Research Article

Challenges and barriers in virtual teams: a literature review

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Abstract
Virtual teams (i.e., geographically distributed collaborations that rely on technology to communicate and cooperate) are central to maintaining our increasingly globalized social and economic infrastructure. "Global Virtual Teams" that include members from around the world are the most extreme example and are growing in prevalence (Scott and Wildman in Culture, communication, and conflict: a review of the global virtual team literature, Springer, New York, 2015). There has been a multitude of studies examining the difficulties faced by collaborations and use of technology in various narrow contexts. However, there has been little work in examining the challenges faced by virtual teams and their use of technology to mitigate issues. To address this issue, a literature review was performed to highlight the collaboration challenges experienced by virtual teams and existing mitigation strategies. In this review, a well-planned search strategy was utilized to identify a total of 255 relevant studies, primarily focusing on technology use. The physical factors relating to distance are tightly coupled with the cognitive, social, and emotional challenges faced by virtual teams. However, based on research topics in the selected studies, we separate challenges as belonging to five categories: geographical distance, temporal distance, perceived distance, the configuration of dispersed teams, and diversity of workers. In addition, findings from this literature review expose opportunities for research, such as resolving discrepancies regarding the effect of tightly coupled work on collaboration and the effect of temporal dispersion on coordination costs. Finally, we use these results to discuss opportunities and implications for designing groupware that better support collaborative tasks in virtual teams.

Keywords Collaboration · Distance · Virtual teams · Literature review

1 Introduction

Virtual teams (i.e., geographically distributed collaborations that rely on technology to communicate and cooperate) have several potentially beneficial aspects that aid productivity. Much like collaboration in co-located teams, collaboration in virtual teams refers to synchronous and asynchronous interactions and tasks to achieve common goals. The use of virtual teams allows organizations to enroll key specialists, regardless of their physical location [106, 151]. This allows organizations to optimize teams by using only the best talent available [63, 136]. In theory, virtual teams also reduce the need for travelling between sites, which should reduce costs in terms of time, money, and stress [196]. It was estimated that by 2016, more than 85 % of working professionals were in some form of virtual team [235]. This implies that, as a result, virtual teams have become vital to maintaining our increasingly globalized social and economic infrastructure.

Similar to co-located teams, virtual teams participate in a variety of collaborative activities such as formal and informal meetings using technology like video conferencing (e.g., Zoom [121] and Skype [175]) and text (e.g., Slack [232] and Microsoft Teams [176]), file transfer, and application sharing [191]. As a result, virtual teams are experiencing difficulties collaborating that are making it difficult

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for them to be as successful as co-located teams [64, 151, 191]. As a result, virtual teams spend substantial time and money to relocate team members for specific projects to avoid the hindrances to teamwork associated with distance [231, 257]. It is therefore important to develop technology that can better support virtual teams, reducing the need for costly re-locations and mitigating the problems that arise when relocation is not a viable solution.

Despite previous research examining the difficulties faced by collaborations and use of technology in specific contexts, such as distributed software development, there has been little work in examining the challenges faced by all virtual teams and their use of technology to mitigate issues. This understanding is vital to the development and utilization of technology to support virtual teams. Thus, this paper has two goals: (1) to elucidate the factors and challenges that hinder collaboration in virtual teams and (2) provide recommendations for designing groupware to better support collaboration in virtual teams, while also identifying opportunities for the Human–Computer Interaction (HCI) community to design this technology.

To achieve our goals, a Literature Review (LR) was performed with a well-planned search strategy that identified a total of 255 relevant studies, primarily focusing on technology use. Based on the selected studies, we categorized challenges as being related to: geographical distance, temporal distance, perceived distance, the configuration of dispersed teams, and diversity of workers. In addition, results from this LR identify opportunities for research, such as resolving discrepancies regarding the effect of tightly coupled work on collaboration, the effect of temporal dispersion on coordination costs, and whether virtual teams encounter more work-culture related problems than co-located teams. From the synthesis of these papers, we present four design implications for designing groupware that better support collaborative tasks in virtual teams.

This literature review explores the factors and challenges associated with collaboration in virtual teams. This paper begins with a review of related LRs in the domain of collaboration in Sect. 2 and progresses to a description of the method used to conduct the LR in Sect. 3. Sections 5 and 6 explore issues related to distance and other contributing factors, respectively. Next, in Sect. 7, findings from Sects. 5 and 6 are summarized, leading to Sect. 8 which completes the LR by presenting a set of four design implications for the development of groupware that supports collaboration in virtual teams.

2 Related work

Prior work includes eight systematic literature reviews surveying various topics related to distance collaboration. These topics fall into two categories: investigations of virtual teams in the domain of distributed software development (DSD) and explorations of the factors that influence collaboration in broader contexts.

Research into the challenges faced in DSD have resulted in determination of the factors associated with the relationship between distribution, coordination, and team performance that are the most commonly studied in software development, namely dimensions of dispersion (e.g., geographical, temporal, organizational, work process, and cultural dispersion) and coordination mechanisms (e.g., organic or social coordination and mechanistic or virtual coordination) [183]. Several challenges (e.g., including geographical, temporal, cultural, and linguistic dispersion [146, 185]) and best practices or practical solutions (e.g., agile methods, test-driven development [146], frequent site visits and face-to-face meetings [185, 233]) have been identified for traditional DSD teams [185] and teams that use a 'follow-the-sun' approach (i.e., where teams hand off work at the end of the day in one time-zone to workers beginning their day in another) [146]. Additional work identified opportunities for future research, such as addressing challenges present in multi-organizational software projects and supporting the development of coordination needs and methods over the course of a project [184]. This category of research also includes a study that classified empirical studies in DSD [64], revealing that communication warrants further exploration to better support awareness in this context [239].

These studies are informative and discuss several of the challenges that appear later in this LR (e.g., geographical, temporal, cultural, and linguistic dispersion). However, it is not guaranteed that the findings from the DSD studies with regards to these dimensions directly translate to collaboration in another context. In contrast, this paper examines distance collaboration in all virtual teams.

Other studies have studied the factors affecting collaboration in general. Mattessich and Monsey identified 19 factors necessary for successful collaboration, including the ability to compromise, mutual respect and trust, and flexibility [167]. Similarly, Patel et al. [201] developed a framework based on the categorization of seven factors related to collaboration (e.g., context, support, tasks, interaction processes, teams, individuals, and overarching factors) for use in collaborative engineering projects in the automotive, aerospace, and construction sectors.

In contrast to the results of the DSD studies, these findings apply to a broad range of contexts. However, since

these literature reviews primarily focus on co-located collaboration, it is difficult to discern how the factors identified by these studies influence virtual teams. This paper differs by focusing only on virtual teams.

3 Method

Relevant papers were extracted for LR using the guidelines proposed by Kitchenham and Charters [138] for performing Systematic Literature Reviews in software engineering, with the adjustments recommended by Kitchenham and Brereton [137]. These guidelines divide the review process into three steps:

1. *Planning the review* In this step, the research questions and review protocol are defined. This will be discussed in the remainder of Sect. 3.
2. *Conducting the review* This step focuses on executing the review protocol created in the previous step. This will also be discussed in Sect. 3.
3. *Reporting the review* This final step documents, validates, and reports the results of the review. This will be the subject of Sects. 5 and 6.

3.1 Planning the review

This subsection will focus on developing the list of research questions used to generate the list of keywords for extracting papers and specify the search methodology.

3.1.1 Specifying research questions

The first stage of this literature review began by defining research questions using the Goal-Question-Metric approach described by Van Solingen et al. [258], which systematically organizes measurement programs. This model specifies the purpose, object, issue, and viewpoint that comprise a goal, which is then distilled into research questions and used to create metrics for answering those questions. The goal of this LR is:

- *Purpose* Understand and characterize
- *Issue* The challenges
- *Object* Related to collaboration
- *Viewpoint* Faced by workers in virtual teams

Using this goal, these research questions were derived:

1. What are the factors and challenges that impact distance collaboration?
   (a) What factors specific to distance cause issues?
   (b) What other factors contribute to these issues?
2. How can we design technology for supporting virtual teams?

The purpose of asking question 1 is to outline previous research investigating collaboration challenges. The expected outcome will be a comprehensive view of challenges affecting collaborations and identification of gaps or areas warranting future exploration. Research Question 1a will be the topic of Sect. 5 while Research Question 1b will be explored in Sect. 6. Research Question 2, however, focuses on the development of technology for supporting collaboration. The answers to this question will yield an overview of design implications for the creation of groupware, which will be discussed in Sect. 8.

3.1.2 Developing and executing the search strategy

The research questions listed above were used to identify keywords to use as search terms. For example, for the subquestion '*What factors can be attributed to distance*?' the following keywords were selected: *collaboration*, *distance*, *challenge*; in addition, synonyms and related words were also searched (e.g., geography, teamwork). This search can be described by the following boolean search query:

(collaboration OR teamwork OR CSCW) AND (challenge OR problem) AND (distance OR geography)

Our search methodology used multiple searches as terms were either exhausted or identified by collected papers. The generated search terms were used to conduct searches using Google Scholar since this search engine conducts a meta-search that returns results from several paper repositories (such as Science Direct, ResearchGate, Academia.edu, and the ACM digital library). During the review, it became apparent that after the first 8–9 pages of results, we reached concept saturation. As a result, we limited our search to the first 10 pages for a total of 1200 potential sources.

In addition, collected papers were used to generate additional searches via a 'snowballing' effect [26, 249]. Specifically, collected papers were used to generate additional keywords, identify additional papers through the bibliography, identify newer papers that cited them, and identify authors who had written important papers published in relevant conferences. These included papers published in the ACM conference on Computer-Supported Collaborative Work (CSCW) and the ACM International Conference on Supporting Group Work (GROUP). These authors were searched for using the identified search engines, and all their papers were evaluated for inclusion. In addition,

Table 1 Paper inclusion and exclusion criteria

Type	#	Description
Inclusion	I1	Paper is concerned with collaboration
	I2	Paper contains empirical evidence
	I3	Findings are generalizable
Exclusion	E1	Paper is not written in English
	E2	Paper is not peer-reviewed (e.g., master's thesis)
	E3	Paper is not related to at least one of the research questions
	E4	Duplicate paper

other researchers proposed sources that were used to boost paper extraction. These additional methods were used because prior work by Greehalgh and Peacock [91] found that less efficient methods like snowballing are likely to identify important sources that would otherwise be missed, since predefined protocol driven search strategies cannot solely be relied on.

3.1.3 Inclusion and exclusion criteria

The first ten pages of results from Google Scholar were reviewed since occasionally keywords resulted in a high amount of potential papers. All papers were reviewed from searches resulting in fewer than ten pages of results. As part of our search methodology, we utilized several inclusion and exclusion criteria to filter the collected papers from the potential papers found using the systematic search and snowballing. These inclusion and exclusion factors are listed in Table 1. Figure 1 shows the number of identified papers that met the inclusion criteria across 5-year periods.

3.1.4 Paper categorization

To facilitate analysis, the papers identified as part of the LR, shown in Fig. 1, were further categorized by study type and contribution. Tables 2, 3, 4, 5, 6, 7 and 8 in the "Appendix" contain each paper organized by these categories.

4 Factors affecting virtual teams

Virtual teams are affected by physical factors such as geographic distance, in addition to temporal and perceive distance, which are time-based and cognitive respectively. These factors are tightly coupled with social and emotional factors, including trust, motivation, and conflicts. Based on the papers in this literature review, we separate these factors into the categories of distance factors, (which include geographical (physical), temporal, and perceived distance) and contributing factors that are driven by distance (including the nature of the work, the presence or need for explicit management, and group composition). Each category correlates with a set of challenges that greatly affect virtual teams. Distance categories and their associated challenges are discussed in Sect. 5 to answer Research Question 1a: what factors specific to distance cause challenges that impact distance collaboration? Contributing factors are discussed later in Sect. 6.

5 Distance factors

Distance can be categorized as being primarily geographical, temporal, or perceived. Each category correlates with a set of challenges that greatly affect virtual teams. Distance categories and their associated challenges are discussed in the following sections to answer Research Question 1a: what factors specific to distance cause challenges that impact distance collaboration?

