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A Bibliometric Analysis of Human-Agent Collaboration in Empathetic Social Agents: Trends, Influences, and Research Frontiers

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ABSTRACT

The rapid growth of artificial intelligence (AI) and affective computing has intensified interest in empathetic social agents such as chatbots, robots, and virtual assistants. These agents are increasingly applied in healthcare, education, and customer service, yet research on human–agent collaboration (HAC) remains fragmented. This bibliometric study maps and analyses the intellectual structure, key contributions, and emerging frontiers of HAC in empathetic social agents from 2020 to 2025. A dataset of 1,164 Scopus-indexed publications was analysed using Scopus Analytics and VOSviewer to examine publication trends, citation networks, and keyword patterns. Results show rapid growth peaking in 2024, with computer science and engineering forming the technological core, complemented by psychology, social sciences, and medicine. Citation analyses identify seminal works anchoring the field, while keyword mapping highlights established themes (HRI, social robotics, AI ethics), evolving topics (ChatGPT, generative AI, user experience), and underexplored areas such as AI intimacy, error management, and therapeutic applications. Overall, the field is consolidating around technical, psychological, and ethical dimensions while shifting toward generative AI and affect-aware collaboration, providing a roadmap for advancing both theory and practice.

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1. INTRODUCTION

The rapid advancement of technology has transformed how humans collaborate with artificial agents (virtual agents/ robots), with emotionally intelligent interaction emerging as a central focus. Among these, empathetic social agents, designed to recognise and respond to users' emotional states, are increasingly recognised for their potential to enhance collaboration in domains such as healthcare, education, and mental health support (Minami et al., 2025; Saffaryazdi et al., 2025; Sanjeewa et al., 2024). Recent studies highlight the importance of empathy and socio-emotional attributes in shaping effective human–agent interactions (Kolomaznik et al., 2024; Sanjeewa et al., 2024), reinforcing the notion that technical performance alone is insufficient for fostering meaningful human-machine partnerships.

Despite growing interest, the research landscape surrounding empathetic social agents and human-machine collaboration remains fragmented, spanning multiple disciplines such as artificial intelligence (AI), psychology, and human–agent collaboration (HAC). While this interdisciplinary nature promotes innovation, it also presents challenges in tracing intellectual progress, identifying key contributors, and synthesising emerging themes. Genç and Verma (2024) highlight this conceptual fragmentation and the lack of consensus surrounding empathy in HAC in their scoping review. However, such qualitative syntheses are limited in scope and cannot fully capture the structural dynamics of the field. A bibliometric approach addresses these gaps by systematically mapping publication trends, citation networks, and thematic clusters, enabling the identification of key contributors as well as the field's intellectual structures and trajectories (Donthu et al., 2021). To this end, this study presents a comprehensive bibliometric analysis of human–agent collaboration in empathetic social agents, with the following research questions:

(1) What are the recent publication patterns in human–agent collaboration in empathetic social agents, in terms of annual growth, document types, and subject areas?
(2) Which authors and countries are the most productive in publishing research on human–agent collaboration in empathetic social agents?
(3) Which articles are the most influential in shaping the field, as indicated by citation analysis?
(4) What emerging themes, evolving concepts, and underexplored areas can be identified through keyword co-occurrence analyses?

The rest of this paper is structured as follows: Section 2 introduces human–agent collaboration in empathetic social agents, providing the conceptual background and definitions underpinning the study. Section 3 describes the methodology and data sources used for the bibliometric analysis. Section 4 presents the findings and visualisations related to the research questions, and Section 5 concludes the paper with key insights and future research directions.

2. LITERATURE REVIEW

2.1 HUMAN-AGENT COLLABORATIONS IN EMPATHETIC AGENTS

Human-agent collaboration (HAC) refers to a cooperative, dynamic, and interdependent interaction between humans and autonomous artificial agents to achieve shared goals (Cila, 2022). In the context of empathetic social agents, this collaboration extends beyond functional coordination to encompass emotional understanding, adaptive behavior, and affective communication (Kolomaznik et al., 2024; Sanjeewa et al., 2024). Such agents are not merely task-oriented systems but are increasingly framed as social partners capable of interpreting and responding to human emotions in ways that foster trust, engagement, and mutual understanding.

