

THE ALGORITHMIC LEADERSHIP PARADOX: BALANCING AUTONOMY AND ACCEPTANCE IN HUMAN-ROBOT TEAMS

RICARDO PEREIRA

UNIVERSIDADE FEDERAL DE SANTA CATARINA (UFSC)

KARLA CRISTINA ROCHA BOTÃO

UNIVERSIDADE FEDERAL DE SANTA CATARINA (UFSC)

MAURÍCIO FERNANDES PEREIRA

UNIVERSIDADE FEDERAL DE SANTA CATARINA (UFSC)

CRISTIANO JOSÉ CASTRO DE ALMEIDA CUNHA

UNIVERSIDADE FEDERAL DE SANTA CATARINA (UFSC)

Agradecimento à orgão de fomento:

This work was supported by the Foundation for Support to Research and Innovation of the State of Santa Catarina (FAPESC).

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1. INTRODUCTION

The increasing integration of autonomous robots into organizational settings has significantly transformed collaborative dynamics, challenging traditional leadership models. This context has led to the emergence of human-robot teams (HRTs), which comprise humans and robotic agents working interdependently in complex environments, demanding new forms of coordination, communication, and role allocation (Johnson et al., 2014; Lewis et al., 2018). As part of these transformations, the concept of algorithmic leadership has surfaced, characterized by the ability of AI systems and robots to coordinate tasks, make decisions, and influence the social dynamics of teams. Robotic autonomy extends these functions by enabling adaptive behaviors, such as role switching, formation control, and proactive task intervention (Few et al., 2006a; Mandischer et al., 2024).

However, the effects of algorithmic leadership remain poorly understood, particularly regarding psychosocial aspects such as acceptance, perceived empathy, and trust (You & Robert, 2018; Wolf & Stock-Homburg, 2021). Studies suggest that factors like technological familiarity and the leadership style adopted by robots directly impact team performance and cohesion (Luo et al., 2024; Scheggi et al., 2014).

Given this context, the main objective of this study is to map and characterize the field of algorithmic leadership in human-robot teams (HRTs), with a focus on the effects of robotic autonomy on leadership dynamics and effectiveness in organizational contexts.

To this end, the following specific objectives have been established: to identify the key concepts and theoretical approaches related to algorithmic leadership in HRTs; to classify the levels of robotic autonomy and their implications for task division and decision-making processes in hybrid teams; to analyze the empirical evidence on the impacts of robotic autonomy on team effectiveness in organizational settings; and to delineate research gaps concerning psychosocial aspects—such as acceptance, empathy, and trust—highlighting the need for further in-depth qualitative investigations.

This study is guided by the central hypothesis that robotic autonomy, when balanced with social adaptability, tends to enhance effectiveness and cohesion in hybrid teams, whereas extreme models—of either low or full autonomy—may lead to adverse effects on team acceptance and performance.

2. CONCEPTUAL FRAMEWORK

The digital transformation and advancements in artificial intelligence have spurred significant changes in organizational settings, particularly through the increasing adoption of autonomous robots in collaborative environments. This chapter outlines the key concepts that underpin this review, structured around three core themes: robotic autonomy, human-robot teams (HRTs), and algorithmic leadership and its robotic manifestation.

2.1 Robotic Autonomy and Social Robots

Robotic autonomy refers to the ability of an artificial agent to operate independently, with varying degrees of human intervention. It can range from programmed commands to complex behaviors based on machine learning, real-time adaptation, and advanced data processing (Wolf & Stock-Homburg, 2021). Within this spectrum are social robots, designed for socially competent interactions and responding to human emotional and behavioral cues.

The literature indicates that, in collaborative environments, social interaction facilitated by robots enhances human engagement, improves collaboration efficiency, and contributes to greater acceptance of the robotic presence (Lopes et al., 2021; Scheggi et al., 2024).

2.2 Human-Robot Teams (HRTs)

Human-robot teams (HRTs) comprise humans and robotic agents working interdependently to achieve common goals. Johnson et al. (2014) highlight that such teams require dynamic task coordination, mutual adaptation, and continuous communication.

Three primary leadership structures are identified in HRTs (Few et al., 2006a; Mioch et al., 2018):

- *Human-led team*: humans lead and supervise robots on specific tasks.
- *Shared-leadership team*: humans and robots share leadership and execution roles, adjusting according to their respective competencies.
- *Predominantly autonomous team*: robots operate with high autonomy, assuming decision-making roles with minimal supervision.

These configurations profoundly influence team performance, the level of human trust, and the perceived utility of the robots (Donner et al., 2017).

2.3 Algorithmic and Robotic Leadership

The concept of algorithmic leadership emerged to describe the role of artificial intelligence-based systems that not only distribute tasks but also perform monitoring, feedback, and social coordination functions within teams (Harms & Han, 2019). It represents the invisible logic that governs team dynamics, structuring role distribution based on factors such as performance, context, and "capability deltas"—the capacity gaps between humans and robots (Mandischer et al., 2024).