5.1 Geographical distance

Geographical distance has been defined as a measurement of the amount of work needed for a worker to visit a collaborator at that collaborator's place of work, rather than the physical distance between the two collaborators [2]. Thus, two physically distant locations could be considered geographically close if they have regular direct flights. Even a distance as small as 30 meters has been

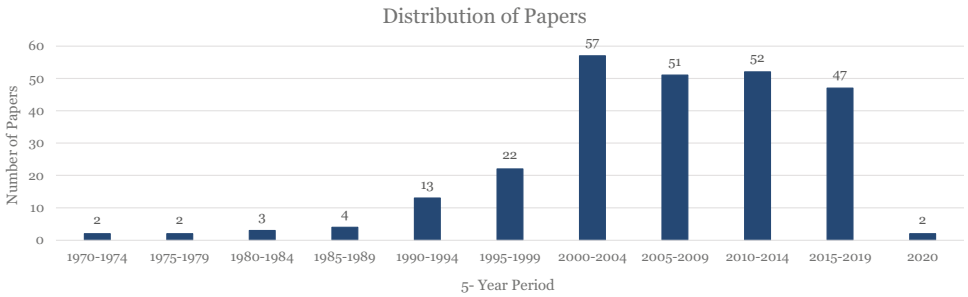

Fig. 1 Distribution of cited papers across time

shown to have a profound influence on communication between collaborators [4].

Furthermore, geographical distance is well known to pose challenges for virtual teams [191]. Olson and Olson explored these challenges at length in 2000 [191] and 2006 [193]. Their first work compared remote and co-located work through an analysis of more than ten years of laboratory and field research examining synchronous collaborations [191]. The 2006 paper presented a follow-up study that synthesized other prior work [78, 190] to expand their 2000 contribution [193]. Findings from both studies identified the following ten challenges that hinder distance work:

1. Awareness of colleagues and their context
2. Motivational sense of presence of others
3. Trust is more difficult to establish
4. The level of technical competence of the team members
5. The level of technical infrastructure
6. Nature of work
7. Explicit management
8. Common ground
9. The competitive/cooperative culture
10. Alignment of incentives and goals

Challenges 1–5 will be discussed in this section while Challenges 6–10 will be topics of interest later in Sect. 6.

5.1.1 Motivation and awareness in distributed collaborations

The motivational sense of the presence of others has well established 'social facilitation' effects, particularly the observation that people tend to work harder when they are not alone [193]. However, these effects are harder to find and cultivate in remote work, which poses an additional challenge to collaboration. In a similar vein, the difficulties associated with maintaining awareness of collaborators' work progress at remote locations without the ability to casually 'look over their shoulder' is a significant challenge to collaboration [193]. The cause of these problems is likely because co-located workers have more opportunities for casual encounters and unplanned conversations [144], which boosts awareness. Similarly, distance prevents the informal visual observations necessary for maintaining awareness [8]. This is important since workers use the presence of specific teammates in a shared space to guide their work and prefer to be aware of who is sharing their work space [71]. Furthermore, the inability of virtual team members to observe each other's actual effort tends to lead to a greater reliance on perceptions and assumptions that could be both biased and erroneously negative [206]. In addition to this, in situations where disengagement is not apparent, virtual team's reliance on technology to communicate allows team members to disengage from the team due to decreased social impact [16]. Isolation can have an effect as well—when members of a virtual team become more isolated, their contributions and participation with the team decrease [32].

The importance of awareness in collaboration is discussed at length by Dourish and Bellotti [62], who investigate awareness through a case study examining ShrEdit [171], a text editor that supports multiple users synchronously. In this paper, awareness is defined as 'an understanding of the activities of others, which provides a context for your own activity' [62]. Dourish and Bellotti further stipulate that this context is necessary for guaranteeing that each person's contributions are compatible with the group's collective activity and plays a critical role in assessing individual actions in accordance with the group's goals and progress. This context further allows individuals to avoid duplication of work. Collaborative work is significantly delayed without such awareness [193]. Moreover, awareness is a mandatory requirement for coordinating group activities, independent of the domain [62].

Many computer-based technologies have been developed to assist distance workers in maintaining awareness of their collaborators. Research suggests that the adoption of tools that allow members of virtual teams about the timing of each other's contributions and activities may improve team coordination and learning [18]. Systems that provide real-time visual feedback about the behaviors of team members can be used as tools to mitigate various sources of "process-loss" in teams (e.g., team effort) [89]. Some early systems (e.g., [17, 81, 160]) were designed to feature computer-integrated audiovisual links between locations that were perpetually open, the idea being that providing unrestricted face-to-face communication and a 'media space' would facilitate collaboration as though the workers were in the same physical space. Since then, a number of modern systems (e.g., [153, 197]) have been developed. For example, Glikson et al. [89] developed an effort visualization tool that calculated effort based on the number of keystrokes that team members made in a task collaboration space. They found that the visualization tool increased team effort and improved performance in teams that had a low proportion of highly conscientious members [89]. This effect did not hold true for teams with a high proportion of highly conscientious members. See the work of [154] for a more comprehensive review of awareness-supporting technology.

The concept of awareness as a direction for research has been criticized. In 2002, Schmidt argued that the term awareness was 'ambiguous and unsatisfactory (p. 2)' due

to its exceptionally wide range of diverse applications and tendency to be paired with an adjective (e.g., 'passive awareness' [62]) in an attempt to lend some specificity. Instead, Schmidt recommended that researchers pursue more explicit, 'researchable questions (p. 10)' rather than focus on the enigmatic concept of awareness. This is more than a call to change terminology, but rather a fundamental shift in the way that research in this area is approached. Despite this recommendation, the awareness approach is still a commonly explored area [7, 134], indicating disagreement within the community that has yet to be resolved, presenting a research opportunity.

5.1.2 Establishing trust

Throughout the relevant studies canvassed in this paper, trust has been defined in a multitude of ways. Cummings and Bromily [53] define trust within a collaboration as the worker's belief that their team (a) 'makes a good-faith effort to behave in accordance with any commitments both explicit or implicit, (b) is honest in whatever negotiations preceded such commitments, and (c) does not take excessive advantage of another even when the opportunity is available'. Pinjani and Palvia [208], in contrast, have a simpler definition of trust as the 'level of confidence exercised among team members,' and Choi and Cho [42] describe interpersonal trustworthiness as characterized by ability, benevolence, integrity, and goal congruence. Trust in the business literature is described as a person's psychological state which indicates the person's expectation that their team member will not act in a self-interested manner at the expense of the person's welfare, which increases readiness to accept vulnerability [44]. Cho redefines this as a person's believe in the beneficial actions of another even with the other is given the opportunity to act in self-interest [41]. Along with this, De Jong et al defines trust as 'a shared and aggregate perception of trust that team members have for each other' [59]. Lastly, Meyerson et al. [174] describe a specific type of trust, known as 'swift trust', which occurs in temporary organizations. The commonalities among these definitions include a perception that trust involves the belief that a collaborator will act in a beneficent manner as opposed to self-interest, acts in good-faith to honor commitments.

According to prior work [23, 42], trust is the key variable that is crucial for all aspects of collaboration This includes team effectiveness, since trust determines whether team members ask each other for help, share feedback, and discuss issues and conflicts [23]. Team trust has a significant effect on team performance [59] and can be considered the 'glue' that holds collaborations together [48]. In fact, building mutual trust and personal knowledge about collaborators is more important to a good collaboration than resolving technical issues [250]. Furthermore, trust is particularly important in virtual teams since interactions on computer-mediated communication (CMC) technologies tend to be superficial (i.e., lacking contextual cues such as facial expressions and tone of voice) [38, 155, 267], impersonal, and less certain [155].

Trust is linked to positive aspects of collaboration. For example, commitment to the team and project is greatly influenced by trust [28]. Trust can also improve collaboration infrastructure [10] and is also crucial for the occurrence of normative actions [48]. Maurping and Agarwal [165] found that building trust early on in a virtual collaboration plays a critical role in developing adequate group functioning and the ability to manage social activities. In addition, virtual teams that develop trust early may notice information confirming the competence of their team members and may not notice contradicting evidence [273]. As a result of their early development of trust, members of these teams also gain the confidence to engage in normative actions that sustain both trust and later performance [48]. While some research has found that the relationship between early trust and performance is stronger in highly virtual teams than in less virtual teams [163], whether the performance actually improves is up for debate. Some prior work [128] reports positive effects of trust on performance while others report negligible or no effects [124]. That being said, trust has an affect on the perception of performance such that when trust is high in a collaboration, the team's perception of its performance is higher [182].

Trust is more difficult to establish and maintain in geographically dispersed collaborations [170, 193, 220] for a variety of reasons including the lack of strong relationships common to co-located teams [36–38, 123] difficulties having in-depth personal interactions due to the absence of nonverbal cues and difficulties inferring the intentions of others [67]. Trust is also dependent on frequency of interactions, which may be less in virtual teams [273]. Swift trust in virtual teams is particularly fragile due to the unexpected disruptions and differences across time, distance, organization, and culture in virtual teams [266]. Teams that interact virtually are considerably less likely to develop trust [216]. Furthermore, trust develops in a sequential approach in co-located tams but follows an ad-hoc, unpredictable approach in virtual teams [147].

This difficulty in establishing trust has profound effects on collaboration, (e.g., (1) corrosion of task coordination and cooperation [193], (2) decreased eagerness to communicate [101], (3) inability to systematically cope with unstructured tasks and uncertainty [123], (4) fewer members willing to take initiative [123], (5) lack of empathy for teammates [132], (6) lower amounts of feedback from collaborators [123]), and increased risk [218]. Additionally,

several studies (e.g., [116, 142, 188]) showed that low trust caused by distance affected workers' identification of themselves as belonging to a team spanning locations. These issues have detrimental effects on collaborations that can delay or even halt the progress of a project.

Lack of trust is most pronounced during the initial stage of the collaboration and tapers off throughout the course of the project [21], implying that there are mitigating factors for the effect of distance on trust. Taking social approaches, such as promoting social exchanges early on in the life of a project [123], or creating opportunities for casual, non-work-related interactions between collaborators [193], can improve trust. However, these types of informal interactions more commonly occur face-to-face [193]. Furthermore, [186] identified face-to-face communication as having an 'irreplaceable' role in building and repairing trust.

Face-to-face communication is not always possible in distance collaborations, which is why [20] investigated challenges associated with trust—particularly delayed trust (slowed rate of progress towards full cooperation) and fragile trust [susceptibility towards negative 'opportunistic behavior (p. 1)']—via an evaluation of four communication methods commonly used in distance collaborations: face-to-face, audiovisual (e.g., Skype [175], Google Hangouts [90], FaceTime [6]), audio (telephone), and text-based (email, [232]) tools. They found that the absence of body language, subtle voice inflections, facial expressions, etc. cause delays in workers' decisions whether to trust a new collaborator and impede expression of their own trustworthiness. This finding agrees with Olson and Olson's assertion that the presence of video when communicating helps in situations where workers are not familiar with each other [193]. The effect of stripping body language, subtle voice inflections, facial expressions, etc. from communication was clearly shown by the performance of people participating in a social dilemma game who relied on distance technology for communication—these collaborations markedly showed more fragile trust than those that communicated face-to-face. Textual communication was especially worse with regards to establishing and maintaining trust, although audiovisual and audio technologies did have some effect on delayed and fragile trust. It is unsurprising then that trust development is enhanced by facilitating an initial face-to-face meeting at the beginning of a team's relationship [163]. Furthermore, the effectiveness, reliability, and usefulness of the CMC technology used by the virtual team affects trust [42]. The personal characteristics of team members (e.g., ability, integrity, competence, fairness, honesty, openness) and the level of autonomy in a team play an important part in establishing trust [42].

From these works, we see that not only does distance influence trust, but this effect can partially be attributed to the use of communication technology adopted by distance collaborations. This influence may be further affected by the manner in which communication technology is used, since irregular, unpredictable, and inequitable communication between collaborators hampers trust [123]. Thus, it is important for future research seeking to address trust in collaboration to consider communication methods, particularly since trust in collaboration is still a relevant issue [29, 30, 217].

