Extending Process Virtualization Theory for Digital Collaboration:

Social Presence, Situation Awareness, and Leadership in Virtual and AI-Augmented Teams

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Abstract—**Virtual collaboration has become a central mode of organizing knowledge work, yet sustaining social and informational dynamics in digitally mediated teams remains a persistent challenge. Building on an earlier conference publication presented at the DIGITAL 2025 Conference on Advances on Societal Digital Transformation, this article extends a systematic literature review on digital collaboration tools by broadening its theoretical foundation, integrating leadership as a contextual factor, and incorporating a complementary exploratory review on artificial intelligence (AI) in virtual collaboration. Anchored in Process Virtualization Theory, and enriched by insights from Media Richness Theory, Media Synchronicity Theory, and Social Exchange Theory, the study examines how digital collaboration tools contribute to social presence and situation awareness in virtual teams. Using qualitative content analysis, the review synthesizes findings from peer-reviewed literature to identify recurring patterns in how collaboration technologies support interpersonal connection, shared understanding, and trust in remote work settings. The results show that social presence is primarily fostered through media-rich and synchronous interaction formats, informal communication opportunities, and practices that strengthen belonging, while situation awareness is supported by persistent information structures, transparent communication routines, and ongoing knowledge exchange. Trust emerges as a cross-cutting condition that links these dimensions and mediates the effectiveness of digital collaboration. Leadership practices play a pivotal role in shaping how technological affordances are used, influencing whether tools enhance cohesion and awareness or contribute to overload and control perceptions. The complementary AI-focused review highlights an emerging ambivalence: while AI-enabled functionalities may enhance efficiency, transparency, and coordination, they also pose risks to trust and social presence when algorithmic processes become opaque or intrusive. By synthesizing these insights, the article advances a socio-technical and socio-algorithmic extension of Process Virtualization Theory and offers implications for research, leadership practice, and the design and governance of digital collaboration tools.**

Keywords—digital transformation; virtual collaboration; process virtualization theory; collaboration tools.

I. INTRODUCTION

This paper builds upon an earlier study presented at the DIGITAL 2025 Conference on Advances on Societal Digital Transformation [1], in which a systematic literature review examined how digital collaboration tools enhance social presence and situation awareness in virtual collaboration. The present article extends this analysis by broadening the theoretical foundation through the inclusion of Media Richness Theory (MRT), Media Synchronicity Theory (MST), and Social Exchange Theory (SET), thereby allowing for a more differentiated understanding of collaboration processes in virtual settings. In addition, leadership is being analyzed as a critical moderating component in this context. Furthermore, a complementary literature review is conducted to explicitly examine the role of AI in digital tools used for virtual collaboration. This additional review systematically synthesizes findings from the broader body of academic research on AI-enabled functionalities, such as automated facilitation, adaptive feedback mechanisms, and intelligent support, to evaluate how the integration of AI shapes interaction quality, efficiency, and relational dynamics within virtual teams.

Virtual collaboration has become an integral part of organizational operations, driven by advancements in digital collaboration technologies and further accelerated by the COVID-19 pandemic. Virtual collaboration is commonly used as an umbrella term for digitally mediated work practices, although it often encompasses analytically distinct processes of coordination, communication, and collaboration. In a narrower sense, collaboration refers to the joint production of outcomes based on shared goals, while coordination concerns the alignment of interdependent activities and communication the exchange and interpretation of information [2].

Virtual teams have evolved from a niche practice to a widespread organizational norm [3]. The transition from traditional office environments to remote and hybrid models has necessitated the virtualization of work processes, as defined by the Process Virtualization Theory (PVT) [4]. PVT assesses how physical processes translate to virtual settings.

The pandemic-induced shift to remote work challenged existing assumptions about the limitations of virtual processes, demonstrating that even knowledge work processes with high relational demands could be effectively virtualized [5]. This evolution from a temporary adjustment

to a new post-pandemic digital era has opened opportunities to re-evaluate how digital tools can support not only operational efficiency but also the social and relational aspects of teamwork. Central to this discussion are the Information Technology (IT) characteristics of social presence and situation awareness, which contribute to creating a sense of interpersonal connection and maintaining contextual understanding within remote teams.

Through an extended systematic literature review, this paper advances current understanding of how digital collaboration tools shape social presence and situation awareness in virtual teams and how these effects are influenced by leadership practices and emerging technological capabilities. Building on insights from MRT, MST, and SET, the analysis integrates complementary theoretical lenses to explain not only how communication technologies enable interaction, but also why certain configurations foster trust, cohesion, and effective coordination in remote work settings. Furthermore, by incorporating an additional review of AI-augmented collaboration tools, the article examines how intelligent functionalities increasingly mediate virtual teams and influence social presence and situation awareness. In doing so, this research contributes to digital transformation scholarship by offering a more nuanced, socio-technical perspective on virtual collaboration that accounts for leadership, theory-driven interpretation, and the growing role of AI in shaping contemporary remote work practices.

Following this introduction, Section II establishes the theoretical foundation of the study by outlining PVT and synthesizing prior research on social presence and situation awareness, complemented by additional perspectives from MRT, MST, and SET. Section III details the methodological approach, including the systematic review protocol, data analysis procedures, and the extension of the original review conducted for the earlier conference publication, as well as limitations. Section IV presents the findings of the qualitative content analysis, structured around social presence, situation awareness, trust, and leadership as key analytical categories. To further contextualize these findings, Section V illustrates concrete examples of collaboration tool use drawn from the reviewed literature. Section VI reports the results of the complementary exploratory review on AI-enabled collaboration tools and discusses their opportunities and limitations within virtual teamwork. Section VII synthesizes the conceptual contributions and implications of the study, extending PVT and outlining practical and research-related implications. Finally, Section VIII concludes the article by summarizing the extended perspective and situating the findings within the broader discourse on digital and AI-mediated collaboration.

II. Theoretical Foundation of Virtual Collaboration

The increasing prevalence of remote and hybrid work models has fundamentally reshaped contemporary office settings, leading to a growing reliance on virtual modes of collaboration [3]. This shift is particularly pronounced in the domain of knowledge work, which is characterized by activities centered on the creation, dissemination, and application of knowledge rather than on manual or physical labor. Within this context, virtual teams have become an important and widely established organizational form. They are commonly understood as groups of individuals working toward a shared objective while being geographically dispersed and depending primarily on digital technologies to structure their collaboration and bridge spatial, temporal, and organizational divides [6]. The COVID-19 pandemic, coupled with mandatory remote work policies, further accelerated the adoption of both remote and hybrid team structures [7]. As a result, most organizations today exhibit some degree of virtuality, which increasingly blurs the boundaries between virtual and non-virtual teams and highlights the need for frameworks capable of explaining this transformation [8]. In this regard, PVT offers a valuable perspective by providing a conceptual approach to assessing, which organizational processes can be effectively transferred to virtual environments [4]. The next section will explore this theory in more detail. It will outline the theory's core concepts, review its empirical applications, and discuss its current extensions. Building on this foundation, the subsequent section introduces additional theoretical lenses. MRT, MST, and SET refine the analysis of technology-mediated collaboration and illuminate complementary mechanisms that PVT alone does not fully capture.