Empathetic agents such as chatbots, social robots, and virtual assistants draw on advances in affective computing, social robotics, and natural language processing to detect, interpret, and respond to affective cues (Ischen et al., 2020; Yim, 2023). These capacities aim to enhance engagement and relational quality

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in human–AI interaction. Recent research increasingly integrates psychological theories of empathy with AI-driven models of emotional intelligence, signalling a move toward socially adaptive and context-aware systems (Liu-Thompkins et al., 2022; Zhang et al., 2024). The emergence of generative AI and large language models (LLMs) such as ChatGPT has further expanded these possibilities, allowing agents to simulate empathy through natural and emotionally resonant communication (Crolic et al., 2022; Maslej et al., 2025).

Despite these advances, achieving authentic empathy and maintaining user trust remain persistent challenges. Studies on trust calibration, error management, and affective alignment suggest that mismatched or exaggerated empathic responses can reduce perceived credibility or cause user discomfort (Klein et al., 2024; Faria et al., 2025). Balancing responsiveness with authenticity thus remains a central concern. Addressing these challenges requires interdisciplinary approaches that combine computational modelling with insights from psychology, ethics, and social cognition. Overall, human–agent collaboration in empathetic systems reflects a convergence of technical innovation and human-centred design. The field is moving toward the development of emotionally intelligent agents capable of trustworthy, context-sensitive collaboration across domains such as healthcare, education, customer service, and therapy (Bozdağ, 2024; Faria et al., 2025). As empathetic agents continue to evolve, their long-term impact will depend on achieving a sustainable balance between emotional expressiveness, ethical responsibility, and user well-being.

3. METHODOLOGY

To conduct a comprehensive bibliometric analysis of human-agent collaboration in empathetic social agents, a systematic data collection and analysis process was followed. This section outlines the data source, search strategy, keyword selection, inclusion and exclusion criteria, and the tools used for visualisation.

3.1 Data Collection and Search Strategy

The bibliometric data for this study were retrieved from the Scopus database on 19 August 2025. Scopus was selected due to its extensive coverage of peer-reviewed literature across disciplines relevant to this study, including artificial intelligence, psychology, and human–computer interaction. The search was limited to publications from 2020 to 2025 to capture recent developments while maintaining a manageable scope. To identify relevant literature, a targeted search string was developed to capture studies that intersect three key dimensions: collaboration or interaction, agent technologies, and emotional or affective responsiveness. The search was applied to the title, abstract, and keywords fields, with collaboration terms restricted to the title to improve precision. Table 1 presents the exact query.

Table 1. Search string

Database	Search String
Scopus	(TITLE ("collaborat*" OR "interact*" OR "team*") AND TITLE-ABS-KEY ("AI" OR "robot" OR "chatbot" OR "virtual assistant*" OR "intelligent agent" OR "agent" OR "embodied conversational agent*") AND TITLE-ABS-KEY ("empathetic" OR "affective" OR "emotion-aware" OR "emotional*" OR "socially aware" OR "affective computing" OR "empathetic computing"))

This search string was designed to retrieve literature that explicitly discusses collaborative dynamics involving emotionally responsive or intelligent agents across diverse technological platforms. Keywords were selected to reflect the study's thematic axes: (a) *collaboration/interaction*, (b) *agent technologies*, and (c*) emotional or affective responsiveness*. Table 2 provides a breakdown of keywords and justifications.

Table 2. Keyword justification

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No	Keyword	Justification
1	“collaborat*” OR “interact*” OR “team*”	Ensures inclusion of studies explicitly focused on collaboration, interaction, or teamwork.
2	"AI" OR "robot" OR "chatbot" OR "virtual assistant*" OR "intelligent agent" OR "agent"	Covers a wide range of agent technologies, from embodied robots to software-based assistants.
3	“empathetic" OR "affective" OR "emotion-aware" OR "emotional*"	Targets affective/emotional dimensions in human–agent interaction.
4	"socially aware" OR "affective computing" OR "empathetic computing" OR "embodied conversational agent*"	Captures adjacent constructs in affective HCI and socially interactive systems.

To ensure transparency and reproducibility, explicit inclusion and exclusion criteria were defined for the selection of publications. These criteria are summarised in Table 3.

Table 3. Selection criteria

Criteria	Inclusion	Exclusion	Justification
Timeline	2020-2025	Before 2020	Captures recent developments while maintaining a manageable scope.
Publication type	Journal article, conference article	Review article, book chapter. book	Excluded to focus on primary research
Language	English	Non-English	Ensures consistency in bibliometric parsing, though this may omit contributions from non-English research communities.