5.1.3 Informal and face-to-face communication

Prior work has identified team communication as one of the fundamental challenges associated with virtuality [5]. Communication in virtual teams is a key predictor of various outcomes such as improved performance and increased commitment [76]. Often in co-located collaborations, informal communication (i.e., 'coffee talk' [57]) accounts for up to 75 minutes of a workday [102]. These crucial exchanges often occur after meetings or during unplanned encounters in the hallway [8] and have profound effects on collaboration. In contrast, communications in virtual teams are often more formal than in co-located settings and focus more on work-related issues [13]. This is as a result of limited opportunities for the informal and unintentional information exchanges that often happen in shared spaces such as the hallway, water cooler, or parking lot [13]. This in turn diminishes a virtual team's ability to share knowledge [92]. Informal contact plays an important role in facilitating trust and critical task awareness [2]. Spontaneous, informal communication has been shown to foster the feeling of being a part of a cohesive team [11, 102, 132] and assist the provision of corrective feedback [8]. These types of informal encounters are particularly important for unstable, dynamic groups [2].

Informal communication is associated with face-to-face encounters [73, 191], thus, face-to-face communication plays an important role in collaboration [64] and has been described as being 'crucial' [196] or 'indispensable' [11], particularly at the beginning of a project. Frequent face-to-face interactions enable collaboration in virtual teams [54] and is credited with the ability to dramatically boost the strength of work and social ties within the team [133], which promotes a worker's sense of belonging to the team and awareness of group activities [2], as well as boosting mutual trust and understanding, which is critical for preventing conflicts [8]. In addition, face-to-face communication is associated with higher levels of consensus within groups, higher perceived quality, more communication, and greater efficiency in completing tasks [86]. For this reason, it is recommended by many authors that

members of virtual teams meet face-to-face when possible, particularly during the initial launch [136, 151, 265], when a face-to-face meeting can create a lasting bridge across geographical, temporal, and socio-cultural distance [265]. (Socio-cultural distance will be discussed in further depth later in Sect. 6.4.2) It is unsurprising, then, that traveling for obtaining face-to-face contact is imperative for project success [116].

Opportunities for informal interactions are greatly reduced by geographic distance between collaborators [93, 132]. As a result, remote collaborators are often excluded from spontaneous decisions that are made outside formal meetings [8]. This exclusion is partly as a result of the increased effort needed to reach out and contact a teammate [101], and likely partly due to the correlation between distance and diminished face-to-face communication [52, 133, 141, 144]. Geographic barriers to face-to-face communication include an increase in cost and logistics [2] and the burdens of travel in terms of money and time [11].

It is no surprise, then, that virtual teams show a marked increase in online activity [191, 213] and have a higher reliance on CMC technology [215]. computer-mediated communication technology refers to the use of computers for communication between individuals []. This technology includes audiovisual, audio, and text-based tools. Use of this technology comes with significant challenges. Synchronous technology (i.e., audio and audiovisual tools) requires that all parties be available at a particular time. Some research has shown that it may be difficult to ascertain a remote collaborator's availability for a synchronous meeting [101] and electronic-communication dependence constrains informal, spontaneous interaction [61], while others argue that CMC is dynamic and can be used on an ad-hoc and as-needed basis with no need for scheduling, presenting fewer logistical challenges [234]. However, it is important to note that, like in the case of the telephone, initiating spontaneous communication could be perceived as intrusive [144]. In addition, audio technology 'distorts' verbal cues and removes visual cues [20]. Audiovisual technology is also known to mask both verbal and visual cues in addition to constraining the visual field [20]. CMC often lacks support for non-direct and nonverbal interactions (e.g., body language, facial expressions) which greatly hinders communication in geographically dispersed virtual teams [67] by making interactions more difficult [92]. Thus, the choice of CMC technology has a heavy influence on communication because each method offers a different capacity to convey verbal and nonverbal cues [178]. It is therefore recommended to use several types of CMC technologies either concurrently (e.g., face-to-face communication accompanied by documents; telephone conferencing with synchronous electronic conferencing) or consecutively (e.g., conveying information via e-mail first, followed by con verging over the phone) [60].

Virtual teams that rely on CMC in lieu of face-to-face communication are more likely to experience less positive affect and have a diminished affective commitment to their teams [126]. Furthermore, compared to face-to-face feedback, computer-mediated feedback reduces perceptions of fairness [3]. This lack of face-to-face contact results in virtual teams having a lower sense of cohesion and personal rapport between team members [263]. Members of virtual teams may also divide their attention between various tasks while simultaneously participating in teamwork interactions due to the asynchronous nature of communication media, resulting in a lack of investment in the tasks [163]. As a result, communication timeliness has a higher influence on performance in virtual teams [163]. Furthermore, virtual teams that rely on CMC technology (e.g., instant messaging) to supplement communication in the absence of face-to-face interactions may have difficulties in their decision-making processes [173].

However, overall, communication technologies (including text-based tools) take more time and effort to effectively communicate information and are missing important social information and nonverbal cues that help establish ties between collaborators [64]. This has important implications for situations where a high volume of communication is necessary. Due to the extra effort required to communicate through computer-mediated modalities (e.g., email), virtual teams must put in extra effort to manage high volumes of messages, which can hinder performance [163]. Furthermore, when teams use email for communication, it becomes difficult to determine whether the information contained within the email was understood in the absence of vocal and nonverbal cues [163]. To combat this, Marlow et al. [163] suggest using closed-loop communication to prevent misunderstandings by providing opportunities for clarification that would otherwise not accompany virtual communication. They argue that the use of closed-loop communication will enhance performance in virtual teams [163].

Since remote collaborations must rely on technology in lieu of face-to-face communication, the level of technical competence of the team members can pose an additional challenge [193]. Teams that are unable to adopt and integrate basic technology into their everyday workflow are unlikely to use more complicated and sophisticated collaboration technology (e.g., multi-pane videoconferencing) [191] that may better support visual and verbal cues, enriching distance communication. Furthermore, the level of technical infrastructure can also create collaboration challenges [193]. Technology for remote work fails without adequate technical support or resources. Reliability is also an issue with communication technology—new

technology must be stable enough to 'compete with the well-established reliability of the telephone' [15].

There are some advantages to using commuter-mediated communication technology in virtual teams. For example, asynchronous technology (e.g., text-based tools) provide provide the ability to take one's time when asking a question or crafting a response [144, 261], which leads to efficient, focused conversations [77, 144] that can be quicker than other forms of communication. CMC is also shown to increase participation among team members [212], facilitate unique ideas [86, 212], and reduce the number of dominant members [212]. In a similar vein, Fjermestad [79] found that groups that relied on CMC experienced higher decision quality, depth of analysis, equality of participation, and satisfaction than groups that primarily met face to face. Finally, virtual teams that do not meet face to face may be better at adapting their conceptualization of a task in response to a team member completing a task in a novel manner [163]

Additional factors, such as experience with a task, interdependence, and the temporal stage of team development can impact team performance when relying on CMC technology. For example, when teams have experience with the task at hand, with each other, and with their communication method, there is less of a need for synchronous CMC technology (e.g., video conferencing) [60]. In contrast, when teams do not have this extensive experience, there is a greater need for synchronous CMC technology [60]. Organizational structure, levels of interdependence, and media richness (which ranges from face-to-face communication to simple documents) also influence the effectiveness of communication [140]. These factors vary depending on the communication method's capacity for immediate feedback, ability to facilitate nonverbal cues, and level of personalization [140]. In addition to this, Maruping and Agarwal [165] found that matching the functionalities of the CMC technology to specific tasks will result in higher levels of effectiveness in virtual teams. Furthermore, stage at which a virtual team is at in their development will also affect communication [165]. Teams in their early stages of development should use CMC technologies that facilitate expression in order to mitigate relationship conflict [165]. Video-conferencing technologies are particularly suited for this situation being both synchronous and media rich [165].

From the identification of these challenges, we can clearly see that existing tools and infrastructures have limitations that are preventing communication technology from fully supporting informal interactions. Thus, we are left with a need for other methods that support informal communication in geographically dispersed collaborations.

5.1.4 Intra-team conflict

In Jehn et al.'s exploration of everyday conflict through qualitative investigation of six organizational work teams, intra-team conflict is categorized as being either affective (i.e., interpersonal), task-based, or process-based (i.e., relating to responsibilities and delegation of workers for tasks) [125]. All three types of conflict have been investigated within the context of geographically distributed versus co-located teams, with mixed results. Several researchers have concluded that geographically distributed teams experience higher levels of conflict [8, 46, 103, 108, 188, 261]. In particular, geographically distributed teams are more susceptible to interpersonal [108] and task-based conflict [108, 179]. There is some evidence that conflict has a more 'extreme' [107, 159] or 'detrimental' [179] effect on distributed teams as opposed to co-located ones. This effect can likely be attributed to the evidence that conflict in distributed teams is known to escalate and often remains unidentified and unaddressed for long periods of time [8]. As a result of reliance on computer-mediated communication, virtual teams featuring high geographical dispersion have higher perceptions of unfairness, which also leads to internal conflict [244].

One pervasive issue is the development of geographically based subgroups within a collaboration that provoke us-versus-them attitudes [8, 46]. Armstrong and Cole observed that the word 'we' was often used to refer to co-located workers, regardless of which group the workers were assigned [8]. In another case, a team of international collaborators spread across four sites 'fought among themselves as if they were enemies'. Interviews exposed that the team was actually comprised of four groups under one manager and did not act or feel like one cohesive team [8]. These conflicts are similar to those associated with communicating at a distance. Conflicts frequently occur as a consequence of assumptions and incorrectly interpreted communications [103]. Furthermore, missing information and miscommunications between geographically distant sites result in teammates making harsh attributions about their collaborators at other locations [46]. These types of intra-group conflicts can have important ramifications for distant collaborations. Us-versus-them attitudes often lead to limited information flow, which in turn leads to reduced cohesion and faulty attributions [46]. Moreover, intra-team conflict causes problems that result in delays in work progress [8] and resolution of work issues [103].

Researchers have identified several things that can mitigate conflict in virtual teams. Both shared context [108] and a shared sense of team identity have a moderating effect on conflict [108, 179], particularly task and affective conflict [108, 179]. Familiarity, in addition, has been shown to reduce conflict [107]. Spontaneous

communication—which, as previously discussed, is primarily achieved face-to-face—has been demonstrated to mitigate conflict in virtual teams, particularly due to its role in facilitating the identification and handling of conflict [108]. There are also more instances of task conflict in teams that rely heavily on communication technology [179]. Specific types of conflict can be managed through different forms of computer-mediated communication technology. Task related conflict, for example, is best managed through synchronous communication technologies such as video-conferencing [165]. Conflict related to processes can be effectively handled using asynchronous communication technologies that also document the team's agreements regarding tasks and responsibilities [165]. In this case, immediate feedback is not as necessary [165].

Although the above work has come to an agreement as to whether geographic distance has a negative effect on conflict, contradictions do exist in the literature. In particular, Mortensen and Hinds' [179] examination of 24 product development teams found no significant difference in affective and task-based conflict between co-located and distributed teams, which is in direct conflict with their later work [108]. This discrepancy is particularly interesting given that the participants in both studies did research and product development, and are therefore comparable. Thus, it is uncertain as to which conclusion is accurate, presenting an open question.

5.2 Temporal distance

Temporal distance is distinctly different than geographical distance and should be treated as a separate dimension [49]. While geographical distance measures the amount of work needed for one collaborator to visit another at that collaborator's place of work, temporal distance is considered to be a directional measurement of the temporal displacement experienced by two collaborators who want to interact with each other [2]. Temporal distance can be caused by both time shifts in work patterns and differences in time zones [219]. In fact, time zone differences and time shifts in work patterns can be manipulated to either decrease or increase temporal distance [2]. It can be argued that temporal distance is more influential than geographic distance [75, 213, 243, 250] due to the challenges it poses on coordination [49, 74, 75, 141, 183, 213, 243].