A. Process Virtualization Theory

The virtualization of work processes is a fundamental prerequisite for enabling remote collaboration. PVT provides a theoretical framework for analyzing the digital transformation of business processes by examining the extent to which physical processes can be effectively replicated in virtual environments [4]. At the core of PVT lies the concept of process virtualizability, which determines how well a process can be executed without reliance on physical interactions between individuals or individuals and objects. Process virtualizability is specified as the dependent construct and is commonly operationalized either by the quality of outcomes produced by the virtualized process or by indicators of its actual usage. This concept plays a crucial role in guiding organizations through digital transformation by identifying, which processes are most suited for virtualization [9]. Four constructs determine whether a process can be effectively virtualized: *sensory*, *relationship*, *synchronization*, as well as *identification and control requirements* [4], [9]. These factors negatively affect virtualizability, meaning that as their importance increases, the feasibility of virtualization decreases [4].

Sensory requirements denote the extent to which a process demands the reproduction of rich, embodied experience for its participants, encompassing not only the classic modalities of sight, sound, touch, taste, and smell, but also the felt, affective qualities that accompany participation, such as excitement or vulnerability [4]. When successful execution requires direct sensory access to other people or to physical artifacts, the process becomes dependent on a material context that current virtual environments typically cannot fully replicate. Because virtualization removes or

weakens these forms of physical co-presence and object interaction, high sensory requirements systematically constrain the feasibility of migrating such processes into virtual settings.

Relationship requirements refer to the extent to which a process relies on sustained interpersonal engagement in social or professional contexts, through which participants exchange knowledge, build trust, and sometimes form friendships [4]. Conceptually, these requirements are closely aligned with sensory requirements, as both concern facets of embodied, interpersonal experience, that are difficult to reproduce in digital settings [10]. Empirical work shows that meaningful relationships can develop via virtual media when participants have sufficient time to interact and gain familiarity with the tools [4]. However, high relationship requirements typically necessitate compensatory arrangements, such as occasional in-person encounters, structured opportunities for rapport-building, or the deliberate cultivation of a shared identity, which raise the effort needed to virtualize the process and increase resistance to virtualization.

Synchronization requirements capture the extent to which a process depends on tightly coordinated timing, whether in real time or in carefully ordered sequences, so that individual activities must occur with minimal delay [4]. Physical settings typically satisfy these requirements by default, since co-located participants can interact with one another and with relevant artifacts almost instantaneously, provided the number of actors and objects remains manageable. By contrast, virtual environments do not inherently guarantee low-latency coordination. Achieving near–real-time interaction often entails additional technological and organizational effort. Notably, asynchronous arrangements can also be advantageous, enabling participants to contribute at personally convenient times and to engage in more deliberate, reflective responses. Overall, while synchrony tends to be "built in" to collocated processes, it must be actively engineered in virtual ones, making high synchronization requirements a potential obstacle to virtualization.

Identification and control requirements describe the extent to which a process depends on reliably establishing the unique identity of participants and on exercising effective oversight or influence over their behavior [4]. Such requirements are generally associated with lower process virtualizability, because virtual settings heighten risks of identity fraud and reduce the transparency needed to attribute actions and enforce norms. When the actors cannot be physically verified and their conduct is less observable, detecting who performs which activity and shaping their behavior becomes more difficult, thereby increasing the effort required to virtualize the process. At the same time, anonymity can be beneficial in processes that do not depend on knowing the identity of others. For instance, anonymous group brainstorming may stimulate creativity and reduce excessive reluctance to speak up in front of high-ranking participants.

Process virtualization can be achieved with or without digital technologies [4]. Any arrangement that enables execution without immediate physical co-presence, whether technological or not, constitutes virtualization. Books are historical examples that demonstrate virtualization predates contemporary computing by enabling information exchange without face-to-face interaction. What distinguishes the present era is the dramatic expansion of virtual processes driven by increasingly capable and widely accessible IT, particularly the internet. To clarify how technology shapes this development, the core PVT model specifies three IT characteristics, that positively moderate the relationship between the theory's main constructs and process virtualizability: representation, reach, and monitoring capability.

Representation refers to IT's ability to present process-relevant information in a way that makes actors, objects, their properties, and their interactions understandable to those involved [4]. IT enables multimodal portrayals through audio and video and, increasingly, through haptic and olfactory interfaces, which help to meet higher sensory requirements. Sight and sound are well established, but smell and touch remain more challenging. However, they continue to advance. Non-IT media also provide representational functions. For example, a physical team Kanban board depicts tasks, status, and interdependencies for co-located collaborators. What differentiates IT-based representation is its dynamism: digital renderings can be updated in real time as conditions change, whereas non-IT representations are typically static. In addition, IT-enabled profiling and matching can support relationship-intensive processes by aligning participants not only on complementary interests but also on similar competencies or overlapping functional domains in organizational settings.

Reach refers to IT's capacity to decouple process participation from shared time and place, enabling engagement across both temporal and geographic boundaries [4]. Temporally, reach allows team processes to continue outside of conventional working hours. For example, distributed development teams use issue trackers, code repositories, and document comment threads to progress work, so that one site can hand off at the end of the day and another can pick up later. Spatially, reach lets dispersed colleagues participate in the same workflow by co-authoring in real time, conducting virtual stand-ups, or pairing remotely on code and models via shared sessions. By connecting individuals who might not otherwise interact and helping them discover peers with related competencies or overlapping domains through enterprise profiles and communities of practice, reach makes high relationship requirements easier to satisfy. It also meets the demand for highly synchronized collaboration by enabling live, two-way collaboration in incident "war rooms," shared whiteboards, and remote pair-programming environments where participants can respond and seek clarification in real time. In tandem with representation, which provides richer interaction contexts, reach helps teams find one another and sustain timely, effective engagement, thereby strengthening process virtualizability.

Monitoring capability refers to an IT system's ability to authenticate participants and record, attribute, and analyze

their actions. This eases processes with strict identification and control requirements [4]. In IT-mediated settings, users typically authenticate via credentials or comparable methods, enabling systematic, fine-grained, and automated tracking of participation and behavior. Although risks such as identity spoofing persist, advances in identification technologies, for example biometrics, help to mitigate these vulnerabilities. In some cases, the oversight resulting from this can exceed what is feasible in face-to-face contexts, providing a greater capacity for identification and control in practice. Non-IT arrangements also support monitoring, for example, punch clocks and timecards provide basic attendance records, but the automated and analytic affordances of IT offer a qualitatively different level of observability.

B. Extensions to PVT

PVT has been applied and extended across a growing range of contexts, underscoring both its explanatory reach and its boundary conditions. In higher education, researchers show that virtualization requirements embedded in the learning process shape undergraduates' satisfaction and their continuance intentions in online settings [11]. In consumer finance, research on online banking shows that the core PVT requirements serve as prerequisites for attitudes toward virtualizability, user resistance, and actual use [12]. Public-sector evidence indicates that perceived virtualizability predicts intentions to adopt government e-services and is intertwined with resistance dynamics among users of an e-pay slip system [13]. Beyond these domains, PVT has been applied to analyze accommodation services [14]. Used in fintech research, it shows that rising synchronism and identification/control readiness can outweigh declining relationship readiness and boost customers' intention to use [15]. Studies on remote work emphasize sensory and synchronization requirements as significant obstacles to effective virtualization [16]. Others expand PVT by incorporating e-commerce-specific attributes [17] and participant-related factors [18].