These criteria provided a consistent framework for screening, ensuring that only publications directly relevant to the study’s objectives were included in the bibliometric analysis.

3.2 Data Analysis

To conduct a comprehensive bibliometric analysis of human–agent collaboration in empathetic social agents, a systematic data analysis process was implemented following the data collection phase. This section outlines the tools and techniques used to process, visualise, and interpret the bibliometric data. The bibliographic records retrieved from Scopus were exported in .csv format and imported into VOSviewer (Version 1.6.20). The search and screening process followed a structured flow, beginning with topic definition, scope and coverage parameters, keyword-based searching, data extraction, and screening. In total, 1,164 records were identified on 19 August 2025, all meeting the eligibility criteria and included for analysis. Fig. 1 presents the flow diagram of this process.

To address the study’s research questions, a combination of Scopus built-in analytics (Analyse Documents) and VOSviewer (Version 1.6.20) was employed. The analysis was structured around four guiding questions. First, publication trends were examined using Scopus Analyse to track annual output, document types, and subject areas. Second, research productivity was assessed by mapping the most active authors and countries through Scopus Analyse. Third, influential articles were identified through citation analysis, using citation counts as indicators of scholarly impact. Finally, research trends and future directions were explored through keyword co-occurrence mapping and overlay visualizations, which revealed established thematic clusters, highlighted evolving concepts, and pointed to underexplored areas for further study. Taken together, Scopus provided quantitative insights, while VOSviewer uncovered relational structures and thematic networks, enabling a comprehensive understanding of the research landscape.

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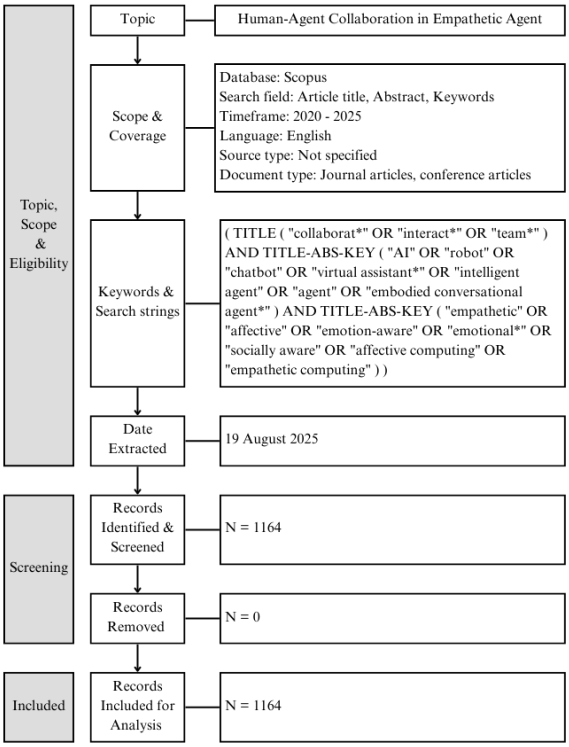

Fig.1. Flow diagram of the search strategy

4. RESULTS AND DISCUSSION

This section presents the results of the bibliometric analysis, structured around four research questions: publication trends, influential contributors, influential articles, and future research directions.

4.1 Publication Trends

To understand the evolution of research on human–agent collaboration in empathetic social agents, publication output from 2020 to 2025 was analysed using Scopus data.

4.1.1 Annual Distribution of Publications

The annual distribution of publications shows a clear upward trajectory over the six years (Fig. 2). The number of publications increased from 99 in 2020 to a peak of 302 in 2024, representing the peak year within the dataset. In 2025, a total of 293 documents were recorded as of August 19, 2025. This figure already approaches the 2024 peak, indicating that the final total for 2025 is likely to surpass previous years once the year's publications are fully indexed. Thus, the apparent decline from 2024 to 2025 reflects the partial-year cutoff rather than a genuine drop in research activity.