One key disadvantage to high temporal distance is the reduced number of overlapping work hours between collaboration sites [11, 33, 132]. Although in an ideal situation, having team members dispersed across time zones can allow continual progress on a project as each team member works within their respective workdays [256], this isn't always the case. In fact, temporal distance can lead to incompatible schedules that result in project delays and can only be overcome with careful planning [230]. Fewer overlapping work hours results in communication breakdowns, such as an increased need for rework and clarifications, and difficulties adjusting to new problems [73, 74]. Additionally, reduced overlap in work hours results in coordination delays [49]. For example, a distant teammate may not be available when their expertise is needed [2]. In some cases, this unavailability causes the collaborator in need of help to make assumptions based on local culture and preferences in order to reach an immediate resolution of issues—which can cause rework when these assumptions are incorrect [250]. The issue of the lack of overlapping work hours also causes problems with synchronization; synchronous communication is often significantly limited in temporally dispersed collaborations, which can delay vital feedback [2] and increase response time [219]. In fact, scheduling global meetings can be virtually impossible for this reason [250]. Furthermore, as with geographic distance, temporal distance decreases the number of opportunities for informal communication [93, 132] since the window in which all collaborators are available is small.

Communication can be disrupted by temporal distance in other ways. Bjørn and Ngwenyama found that in some virtual teams, communication would become limited to temporally co-located teammates because it was easier, bypassing teammates at other sites who should have been included [14]. This invisible communication would result in collaborators feeling left out of key decisions, which had toxic effects on the project. This effect is especially unfortunate given that temporal distance makes repairing the consequences of misunderstandings and reworking portions of the project more costly [73].

In addition to these issues, temporally dispersed collaborations are often plagued by delays, while co-located collaborations are considered more efficient [19]. Coordination delay increases with temporal distance—delay between collaborators located in the same city was smaller than that for collaborators in different cities, which was smaller than the delay found in collaborators located in different countries [49]. Delays in responses from collaborators can be especially frustrating and problematic [116] and can lengthen the amount of time required to resolve issues [19], sometimes dragging problems out across multiple days [120, 132]. When work is organized such that a team member's contribution is dependent upon a task completed by a team member in an earlier time zone, a failure to complete the earlier task can result in the loss of an entire workday [250]. Thus, timely completion of tasks in temporally dispersed collaborations is crucial [250]. Coordination delays are also shown to cause additional problems, particularly decreased performance in terms of

meeting key requirements, staying within the budget, and completing work on time [49].

There are several social approaches to mitigating these issues. For example, collaborators can cultivate flexible work schedules [116], often by modifying a 'typical' workday by working either extremely early in the morning or very late at night so that there are overlapping work hours [250]. In contrast, Holmstrom et al. found that both Hewlett Packard (HP) and Fidelity employed a 'follow-the-sun' concept where work is handed off at the end of the day in one time-zone to workers beginning their day in another [116]. Follow-the-sun methodologies, if used effectively, can result in efficient, 24/7 productivity since work can be completed by one team member during another's off hours [2, 93, 103]. However, this technique requires additional oversight time to facilitate the transfer of work from one team to the other, including time to discuss arising issues [250]. A competing technique is to limit the number of time zones in which sites are located [116]. Additionally, some coordination issues can be mitigated by careful division of work which takes into account being separated by several time zones [49].

Technology also plays a key role in mitigating the effects of temporal distance. Asynchronous communication tools (e.g., email, fax [19, 57]) allow collaborators to coordinate shared efforts across time and distance with the additional benefits of leaving a written communication history [31] that supports accountability and traceability [2]. However, using asynchronous tools is known to increase the amount of time that a collaborator has to wait for a response [2] and make temporal boundaries more difficult to overcome than spatial boundaries in instances where sites do not have overlap in their workdays [49]. Furthermore, the process of writing ideas in emails increases the risk of misunderstandings between collaborators [57] over talking in person or via the telephone. Finally, developers starting their workday may become overwhelmed by the number of asynchronous messages left during the previous night [19]. Given these drawbacks to current technology and the unlikelihood that global collaboration is going to stop, it is worthwhile to ask how can we better support communication in temporally distant work.

There is also some question as to whether coordination costs are higher in teams that are temporally distributed. Both Ågerfalk et al. [2] and Battin et al. [11] assert that temporal distance greatly increases the cost and effort of coordination due to the added difficulties of dividing work across multiple time zones. Espinosa and Carmel [73], however, state that temporal distance reduces coordination costs when team members are not working concurrently because no direct coordination takes place when the two teammates are not working at the same time [2]. Clearly, this discrepancy needs to be resolved.

5.3 Perceived distance

As previously discussed in Sects. 5.1 and 5.2, distance is commonly conceptualized in terms of geography or time zones [4] (i.e., spatio-temporal distance). In contrast, perceived (a.k.a. subjective) distance is characterized by a person's impression of how near or how far another person is [270]. These perceptions of proximity have both an affective and a cognitive component [189]. In this case, the cognitive component refers to a mental judgement of how near or distance a virtual teammate seems while the affective component is concerned with the idea that a person's sense of perceived proximity is neither purely conscious or rational but is instead dependent on emotions [189]. Perceived distance is a distinctly different idea than spatio-temporal distance and one is not necessarily related to the other [215]. Rather, perceived distance is the "symbolic meaning" of proximity rather than physical proximity and is suggested to have a greater effect on relationship outcomes [189]. This symbolic meaning is defined by the teams sense of shared identity and their use of communication media, which is primarily synchronous [189]. In fact, as people interact strongly and frequently with other team members, they can create a sense of closeness independent of physical proximity [214]. For example, free and open source software developers often perceive high levels of proximity due to their strong and intense communication and "hacker" identities [214]. The concept of perceived distance is why collaborators may be geographically distant and yet feel as though they are proximally near [162]. Perceived proximity can have a profound influence on team interaction [34, 82, 189] For example, perceptions of proximity are known to influence decision making in virtual teams [198].

In 2014, Siebdrat et al. surveyed 678 product developers and team leaders in the software industry to investigate perceived distance and challenge the notion that geographic and temporal distance directly translates to perceived distance. They found that perceived distance was more strongly affected by a team's national heterogeneity than by their spatio-temporal distance. Furthermore, Siebdrat et al. found that perceived distance had a significant effect on collaboration while spatio-temporal distance had no impact. As a result, they concluded that perceived distance is more indicative of collaboration challenges than spatio-temporal distance.

Findings from other work implies that distance can affect collaborators that are all in the same country at a single site [4], with low national heterogeneity and low spatio-temporal distance. It is uncertain whether this situation would still have high perceived distance given the limited work available. Therefore, there is a clear need for a better

understanding of the relationship between perceived distance, spatio-temporal distance, and collaboration.

6 Contributing factors

In addition to the challenges associated with the three main types of distance discussed previously in this paper (i.e., geographic, temporal, and perceived distance), several contributing factors intersect with distance to cause additional challenges for virtual teams. To answer Question 1b (What other factors contribute to the factors and challenges that impact distance collaboration?), this paper will discuss these key factors, namely the nature of work, the need for explicit management, configuration, and diversity of workers in a collaboration.

6.1 Nature of work

Work can be categorized as either loosely or tightly coupled [191]. Tightly coupled work relies heavily on the skills of groups of workers with exceedingly interdependent components; this type of work necessitates frequent, rich communication and is usually non-routine. Loosely coupled work, in contrast, is typically either routine or has fewer dependencies than tightly coupled work. Interdependence between components, and thus tightly coupled work, is at the heart of collaboration [225]. In addition, complex tasks lead to higher trust and collaboration than simple tasks and task complexity is a critical factor that molds the interactions and relationships between team members [42]. Furthermore, interdependence is not merely an issue of sharing resources, but instead 'being mutually dependent in work means that ***A*** relies positively on the quality and timeliness of ***B***s' work and vice versa and should primarily be conceived of as a positive, though by no means necessarily harmonious interdependence' [225]. Marlow et al. [163] found that as interdependence increases, communication becomes increasingly critical. They therefore suggest that communication becomes increasingly important to promoting high levels of performance. In 1988, Strauss described the additional work necessary for collaborators to negotiate, organize, and align their cooperative (yet individual) activities that occur as a result of interdependence. In doing so, Strauss discusses the concept of articulation work—by his definition, work concerned with assembling tasks and adjusting larger groups of tasks (e.g., sub-projects and lines of work) as a part of managing workflow. Articulation work is further described as the additional work needed to handle the interdependencies in work between multiple collaborators [72].

Virtual teams face greater challenges when managing these dependencies as a result of distance, both spatial and temporal, and culture [72]. Because interdependent (i.e., tightly coupled) work requires a high amount of interaction and negotiation, it is very difficult to do at a distance [191]. In contrast, loosely coupled work does not require as much communication as tightly coupled work, and so is easier to complete in geographically distant collaborations. Thus, tightly coupled work in virtual teams leads to less successful projects [193]. This observation is important since most projects have both varieties of work [191].

To combat the challenges associated with relying on tightly coupled work, many organizations take a social approach that arranges for co-located team members to work on tightly coupled aspects of the project while distance workers tackle loosely coupled parts [64, 193], facilitated by deconstructing tasks into smaller pieces [93]. For tightly coupled work, some organizations choose to use extreme [161] or radical [246] collaboration setups where teams work in an enclosed environment in order to maximize communication and facilitate the flow of information. In contrast, for loosely coupled work, some organizations choose to minimize interaction [104]. Creating rules and norms for communication between team members early in the team's life cycle can also increase effective communication and therefore improve performance during complex tasks [262]. This is essential for managing highly complex tasks and avoiding misunderstandings that can arise as a result of high task complexity combined with high virtuality [163].

However, the idea that tightly coupled work challenges collaboration is contested by Bjørn et al. [15]. This case study is centered on a large research project investigating global software development with several geographically dispersed partners. This study also provides evidence that tightly coupled work resulted in stronger collaborations. They observed that tightly coupled work required collaborators to frequently interact to do their work and, as a result, forced these collaborators to know more about each other, help each other, and cultivate strong engagement despite being at geographically distant sites. In contrast, loosely coupled work did not require the same level of engagement, resulting in collaborators feeling more detached from the project. Thus, Bjørn et al. proposed that tightly coupled work in geographically distributed teams involves processes that help collaboration [15].

Complex, tightly coupled tasks may be more difficult to the reliance of virtual teams on virtual tools and tendency to disband after a task has been completed [12]. Furthermore, the combination of high task complexity and high levels of virtuality lends itself to misunderstandings and mistakes [163]. As a result, effective communication

is more critical for high performance in virtual teams for these tasks [163]. Despite this, Marlow et al. suggest that virtual teams can successfully complete these tasks if team members cultivate shared cognition. Given the characteristics of CMC technologies like video conferencing, which preserve much of the nuances present in face-to-face communication, we posit that shared cognition can be developed through the frequent, consistent use of this medium for communication.

Given the contrast between the work suggesting that tightly coupled work hinders distance collaboration [72, 191, 193] and work by Bjørn et al. [15] that suggests the opposite, there is clearly room for further research on the subject. This is especially true since Bjørn et al. focused only on global software development, and thus their findings might not generalize to other types of collaboration.

6.2 Explicit management and leadership

One of the largest challenges faced by virtual teams is the management of team effort [207]. Explicit management is needed for distributed, collaborative work, particularly by leaders trained in project management, in order to ensure the success of a project [150, 193]. Collaborative projects are considered difficult to manage, especially as the number of workers associated with the project increases. Leadership is challenging in geographically dispersed teams because effective leadership is highly dependent on quality interactions that are more difficult across distance [157]. For example, Hoch and Kozlowski [111] found that hierarchical leadership is less effective in geographically dispersed teams than in co-located teams. It is also more challenging to ensure that the team's work is given priority by the team members in geographically dispersed teams [131]. Furthermore, distributed projects face even more obstacles, such as increased coordination problems [188] including identifying and overcoming cultural differences, ensuring that all team members are heard [193], and regulating the inter-dependencies between resources, task components, and personnel [158].