The COVID-19 pandemic has provided a unique context for re-evaluating PVT through a crisis-driven perspective [5]. The global health crisis necessitated the rapid virtualization of knowledge work processes, many of which had previously been resistant to digital transformation. As a result of this accelerated transformation, virtualizability evolved from a dependent variable to a determining factor in the fulfillment of process requirements. Organizations increasingly relied on IT characteristics to address these virtualization challenges, leveraging digital tools to simulate sensory elements, facilitate relationship-building, support synchronous interactions, and enhance monitoring capabilities. In this revised understanding of PVT, two additional IT characteristics — social presence and situation awareness — were identified, which further contribute to the effective virtualization of knowledge work processes. Social presence refers to the ability of IT to create a sense of interpersonal connection in virtual settings. The Social Presence Theory states that the degree of perceived psychological and emotional connection between individuals in a mediated communication environment influences the effectiveness and quality of interactions [19], [20]. Social presence refers to the psychological experience in technology-mediated interaction whereby communication partners are sensed as tangible, "real" others, despite the exchange occurring through computer-mediated tools and electronic platforms [21]. It emphasizes how communication technologies vary in their ability to convey social cues in virtual settings.

Situation awareness — essentially "knowing what is going on" [22] — centers on perceiving relevant context information, interpreting its meaning, and anticipating its future development. When shared among team members, this becomes team situation awareness [5], a collective view of conditions, implications, and likely trajectories that is vital for the relational demands of remote work.

The digital age has challenged the notion that processes can only be virtualized to a limited extent, as the empirical reality of widespread remote work has shown that IT can indeed support the social aspects of collaboration in virtual teams. Although some critics have pointed out that many recommendations overlooked the involuntary nature of pandemic-related remote work [23], the urgency to virtualize has receded in today's post-pandemic digital era. This transition creates an opportunity to reflect on progress made in remote collaboration and to reevaluate the potential of collaboration tools through the lens of social presence and situation awareness. Both of these IT characteristics present innovative pathways for understanding how virtual environments can foster not only operational efficiency but also the interpersonal and contextual dimensions of teamwork.

C. Complementary Theoretical Perspectives on Digital Collaboration

To enhance the explanatory power of PVT and deepen the understanding of how collaboration tools influence social presence and situation awareness, this study also draws upon three complementary theoretical perspectives: MRT, MST, and SET. These frameworks provide valuable insights into how digital collaboration tools shape relational dynamics, cognitive alignment, and trust development in virtual teams.

MRT posits that communication media vary in their capacity to effectively convey information, especially in ambiguous or unclear situations [24]. Richer media, such as face-to-face interaction or video conferencing, enable immediate feedback, the transmission of multiple cues (e.g., gestures, tone of voice), and personal focus, thereby supporting the exchange of nuanced and emotionally rich messages. Leaner media, for example email or text messaging, have limited bandwidth for relational and contextual cues and are therefore less suitable for interactions requiring emotional engagement or complex interpersonal coordination.

In the context of virtual collaboration, MRT thus provides a theoretical foundation for understanding why certain technologies are more effective in fostering social presence and affective trust. At the same time, the theory also informs decisions about how task-related information should be communicated in order to support situation awareness. Richer media are particularly appropriate when

shared understanding of evolving tasks, interdependencies, or unexpected changes are required, whereas leaner media may suffice for the dissemination of routine updates or clearly structured information. From this perspective, media richness influences not only relational outcomes but also the extent to which team members can develop and maintain a coherent understanding of the current work situation.

Compared to PVT, which evaluates the conditions under which entire organizational processes, including both person-to-person and person-to-object interactions, can be effectively migrated into virtual settings, MRT addresses a more focused question: how individuals select communication media for specific interpersonal tasks. Its unit of analysis is the medium's capacity to convey cues relative to task ambiguity. MRT explains media choice in bilateral communication, PVT captures the broader feasibility of virtualizing diverse process types beyond communication alone [4].

MST further refines this perspective by distinguishing between two fundamental communication processes: conveyance, referring to the transmission of new or factual information, and convergence, which involves the development of shared understanding among communication partners [25]. According to MST, synchronous communication tools, such as chat or video conferencing platforms, are particularly well suited for convergence processes, as they enable rapid feedback, mutual adjustment, and the co-construction of meaning. These characteristics support not only the alignment of interpretations and expectations, but also the experience of social presence through ongoing interpersonal engagement.

Asynchronous tools, by contrast, primarily facilitate conveyance by allowing time for reflection, parallel information processing, and the structured dissemination of task-related content. From this perspective, MST helps explain how different temporal configurations of communication media contribute to situation awareness: synchronous interaction supports real-time awareness of team dynamics and emerging issues, while asynchronous communication sustains a shared understanding of tasks, responsibilities, and progress over time. In this way, MST complements PVT by specifying how the temporal organization of communication within virtual processes shapes both social presence and situation awareness in digitally mediated collaboration.

In addition to media theories, SET offers a relational lens to understand how digital interactions cultivate trust and commitment within remote teams. SET argues that social behavior is driven by reciprocal exchanges that generate mutual obligations and affective bonds over time [26]. In virtual environments, where informal interactions and spontaneous reciprocity are constrained, the strategic use of digital tools becomes essential for initiating and maintaining such social exchanges. For instance, routine social check-ins or informal chats can simulate reciprocal behavior and foster perceptions of goodwill and reliability, critical foundations for trust [27]. SET thereby informs how collaboration tools can be intentionally used to reinforce relational stability and long-term cooperation despite geographic and temporal dispersion.

Together, these theoretical lenses enrich the interpretation of how collaboration tools influence virtual team processes and offer a broader conceptual grounding for analyzing the findings of this study.

III. Research Design and Methodological Approach

This paper builds on a systematic review of the existing body of literature to gain deeper insights and a more comprehensive understanding of the contribution of digital collaboration tools to the social aspects of virtual collaboration. By analyzing prior research, the study seeks to clarify how digital collaboration tools influence key social mechanisms in virtual teams. Specifically, this systematic literature review analyses how digital collaboration tools shape social presence and situation awareness in distributed work settings. Against this background, the review is guided by the following research questions:

RQ1: In what ways do digital collaboration tools foster social presence in remote settings?

RQ2: In what ways do digital collaboration tools enhance situation awareness in remote teams?

A. Systematic Literature Review Design and Search Procedure

The review employed a structured approach to address the research questions [28]. The review scope was defined as a summary of previous research activities and their underlying theories on remote work, collaboration tools, and virtual team collaboration [29]. The research covered several relevant databases (ACM, EBSCO, Emerald, IEEE, Science Direct, Springer). The systematic search combined the keywords "collaboration tool," "new work," "remote work," "hybrid work," "team cohesion," "social bonding," "group cohesion," "sense of community," and "virtual team dynamics" with Boolean AND/OR operators to ensure comprehensive, relevant results. Figure 1 summarizes the four-iteration review process and resulting article counts as proposed by [30].