2.3.1 The Robotic Manifestation of Leadership

Robotic leadership corresponds to the physical manifestation of algorithmic leadership, wherein the robot visibly acts as a leader to the human team members. Robots can adopt classic leadership styles, such as:

- *Transformational*: promoting inspiration, motivation, and cohesion (Wolf & Stock-Homburg, 2021).
- *Transactional*: regulating performance based on rewards or punishments (Lopes et al., 2021).
- *Facilitative*: actively seeking to reduce cognitive load and foster adaptation (Few et al., 2006b).

The acceptance of the robot as a leader is directly related to how it communicates intentions, demonstrates perceived empathy, and adapts to the group's needs (You & Robert, 2018; Luo et al., 2024). In summary, although the literature shows advances in conceptual definition and prototype development for algorithmic leadership, the evidence is largely fragmented. There is a lack of integrative studies that combine technical and psychosocial perspectives, particularly in real-world organizational settings. This scenario highlights the need for a comprehensive mapping, the central objective of this study.

3. METHODOLOGY

This study maps the existing literature on algorithmic leadership in hybrid teams composed of humans and collaborative robots, with a focus on the role of robotic autonomy in leadership dynamics and team effectiveness. To achieve this, the study employs a scoping review methodology (Arksey & O’Malley, 2005; Levac et al., 2010; Peters et al., 2020). This methodological approach is designed to explore the key concepts of a topic, ascertain the extent, range, and nature of the research, summarize and disseminate the findings, and identify existing research gaps (Arksey & O’Malley, 2005). Furthermore, scoping reviews are useful for examining emerging evidence when the specific questions for a more focused synthesis are still unclear (Peters et al., 2020), often serving as precursors to systematic reviews. They are also employed to identify the types of available evidence in a given field, analyze knowledge gaps, and clarify key characteristics or factors related to a concept (Munn et al., 2018). In essence, scoping reviews are particularly appropriate when a topic or body of knowledge is new, emerging, or has not been extensively documented in the literature. This method is therefore highly suitable for the present study, which requires a broader examination of the definitions of algorithmic leadership and human-robot teams, as well as an assessment of their theoretical, practical, and societal implications.

The eligibility criteria for this study included exclusively peer-reviewed articles published in scientific journals and indexed conference proceedings. No time or language restrictions were applied, in order to capture the largest possible number of relevant studies. Empirical articles, literature reviews, and theoretical and experimental studies related to algorithmic leadership in human-robot teams were considered eligible. Duplicate publications were excluded, as detailed in Figure 1, along with non-scientific materials such as editorials, opinion pieces, essays, or book chapters, thereby ensuring a focus on established scholarly evidence.

This study was guided by the framework proposed by Arksey & O’Malley (2005) and further developed by Levac et al. (2010). The methodological steps followed are described in Table 1.

Table 1
Methodological procedures. Source: Adapted from Arksey & O’Malley (2005), Levac et al. (2010), Peters et al. (2020), and Pereira et al. (2023).

Scoping review Stages as proposed by Arksey and O’Malley (2005)	Definition (as per Arksey & O’Malley, 2005; Levac et al., 2010; Peters et al., 2020)	Steps implemented in this study
Stage 1: Identifying the research question and defining the study objective	This stage aims to align, clarify, and link the objective to the research question. In a scoping review, the research question must be clearly defined, as it plays a critical role in guiding the subsequent stages.	<p><i>Research question:</i> What are the available concepts, approaches, and evidence regarding the role of algorithmic leadership in human-robot teams within organizational settings?</p> <p><i>Objectives:</i></p> <ul style="list-style-type: none"> • To identify the key concepts and theoretical approaches related to algorithmic leadership in HRTs; • To classify the levels of robotic autonomy and their implications for task division and decision-making processes in hybrid teams; • To analyze the empirical evidence on the impacts of robotic autonomy on team effectiveness in organizational settings; • To delineate research gaps concerning psychosocial aspects.