Virtual teams face challenges related to leadership, such as nourishing an environment that fosters creativity [96] and emergent leadership [35]. Effective leadership benefits geographically dispersed virtual teams in a multitude of ways, including helping virtual teams overcome many of the challenges caused by distance, including facilitating satisfaction and motivation [88, 169]. Virtual leadership can help collaboration within the team through providing training, guidance, resources, coaching, and facilitating relationship building [150]. Furthermore, leadership in virtual teams can facilitate knowledge sharing and the building of shared mental models [150]. Mental models are defined by Johnson-Laird [126] as internal representations of knowledge that match the situation they represent and consist of both abstract concepts and perceptible objects and images. These mental models may reflect detailed information about how the task is to be performed (i.e., task-related team mental models) or information about team member's roles, tendencies, expertise, and patterns of interaction (i.e., teamwork-related mental models) [226]. These benefits, in turn enhance virtual team effectiveness [150]. Task complexity can be a mitigating factor in the effectiveness of leadership. Leadership benefits the team more in an environment where tasks are highly interdependent and/or highly complex [150]. In addition to this, team members' perceptions of their leaders' use of communication tools and techniques can impact their perceptions of overall team performance [182]). In particular, positive perceptions of leadership communication results in positive perceptions of performance [182].

Leadership can have a strong influence on interpersonal team dynamics and trust as well. Prior work indicates that leaders play an important role in enhancing team performance by demonstrating empathy and understanding [131], monitoring and reducing tensions [260], and clearly articulating role and relationship expectations for team members [131]. Leaders in virtual teams have the capacity to prevent and resolve team relationship and task conflicts [150]. Furthermore, effective leadership can have a positive influence on affection, cognition, and motivation [150]. It is particularly important for leaders to bridge co-located and remote team members in order to promote team effectiveness [150]. Leaders can build trust within virtual teams by engaging in behaviors such as early face-to-face meetings, using rich communication channels, and facilitating synchronous information exchange [150]. High levels of consistent communication between leaders and team members is positively related to trust and engagement within virtual teams [80].

Individual leadership styles have their own impact on virtual team productivity. Prior work has focused on four key types of leadership: transformational, empowering, emergent, and shared. Transformational leadership is characterized by idealized influence, inspirational motivation, individual consideration, and intellectual stimulation [65]. This type of leadership enables followers to reach their potential and maximize performance [65]. However, transformational leadership, while effective in co-located or slightly dispersed teams, is less effective in improving the performance of highly geographically dispersed teams [69]. This may be due to the difficulties associated with facilitating communication across distance, which can cause the leader's influence to have counterproductive effects [69]. In this case, the leader is likely to be "too far removed" to authentically want to make a difference [69]. In fact, a transformational leader's influence on team

communication decreases as the team becomes more and more dispersed [69].

Empowering leadership combines sharing power with individual team members while also providing a facilitative and supportive environment [236]. High empowering leadership has the effect of positively influencing team members' situational judgement on their virtual collaboration behaviors and, ultimately, individual performance [105]. Moreover, empowering leadership has a positive effect on team performance at high levels of team geographic dispersion [105]. However, it is important to note that teams may miss out on the benefits provided by empowering leadership if they lack situational judgement [105]

Emergent leaders are people who exert significant influence over other members of a team, even though they may not be vested with formal authority [227]. Emergent leadership has a positive relationship with virtual team performance [110]. In particular, emergent leadership has positive relationships with team agreeableness, openness to experience at the individual team member level, and emotional stability [110]. In addition, emergent leadership has a positive relationship to individual conscientiousness, which is associated with being careful, responsible, and organized [110]. These all have positive influences on virtual team performance [110].

Shared leadership is a collective leadership processing featuring multiple team members participating in team leadership functions [110]. This form of leadership can be described as a "mutual influence process" where members of a team lead each other towards the accomplishment of goals [109]. Shared leadership has a positive influence on the performance of virtual teams [110, 150]. The structural support provided by shared leadership can supplement traditional leadership; in this situation, shared leaders assume the responsibility of building trust and relationships among team members [150]. Shared leadership provides many benefits to virtual teams such as emotional stability, agreeableness, mediating effects on the relationship between personality composition and team performance [110]. Shared and emergent leadership styles share some effects on virtual teams. Specifically, these types of leadership will affect the relationships between team conscientiousness, emotional stability, and team openness such that they will be stronger in teams with higher levels of virtuality than in teams with lower levels of virtuality [110]. However, shared leadership is facilitated by the socially-related exchange of information that creates commitment, trust, and cohesion among team members [110]. In co-located teams, this exchange of knowledge is enabled through social interactions like informal conversations, socializing outside of work, and through meetings [110]. However, this type of informal and face-to-face communication is less common and feasible in virtual teams for reasons that will be discussed later. As a result, it is necessary for organizations to make efforts to facilitate shared leadership through training [110].

In addition to leadership style, the level of authority differentiation and skill level of the team members have an affect on team-level outcomes. Among teams with less skilled members, centralized authority (i.e., high authority differentiation) will have a positive influence on efficiency and performance in virtual teams [223]. In contrast, centralized authority has a negative influence on team innovation, learning, adaption, and performance as well as member satisfaction and identification among teams with highly skilled members [223]. Decentralized authority (i.e., low authority differentiation) when combined with careful intervention of a formal or informal leader can benefit coordination, learning, and adaptation in virtual teams with high skill differentiation and high temporal stability [150].

Other studies showed that virtual teams face challenges that could be mitigated with explicit management [83, 188, 243, 261]. O'Leary and Mortensen investigated the effects of configuration (i.e., the distribution of team members across multiple sites) on team dynamics at the individual, subgroup, and team level [188]. They found that geographically defined subgroups led to significantly negative outcomes with regards to coordination problems (e.g., difficulties with coordination-related decisions about schedules, deadlines, and task assignments). The effects of configuration on distance work will be discussed further in this section. Similarly, problems of coordination (e.g., 'reaching decisions' and 'division of labor") were significantly increased by distance [261]. These results are complemented by findings that distance hampers the coordination of virtual teams via synchronous meetings [243]. Similarly, coordination in distance collaborations is hindered by difficulties in scheduling synchronous meetings due to limited windows of time where all parties are able to be present [83]. These findings complement those of Sect. 5.2 discussing the effect of temporal distance on collaboration.

Prior work has suggested various strategies for effective leadership and explicit management. For example, Hill and Bartol [105] suggest team training that focuses on strategies for overcoming challenges encountered in dispersed teamwork. Another, related, strategy is to focus more attention on setting norms for behavior that may aid appropriate situational judgment among team members when launching geographically dispersed teams [105]. A different approach is to consider personality dimensions such as agreeableness, conscientiousness, openness, emotion stability, and moderate extroversion, which all have

positive influences on team performance, when selecting virtual team members [110].

However, some types of collaborations, particularly research collaborations consisting mainly of scientists, avoid the application of explicit management in their projects [193]. There is an opportunity for research to investigate how to support explicit management in distance collaborations that typically reject this type of administration.

6.3 Configuration

Like O'Leary et al. [188], in this paper, configuration is subdivided into three dimensions: site, imbalance, and isolation. Site dispersion is best characterized as the degree to which collaborators are at distinct geographic locations [187]. There is an inverse relationship between the number of sites and project success [50, 51, 133]. High site dispersion is associated with higher amounts of faultlines (i.e., theoretical divisions within a group that create subgroups) which damage team collaboration [47, 210]. Specifically, faultlines escalate polarization, subgrouping, and the effect of causing collaborators in other locations to feel more distant [47]. Having a large number of sites, in particular, increases the odds that differences in demographics will create these divisions [47]. Additionally, greater numbers of sites predict fewer coordination activities and decreased outcomes [133]. Knowledge sharing decreases [40, 83] and the cost of managing team goals increases [97] as the number of sites increases.

Imbalance refers to the proportion of collaborators dispersed across a set of sites and can have negative effects on collaboration, such as conflicts between large and small sites [8]. For example, imbalanced teams often have unequal amounts of contribution towards shared team tasks [188]. Furthermore, levels of conflict and trust differ between imbalanced and balanced teams [188, 210]. In particular, larger subgroups in imbalanced teams feel stronger effects from faultlines on conflict and trust [210]. However, it is unclear what the ramifications are of these differences in trust and conflict [188, 210], presenting an opportunity for research.

Imbalanced teams consisting of one isolated collaborator working with a co-located team function differently than highly dispersed, balanced teams [188]. For instance, communication in these imbalanced teams is different because the co-located team members communicate both face-to-face and electronically with each other, but, in the absence of travel, only communicate electronically with the isolated team member [231]. This disparity in communication methods impedes informal interaction and spontaneous communication [45]. This also has a unique effect on communication where the co-located team feels compelled to communicate with those isolated collaborators more frequently to make up for this difference [188]. Also, isolated members tend to contribute more frequently than their co-located counterparts because they feel as though they need to 'speak up' and be 'heard' over the co-located team [141, 188].

Furthermore, isolation negatively affects a worker's awareness of collaborator's activities [187]. Isolated workers are also more likely to feel the effects of a lack of motivational sense of the presence of others [193]. These isolated workers identify less with the team and feel less like they are part of the group, leading to a feeling of distance from the rest of the team [45], which translates to feeling differently about group processes and outcomes [27]. Furthermore, isolation and feelings of alienation can have a negative effect on relationships among workers in geographically dispersed virtual teams, increasing the likelihood of feeling discomfort and reducing the likelihood of trusting team members that they do not know well [67].

Configurationally imbalanced teams (i.e., teams that have an uneven distribution of members across sites) tend to have lower identification with teammates and higher levels of conflict [188]. Conflict can be reduced by a shared sense of team identity [108, 179], meaning that fostering this sense of identification with the team can mitigate both problems. Since team identification can be built via face-to-face communication [54]; we posit that in the absence of face-to-face communication, imbalanced teams should make use of CMC technologies that facilitate nuanced expression, such as video conferencing tools.

6.4 Group composition

The diversity of a team encompasses several factors that correlate with a set of challenges that greatly affect virtual teams. This section will focus on the issues of common ground, socio-cultural distance, and work culture. In the process, this section will discuss the remaining challenges identified by Olson and Olson [191, 193], (continued from Sect. 5): common ground, the competitive/cooperative culture, and alignment of incentives and goals.

6.4.1 Common ground

Distance collaboration becomes easier if team members have common ground (i.e., have worked together before [54], have shared past experiences [54], vocabulary [191], or mental models [168] etc.) since it allows them to communicate via technology without requiring frequent clarification [193]. This challenge is also referred to as the 'mutual knowledge problem' [46]. The concept of mutual knowledge between teammates is based on the idea of 'grounding' in communication [43], which is done by both communicating and confirming understanding using

words or body language [43]. Schmidtke and Cummings [226] found that as virtualness increases in a team, mental models become more complex, which negatively affects teamwork. They also found that as virtualness increases, similarity and accuracy of mental models decreases [226]. Accuracy and similarity play vital roles in reducing the negative effect of complexity on teamwork behaviors [226]. Fortunately, specialized training can increase mental model accuracy [226].

As virtual teams rely more on computer mediated communication, temporal stability (i.e. "the degree to which team members have a history of working together in the past and an expectation of working together in the future" [115]) more strongly influences teamwork [223]. High temporal stability is associated with positive team outcomes related to related to adaptation, learning, innovation, and performance, as well as satisfaction and identification with the team [223]. In addition to this, the extent to which virtual team members share common goals is critical in determining the success of the team [42, 230]. For this reason, team leaders should ensure that team members commit to the task and common goals [10].

Research [168] has shown that it is more difficult for virtual teams that are geographically dispersed to develop a shared mental model. In particular, the process of grounding is made more difficult when there is a higher risk of misinterpretation, such as in the presence of multiple cultural practices and languages [191].The significant amount of time required to establish common conceptual frameworks and personal relationships can pose a significant constraint on collaboration in virtual teams [54].

The consequences of lack of common ground are primarily difficulty building trust [123, 202, 273] and difficulties associated with communication. Lack of common ground can limit the ability to communicate about and retain contextual information about teammates located at other sites, including their teammates situation and constraints, especially as the number of sites increases, in turn hindering their collaborative interactions and performance [46, 230]. This contextual information includes, but is not limited to, local holidays and customs, site-specific processes and standards, competing responsibilities, and pressure from supervisors and teammates [46]. Common ground is also necessary to understand which messages or parts of messages are the most salient, which is particularly problematic because there may be restricted feedback [46]. The lack of common ground can also create problems interpreting the meaning of silence, which makes it difficult to know when a decision has been made [46]. Furthermore, lack of common ground can result in an uneven distribution of information and differences in speed of access to that information, which causes teammates at different sites to have different information and creates misunderstandings that are nontrivial to rectify [46].

