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The Changing Nature of Human-AI Relations: A Scoping Review on Terminology and Evolvement in the Scientific Literature

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ABSTRACT
Recent years have brought immense progress in the development of AI technology. This broadened its application fields but also led to a surge of interest in many research domains and increasing significance of human-AI relations for the development of AI technology. This rapid growth and evolvement is reflected by the establishment of a great variety of terms, potentially leading to what is known as jingle and jangle fallacies. With our scoping review of the terminology used in scientific literature to describe human-AI relations and its evolvement over time (with 803 records screened, 658 finally included), we capture the variety and development of human-AI terminology in accordance with the shift from *interaction* to *collaboration* between humans and AI. We aim to raise awareness of these developments spanning over different research communities and provide a solid basis for future researchers and practitioners conducting complementary, cross-domain research. Our review comprises terminological, bibliometric and thematic analyses, e.g., reporting on the historical development of terms and term composition patterns, but also identifying key authors and publications, geographic distribution of relevant research, and elaborating on term conception and usage, and co-occurrences throughout the literature.

KEYWORDS
Scoping review; artificial intelligence; human-ai relations; human-centered ai

1. Introduction

The rapid advancements of Artificial Intelligence (AI) technology led to a shift in research and a stronger focus on the humans interacting with AI, establishing a trend towards *human-centered AI* which is also reflected by the wealth of related recent literature (see, e.g., Bingley et al., 2023; Del Giudice et al., 2023; Garibay et al., 2023; Qadir et al., 2022; Shneiderman, 2021, 2022). This *human-centeredness* does not only refer to respecting humans' needs during their interaction with AI, but also to their general role in the relation with AI. While this opens up a lot of interesting research questions and bears potential for significant cross-domain findings, it is especially this interdisciplinarity in combination with the speed of progress that holds a risk for inconsistencies in the terminology used in scientific literature, as explained by Graziani et al. (2023). They point out that inconsistencies between domains frequently occur already in the wording of concepts and illustrate this at the example of "terms such as *interpretable*, *explainable* and *transparent* being often used interchangeably in methodology papers" while they "convey different meanings and are "weighted" differently across domains, for example in the technical and social sciences" (Graziani et al., 2023, p. 1). In line, *Capel and Brereton* point out in their recent review (Capel & Brereton, 2023) that *human-centered AI* might range from *explainable* and *interpretable* AI, "[aiding] a human in understanding the decisions or predictions made by the AI" (Capel & Brereton, 2023, p. 5) to humans teaming with AI, where "[t]he strengths of AI and humans complement each other, developing the competencies and capabilities of both" (Capel & Brereton, 2023, p. 8). In addition to these inconsistencies it should also be noted that while terms such as "explainability" are usually positively connoted in the scientific literature, there are also examples of studies that suggest potential detrimental effects (Cabitza et al., 2024, 2023; Ebermann et al., 2023) or at least dissatisfaction (Wang & Yin, 2021). For instance, in case explanations are misleading, they might further cause misjudgement on the user's side (Cabitza et al., 2024). The general terminological inconsistencies impede complementary research and consequently also mutual benefit across domains; we might observe what *Block* described as the *jingle and jangle fallacies* (Block, 1995). *Jingle fallacies* in this context are terms used ambiguously, leading to the assumption that the concepts they refer to are the same, while they are actually not. *Jangle fallacies* are ambiguities in the other direction, i.e., different terms used for the same concept (Block, 1995).

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The recent intense research interest in AI seems to particularly foster such inconsistencies in terminology. Discussions of ambiguities and a lack of conventions in scientific literature, e.g., *Wang* pointing out that "there is no widely accepted definition of Artificial Intelligence" and that the term AI "has been used with many different senses, both within the field and outside it" (Wang, 2019, p. 1), but also intensified political discourse ultimately led to the development of standardized definitions, e.g., provided in the European AI Act,[1] where an "AI system" is defined as a

> machine-based system that is designed to operate with varying levels of autonomy and that may exhibit adaptiveness after deployment, and that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

or in ISO/IEC 22989:2022,[2] which emphasizes a system's capability to acquire, process, and apply knowledge and skills. Further, the Organization for Economic Co-operation and Development (OECD)[3] provides a recently updated definition,[4] describing an AI-based system as

> machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as predictions, content, recommendations, or decisions that can influence physical or virtual environments.

Further, and in line with the definition in the European AI Act as quoted above, the OECD points out that "[d]ifferent AI systems may vary in their levels of autonomy and adaptiveness after deployment". However, even though this recent development towards a shared understanding of AI, the fact that inconsistencies used to affect even the general term of *AI* for years suggests that such issues may be even more pronounced when dealing with specialized, less established terminology in sub-fields of AI. Specifically relating to the *human* in *human-centered AI*, Langer et al. recently studied the effects of terminology and identified considerable differences in humans' perception and evaluation of systems, introduced through different wording (Langer et al., 2022). They point out that users may judge a system's competence and technological advancement differently solely based on the terminology used to describe it, which in turn impacts their willingness to adopt or team-up with the system. They compare terms such as "algorithm", "automated system", "computer program", "robot" or "artificial intelligence", referring to what they subsume under "algorithmic decision-making systems". Further, Wischnewski et al. in their research on measuring and understanding human trust calibrations for automated systems, point to terminological ambiguities in previous work, explaining that "[a]utomation can refer to various different systems with varying capabilities, ranging from rather simple rule-based to sophisticated machine-learning algorithms" (Wischnewski et al., 2023, p. 4). They also hint that this variety imposed challenges for their study because it was difficult to actually gain insights into the nature of the systems different authors described as "automated".

The frequent terminological ambiguities related to AI research may have critical implications to society. Benefo et al. describe a set of ethical, legal, societal and economic (ELSE) implications of AI (Benefo et al., 2022). Terminological transparency is essential for adequate assessment especially when different stakeholders' perspectives are included. For example, Fernández-Llorca et al. investigate definitions of several key concepts of AI, e.g., AI system, model, or generative AI from a technical and legal perspective and highlight that "[p]recise definitions accessible to both AI experts and lawyers are crucial for the legislation to be effective" (Fernández-Llorca et al., 2024, p. 1). Benefo et al. state that "[a]ny field that could benefit from rapid, aggregate data processing has the potential to be shaped and changed by AI" and that "AI could become an integral part of medicine, economics, policy, scientific research, marketing, customer service, engineering, and beyond" (Benefo et al., 2022, p. 10), indicating the magnitude of the potential ELSE implications. These examples illustrate the urgent need for a shared understanding of concepts and terminology around human-AI relations, eventually resulting in a global terminology as suggested by Graziani et al. (2023). The first necessary step towards this goal is an exhaustive overview of existing terminology across different domains.

In this article, we thus aim at mapping the landscape of the terminology used to describe relations between humans and AI in the scientific literature across time and different communities. We provide a broad overview of terminology usage and its evolution, research coverage and potential research gaps, which may serve as a basis for future research in the field of *human-centered AI*. Further, we derive and analyze thematic clusters in the identified terminology, investigate different geographic origins of certain terms and look into differences in conception and usage. To this end, we perform a scoping review (see a detailed description of the methodology in Section 2) of existing literature with 658 publications finally included, 803 screened. Our analysis is structured in three blocks (terminological, bibliometric and thematic analysis, see Sections 3–5) and guided by eight concrete research questions in total, as described in further detail the following.

First, we aim to provide an overview of the evolvement of the scientific field (not targeting development of AI in general but its use in human-AI relations), resulting in our first research question (*RQ1: How did human-AI terminology evolve over time in the scientific literature?*), also see Section 3.1. Relatedly, we also aim to study the terminology used to refer to what we describe as "human-AI relations" in this article, in the existing scientific literature. We expect this to be of specific interest to the community since several publications (including such just recently published, e.g., Longo et al.'s "manifesto" of open challenges and interdisciplinary research directions related to explainable AI (Longo et al., 2024) from 2024) still point to "inconsistencies" (Graziani et al., 2023), "conceptual confusion" (Longo et al., 2024) or "considerable ambiguity" (Capel & Brereton, 2023) when it comes to terminology, its usage and underlying understandings. We reflect these aspects in our research questions *RQ2: Which term composition patterns can be observed?* (see Section 3.2) and *RQ3: Which terms are used to refer to human-AI relations and how consistent are they?* (see Section 3.3). Based on those, we further investigate terminology in forming thematic clusters (cf. *RQ4: Which thematic clusters can be derived from human-AI terminology?*). Subsequently, and aiming at identifying the most influential publications and authors researching human-AI relations, and thus also pointing readers to them, we answer our *RQ5: Which key authors and publications can be identified in human-AI literature?* (see Sections 4.1 and 4.2). In addition to our focus on different terminology, its application in scientific work and the underlying concepts, in *RQ6*, we also analyze our data based on its geographic distribution (*Which geographic differences can be seen in human-AI terminology?*, as discussed in Section 4.3), in order to be able to potentially identify terminological trends that mainly affect specific regions of the world (i.e., continents or countries). Finally, we, in the scope of our thematic analysis of the literature in our corpus, answer our *RQ7: Which themes of term conception and usage consist in human-AI literature?* (see Section 5.1), aiming to provide a deeper understanding of how the various sources use certain terminology (pointing also to specific inconsistencies across specific domains or research fields), and *RQ8: Which semantic associations can be found in human-AI terminology?*, for which we identify popular co-occurrences of terms (see Section 5.2).

2. Scoping review

A scoping review of scientific literature typically provides a broad overview of a certain research area. According to Munn et al. it can be used to "identify the types of evidence in a given field", to "clarify key concepts/definitions in the literature", to "examine how research is conducted on a certain topic or field", to "identify key characteristics or factors related to a concept", or to "identify and analyse knowledge gaps" (Munn et al., 2018, p. 2). Similarly, Arksey and O'Malley point out that scoping studies might be conducted to "examine the extent, range and nature of research activity", "determine the value of undertaking a full systematic review", "summarize and disseminate research findings", or "identify research gaps in the existing literature" (Arksey & O'Malley, 2005, p. 21). According to Peters et al. scoping reviews are commonly used to "clarify working definitions and conceptual boundaries of a topic or field" (Peters et al., 2015, p. 1). Further, they argue that scoping reviews are particularly useful when "a body of literature has not yet been comprehensively reviewed, or exhibits a large, complex, and heterogeneous nature not amendable to a more precise systematic review" (Peters et al., 2015, p. 1). In the context of our research questions raised in Section 1, a scoping review is a great methodological fit: we aim at clarifying terminology and key concepts behind human-AI relations, we strive to analyze potential gaps and clarify conceptual boundaries between different fields, and the body of literature is exceptionally heterogeneous. For our review, we adopted the guidelines defined by Kitchenham and Charters (Kitchenham & Charters, 2007) which have been originally defined for the domain of software engineering (e.g., applied by Kitchenham & Brereton, 2013), and which have been already employed in numerous previous systematic reviews in the broader field of HCI, see e.g., (Butler et al., 2021; de Andrade et al., 2024; Doherty & Doherty, 2018; Kim, Laine, et al., 2021, Neumayr & Augstein, 2020; Klock et al., 2020; Nunes & Jannach, 2017; Stefanidi et al., 2023; Stepin et al., 2021). This section further explains our process of planning and executing the scoping review. The results are then presented in Sections 3–5.

Search queries. Our data collection process contains three queries Q1–Q3 that build upon each other and are successively refined to answer our research questions raised in Section 1. Hereby, the aim for Q1 was to identify all literature that directly combines "human" with "ai". The query was thus kept as general as possible, to avoid biases as potentially introduced by over-specification of search terms. This query was expected to lead to a large body of results, intended for terminological (see Section 3) and bibliometric (see Section 4) analyses, but also as a basis for the literature-driven extraction of relevant conjunctive terms that can be considered descriptive of human-AI "relations" (e.g., "collaboration" in "human ai collaboration"). This approach was chosen to ensure objectivity in selection of terms describing human-AI relations, and to ensure they actually reflect the existing scientific literature. Q2 then built upon Q1, adding the most commonly used (i.e., in the body of literature extracted from Q1) "relation" terms to the Q1 query ("human ai"), such as "interaction", "collaboration" or "team". Additionally, we considerably extended the scope and reach of Q2 by adding alternative terms for the "ai" part of the query, such as "agent", "system" or "algorithm". These alternative terms were extracted from the body of literature resulting from Q1. The results of Q2 then were intended as a basis for the analysis historical development and evolvelment of terminology in the field (see RQ1 and Section 3.1). Finally, Q3 built upon Q2, again broadening its scope and reach with a focus on the "human" part of the query, by adding commonly used synonyms for "human", such as "user" (extracted from established dictionaries, see Section 2.3). The results of Q3 built the basis for an analysis of term composition patterns (see Section 3.2). This iterative and reflexive approach (as also depicted in Figure 1) facilitates a general view of the available literature with deeper inspection of specific aspects and is commonly applied in scoping reviews according to Arksey and O'Malley. In total, this process resulted in the accumulation of 36 specific search queries for Q2 (see Section 2.2) and 144 unique queries for Q3 (see Section 2.3). The three queries were conducted between August and September 2024 and are further described in Sections 2.1–2.3.

Database selection. Aiming for a broad overview of established terminology in different research domains, we included three databases for data retrieval in our scoping review: Scopus, ACM Digital Library and IEEE Xplore. Two of them (Scopus and ACM DL) have been rated as "principal" search systems by Gusenbauer and Haddaway's systematic evaluation of academic search systems (assessing their suitability for systematic reviews or meta-analyses) (Gusenbauer & Haddaway, 2020). IEEE Xplore, by their review, was assessed as "supplementary" search system (those can be used as supplement to any "principal" system, "where they might still provide great benefit" (Gusenbauer & Haddaway, 2020)). In summary, the ACM Full Text

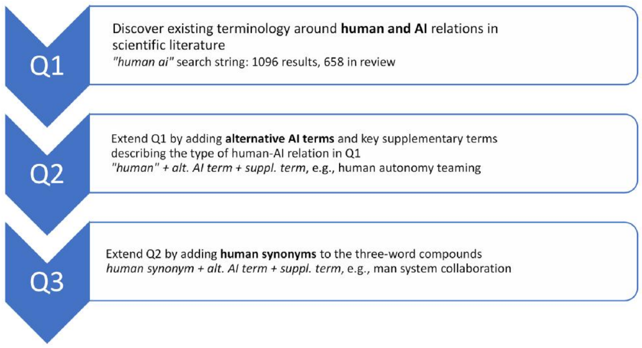


Figure 1. Queries Q1-Q3 subsequently extending the scope to discover a broad overview of the terminology used to describe human and AI relations in scientific literature.

Collection of the ACM Digital Library[5] covers a large proportion of scientific literature in computer science with obvious relevance to human-AI relations. As human-AI relations however are an interdisciplinary field of research, we extended the scope by including Scopus[6] as a broader database covering a wide range of different domains and further the IEEE Xplore[7] database. This is in line with the findings of Bar-Ilan, who highlights the differences in coverage between three databases and urges "to search in multiple databases if there is need for comprehensive data" (Bar-Ilan, 2018, p. 3). She further shows that the overlap of coverage may be smaller than expected and that subject-specific databases, such as the ACM Digital Library, not necessarily offer the most exhaustive coverage for individual search terms within that field (Bar-Ilan, 2018). While Gusenbauer lists Scopus as an interdisciplinary database, we acknowledge that our selected databases still represent a strong focus on Computer Science and Engineering (Gusenbauer, 2022). Future studies, especially those that examine the relations of humans and AI in more depth, may benefit from additional reinforced inclusion of perspectives from, e.g., Sociology and Psychology.

2.1. Q1: Overview of terminology on human-AI relations

The first query provides an initial overview of existing terminology. To obtain unbiased results, we tried to avoid assumptions in data collection and framing of the review. To satisfy this objective, we decided for a broad search term for the initial query, including both "human" and "AI", as explained in detail above. We ran exploratory queries prior to the actual review to find a search string broad enough to capture the variety of human-AI literature yet narrow enough not to include unprocessable amounts of irrelevant data. These preliminary queries included specific aspects of or designations for human and AI relations, e.g., "human-AI interaction" and "human-AI collaboration", which certainly would miss broader parts of human-AI literature. Concurrently, we experimented with more general approaches, e.g., using the selected databases' standard search options without the requirement of an exact match. Too broad searches returned an unmanageable amount of data, including many irrelevant publications. With "AI" as a common abbreviation of "Artificial Intelligence" (note: case-insensitive), we found "human AI" to be a suitable search string covering a large variety of human and AI relations.[8] The reverse order, "AI human", yielded a smaller number of results. Further, we hypothesized based on preliminary queries, that the reversed order in "AI human" may implicitly associate differences in authority. Also, the results using this version of the query contained a lot of false positives where "human" directly followed "AI" without any direct semantic connection, e.g., "[…] ethical AI: human rights […]". The final search string was thus defined to be "human AI" and searched for as an exact phrase in titles only. We defined the criterion for inclusion of relevant data in our scoping review as follows:

- IC: Presence of a specific human-AI term in the publication's title, including both "human", "AI" and a supplementary term indicating a human-AI relation.

We applied a rule-based approach to ensure structured inclusion of data that is relevant to our scoping review on human-AI terminology. This approach supports transparency and clarity in decisions of whether or not to consider a term and include the respective publication. One main researcher judged the resulting publications based on the inclusion criterion and marked ambiguous cases for group discussion to minimize potential researcher bias, making the process consistent with the vast majority of other reviews in the field (e.g., Butler et al., 2021; de Andrade et al., 2024; Kim, Laine, et al., 2021; Neumayr & Augstein, 2020; Nunes & Jannach, 2017; Stefanidi et al., 2023) as pointed out by Stefanidi et al.'s review of reviews in HCI (Stefanidi et al., 2023). The presence of a human-AI term was considered if "human", "AI" and one supplementary term connecting the two was present. This led to the inclusion of publications using "human-AI interaction", where interaction is the supplementary term connecting human and AI. In contrast, the presence of human, AI and a supplementary term in a sentence was not sufficient: "humans interacting with AI" was not considered a valid term. We further included terms which did not follow our three-part compound scheme, but describe known concepts and are therefore established in the scientific literature, as for example "human-centered AI". Note that the inclusion of these terms did not result from additional searches, as that would contradict the *systematic* search strategy. Some publications used descriptive terms, e.g., adjectives indicating the nature or focus of the human-AI relation (e.g., trustworthy, collaborative) or additional words specifying the context (e.g., human-AI *music* co-creation). Such cases were included if they were directly connected to the term, i.e., placed immediately before or within the three-part compound term, and were considered relevant to the focus and understanding of the term. Disregarded adjectives mostly concerned cases where publications aimed to improve a named concept, and therefore used "better", "enhanced" or similar adjectives.

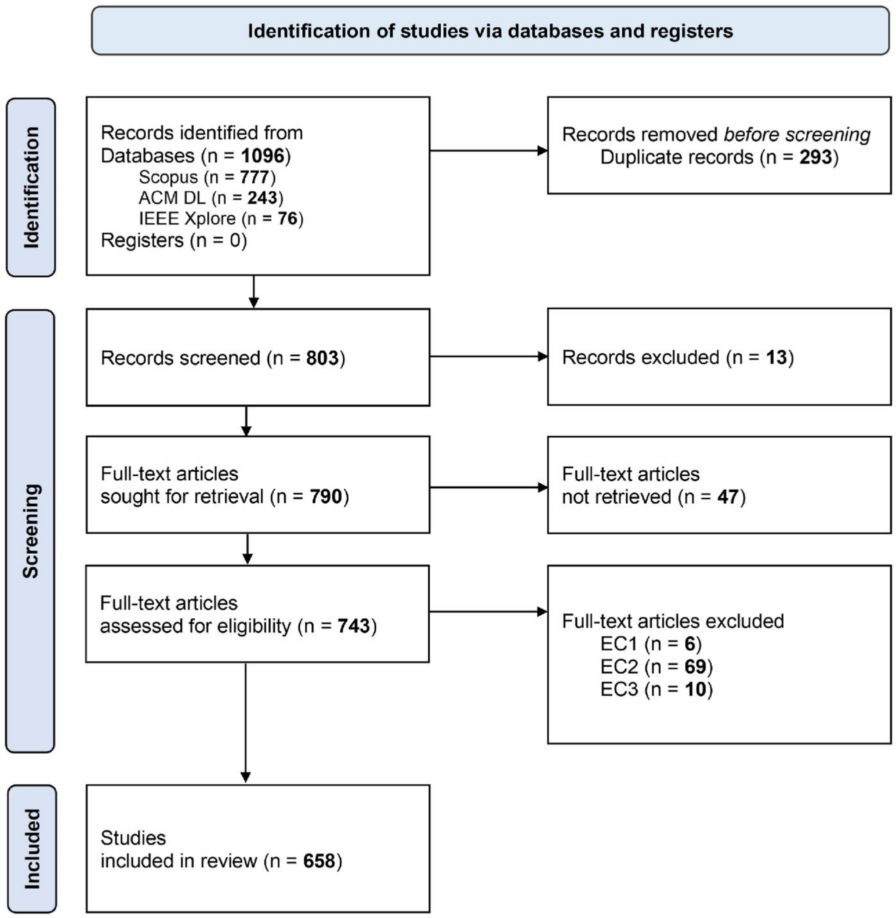


Figure 2. Modified PRISMA flow diagram showing the review process for Q1. 658 of 1,096 initially identified records were finally included.

