Compensatory and Supportive AI in Human-AI Collaboration: Roles and Implications in HCI Research

1. Introduction

The integration of artificial intelligence (AI) into human-computer interaction (HCI) has led to the emergence of "compensatory" and "supportive" AI systems, which play pivotal roles in human-AI collaboration. Compensatory AI aims to offset human limitations, while supportive AI augments human strengths, both striving to enhance joint performance beyond what either humans or AI could achieve alone (Inkpen et al., 2022; Gao et al., 2023; Hemmer et al., 2024; Steyvers & Kumar, 2023; Jarrahi, 2018). Recent research highlights that the effectiveness of these systems depends on factors such as user expertise, trust calibration, transparency, explainability, and the adaptability of AI to human needs (Inkpen et al., 2022; Endsley, 2023; Okamura & Yamada, 2020; Cabrera et al., 2023; Vössing et al., 2022; Senoner et al., 2024; Westphal et al., 2023; Hauptman et al., 2022). Studies demonstrate that well-designed compensatory and supportive AI can improve decision-making, foster empathy in social tasks, and facilitate learning and creativity, but also reveal challenges such as over-reliance, cognitive overload, and the need for nuanced work design (Sharma et al., 2022; Vaccaro et al., 2024; Fan et al., 2022; Jain et al., 2022; Chowdhury et al., 2022). Meta-analyses and systematic reviews underscore the heterogeneity of outcomes, emphasizing that the benefits of human-AI collaboration are context-dependent and often hinge on the alignment of AI capabilities with human strengths and weaknesses (Vaccaro et al., 2024; Hemmer et al., 2024; Jarrahi, 2018). This review synthesizes the current state of research on the roles, mechanisms, and design considerations for compensatory and supportive AI in HCI, drawing on empirical, theoretical, and interdisciplinary perspectives.

2. Methods

A comprehensive search was conducted across over 170 million research papers in Consensus, encompassing databases such as Semantic Scholar and PubMed. The search strategy included targeted queries on compensatory and supportive AI in human-AI collaboration, with a focus on HCI research. In total, 940 papers were identified, 619 were screened, 563 were deemed eligible, and the top 50 most relevant papers were included in this review.

Search Strategy

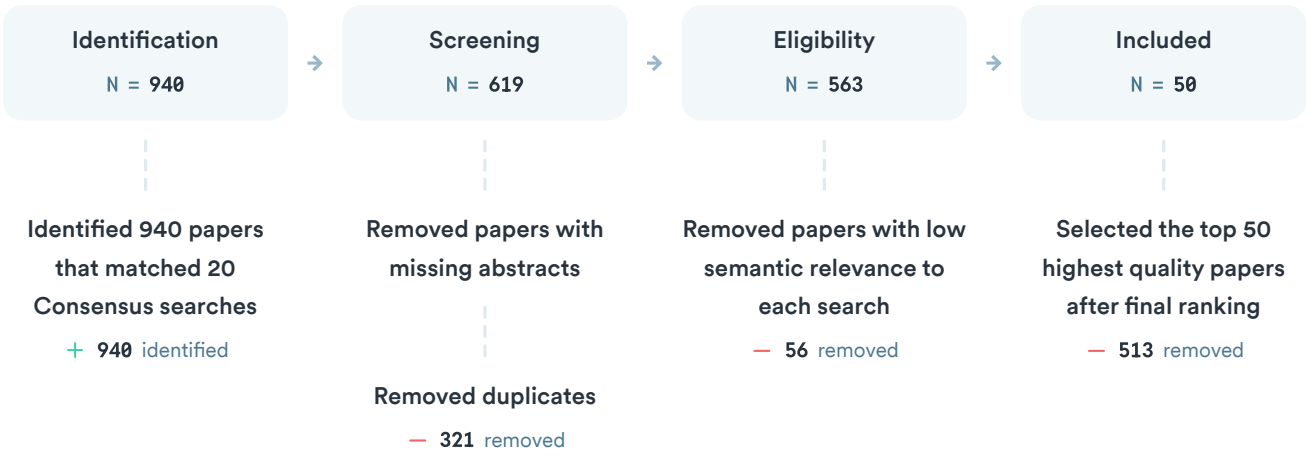

FIGURE 1 Flow diagram of the literature search and selection process.