This trend highlights the growing scholarly recognition of the importance of emotionally intelligent agents in collaborative settings. The notable surge between 2022 and 2024 suggests intensified interdisciplinary research activity, likely driven by advances in affective computing, conversational AI, and social robotics. The timing aligns with the rapid mainstream adoption of large language models and

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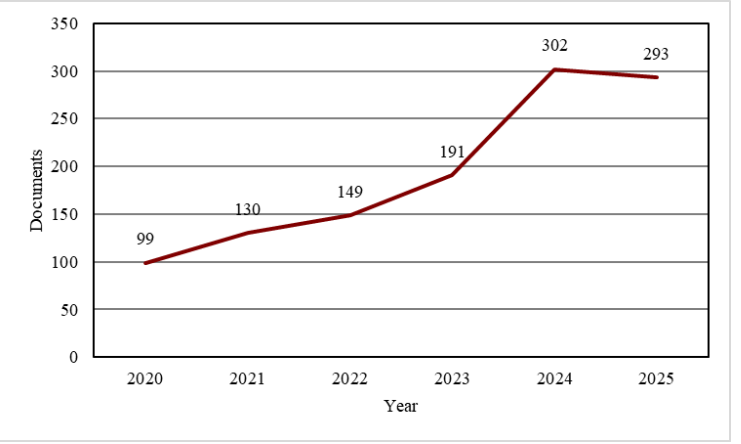
generative AI tools, which likely stimulated new research into empathy, trust, and ethical interaction in social agents.



*2025 data reflect publications indexed up to 19 August 2025

Fig. 2. Annual publication output (2020 – 2025)

Overall, these findings suggest not only expanding research activity but also a maturing field moving toward conceptual consolidation. The increasing volume of publications, alongside a rise in influential and highly cited works during this period, points to a transition from exploratory studies to more theory-driven and application-oriented research in empathetic human–agent collaboration.

4.1.2 Documents by Type Analysis

As shown in Fig. 3, journal articles account for 601 documents, while conference papers comprise 563 documents. This slight predominance of journal articles suggests that researchers in this domain tend to favour publishing in peer-reviewed journals, which typically reflect more comprehensive and validated studies. On the other hand, the substantial number of conference papers highlights the dynamic and rapidly evolving nature of the field, where preliminary findings and innovative ideas are frequently shared.

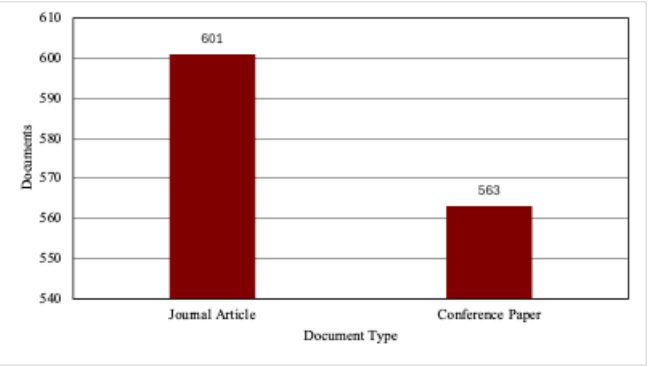


Fig. 3. Documents by type

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The document type distribution indicates a transition from exploratory, conference-based idea sharing towards more rigorous and cumulative research published in journals. This balance between journal and conference papers suggests that research on empathetic social agents is becoming more established while still encouraging innovation through new methods and applications in AI, affective computing and human-agent collaboration.

4.1.3 Subject Area

This section analyses the top 10 subject areas contributing to research on human–agent collaboration in empathetic social agents, selected from a total of 26 subject areas identified in the dataset. Fig. 4 presents the number of documents published in each of the top 10 subject areas. Computer Science leads with 858 documents, followed by Engineering (368) and Social Sciences (231). These areas form the technological and human-centred backbone of the field. Other significant contributors include Mathematics (208), Psychology (133), and Medicine (96), which support the analytical, behavioural, and health-related aspects of empathetic agent design. Fields such as Arts and Humanities, Business, Management and Accounting, Decision Sciences, and Neuroscience also appear, reflecting the interdisciplinary nature of the domain.