Stage 2: Identifying relevant studies	This stage involves developing a comprehensive search plan, specifying the sources, search terms, time frame, and language parameters. The objective is to balance feasibility with the breadth and comprehensiveness of the scoping process. It is crucial to develop and align the inclusion criteria with the study's research question and objectives.	The search strategy for this study was defined using the following string in the Scopus and IEEE Xplore databases: (TITLE-ABS-KEY ("hybrid teams") OR TITLE-ABS-KEY ("human-robot teams") OR TITLE-ABS-KEY ("human and robot collaboration")) AND TITLE-ABS-KEY (leader*) No time or language restrictions were applied. The number of publications retrieved at this stage is detailed in Figure 1.
Stage 3: Study Selection	Study selection is not a linear process but an iterative one, involving searching the literature, refining the search strategy, and reviewing articles for inclusion. The planned approach for evidence searching, selection, data extraction, and evidence presentation should be described.	In this stage, the titles, abstracts, and keywords of the publications were screened. The selected studies were then organized and identified. The number of publications retained at this stage is detailed in Figure 1.
Stage 4: Charting the Data	A data charting form is developed to extract relevant information from each study. This process often involves a 'descriptive-analytical' approach to capture contextual and process-oriented data.	Following the final selection of articles, key data from each study were extracted and compiled into a synthesis matrix (Garrard, 2011).
Stage 5: Collating, Summarizing, and Reporting the Results	This final stage involves analyzing the findings to identify their implications for policy, practice, and research. An analytical framework, such as thematic analysis, is used to synthesize the data and provide an overview of the literature's breadth.	The selected articles were analyzed using the thematic analysis framework of Braun and Clarke (2006) and similarity visualization with VOSviewer software. This approach facilitated the identification, coding, and categorization of themes during the full-text review of the publications.

The selection process, summarized in Figure 1, yielded a final corpus of 24 publications for analysis and discussion.

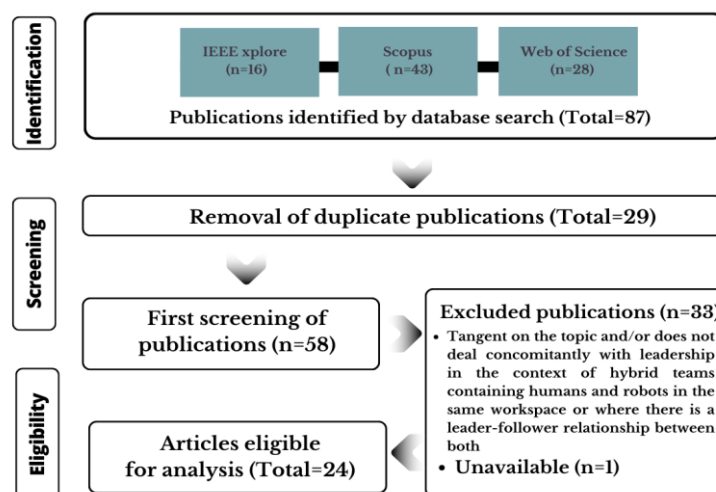


Figure 1
Flowchart of the study selection process. Source: Authors (2025).

4. ANALYSIS OF RESULTS

4.1 Field Mapping (Qualitative Analysis)

A keyword co-occurrence analysis was conducted, a technique that uses terms from the selected documents to identify conceptual relationships and structure the intellectual domain of a research field (Pereira, Rosa & Cunha, 2023). The underlying premise is that when words frequently appear together across different publications, the concepts they represent are indeed linked. This method analyzes the textual content of the documents to construct a similarity measure between terms, enabling the mapping of a conceptual space through the relationships among the addressed topics (Zupic & Cater, 2015). The final output of this analysis is a network of interconnected themes that reflects the conceptual structure of the field of study.

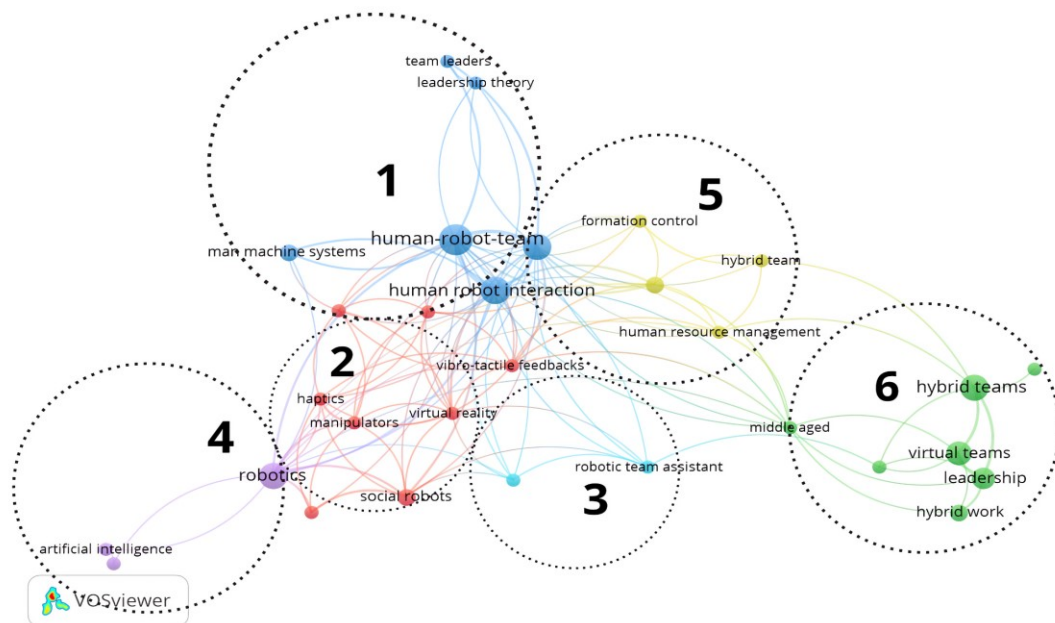


Figure 2

Keyword Co-occurrence Map. Source: Created by the authors using the VOSviewer tool (2025).

