.2024.3406737>
- Shah, R., Doss, A. S. A., & Lakshmaiya, N. (2025). Advancements in AI-enhanced collaborative robotics: Towards safer, smarter, and human-centric industrial automation. *Results in Engineering*, 27, 105704. <https://doi.org/10.1016/j.rineng.2025.105704>
- Song, M., Liu, Q., Xu, X., Wang, B., Lu, Y., Yang, L., Liu, X., Wang, Y., Li, M., & Wang, D. (2025). A Fabric-Based Multimodal Flexible Tactile Sensor With Precise Sensing and Discrimination Capabilities for Pressure-Proximity-Magnetic Field Signals. *Advanced Functional Materials*, 35(19), 2420445. <https://doi.org/10.1002/adfm.202420445>
- Suarez-Amaran, L., Song, L., Tretiakova, A. P., Mikhail, S. A., & Samulski, R. J. (2025). AAV vector development, back to the future. *Molecular Therapy*, 33(5), 1903–1936. <https://doi.org/10.1016/j.ymthe.2025.03.064>
- Tariq, M. U. (2024). Bridging Generations: Digital Transformation and Its Multifaceted Impact Across Societal Sectors. In M. Anshari, M. N. Almunawar, & P. Ordóñez De Pablos (Eds.), *Advances in Human and Social Aspects of Technology* (pp. 1–22). IGI Global. <https://doi.org/10.4018/979-8-3693-6366-9.ch001>
- Tuo, Y., Wu, J., Zhao, J., & Si, X. (2025). Artificial intelligence in tourism: Insights and future research agenda. *Tourism Review*, 80(4), 793–812. <https://doi.org/10.1108/TR-03-2024-0180>
- Wang, R., Guo, C., Shabaz, M., Rida, I., Cambria, E., & Zhu, X. (2025). CIME: Contextual Interaction-Based Multimodal Emotion Analysis With Enhanced Semantic Information. *IEEE Transactions on Computational Social Systems*, 1–11. <https://doi.org/10.1109/TCSS.2025.3572495>
- Yang, R., Yang, X., Qi, L., Meng, X., Dai, L., Jin, X., Zhou, J., Lu, H., Xia, C., & Li, J. (2025). Adhesive conductive wood-based hydrogel with high tensile strength as a flexible sensor. *Carbohydrate Polymers*, 351, 122954. <https://doi.org/10.1016/j.carbpol.2024.122954>
- Yang, X., Wang, Y., Lin, Y., Zhang, M., Liu, O., Shuai, J., & Zhao, Q. (2025). A Multi-Task Self-Supervised Strategy for Predicting Molecular Properties and FGFR1 Inhibitors. *Advanced Science*, 12(13), 2412987. <https://doi.org/10.1002/advs.202412987>
- Zhang, T., Manshahi, F., Bowen, C. R., Zhang, M., Qian, W., Hu, C., Bai, Y., Huang, Z., Yang, Y., & Chen, J. (2025). A flexible pressure sensor array for self-powered identity authentication during typing. *Science Advances*, 11(11), eads2297. <https://doi.org/10.1126/sciadv.ads2297>

Zhou, X., Chen, X., Yang, B., Luo, S., Guo, M., An, N., Tian, H., Li, X., & Shao, J. (2025). Advancements in Functionalizable Metal-Organic Frameworks for Flexible Sensing Electronics. *Advanced Functional Materials*, 35(32), 2501683. <https://doi.org/10.1002/adfm.202501683>

Zhu, X., Liu, Z., Cambria, E., Yu, X., Fan, X., Chen, H., & Wang, R. (2025). A client–server based recognition system: Non-contact single/multiple emotional and behavioral state assessment methods. *Computer Methods and Programs in Biomedicine*, 260, 108564. <https://doi.org/10.1016/j.cmpb.2024.108564>

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