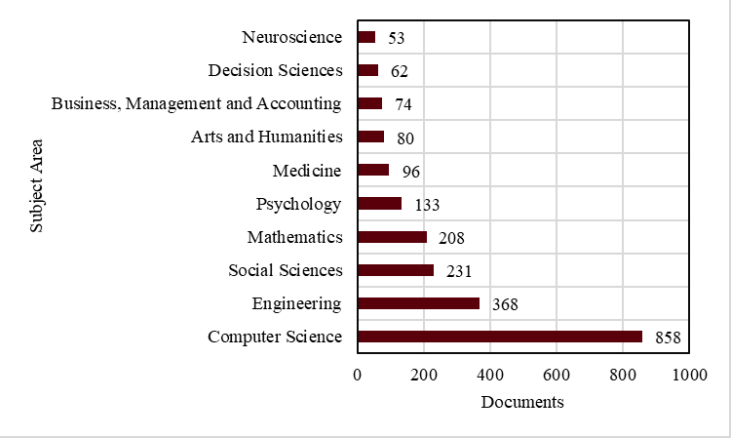

Fig.4. Top 10 subject areas

The subject area distribution highlights the research on empathetic social agents is both evolving and interdisciplinary. While Computer Science and Engineering remain dominant, the increasing involvement of Psychology, Social Sciences, and Arts and Humanities shows a shift toward more human-centred and ethical approaches. The mix of disciplines suggests that the field is moving beyond technical development to focus more on emotional intelligence, social interaction and user experience, the key aspects for designing genuinely empathetic and collaborative agents.

4.2 Research Productivity

To understand the influence of key contributors in advancing research on human–agent collaboration in empathetic social agents, the scholarly output from 2020 to 2025 was analysed using Scopus data. Rather than focusing solely on the number of publications, this analysis highlights the contributors whose work has had the greatest impact, measured by their repeated presence, consistency, and contributions across multiple studies in the field.

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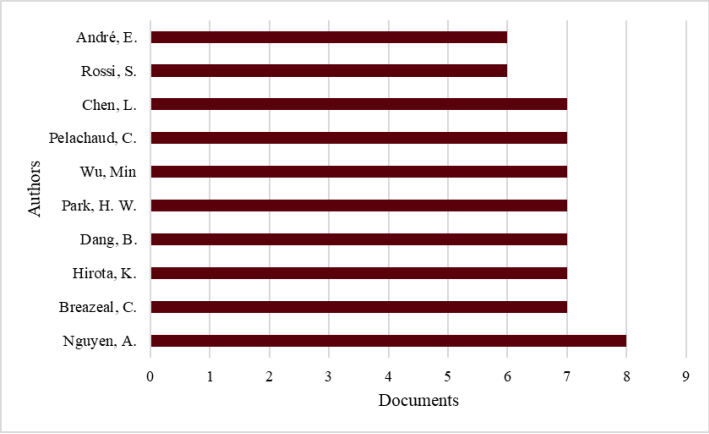
4.2.1 Productive authors

An analysis was conducted on the authors with the highest productivity from 2020 to 2025. Based on the statistics available as of 19 August 2025, a total of 4,354 unique authors contributed to publications on this topic during the specified period. This substantial number of distinct contributors highlights the wide diversity of voices represented in the dataset. Among these authors, the top 10 most prolific contributors (measured by the number of documents authored or co-authored) are presented in Fig. 5. Each of these authors produced at least six publications, with the most prolific author contributing to eight. The figure illustrates the names of these leading contributors alongside their corresponding publication counts, offering a clear view of their relative productivity within the research period.



*Data reflect publications indexed up to 19 August 2025

Fig. 5. Top 10 most productive authors

4.2.2 Productivity by Country

An analysis of publication output by country from 2020 to 2025 reveals a diverse and geographically expansive research landscape, highlighting contributions from a wide range of nations. The top 10 most productive countries in this dataset are presented in Fig. 6. The United States continues to lead in AI model development, producing 40 models in 2024, surpassing both China and Europe (AlShebli et al., 2024; Maslej et al., 2025). This trend aligns with long-term patterns, as China now rivals the U.S. in terms of AI research impact and productivity, with both countries leading in workforce size and scholarly output. With its recent strategic push toward AI adoption, China is increasingly challenging the U.S.'s position as the global leader in this field (AlShebli et al., 2024).

The distribution shown in Fig. 6 highlights a globally interconnected research ecosystem. While the United States and China act as leading centers of productivity, Europe's collaborative research networks and Asia's emerging contributors, particularly India, Japan, and South Korea, where they play an increasingly important role in expanding the knowledge base. This pattern suggests that research on empathetic social agents is becoming more international, with expertise spreading beyond traditional AI powerhouses. Such diversity promotes cross-cultural perspectives and strengthens the field's capacity to address ethical, social, and technical challenges in human–agent collaboration.