Eight unique search groups were executed, systematically covering terminology, core concepts, critiques, interdisciplinary perspectives, and adjacent constructs in human-AI collaboration.

3. Results

3.1. Definitions and Conceptual Distinctions

Compensatory AI refers to systems designed to offset human weaknesses or limitations, such as cognitive biases or lack of expertise, by providing corrective input or taking over specific tasks (Inkpen et al., 2022; Gao et al., 2023; Hemmer et al., 2024; Steyvers & Kumar, 2023). Supportive AI, in contrast, aims to augment human strengths, facilitate learning, and enhance creativity or empathy, often by providing adaptive feedback, explanations, or collaborative input (Sharma et al., 2022; Conati, 2024; Edwards et al., 2024; Järvelä et al., 2023). The distinction is not always clear-cut, and many systems blend both roles depending on context and user needs (Inkpen et al., 2022; Hemmer et al., 2024; Zhao et al., 2022).

3.2. Mechanisms and Design Principles

Key mechanisms for effective human-AI collaboration include algorithmic tuning to complement user strengths and weaknesses (Inkpen et al., 2022), adaptive personalization (Conati, 2024; Zhao et al., 2022), transparency and explainability (Endsley, 2023; Cabrera et al., 2023; Vössing et al., 2022; Senoner et al., 2024), and trust calibration (Okamura & Yamada, 2020; Westphal et al., 2023). Studies show that AI systems that dynamically adjust their support based on user expertise and task complexity yield better outcomes (Inkpen et al., 2022; Liu et al., 2024; Zhao et al., 2022). Explanations and transparency features can improve trust and performance, but may also increase cognitive load if not well-designed (Westphal et al., 2023; Fan et al., 2022; Cabrera et al., 2023; Vössing et al., 2022; Senoner et al., 2024).

3.3. Empirical Outcomes and Contextual Factors

Empirical studies reveal that compensatory and supportive AI can significantly improve performance in decision-making, creative, and social tasks, especially for novice users or in complex environments (Inkpen et al., 2022; Sharma et al., 2022; Gao et al., 2023; Roveda et al., 2020; Senoner et al., 2024; Reverberi et al., 2022). However, the benefits are highly context-dependent. For example, meta-analyses indicate that human-AI teams often underperform compared to the best individual agent, except in creative tasks or when human strengths are well-matched with AI capabilities (Vaccaro et al., 2024; Hemmer et al., 2024; Jarrahi, 2018). Over-reliance on AI, poor mental models, and misaligned division of labor can undermine collaboration (Steyvers & Kumar, 2023; Okamura & Yamada, 2020; Westphal et al., 2023; Liu et al., 2021; Jain et al., 2022).

3.4. Challenges, Limitations, and Future Directions

Challenges include ensuring appropriate trust calibration to avoid over- or under-reliance (Okamura & Yamada, 2020; Westphal et al., 2023; Lee & Chew, 2023), designing for transparency without cognitive overload (Endsley, 2023; Cabrera et al., 2023; Vössing et al., 2022; Senoner et al., 2024), and addressing the heterogeneity of user expertise and task demands (Inkpen et al., 2022; Gao et al., 2023; Hauptman et al., 2022; Jain et al., 2022). There is a need for more nuanced work design, interdisciplinary frameworks, and adaptive systems that can flexibly shift between compensatory and supportive roles (Puerta-Beldarrain et al., 2025; Zhao et al., 2022; Gupta et al., 2023; Kolbjørnsrud, 2023).