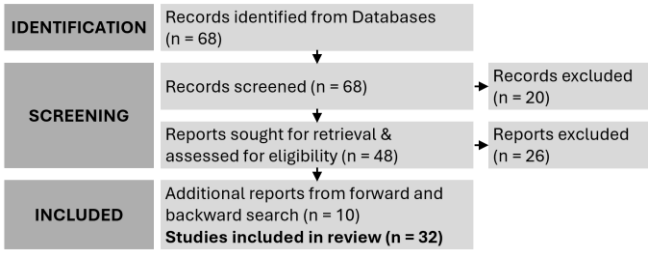

Figure 1. First Review Process.

A database search using the predefined terms was followed by abstract screening based on the criteria in Table I, full-text review using the same exclusions, and forward and backward citation tracking, adding ten articles and yielding 32 eligible studies.

TABLE I. EXCLUSION CRITERIA.

Exclusion Criteria	Published before 2010. No use of collaboration tools. Focus on teams without a degree of virtuality. Articles in any other language as German and English

B. Qualitative Content Analysis and Coding Scheme

The collected data was analyzed using qualitative content analysis [31]. Recurring themes and patterns were identified that shed light on key factors in the use and effectiveness of collaboration tools for supporting social presence and situation awareness.

Social presence is understood as the degree to which digital collaboration tools facilitate awareness of the other person and interpersonal relationships during interaction [19]. Accordingly, the category of *interpersonal relationship/team cohesion* was included, complemented by the concepts of *collaboration* and *community/belonging*. These categories capture the extent to which digital platforms can replicate or substitute the relational dynamics of face-to-face settings, which are essential for long-term engagement and collective performance in virtual teams.

Situation awareness, in contrast, highlights the informational dimension of virtual collaboration. It refers to the collective understanding of work dynamics within a team, encompassing awareness of colleagues' tasks, progress, and interdependencies. In remote settings, this awareness cannot emerge spontaneously, as in co-located offices, but must be actively supported through deliberate communication practices and digital tools. For this reason, *knowledge exchange* was defined as a key category. Closely related is *informal communication*, which plays a vital role in filling contextual gaps, enabling quick clarifications, and creating shared mental models of ongoing work. Without such informal channels, situation awareness can easily break down, resulting in delays, misunderstandings, and weakened trust.

Finally, the analysis revealed *trust* as a cross-cutting concept that underpins both social presence and situation awareness. Trust determines whether employees are willing to disclose problems, share incomplete information, and rely on one another in the absence of direct oversight. It also mediates the effectiveness of digital communication, as technological affordances alone cannot ensure openness or psychological safety. Consequently, trust was integrated into the framework as an essential condition for virtual collaboration.

In addition to the analytical categories originally derived from the systematic review reported in the earlier conference publication [1], the review process was extended in the context of developing the present journal article. This extended review introduced *leadership* as an additional analytical category. The extension was motivated by recurring evidence across the literature indicating that leadership practices play a decisive role in shaping social presence and situation awareness in virtual teams. Accordingly, relevant text segments were newly coded, enabling the analysis to capture how leadership-related behaviors, such as structuring communication processes, providing feedback, or demonstrating empathy, interact with digital collaboration tools to influence the social and informational dynamics of remote collaboration. The appendix presents the resulting concept matrix, which presents the analysis of the literature, additionally classified by research design and tool type.

C. Exploratory Review of AI-Enabled Collaboration Tools

To broaden the conceptual scope of this study and critically reflect on emerging trends in digital collaboration, an additional exploratory literature analysis was conducted on the role of AI in virtual teamwork. While the original systematic review focused on collaboration tools in general, this supplementary analysis aimed to examine how AI-enabled functionalities, such as meeting summarizers, smart assistants, emotion detection, and intelligent task coordination, may influence social presence and situation awareness.

The rationale for this extension stems from the increasing integration of AI into mainstream collaboration platforms and the potential shift in how interpersonal and contextual dynamics are mediated. As AI technologies increasingly shape how information is exchanged and interpreted in virtual teams, they raise new questions about the boundaries and assumptions of PVT.

To identify relevant literature, a structured keyword-based search was conducted in July 2025 across the following academic databases: ACM Digital Library, EBSCO, IEEE, Science Direct and Springer. The search combined the terms "artificial intelligence" AND "collaboration tools" AND "remote work". Only peer-reviewed journal articles and conference proceedings published in English were considered. Figure 2 illustrates the review process in accordance with the PRISMA protocol [30].

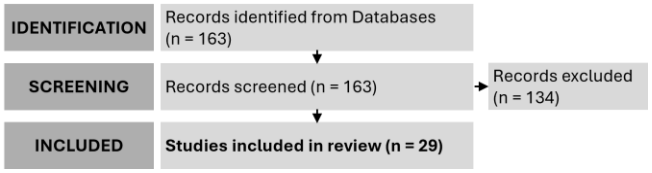

Figure 2. Second Review Process.

The search yielded 163 documents. After screening them based on their relevance to the research scope, 29 were included. These sources were analyzed using qualitative content analysis, focusing on AI functions, positive as well as negative effects of AI use in virtual collaboration and future uses of AI [31].

This supplemental dataset does not feed directly into the original concept matrix, as its thematic focus differs from the initial review sample. The results inform a separate critical

discussion on the opportunities and limitations of AI-augmented collaboration within the framework of process virtualization (see Section VI).

D. Methodological Limitations

Although the reviews followed a structured protocol across multiple databases, the reliance on a single researcher remains a significant limitation. Potential selection bias might have affected the breadth and inclusivity of identified studies, as different reviewers could have interpreted inclusion and exclusion criteria differently or identified additional relevant publications. Moreover, focusing on specific search terms may have overlooked research addressing remote collaboration from adjacent perspectives (e.g., organizational psychology, workplace design). Together, these factors could limit the generalizability of the findings and should be considered when interpreting the results.

IV. Findings: Social and Informational Dimensions of Virtual Collaboration

This section presents the results of the qualitative content analysis and synthesizes recurring patterns identified across the reviewed literature. The findings illustrate how digital collaboration tools are discussed in relation to social presence, situation awareness, and trust in remote team settings, while also highlighting leadership as a key factor shaping these dynamics. The following subsections report the findings in accordance with the analytical categories and summarize dominant themes identified across the analyzed studies.

A. Social Presence in Virtual Teams

Social presence is a critical factor in virtual collaboration. Many studies emphasize that digital platforms can be designed to foster the feeling of togetherness typically experienced in face-to-face settings. Synchronous communication tools, such as video conferencing and instant messaging, have been found to be particularly effective at cultivating social presence by enabling immediate, reciprocal interaction and conveying rich social cues (e.g., facial expressions and gestures), all of which are vital for establishing and maintaining interpersonal bonds [32], [33].

According to MST, convergence-oriented tasks such as relationship-building benefit from high synchronicity media, which facilitate real-time feedback and emotional resonance [25]. Immersive digital environments, such as virtual workspaces and avatars, can further strengthen this sense of connection by simulating physical co-presence, thereby enhancing engagement and team cohesion [34], [35]. For instance, the platform Gather lets remote colleagues initiate spontaneous interactions by virtually approaching one another [34] (further elaborated in Section V). This ability for rapid, informal encounters can mitigate the isolation that often arises in remote settings [32], [36], [37].

These findings align with MRT, which suggests that media capable of transmitting multiple cues and supporting immediate feedback are more suitable for conveying relational and affective content than leaner, text-based alternatives [24].