The analysis of the co-occurrence clusters (Figure 2) revealed the conceptual structure of the field, enabling the identification of core thematic areas. The interpretive process for defining these categories was as follows:

- Clusters 1 (blue) and 2 (red), which are densely connected and centered on terms such as human-robot interaction, haptics, social robots, and manipulators, represent the literature focused on the technical means and interfaces of collaboration. The emphasis here is on how the interaction occurs.
- Cluster 3 (turquoise), featuring the term robotic team assistant, and Cluster 4 (purple), with artificial intelligence, represent the enabling elements of leadership—that is, the foundational technologies that make it possible.
- Clusters 5 (yellow) and 6 (green), which group terms such as hybrid team, formation control, human resource management, and leadership, shift the focus toward organizational dynamics and interaction outcomes. Here, the focus moves from how to for what purpose and with what effect.

Based on this interpretation, the clusters were grouped and synthesized into four thematic categories that frame the subsequent discussion. Table 2 details these categories, their underpinning keywords, and the representative studies for each.

Table 2
Clusters, Themes, and Related Work. Source: Prepared by the authors (2025)

Cluster Number	Cluster Color	Thematic Category	Underpinning Keywords	Representative Studies
1	Blue	Leadership configurations and dynamics in HRTs	Human-robot interaction and Human-robot teams	(Philip & Wong, 2024; Wolf & Stock-Homburg, 2025; Wolf & Stock-Homburg, 2021; Wolf & Stock-Homburg, 2023; Li, et al., 2021; Lopes et al., 2021, Few et al., 2006a, 2006b)
2	Red	Interaction and collaboration mechanisms	robotics, social robots, haptics, virtual reality ; manipulators; vibro-tactile feedbacks	(Yazdani et al., 2016; Sheng et al., 2015; Scheggi et al., 2014; Sirintuna et al., 2024; Donner et al., 2017; Walker et al., 2024; Beetz et al., 2017; Mandischer et al., 2024; Wolf & Stock-Homburg, 2023)
3	Turquoise		robotic team assistant	
4	Purple		artificial intelligence	
5	Yellow	Human Factors and Psychosocial Impact	human resource management; hybrid team; formation control (forte relação com o nó human- robot interaction do Cluster azul	Genovese & Sabatini, 2006; Knopp et al., 2017; Alboul et al., 2008; Mioch et al., 2018
6	Green	Team Effectiveness and Performance Outcomes	hybrid teams; hybrid work; leadership	Parks & Allison, 2023; Luo et al., 2024; Few et al., 2006a, 2006b; Sicut et al., 2017

Overall, the findings indicate that while various definitions of algorithmic and robotic leadership exist, the field remains conceptually fragmented, characterized by diverse terminologies and the lack of a consolidated definition, as noted by Harms and Han (2019) and Wolf and Stock-Homburg (2023). Regarding leadership mechanisms enacted by robots, studies by Sheng, Thobbi, and Gu (2015) and Scheggi, Aggravi, and Prattichizzo (2014) highlight practices such as formation control, role switching, and situational leadership. However, these mechanisms are predominantly analyzed in simulated or experimental settings, with their practical application in real-world organizations remaining incipient.

A recent advance is also observed in the consideration of psychosocial factors, particularly in the acceptance of robotic leadership, perceived empathy, and technological familiarity, as evidenced by the work of You and Robert (2018), Latikka, Turja, and Oksanen (2021), and Wolf and Stock-Homburg (2021), although this research is often restricted to short-term scenarios. Analysis of hybrid team effectiveness reveals significant contributions, such as the reduction of errors and cognitive load in collaborative tasks (Few et al., 2006b; Parks & Allison, 2023), but this area is still limited by a scarcity of investigations that integrate technical performance with human factors in dynamic organizational contexts.

Finally, the analysis of clusters and temporal trends reveals a clear gap in longitudinal studies and in approaches that simultaneously articulate robotic autonomy, leadership, and psychosocial factors in productive environments, indicating a promising avenue for future research.

5. DISCUSSION

Algorithmic leadership emerges as a theoretical frontier at the intersection of management, engineering, and organizational psychology. This review reveals a fragmented field undergoing consolidation, where technical approaches (focused on automation and control) coexist with psychosocial perspectives (centered on acceptance and trust). The most significant gap is the paucity of longitudinal studies in real-world organizational settings, as well as the lack of unifying theories.