Publications were excluded from the review if they met at least one of the following three Exclusion Criteria (EC):

- EC1: The retrieved item is a non-English language publication.
- EC2: The retrieved item is a non-scholarly publication of four or fewer pages (e.g., workshop proposals).
- EC3: The retrieved item is not a single publication (e.g., retrieved items are collections containing multiple workshop papers).

We excluded non-English publications (EC1) to avoid bias due to translation issues and the resulting impeded comparability. Regarding EC2, we excluded particularly short papers such as proposals, invitations or abstracts. While they may use relevant terminology, their scope likely is insufficient for later content-related analyses. EC3, in contrast, concerns collections of several papers or articles, such as books containing chapters, or workshop proceedings containing workshop papers. Our unit of analysis consists of single publications. We, therefore, include individual book chapters, workshop papers of sufficient length, journal articles, conference papers and reports but not the collections per se.

The PRISMA flow diagram in Figure 2 summarizes the data retrieval process for Q1. All items were screened by one main researcher (the first author) to avoid discrepancies in assessment; however, uncertain cases were discussed in a group of three of the authors to find objective consensus, as described above.

Q1 was executed across the selected databases from August 7 to 15, 2024, leading to 1,096 results (Scopus: 777, ACM Digital Library: 243, IEEE Xplore: 76), of which 293 duplicates were identified across and within the databases, which were consequently removed. Of the remaining 803 items, 13 did not fulfill the inclusion criterion. In one case, a term technically fulfilling the previously defined pattern was found, but concerned specific proteins ("ai") in humans, published in the field of biology (e.g., Fidge et al., 1989; Morrison et al., 1990). Full-texts of 790 items were sought for retrieval and, if not directly available via the publisher, searched for using Google's search engine, authors' websites and ResearchGate.[9] For 47 items, full-texts could not be retrieved, which resulted in 743 publications with full-text available. Further, six articles not written in English were excluded (cf. EC1), and 69 were excluded as they did not qualify as scholarly publications (e.g., workshop invitations, abstracts or position papers, cf. EC2). Ten items were collections rather than individual items and were therefore excluded (cf. EC3).

During the screening process, we extracted all human-AI terms in harmonized form, i.e., removed special characters and aligned singular and plural forms as well as different spelling of the same term, from the publications' titles. This resulted in a total of 253 unique extracted terms for further analysis (see Sections 3–5). The frequency distribution of the terms showed only few very prominent terms and a great variety of terms with only single occurrences (maximum: 139, minimum: 1, mean: 2.6, median: 1) resembling a long tail distribution (Anderson, 2006). Terms with highest frequencies were "human-AI collaboration" (139 occurrences), "human-AI interaction" (94), "human-AI team" (31) and "human-AI teaming" (30), where the very strong popularity of few terms already becomes obvious. The conjunctive terms of the most prominent human-AI terms were later integrated into search string construction for Q2 (see below). "Team" and "teaming" were handled as separate terms as they differ regarding the application domain (Capel & Brereton, 2023): "team" is used for decision-making in which humans seek complementarity rather than relying on one individual decision maker's capabilities, while "teaming" is more related to co-creation and creativity.

Subset for thematic analysis. For the thematic analysis in Section 5, we extracted terms that occurred at least three times in our Q1 data as to capture more established terms rather than just single occurrences. Of each of these terms, we drew a sample of a maximum of five publications per year by citation count to represent the data appropriately. This reduced the amount of publications from 139 to 29 for "human-AI collaboration" and from 94 to 28 for "human-AI interaction". We decided for this approach to ensure to capture relevant terminology in human-AI relations rather than outliers. At the same time however, novel discussions may be left out by this decision, as related terminology may not yet be sufficiently established to be reflected in publications' titles. To explore the origin and emergence of novel terms in more detail, thorough analysis of full-texts rather than titles may be required.

2.2. Q2: Alternative AI terms

The notably short temporal coverage of Q1 data with publication dates only ranging from 2011[10] onwards (see Section 3) indicated that other terms might have been used to describe human and AI relations in earlier literature. Following the commonly reflexive nature of scoping reviews (Arksey & O'Malley, 2005), we therefore decided to extend our query with alternative AI terms, aiming to consecutively cover the area of interest more comprehensively. We derived alternative AI terms from all identified records of Q1 and consulted online dictionaries and thesauri such as Merriam-Webster[11] and PowerThesaurus[12] and the list of terms provided in the EU-U.S. Terminology and Taxonomy for Artificial Intelligence[13] to finally obtain a set of eight unique alternative AI terms, shown in the second column of Table 1. We further sought alternative terms for "AI" and similar systems by screening literature reviews. The

Table 1. Alternative terms for "AI" and "human", and most prominent conjunctive terms describing relations between humans and AI (listed in alphabetical order).

Human terms	AI terms	Conjunctive terms
Human	Agent	Collaboration(s)
Man	Ai	Interaction(s)
Person	Algorithm	Teaming
User	Autonomy	Team(s)
	Computer	
	Machine	
	Robot	
	System	
	Technology	

identified terms were either focused on specific applications, e.g., "reasoning", "recognition" and "segmentation" (Hirzle et al., 2023), and did not represent AI in general, or were more specific definitions of system or program, as in "decision support system" and "computer program" (Langer et al., 2022). Thus, our list of alternative AI terms was not further extended.

Q2 search string construction. We first combined "human" with each of the extracted alternative AI terms. As this would lead to large amounts of irrelevant data, e.g., "human agent" would likely refer to an agent of human nature, not the combination of a human and an agent, we added the most prominent conjunctive terms from Q1 data (see Table 1) and formed three-part compounds, e.g., "human agent interaction" or "human system collaboration". While this constraint again narrowed the scope, the distribution of term frequency in Q1 showed that large parts of human-AI literature were covered by these terms. We manually evaluated the queries' results to ensure their effectiveness. Cases of uncertainty were resolved in group discussions and more in-depth evaluation. For example, combinations with *autonomy* as the alternative AI terms were checked thoroughly to indeed refer to human-AI relations rather than the autonomy of humans (see also Section 3.1). A total of 36 individual queries were performed for each database within Q2, with search strings including singular and plural versions of the conjunctive terms (e.g., "collaboration" and "collaborations"). For our analysis, the result counts per individual term composition were essential. For this reason, we only used Boolean operators to combine singular and plural versions of the same conjunctive term, e.g., *"human agent collaboration" OR "human agent collaborations"*. A comprehensive overview of all queries and result counts of Q2 and Q3 (see Section 2.3) is available in the Supplementary Material.

Q2 result counts. For Q2 and Q3, only the result counts per query, and for Q2 per year were collected, as the goal was different from Q1, and the number of queries led to unmanageable amounts of publications to analyze individually. The reduction to result counts is suitable for giving broad overviews, however, it should be noted that a certain share of irrelevant data may be included. We intentionally disregarded certain terms that yielded an unmanageable number of results, where a large part can be expected to be false positive as these terms are known to be widely used in contexts other than AI. We investigated this expectation prior to our actual search and e.g., found more than 6,200

Table 2. Overview of search strings, included terms and result counts for Q1-Q3.

	Q1	Q2	Q3
Individual Queries	1	36	144
Results Retrieved	1,096	20,341	20,881
Results Included	658	2,755	3,295
Databases	Scopus, IEEE, ACM DL	Scopus, IEEE, ACM DL	Scopus, IEEE, ACM DL
Searched In	Publications' Titles, Exact Match	Publications' Titles, Exact Match	Publications' Titles, Exact Match
Human Terms	Human	Human	Human, Man, Person, User
AI Terms	AI	Agent, Algorithm, AI, Autonomy, Computer, Machine, Robot, System, Technology	Agent, Algorithm, AI, Autonomy, Computer, Machine, Robot, System, Technology
Relation Terms	None	Collaboration(s), Interaction(s), Teaming, Team(s)	Collaboration(s), Interaction(s), Teaming, Team(s)
Example Query	"human ai"	"human agent collaboration" OR "human agent collaborations"	"user ai teaming"

results for the term *Human-Computer Interaction(s)* (see below), 4,600 in one single database (Scopus). Similarly, a query for *Human-Robot Interaction(s)* yielded more than 7,300, and for *Human-Robot Collaboration(s)* more than 2,200 results. Subsequently we estimated the false positive rate based on further queries adding requirements of occurrences of "AI" in title, abstract or keywords of the articles. For instance, on Scopus only about 180 of the 4,600 articles fulfilled this criterion, suggesting an overall false positive rate of more than 96%. After these preliminary test runs, we thus excluded the following terms:

- *Human-Computer Interaction(s)*, *Human-Machine Interaction(s)* and *Human-Robot Interaction(s)*: these are strong research fields regarding the interaction between humans and different systems, which not necessarily relate to AI. The broadness of these research fields may introduce separate terminology, which enables further cross-domain investigations but exceeds the scope of our review of human-AI terminology.
- *Human-Robot Collaboration(s)*: This mostly concerns the collaboration between humans and industrial robots and can arguably be regarded a separate research field.

In total, we retrieved 2,755 results for Q2 (Scopus: 1,962, ACM Digital Library: 358, IEEE Xplore: 435): 580 for combinations with "robot", 469 for "machine", 521 for "agent", 626 for "AI", 166 for "system", 100 for "technology", 215 for "autonomy", 61 for "computer" and 17 for "algorithm". Note that as reasoned above, combinations with "robot" (2,255 results across databases) were removed from result counts for "collaboration(s)" as were combinations with "computer" (6,233), "machine" (1,765), and "robot" (7,333) for "interaction(s)".

2.3. Q3: Alternative human terms

Although not present in our Q1 data, it is most likely that alternative human terms exist, which could further enhance the comprehensiveness of our scoping review. After using Power Thesaurus[14] and DeepL Translator[15] to identify synonyms, we included "person" and "man"[16] as general terms as well as "user", considering the context. Three-part compounds were formed as in Q2, connecting all terms of all columns in Table 1. This resulted in unique search strings like "human agent collaboration" and "person system teaming" (all individual queries and their result counts per database are listed in the Supplementary Material). For each of the selected databases, 144 individual queries were performed, from which only the total result counts were retrieved. Overall, 20,341 items were retrieved (Scopus: 14,147, ACM Digital Library: 1,862, IEEE Xplore: 4,332), which we visualized to analyze term composition patterns in human-AI terminology in Section 3.2.

Table 2 summarizes the specifics and differences of queries Q1–Q3. All queries were applied to the same set of databases as exact matches in publications' titles. Differences can be seen in the expansion of the search strings and resulting numbers of retrieved and included items in the review. While Q1 search string only contains human and AI (resulting in "human ai"), both Q2 and Q3 use a set of different potential *AI* terms in combination with terms that describe the relation between humans and AI, e.g., collaboration or interaction. Q3 further contains synonyms for *human* to further extend the scope. The numbers of retrieved and included items per query show a strong increase in scope when including different AI terms from Q1 to Q2 while the exclusion of highly generic terms (e.g., HCI) is reflected in the drastic gap between retrieved and included items in Q2 and Q3. The inclusion of synonymous human terms did not substantially expand the scope further.

The following sections contain results of our analyses structured in three blocks. Section 3 gives an overview of the terminology, its development and derived topics of interest. Later sections include analyses of influential authors and publications and the geographic distribution of contributions (Section 4) and more in-depth thematic analyses focusing on the conception, usage and co-occurrence of the found terms (Section 5).

3. Terminological analysis

Analyses in this section are based on the presence and phrasing of terms in human-AI literature. In Section 3.1, visualizations of data obtained through Q2 and Q3 show the temporal development of term usage, Section 3.2 shows term composition patterns using alternative human- and AI-

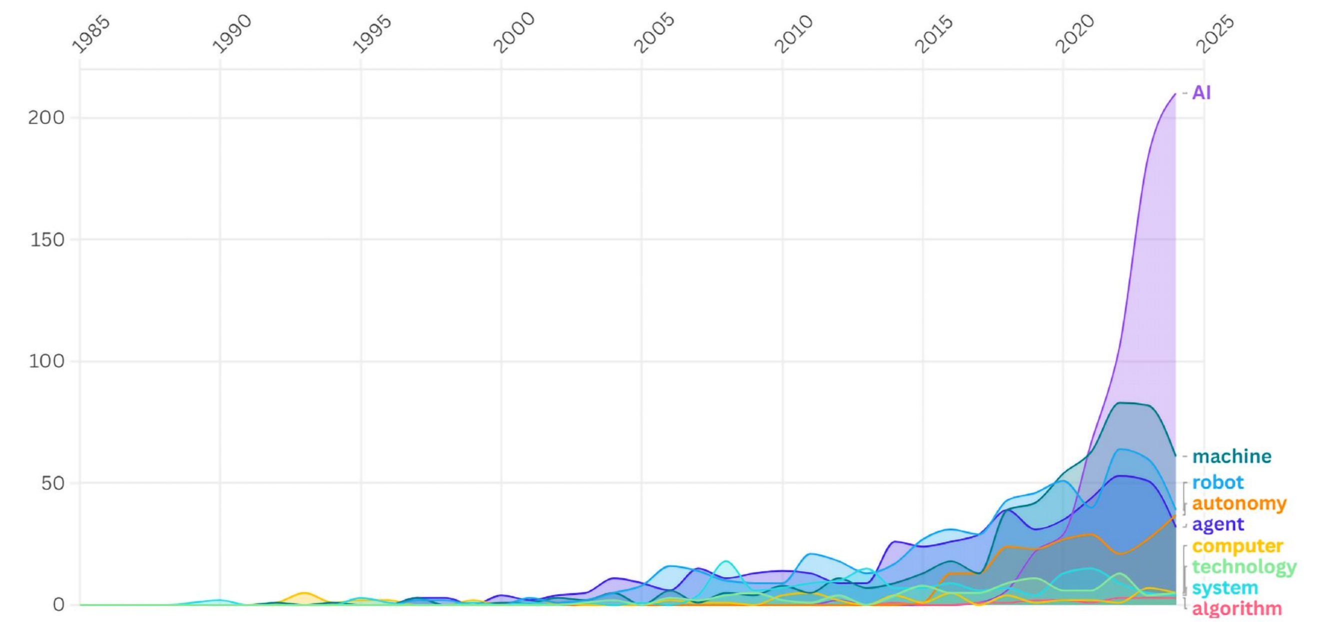


Figure 3. Development of the popularity of different terms in the human-AI context ranging from 1989 to September 2024 with respective publication counts on the y-axis. Alternative AI terms were extracted from Q1 results. Terms describing separate research fields, e.g., HCI, were excluded for this visualization.

terms. We investigate the variety of human-AI terms found through Q1 in Section 3.3 and form thematic clusters in Section 3.4.

3.1. Historical development

Developments such as the shift of AI research towards complementarity between humans and AI are likely represented in dynamically changing terminology. As the terms in use often implicitly convey characteristics and influence the perception of the AI system (Langer et al., 2022), we investigate with RQ1 whether and how human-AI terminology has changed over time, including alternative terms and term combinations.

RQ1: How did human-AI terminology evolve over time in the scientific literature? We first investigate Q1 data, where earliest retrieved items were published in 2011 and 2012. The initial sparse coverage is followed by an almost exponential increase in publication counts from 2017 to 2023.[17] We concluded from this rapid development and the apparent gap before 2011 that "human-AI" terms may have evolved with the shift towards human focus and complementarity, and that other terminology may have been popular before.

We first focused on "AI" possibly being a trending term with less prominence in earlier research. In Q2, we therefore searched for alternative terms (see Section 2.2) describing similar topics before the sharp increase in human-AI research interest. We used alternative AI terms in combination with the key supplementary terms (see Table 1, e.g., "human algorithm teaming"). Figure 3 shows absolute numbers of publications summed per alternative AI term (e.g., for "algorithm", results stem from queries including "human", "algorithm" and each of the key supplementary terms). We excluded combinations that are popular terms in other research fields and less specifically relevant to human-AI relations, such as "Human-Computer Interaction", from this visualization (see also Section 2.2). Still, "computer" remained in the visualization, as e.g., "human-computer collaboration" may indeed refer to collaborative AI systems. The remaining sparsely covered area in the visualization indicates that "computer" is mainly associated with interaction rather than collaborative approaches. We used the same procedure for combinations of "machine" and "robot" with "interaction" as well as "robot" with "collaboration" (cf. Section 2.2). The graph still shows large areas for remaining combinations with "machine" and "robot", indicating that research in these fields goes beyond interaction. We specifically reviewed "human-autonomy" combinations, double-checking whether they actually refer to a relation, not the autonomy of humans (despite our search terms being quite specific). Against our expectations, all publications in our sample actually used the term to refer to a relation between humans and autonomous systems, most prominently, autonomous aviation (Demir et al., 2019) and marine (Thieme & Utne, 2017) systems, indicating it might be specific to these domains. Figure 3 further shows that some terms were used consistently with small fluctuations throughout the years, e.g., "robot" and "agent" with large proportions of the overall data, or "computer", "system" and "technology", covering small proportions. Other terms emerged in recent years ("AI", "algorithm", "autonomy") or experienced a sharp increase in research interest ("AI", "machine"), with publication counts for "AI" exceeding other combinations greatly in recent years.

Figures A1(a to i) (see Appendix A) allow for a more detailed analysis of the development of human-AI terminology by splitting up Q2 data with respect to the individual

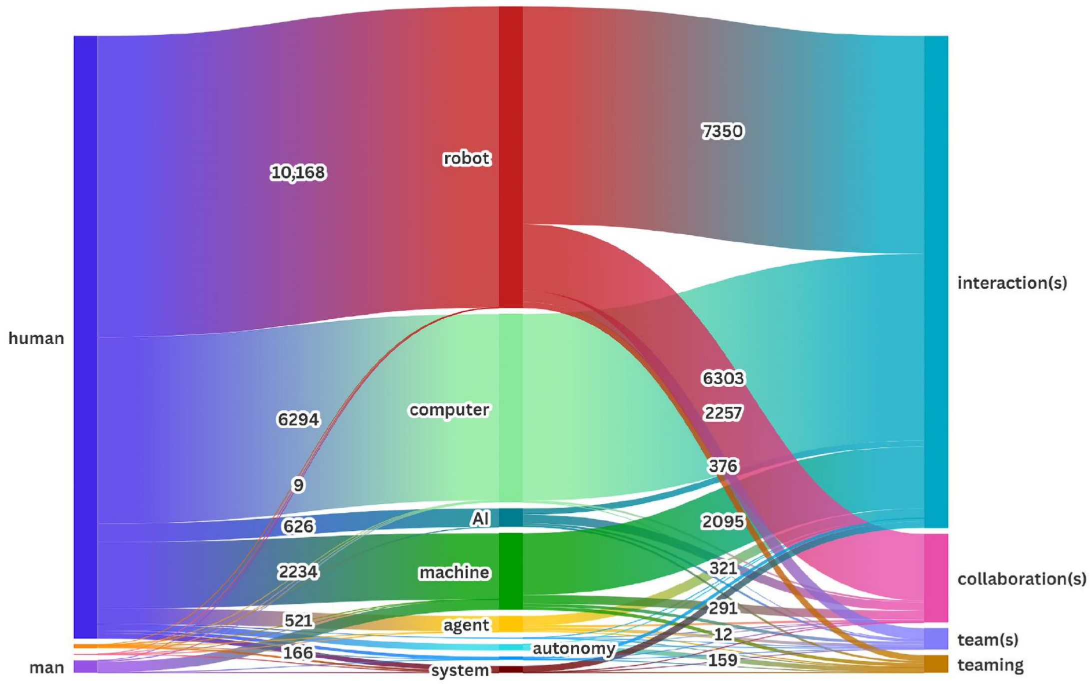


Figure 4. Initial Sankey diagram showing connection strength of different three-part compound terms (left: alternative *human* terms, middle: alternative *AI* terms, right: most popular *supplementary* terms).