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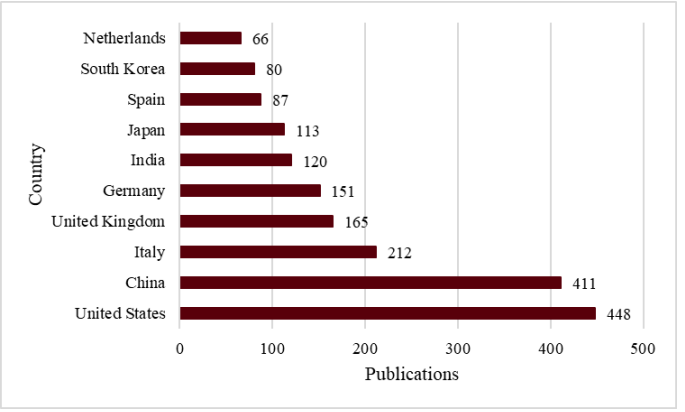

Fig. 6 Top 10 Most Productive Countries

4.3 Influential Articles

A citation analysis was conducted using VOSviewer, with individual documents as the unit of analysis and a minimum threshold of two citations per document. Of the 1,164 Scopus-indexed publications, 627 met this criterion and were included in the analysis. These papers formed a connected network, from which the top 10 most cited articles were identified (Table 4). The most influential publication is *Blame the Bot: Anthropomorphism and Anger in Customer–Chatbot Interactions* (Crolic et al., 2022), with 430 citations, which has strongly shaped research on chatbot anthropomorphism and emotional responses in customer-AI interactions. The second most cited paper, *Artificial Empathy in Marketing Interactions* (Liu-Thompkins et al., 2022), with 190 citations, reinforces the importance of empathy and affective design in AI-mediated customer experiences.

Mid-tier influential studies include Ischen et al. (2020) with 68 citations, which explores persuasive chatbot strategies, and "Think Like a Robot" (Liao et al., 2024) with 36 citations, focusing on humanoid service robots and consumer decision-making. More recent contributions, such as Zhang et al. (2024) and Bozdağ (2024), show early but promising influence, while Faria et al. (2025) and Klein et al. (2024) signal new directions in affective computing and error management.

Table 4: Top 10 influential articles

No	Title	Year	Citations
1	Blame the Bot: Anthropomorphism and Anger in Customer–Chatbot Interactions (Crolic et al., 2022)	2022	430
2	Artificial Empathy in Marketing Interactions: Bridging the Human-AI Gap in Affective and Social Customer Experience (Liu-Thompkins et al., 2022)	2022	190
3	"I Am Here to Assist You Today": The Role of Entity, Interactivity and Experiential Perceptions in Chatbot Persuasion (Ischen et al., 2020)	2020	68
4	Think Like a Robot: How Interactions with Humanoid Service Robots Affect Consumers' Decision Strategies (Liao et al, 2024)	2024	36
5	Effect of AI Chatbot's Interactivity on Consumers' Negative Word-of-Mouth Intention: Mediating Role of Perceived Empathy and Anger (Yim, 2023)	2023	20
6	The Impact of Emotional Expression by Artificial Intelligence Recommendation Chatbots on Perceived Humanness and Social Interactivity (Zhang et al., 2024)	2024	13
7	The AI-Mediated Intimacy Economy: A Paradigm Shift in Digital Interactions (Bozdağ, 2024)	2024	3
8	Examining the Effects of Conversational Chatbots on Changing Conspiracy Beliefs about Science: The Paradox of Interactivity (Wang & Tanes-Ehle, 2023)	2023	3
9	How Interaction Mechanism and Error Responses Influence Users' Responses to Customer Service Chatbots (Klein et al., 2024)	2024	3
10	Advancing Emotionally Aware Child–Robot Interaction with Biophysical Data and Insight-Driven Affective Computing (Faria et al., 2025)	2025	2

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The citation landscape reveals both concentration and evolution. A small set of highly cited works, particularly those by Crolic et al. (2022) and Liu-Thompkins et al. (2022), currently anchors the field, shaping much of the conceptual and empirical direction. However, the rise of newer publications from 2023 onward indicates shifting research priorities, from customer-facing empathy and anthropomorphism to themes of emotional expression, trust calibration, and error management in broader human–agent contexts.