Thus, the establishment of common ground is of utmost importance to virtual teams.

6.4.2 Socio-cultural distance

Socio-cultural distance has been defined as a measurement of a team member's perception of their teammate's values and usual practices [2]. This concept encompasses national culture and language, politics, and the motivations and work values of an individual [2]. It is known that geographically distributed collaborations are more socio-culturally diverse than co-located ones [179] because distance typically increases demographic heterogeneity (especially racial or ethnic heterogeneity) [107]. Members of a virtual team with different cultural backgrounds are likely to have different behaviors within the teams, including how they interact with their teammates [123]. For this and other reasons, virtual team's cultural composition is the key predictor of the team's performance [242].

Cultural differences go beyond national differences. There is a tendency for researchers studying cross-cultural organizational behavior to focus on national issues or use nation as a substitute for cultural values [245]. However, nation is not the only meaningful source of culture [84, 149]. In addition to this, there may be multiple subcultures within a nation and the national culture may not be completely shared [135]. In fact, variation of cultural values within a country may be higher than variation between countries [114]. Therefore, a virtual team with high national diversity may not necessarily be culturally diverse [86].

Prior research has identified three levels of diversity: surface-level, deep-level, and functional-level [99, 177]. Surface-level diversity is primarily observable differences such as race, age, and sex, while deep-level diversity is comprised of more subtle differences in personal characteristics such as attitudes, beliefs, and values, which are communicated through interaction between team members and information gathering [177]. Functional-level diversity, in contrast, refers to the degree to which team members have vary in knowledge, information, expertise, and skills [10].

The individualism-collectivism dichotomy is a 'major dimension of cultural variability' [112] that contributes to high socio-cultural distance. Socio-cultural distance is associated with higher levels of conflict as well as lower levels of satisfaction and cohesion [238] and has a profound impact on team performance [70]. Hardin et al. [98] found that the individualistic-collectivist dichotomy results in some cultures being more open to working in

geographically dispersed environments due to their levels of self-efficacy beliefs about virtual teamwork.

Collectivist cultures place the needs, beliefs, and goals of the team over the those of an individual [94, 112]. Virtual teams characterized by collectivist culture are less likely to use CMC technologies [143]. When they do choose to adopt CMC technologies, collectivist teams tend to choose synchronous methods that provide high relationship-related informational value [143]. Informational value in this context refers to the extent to which CMC technologies convey information benefits team effectiveness [143]. Virtual teams that favor in-group members and accept perceptions of inequality are said to be characterized by "vertical collectivism" [254]. These teams are less likely to rely on CMC technologies, and are more likely to accept varying forms of informational value [143]. They are also more likely to employ asynchronous methods [143]. In contrast, teams that perceive equality amongst team members regardless of their role within the organization experience "horizontal collectivism" [253]. In this case, members of the team view themselves as being part of a collective and treat all team members as equal. [253]. While these teams are also likely to limit reliance on CMC technologies, they tend to require higher informational values and prefer synchronous methods [143].

In contrast to collectivist cultures, individualist cultures place the needs, beliefs, and goals of the individual over the those of an team [112]. Virtual teams with high levels of individualism are more likely to use CMC technologies, especially those that are high in task-related informational value, and tend to work asynchronously [143] Furthermore, team members from individualist cultures tend to communicate more openly and precisely [112, 113] and are more willing to respond to 'ambiguous messages' [94], which is considered to be an indicator of trust [203]. This observation indicates that team members from individualistic cultures may be more ready to trust other teammates when communicating via technology than team members from collectivist cultures [123]. Thus, the issues and recommendations regarding technology and trust are applicable.

Teams with members that prioritize their own intrinsic and extrinsic goals while also favoring status differences are said to be "vertically individualistic" [156]. These teams are characterized by competitive members that are motivated to "win" [156]. In addition, while these individuals tend to belong to more in-groups than collectivists, they are not very emotionally connected to these groups [181]. Virtual teams with high levels of vertical individualism are more likely to adopt CMC technologies, tolerate varying forms of informational value, and will use asynchronous methods when required by superiors than teams characterized by horizontal individualism or any type of collectivism [143]. Team members with horizontal individualistic orientation prioritize their own self-interest while also viewing their teammates as equals [143]. Virtual teams with high levels of horizontal individualism are more likely to adopt CMC technologies, tend to require higher informational value, and will use synchronous methods when required by superiors as opposed to teams characterized by vertical individualism or any type of collectivism [143].

Socio-cultural diversity can also be characterized by the temporal orientation of their goals. Teams that focus upon the future and are willing to delay success or gratification for the purposes of future gain have a "long-term orientation" culture [143]. Cultures with long-term orientation tend to value perseverance, persistence, and focus on future-oriented goals [143]. In contrast, cultures characterized by "short-term orientation" are focused on the immediate needs of their teams with little consideration of the impact of their decisions on the future [143]. Virtual teams defined by long-term orientation are more likely to adopt asynchronous tools with high informational value and tend to be slower to rely on CMC technologies than short-term orientated teams, which prefer synchronous tools with low informational value [143].

Cultures can also be characterized by the amount of contextualizing is performed by an individual during communication [95]. For example, Japan, a high-context culture, relies more on the use of indirect communication via contextual cues (e.g., body language) to convey information [139]. Contextualization also affects choice of CMC technologies. High-context teams tend not to rely on CMC technologies and will prefer tools that high high informational value [143]. Low-context teams, in contrast, will rely on CMC technologies and will prefer those with low informational value [143].

Virtual teams are also affected by the levels of affectiveness/neutrality present in their culture. Affectiveness in this context refers to the amount of emotion that individuals usually express when they communicate [143]. For example, individuals from affective cultures such as Italy commonly exhibit their emotions publicly. [143]. In addition, individuals from affective cultures often feel that more neutral cultures (e.g., Japan) are more intentionally deceitful because they tend to hold back on their emotions [240]. Affective teams will be less likely to rely on CMC technologies and will prefer ones with high informational value [143]. In contrast, teams with neutral cultures will highly rely on CMC technologies and will prefer tools with low informational value [143].

Other types of socio-cultural diversity influence the performance of virtual team. For example, heterogeneity in the extent to which gender roles are traditional is positively related to team performance [70]. In a similar vein, heterogeneity in the extent to which there is discomfort

with the unknown has a positive effect on issue-based conflict [70]. Uncertainty avoidance also affects tool use in virtual teams. Teams that have high amounts of uncertainty avoidance are more likely to use a synchronous CMC technology with high informational value. In contrast, teams with low uncertainty avoidance are unlikely to have a preference [143]. In addition to this, the degree of inequality that exists among members of virtual teams has an affect on the tools chosen for communication [143]. Teams with a high degree of inequality (i.e., high power distance) are more likely to use synchronous tools while teams with a low degree of inequality (i.g., low power distance) will prefer asynchronous tools [143]. Specificity also plays a role in virtual team performance. Someone from a specific culture (e.g., the United Kingdom) is more likely to view their coworkers as people with whom they only have a business relationship with, [87]. In contrast, more diffuse cultures (e.g., China) are more likely to view their teammates as friends and include them in their social lives [143]. This affects the choice communication methods employed by the team as teams characterized by high specificity are more likely to rely on CMC technologies than diffuse teams [143].

High socio-cultural distance is the cause of several types of collaboration problems. For example, high socio-cultural distance reduces communication and increases risk [2] caused by relationship breakdowns between distributed teams [250] and results in more processes challenges and lower team performance [86]. Socio-cultural distance also tends to worsen the way leaders sense, interpret, and respond to problems [271]. Cultural heterogeneity also tends to result in divergent subgroup identification [68] that may subsequently have a negative effect on team interactions and performance [67]. Furthermore, in accordance with similarity/attraction theory, team members attribute positive traits to team members that they believe are similar to themselves and prefer to interact with them [216, 255]. Negative traits are thus associated with teammates that they believe are dissimilar from them and sometimes actively avoid interactions with those teammates [24]. As a result, the belief that others are different in terms of education, race, and attitudes (i.e., perceived diversity) is frequently associated with the negative consequences of team heterogeneity [100], such as unwillingness to cooperate and coordinate activities [56, 117, 148].

Furthermore, teams with high socio-cultural distance are more likely to have issues with integration and communication and have more conflict [269]. Both task and affective conflict are increased as a result of the differences in perspectives and approaches related to work, which further exacerbates differences in expectations, attitudes, and beliefs [195, 204]. These differences in belief structures are particularly common in heterogeneous groups (i.e., groups with high socio-cultural distance) [268] which, in turn, increases conflict due to differences in interpretations and opinions of work processes [205]. Thus, there is a vicious cycle between differences in belief and intra-group conflict that is detrimental to collaboration.

The most commonly experienced problems correlating with socio-cultural distance are difficulties associated with diversity in language preferences, proficiency, and interpretation, which can create barriers for many projects [116], such as requiring increased effort [74, 170, 183]. This challenge is not just a matter of different languages, even native speakers of one language may have problems because of differences in dialects and local accents [33]. In many global collaborations, some (if not all) of the collaborators only speak English as a second language [132, 219]. This situation causes problems when collaborators need to synchronously communicate via teleconferencing—these team members can become overwhelmed with trying to keep up with the conversation [132, 219]. Furthermore, this language-based disadvantage can cause non-native speakers of the dominant language to feel alienated and as though they have a disadvantage when speaking [219]. Prior work has also shown that virtual teams whose members have different first languages have more conflict and lower levels of satisfaction and cohesion [238].

Misunderstandings can occur even in cases where all collaborators are fluent in a language if there are other differences in culture—a seemingly harmless joke could have a massively detrimental impact on the success of a project if it is misunderstood as an insult [250]. Olson and Olson observed one such misunderstanding where team members in the United States ended a video conference without expressing a 'proper farewell' to a European teammate [191]. In this case, the curtness was due to pressure on the American team, who were unaware of the cultural expectations regarding farewells, to cut costs by conducting short video conferences [191]. The European team, however, was unaware of this pressure and perceived the lack of a proper farewell as an insult [191]. Also, conflicts can arise when teammates from a culture where saying 'no' is considered impolite (even when saying 'yes' is a problematic answer) interact with teammates who do not share this compunction [116]. Treinen and Miller-Frost encountered an instance where collaborators from one culture did not ask many questions of their teammates and instead affirmed that they had a clear understanding of requirements, but were in reality too polite to express concerns [250]. In this situation, the other collaborators were unaware of this cultural difference and did not realize that their questions should not have formulated as 'yes or no,' but rather should have elicited responses that indicated understanding.

Other types of socio-cultural differences such as those caused by religion, generation, and doing orientation, can also affect virtual team success. Religious differences, for example, can make it difficult for team members to understand each others norms and traditions, which has a negative influence on collaboration [221]. Generational differences can affect how a team member responds to collaborating via CMC technology because not every has the high levels of technical expertise that makes them a "digital native" [129]. Finally, differences in the extent to which work is valued as a central life interest (i.e., "doing orientation") is negatively linked to productivity [135]. However, differences in the extent to which team members have a sense of personal control over their work and life events are positively linked to team productivity, cooperation, and empowerment [135].

A review of literature reviews and meta-analyses suggests that the "main-effects" approach, where researchers focus on relationships between outcomes and diversity dimensions, ignoring moderating variables, cannot truly account for the effects of diversity [86]. The effect of socio-cultural diversity depends on other features of the team [272], such as how long members have interacted, the types of diversity investigated, and the types of outcomes under scrutiny [86]. High task complexity, high tenure, large team size, and low levels of geographic dispersion are found to moderate the effects of socio-cultural diversity on virtual teams [237]. Experience with CMC technology can also moderate socio-cultural diversity; high heterogeneity in technical experience heightens the negative effect that differences in nationality has on creativity [164]. Socio-economic variables (e.g., human development index (HDI)) has a significant impact on a country's scientific production and collaboration patterns [118, 152, 199]. Kramer et al. found that socioeconomic similarities and economic agreements between countries have contributed to increased collaboration in the scientific field [143], which is likely to be virtual. The phase in which a virtual team is at in the project life-cycle affects assessment of team performance in culturally diverse teams. Culturally heterogeneous virtual teams will outperform culturally homogeneous teams during the later part of the project life-cycle [264]. This is likely a result of teams becoming more homogeneous over time as shared team values, associated norms, and identity enables the team to overcome process challenges that occur when team members encounter cultural differences [86, 264].