Key Papers

Paper	Methodology	Context/Domain	Key Results	User Population
(Inkpen et al., 2022)	Experimental study	Medical decision-making	AI recommendations improve user performance, especially for novices; tuning AI to complement user strengths is critical	140 participants, varied expertise
(Sharma et al., 2022)	RCT	Peer-to-peer mental health support	AI-in-the-loop feedback increases conversational empathy, especially for less confident supporters	300 peer supporters
(Vaccaro et al., 2024)	Systematic review & meta-analysis	Multiple domains	Human-AI teams often underperform best individual agent; gains in creative tasks, losses in decision tasks	106 studies, 370 effect sizes
(Hemmer et al., 2024)	Theoretical & empirical	Decision-making	Formalizes complementarity; identifies information and capability asymmetry as key sources	2 empirical studies
(Senoner et al., 2024)	Preregistered experiments	Manufacturing & medicine	Explainable AI (heatmaps) improves task performance over black-box AI	Factory workers, radiologists

FIGURE 2 Comparison of key studies on compensatory and supportive AI in human-AI collaboration.

Top Contributors

Type	Name	Papers
Author	G. Satzger	(Westphal et al., 2023; Hemmer et al., 2024; Vössing et al., 2022)
Author	M. H. Jarrahi	(Jarrahi, 2018; Jarrahi et al., 2022)
Author	Andy Nguyen	(Edwards et al., 2024; Nguyen et al., 2024)
Journal	*Comput. Hum. Behav.*	(Endsley, 2023; Westphal et al., 2023; Hauptman et al., 2022)
Journal	*Proceedings of the ACM on Human-Computer Interaction*	(Fan et al., 2022; Cabrera et al., 2023; Gao et al., 2023; Cabitza et al., 2023; Shi et al., 2023; Lee & Chew, 2023; Muralikumar & McDonald, 2025; Jiang et al., 2021)
Journal	*Br. J. Educ. Technol.*	(Edwards et al., 2024; Järvelä et al., 2023)

FIGURE 3 Authors & journals that appeared most frequently in the included papers.

4. Discussion

The literature demonstrates that compensatory and supportive AI systems can meaningfully enhance human-AI collaboration, but their effectiveness is highly contingent on thoughtful design and context alignment (Inkpen et al., 2022; Sharma et al., 2022; Gao et al., 2023; Hemmer et al., 2024; Vaccaro et al., 2024; Senoner et al., 2024). High-quality evidence supports the value of complementarity—where AI and humans each contribute unique strengths—especially when systems are tuned to user expertise and task demands (Inkpen et al., 2022; Hemmer et al., 2024; Senoner et al., 2024; Reverberi et al., 2022). However, meta-analyses and empirical studies caution that human-AI teams do not always outperform the best individual agent, particularly in decision-making tasks, highlighting the need for careful work design and division of labor (Vaccaro et al., 2024; Jarrahi, 2018; Jain et al., 2022). Trust calibration, transparency, and adaptive support are critical for avoiding pitfalls such as over-reliance, cognitive overload, and reduced user agency (Endsley, 2023; Okamura & Yamada, 2020; Westphal et al., 2023; Cabrera et al., 2023; Vössing et al., 2022; Lee & Chew, 2023). The field is moving toward more nuanced, interdisciplinary frameworks that recognize the dynamic, context-dependent nature of human-AI collaboration (Puerta-Beldarrain et al., 2025; Zhao et al., 2022; Gupta et al., 2023; Kolbjørnsrud, 2023). Despite significant progress, gaps remain in understanding how to best balance compensatory and supportive roles, especially in complex, creative, or high-stakes environments.