AI terms and supplementary terms (Table 1, second and third column). Note that Figures A1(g) (related to "robot"), Figure A1(f) (related to "machine") and Figure A1(e) (related to "computer") do not include "interaction" and Figure A1(g) does also not include "collaboration", as mentioned earlier. Therefore, the respective dashed lines represent only zero-values. Earliest data is available for combinations with "computer" (without combinations including "interaction") and "system". Combinations of both "system" and "technology" with "interaction" are steadily covered over time, with an increase after 2005 of "system" followed by an increase of "technology". This may be due to significant technological advancements around that time, such as the emergence of cloud computing (García-Valls et al., 2018) and increased popularity of smartphones (O'Regan & O'Regan, 2008). Further increases can be found for "human machine collaboration" around 2014 and 2017, followed by a remarkable rise of "human AI collaboration" popularity starting around 2017, indicating a strong shift towards collaborative relationships.

3.2. Term composition

In multi-part terms, term composition patterns and frequent combinations may give information about the attributed properties of combinations, for example, competence or sociality in the context of "human" and "AI" combinations. RQ2 concerns observed patterns in human-AI terminology.

RQ2*: Which term composition patterns can be observed?* As explained in Section 2.3, we combined all human, AI and supplementary terms to three-part compounds, e.g., "human agent collaboration" or "user computer interaction" in Q3. Figure 4 shows the connections between all included terms and gives a general overview of commonly used combinations. Strongly dominant terms are visualized with large bars, where the size is determined by the connection strength to each of the terms in the neighboring column. The magnitude of "human" and "interaction" in comparison to all other terms is particularly noticeable. This again stems from a certain combination of terms, e.g., "Human-Computer Interaction", referring to separate research fields that do not necessarily concern human-AI relations. For this reason, we removed these compounds in Figure 5 to obtain a less cluttered view and set a focus on the apparently less dominant, yet relevant terms.

There are two perspectives to this more detailed view. The connections between the first and second column show which human synonyms are combined with which potential AI terms. E.g., the connection to "user" is stronger for "system" and "computer", while barely present for the other terms. This links to "computer" and "system" typically being used in combination with "interaction", as shown previously in Section 3.1. Combinations with "user" may indicate a lesser degree of autonomy and collaboration between humans and AI, unidirectional communication and focus more on a tool- rather than partner-relationship. "Man" specifically shows connections to "machine". This combination comes from earlier research conducted decades ago, where "man" was used as synonymous for "human" (among them Licklider's prominent early vision of "man-computer symbiosis" (Licklider, 1960) or Sutherland's likewise prominent description of a "man-machine graphical communication system" (Sutherland, 1963). The connections between the second and third column show the relation that is mostly

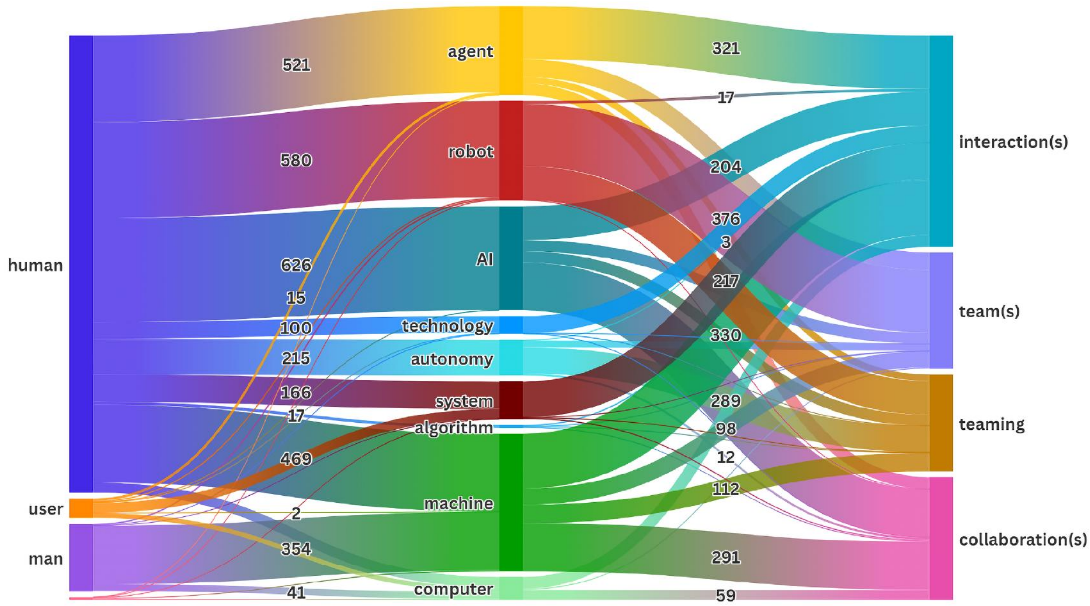


Figure 5. Connection strength of different terms after removing terms of separate research fields. A less cluttered view allows for different views on the connections and conclusions on the nature of the connections to be drawn.

seen between humans and the respective alternative AI term. Notably, "autonomy" is strongly connected specifically to "teaming". This indicates "human autonomy teaming" being an established term, which emerged from "human automation interaction" according to Lyons et al. (2021). "AI" shows the strongest connection to "collaboration", mostly stemming from the recent surge in research interest as shown in Section 3.1. The overall picture given by this visualization is a likely collaborative, bidirectional partnership between humans and AI, contrary to terms connected to "user" on the left side of the diagram tending to focus on "interaction" rather than "collaboration", which supports the assumption of rather unidirectional tool usage.

3.3. Human-AI terminology

Given the rapidly increasing popularity of explicit *human-AI* terminology in Section 3.1, RQ3 suggests an overview of the variety of supplementary terms specific to human and AI relations.

RQ3*: Which terms are used to refer to human-AI relations and how consistent are they?* For this initial overview, we extracted all terms during the screening process of Q1 (see Section 2.1) in a harmonized form to reach 253 unique terms. We included words descriptive of the task or application of the human-AI relation in brackets, whereas adjectives were considered part of the term if they satisfied the pattern for human-AI terms described in Section 2.1. Table B1 contains a list of individual terms (third column). Note that, due to the inclusion of descriptive words, the table may include seemingly redundant terms, such as different terms including *interaction*. For a less cluttered view, Figure 6 shows only the most prominent terms (i.e., those with more than two occurrences in our Q1 data). It becomes clear that only few of the large amount of individual terms occur more than twice in our data at all, which may reflect the essential research focus in human-AI relations. The inclusion of descriptive words and adjectives may provide additional insights into term usage, existing challenges or research goals and potentially affect term conception, while the strong popularity of few terms remains clearly discernible in Table B1. Further, we hypothesize that a large amount of individually used terms in combination with few prominent terms in a yet evolving field may stem from the ongoing development and search for conventions, with a variety of emerging terms and few trending ones rapidly gaining popularity. To investigate this further, we focus on thematic patterns in the usage of popular terms in Section 5.1. Note that this overview is specific to terminology explicitly using "human-AI" combinations, given our search string for Q1. Human-AI relations are further referred to with a variety of terms that are not included in this view even though they may be highly relevant, e.g., hybrid intelligence (Dellermann, Ebel, et al., 2019). While including *all* possible terms may be infeasible in terms of systematic searches and exceeds the scope of our review, our overview may serve as a starting point for further analyses.

3.4. Thematic clusters

The given terminology may include similar terms or topics, from which we derive thematic clusters with respect to RQ4. In the later thematic analysis we aim for deeper analysis of the actual usage, conception and interpretation (see Section 5.1), which may hint towards hidden similarities or differences as well as jingle and jangle fallacies between terms.

RQ4: Which thematic clusters can be derived from human-AI terminology? Clustering based on the terminology used in a specific field can unveil frequently discussed challenges and opportunities, applications and domains. We clustered the terms extracted through Q1 based on terminological and semantic similarity, following a human clustering approach inspired by what Holtzblatt et al.

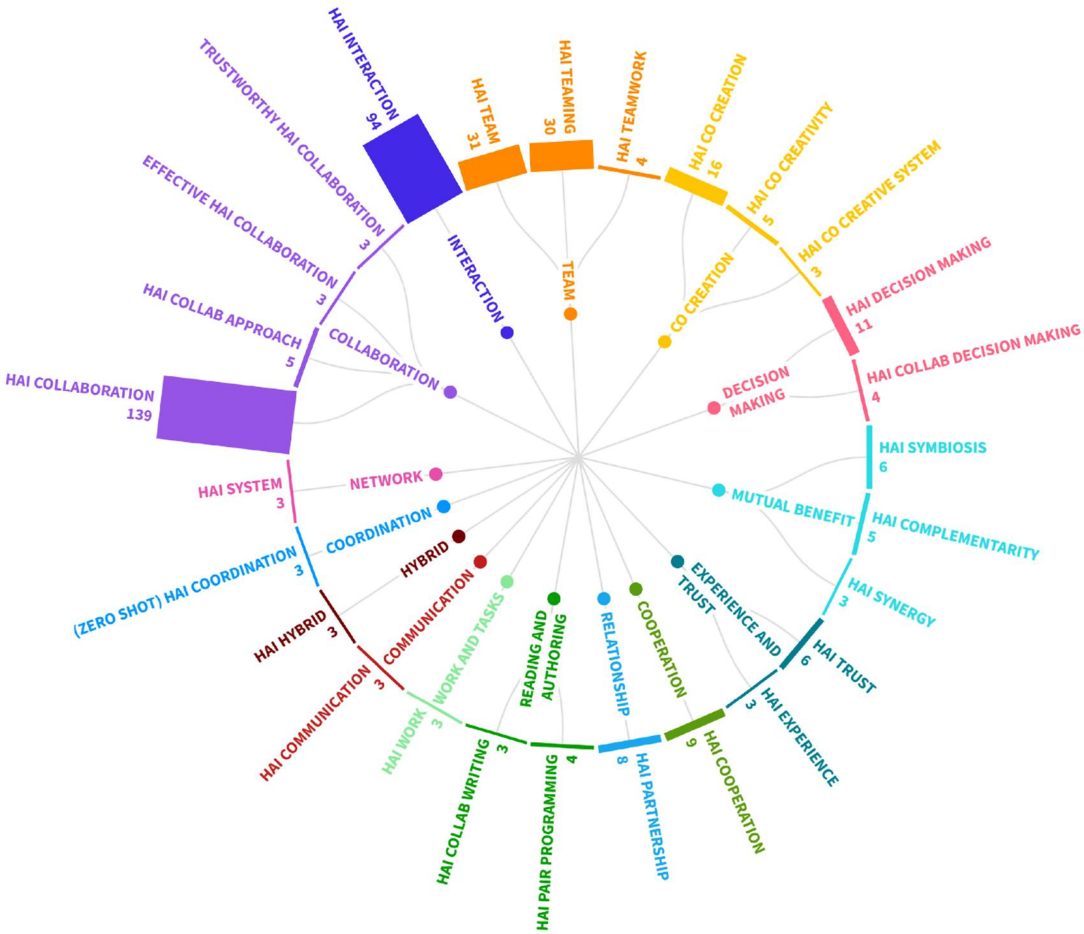


Figure 6. Excerpt of prominent terms in human-AI relations stemming from Q1 data. All terms with more than two occurrences are included in this visualization, along with the respective subcluster. An overview of all terms is available in Table B1 in Appendix B.

(2005) describe for their "affinity building" phase within the Contextual Design methodology. As a first step in this process, one main researcher judged similarities to find initial clusters. Then, a group of three researchers, including the one that did the first clustering (all among the authors of this article) discussed and rearranged the clusters in an interactive team process to find consensus. This process facilitated transparency and structure, and mitigated researcher bias despite human judgment. We identified a total of 30 clusters, which then were clustered again in four resulting higher-level clusters: *Applications*, *Connection*, *Design* and *Working Together*. Subsequently, the 30 clusters (see Table B1, second column) will be referred to as subclusters. The four main clusters with their respective subclusters are described in Sections 3.4.1 to 3.4.4, the concrete assignment of publications to (sub)clusters can be found in Table B1 in Appendix B. While some of the clusters are clearly larger than others, this does not necessarily mean that the same proportion of our corpus of literature concerned this cluster. More accurately, these clusters can span a wider range of different individual terms, which could reflect research interest in the area, great focus on adjectives describing individual terms, but also hint a lack of accepted conventions.

3.4.1. Connection

Terms in this cluster may indicate social connections such as friendship or partnership but also include differences and dissimilarities as well as complementarity and resulting benefits. The concrete subclusters (highlighted in bold below) can be described as follows. In contrast to the commonly collaborative and target-oriented nature of teams, the concept of **Relationship** does not necessarily imply working towards a shared goal, but may include friendships and intimate relationships (Brandtzaeg et al., 2022), that indicate some degree of social binding. **Integration** relates to a seamless combination of humans and AI. **Mutual Benefit** may refer to synergistic effects and complementarity of humans and AI, taking advantage of each others' capabilities. **Network**, e.g., including human-AI "(eco)systems", can be seen to describe the connection between humans and AI regarding their communication and information sharing. **Hybrid** "approaches" and "systems" imply bi-directional contribution of human and AI parts and may partially be seen as a degree of involvement. As "hybrid"-terms were frequently used to describe the union of humans and AI as one, we decided to create a separate subcluster. **Team** is the most prominent subcluster with several terms related to teams, teamwork and teaming constellations with human and AI teammates. We included "team" and "teaming" as separate terms, as Capel and Brereton explain different contexts: "teaming" is associated with a more creative context, whereas "team" is used for decision making in which humans do not want to rely on their own or the AI's decision alone, but take advantage of the complementarity (Capel & Brereton, 2023).

3.4.2. Working together

This cluster contains the aspects commonly associated with Computer Supported Cooperative Work (CSCW). The focus of this cluster is collaborative work and creation, including topics such as task distribution as well as ways of communication and interaction between humans and AI. There are many different approaches how to define and interrelate individual concepts in the CSCW domain, such as collaboration and cooperation. According to Schmidt and Bannon, cooperation involves interdependence of tasks with *different* goals, while collaboration involves joint work on resources with *common* goals (Bannon & Schmidt, 1989; Schmidt & Bannon, 1992). Dillenbourg distinguishes cooperation and collaboration based on task distribution ("In cooperation, partners split the work, solve sub-tasks individually and then assemble the partial results into the final output. In collaboration, partners do the work 'together'" (Dillenbourg, 1999, p. 8)) as well as cognitive processes (Dillenbourg, 1999). We mostly follow the structure and nesting of CSCW concepts proposed by Shah (2010). **Collaboration** implies productively working on a shared goal including task-related communication, interaction and task distribution to reach complementary performance. **Cooperation** is one essential part of collaboration and includes contributing together to a shared goal (contrary to the categorization of Schmidt & Bannon, 1992; Bannon & Schmidt, 1989). In contrast to collaboration, the outcome does not exceed the result of the shared contributions (Shah, 2010). **Coordination** is nested within cooperation according to Shah (Shah, 2010) and includes communication and task distribution (which are described as separate subclusters) to ensure smooth collaboration and the best usage of resources within a team. **Communication** as an essential part of coordination may concern communication direction, modalities and interfaces. We also included conversation in this cluster if the term indicated a focus on the peculiarities of communication between humans and AI, while terms focusing on application cases of *dialog systems* are found in the *Applications* cluster. **Co-creation** can be seen as a specific collaboration aiming at joint creation, often of innovative or creative content, e.g., "music co-creation". **Task Distribution** is another aspect of coordination, while **Work and Tasks** focuses on the joint work or specific tasks and their implications rather than their efficient assignment. Terms in the **Interaction** subcluster mainly focus on the way and nature of interaction and also include dynamics, interplay and interactive approaches. **Experience and Trust** in human-AI relations may influence appropriate reliance and the willingness to work together.

3.4.3. Applications

Several publications reflected specific application cases of human-AI relations in their titles. Human-AI **Decision Making** includes both parties to find decisions based on hybrid knowledge. The **Learning** subcluster involves learning and teaching. Learning includes joint efforts to support human learning (van den Bosch et al., 2019) as well as mutual learning about the collaboration partners (Schoonderwoerd et al., 2022). **Control** rarely reflects the intuitive interpretation of human control and autonomy in the interaction with AI (Lundberg et al., 2021), most terms in this cluster rather describe a complementary approach of sharing control of some external aspect, e.g., the switch from one learning situation to another (Echeverria et al., 2020; Li, Huang, et al., 2022). The subcluster **Reading and Authoring** suggests reading, writing and editing as collaborative applications with focus on interaction dynamics (Yang et al., 2022), capabilities of large language models (LLMs) (Lee, Liang, et al., 2022) and complementarity during the respective process (Chen, Wu, et al., 2023). **Dialog Systems** include conversational systems and chatbots. **Data Processing and Analysis** includes collaborative approaches of humans and AI aiming to facilitate data analysis, e.g., by coding and labeling (Brachman et al., 2022; Gebreegziabher, Zhang, et al., 2023). Publications regarding human-AI **Sensemaking** are either directed towards the mutual understanding of the interaction partners themselves to be able to interact and collaborate effectively (Shen et al., 2021) or towards the shared effort to make sense of some external, complex data (Dorton & Hall, 2021). **Collaborative Design** refers to applications where humans and AI design together, rather than the design of human-AI interactions as describes in the *Design* cluster and respective subcluster. **Exploration and Detection** includes joint detection of patterns or information (Schmitt et al., 2024; van Zoelen et al., 2023) and exploration of design spaces (Viros-I-Martin & Selva, 2021). Terms which describe specific application cases outside the scope of the described subclusters and were only found once in the data even after harmonizing the terms were collected separately in a **Miscellaneous** pool.

3.4.4. Design

This cluster focuses on foundations to build on, guidance for practitioners or researchers and guidelines to be followed to potentially support the development of suitable solutions for interaction and collaboration between humans and AI. **Design** terms mostly concern frameworks and interfaces (Guimaraes et al., 2021; Marhraoui et al., 2022), protocols and workflows (Fogliato et al., 2022; Liu et al., 2020).

4. Bibliometric analysis

Identifying key authors and publications in a field can reveal developments initiated by influential researchers or networks among them, as well as key findings that may have strongly influenced the research landscape. In the context of this work, emerging terminology may have been shaped by highly popular publications. To complement the findings directly related to the terms themselves, we thus conducted a bibliometric analysis (cf. RQ5), aiming at focusing on a small number of both authors and publications, in order to specifically point readers to them. Due to the high number of overall publications in our review, these outstanding researchers and pieces of work would be hard to localize in the corpus otherwise.

RQ5: Which key authors and publications can be identified in human-AI literature? We extracted key authors and key publications from Q1 data, based on numbers of publications they were involved with for key authors and citations for key publications as metrics. We considered not only absolute, but also average citation counts per year for publications.

4.1. Key authors

We identified key authors on the basis of Q1 and referring to the number of publications the individual authors were involved in, where authorship was generally considered regardless of the authors' order or role in the papers. Overall, 2,254 individual authors were found, 589 of which were first authors in at least one publication. Most authors (1,958) contributed to only one publication. Table 3 shows the key authors listed by publication counts including their affiliations and publications. We selected all authors within the 99th percentile of publication counts in our corpus of literature (please note that several authors have identical publication counts). Most of the selected key authors contributed as *first* authors in only a small share of their publications. Notable exceptions are António Correia and Jeba Rezwana who are both listed as first authors for six of their seven publications shown in Table 3.

4.2. Key publications

Key publications are relevant to a comprehensive understanding of the research landscape and its development. The large impact of, usually, a small number of outstandingly influential, publications can be observed by their absolute citation count on one hand (which is however generally biased with regard to publication date), which indicates that a large portion of the literature refers to concepts and findings described in these publications. On the other hand, citation counts could also be averaged per year, which allows for a more inclusive approach related to more recent publications (we acknowledge that this reduces but does not fully removes the aging bias which generally prevails in such listings). Additionally, differences in coverage of different databases may however influence the computation of citation counts, as Bar-Ilan states that "each database draws the citations only from the items covered by it" (Bar-Ilan, 2018, p. 3). Further, databases may show differences regarding publication type of most frequently cited publications. Bar-Ilan shows that proceedings being a popular publication format in computer science is reflected in the most cited publications in the ACM Digital Library in comparison to the popularity of journal articles in Scopus (Bar-Ilan, 2018). For better comparability of publications from the different databases, we therefore retrieved citations counts from Google Scholar using SerpAPI's Google Scholar API.[18] Table B2 in Appendix B shows both total (cumulative) and average (per year) citation counts per publication along with extracted keywords and a brief summary.

Tables 3 and B2 show little overlap: only two publications (Amershi et al., 2019; Bansal et al., 2019a) are also found in the publications of key authors. Notably, both are joint efforts by researchers affiliated with Microsoft Research, indicating the institution's impact in the field. The publications mainly focus on complementarity, perception and interaction in human-AI relations. Designing and facilitating human-AI interaction seems particularly challenging yet crucial for complementary performance. Besides interaction design, human perception greatly impacts team-up willingness. Overall, the key publications show a collective shift towards working together rather than competing against each other, aiming for performance that neither of the parties could reach alone.