Computer-mediated communication technology (e.g., email, video-conferencing) can reduce the negative effects of socio-cultural diversity early on in the life of a diverse virtual team due to their reductive capabilities [32]. In fact, use of these tools may even be beneficial for diverse teams for this reason [32]. Many issues regarding language barriers are surmounted by the use of asynchronous technology that allows workers to reflect and carefully consider their position before answering a question posed by a collaborator that primarily speaks another language [2, 116]. These benefits result in the heavier use of asynchronous tools, which introduces the disadvantages of asynchronous tools (e.g., increased time and effort to effectively communicate, absence of important social information and nonverbal cues) [2]. Furthermore, asynchronous communication is not feasible in every situation. And, as discussed above, language barriers can cause problems during synchronous communication. Thus, developing technology that better supports synchronous communication across a language barrier is a promising opportunity for research in supporting collaboration.

Contradictions exist in the literature with regard to the effect of socio-cultural diversity on team performance. Edwards and Shridhar [66], for example, found no relationship between a team's socio-cultural diversity and the learning, satisfaction, or performance of its members. Other research has suggested that socio-cultural diversity is unrelated to conflict [108]. Finally, Weijen found that whether or not members of a virtual team spoke English (specifically) did not have an influence on international collaboration, likely due to the pervasiveness of English as the default language for many international journals and indexed databases [259].

It is also recommended that the addition of basic cultural awareness [250] and language training [120] be incorporated into the beginning of every project to mitigate these issues before they become major problems. One specific suggestion is to employ some of the guidelines from agile development methodology (i.e., Scrum), such as daily status meetings, to mitigate the effect of assumptions by providing an opportunity to address issues or questions during the hand-off and allocation of tasks [250]. Given the plethora of tools developed for supporting Scrum (e.g., [209, 229, 251]), it would be interesting to see how these tools could be adapted to smooth over collaboration issues arising from cultural differences.

6.4.3 Work culture

Socio-cultural distance can be highly influenced by the work culture dimension. For example, there may be conflicts from high socio-cultural distance between two teammates from the same country that come from very different company backgrounds [8], while the opposite may be true of teammates with different cultural and national backgrounds who share a common work culture [2]. The success of a virtual team can hinge on factors such as differences in understanding with regards to processes and knowledge, institutional bureaucracy, status differences

between team members, unworkable expectations regarding shared goals and products, and conflicting or competing institutional priorities [54]. Power asymmetries in particular can create systemic bariers that need to be explicitly navigated (as opposed to expecting perfect process design will resolve them) [54]. While differences in work culture have the potential for stimulating innovation, proving access to richer skill sets, and sharing best practices, it also has the potential to cause misunderstandings [2] and communication breakdowns [14] between teammates. This influence is partly due to the difficulties associated with communicating subtl aspects of the team culture over distance (e.g., 'how we do things around here' [8]). For example, differences in the competitive or cooperative culture of a workplace can pose challenges [191]. Workers are less likely to be motivated to share their skills or 'cover for each other (p. 1)' in organizations or cultures that promote individual competition rather than cooperation. In contrast, cooperative cultures facilitate sharing skills and effort. This issue is particularly difficult to overcome in virtual teams.

Other differences in organizational structure and leadership can have a profound impact on successful collaboration in distributed groups. The characteristics of authority and authoritative roles vary across cultures [8, 145] which can cause conflicts and undermine morale [2]. For example, [33] observed that in a collaboration between teams located in Ireland and the United States, the Irish workers required that authority figures earn their respect while the American workers were more likely to unquestioningly give respect to superiors. Another study that focused on a collaboration between teams in the United States and Europe had contrasting results [8]. Instead of the unquestioned respect found by Casey and Richardson, [8] saw that American workers were more confrontational with their superiors and verbally expressed objections and questions while the European teams had a more formal, hierarchical management structure. These differences indicate that support for differing work cultures needs to focus on the needs and conventions of the individual organizations and refrain from imposing standards based solely on the country in which the organization resides. The degree to which an organization allows autonomous decision-making afects relationships and behaviors between teammates and can inpact things like readiness to use technology in the collaboration or willingness to exchange knowledge [166, 180].

Teams can also vary in their goals, norms, and incentives. A lack of alignment of incentives and goals as well as differences in expectations can pose very serious problems for a collaboration [191]. These misalignment's are difficult to detect at a distance and require substantial negotiation to overcome [191], which is nontrivial using today's technology. For example, collaborators may have different perceptions of time as a result of temporal discontinuities caused by differences in time zones, which may further reflect differences in the value systems of collaborators at each site [222]. Tensions may arise between workers at an American site that views time as a scarce commodity and perceives time as being something that can be spent, wasted, or lost, and collaborators at a Japanese site that view time as a cyclical, recurrent entity that is in unlimited supply [222]. Along with this finding comes different expectations with regards to how many hours a day team members are expected to work, or differing definitions of what it means to work hard [14], which often varies between countries [22]. These differences in expectations are particularly problematic when one team expects that another work more hours than they previously had been working [14]. Building a sense of shared goals and expectations happens more slowly in distributed groups [8], a process that could likely be assisted by the development of new communication technology. In addition, competing incentives can undermine a team's performance [54].

Competitive funding models may affect willingness to collaborate and disincentivize team members to share skills, knowledge, and unpublished data [247]. For example, for the Collaborative Adaptation Research Initiative in Africa and Asia project, the core partners each created an individual grant agreement with the International Development Research Centre [54]. However, while the expectation was that partners would collaborate with each other, the partners were disincentivized to collaborate due to the individual grant agreements since the partners reported individually to the funding agency, rather than collectively [54]. Unfortunately, it is frequently unrealistic to expect these dynamics to resolve themselves in a short period of time and shift into an open and trusting relationship [54].

Expectations can be strongly influenced by the language used by different groups (e.g., 'test procedure,' 'phase completion') within a virtual team, sometimes creating animosity [8]. Language is further associated with methodology—for example, disparities in definitions of quality can be reflected in different assessment procedures [8]. Misunderstandings caused by differences in work practices and methodologies can affect coordination and cooperation [2], causing delays and conflicts [8]. In these situations, a common technical language must be developed to ensure understanding, which can be an extremely difficult task [15, 122, 172, 252]. This need provides an opportunity for the development of technology to assist the creation and use of project-specific technical language.

In addition to differences in technical language, various groups within a virtual team may have different backgrounds that need to be reconciled, as different

organizations within a group may have different expertise and experience that create incompatible views [55]. This issue is often unavoidable since one group may have specific knowledge necessary for the project to succeed [120]. Furthermore, differences in discipline and background have a stronger effect for distributed collaborations [211]. However, there are inconsistencies in the literature with regards to the effects of discipline on collaboration. Cummings and Kiesler, for example, found that field heterogeneity has a positive effect on distributed project success [50]. Specifically, they showed that projects including many disciplines had disclosed as many positive outcomes as did projects that involved fewer. However, in an earlier study, they found that projects incorporating many disciplines were less successful than projects that relied on fewer disciplines [133]. Thus, it is uncertain as to which conclusion is accurate, presenting open questions.

The way that administrative communication is managed [250] and tasks are allocated can play a big role [8] in the success of a virtual team. For example, a project manager could assign tasks differently and adjust the way that he or she communicates with management in accordance with the team's culture and nationality [8]. Collaborations can further benefit from creating structured understandings about how to best work together by establishing expectations and definitions to undercut assumptions [8]. The challenge then becomes finding ways to develop technology that supports these structures while still facilitating innovation, ingenuity, and 'rapid response to organizational threats or opportunities' [64]. However, there are also inconsistencies between studies exploring the effects of work culture on collaboration. While Walsh and Maloney [261] stated that remote collaborations did not experience more work culture problems than co-located teams, McDonough et al. [170] found that differences in work culture and practices resulted in management problems in virtual teams. This disparity presents another open question.

7 Summary of findings and open questions

In this literature review, the major factors and challenges that impact collaboration in virtual teams were identified. Section 5 discussed distance factors (geographical, temporal, and perceived distance) and their associated challenges, including reduced motivation and awareness and difficulty establishing trust. In addition, barriers to informal and face-to-face communication, particularly the team's technical competence and access to the appropriate technical infrastructure as well as prevalence of intra-team conflict were reviewed. Additional factors that particularly affect distance collaborations were outlined in Sect. 6, namely the nature or coupling of the work, the need for explicit management, the configuration of dispersed sites and intra-team diversity along the dimensions of common ground, socio-cultural distance, and work culture. Several open questions and directions for future research were identified in the process of conducting the review; these are divided into questions of theory, questions of technology, and recommendations for future research. These findings are used to create design implications for the development of groupware targeted towards virtual teams later in Sect. 8.

7.1 Questions of theory

7.1.1 Should future research pursue 'awareness'?

There is currently disagreement within the community as to whether or not 'awareness' should be taken as a conceptual approach to investigating collaboration challenges. Critics of 'awareness' describe the term as 'ambiguous and unsatisfactory' [224] and point towards it's tendency to be paired with an adjective (e.g., 'passive awareness' [62]) in an attempt to lend some specificity [224]. Despite this, the awareness approach is still a commonly explored method [7, 134], which suggests that there is a research opportunity to address this controversy.

7.1.2 Are coordination costs higher in teams that are temporally distributed?

There is also a lack of consensus within the community as to whether coordination costs are higher in teams that are temporally distributed. For example, while Espinosa and Carmel [73] state that coordination costs are reduced when team members are not working concurrently because no direct coordination takes place when the two teammates are not working at the same time, Ågerfalk et al. [2] and Battin et al. [11] assert that temporal distance significantly increases the cost and effort of coordination due to the added difficulties of dividing work across multiple time zones.

7.1.3 How do the disparities in levels of conflict and trust between balanced and imbalanced teams affect collaboration?

As previously discussed, levels of conflict and trust differ between balanced and imbalanced teams [188, 210]. Specifically, subgroups in balanced teams experience weaker effects from faultlines on conflict and trust than large subgroups in imbalanced teams [210]. However, the ramifications are of these differences in trust and conflict are unknown, suggesting an opportunity for research.

7.1.4 Does tightly coupled work have a negative or a positive effect on collaboration?

Several studies [72, 191, 193] suggest that that tightly coupled work hinders distance collaboration. However, [15] found that tightly coupled work required collaborators to frequently interact to do their work and, as a result, forced these collaborators to know more about each other, help each other, and cultivate strong engagement despite being at geographically distant sites—which actually helps distance collaboration. Given the contrast between these conclusions, there is an opportunity for further research to investigate the effects of tightly coupled work, particularly in domains other than global software development.

7.1.5 What effect does geographic dispersion have on task and affective conflict?

Contradictions exist in the current literature as to the effect of geographic distance on affective and task-based conflict. Specifically, [179] found no significant difference in affective and task-based conflict between co-located and distributed teams. This, however, is in direct conflict with their later work [108]. These contradictions are particularly interesting given that the participants in both studies did research and product development, and are therefore directly comparable. It is therefore uncertain as to which conclusion is accurate.

7.1.6 Does background heterogeneity have a positive or a negative effect on collaboration?

This question is also currently unresolved, given the contradictions in literature. In 2002, Kiesler and Cummings found that projects incorporating many disciplines were less successful than projects that relied on fewer disciplines [133]. However, later they found that field heterogeneity has a positive effect on distributed project success [50].

7.1.7 Do virtual teams encounter more work-culture related problems than co-located teams?

This is yet another example of the community's lack of consensus on issues surrounding collaboration. For example, while McDonough et al. [170] found that differences in work culture and practices resulted in management problems in virtual teams, Walsh and Maloney [261] stated that remote collaborations did not experience more work culture problems than co-located teams.

7.2 Questions of technology

7.2.1 How can we better support communication in temporally distant work?

Due to the differences in work schedule caused by differences in time zones, particularly when sites do not have overlapping workdays, distance workers rely on asynchronous technology (e.g., email, fax) to communicate with their collaborators. However, this method has several drawbacks. Asynchronous tools tend to increase the amount of time that a collaborator has to wait for a response [2] and can leave the recipient feeling overwhelmed by the number of asynchronous messages left during the previous night [19]. Moreover, the process of writing ideas in emails increases the risk of misunderstandings between collaborators [57] over talking in person or via the telephone.