Critically, the top-cited studies expose several conceptual and methodological gaps. “Empathy” remains inconsistently defined, appearing variously as anthropomorphism and emotion regulation (Crolic et al., 2022), affective marketing (Liu-Thompkins et al., 2022), interactivity (Yim, 2023), or emotional expression (Zhang et al., 2024). This fragmentation limits theoretical integration across studies. Moreover, technical and behavioural aspects, such as error handling (Klein et al., 2024) and long-term adaptation remain underexplored. Emerging research on AI intimacy (Bozdağ, 2024) and therapeutic applications (Faria et al., 2025) has yet to gain traction but points toward diversification of the field.

Overall, citation patterns suggest that empathetic social agent research is transitioning from foundational explorations toward more nuanced, application-driven studies. While a few seminal works continue to dominate, intellectual influence gradually dispersing, signaling a broadening and maturation of the research landscape.

4.4 Future Direction

To explore the future research directions and identify future frontiers, a keyword co-occurrence analysis was conducted in VOSviewer (full-counting, association-strength normalization; minimum keyword occurrence = 5). The resulting network (Fig. 7) contained several distinct thematic clusters. The largest cluster focused on human-robot interaction (HRI), incorporating terms such as *emotion recognition, machine learning, humanoid robots,* and *emotional intelligence.* This reflects a sustained interest in the technical and affective mechanisms underpinning human–AI engagement. A second major cluster emphasised *artificial intelligence, social robots, trust, collaboration*, and *ethics,* indicating a mature knowledge base concerned with the social and organizational integration of AI technologies. Together, these clusters demonstrate the close integration of technical capability, psychological understanding, and ethical awareness in the study of empathetic social agents.

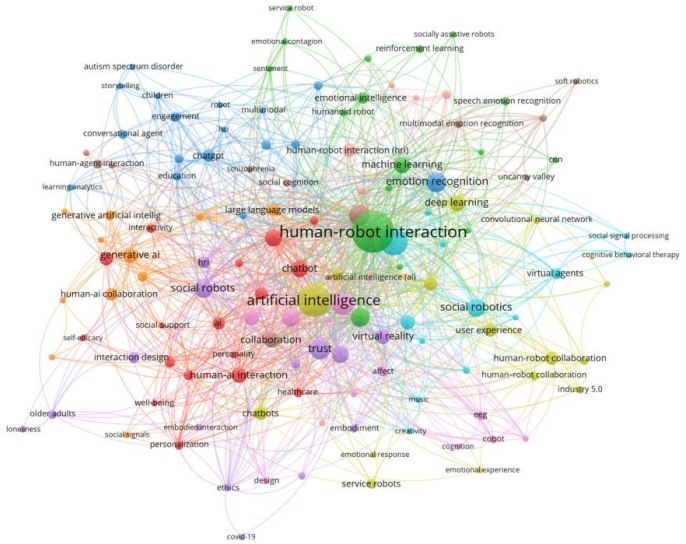

Fig. 7. Established themes

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Overlay visualisation (Fig. 8), colour-coded by average publication year, highlighted a sharp rise in attention to *ChatGPT, large language models,* and *generative AI* since 2022. These terms increasingly co-occur with traditional HRI and marketing keywords, suggesting a shift from rule-based systems to more conversational, context-aware AI. The growing prominence of keywords related to *human–AI collaboration, user experience,* and *emotional authenticity* suggests that the field is moving toward designing agents capable of more natural, trust-based, and emotionally resonant interactions.

This transition indicates that research is expanding beyond technological innovation to include deeper questions of trust, empathy, and user alignment**.** The convergence of affective computing and generative AI points to a new research phase focused on socio-emotional intelligence and the ethical governance of increasingly autonomous agents.