5.1 Leadership Configurations and Dynamics in HRTs

The literature on human-robot teams (HRTs) indicates that leadership transcends the mere delegation of tasks to a robotic agent. Instead of static configurations, studies reveal a continuous spectrum of authority where the central challenge is not defining who leads, but rather how authority is dynamically distributed, transferred, and negotiated to maximize team effectiveness (Wolf & Stock-Homburg, 2023).

At one end of this spectrum lies the human-directive leadership model, where the robot functions as a subordinate, executing commands under supervision. Although this configuration provides role clarity, it underutilizes the potential of robotic autonomy and fails to capitalize on the robot's capacity to independently optimize processes.

At the center of the spectrum, mixed and situational leadership configurations emerge. Here, leadership ceases to be a fixed role and becomes a function that can be assumed by the most capable agent for a given subtask. The research by Li et al. (2021) formalizes this dynamic by modeling latent leader-follower structures, demonstrating that robots can not only follow humans but also proactively influence the team's structure to achieve a goal. This capacity for role switching is fundamental. Similarly, the work of Nizette & Yu (2011), which categorizes classic leadership styles—directive, transactional, transformational, and empowerment—in specific HRT scenarios, particularly in autonomous exploration and navigation tasks, empirically shows that the suitability of a leadership style depends on time criticality, task knowledge, and the need for collaboration, providing a practical framework for the dynamic allocation of authority.

However, its acceptance remains a significant hurdle. Wolf & Stock-Homburg (2021, 2025) demonstrate that the willingness to accept a robot as a leader is highly contextual. While perceived utility (task performance) is readily accepted and even expected, the acceptance of relational characteristics (e.g., attitude, empathy) is fragile. Any deviation from expectations in the relational domain can lead to a sharp rejection of robotic leadership.

At the most advanced end of the spectrum, we find the concept of paradoxical and dynamic leadership, which represents the most mature form of HRT collaboration. The work of Philip & Wong (2024) argues that effective human leaders in HRTs must adopt paradoxical behaviors—for instance, simultaneously empowering human autonomy (job crafting) and imposing the structure required for robot collaboration. This connects directly to the idea of facilitative leadership by Few et al. (2006a). In their study, leadership is not "mixed" in the sense of a simple role swap, but "facilitated": the system arbitrates authority, restricting human initiative when the robot is better positioned to act (e.g., in navigation) and vice versa. This dynamic arbitration reduces cognitive load and errors, enhancing the human operator's sense of control, even if their authority is momentarily suppressed.

Lopes et al. (2021) provide empirical evidence for the viability of robots adopting classic leadership styles (transactional vs. transformational), showing that both can yield positive organizational outcomes, albeit in different dimensions (productivity vs. engagement). This reinforces that "robotic leadership" is not a monolithic concept but a set of programmable behaviors that can be adapted to the team's context and objectives.

The literature, at this point, converges on a view of leadership in HRTs as a process of continuous negotiation of control, not as a fixed hierarchical structure. Effectiveness lies not in defining whether the robot is the leader or the follower, but in designing systems and training humans for a fluid transition of authority across the spectrum, such that this transfer is perceived as legitimate, predictable, and beneficial to the mission.

5.2 Interaction and Collaboration Mechanisms

Effective collaboration in hybrid teams hinges on the quality of their interaction mechanisms. The literature reveals a clear transition from command-and-control interfaces to sophisticated systems whose primary function is to manage information flow and cognitive load, thereby ensuring shared situational awareness. These mechanisms constitute the infrastructure that enables the leadership dynamics discussed in the previous section, translating system state and intent into intuitive human perceptions.

Initially, interaction was conceptualized as a language translation problem. The work of Yazdani et al. (2016) exemplifies this approach, focusing on how robots can interpret vague natural language commands (e.g., "go over there") within a specific mission context (rescue). The system leverages reasoning about the robot's capabilities and the environment to resolve ambiguity, demonstrating the need for a computational "theory of mind" wherein the robot infers human intent.

However, exclusive reliance on verbal or visual communication can overload an operator's cognitive channels. In response, research has explored low-overhead communication channels, most notably haptic feedback. The study by Scheggi et al. (2014) is seminal in this area, using a vibrotactile wristband to guide a human leader by alerting them when their chosen path becomes unfeasible for the robot followers. This approach transforms communication from an explicit information exchange to an implicit, proprioceptive perception, correcting the human's behavior without demanding their visual or auditory attention. Sirintuna et al. (2024) expand on this idea for collaborative transport tasks, using a haptic belt to warn an operator of obstacles outside their field of view, thereby preventing collisions and enhancing team safety.

The natural evolution of these mechanisms is multimodality, which combines different channels to optimize interaction. The work of Donner et al. (2017) on the cooperative manipulation of flexible objects illustrates this: interaction is mediated by physical force (haptic feedback) and shared rhythm (kinesthetic feedback). The robot does not receive an explicit command but instead mimics the human's energy flow to contribute to the task, demonstrating a highly coupled and implicit form of collaboration.