4.3. Geographic analysis

The worldwide distribution of researchers within a research field implies a variety of cultural backgrounds, local developments and research directions. By conducting a geographic analysis of their affiliations, we investigate the geographic distribution of human-AI terminology but also focal areas and global coverage of the overall research field to answer RQ6.

RQ6: Which geographic differences can be seen in human-AI terminology? We extracted country and continent from authors' affiliations using OpenAI's GPT-4o mini,[19] which is one of the most recent Large Language Models (LLMs). LLMs have the capability of including context into their analysis and offer intuitive interaction, making them a useful tool for text analysis (Rathje et al., 2024), where GPT-4o mini is particularly suitable for extracting searched for information, e.g., location details. In our data extraction process, we considered each country only once per publication if more than one author was affiliated with the respective country. Results were continuously cross-checked by one main researcher. The locations in combination with the associated subclusters per publication yield visualizations that allow for geographic analysis on country and continent level.

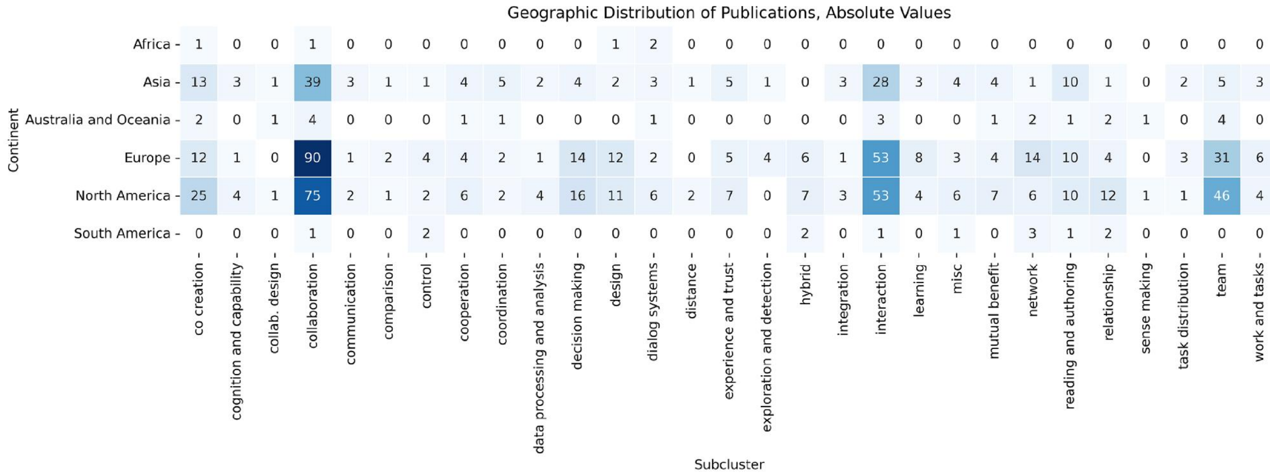
Continent-level. Figure 7a is based on the absolute numbers of publications per terminology subcluster and continent. The heatmap indicates pronounced research contribution in North America, followed by Europe and Asia. Focal points based on continents can be seen for "collaboration" and "interaction" in North America, Europe and Asia and "team" in North America and Europe. Human-AI research was sparsely covered in Australia, South America and Africa. This might be due to disadvantageous legal regulations (Jackson Bertón, 2021) or

Table 3. Key authors in human-AI literature with contributions to up to 14 publications, considering *not* only first-authorship.

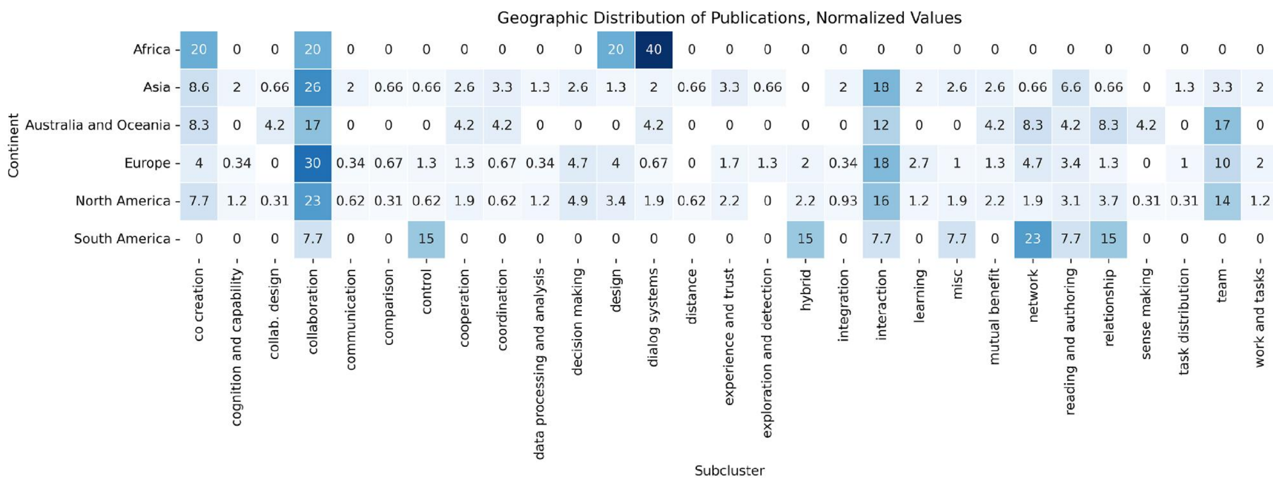
Author	Count	Affiliation	Publications
Nathan J. McNeese	14	Clemson University	(Canonico et al., 2020; Flathmann et al., 2021, 2023, 2024; Hauptman et al., 2023, 2024; Mallick et al., 2024; McNeese et al., 2021; Schelble et al., 2021, 2023, 2024; Zhang, McNeese, et al., 2021; Zhang, Duan, et al., 2023; Zhang, Flathmann, et al., 2024)
Beau G. Schelble	9	Clemson University	(Flathmann et al., 2021, 2023; Hauptman et al., 2023, 2024; McNeese et al., 2021; Schelble et al., 2021, 2023, 2024; Zhang, Flathmann, et al., 2024)
Vincent Aleven	8	Carnegie Mellon University	(Echeverria et al., 2020, 2023; Holstein et al., 2020; Holstein & Aleven, 2022; Karumbaiah et al., 2023; Thomas et al., 2024; Yang et al., 2021, 2023)
Christopher Flathmann	8	Clemson University	(Flathmann et al., 2021, 2023, 2024; Hauptman et al., 2024; Mallick et al., 2024; Schelble et al., 2021; Zhang, Duan, et al., 2023; Zhang, Flathmann, et al., 2024)
Kenneth Holstein	8	Carnegie Mellon University	(Echeverria et al., 2020; Gmeiner et al., 2024; Holstein et al., 2020, 2023; Holstein & Aleven, 2022; Kawakami et al., 2022; Morrison et al., 2023; Yang et al., 2023)
Mary Lou Maher	8	University of North Carolina at Charlotte	(Karimi et al., 2020; Kim, Maher, et al., 2021; Rezwana et al., 2021; Rezwana & Maher, 2023a, 2021, 2023c, 2023b, 2022)
António Correia	7	University of Jyväskylä, University of Nebraska at Omaha, INESC TEC and University of Trás-os-Montes e Alto Douro	(Correia, 2024; Correia et al., 2020, 2021, 2024, 2023; Correia & Lindley, 2022; Guimaraes et al., 2021)
Toby Jia-Jun Li	7	University of Notre Dame	(Gebreegziabher, Zhang, et al., 2023; Ning et al., 2024: Zhang, Ning, et al., 2023; Suh et al., 2024; Yang et al., 2022; Zhang, Xu, et al., 2022; Zhang, Gao, et al., 2023)
Jeba Rezwana	7	University of North Carolina at Charlotte	(Karimi et al., 2020; Rezwana et al., 2021; Rezwana & Maher, 2023a, 2021, 2023c, 2023b, 2022)
Casey Dugan	6	IBM Research	(Ashktorab et al., 2020, 2021, 2023; Brachman et al., 2022; Munyaka et al., 2023; Wang et al., 2019)
Niklas Kühl	6	University of Bayreuth Karlsruhe Institute of Technology	(Jakubik et al., 2023; Morrison et al., 2024; Schemmer et al., 2022; Schoeffer et al., 2024: Schemmer et al., 2023; Vössing et al., 2022)
Q. Vera Liao	6	Microsoft Research	(Ashktorab et al., 2020; Chen, Liao, et al., 2023; Fan et al., 2022; Lai et al., 2022, 2023; Prabhudesai et al., 2023)
Besmira Nushi	6	Microsoft Research	(Amershi et al., 2019; Bansal et al., 2019a, 2019b; Fogliato et al., 2022; Inkpen et al., 2023; Peng et al., 2022)
Nikol Rummel	6	Ruhr-Universität Bochum	(Echeverria et al., 2020, 2023; Holstein et al., 2020; Karumbaiah et al., 2023; Yang et al., 2021, 2023)
Michael Vössing	6	Karlsruhe Institute of Technology	(Hemmer et al., 2022, 2023; Jakubik et al., 2023; Schemmer et al., 2022; Vössing et al., 2022; Westphal et al., 2023)
Rui Zhang	6	Clemson University	(Flathmann et al., 2021, 2024; Schelble et al., 2024; Zhang, McNeese, et al., 2021; Zhang, Duan, et al., 2023; Zhang, Flathmann, et al., 2024)
Zahra Ashktorab	5	IBM Research	(Ashktorab et al., 2020, 2021, 2023; Brachman et al., 2022; Munyaka et al., 2023)
Wen Duan	5	Clemson University	(Flathmann et al., 2024; Hauptman et al., 2024; Schelble et al., 2023; Zhang, Duan, et al., 2023; Zhang, Flathmann, et al., 2024)
Vanessa Echeverria	5	Carnegie Mellon University, Esc. Superior Politécnica del Litoral, Monash University	(Echeverria et al., 2020, 2023; Yan et al., 2024; Yang et al., 2021, 2023)
Eric Horvitz	5	Microsoft Research	(Amershi et al., 2019; Bansal et al., 2019a, 2019b; Fogliato et al., 2022; Segal et al., 2022)
Kori Inkpen	5	Microsoft Research	(Amershi et al., 2019; Fogliato et al., 2022; Inkpen, 2024; Inkpen et al., 2023; Peng et al., 2022)
Ece Kamar	5	Microsoft Research	(Bansal et al., 2019a, 2019b; Liu et al., 2020; Peng et al., 2022; Segal et al., 2022)
Qian Pan	5	IBM Research	(Ashktorab et al., 2020, 2021, 2023; Brachman et al., 2022; Munyaka et al., 2023)
Gerhard Satzger	5	Karlsruhe Institute of Technology	(Hemmer et al., 2022, 2023; Schemmer et al., 2023; Vössing et al., 2022; Westphal et al., 2023)
Zheng Zhang	5	University of Notre Dame	(Gebreegziabher, Zhang, et al., 2023; Ning et al., 2024; Zhang, Gao, et al., 2023; Zhang, Xu, et al., 2022; Zhang, Ning, et al., 2023)

limited economic resources and necessary infrastructure (Kiemde & Kora, 2020). Further, the absolute numbers of human-AI publications are of course also affected by general aspects such as continent size, number of higher education and other research institutes there and similar. For instance, according to the uniRank directory,[20] there are currently 62 officially recognized higher-education institutions in Oceania (including Australia) versus 1,858 in North America or 2,706 in Europe. Additionally, as pointed out by Williams (who also states that "Australia does not yet have an artificial intelligence strategy or roadmap"; Williams, 2019, p. 111), the investment in research and development in general, differs for different nations (e.g., 0.4% of the GDP in Australia compared to 1.18% in South Korea or 0.75% in the US in 2015) (Williams, 2019).

Also, the discrepancies of human-AI research coverage in absolute numbers, do not fully allow for within-continent



(a) Heatmap based on absolute numbers of publications.



(b) Heatmap based on relative numbers normalized by overall number of publications per continent.

Figure 7. Geographic distribution of human-AI terminology on continent-level based on the subclusters found in human-AI literature.

analysis of research interests and terminology usage. For this reason, numbers in Figure 7b are normalized by the overall number of publications per continent to provide a more detailed view of research interests within continents. This visualization can be read line-wise and reveals focal points within continents that vanished in Figure 7a. While collaboration, interaction and team subclusters still stand out in the normalized figure, research activity in South America and Africa does not necessarily seem to align with the main streams visible for other continents. For example, publications affiliated with South America most frequently concern "network", "control", "hybrid" and "relationship" subclusters and "dialog systems" is the most prominent subcluster for publications affiliated with Africa. Normalized values for the "team" subcluster are surprisingly low for Asia, while values for "co-creation" and "reading and authoring" are comparatively high. Europe and North America show similar focal areas with only slight deviations, e.g., higher "co-creation" and "relationship" values for North America and higher "collaboration" and "learning" values for Europe. Note that, due to the sparse coverage of human-AI literature in Africa, Australia and South America, their focal points, e.g., on "hybrid" for South America, are strongly visible, while focal points stand out less strongly for continents with overall broad coverage.

Country-level. Subsequently refining the perspective on the global distribution, countries within continents may contribute to research to different degrees. Especially for continents that consist of a large number of individual countries, such as Europe, differences may be discovered by investigating the countries' focal areas. Figures A2(a to f) in Appendix A show all countries within their respective continents with color intensities indicating their overall contribution in the respective subcluster.

5. Thematic analysis

This section extends our analyses by including the respective publications' contents rather than just the presence of terms in their titles. According to Braun and Clarke, thematic analysis is “a method for identifying, analysing and reporting patterns (themes) within data” (Braun & Clarke, 2006, p. 79), which, even though flexible in nature, commonly “involves the searching across a data set—[…]—to find repeated patterns of meaning” (Braun & Clarke, 2006, p. 86). In our analysis, we aim to find patterns in the conception, usage, perception and co-occurrence of specific terminology in a subset of publications based on terms that occurred at least three times in our Q1 data as described in Section 2.1.

5.1. Term conception and usage

The usage and conception of terminology can unveil hidden discrepancies, similarities and relationships. RQ7 focuses on different themes of conception and usage potentially stemming from a lack of clear definitions and awareness.

RQ7: Which themes of term conception and usage consist in human-AI literature? We extracted the usage and conception of different terms manually by either using explicit definitions stated in the text or by inferring them, e.g., from descriptions of application cases and study tasks the participants were confronted with. We briefly describe each of the terms and their usages and then summarize the findings based on the previously defined thematic clusters (see Section 3.4). The *Design* cluster did not contain any terms with at least three occurrences and is therefore not addressed in this section.

5.1.1. Connection

In our corpus of selected literature, **Human-AI Teams** are seen as collaborative relationships between humans and AI, aiming for complementary performance, e.g., (Bansal et al., 2019b; Zhang, Lee, et al., 2022) and mutual benefit (Babbar et al., 2022). Zhang et al. more specifically describe human-AI teams as “an integrated unit where human and AI teammates, each with a significant degree of agency, coordinate and collaborate to complete team tasks with a shared goal” (Zhang, Flathmann, et al., 2024, p. 2) and state that for potentially superior performance in comparison to human-only teams “both a focus on the technical/task-focused contributions and the human-factors contributions of AI” (Zhang, Flathmann, et al., 2024, p. 2) are crucial. Challenges specific to human-AI teams include awareness (Endsley, 2023) and understanding of teammates (Munyaka et al., 2023), autonomy and interdependence (Ulfert et al., 2024) as well as individual and team trust (Georganta & Ulfert, 2024; Hou et al., 2025; Ulfert-Blank et al., 2023). Berretta et al. define **Human-AI Teaming** as “a process between one or more human(s) and one or more (partially) autonomous AI system(s) acting as team members with unique and complementary capabilities, who work interdependently toward a common goal” (Berretta, Tausch, Ontrup, et al., 2023, p. 23). Literature on human-AI teaming tends to focus on establishing functioning human-AI teams (Hauptman et al., 2023; McNeese et al., 2021) and factors that may enable or influence their effectiveness (Berretta, Tausch, Ontrup, et al., 2023; Koehl & Vangsness, 2023; Milella et al., 2023). Authors describe the need for understanding and awareness, adaptivity and the importance of the AI system being a “real” member of the team rather than a tool, with expectations and standards applied similar to those in human teams (Berretta, Tausch, Ontrup, et al., 2023; Hauptman et al., 2023; McNeese et al., 2021; Schelble et al., 2024). Berretta et al. further point to *human-technology teaming* and *human-autonomy teaming* as related research fields, which we could also identify in Section 3.1. With **Human-AI Teamwork**, researchers investigate interactions and dynamics between human and AI teammates (Jorge et al., 2023; Mallick et al., 2024; Peng et al., 2022; Schecter et al., 2023) and what may be specific to human-AI rather than human-only teams (Schecter et al., 2023).

Kawakami et al. summarize **Human-AI Partnerships** as “configurations of humans and AI systems that can draw upon complementary strengths of each” (Kawakami et al., 2022, p. 1). Further, Xu et al. describe “a genuine human-AI partnership capable of mimicking the dynamic adaptability of humans” (Xu, Hong, et al., 2023, p. 1) and humans and AI as “fellow team members who can both reactively and proactively collaborate” (Xu, Hong, et al., 2023, p. 1). Partnerships may thus be collaborative relationships (Omidvar-Tehrani et al., 2024; Xu, Hong, et al., 2023, Weisz et al., 2021) with discussions including involvement, roles (Omidvar-Tehrani et al., 2024; Waefler & Schmid, 2020), acceptance and reliance (Kawakami et al., 2022; Nguyen et al., 2018; Weisz et al., 2021) and resulting design implications. A **Human-AI System** may broadly be a combination of humans and AI, described as an intertwined sociotechnical system (Naikar et al., 2023). Publications emphasize the importance of human focus in the design of AI interfaces and interactions (Correia & Lindley, 2022; Subramonyam et al., 2022). **Human-AI Complementarity** emphasizes superior performance that can only be reached by combining human and AI capabilities strategically. Publications focus on the optimal integration of human and AI contributions (Tan et al., 2022; Yang, Zhang, et al., 2024), impact factors (Steyvers et al., 2022) and the design and tuning of AI to complement the individual human’s capabilities (Holstein & Aleven, 2022; Inkpen et al., 2023). **Human-AI Symbiosis** may be similar to complementarity and collaboration at first glance, focusing on working together and aiming for AI to support rather than replace humans (Mahmud et al., 2024; Jarrahi, 2018). The distinctive feature of symbiosis appears to be the trigger of an advantageous situation (Bendoly et al., 2024; Ilapakurti et al., 2019; Vuppalapati et al., 2020) that enables humans to act upon. **Human-AI Synergy** may describe a holistic view on complementarity and human focus, taking affordances (Bao et al., 2023) and behavioral science (Van Rooy & Vaes, 2024) into account. Fabri et al. adopt a definition of **Human-AI Hybrids** as “combinations of capabilities of human agents and AI-enabled systems” (Fabri et al., 2023, p. 625). They highlight the importance of clear definitions and investigating human-AI hybrids as close interworking of humans and AI from more than one perspective (Fabri et al., 2023), for which they develop a taxonomy including archetypes of human-AI hybrids ranging from automation to co-evolution. Fahse and Schmitt refer similarly to the concept while focusing on real-life settings (Fahse & Schmitt, 2023). Allred et al. describe a complementary human-AI hybrid that is superior to established techniques for author masking (Allred et al., 2020).

Summary
The *Connection* cluster highlights the importance of human-centered approaches in human-AI relations. This is reflected by the relationship-focused perspective, investigating how connections between humans and AI should be designed and what may impact them. Forming teams or partnerships between humans and AI mostly aims for collaborative and complementary relationships, where human-AI teaming may be the process of establishing functioning human-AI teams and research concerning human-AI partnerships may even more focus on AI as a capable fellow team member. A holistic approach may be reflected in literature describing human-AI synergies, while in human-AI symbiosis leveraging human and AI knowledge to spark a symbiotic effect to help humans may be a different approach to human-centeredness.