One study draws on the Embodied Social Presence Theory (ESPT), which suggests that virtual workspaces should replicate significant aspects of physical interaction to enhance communication and collaboration. This enables participants to interpret nonverbal cues in digital environments [35]. Through the use of synchronous video tools and virtual reality platforms, ESPT's focus on embodied co-presence reduces ambiguity in remote interactions and reinforces interpersonal relationships.

Some authors emphasize that organizational culture and shared values can be reinforced through collaboration tools when they are used for team-building events, recognition programs, and personal updates [38]. Similarly, planned informal interactions can improve social presence by compensating for the lack of casual conversations in the corridor [39]. Teams that allocate time for social check-ins tend to feel more aligned and engaged. Studies further highlight the importance of intentional, well-structured digital communication to replicate the camaraderie of co-located offices [40], [41]. Frequent touchpoints, such as virtual coffee chats and informal communication channels, help remote employees preserve a communal sense of identity [36], [39]. Meanwhile, personalized introductions — including Asynchronous Semi-Guided Professional Introductions (ASGPIs) — facilitate the exchange of personal and professional information, thereby strengthening interpersonal connections [32].

It is also recognized that even asynchronous tools can support social presence by enabling indirect reciprocity and sustained connections over time, yet their overall impact is constrained by the absence of immediate interaction and emotional engagement [35]. According to MST, these asynchronous channels are better suited for conveyance tasks and fall short in facilitating convergence processes that rely on shared understanding and mutual responsiveness [25].

However, studies indicate that an overreliance on asynchronous communication can lead to feelings of social isolation and a reduced sense of belonging, particularly in teams that lack prior face-to-face interactions [38]. The literature stresses that choosing the right mix of synchronous and asynchronous channels is vital for sustaining high-quality interactions [37], [42]. Platforms, such as Slack, Microsoft Teams, Gather, or Zoom, allow for both project-focused conversations and casual "break room" chats [43]. This multimodal approach ensures that teams can adapt their communication methods to both the complexity and urgency of tasks [33]. Well-timed, media-rich interactions, such as video calls at the beginning of a team's lifecycle, foster personal relationships. Text-based channels and shared documents, on the other hand, are sufficient for routine status updates as collaboration progresses [42], [44]. This provides a direct link and a transition to situation awareness.

B. Situation Awareness in Distributed Collaboration

While social presence fosters emotional connection, situation awareness centers on the ability to stay informed about colleagues' work progress, needs, and challenges in

real time, essential for coordinating team efforts and ensuring alignment. While traditional offices often rely on spontaneous observations and overheard conversations [45], remote work environments lack these spontaneous exchanges and must adopt purposeful strategies to maintain comparable levels of context [46]. The inability to observe colleagues' work activities or engage in impromptu discussions often leads to knowledge silos and reduced collaboration efficiency [45]. In addition, researchers found that virtual team members often hesitate to seek help because problems are more difficult to explain and responses are slower [47]. To counteract these effects, many teams have adapted their communication practices by integrating asynchronous chat tools, such as Slack, which facilitate real-time knowledge exchange despite physical separation [39] (further elaborated in Section V). Tools, such as email, shared documents, and discussion forums, contribute to collaboration by supporting structured information exchange and enabling parallel collaboration [33], [48]. Also from the perspective of MST, asynchronous channels, like shared documents or message boards, may be preferable for information distribution (conveyance) [25].

It is underlined that knowledge sharing keeps remote teams aligned and efficient [49]. Similarly, researchers argue that social support, which includes knowledge-sharing practices, strengthens connectivity and reduces workplace stress, fostering a more cohesive understanding of team dynamics [37]. Furthermore, a study indicates that mutual exchange of knowledge builds trust and reinforces collective competence [48]. The authors highlight the significance of informal knowledge exchange in virtual environments, where psychological safety plays a crucial role in facilitating open discussions and information flow. For example, short, informal encounters ("huddle interactions") or informal side chats during official meetings allow members to ask quick questions, seek clarifications, or exchange immediate feedback, much as they might in the physical workspace [39], [45]. Additionally, these ongoing knowledge exchanges, whether over group messaging or video calls, counteract the risk of isolation and misalignment [39], [44].

Well-structured check-ins and routine status updates via shared platforms help team members anticipate when others might need assistance [42]. This transparency not only aids productivity but can also reduce stress and foster mutual trust, as teams learn to predict and fill potential gaps [40], [42], [50]. This more flexible backup behavior can also be enabled by "total information awareness", meaning relevant communications are circulated to all team members, including those not directly involved [51]. Such communication practices are linked to outcomes like improved team performance [48]. Consistent rules and norms can further reinforce positive team functioning in virtual contexts [41], [52], [53]. However, it is emphasized that virtual teams must deliberately invest in relationship-building [47]. For example, proactively introducing new colleagues through informal sessions can foster familiarity even faster than in co-located teams.

C. *Trust as a Cross-Cutting Enabling Condition*

Trust can be defined as a dynamic, shared state that emerges within teams and reflects the belief that colleagues are reliable and aligned in terms of goals and values [27]. In virtual teams, trust is closely intertwined with social presence and situation awareness, as both the relational and informational dimensions of collaboration shape how team members perceive and rely on one another. Research highlights that even brief face-to-face encounters, such as an initial in-person kickoff, can accelerate the development of early trust, which subsequently carries over into virtual collaboration. When in-person interaction is not feasible, structured opportunities for informal exchange, for example virtual teambuilding events or open communication channels, can partially substitute for missing physical closeness and foster interpersonal bonding [47], [54]. In these contexts, digital communication technologies must support both task-related coordination and relational interaction to facilitate the development and maintenance of trust [55]. Trust and team cohesion are highly interdependent: when early trust is established, cohesive collaboration develops more easily, whereas low initial trust complicates maintaining unity across geographic and temporal divides [27].

Similarly, a study highlights that without deliberate efforts to foster socio-emotional bonds, relationships between subordinates and managers can deteriorate in purely virtual settings, further undermining trust [50].

In the context of social presence, shared emotional cues, authentic self-disclosure, and informal interactions foster affective trust. High-synchronicity media convey nonverbal cues that help team members assess intentions, while excessive asynchronous text communication can undermine trust due to misinterpretation [33]. A well-balanced media strategy that supports both structured collaboration and spontaneous social contact strengthens trust at the group level [43], [48].

This finding resonates with SET, which emphasizes that trust develops through reciprocal exchanges that signal commitment and mutual support over time [26]. In virtual contexts, well-designed communication rituals, for example structured check-ins or digital recognition, can function as symbolic gestures that sustain perceived reliability [27].

From a situation awareness perspective, low trust hampers information flow, as individuals hesitate to disclose difficulties or seek help in perceived hostile environments. Weak trust discourages transparent data sharing due to fears of appearing incompetent or misusing sensitive information [51]. Conversely, high-trust teams proactively coordinate, offer support, and monitor emerging challenges, enhancing performance in remote settings [27], [42]. At the leadership level, trust mitigates the "invisibility problem" in remote work, enabling fair treatment, nonintrusive oversight, and accountability without micromanagement [23], [50], [56].

Social presence creates the emotional conditions under which trust thrives. Situation awareness ensures group members have enough insight into one another's actions and challenges to maintain a trustworthy, dependable workflow.