Finally, the current frontier lies in mixed-reality interfaces that aim for the full integration of operator and robot perception. Walker et al. (2024) propose a "Cyber-Physical Control Room," an immersive interface that provides a remote operator with both egocentric (through the robot's "eyes") and exocentric (a 3D overview of the entire environment) perspectives simultaneously. This interface not only improves teleoperation effectiveness but, crucially, enhances teamwork aspects such as social engagement and the perceived leadership qualities of the human partner. The ability to "make eye contact" via the robot's camera, for instance, has been shown to increase engagement between the remote operator and the on-site team member.

In summary, interaction mechanisms have evolved from tools for giving orders to systems for building mutual understanding. The literature reveals a clear progression: from natural language interpretation to the use of alternative sensory channels (haptic) and, ultimately, to the creation of shared virtual realities. The success of an interaction mechanism in HRTs is no longer measured solely by the fidelity of command transmission, but by its capacity to fuse the perceptions of the human and the robot, enabling fluid collaboration and truly dynamic leadership.

5.3 Human Factors and Psychosocial Impact

The "Human Factors and Psychosocial Impact" thematic cluster delves into the collaborative dynamics of hybrid teams, focusing on the mechanisms that foster trust, safety, and interaction effectiveness. Although technically centered on aspects like formation control, the literature within this cluster highlights a central concern with managing the relationship between the human operator and the robotic agents. The analyzed studies demonstrate that the effectiveness of algorithmic leadership depends not only on the robot's technical capabilities but, more critically, on its ability to adapt to human needs and preferences.

A key mechanism for mediating this relationship is the use of "Work Agreements," which are explicit protocols that govern task allocation and coordination in dynamic contexts, such as search and rescue operations (Mioch et al., 2018). The primary psychosocial function of these agreements is to enhance the human operator's trust in the robotic system by making the robot's behavior more predictable. However, research indicates that the implementation of these agreements must be carefully calibrated; an excessive number of notifications, for instance, can lead to information overload, causing operators to ignore them and thus nullifying their benefit. Furthermore, preferences for such agreements are individual, which underscores the need for adaptive systems that can be customized by team leaders. Team experience, shared knowledge, and mutual trust also influence the design and effectiveness of these agreements.

Concurrently, formation control transcends mere navigation to become a strategy for human support and protection (Alboul et al., 2008). In this model, robots form a "coalition" that moves as a single unit around the human, such as a firefighter, who assumes the role of leader. The robotic team, while a follower in the overall mission, takes the lead in the task of safe navigation, avoiding obstacles and preventing the human from colliding with them. The success of such formations is enabled by technologies like reinforcement learning, which allows autonomous robots to control their group behavior in leader-follower scenarios (Knopp et al., 2017). Other technical aids, such as the "differential compassing" proposed by Genovese & Sabatini (2006), directly contribute to enhancing the human operator's situational awareness in indoor environments, which is crucial for the team's navigational effectiveness.

The interplay between these two concepts—explicit agreements and protective formations—converges at the core of human-robot interaction. Work agreements govern the explicit rules of collaboration, while formation behavior offers implicit and continuous support. Both mechanisms aim to reduce the operator's cognitive load and strengthen trust in the team. Effective teamwork is not merely about a momentary allocation of tasks but involves developing trust, cohesion, and the ability to dynamically switch roles over time (Mioch et al., 2018). Therefore, human factors and psychosocial impact are critical dimensions that determine whether algorithmic leadership will be perceived as a valuable support or an unwelcome complication, directly influencing the acceptance and performance of the hybrid team.

In light of this evidence, it becomes clear that the success of algorithmic leadership in human-robot teams depends not exclusively on the systems' technical sophistication but on their capacity to sensitively incorporate human needs and perceptions. Beyond operational

efficiency, the design of algorithmic leadership systems must consider fundamental psychosocial variables such as predictability, decision-making transparency, perceived empathy, and alignment with the users' level of technological familiarity.

Furthermore, recent studies indicate that the acceptance of robotic leadership can vary significantly based on cultural differences and individual characteristics, such as age, prior technological experience, and professional background—aspects that remain underexplored in the literature (Latikka et al., 2021; Wolf & Stock-Homburg, 2021). Thus, the development of effective algorithmic solutions necessarily involves adopting approaches that are customizable, culturally sensitive, and adaptive to the diverse profiles of hybrid team members.

5.4 Team Effectiveness and Performance Outcomes

The analysis of effectiveness and performance in human-robot teams (HRTs) reveals a complex interplay of factors that extends beyond mere productivity metrics. The success of these teams is shaped by the synergy between leadership style, the robot's social acceptance, the system's ability to adapt to human states, and the nature of the task being performed. In this context, algorithmic leadership is an expanding field of study, though it faces significant challenges to its practical and sustainable implementation in organizational settings.