5.1.2. Working together

Human-AI Interaction addresses the characteristics of interaction with AI in comparison to conventional HCI (Amershi et al., 2019; Shin et al., 2019; Wienrich & Latoschik, 2021). Researchers investigate what makes interaction with AI special and which new challenges arise with it (Liu, 2021; Sundar, 2020; Yang et al., 2020), especially considering the uncertainty of the AI's outcome. While commonly the human is in the focus rather than technical aspects, discussions concerning human-AI interaction in our literature range from mere acceptance of an AI system and its decisions (Liu, 2021) to actually investigating the ways humans can interact with AI (Kim et al., 2023) and an overall shift from HCI to human-AI interaction. Crompton describes human-AI interaction in decision making, where "the human agent (re-)acts on the output of the AI, and the AI (re-)acts on the output of the human agent" (Crompton, 2021, p. 1). **Human-AI Collaboration** takes advantage of the complementary skills of both parties, i.e., humans' ability to use intuition and reason based on experience and AI's computational power. In human-AI literature, a range of applications are considered *collaborative* with different degrees of involvement and focus on enhancement of either party. Including an AI collaborator may facilitate human collaboration and educate human collaborators (Sharma et al., 2023; Wang et al., 2019) or reduce the required human effort. Collaboration in decision making frequently refers either to decision support systems or conditional delegation. In this context, it is noteworthy to mention *human-AI collaboration protocols* which specify "how human decision makers should interact with the machines that support them" (Cabitza et al., 2021, p. 2) and deal with the interaction process and questions such as when to present what (decision-related) information. For instance, the sequence of advice presentation (e.g., human-first vs. AI-first) can play in important role in the design of human-AI systems (Cabitza et al., 2023). In summary, decision support systems provide AI recommendations or advice to support humans in their final decision and therefore integrate additional knowledge (Bossen & Pine, 2023; Cabitza et al., 2021; Cabrera et al., 2023; Holstein et al., 2023; Schmidt & Biessmann, 2020). In conditional delegation, both humans and AI delegate decision tasks to the better suited collaboration partner for efficient use of the complementary capabilities (Lai et al., 2022). Integrating human knowledge in AI model development (Siirtola & Röning, 2019) may reflect the AI communities' perspective of human-AI collaboration, where the goal is to improve model performance. Another stream of literature investigates human-AI collaboration in exploratory applications, where the human provides guidance to approach a desired goal (Strobelt et al., 2022). Literature contains critical arguments towards the collaborative nature especially of decision support systems. Simple decision support systems do not include factors frequently considered essential to collaboration, such as reciprocity, equal contribution and learning from each other (Dellermann, Calma, et al., 2019). Several publications concerning human-AI collaboration discuss the importance of feedback, awareness of information available to the collaborator (Holstein et al., 2023) and the calibration of appropriate trust and reliance (Cabrera et al., 2023; Okamura & Yamada, 2020a). Despite the unresolved challenges, human-AI collaboration literature does show endeavors towards hybrid intelligence (Sowa et al., 2021). The term **Human-AI Collaborative Approach** is more frequently used for systems that are intended to perform or enable collaboration, not necessarily focusing on the process and team aspect of collaboration (Lee et al., 2021). In **Human-AI Co-Creation**, humans and generative AI aim to create or explore something new. Examples include, however may not be limited to, areas with a focus on creativity and personal expression, such as painting and music co-creation (Huang et al., 2020; Lyu et al., 2022). Even though intuition and expression as human abilities are difficult for AI to adopt or imitate, human creativity can be enhanced by including AI in the process of collaborative creation (Yu et al., 2022). This is specifically of interest in **Human-AI Co-Creativity**, which "involves humans and AI collaborating on a shared creative product" (Rezwana & Maher, 2023a, p. 62) and is being researched by Computational Creativity and HCI researchers (Kim, Maher, et al., 2021; Moruzzi & Margarido, 2024). Rather than creativity support (Rezwana & Maher, 2023a) or generative creativity (Kim, Maher, et al., 2021), human-AI co-creation reflects a collaborative approach of designing, making music (Rezwana & Maher, 2023a) or creating artwork together. The collaborative and uncertain nature of creating and creativity may shape the specific kind of interaction in human-AI co-creation and co-creativity. Publications using **Human-AI Co-Creative System** focus on the design and dynamics in such collaborative relationships (Buschek et al., 2021; Rezwana & Maher, 2021, 2023b). Application cases of **Human-AI Cooperation** include the assignment of tasks to the better suited (human or AI) teammate for optimal performance (He et al., 2023; Salikutluk et al., 2023), cooperative games (Atkins et al., 2021; Le Guillou et al., 2023; Schelble et al., 2021) and decision making, where "human participants make their initial decision first, observe their teammate's decision, and then make their final decision" (Zhang, Chong, et al., 2023, p. 2). Among other topics, researchers investigate trust (Okamura & Yamada, 2020b, Zhang, Chong, et al., 2023, Schelble et al., 2021), adaptive autonomy (Salikutluk et al., 2023) and mental models (He et al., 2023; Le Guillou et al., 2023) in human-AI cooperation. In **Human-AI Communication**, Pan et al. and Brandtzaeg et al. investigate agency and perception of conversational AI systems (e.g., ChatGPT, communicating in human language) in human-AI communication (Pan et al., 2024, Brandtzaeg et al., 2022). Koçak et al. aim to account for semantic ambiguities different humans may bring into human-AI communication, using potential ambiguities in communication codes in an advantageous manner (Koçak et al., 2022). **Zero-Shot Human-AI Coordination** aims "to develop an agent capable of collaborating with humans without relying on human data" (Yan et al., 2023, p. 1). Zero-shot approaches are relevant to various application cases where adaptation to humans is necessary, yet the collection and integration of human data in the training process is costly, such as conversational systems, robotics, self-driving vehicles and gaming (Lou et al., 2023; Yan et al., 2023; Zhao, Song, et al., 2023). Human data is therefore simulated by agents in approaches such as self-play or population-based methods to train RL models (Yan et al., 2023; Zhao, Song, et al., 2023: Lou et al., 2023). **Human-AI Work** concerns the impact of the introduction of AI in work contexts on work practices, dynamics and workers (Berretta, Tausch, Peifer, et al., 2023; Ruissalo, 2024) as well as configurations of humans and AI working together and technology adoption, e.g., in agricultural settings (Hüllmann et al., 2023). A lack of **Human-AI Trust** commonly stems from the black-box nature of AI models (Lou & Wei, 2023; Wang & Ding, 2024), making it difficult for humans to appropriately calibrate to them. For example, Wang and Ding state that "the lack of trust in algorithms sealed in the "black box" is one of the most challenging barriers to taking advantage of AI in human decision-making" (Wang & Ding, 2024, p. 1). Common approaches to enhance transparency and therefore trust include explanations, however, researchers have noticed the importance of not only establishing, but maintaining trust: Zerick et al. highlight the importance of human-AI trust and specifically focus on recognizing and restoring trust once lost, stating that "by its nature, adoption of AI necessitates more than mere acceptance: it requires trust" (Zerick et al., 2024, p. 1). Further, Li et al. address trustworthiness of AI and human trust towards humans, automation and AI (Li, Wu, et al., 2024), proposing a framework of AI trust informed by psychological perspectives to trust.

Summary
The uncertainty of AI output seems to shape a different kind of interaction which poses new challenges in the design and development in comparison to conventional HCI research. AI and humans possess complementary strengths for a range of different tasks, which may enable and encourage collaboration to reach superior joint performance that could not be reached by either party alone. Complementarity and uncertainty are necessary for specific contexts, e.g., human-AI co-creation in art, as creativity requires uncertainty on the AI side.
Publications refer to a range of settings with different degrees of involvement and directions of support as collaborative. Two main streams of research describing "human-AI collaboration" are related to decision support systems and conditional delegation, which differ from each other in the partition of decisions. In addition, human-AI collaboration includes facilitation and mediation of human collaboration, education and improvement of human capabilities, joint problem solving, guided joint exploration and improvement of AI performance. This wide range of settings considered "collaborative" calls for a more thorough investigation of the definition of collaboration in human-AI relations to avoid jingle fallacies. This is emphasized by arguments in existing literature regarding the collaborative nature of, e.g., decision support systems. A potential risk for jangle fallacies can be seen in some instances of similar use of collaboration and cooperation in human-AI literature.

5.1.3. Applications

Human-AI Decision Making refers to AI assisting the human in the decision making process. Commonly, the human decision maker is provided with AI recommendations or predictions and can then either accept or reject them for the final decision. The noticeably strong focus on explanations (Jakubik et al., 2023; Morrison et al., 2024; Schemmer et al., 2022; Schoeffer et al., 2024) shows an aim for supporting the human decision maker in the decision whether or not to rely on the AI recommendation. Publications on human-AI decision making mention various high-stakes application domains, such as medicine, law and finance. Several publications additionally describe an aim for complementarity. Puranam refers to **Human-AI Collaborative Decision Making** as a setting where "humans and AI algorithms through some form of collaboration, together produce a decision that is implemented by a third party" (Puranam, 2021, p. 75). While the specific terminology may not necessarily reflect a strong difference between decision making and *collaborative* decision making in this case (Cai et al., 2019), Wang et al. emphasize the importance of restoring trust to enable collaboration in human-AI decision making and aim to address explanations and autonomy in collaborative decision making (Wang, Yuan, et al., 2024). Authors further integrate human knowledge in reinforcement learning processes (Mentzas et al., 2021) or focus on the onboarding and introduction to AI assistants (Cai et al., 2019). In **Human-AI Collaborative Writing**, textual content is created jointly by humans and AI. Collaboratively created content is commonly influenced by prompts to retrieve LLM outputs, but also by human the human decision of whether or not to adopt the generated text or to possibly adapt it according to the individual needs (Richburg et al., 2024). Richburg et al. specifically focus on authorship analysis for collaboratively generated content, which becomes increasingly challenging with interdependent contributions of both parties (Richburg et al., 2024). Further, authors investigate LLMs' capabilities in different collaborative writing contexts (Lee, Liang, et al., 2022) and the practical impact of contemporary collaborative writing approaches, i.e., text generation with LLMs, on professional writing (Knowles, 2022). In **Human-AI Pair Programming**, "the practice of two programmers working together on the same task using a single computer, keyboard, and mouse" (Ma, Wu, et al., 2023, p. 1) is applied to humans and AI as programming partners. Authors investigate the differences and potentials of human-AI pair programming in comparison to the conventional setting of human pair programming (Ma, Wu, et al., 2023) and aim to address the common black-box problem in (AI) model development by providing AI advice and visualizations to the human developer (Jiang, Ahmadon, et al., 2024; Jiang, Bin Ahmadon, et al., 2023; Zhang, Wei, et al., 2022).

Summary
Human-AI decision making by itself appears to be a well-defined concept. There is a particularly strong focus on tuning appropriate reliance on the AI's recommendations, but also on complementarity between humans and AI to surpass individual performance of each. The *Applications* cluster further shows a surge in research interest in human-AI collaborative writing, which poses challenges concerning the differentiation of authorship of jointly generated content and the adaptation to and impact on humans. In human-AI pair programming, AI is seen as a partner facilitating programming of, e.g., complex models.

5.2. Co-occurrence

Shared discussions and research interests can indicate conceptual relationships between terms, e.g., communication may be relevant in the context of teaming. With RQ8, we investigate such conceptual relationships and semantic associations.

RQ8: Which semantic associations can be found in human-AI terminology? We performed a co-occurrence analysis on document level to find conceptually related terms. Such an analysis is suitable for investigating term-specific semantic associations and supports the inference of conceptual relations between the different terms in the same document. In our case, rather general, more prominent terms (e.g., "collaboration" or interaction") may have more co-occurrences with other terms than those tailored to one specific problem (e.g., "trustworthy human-AI collaboration"). Thus, our analysis is focused on the most prominent human-AI terms with more than two occurrences as described in Section 5, as including all proved to result in a largely "empty" co-occurrence matrix in preliminary implementations. Figure 8 shows the co-occurrence of the most prominent terms, with connection strength between terms depicted by color intensity.

For the analysis, all co-occurring terms were automatically extracted from all publications in a machine-readable PDF format using a Python script. A co-occurrence was considered if one term occurred with another term in the same file but not with itself. Furthermore, multiple occurrences of the same terms were not quantified, resembling a Boolean data type or nominal scale. The list of terms extracted from Q1 (see Section 2.1) served as a basis to be searched for in the papers. We harmonized both the PDF files and the set of search terms as described in Section 2.1 and Section 3.3 and analyzed the data based on the connection strength shown in Figure 8.

Strong connections among the most popular terms suggest that they do not necessarily represent different research directions but build a strongly intertwined core around "collaboration", "interaction" and "team" in human-AI research. This core focus possibly indicates the need for intuitive interaction between humans and AI to enable collaboration and is also visible in combination with several other terms, such as HAI partnership, HAI decision making, HAI collab. decision making, HAI system and HAI symbiosis. A focus on complementarity is visible for HAI collaboration, HAI team and HAI decision making. HAI collab. decision making, while interpreted similarly to HAI decision making in Section 5.1, seems to be discussed as a "collaborative approach", possibly enabling collaboration in human-AI decision making. With terms related to joint creation and creativity, e.g., "HAI co creation", "HAI co creativity" and "HAI co creative system", concepts otherwise relevant to human-AI relations are hardly discussed: They show weak or no connections to "HAI trust", "HAI complementarity" or "HAI cooperation". Complementarity though is frequently discussed in combination with "HAI collaboration", "HAI interaction" and "HAI decision making", reflecting the use of complementary strengths for optimal *performance*, which may not be the goal in co-creative settings. Some terms show overall weaker connections. This may suggest research performed separately from others, specificity of a term (e.g., "HAI pair programming" may not be discussed frequently as a common part of human-AI relations, but rather reflect a specific approach or application case) or, in contrast, a concept commonly discussed without the need for an explicit human-AI term. For example, *trust* may be relevant to many discussions in human-AI relations, yet, authors may not explicitly refer to it as "human-AI trust" in publications concerning human-AI relations. Investigating such cases may require a more thorough, focused co-occurrence analysis including relevant terms and descriptions of specific concepts rather than our overview of human-AI terminology.

6. Discussion

With our scoping review, we aimed at mapping the landscape of terminology used in scientific human-AI literature to provide a broad overview of the usage and consistency of terms, discussed topics, and the evolvement over time. In the following, we discuss the implications and limitations of our research and identify our main contributions.

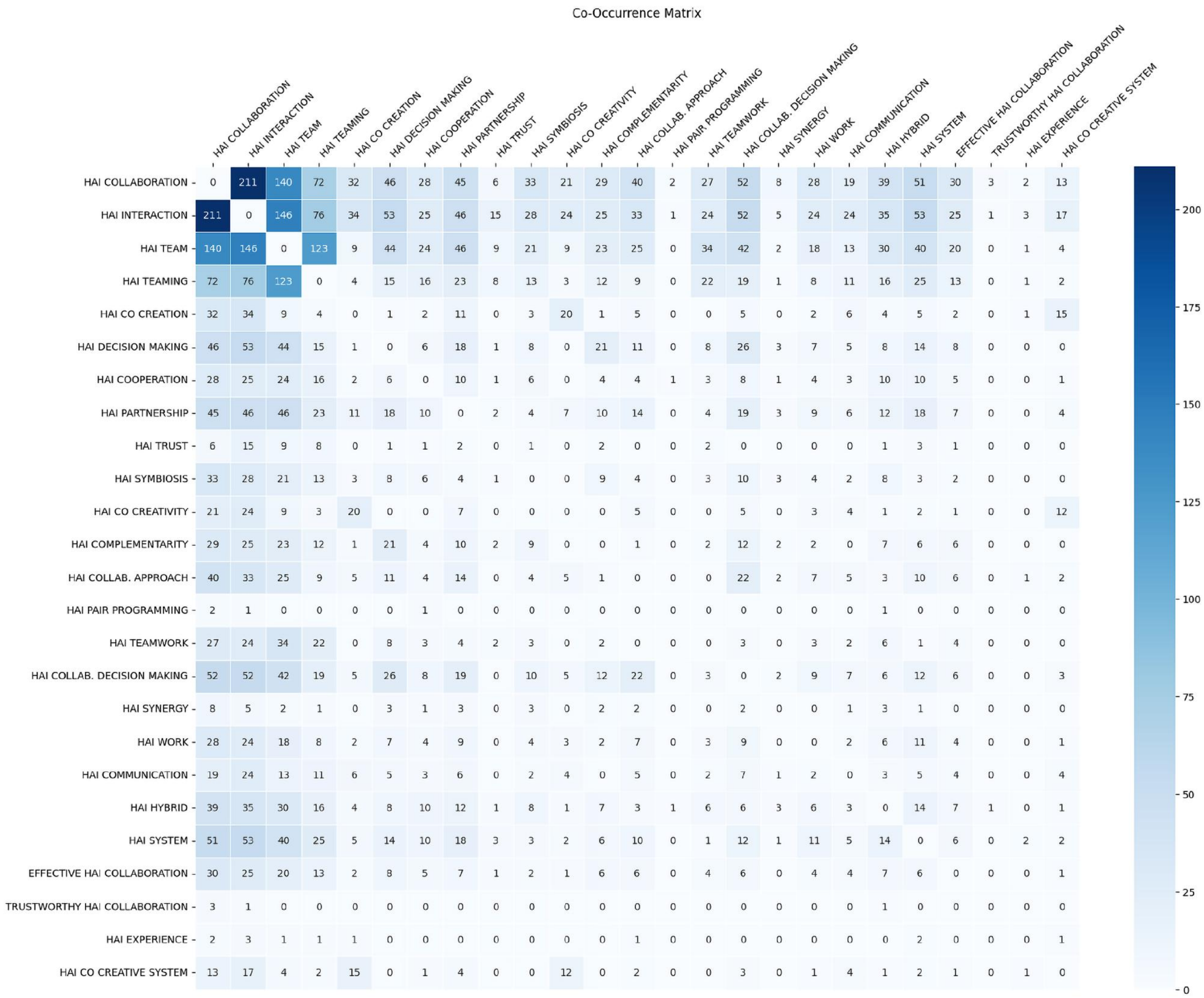


Figure 8. Co-Occurrence matrix of pairs of most popular human-AI terms.

6.1. Implications and contributions

As explained in Section 1, the rapid advancements in AI research in general as well as a shift of its focus towards human-centered AI hold the risk of emerging two-sided inconsistencies (e.g., ambiguities) in the terminology used to characterize relations between humans and AI.

First, as shown in Table 1, we extracted a set of different alternative terms for "AI" from the literature. This is in line with the findings of Langer et al., (2022) and (Graziani et al., 2023), investigating terms used to refer to AI systems. Both Langer et al. (2022) as well as Graziani et al. (2023) already found significant differences in the perception of and expectations towards AI systems depending on the wording. Awareness of the variety of terms and their usage and conception is therefore crucial to identify possible inconsistencies in terminology and facilitate purposeful selection of appropriate terms. Besides the appropriate calibration of individuals' expectations and trust towards AI systems, inconsistent terminology holds risk for societal implications: In legal contexts, precise definition of individual terms may be critical to ensure fair jurisdiction. For instance, in the European Union region, the General Data Protection Regulation (GDPR),[21] regulates how personal data of individuals may be processed and transferred. According to the GDPR, humans are entitled to human judgment in automated decisions, requiring the terminology to be clear on human involvement and authority in the decision-making process. In high-stakes settings, e.g., autonomous vehicles or medical applications of AI, liability of human vs. AI may be decided based on the term precisely describing the situation. Further, inconsistent terminology may impede complementary research especially in interdisciplinary fields.

Our findings confirm and extend Langer et al.'s and Graziani et al.'s observations: as our review indicates, human-AI terminology largely appears to be influenced by the development of a new shape of interaction. Contrary to conventional systems, AI outputs hold uncertainty which leads to potentially unpredictable results. A large proportion of literature therefore focuses on the peculiarities of interaction and the collaborative, complementary relationship of humans and AI. Awareness of trending and emerging terms, such as "human-AI collaboration" or "human-AI symbiosis", supports the consistent use of terminology and development of conventions, while clear definitions are yet to be made.