Claims and Evidence Table

Claim	Evidence Strength	Reasoning	Papers
Compensatory and supportive AI can improve human-AI team performance, especially when tuned to user strengths/weaknesses	Strong	Multiple high-quality studies show performance gains when AI complements human abilities, especially for novices or in complex tasks	(Inkpen et al., 2022; Sharma et al., 2022; Hemmer et al., 2024; Senoner et al., 2024; Reverberi et al., 2022)
Human-AI teams do not always outperform the best individual agent, especially in decision tasks	Strong	Meta-analyses and systematic reviews show mixed or negative effects in decision-making contexts	(Vaccaro et al., 2024; Jarrahi, 2018; Hemmer et al., 2024)
Transparency and explainability features improve trust and task outcomes, but may increase cognitive load	Moderate	Empirical studies show trust and performance benefits, but also highlight risks of overload if not well-designed	(Endsley, 2023; Westphal et al., 2023; Fan et al., 2022; Cabrera et al., 2023; Vössing et al., 2022; Senoner et al., 2024)
Adaptive, personalized AI support enhances collaboration and user satisfaction	Moderate	Studies on adaptive and personalized AI show improved outcomes and user perceptions	(Conati, 2024; Liu et al., 2024; Zhao et al., 2022; Hauptman et al., 2022)
Over-reliance and poor trust calibration can undermine human-AI collaboration	Moderate	Evidence from trust calibration and reliance studies shows risks of over- or under-reliance	(Okamura & Yamada, 2020; Westphal et al., 2023; Lee & Chew, 2023; Liu et al., 2021)
The distinction between compensatory and supportive AI is often blurred in practice	Moderate	Theoretical and empirical work shows many systems blend both roles depending on context	(Inkpen et al., 2022; Hemmer et al., 2024; Zhao et al., 2022; Puerta-Beldarrain et al., 2025)

FIGURE 4 Key claims and support evidence identified in these papers.

5. Conclusion

Compensatory and supportive AI systems play crucial roles in human-AI collaboration within HCI, offering the potential to enhance performance, creativity, and learning when thoughtfully designed and aligned with user needs. However, their effectiveness is context-dependent, and challenges such as trust calibration, transparency, and work design remain central to realizing their full potential.

5.1. Research Gaps

Despite advances, research gaps persist in understanding the optimal balance between compensatory and supportive roles, the impact of adaptive personalization across diverse user populations, and the long-term effects of human-AI collaboration in complex, creative, or high-stakes environments.

Research Gaps Matrix

Topic/Outcome	Novice Users	Expert Users	Creative Tasks	Decision Tasks	High-Stakes Domains
Compensatory AI	7	3	2	8	4
Supportive AI	6	4	7	3	2
Adaptive/Personalized AI	5	2	3	4	1
Trust Calibration	4	2	1	5	2
Transparency/Explainability	6	3	2	6	2

FIGURE 5 Heatmap of research coverage by topic and study attribute.

5.2. Open Research Questions

Future research should explore how to dynamically balance compensatory and supportive roles, personalize AI support for diverse users, and assess long-term impacts in real-world, high-stakes, and creative contexts.

Question	Why
How can AI systems dynamically shift between compensatory and supportive roles based on real-time user needs and task demands?	Understanding this could maximize the benefits of human-AI collaboration and ensure optimal performance across diverse contexts and user populations.
What are the long-term effects of adaptive, personalized AI support on user learning, trust, and reliance in high-stakes environments?	Longitudinal studies are needed to assess whether adaptive AI fosters sustainable improvements or introduces new risks in critical domains.
How can transparency and explainability be designed to enhance trust and performance without causing cognitive overload?	Balancing information provision and cognitive load is crucial for effective, user-friendly human-AI collaboration systems.

FIGURE 6 Open research questions and their significance for future work.

In summary, while compensatory and supportive AI systems hold great promise for advancing human-AI collaboration in HCI, realizing their full potential requires ongoing research into adaptive design, trust calibration, and context-sensitive support.

These papers were sourced and synthesized using Consensus, an AI-powered search engine for research. Try it at ***https://consensus.app***

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