The literature demonstrates that leadership structure and execution directly impact team outcomes. Passive and avoidant leadership styles, such as *laissez-faire*, for example, do not enhance the benefits of automation but instead exacerbate problems like role ambiguity and repetitive work overload. Such an approach hinders an employee's ability to exercise empathic creativity, a crucial competitive advantage in hybrid service environments. In contrast, facilitative leadership, which promotes a fluid arbitration of leadership between humans and robots through collaborative tools like the Collaborative Tasking Module (CTM), has shown promising results, including error reduction, an enhanced sense of user control, and improved performance, even on simultaneous tasks (Few et al., 2006a, 2006b). This reinforces that the strategic sharing of leadership is more effective than simple human supervision.

However, the effectiveness of a robot leader is intrinsically linked to its social acceptance. As observed by Sicat et al. (2017), the perception that a robot is transgressing its expected role as a follower can be interpreted as a malfunction, leading to a breakdown in collaboration. A robot that assumes an authoritarian role without the consent or understanding of the human team can be perceived as a threat, undermining the group's viability and performance. Therefore, overcoming pre-existing biases about robot roles is fundamental to the effectiveness of robotic leadership.

The long-term dynamics of the team also depend on the ability to sustain performance in demanding scenarios, where factors such as human fatigue are a major concern. The research by Parks & Allison (2023) highlights that fatigue impairs the cognitive abilities and situational awareness of human operators. Adaptive autonomy—the ability to adjust the robot's autonomy levels based on the human's physical and cognitive state—emerges as an effective countermeasure, reducing the operator's cognitive load and mitigating errors.

Additionally, the effectiveness of algorithmic leadership is moderated by task type. In routine and operational activities, autonomous systems as leaders tend to increase efficiency. However, in tasks that are creative, strategic, or require contextual judgment, robotic leadership may result in lower human engagement and a perception of inadequacy. The degree of robotic autonomy is also decisive: appropriate and dynamically adjusted levels foster effectiveness, whereas excessive or inflexible autonomy can compromise cooperation, especially in complex contexts.

Thus, the effectiveness of robotic leadership is contingent upon overcoming pre-

existing biases and carefully managing human perception. The challenge is not to maximize autonomy, but to optimize the dynamic balance between technical capability and social adaptability.

In summary, while there have been significant technical advances in robotic leadership, such as the use of haptic feedback and dynamic role switching (Scheggi et al., 2014), the literature remains limited with respect to its application in real-world organizational settings. The predominance of experimental approaches points to a methodological gap, with a scarcity of longitudinal investigations that assess the impact of algorithmic leadership over time and its influence on broader organizational outcomes, such as well-being, satisfaction, and sustainable performance (You & Robert, 2018; Wolf & Stock-Homburg, 2021). Future studies should, therefore, integrate the technical, psychosocial, and contextual dimensions to advance our understanding of how robotic autonomy can be leveraged not only to increase efficiency but also to foster improved working conditions in hybrid teams.

5.5 Contributions, Practical Implications and Future Directions

Theoretical contributions: this study puts forward a key theoretical contribution by reframing the central problem of leadership in human-robot teams (HRTs). We argue that the debate should shift from the arguably simplistic question of whether robots can be leaders to the more nuanced and productive inquiry: how are authority and control negotiated in hybrid teams? Our analysis of the literature reveals that, despite its fragmentation, a consistent pattern emerges: authority in these teams does not manifest in fixed roles but rather along a dynamic spectrum. Based on this finding, this review seeks to formalize this very spectrum, positioning it as the conceptual axis for a new theory of HRTs. From this perspective, leadership is no longer understood as a static attribute of an agent—be it human or robot—but is instead viewed as a fundamentally emergent and negotiated process.

Practical contributions: the findings of this review indicate that, in organizational settings, the adoption of robotic leadership should prioritize dynamic models of authority distribution, balancing technical performance with human acceptance. Designing these systems is not a matter of simply delegating control. It is, rather, a matter of mediating a negotiation. This challenges the designer to move beyond the programming of static leadership styles. The solution lies in creating interaction mechanisms—such as haptic feedback or mixed-reality interfaces—that render the robot's deliberation transparent. The expected outcome is that the machine's assumption of control becomes not only predictable but, above all, justifiable to its human partner. This same paradigm shift reverberates into the managerial sphere. Here, the challenge transcends task optimization; the focus shifts to managing the psychosocial contract that binds the team. The implementation of explicit Work Agreements (Mioch et al., 2018) thus becomes a concrete tool for renegotiating expectations. However, such agreements are insufficient on their own. It is imperative that they are accompanied by active psychosocial support, including channels for empathic feedback and targeted training to prepare individuals for the new power configuration. Ultimately, the legitimacy of and trust in the robot leader are not givens but are actively constructed, without which the desired technical efficiency becomes unattainable.