To further support clear terminology in human-AI relations, existing standard definitions, e.g., in ISO/IEC 22989:2022 or the European AI Act, may provide a solid base for future research. Researchers may leverage standard definitions and focus on contributions, conceptions and influences of different domains, such as Computer Science including HCI and AI, Psychology, Sociology and Linguistics, to find common concepts or even important differences. With respect to trends and newly emerging terminology in human-AI relations, future research may systematically explore the origin and development of individual terms in scientific literature. This may reveal relatedness of terms across disciplines, or between newly emerging and already established terms. Complementarily, we argue that collaborative approaches towards establishing precise terminology may be particularly suitable for interdisciplinary research. Towards this end, we, on one hand, suggest a systematic integration of the terminological discussion in the premier scientific venues of the relevant communities – e.g., in the form of dedicated workshops at conferences such as ACM CHI or ACM IUI (where, typically, the HCI and AI audience meets). On the other hand, we suggest dedicated studies for the development and evaluation of a shared terminology across scientific communities. One suitable method for such studies could be inspired by the Delphi technique, which has been originally conceptualized as a systematic method for eliciting expert opinion. While various authors reflected overly critically on the original Delphi method, pointing out problematic aspects such as "unaccountable sampling" of "experts", "[s]eriously confusing aggregations of raw opinion with systematic prediction", "capitalizing on forced consensus based on group suggestion", or "denigrating group and face-to-face discussion" (Sackman, 1974, p. 69, 70), or "complicated facilitator tasks", "lack of real-time presentation of results" or "difficulties in tracking progress over time" (Gnatzy et al., 2011, p. 1), methodologically revised approaches aim to address the weaknesses of the conventional Delphi method while preserving its potentials to establish consensus of a particular topic among a group of experts (Turoff, 1970). Related to our use case on the establishment of a shared terminology within and across scientific communities, Delphi studies have, also in recent years, been successfully applied in similar endeavors. For instance, Schapira et al. in Schapira et al. (2020) describe a "modified Delphi process" for seeking consensus on the terminology of value-based transformation of health care. Other recent examples on endeavors for standardization of terminology in the health sector can be found in Denman et al., (2021) and Taze et al. (2022). Examples for Delphi studies in the broader fields of Computer Science and HCI can be found in Danial-Saad et al. (2013), where Danial-Saad et al. describe establishment of an ontology for assistive technology, in Parekh et al. (2018), where Parekh et al. identify core concepts of cybersecurity, or in Dawood et al. (2021) where Dawood et al. aim to establish a unified criteria model for usability evaluation in the context of open source software.

Furthermore, conjunctive terms used to describe human-AI relations are ambiguous in the opposite sense. The excessive use of trending terms, e.g., "collaboration" or "co-creation" indicates either a rapid increase in research interest or term ambiguity (or both). The analysis of our comprehensive corpus of literature actually revealed considerable disparities in the use of specific terms (cf. Section 5.1 and *RQ7*), a trend which seems to persist in literature beyond the scope of our review – just lately, Sarkar (Sarkar, 2023) complained about excessive use of "human-ai collaboration" in recent scientific literature. For instance, in Gebreegziabher, Zhang, et al. (2023), "collaboration" between humans and AI is used to refer to a scenario in which an AI system and a human actually interact in a closely interwoven way (where, however, it remains the human who makes the decisions) to solve qualitative coding tasks, in Kuang et al. (2023), "collaboration" describes the interaction with a conversational AI in a Q & A style in the domain of UX evaluation, and in Xu, Lien, et al. (2023), "collaboration" is used to refer to AI assistance in annotation tasks. Additionally, it is remarkable that most of the recent literature on human-AI relations does not provide an exact definition of what is understood by e.g., "collaboration".

Further, whereas the terms chosen for our review were defined to explicitly include "human" and "AI", there are also terms containing only one of these words while implicitly considering the other party (e.g., "AI-assisted", "AI-enhanced", or "AI-supported"). While these terms often implicitly include humans, we assume that the integration of the second party involved can be seen as more single-sided and unbalanced or might be absent at all (e.g., in AI-enhanced computer systems). The *diversity in degrees of involvement* may range from mostly human- to mostly AI-sided involvement, with "collaboration" integrating both parties to a similar extent. Different degrees of involvement may shift roles and raise questions concerning autonomy, responsibility and ethics within the human-AI relationship. Subsequent targeted literature reviews could determine the differentiation and possibly provide a taxonomy systematically capturing the *different degrees of human-AI involvement*.

Our geographic analysis revealed that contributions mostly stem from countries associated with WEIRD (Western, Educated, Industrialized, Rich, Democratic) societies (Henrich et al., 2010). In line with this, Bol et al. highlight the higher prevalence of scientific journals in North America and Europe compared to the Global South and state that "Global North journals are often associated with international and global-level prestige, while Global South journals are presumed to be local, national or regional in scope" (Bol et al., 2023, p. 1). Legal regulations (Jackson Bertón, 2021) and limited economic resources (Kiemde & Kora, 2020) may contribute to this geographic disparity, causing different perspectives of underrepresented populations to remain unconsidered in the research and terminology of human-AI relations. The academic disadvantage of geographical regions, such as the Global South, may be counteracted by conscious citation of respective work or co-publishing of Global North and Global South publishing spaces to reach greater audiences (Bol et al., 2023). Bol et al. further discuss the potential advantage of decentralized editorial boards and journal indexing to support geographic equality in academic publishing (Bol et al., 2023). Future visions of a culturally more inclusive human-AI research community may offer diverse perspectives more representative of the world's population.

Our main contributions can be summarized as follows. With this scoping review, we provided a *comprehensive overview of the terminology* used in scientific human-AI literature. Our results offer insights into *thematic clusters* and capture the *changing nature of human-AI relations over time* (e.g., from AI as a tool to AI as a team member). Analyses with different focal points provide a *general overview of the research field* while *enabling researchers to find specific literature*. Thematic analyses consider not only the choice of terminology, but also differences in conception and usage and the consequent co-occurrence with other terms. We strongly aim to contribute to the *harmonization of human-AI terminology* and facilitate the establishment of *more precise definitions* of prominent terms in the literature. This is of utmost importance as, according to Langer et al. (2022), consistent and precise terminology does not only impact human perception of and expectation towards AI systems, it also enhances the robustness and replicability of research findings. Our review further intends to *facilitate future research across domains and communities*. To this end, we aim to *raise awareness of research* but also *terminology used* in complementary or contrasting fields. This, according to our observation, is imperative because the recent surge of scientific activities around human-AI relations has clearly revealed that currently, there is a lack of established terminology across domains, but also continents and countries. This gap is further continuously amplified by intra-domain reinforcement (e.g., through names of workshops or newly established conferences).

6.2. Limitations

In the following, we summarize the main limitations inherent to our scoping review.

Selection of human-AI terms. Our review relies on a certain set of keywords included throughout Q1 to Q3. Even though we systematically researched alternative terms for both "human" and "AI", we acknowledge that the selection might still not be exhaustive. For instance, Hirzle et al. (2023) and Langer et al. (2022) provide more extensive collections of alternative AI terms and keywords than those listed in Table 1. Examples include adjectives such as "supervised", "generative" or "intelligent", and terms for specific applications, such as "reasoning", "recognition" and "segmentation" (Hirzle et al., 2023). While combinations of these may capture a wider range of human-AI literature, they oftentimes focus on specific applications or leave room for ambiguous interpretation, depending on the chosen combination. Langer et al.'s list of AI terms in use includes "algorithm", "computer" and "robot", which are also considered in our review. Further suggested terms comprise "decision support system", "automated system", "technical system" and "computer program" (Langer et al., 2022). While not explicitly present in our set of keywords, these terms are semantically covered by "system" and "computer" in Q2 and Q3 of our review. Additional unconsidered terms mentioned by Langer et al., (2022) include "machine learning" and "sophisticated statistical models". We are aware that our systematic approach to data collection based on term composition patterns may lead to the underrepresentation of relevant discussions with terminology diverging from the defined pattern. For example, Matamoros et al. only slightly diverge from our defined pattern by specifying a particular group of humans in "Teachers-AI Collaboration" (Matamoros et al., 2021). Their publication is therefore not included in our review, even though its investigation of educational recommender systems may be a highly relevant application case of human-AI collaboration. Further, Knijnenburg et al. discuss interaction methods for recommender systems (Knijnenburg et al., 2011), which one may clearly consider an application case of human-AI relations. Their publication's title however does not state a specific human-AI term according to our defined pattern and is therefore not represented in our work. While we could not consider terminology specific to recommender systems, literature was included if it contained a, to our definition, valid human-AI term, e.g., in "Towards the design of user-centric strategy recommendation systems for collaborative Human–AI tasks" (Dodeja et al., 2024). Further, research communities such as IUI and Affective Computing are heavily engaged with human-centered approaches of AI. The relation in this case may be more implicit with a strong focus on adaptability derived from, e.g., the context and emotional state of the human, not necessarily reflecting a two-sided relation with equal consideration of both sides. This may be reflected in the terminology and thus, despite potentially containing highly relevant topics of human-AI relation, these research fields may be underrepresented in our work.

Moreover, for the analyses in Section 5, we only considered terms with at least three occurrences, and for popular terms, we selected only five publications per year. While we chose this sampling method as it represents the data well, it leaves out some publications that may include different conceptions, interpretations and co-occurrences.

We showed that terminology does not appear to be settled, seems to be partly volatile (see, e.g., the dynamic development reflected in Figure 3) and some terms have entirely fallen out of favor (e.g., "man" to mean humanity, which we, however, intentionally included to not omit older publications, such as Licklider's work). As argued above, the emergence of new terms may not immediately be reflected in terms being used prominently in publications' titles. While we focused on established terminology in our thematic analysis to capture the conception and underlying discussions of particularly *prior* and *recently prominent* terms, *future* studies focused on newly emerging terminology could highlight the evolvement of human-AI term usage beyond publications' titles and investigate particularly origin and relatedness to established concepts.

Considered combinations. We did not include terms indicating *unbalanced involvement* of humans and AI (e.g., "AI-assisted human labeling") or ambiguous terms that potentially refer to other parties than humans or AI, or include only one party, e.g., "ai-enhanced software". The combination of "human" and "AI" in close proximity within a term ensured less ambiguous results. Further analyses concerning all combinations of human and AI relations, including those that only implicitly include one (e.g., "AI-enhanced learning", "AI-guided navigation") or both (e.g., "collaborative intelligence") of the two parties, can however add further value and broaden the view of the field.

Depth of content-wise insights. Following the goals of a scoping review, we aimed for a broad overview rather than an in-depth content-wise analysis. We performed thematic analyses to complement our findings based on the terminology, we, however, consider it an interesting part of future work to perform a subsequent systematic literature review to gain further insights into the associated content discussed in the human-AI literature. This subsequent review should be narrowed to specific parts of the field identified in this article, such as "collaboration", "interaction" or "communication" among humans and AI.

Database selection. We purposefully selected databases to represent the primary context of human-AI relations in Computer Science (including, e.g., HCI research), while at the same time considering the interdisciplinarity of human-AI relations. Thus, we selected Scopus as an interdisciplinary primary database and further ACM Digital Library and IEEE Xplore as specialized supplementary databases [205, 206]. This selection provides a broad interdisciplinary inclusion of literature with focus on highly relevant areas given the specific context, however, we are aware that the strong focus on Computer Science and Engineering may undermine perspectives of further relevant research fields. Despite the relevance of diverse research fields to human-AI relations, we decided against the further inclusion of highly specialized databases as they did not yield sufficient amounts of relevant data for our specific analysis of human-AI terminology due to their narrow scope (Gusenbauer, 2022) and limited full-text availability in our preliminary searches. More in-depth content-wise analyses may however require the inclusion of further specialized databases, e.g., focusing on Social Sciences and Psychology, to holistically capture the nature of human-AI relations and potential societal impacts.

7. Summary and conclusion

In this article, we first analyzed the *historical development* (Section 3.1) and *term composition patterns* (Section 3.2), including alternative terms for "human" and "AI" leading to the current human-AI terminology. We then provided a *general overview of the terminology* (Section 3.3) present in our Q1 data, derived four *thematic clusters* with 30 subclusters and the meaning of terms within them (Section 3.4). Further, we identified *key authors* and the most *influential publications* in Sections 4.1 and 4.2 and described the *geographic distribution* of terms to refer to human-AI relations by researchers all over the world (Section 4.3). Finally, we investigated the *conception and interpretation* of terms in human-AI literature (Section 5.1) and *co-occurrences* of specific terms (Section 5.2).

Our analysis revealed that the rapid advancement of AI and shift towards HCAI spiked research interest in a newly shaped kind of interaction different from conventional HCI. This led to the emergence of a variety of terms to describe collaborative relationships and efforts toward seamless integration of humans and AI with a lack of conventions and precise definitions. We could identify a large pool of terms relevant across domains and communities and investigated their conception and usage, where we could identify ambiguities in the evolving terminology. We further backed our findings with additional analyses for a comprehensive overview of the historical and current terminology in human and AI relations to provide a profound basis for future cross-domain research activities. While arguing for the development of terminological conventions in scientific literature, the rapid evolvement of AI technology and its terminology may limit the longevity of our own work. While longevity concerning the frequently discussed *publish-or-perish* mentality (Van Dalen & Henkens, 2012) and the limited lifespan of publications frequently poses challenges to researchers, we are confronted with obsolescence of research findings due to terminology evolvement. Though, we aim to capture the variety of terminology and advocate for its clear definition *at the present time*.

In conclusion, our scoping review opens a range of research questions to be further investigated. In our own future work, we foremost aim at analyzing in depth the concept of "human-AI collaboration", establishing not only a profound definition but also a global and cross-domain taxonomy of prerequisites, components and characteristics.

Notes

1. https://artificialintelligenceact.eu/article/3/, last access: 2024-10-13.
2. https://www.iso.org/standard/74296.html, last access: 2024-10-14.
3. https://www.oecd.org/en.html, last access: 2024-10-14.
4. https://oecd.ai/en/wonk/definition, last access: 2024-10-14.
5. https://dl.acm.org/, last access: 2024-10-12.
6. https://www.scopus.com/, last access: 2024-10-12.
7. https://ieeexplore.ieee.org/, last access: 2024-10-12.
8. We also experimented with "Artificial Intelligence" but found a significantly lower number of results (1,450 for the query using "AI" vs. 175 for "Artificial Intelligence").
9. https://www.researchgate.net/.
10. Please keep in mind that we explicitly did not restrict our review to publications after a certain publication date.
11. https://www.merriam-webster.com/.
12. https://www.powerthesaurus.org/.
13. https://digital-strategy.ec.europa.eu/en/library/eu-us-terminology-and-taxonomy-artificial-intelligence.
14. https://www.powerthesaurus.org/.
15. https://www.deepl.com/translator.
16. By "man" we do not specifically refer to male persons but to any persons in general (especially older literature regularly uses it to mean "mankind"). To ensure inclusiveness we ran a test search with "woman" as alternative *human* term which however did not yield any results.
17. 2024 data is only available until September 2024, we however expect an ongoing development to be likely.

18. https://serpapi.com/google-scholar-api.
19. https://platform.openai.com/docs/models/gpt-4o-mini.
20. https://www.4icu.org/.
21. https://eur-lex.europa.eu/eli/reg/2016/679/oj, last access: 2024-12-16.

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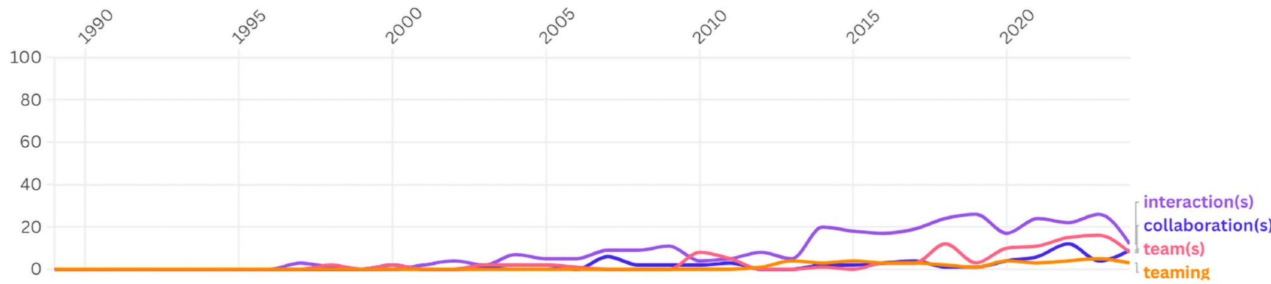
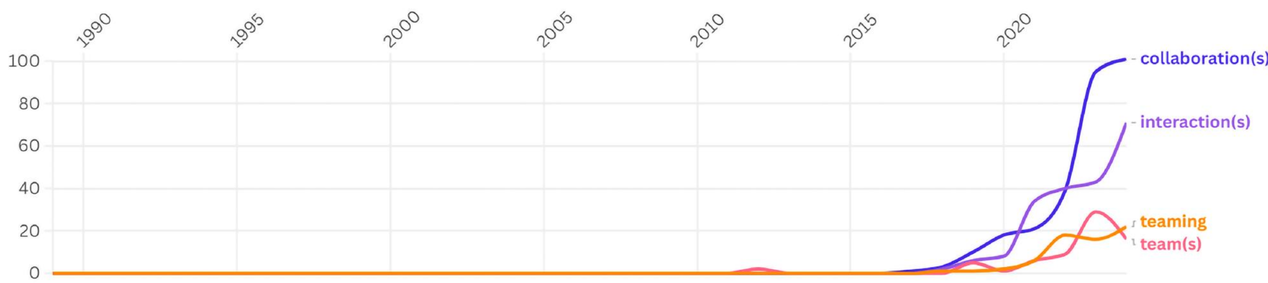
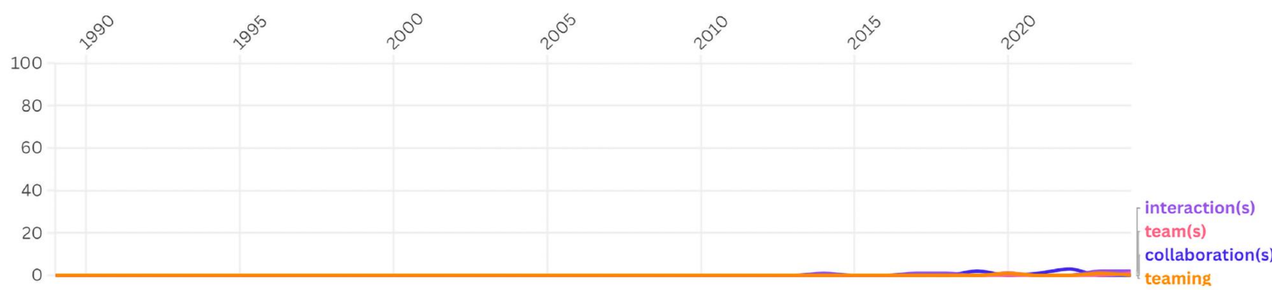
Appendix A. Additional figures



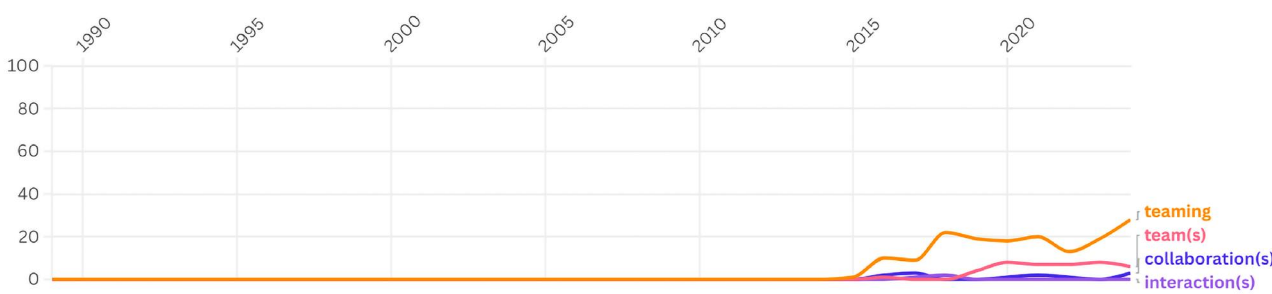
(a) Development of terminology using human-*agent* combinations, e.g., "human agent interaction".



(b) Development of terminology using human-*AI* combinations, e.g., "human ai interaction".

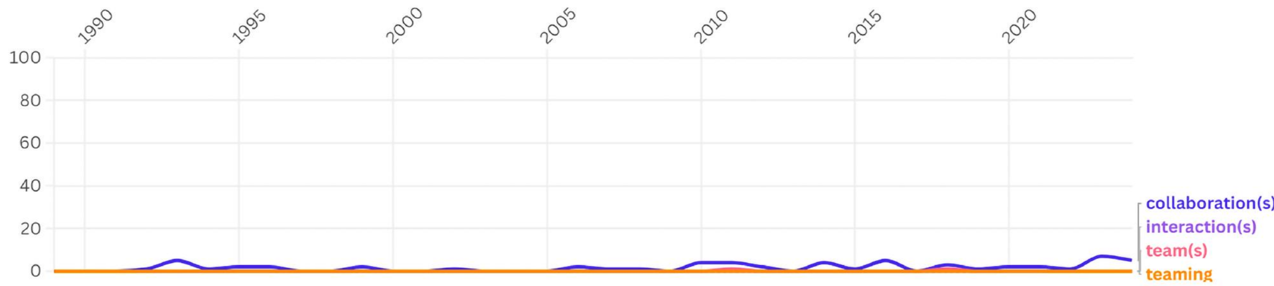


(c) Development of terminology using human-*algorithm* combinations, e.g., "human algorithm interaction".