7.2.2 How can we better support informal communication?

There is an additional challenge associated with communication technology in that there is insufficient support for determining a collaborator's availability for spur-of-the-moment, informal communication [101]. This drawback, in particular, hampers informal communication that would otherwise happen during chance encounters in a co-located environment.

7.2.3 How can we design technology to assist in the development of trust?

Research shows that body language, subtle voice inflections, facial expressions, etc., which are notably more difficult to convey via communication technology, are essential to the development of trust [20, 193]. Furthermore, communication technology is frequently used in an irregular, unpredictable, and inequitable manner, which hampers trust [123]. As a result, it is clear that current technology needs to be updated to better assist the development of trust in distance collaborations.

7.2.4 How do we support explicit management in teams that reject formal administration?

Explicit management is necessary for successful distributed, collaborative work [193]. However, some particular types of collaboration, such as research collaborations consisting mainly of scientists, avoid the application of explicit management in their projects [193].

7.2.5 How can we support synchronous communication across language barriers?

Language barriers are of significant concern in collaborations where collaborators have different socio-cultural backgrounds (i.e., speak different languages) [116] or different work backgrounds (i.e., use different jargon) [8]. In these cases, asynchronous communication allows collaborators to reflect before responding to each other, giving them a chance to look up unfamiliar terminology or become familiar with new ideas. However, asynchronous communication has several drawbacks, as mentioned earlier, and is not feasible in every situation.

7.2.6 How do we develop technology that supports structures for negotiating terminologies and methodologies while still facilitating flexibility?

Along with the issue of surmounting technical language barriers in synchronous communication comes the need to create and use a common technical language to ensure understanding in meaning and methodology. The development of a project-specific technical language is not an easy task [17, 55, 172, 252], but is important enough to collaboration to warrant assistance from technology. It is also important to ensure that this technology is flexible enough to withstand changes that may be made to the project.

7.2.7 How can we leverage existing tools developed for supporting Scrum to mitigate problems caused by cultural differences?

It has been suggested that distance collaborations employ guidelines from agile development methodology, such as daily status meetings, to mitigate the effect of incorrect assumptions caused by socio-cultural or work culture differences. The existence of a vast number of tools developed specifically to assist Scrum (e.g., [209, 229, 251]) presents an opportunity to investigate how these technologies can be adapted to mitigate collaboration issues arising from cultural differences.

7.2.8 How can we design communication technology to support building a sense of shared goals and expectations?

Variances between times with regards to goals, norms, incentives, and expectations can pose very serious problems for a collaboration [191]. Overcoming these differences by building a sense of universal goals and standards is a slow, but vital, process for distributed groups [53]. Furthermore, these types of misalignments are hard to recognize in distance collaborations and require substantial negotiation to overcome [191], which is nontrivial given the limitations of today's technology

7.3 Recommendations for future research

Siebdrat et al found that perceived distance was more strongly affected by a team's national heterogeneity than by their spatio-temporal distance, and subsequently asserted that perceived distance is more indicative of collaboration challenges than spatio-temporal distance [231]. However, other work has demonstrated that distance can affect collaborators that are all in the same country at a single site [4], with low national heterogeneity and low spatio-temporal distance. Despite this, it is unclear whether perceived distance was high or low in this case due to the context of the study. Given the apparent influence of distance on collaboration, whether it is perceived, temporal, or spatial, it is therefore important to gain a better understanding of the relationship between these types of distance and their effects on collaboration.

8 Implications for design

This section uses the findings of this LR to address the final question, Research Question 2: How can we design technology for supporting virtual teams? To do so, the following four design implications for the development of groupware that supports collaboration in virtual teams are outlined.

8.1 Assist creation of common ground and work standards

Virtual teams consisting of workers with different expertise and organizational backgrounds require conversations about project-specific technical language, methodologies, and best practices. Technology should expedite and document these conversations and decisions to both create and facilitate the everyday use of technical language. Furthermore, since systems often incorrectly assume a shared knowledge of information [1] as recommended by [192], systems should document in a manner that allows users to search for abstract representations of information. Moreover, since methodologies, best practices, and technical language tend to evolve over time, this technology needs to also support the resulting negotiation and discussion processes, as opposed to only facilitating the initial decision-making process.

8.2 Facilitate communication

Both rich discourse (i.e., containing social information and nonverbal cues as well as words, typically provided by face-to-face communication), and spontaneous, informal communication have been identified as key to preventing conflict and improving trust in virtual teams. Thus, it is imperative that technology is designed to provide the benefits of face-to-face conversations (e.g., video conferencing), such as ease in immediately detecting confusion. This is important not only for synchronous communication but also asynchronous conversations since those are the most likely to have misunderstandings that could be mitigated with additional non-verbal information. Mechanisms for supporting informal communication (e.g., chance encounters) is similarly necessary. In addition, given the difficulties experienced by virtual teams where workers are required to speak in a language that is not native to them, it is important to consider means for supporting synchronous communication across language barriers.

8.3 Provide mechanisms for work transparency

One of the key challenges faced by virtual teams is feeling a sense of connectedness to the rest of the team. This is both due to the motivational effects of not feeling isolated and the increased effort required to feel heard and acknowledged by the rest of the team located at another site. Thus, technology should be designed to provide transparency that allows workers to feel aware of their teammates, Furthermore, this technology should highlight and encourage the contributions of an individual and boost visibility within the team.

However, technology that promotes transparency, particularly technology that creates the sense of a shared workspace through open video connections, should be wary of infringing on the privacy of the team since the more information a person sends, the greater the impact on one's privacy [119]. Furthermore, the more information a person receives, the greater the chance of disturbing work [119]. Thus, it is important to reach a good balance between providing awareness and preserving privacy and limiting distractions.

8.4 Design lightweight, familiar technology

Technical infrastructure varies across organizations—teams may not have the resources to support data-heavy communication tools, limiting their access to sophisticated collaboration technology (e.g., multiplane video conferencing). Furthermore, infrastructure may even vary within a virtual team, limiting tool use for the entire group since it is important that communication capabilities be evenly distributed [193]. Thus, care should be taken to engineer technology that is as lightweight as possible, maximizing the number of potential users. Virtual teams also face challenges related to the technical competence of their team members. It is therefore recommended that designers create technology with enough similarities to the technology currently employed by the team to facilitate adoption. New technology also needs to be compatible with existing tools, to promote adoption [194].

9 Conclusion

This literature review provided an overview of the collaboration challenges experienced by virtual teams as well as current mitigation strategies. This review utilized a well-planned search strategy to identify a total of 255 relevant studies, which chiefly concentrated on computer supported cooperative work (CSCW). Using the selected studies, we described challenges as belonging to five categories: geographical distance, temporal distance, perceived distance, the configuration of dispersed teams, and diversity of workers. Findings also revealed opportunities for research and open questions. Finally, opportunities and implications for designing groupware that better support collaborative tasks in virtual teams was discussed through the description of four design implications: assist the creation of common ground and work standards; facilitate communication; provide mechanisms for work transparency; and design lightweight, familiar technology.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Appendix

Tables 2, 3, 4, 5, 6, 7 and 8.

Table 2 Case study papers by contribution

Distance (Section IV)	
Geographic distance	
Motivation and awareness	[8, 11, 63, 102, 103, 132]
Establishing trust	[30, 31, 38, 55, 102, 117, 123, 128, 132, 142, 147, 248]
Informal and face-to-face communication	[8, 11, 58, 59, 102, 103, 117, 132]
Intra-team conflict	[8]
Temporal distance	
All	[11, 14, 19, 34, 58, 75, 76, 117, 121, 132, 218, 248, 254]
Contributing factors (Section V)	
Diversity	
Common ground	[8, 11, 14, 22, 34, 47, 56, 57, 75, 101, 117, 121, 122, 123, 125, 145, 172, 178, 194, 201, 248, 271]
Socio-cultural distance	[41, 132]
Work culture	[55]

Table 3 Experiment papers by contribution

Distance (Section IV)	
Geographic distance	
Nature of work	[12, 260]
Explicit management	[66, 90, 130, 131, 187, 206]
Motivation and awareness	[16, 40, 90, 206]
Establishing trust	[20, 21, 37, 49, 124, 155, 187, 209, 215, 265]
Informal and face-to-face communication	[3, 39, 173, 214, 265]
Intra-team conflict	[20, 187, 242]
Perceived distance	
All	[197, 214]
Configuration	
All	[28, 46, 187, 209]
Contributing factors (Section V)	
Diversity	
Common ground	[118, 214, 215, 253]
Socio-cultural distance	[67, 164, 236, 262]
Work culture	[36]

Table 4 Interview papers by contribution

Distance (Section IV)	
Geographic distance	
Explicit management	[84, 97, 157, 241]
Informal and face-to-face communication	[65, 140, 141, 195, 212, 232]
Intra-team conflict	[109]
Temporal distance	
All	[212, 241]
Perceived distance	
All	[86]
Configuration	
All	[141, 212]
Contributing factors (Section V)	
Diversity	
Common ground	[65, 250]
Socio-cultural distance	[84, 88, 246]
Work culture	[65]
Implications for design	
All	[65]

Table 5 Survey papers by contribution

Distance (Section IV)	
Geographic distance	
Explicit management	[68, 181, 234, 258, 259]
Motivation and awareness	[50]
Establishing trust	[9, 29, 42, 43, 68, 170, 181, 207, 216, 219, 271]
Informal and face-to-face communication	[5, 43, 53, 68, 126, 177]
Intra-team conflict	[43, 68, 71, 104, 204, 259]
Temporal distance	
All	[50]
Perceived distance	
All	[68, 188, 230]
Configuration	
All	[50, 68, 230]
Contributing factors (Section V)	
Diversity	
Common ground	[43, 51, 52, 68, 95, 170, 259]
Socio-cultural distance	[51, 52, 68, 71, 98–100, 156, 204, 251, 252]
Work culture	[43, 68]
Challenges and Barriers in Virtual Teams	[45]

Table 6 Literature review papers by contribution

Distance (Section IV)	
Geographic distance	
Nature of work	[163, 190, 192, 224]
Explicit management	[89, 111, 150, 158, 190, 192, 222]
Motivation and awareness	[2, 25, 33, 79, 108, 192, 223, 237]
Establishing trust	[23, 45, 60, 87, 163, 165, 192, 217]
Informal and face-to-face communication	[2, 13, 33, 61, 74, 79, 80, 93, 133, 163, 165, 190, 227, 263]
Intra-team conflict	[87, 108, 165, 227]
Temporal distance	
All	[2, 32, 74, 87, 182, 221, 263]
Perceived distance	
All	[35, 83, 87, 162, 268]
Configuration	
All	[48, 78, 182, 186, 190, 192]
Contributing factors (Section V)	
Diversity	
Common ground	[2, 24, 32, 108, 116, 133, 148, 182, 190, 192, 202, 203, 222, 225]
Socio-cultural distance	[33, 85, 87, 133, 139, 143, 176, 199, 227, 243, 263]
Work culture	[1, 179, 190, 192]
Implications for design	
All	[1, 32, 192]

Table 7 System papers by contribution

Distance (Section IV)	
Geographic distance	
Motivation and awareness	[17, 72, 82, 154, 160, 171, 196]
Informal and face-to-face communication	[261]

Table 8 Other papers by contribution

Distance (Section IV)	
Geographic distance	
Nature of work	[239]
Explicit management	[226]
Motivation and awareness	[7, 18, 120, 134, 144]
Establishing trust	[54, 167, 174, 264]
Informal and face-to-face communication	[4, 62, 77, 127, 144, 151, 185, 211]
Intra-team conflict	[267]
Temporal distance	
All	[229]
Perceived distance	
All	[4, 213]
Contributing factors (Section V)	
Diversity	
Common ground	[113, 114, 168, 210, 229]
Socio-cultural distance	[44, 69, 96, 115, 119, 129, 135, 149, 152, 164, 180, 198, 220, 229, 235, 238, 256, 266, 267, 269, 270]
Implications for design	
All	[120, 193]

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