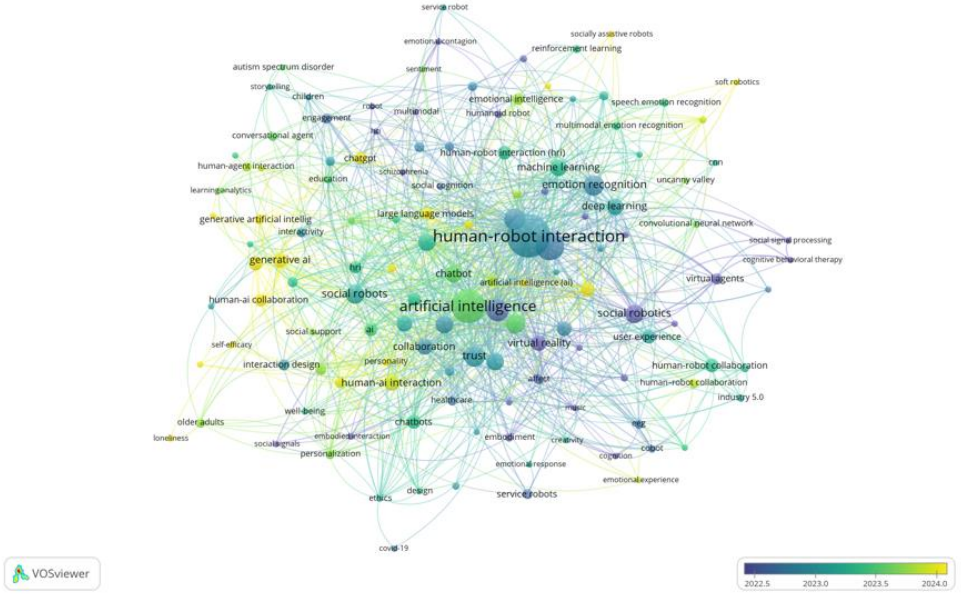

Fig. 8. Evolving concepts

Several emergent but recent keywords highlight potential avenues for future research. Topics such as *emotional experience, AI intimacy, error management,* and *cognitive behavioral therapy* appear infrequently but cluster near emerging nodes. These emerging areas have not yet been fully integrated into mainstream research but point to growing interest in affect, well-being, and human vulnerability in AI-mediated interactions. Exploring these underdeveloped themes could enhance understanding of long-term trust, acceptance, and emotional resilience in human–AI relationships.

Overall, the co-occurrence and overlay analyses suggest that while core themes such as HRI, AI ethics, and social robotics remain central, the field is steadily shifting toward generative *AI, affect-aware design,* and *cross-domain applications* in areas such as healthcare, education, and therapy. Engaging with these new directions offers valuable opportunities to strengthen both theoretical frameworks and applied innovations.

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5. CONCLUSION

This study provides a bibliometric mapping of human–agent collaboration in empathetic social agents between 2020 and 2025. Drawing on 1,163 Scopus-indexed publications and VOSviewer visualisations, it examines publication trends, influential authors and articles, and emerging research frontiers. Three key insights emerge from the analysis. First, the field shows sustained growth and increasing interdisciplinary convergence across computer science, engineering, psychology, and the social sciences. This reflects growing recognition that technical performance alone is insufficient for achieving meaningful human–AI collaboration. Second, the citation and co-citation analyses reveal a dual structure of influence: highly cited works anchor current debates, while enduring theoretical frameworks continue to support the conceptual foundation of empathetic interaction. Newer studies, particularly those published from 2023 onward, indicate expanding interest in emotional expression, trust calibration, and error management. Third, the keyword co-occurrence and overlay analyses show that established themes such as human–robot interaction, social robotics, and AI ethics remain central, while research frontiers are shifting toward generative AI, affect-aware design, and applications in healthcare, education, and therapy. Emerging topics, including AI intimacy, affect in therapy, and error recovery, highlight underexplored areas with strong potential for future work.

The study focuses on publications from 2020 to 2025 to capture recent developments and trends. However, this temporal scope represents a limitation, as it excludes earlier foundational research and long-term citation trajectories that could provide a broader historical context. Future studies could extend this period to build a more comprehensive understanding of how empathetic social agents have evolved over time. Overall, the findings demonstrate that the field is consolidating around technical, psychological, and ethical dimensions while opening new directions driven by generative AI and affect-aware design. By identifying influential works, mapping intellectual foundations, and highlighting emerging and underexplored areas, this study offers a systematic foundation for advancing both theory and practice in empathetic human–AI collaboration.

6. ACKNOWLEDGEMENTS/FUNDING

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7. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

8. AUTHORS' CONTRIBUTIONS

Nurul Husna Mukhtar conceptualised the study, curated and analysed the data, prepared the original draft, and developed the visualisations. Azizi Aziz acquired funding, supervised the research process, and contributed to the review and editing of the manuscript. Husniza Husni provided supervision and contributed to the reviewing and editing of the manuscript.

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