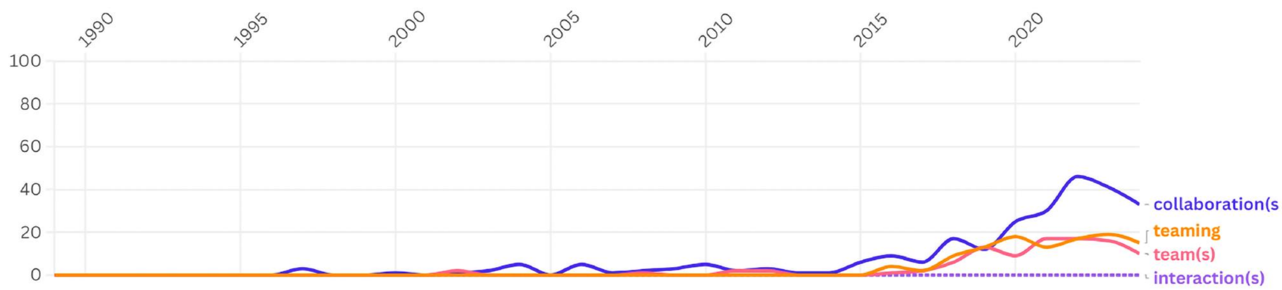


(d) Development of terminology using human-*autonomy* combinations, e.g., "human autonomy interaction".

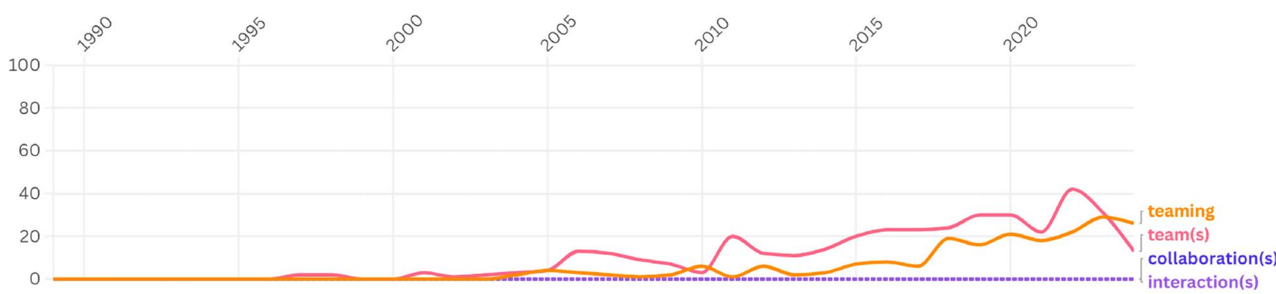
Figure A1. Historical development of terminology usage with different alternative terms that may refer to AI, ranging from 1989 to 2024. Values show publication counts for three-part compounds of "human", alternative AI terms, and the key supplementary terms introduced in Section 1.



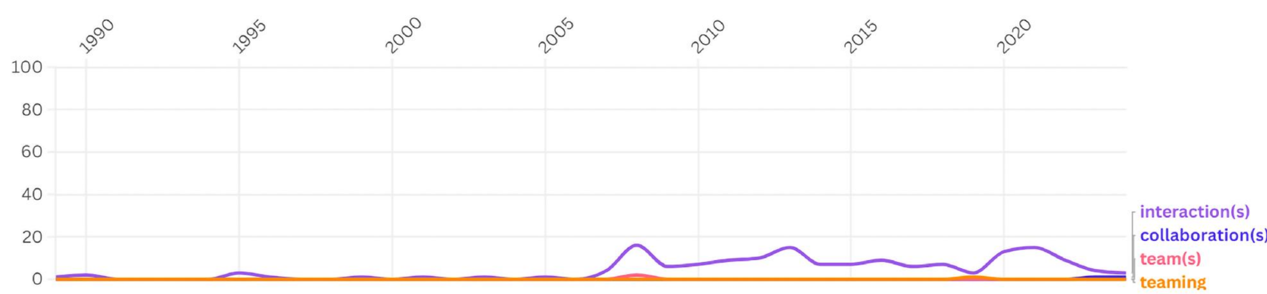
(e) Development of terminology using human-*computer* combinations, e.g., "human computer interaction".



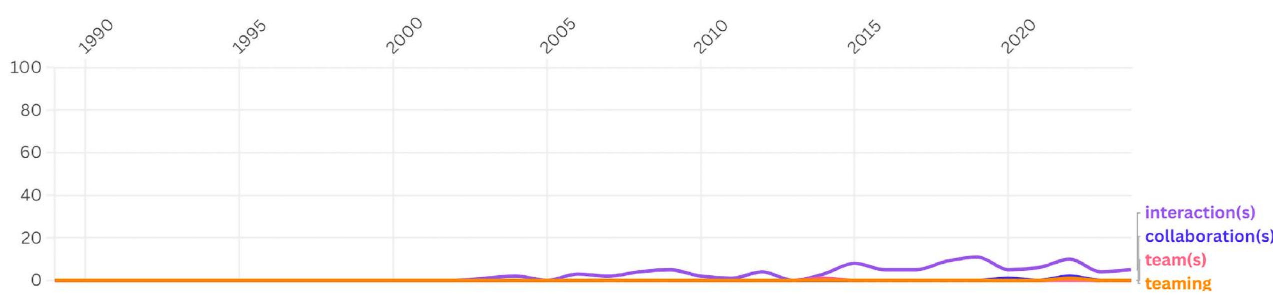
(f) Development of terminology using human-*machine* combinations, e.g., "human machine interaction".



(g) Development of terminology using human-*robot* combinations, e.g., "human robot interaction".

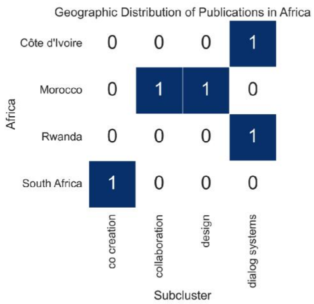


(h) Development of terminology using human-*system* combinations, e.g., "human system interaction".

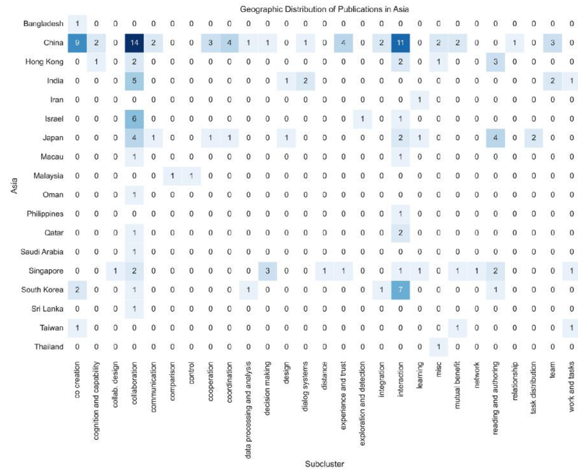


(i) Development of terminology using human-*technology* combinations, e.g., "human technology interaction".

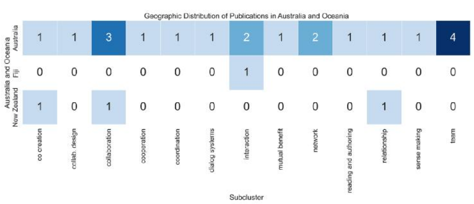
Figure A1. Continued.



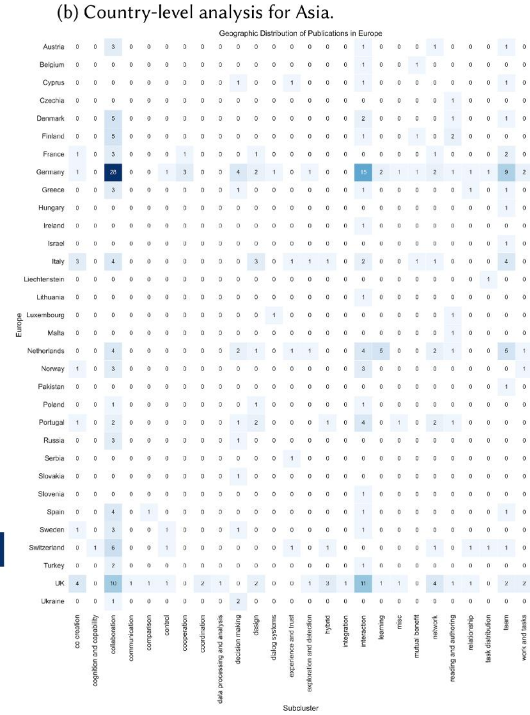
(a) Country-level analysis for Africa.



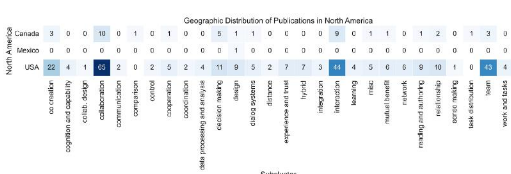
(b) Country-level analysis for Asia.



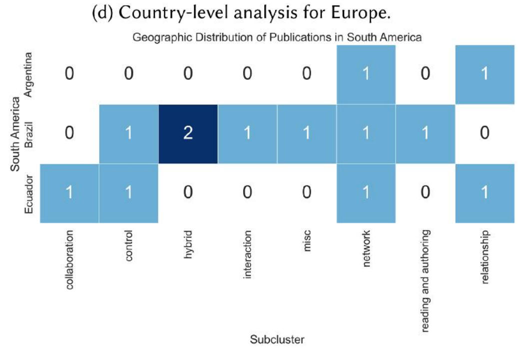
(c) Country-level analysis for Australia and Oceania.



(d) Country-level analysis for Europe.



(e) Country-level analysis for North America.



(f) Country-level analysis for South America.

Figure A2. Geographic distribution of human-AI terminology on country-level, per continent. Only countries and subclusters with publication counts > 0 are considered.

Appendix B. Additional tables

Table B1. Overview of all clusters, subclusters, individual terms and the included publications.

Cluster	Subcluster	Term	Publications
Connection	Team	HAI Team	(Andrews et al., 2023; Babbar et al., 2022; Bansal et al., 2019b; Bendell et al., 2021; Bruni, 2024; Carolina Centeio et al., 2022; Cummings et al., 2021; de Visser et al., 2023; Endsley, 2023; Flathmann et al., 2023; 2024; Frattolillo et al., 2024; Georganta & Ulfert, 2024; Hagemann et al., 2023; Harris-Watson et al., 2023; Hauptman et al., 2024; Hou et al., 2025; Kraus et al., 2023; Lemmer et al., 2023; Liang et al., 2019; Munyaka et al., 2023; Naser & Bhattacharya, 2023; Schelble et al., 2023; Siu et al., 2021; Tag et al., 2023; Ulfert et al., 2024; Ulfert-Blank et al., 2023; Westby & Riedl, 2023; Zhang, Lee, et al., 2022; Zhang, Duan, et al., 2023; Zhang, Flathmann, et al., 2024)
		HAI Teaming	(Amresh et al., 2023; Andre et al., 2023; Attig et al., 2024; Baruwal Chhetri et al., 2024; Boy, 2024; Berretta, Tausch, Ontrup, et al., 2023; Bienefeld et al., 2024; 2023; Dubey et al., 2020; Gopinath et al., 2022; Haindl, Hoch, et al., 2022; Haindl, Buchgeher, et al., 2022; Hauptman et al., 2023; Hobbs & Li, 2024; Hong et al., 2024; Hughes et al., 2022; Kannally et al., 2023; Kleanthous, 2024; Koehl & Vangsness, 2023; Largent et al., 2018; Li, Li, et al., 2024; McNeese et al., 2021; Milella et al., 2023; Samadi et al., 2024; Schelble et al., 2024; Shukla et al., 2019; Simón et al., 2024; Stephens et al., 2023; 2021; Zhang, McNeese, et al., 2021)
		HAI Teamwork	(Jorge et al., 2023; Mallick et al., 2024; Peng et al., 2022; Schecter et al., 2023)
		HAI Team Performance	(Bansal et al., 2019a; Subramanian et al., 2024)
		Effective HAI Team	(Hemmer et al., 2022; Mozannar et al., 2023)
		HAI Team Accuracy	(Nguyen et al., 2022; Singh et al., 2023)
		HAI Robot Teaming	(Holder et al., 2021; Lematta et al., 2022)
		HAI (Military) Team	(Devitt, 2024)
		HAI (Diagnostic) Team	(Zhao et al., 2024)
		HAI Cognitive Teaming	(Vold, 2024)
		HAI Teaming Language	(Abbass et al., 2022)
		Adaptive HAI Teaming	(Malakis et al., 2023)
		HAI Teaming Intelligence	(Hoch et al., 2022)
		Collective HAI Teaming	(Zhao et al., 2022)
		HAI Teaming Approach	(Seveso et al., 2021)
		Ethical HAI Team	(Flathmann et al., 2021)
		Hybrid HAI Teaming	(Caldwell et al., 2022)
		HAI Hybrid Team	(Fuchs et al., 2024)
	Relationship	HAI Partnership	(Canonico et al., 2020; Kawakami et al., 2022; Metcalfe et al., 2021; Nguyen et al., 2018; Omidvar-Tehrani et al., 2024; Waefler & Schmid, 2020; Weisz et al., 2021; Xu, Hong, et al., 2023)
		HAI Friendship	(Brandtzaeg et al., 2022; Weijers & Munn, 2022)
		HAI Partnership Roles	(Tran, 2024)
		HAI Relationship Perception	(Tschopp & Sassenberg, 2024)
		HAI Resource Relations	(Kaartemo & Helkkula, 2024)
		HAI Companionship	(Ciriello et al., 2024)
		HAI Expert	(Virvou & Tsihrintzis, 2023)
		HAI Relations	(AI, 2023)
		Trustworthy HAI Partnership	(Ramchurn et al., 2021)
		HAI Copilot	(Li, Peng, et al., 2022)
		HAI Copilot System	(Wang, 2023)
	Integration	HAI Integration	(Collazo et al., 2024; Rago, 2022)
		HAI Co Evolution	(Ziegler & Donkers, 2024)
		HAI Roles	(Allen et al., 2022)
		HAI Loop Approach	(Bhardwaj et al., 2020)
		Adaptive, Explainable HAI Loop	(Orzikulova et al., 2024)
		Human-Aware AI	(Sreedharan, 2023)
		HCAI	(Xu & Gao, 2024)
	Network	HAI System	(Correia & Lindley, 2022; Naikar et al., 2023; Subramonyam et al., 2022)
		HAI Ecosystem	(Contucci et al., 2022; Mulder & Meyer-Vitali, 2023)
		HAI Centric (Performance Evaluation) System	(Graça & Camarinha-Matos, 2024)
		HAI Co Orchestration	(Yang et al., 2023)
		HAI Community	(Ashktorab et al., 2023)
		HAI Ensemble	(Choudhary et al., 2025)
		HAI Entities	(Swan & Dos Santos, 2023)
		HAI Nexus	(Askarisichani et al., 2022)
		HAI Society	(Peeters et al., 2021)
		HAI Work Systems	(Klein et al., 2023)
		Hybrid HAI Orchestration	(Echeverria et al., 2023)

(*continued*)

Table B1. Continued.

Cluster	Subcluster	Term	Publications
		Proactive HAI System	(Grosinger, 2022)
		Safe, Trusted HAI System	(Akintunde et al., 2023)
	Hybrid	HAI Hybrid	(Allred et al., 2020; Fabri et al., 2023; Fahse & Schmitt, 2023)
		HAI Hybrid Approach	(Paiva & Bittencourt, 2020; Zhang, Kaushik, et al., 2023)
		HAI Hybrid System	(Fuchs et al., 2023; Pereira et al., 2021)
		Hybrid HAI Tool	(Correia et al., 2023)
	Mutual Benefit	HAI Symbiosis	(Bendoly et al., 2024; Ilapakurti et al., 2019; Jarrahi, 2018; Mahmud et al., 2024; Vuppalapati et al., 2020; Zhang, Wei, et al., 2022)
		HAI Complementarity	(Holstein & Aleven, 2022; Inkpen et al., 2023; Steyvers et al., 2022; Tan et al., 2022; Yang, Zhang, et al., 2024)
		HAI Synergy	(Bao et al., 2023; Cau & Spano, 2024; Van Rooy & Vaes, 2024)
		HAI Enrichment	(Su et al., 2022)
		HAI Collab. (Bayesian) Optimization	(Arun Kumar et al., 2022)
	Distance	HAI Alignment	(Boggust et al., 2022)
		HAI Chasm	(Kambhampati et al., 2022)
		HAI Gap	(Liu-Thompkins et al., 2022)
		HAI (Team Mate) Gap	(Ong et al., 2012)
	Comparison	Direct HAI Comparison	(Voudouris et al., 2022)
		HAI Confrontation	(Zhang, Wei, et al., 2022)
Working Together	Collaboration	HAI Collaboration	(Agarwal, 2024; Ala-Luopa et al., 2024; Arai et al., 2023; Arias-Rosales, 2022; Ashktorab et al., 2020; Bao et al., 2021; Ben Chaaben, 2024; Biloborodova & Skarga-Bandurova, 2023; Bossen & Pine, 2023; Bousdekis et al., 2021; Braun et al., 2023; Brusilovsky, 2024; Burukina, 2020; Cabrera et al., 2023; Cabrero-Daniel et al., 2024; Cao et al., 2023; Chakravorti et al., 2023; Chang & Huang, 2021; Chen et al., 2024; Cichocki & Kuleshov, 2021; De Brito Duarte, 2023; Dellermann, Calma, et al., 2019; Dhillon et al., 2024; Erdogan et al., 2024; Eriksson et al., 2023; Erlei et al., 2024; Fan et al., 2022; Feuston & Brubaker, 2021; Figoli et al., 2022; Gamboa et al., 2022; Gao et al., 2021; Gass, 2023; Gaurav et al., 2024; Gianet et al., 2024; Göbel et al., 2022; Goel et al., 2023; Gu et al., 2024; Gupta et al., 2023; Hartikainen et al., 2024; Hassany, Ke, et al., 2024; Haupt et al., 2025; Hemmer et al., 2023; Heyman et al., 2024; Hitsuwari et al., 2023; Hohenstein et al., 2022; Holstein et al., 2023; Holter & El-Assady, 2024; Hong et al., 2021; Hou et al., 2023; Hu, Zhang, et al., 2024; Huang & Xiong, 2024; Introzzi et al., 2024; Jacobsen et al., 2020; Jaszcz et al., 2023; Jiang et al., 2021; Jiang, Liu, et al., 2023; Jones & Tanimoto, 2018; Karakose, Demirkol, Aslan, et al., 2023; Karakose, Demirkol, Yirci, et al., 2023; Khadpe et al., 2020; Kilic et al., 2023; Kim et al., 2022; 2024; Kolbjørnsrud, 2024; Kwon, Sun, et al., 2024; Lai et al., 2022; 2021; Laney & Dewan, 2024; Lauer & Wieland, 2021; Lee, Yu, et al., 2022; Li, Wang, et al., 2024; 2020; Lindner & Schulte, 2024; Linnyk & Teetz, 2023; Loo et al., 2023; Loske & Klumpp, 2021a; 2021b; Lu & Peng, 2024; Mehta et al., 2023; Meier & Glinka, 2023; Memmert & Bittner, 2024; 2022; Mlynář et al., 2024; Mohanty et al., 2024; Neuwirth & Migliorini, 2022; Okamura & Yamada, 2020a; Padovano & Cardamone, 2024; Papachristos et al., 2021; Pereira et al., 2023; Petrescu & Krishen, 2023; Prajwal et al., 2023; Puerta-Beldarrain et al., 2023; Puig et al., 2021; Qian & Wexler, 2024; Rana & Bansal, 2023; Rastogi et al., 2023; Rinott & Shaer, 2024; Sachan et al., 2024; Sadeghian et al., 2024; Saffiotti et al., 2020; Salah et al., 2023; Salikutluk et al., 2024; Sarkar, 2023; Sarkar et al., 2023; Schmidt & Biessmann, 2020; Schroder et al., 2022; Segal et al., 2022; Sharma et al., 2023; Shenoi et al., 2024; Siemon, 2022; Siirtola & Röning, 2019; Söllner et al., 2023; Song et al., 2024; Sowa et al., 2021; Strobelt et al., 2022; Sun et al., 2024; Svensson & Keller, 2024; Tian, 2024; Tkiouat et al., 2022; Tülübaş et al., 2023; Tuncer & Ramirez, 2022; Tutul et al., 2023; 2024; Vodrahalli, Gerstenberg, et al., 2022; Wang et al., 2019; Wang, Liu, et al., 2023; Wang, Nan, et al., 2024; Weber et al., 2023; Wellsandt et al., 2023; Westphal et al., 2023; Wiegreffe et al., 2022; Wienrich et al., 2024; Xu et al., 2020; Yan et al., 2024; Yiwen et al., 2024; You & Lowd, 2022; Yu et al., 2024; Zhang, Yu, et al., 2024; Zhao, Zhu, et al., 2023)
		HAI Collab. Approach	(Arous et al., 2020; Gomez et al., 2022; Huang, Wood, et al., 2024; Lee et al., 2021; Mesbah et al., 2023)
		Effective HAI Collaboration	(Nols et al., 2023; Reverberi et al., 2022; Vössing et al., 2022)
		Trustworthy HAI Collaboration	(Baniecki et al., 2023; Li, Karim, et al., 2023; Razmerita et al., 2022)
		HAI Collaboration Type	(Smirnov, Levashova, et al., 2023; Yue & Li, 2023)
		HAI Collab. Tool	(Kariyawasam et al., 2024; Zhang, Ning, et al., 2023)
		Process Oriented HAI Collaboration	(Heinzl et al., 2024)

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Table B1. Continued.