Tying these two elements together, trust becomes the linchpin that channels technological affordances into truly cohesive remote teamwork.

D. Leadership as a Contextual Shaping Factor

Leadership plays a central role in shaping how digital collaboration tools foster social presence and situation awareness in remote work. Studies show that leaders must actively structure digital communication to strengthen interpersonal connection and team cohesion. Inclusive leadership practices, such as fair recognition and open participation, help employees feel part of the group and thus increase social presence [23], [34]. At the same time, compassionate leadership that emphasizes empathy and individualized support reduces the sense of isolation in virtual settings and helps maintain engagement when face-to-face cues are absent [37]. Conversely, insufficient contact or lack of feedback from managers working remotely can weaken trust and reduce perceived presence [51].

With respect to situation awareness, leaders are responsible for ensuring transparency and visibility of work progress. Digital routines such as structured check-ins, clear goal-setting, and regular updates provide team members with the contextual information needed to anticipate each other's needs [40], [42], [57]. Shared leadership models can also strengthen situation awareness when responsibilities are distributed fairly and task interdependencies are made explicit [41]. However, it is cautioned that not all leadership functions can be shared without risking confusion. Some decision-making authority remains essential with the formal leader to maintain clarity.

Digital collaboration tools are both an enabler and a challenge in this context. On the one hand, platforms, messaging tools, and video conferencing enhance awareness of team activities and make collaboration visible [44], [58]. On the other hand, excessive monitoring or rigid control mechanisms may erode trust and reduce employees' willingness to share information, thereby undermining situation awareness [38], [52]. Training initiatives are therefore critical. Leaders who are skilled at using digital tools strategically can align digital practices with organizational goals, fostering social presence and contextual awareness among their teams [36], [49], [54], [55].

V. Illustrative Case Examples from Literature

To further contextualize the findings of this review, this section presents two illustrative examples from the literature that demonstrate how specific collaboration tools establish social presence and situation awareness as central IT characteristics of virtual collaboration. The examples illustrate how these socially oriented characteristics are embedded in concrete tool affordances and everyday communication practices.

A. Gather: Virtual Office Environments Supporting Social Presence and Situation Awareness

The use of Gather as a virtual office environment in remote software engineering teams provides a particularly illustrative example of how social presence and situation awareness can be jointly supported through digital technology [34]. Gather simulates key spatial features of co-located work environments by allowing team members to navigate shared virtual spaces with avatars and to initiate interactions based on proximity. This design enables spontaneous, low-threshold encounters that closely resemble informal office interactions, thereby fostering a strong sense of social presence grounded in perceived co-presence and interpersonal accessibility. At the same time, these spatial and visual affordances support situation awareness by making social and task-related activity continuously observable. Team members can see who is present, who is engaged in conversations, and how different areas of the virtual workspace are used, which contributes to an ongoing shared understanding of availability, interaction patterns, and work context. Accordingly, Gather demonstrates how social presence and situation awareness serve as enabling IT characteristics that compensate for the absence of physical co-location, enabling meaningful collaboration in virtual settings.

MRT further helps explain why Gather is particularly effective for interactions involving ambiguity or negotiation, as it combines multiple cues, instantaneous communication, and personal focus. In addition, MST highlights how the platform supports convergence processes through real-time interaction, allowing teams to align interpretations and coordinate action in situ. Leadership practices play a mediating role by encouraging participation in shared spaces and legitimizing informal interaction, thereby reinforcing the reciprocal social exchanges through which trust and cohesion emerge over time.

B. Slack: Asynchronous Communication and Coordination in Remote Work

Another example is offered by a study investigating Slack adoption during the abrupt transition to remote work at the onset of the COVID-19 pandemic [39]. In this context, professional service teams initially tried to recreate in-office collaboration by holding frequent synchronous video meetings. However, this approach soon led to fatigue and inefficiencies. As a response, many teams shifted to Slack as their primary coordination channel. Through persistent channels and threaded discussions, Slack supported situation awareness by making task updates, process decisions, and contextual information visible and accessible across time. Team members were able to reconstruct the state of ongoing work, monitor progress, and understand dependencies without requiring continuous real-time interaction. Simultaneously, Slack sustained a baseline level of social presence through informal messages, quick questions, and lightweight interpersonal exchanges that approximated the ease of brief, in-person interactions. This example illustrates how social presence and situation awareness operate as core IT characteristics that enable distributed coordination and mutual orientation in asynchronous collaboration. MST helps clarify how Slack primarily supports conveyance processes, allowing parallel information processing and reflection, while still enabling convergence through focused discussions when needed. Leadership practices were central in shaping

these dynamics by establishing norms around responsiveness, channel use, and availability, thereby balancing efficiency concerns with the maintenance of relational connection and inclusiveness. From a SET perspective, these practices support sustained reciprocity by signaling commitment and accessibility without imposing constant immediacy.

These examples demonstrate how different categories of collaboration tools operationalize social presence and situation awareness as key IT characteristics of virtual collaboration. Immersive environments such as Gather emphasize embodied co-presence and real-time mutual awareness, whereas asynchronous platforms like Slack foreground persistence, transparency, and temporal flexibility. Both cases highlight the central role of tool affordances in fostering social presence and situation awareness and demonstrate how leadership practices mediate their effective integration into remote workflows.

VI. AI-Augmented Collaboration in Virtual Teams

Recent advances in AI are increasingly reshaping digital collaboration tools used in remote work settings. While collaboration technologies have traditionally been conceptualized as infrastructures that mediate interaction and support shared understanding across spatial distance, recent research highlights a shift toward AI-driven functionalities that actively structure communicative processes. Across a wide range of organizational and technological contexts, studies describe how AI is embedded in collaboration environments, where it supports coordination, filters information, and augments communicative exchanges among geographically distributed team members [59], [60], [61]. Through these mechanisms, AI is involved in establishing social presence by influencing perceptions of availability, responsiveness, and emotional expression. At the same time, AI affects situation awareness by organizing access to relevant information and collective states.

Moreover, the literature consistently emphasizes the ambivalent character of AI-mediated collaboration. Several contributions suggest that AI-enabled features can strengthen social presence in remote teams by reducing interactional friction and supporting more continuous and context-sensitive communication, for instance through intelligent interface design, personalization mechanisms, or enhanced virtual meeting environments [62], [63], [64].

Other studies warn that increased algorithmic mediation may weaken social presence when communication becomes standardized, opaque, or overly optimized, thereby constraining opportunities for informal interaction and mutual sensemaking [65], [66]. Comparable tensions are evident with regard to situation awareness, which may be enhanced through AI-supported analytics while simultaneously becoming detached from socially grounded cues.

Studies further illustrate that AI-mediated functionalities are no longer peripheral but increasingly embedded in routine collaboration and managerial practices. Current uses of AI in collaboration tools include automated scheduling, intelligent task allocation, real-time transcription, sentiment analysis, and workflow automation, often in conjunction with cloud-based infrastructures and enterprise systems [67], [68], [69]. In software development and engineering contexts, AI-supported meeting tools and analytics are described as particularly relevant for maintaining shared situation awareness in distributed teams [53], [70]. These applications are frequently framed as responses to the growing complexity of remote collaboration, where maintaining awareness of tasks, roles, and progress requires continuous coordination across temporal and spatial boundaries.