Limitations and future directions: despite clear advances, the field lacks longitudinal investigations in real-world organizational contexts, being largely based on short-term experiments. Future studies should explore the proposed "negotiated adaptive leadership" model, integrating mediators such as dynamic trust and the perceived legitimacy of algorithmic authority. The literature also points to significant gaps related to cultural differences and individual profiles, calling for customizable approaches in HRT design.

A central challenge pervading this field, and one naturally reflected in the scope of this review, is the notable scarcity of longitudinal studies conducted in authentic organizational contexts. Current knowledge, while valuable, is predominantly derived from short-term experiments, leaving critical questions about the long-term dynamics of hybrid teams unanswered. For the field to advance robustly, a more contextualized research agenda is essential. We outline three priority areas for investigation below:

First, the operationalization and empirical validation of the Negotiated Adaptive Leadership model proposed herein is imperative. Future investigations will need to elucidate how key mediators—such as dynamic trust, perceived legitimacy, and cultural specificities—moderate the delicate autonomy-acceptance paradox across a variety of real-world tasks and scenarios.

Second, the execution of longitudinal field studies to map the evolution of the psychological contract in these teams is equally imperative. It is necessary to track the trajectory of trust, acceptance, and performance over time to answer critical questions. How, for example, does the perception of robotic leadership transition from a novelty phase to one of consolidated routine? And how must Work Agreements be dynamically renegotiated as the team develops maturity and synergy?

Third, a final pillar for this agenda is the development of integrated metrics. Effectiveness in human-robot teams is a multifaceted construct that cannot be adequately measured by productivity KPIs alone. Research, therefore, requires instruments that simultaneously capture both the technical performance and the psychosocial health of the team, encompassing indicators of cohesion, mutual trust, and employee well-being.

6. FINAL CONSIDERATIONS

This scoping review has mapped and characterized the emerging field of algorithmic leadership in human-robot teams (HRTs), focusing on the effects of robotic autonomy on leadership dynamics and effectiveness in organizational settings. The analysis revealed a significant evolution of the topic in recent years, shifting from a technical-operational focus to a growing concern for the psychosocial dynamics involved in robot-enacted leadership.

The results showed that, despite technological advances in coordination algorithms, formation control, and programmable leadership styles, the literature remains fragmented regarding the integration of technical performance and human factors. The acceptance of robotic leadership, the building of trust, perceived empathy, and the dynamic negotiation of authority emerge as critical dimensions that remain underexplored, particularly in real-world organizational settings.

The analysis also highlighted a scarcity of longitudinal studies capable of assessing the evolution of algorithmic leadership acceptance over time, as well as its impact on the well-being, cohesion, and sustained effectiveness of teams. This theoretical and methodological void compromises a deeper understanding of the benefits and limitations of robotic leadership in day-to-day corporate life.

In light of this evidence, we conclude that the primary gap in the field lies not merely in the development of technical models for algorithmic leadership, but in the absence of integrative models capable of articulating the dynamics of robotic autonomy with fundamental psychosocial variables. We advocate for advancing toward a model of "negotiated adaptive leadership," wherein levels of autonomy and control are continuously adjusted based on explicit rules, the team's psychosocial states, and the progressive building of trust.

For scientific advancement, we recommend three primary directions for future research: 1) the development and empirical validation of integrated models that combine metrics of technical effectiveness with psychosocial indicators of trust, acceptance, and well-

being; 2) the execution of longitudinal studies in real-world organizational contexts to understand the sustained effects of algorithmic leadership on work teams; and 3) the adoption of customizable approaches that consider cultural differences, individual profiles, and task context, thereby ensuring greater adherence to and acceptance of robotic leadership in diverse productive environments.

Finally, this study reinforces that algorithmic leadership can be a strategic asset for creating more efficient, collaborative, and humanized organizational environments. However, to fulfill this potential, it is imperative to move beyond a mechanistic view of robotic leadership and to adopt a perspective centered on human and organizational dynamics, where technology acts as an intelligent facilitator of cooperation, not as a mechanical substitute for human leadership.

STATEMENT ON THE USE OF GENERATIVE AI IN RESEARCH

During the preparation of this work, the author (s) utilized the tools and services SciSpace and NotebookLM to support data extraction and the evaluation of selected articles. Rayyan was used to help with organising, blind screening and detecting conflicts between reviewers. Additionally, the Gemini tool was used to assist in the translation of the manuscript. After using these resources, the author (s) thoroughly reviewed and edited the content as necessary and assume full responsibility for the accuracy and integrity of the publication.

ACKNOWLEDGMENTS

This work was supported by the Foundation for Support to Research and Innovation of the State of Santa Catarina (FAPESC).

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