Cluster	Subcluster	Term	Publications
		Expert Knowledge Driven HAI Collaboration	(Kamboj et al., 2024)
		HAI Collaboration Patterns	(Nguyen et al., 2024)
		HAI Collab. Process	(Sankaran et al., 2022)
		Adaptive HAI Collaboration	(Shih et al., 2021)
		Constructive HAI Collaboration	(Süße et al., 2021)
		Collab. HAI	(Codella et al., 2018)
		Intuitive HAI Collab. (3D Modeling) Approach	(Cai, 2024)
		HAI Collaboration Practices	(Bogdanova, 2024)
		HAI Collab. Analysis	(Kuang, 2023)
		Critical-Reflective HAI Collaboration	(Glinka & Müller-Birn, 2023)
		HAI Collab. System	(Shi et al., 2023)
		HAI Collab. Work	(Muller et al., 2024)
		Graphical HAI Collaboration	(Hong et al., 2022)
		HAI Collab. (Navigation) System	(Gu, Yang, et al., 2023)
	Cooperation	HAI Cooperation	(Atkins et al., 2021; Okamura & Yamada, 2020b; Berberian et al., 2023; He et al., 2023; Li, Huang, et al., 2022; Salikutluk et al., 2023; Schelble et al., 2021; Spina et al., 2023; Zhang, Chong, et al., 2023)
		HAI (Agent) Cooperation	(Le Guillou et al., 2023)
		Effective HAI Cooperation	(Wittmann & Morschheuser, 2022)
		Cooperative HAI Games	(Chattopadhyay et al., 2017)
		Intention Aware HAI Cooperation	(He et al., 2024)
	Coordination	(Zero Shot) HAI Coordination	(Lou et al., 2023; Yan et al., 2023; Zhao, Song, et al., 2023)
		HAI Coordination	(Carroll et al., 2019; Hu & Sadigh, 2023)
		(Real Time) HAI Coordination	(Liu, Yu, et al., 2024)
	Communication	HAI Communication	(Brandtzaeg et al., 2023; Koçak et al., 2022; Pan et al., 2024)
		HAI Negotiation	(Sato et al., 2023)
		HAI Collab. Conversation	(Wei et al., 2022)
	Co Creation	HAI Co Creation	(Du et al., 2024; Fu & Zhou, 2020; Gmeiner et al., 2024; Suh et al., 2024; Hassany, Ke, Brusilovsky, Arun, et al., 2024; Hofmann & Preiß, 2023; Huang et al., 2020; Lyu et al., 2022; Ning et al., 2024; Rezwana & Maher, 2023a; Turchi et al., 2023; Wang, Ning, et al., 2024; Wang, Nan, et al., 2024; Wu, Kim, et al., 2022; Zhong & Zheng, 2023; Zhu et al., 2024)
		HAI Co Creativity	(Kim, Maher, et al., 2021; Moruzzi & Margarido, 2024; Rezwana & Maher, 2023c; Karimi et al., 2020; Wan et al., 2024)
		HAI Co Creative System	(Buschek et al., 2021; Rezwana & Maher, 2023b; Rezwana & Maher, 2021)
		HAI Knowledge Co-Construction	(Robertson et al., 2024)
		HAI System Co Creativity	(Serbanescu, 2024)
		HAI Text Co Creation	(Ding et al., 2023)
		(Real-Time) HAI Co Creation	(Zheng, 2023)
		HAI Co Creation Model	(Wu et al., 2021)
		HAI Co Creative Songwriting	(Micchi et al., 2021)
		HAI Co Creative (Design) Ideation	(Rezwana et al., 2021)
		HAI (Music) Co Creation	(Zhang, Xia, et al., 2021)
		Generative HAI Co Creation	(Chung et al., 2022)
		Creative HAI (Image) Co Creation	(Fan et al., 2024)
		HAI Co Creation Practice	(Yu et al., 2022)
		HAI Co Creative Drawing	(Lawton et al., 2023)
	Task Distribution	HAI Delegation	(Adam et al., 2024; Grisold & Schneider, 2023)
		HAI Crowd Task Assignment	(Kanda et al., 2022; Kobayashi et al., 2021)
		Integrated HAI Forecasting	(Li, Yin, et al., 2024)
		Hybrid HAI Forecasting	(Li & Lafond, 2023)
	Interaction	HAI Interaction	(Abedin et al., 2022; Ahn et al., 2024; Alon-Barkat & Busuioc, 2023; Amershi et al., 2019; Anderson et al., 2024; Ashktorab et al., 2021; Bach et al., 2024; Bernardo & Seva, 2024; Bondi et al., 2022; Bozdag, 2023; Calisto et al., 2022; Chen & Schmidt, 2024; Cheng et al., 2022; Cotino Arbelo et al., 2023; Crompton, 2021; Correia et al., 2021; Ding, 2024; Dynel, 2023; El-Assady & Moruzzi, 2022; Giudici et al., 2024; Gammelgård-Larsen et al., 2024; Guingrich & Graziano, 2024; Guttman et al., 2021; Gurney et al., 2023; He & Jazizadeh, 2024; Heyder et al., 2023; Hois et al., 2019; Hu, 2024; Hu, Liu, et al., 2024; Jang & Nam, 2022; Jiang et al., 2022; Jiang, Sun, et al., 2024; Jiang, Karran, et al., 2023; Jin & Youn, 2023; Judkins et al., 2024; Kiyemba et al., 2024; Kim et al., 2023; Krakowski et al., 2024; Krueger & Roberts, 2024; Kwon, Yoo, et al., 2024; La Sala et al., 2024; Lee, Hong, et al., 2023; Lee, Lee, et al., 2023; Legaspi et al., 2024; Li, Vorvoreanu, et al., 2023; Li & Lu, 2024; Liu, 2021; Liu & Siau, 2023; Lu et al., 2023; Ma & Huo, 2024; Maadi et al., 2021; Maeda & Quan-Haase, 2024; Maletzki et al., 2024; Meske & Bunde, 2020; Mucha et al., 2021; Muijlwijk et al., 2024; Navidi & Landry, 2021; Park et al., 2021; Pham et al., 2022; Raees et al.,

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Table B1. Continued.

Cluster	Subcluster	Term	Publications
			2024; Rajagopal & Vedamanickam, 2019; Roeder et al., 2023; Schoenherr & Thomson, 2024; Shergadwala & El-Nasr, 2021; Shin et al., 2019; Snatos et al., 2024; Sqalli et al., 2021; Sreedharan, 2023; Sreedharan et al., 2021; Süße et al., 2023; Sundar, 2020; Tenhundfeld, 2023; Tchemeube et al., 2023; Thieme et al., 2020; Tsiakas & Murray-Rust, 2024; Ueno et al., 2022; van Berkel et al., 2021; Vassilakopoulou et al., 2023; Veitch & Alsos, 2022; Villareale et al., 2023; Vorm, 2020; Vodrahalli, Daneshjou, et al., 2022; Wallinheimo et al., 2023; Wang et al., 2021; Wang, Liu, et al., 2023; Wienrich & Latoschik, 2021; Wu, Kim, et al., 2022; Xu & Ge, 2024; Yang et al., 2020; Yang, Xie, et al., 2024; Yao et al., 2024; Kang & Lou, 2022; Liao & Sundar, 2021; Hwang & Won, 2022)
		HAI Dynamics	(Khushk et al., 2024)
		HAI Metaphorical Interplay	(Correia, 2024)
		HAI Interaction Dashboard	(Kongmanee et al., 2024)
		Tangible HAI Interaction	(Adan & Houben, 2023)
		Multimodal HAI Interaction	(Scotte & De Silva, 2023)
		HAI Robot Interaction	(Feng & Wang, 2023)
		HAI Information Interaction	(Pawlick-Potts, 2022)
		Dynamic HAI Interplay	(Meyer & Voigt, 2022)
		HAI Interactive Approach	(Kou et al., 2022)
		HAI Interaction Dynamics	(Kim & Trewhitt, 2022)
		Purposeful HAI Interaction	(Hinsen et al., 2022)
		HAI Interface	(Holzinger & Müller, 2021)
		Explainable HAI Interaction	(Guerdan et al., 2021)
		Voice-Based HAI Interaction	(Shin et al., 2021)
		HAI Interaction Patterns	(Grabe et al., 2022)
		HAI Attention	(Zhang et al., 2020)
		HAI Hybrid Adaptivity	(Holstein et al., 2020)
		HAI Social Interaction	(Mou & Xu, 2017)
		Actionable HAI Interaction	(Bhattacharya, 2024)
		Beginner Friendly HAI Platform	(Overney et al., 2024)
		HAI Interaction Model	(Hussain et al., 2024)
		HAI Physical Interface	(EL-Zanfaly et al., 2022)
		Transparent, Controllable HAI Interaction	(Wu, Terry, et al., 2022)
		Conversational HAI Interaction	(Zheng et al., 2022)
		HAI Interaction Loop	(Ou et al., 2022)
		HAI Interaction Design Space	(Zhang, Liu, et al., 2021)
		Bidirectional HAI Interaction	(Yasser & Abu-Elkhier, 2022)
		Combined HAI Personalization	(Chine et al., 2022)
	Experience and Trust	HAI Trust	(Bui et al., 2023; Li, Wu, et al., 2024, Lou & Wei, 2023; Schwalb et al., 2022; Wang & Ding, 2024; Zerick et al., 2024)
		HAI Experience	(Inkpen, 2024; Sergeyuk et al., 2024; Weekes & Eskridge, 2022)
		HAI Interaction Satisfaction	(Xie et al., 2023)
		HAI Performance	(Hoffman et al., 2023)
		HAI Trust Dynamics	(Gerlich, 2024)
		HAI Trust Factors	(Pham et al., 2022)
		Hybrid HAI Performance	(Lemus et al., 2023)
	Work and Tasks	HAI Work	(Berretta, Tausch, Peifer, et al., 2023, Hüllmann et al., 2023; Ruissalo, 2024)
		HAI Collab. Task	(Dodeja et al., 2024; Weerawardhana et al., 2024)
		HAI Collaboration Task	(Sharma et al., 2024; Xu, Lien, et al., 2023)
		HAI Coworking	(Huang, Chen, et al., 2024)
		HAI Crowdsourcing	(Tamura et al., 2024)
		Effective HAI Work Design	(Jain et al., 2023)
		HAI Collab. (Sub-Goal) Optimization	(Ma, Vo, et al., 2023)
		HAI Complex Task Planning	(Nikookar, 2023)
		HAI Joint Task Performance	(Constantinides et al., 2024)
Applications	Decision Making	HAI Decision Making	(Salimzadeh et al., 2024; Jakubik et al., 2023; Morrison et al., 2024; Schoeffer et al., 2024; Goyal et al., 2024; Chen, Wu, et al., 2023; Prabhudesai et al., 2023; Salimzadeh et al., 2023; Lai et al., 2023; Schemmer et al., 2022; Liu et al., 2021)
		HAI Collab. Decision Making	(Wang, Yuan, et al., 2024, Mentzas et al., 2021; Puranam, 2021; Cai et al., 2019)
		Effective HAI Decision Making	(Schemmer et al., 2023; Buçinca 2024)
		Collab. HAI Decision Making System	(Oksana et al., 2022; Dolgikh & Mulesa, 2021)
		HAI Collab. Decision Support System	(Smirnov, Ponomarev, et al., 2023)
		HAI Visual Decision Making	(Morrison et al., 2023)
		HAI Collab. (Clinical) Decision Making	(Lee & Chew, 2023)
		HAI Collab. (Clinical) Decision Support System	(Lee, Siewiorek, et al., 2022)
	Learning	HAI Co Learning	(Schoonderwoerd et al., 2022; van den Bosch et al., 2019)
		Hybrid HAI Regulation	(Molenaar, 2022a)
		Hybrid HAI Tutoring	(Thomas et al., 2024)

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Table B1. Continued.

Cluster	Subcluster	Term	Publications
		Hybrid HAI Curriculum Development	(Tavakoli et al., 2022)
		HAI Learning Performance	(Pandya et al., 2019)
		HAI Hybrid Teaching	(Karumbaiah et al., 2023)
		Hybrid HAI Learning Technologies	(Molenaar, 2022b)
		HAI (Sleep Coaching) Model	(Liu, Ito, et al., 2024)
	Control	HAI Control	(Yang et al., 2021; Echeverria et al., 2020)
		HAI Shared Control	(Li, Huang, et al., 2022)
		Joint HAI Control	(Lundberg et al., 2021)
		Collab. HAI Control	(Niehaus & Weyhrauch, 2011)
	Reading and Authoring	HAI Pair Programming	(Jiang, Ahmadon, et al., 2024; Ma, Wu, et al., 2023; Jiang, Bin Ahmadon, et al., 2023; Zhang, Wei, et al., 2022)
		HAI Collab. Writing	(Richburg et al., 2024; Knowles, 2022; Lee, Siewiorek, et al., 2022)
		HAI Music Composition	(Correia et al., 2024)
		HAI Collab. Music Composition	(Bian et al., 2023)
		Mixed HAI Authoring	(Chugh et al., 2019)
		HAI Collab. Authoring	(Choi et al., 2024)
		HAI Authoring Tool	(Liapis et al., 2023)
	Dialog Systems	HAI Simulator	(Armaselu, 2024)
		Knowledge-Aware HAI Dialogue	(Huang, Li, et al., 2024)
		Thoughtful HAI Conversation	(Varshini Devi et al., 2024)
		HAI Dialog	(Demidova, 2018)
		Domain-Specific HAI Conversation	(Biyani et al., 2024)
		HAI Hybrid Conv System	(Gao & Jiang, 2021)
		HAI Collab. Chatbot	(Zhang, Xu, et al., 2022)
		HAI Hybird Conv Assistant	(Cannanure et al., 2020)
	Data Proc. and Analysis	HAI Collab. Image Retrieval	(Ray et al., 2019)
		HAI Collab. Qualitative Coding	(Gebreegziabher, Zhang, et al., 2023)
		HAI Collab. Data Labeling	(Brachman et al., 2022)
		HAI Hybrid (Knowledge Graph) Annotation	(Lee, Chung, Kim, et al., 2022)
	Sense Making	Collab. HAI Sensemaking	(Dorton & Hall, 2021)
		HAI Interactive Continuous Sensemaking	(Shen et al., 2021)
	Collab. Design	HAI Design Collaboration	(Lee et al., 2025)
		HAI Collab. (Architectural) Concept Design	(Dai et al., 2023)
		HAI Collab. (Font) Design	(Zeng et al., 2022)
		HAI Collab. (In-Situ Fashion) Design	(Zhao & Ma, 2018)
	Exploration and Detection	HAI Collab. (Design Space) Exploration	(Viros-I-Martin & Selva, 2021; Khan et al., 2023)
		Shared HAI Recognition	(van Zoelen et al., 2023)
		Collab. HAI Disinformation Detection	(Schmitt et al., 2024)
		Hybrid HAI Misinformation Detection	(Zeng et al., 2024)
	Miscellaneous	HAI Co Dancing	(Pataranutaporn et al., 2024)
		Hybrid HAI Enabled Scientometrics	(Correia et al., 2020)
		Pathological HAI Collab. Diagnosis	(Zhang, He, et al., 2023)
		HAI Joint (Face Matching) Task	(Salehi et al., 2021)
		HAI Scoring System	(Liu et al., 2022)
		HAI Diagnosis System	(Gu, Yang, et al., 2023)
		HAI Collab. (Recidivism) Risk Assessment	(Chiang et al., 2023)
		HAI Collab. Gameplay	(Lobo et al., 2024)
Design	Design	HAI Interaction Design	(Hwang et al., 2024; Rezwana & Maher, 2022)
		HAI Interaction Paradigm	(Desolda et al., 2024; Franklin & Lagnado, 2022)
		HAI Workflow	(Shin et al., 2024; Fogliato et al., 2022)
		HAI Collaboration Protocols	(Cabitza et al., 2023; 2021)
		HAI Guidelines	(Yildirim et al., 2023)
		HAI Engineering	(Meyer-Vitali & Mulder, 2024)
		Integrated HAI Framework	(Marhraoui et al., 2022)
		HAI Framework	(Nazarenko & Camarinha-Matos, 2024)
		HAI Hybrid Framework	(Guimaraes et al., 2021)
		Conversational HAI Interaction Design	(Marri, 2023)
		HAI Collaboration Framework	(Muller & Weisz, 2022)
		HAI (Agent) System Design	(Duncan et al., 2023)
		HAI Protocols	(Ogiela et al., 2022)
		HAI Collaboration Workflow	(Casini et al., 2023)
		HAI (Quantum Experience) Design Paradigm	(Germanakos, 2024)
		Continuous Learning HAI Interface	(Daish et al., 2024)
		Hybrid HAI Workflow	(Liu et al., 2020)

Table B2. Key publications with citation counts within the 99th percentile, average citation counts per year are shown in brackets.

Publication	Authors	Year	Cites (Avg.)	Cluster	Keywords and Description
(Jarrahi 2018)	Jarrahi	2018	2,027 (290)	Connection	Artificial intelligence; Organizational decision making; Human-machine symbiosis; Human augmentation; Analytical and intuitive decision making This paper attempts to mitigate fears of human replacement and loss of employment with AI emergence in business contexts. It highlights the opportunity for enhancement rather than replacement of human capabilities due to the human-AI complementarity in complex decision making processes.
(Amershi et al., 2019)	Amershi et al.	2019	1,563 (261)	Working Together	Human-AI interaction; AI-infused systems; design guidelines A set of 18 evaluated guidelines for human-AI interaction is proposed to account for the rapid advances of AI systems and the adoption of human-AI systems, overgrowing the research in past decades. Guidelines are categorized by the time of occurrence ranging from before to during the interaction, error handling and over time adaptability.
(Yang et al., 2020)	Yang et al.	2020	527 (105)	Working Together	User experience, artificial intelligence, sketching, prototyping The design of human-AI interaction proves to be more challenging to HCI researchers and practitioners than regular prototyping and sketching of complex systems. This paper shifts away from focusing on the technical complexity of AI systems and rather identifies properties such as uncertainty and adaptability of AI systems as challenges in interaction design.
(Cai et al., 2019)	Cai et al.	2019	462 (77)	Applications	Human-AI interaction; machine learning; clinical health A qualitative lab study shows that explanations in human-AI collaboration are not enough for human medical experts. Comprehensive information about the general function, expectable capabilities and limitations helps in finding a compatible partner that can be relied on for collaborative decision making.
(Bansal et al., 2019a)	Bansal et al.	2019	456 (76)	Connection	no keywords Human-AI teams can exceed individual performance. To be able to utilize the complementary capabilities, however, it is essential that the two parties can estimate each other's capabilities and how to complement them. This study focuses on the impact of human mental models of AI systems in AI-advised decision making.
(Sundar 2020)	Sundar	2020	444 (89)	Working Together	Source Interactivity; Machine Heuristic; Artificial Intelligence (AI); Algorithms; User Experience; Human-AI Interaction (HAII); Theory of Interactive Media Effects (TIME) Research in computer-mediated communication (CMC) no longer focuses solely on supporting human communication but has shifted towards humans actually communicating with the technology itself, too. The different degrees of agency and interactivity shape the human-AI collaboration potential and the authors expect a conversion from HCI to HAII (Human-AI Interaction) research.
(Carroll et al., 2019)	Carroll et al.	2019	397 (66)	Working Together	no keywords In human-AI coordination there is a gap in agent's capability to adapt to agents or to human partners. To reach complementarity rather than individual peak performance, agents need to encounter humans during the training process, which is missing in the common training strategies.