Across the reviewed literature, positive effects of AI-augmented collaboration tools are frequently associated with enhanced transparency, efficiency, and informed decision-making [53], [67], [71], [72]. Several studies report that AI-based analytics increase visibility into participation patterns, workload distribution, and performance indicators, thereby supporting situation awareness in complex organizational environments [73], [74]. In crisis-related contexts, AI-enabled tools are described as helping organizations sustain coordination and awareness despite disruption and uncertainty [75]. From this perspective, AI is portrayed as reinforcing shared understanding and continuity in distributed collaboration, particularly where direct interaction is limited.

However, negative effects and unintended consequences are equally prominent in the literature. Multiple contributions raise concerns about surveillance, loss of autonomy, and the normalization of pervasive monitoring through AI-driven systems, which may undermine trust and weaken social presence [66], [71]. Other studies highlight risks related to algorithmic bias, security vulnerabilities, and misuse of AI-enabled infrastructures, which may distort awareness structures and marginalize certain actors or interaction styles [76], [77], [78]. These findings point to a tension between efficiency gains and the erosion of socially grounded cues that are central to effective collaboration.

Looking ahead, the literature anticipates a continued expansion of AI capabilities within collaboration tools and organizational systems. Future developments are expected to include more adaptive, predictive, and autonomous systems that integrate collaboration data with broader human capital and labor market analytics [79], [80]. At the team level, AI-driven feedback and support systems are discussed as potential mechanisms for sustaining well-being, performance, and awareness in remote settings [81]. At the same time, several contributions emphasize that the implications of these developments depend on governance frameworks, ethical considerations, and organizational choices [82], [83]. Rather than converging on a single trajectory, the literature portrays AI-augmented collaboration as an evolving and contested domain, in which opportunities for enhanced social presence and situation awareness coexist with significant risks of fragmentation, depersonalization, and loss of agency.

VII. Conceptual Contributions and Practical Implications

Based on the results presented, this study makes several conceptual contributions to the field of virtual collaboration research. It extends the PVT model and refines its applicability to contemporary, digitally mediated knowledge work. In contrast to traditional interpretations of PVT, which focus on assessing the virtualization potential of organizational processes based on sensory, relational, synchronous, and identification and control requirements [4], [9], this review builds on and systematizes more recent extensions of the theory by explicitly foregrounding social presence and situation awareness as IT characteristics of digital collaboration [5]. The contribution of this study lies in synthesizing and structuring existing literature to demonstrate how these socially oriented IT characteristics enable the virtualization of relationally demanding collaboration processes. By integrating these characteristics into a broader PVT-informed analysis, the review clarifies their role in shaping interaction quality, shared understanding, and coordination in contemporary virtual work settings.

Building on crisis-driven extensions of PVT [5], the findings indicate that these characteristics are not merely supportive conditions but constitute core mechanisms through which virtual collaboration becomes sustainable beyond temporary or emergency contexts. Social presence captures the relational dimension of process virtualization by enabling interpersonal connection, belonging, and cohesion in the absence of physical co-location, whereas situation awareness reflects the informational dimension by supporting shared understanding of tasks, roles, and interdependencies [19], [22].

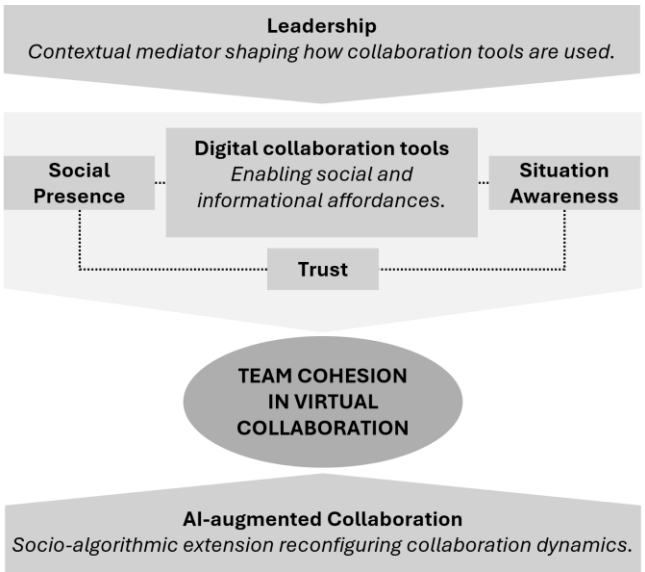

Figure 3. Conceptual synthesis of how digital collaboration tools support team cohesion in virtual collaboration.

Figure 3 synthesizes the core findings of this review by illustrating how digital collaboration tools contribute to team cohesion in virtual collaboration through distinct but interrelated social mechanisms. The analysis shows that collaboration tools primarily foster social presence and situation awareness by enabling social and informational affordances. Social presence supports relational closeness and a sense of interpersonal connection, while situation awareness facilitates shared understanding of tasks, activities, and coordination processes. Trust emerges as a central, relational outcome of the dynamic interplay between these two mechanisms rather than as an isolated characteristic, reinforcing both relational continuity and collaborative stability over time. Leadership is conceptualized as a contextual mediator that shapes how collaboration tools and their affordances are used in practice, thereby influencing the extent to which social presence, situation awareness, and trust can develop. Finally, AI-augmented collaboration is positioned as a socio-algorithmic extension that increasingly reconfigures collaboration dynamics by reshaping coordination, visibility, and sensemaking processes, without replacing the underlying social mechanisms on which team cohesion in virtual collaboration ultimately depends.

A key conceptual contribution of this article lies in its explicit integration of AI as an emerging layer of mediation in virtual collaboration. Whereas PVT traditionally conceptualizes information technology as an enabling infrastructure, the reviewed literature on AI-enabled collaboration tools points to a qualitative shift in how collaboration is shaped. AI has evolved from being a passive support technology to playing a more active role in group interactions [59], [62]. AI-supported functionalities increasingly structure communication, prioritize information, coordinate tasks, and interpret collective states, thereby actively influencing both social presence and situation awareness. This socio-algorithmic dimension challenges implicit assumptions of PVT regarding the passive role of IT and suggests the need to conceptualize algorithmic agency as an integral component of process virtualization in contemporary collaboration settings.

The study further refines virtualization research by integrating complementary theoretical lenses that address limitations of PVT when applied to socially complex work processes. MRT explains why media-rich communication formats remain crucial for sustaining social presence and affective trust in ambiguous contexts [24]. MST clarifies how communication structures support either convergence or conveyance processes that underpin situation awareness [25]. SET adds a relational perspective by emphasizing that trust and commitment emerge through reciprocal interactions over time, even in digitally mediated environments [26]. Together, these perspectives support a socio-technical and socio-algorithmic extension of PVT that foregrounds communication dynamics, relational expectations, and trust as central elements of virtual collaboration.

Another important contribution is the explicit incorporation of leadership as a contextual shaping force. The reviewed literature demonstrates that leadership

practices influence how digital and AI-enabled collaboration tools are used, interpreted, and legitimized in everyday work. By structuring communication routines, setting norms for transparency, and regulating visibility and monitoring features, leaders shape whether collaboration technologies foster trust, social presence, and shared awareness or instead contribute to overload, disengagement, and perceptions of control [23], [41], [52]. Conceptually, framing leadership as a contextual factor shaping how digital collaboration tools are used in practice extends PVT toward a more explicitly organizational and practice-oriented perspective.

From a practical standpoint, the findings imply that organizations should move beyond technology-centric approaches to virtual collaboration. Effective digital collaboration requires communication environments that combine synchronous and asynchronous interaction, support informal as well as task-oriented exchanges, and provide persistent yet adjustable visibility into work processes [39], [47]. Leadership development initiatives should therefore emphasize relational, communicative, and ethical competencies alongside technical skills, particularly in increasingly AI-mediated collaboration settings. For designers of collaboration tools, the results highlight the importance of configurable systems that allow teams to calibrate interaction richness, synchronicity, and algorithmic intervention in line with evolving task and relational demands [56], [84].

VIII. Conclusion and Future Work

This article extends an earlier conference publication [1] by broadening the theoretical and conceptual understanding of virtual collaboration and by integrating additional analytical perspectives on leadership and AI. Drawing on systematic literature reviews, the study demonstrates that virtual collaboration can replicate many relational and informational aspects of co-located work when technological affordances are aligned with communication practices, leadership behaviors, and organizational norms. Anchored in PVT [4], [9] and complemented by MRT [24], MST [25], and SET [26], the analysis highlights social presence and situation awareness as central mechanisms through which trust, cohesion, and shared understanding can be sustained in digitally mediated collaboration [19], [22].

Across the reviewed literature, social presence emerges as a relational outcome that is particularly supported by media-rich and synchronous interaction formats, informal communication opportunities, and practices that foster belonging and interpersonal connection [32], [35], [39]. Situation awareness, in contrast, is primarily enabled by persistent information structures, transparent communication routines, and ongoing knowledge exchange that make tasks, roles, and interdependencies visible to distributed team members [47], [48], [57]. Trust operates as a cross-cutting condition that links these two dimensions by shaping whether individuals are willing to share information, disclose uncertainty, and rely on one another in the absence of physical co-location [27], [51]. Leadership plays a decisive role in translating technological affordances into meaningful social and informational outcomes by structuring communication, legitimizing tool use, and balancing transparency with autonomy [23], [41], [52].

At the same time, the findings underscore that technology alone cannot ensure effective virtual collaboration. The complementary analysis of AI-enabled collaboration tools reveals an ambivalent dynamic: while AI-supported functionalities may enhance efficiency, coordination, and transparency [73], [75], they also raise concerns related to agency, surveillance, and the erosion of socially grounded interaction cues when algorithmic processes become opaque or intrusive [66], [71]. These tensions reinforce the conclusion that digital and AI-enabled tools must be embedded in appropriate governance structures and leadership practices to avoid undermining trust and social presence [84].

Beyond summarizing these contributions, this study points to several avenues for future research. Conceptually, future work would benefit from a more consistent analytical differentiation between coordination, communication, and collaboration in studies of virtual work. Rather than subsuming these dimensions under the broad label of virtual collaboration, distinguishing them as related but distinct processes can support more precise theorizing and empirical operationalization of digital collaboration processes [2].

Methodologically, longitudinal and experimental research designs are needed to move beyond descriptive studies and examine causal relationships between specific digital affordances, leadership behaviors, and outcomes such as trust, cohesion, and team performance [42]. Comparative studies across organizational contexts, industries, and cultural settings could further illuminate boundary conditions of PVT and clarify how virtual collaboration evolves over time.

In addition, the growing integration of AI into collaboration tools points to a distinct and increasingly urgent research agenda. While existing studies predominantly focus on short-term efficiency gains and coordination benefits, comparatively little is known about the long-term effects of AI-mediated collaboration on social presence, situation awareness, and trust [59], [60]. As AI systems increasingly structure communication flows, prioritize information, and generate interpretations of collective states, they assume a more active role in shaping collaboration processes rather than merely supporting them. Future research should therefore examine how different degrees of algorithmic mediation affect perceptions of agency, accountability, and reciprocity over time, particularly in contexts where AI substitutes for human judgment or interaction [67], [68], [69]. Longitudinal studies could shed light on whether AI-enhanced transparency and efficiency stabilize collaboration or gradually erode relational quality and trust when algorithmic processes remain opaque or are perceived as intrusive [66]. Moreover, further research is needed to identify governance mechanisms and design principles that allow organizations to calibrate AI support in ways that preserve socially grounded cues, maintain psychological safety, and align algorithmic intervention with task complexity and relational demands [82], [83].

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I. APPENDIX

EXPANDED CONCEPT MATRIX

	Classification		Concepts						
Article	Research Design	Tool-Types mentioned	Social Presence			Situation awareness		Trust	Leadership
			Interpersonal Relationship/ Team Cohesion	*Collaboration*	*Community/ belonging*	*Knowledge exchange*	*Informal Communication*		
[23]	REV	Vid, Pl	x		x		x	x	x
[27]	REV + Q	Vid, Em	x	x	x		x	x	
[32]	CON	Vid, Pl	x	x	x	x	x	x	
[33]	REV + CON	VR,Vid,Ch	x	x	x			x	
[34]	Q	VR, Vid, Ch, Pl	x	x	x		x		x
[35]	CON	Pl	x		x				
[36]	CON	Pl	x		x		x		x
[37]	QU	Vid, Ch	x		x	x		x	x
[38]	REV	Pl, Em	x		x	x	x	x	x
[39]	Q	Vid, Ch, Em	x				x		
[40]	Q	Pl	x	x	x		x		x
[41]	QA	ND	x	x	x			x	x
[42]	REV	Vid, Ch, Pl, Em					x	x	x
[43]	QM	Ch, NT	x				x		
[44]	REV	VR, Vid, Ch, Pl, Em	x	x		x		x	x
[45]	Q	Vid, Ch, Pl, Ph	x	x				x	
[46]	Q + CON	Vid, Ch					x		
[47]	Q	Vid, Ch, Em, Ph	x		x		x		
[48]	Q	VR, Vid, Ch, Em	x			x	x	x	
[49]	Q	Vid, PL	x	x		x		x	x
[50]	QU	Vid, Ch, Pl, Em, Ph				x		x	
[51]	QU	Em, Ph, ND	x				x	x	x
[52]	CON	Pl						x	x
[53]	RE	VR, Vid, Ch, Pl, Em	x	x	x		x	x	
[54]	QM	ND		x	x				
[55]	QU	Vid, Ch, Pl		x	x	x			x
[56]	CON	Vid, Ch, Pl, Em, Ph	x	x				x	
[57]	REV + QU	Vid, Ch, Pl, Em	x					x	x
[58]	CON	Vid, Ch, Pl, Em, Ph	x	x	x		x	x	x
[84]	Q	VD	x				x		
[85]	Q	Vid, Ch, Pl, Em, Ph	x	x		x		x	
[86]	QU	Vid, Ch, Pl,	x	x			x		
∑ *(Research Design/ Tool-Types/ Segments with concept)*	Q = 10 CON = 8 REV = 7 QU = 6 **QM = 2** **EXP = 0**	Vid = 22 Pl = 18 Em = 13 Ch= 15 Ph = 7 **VR = 5** ND = 3	85	28	36	16	106	53	110