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Review

Leading teams in the digital age: Four perspectives on technology and what they mean for leading teams

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ABSTRACT

Digital technologies are changing the nature of teamwork in ways that have important implications for leadership. Though conceptually rich and multi-disciplinary, much of the burgeoning work on technology has not been fully integrated into the leadership literature. To fill this gap, we organize existing work on leadership and technology, outlining four perspectives: (1) technology as context, (2) technology as sociomaterial, (3) technology as creation medium, and (4) technology as teammate. Each technology perspective makes assumptions about how technologies affect teams and the needs for team leadership. Within each perspective, we detail current work on leading teams. This section takes us from virtual teams to new vistas posed by leading online communities, crowds, peer production groups, flash teams, human-robot teams, and human-artificial intelligence teams. We identify 12 leadership implications arising from the ways digital technologies affect organizing. We then leverage our review to identify directions for future leadership research and practice.

Introduction

The digital age has changed the nature of work in ways that were unimaginable even a decade ago (Barley, Bechky, & Milliken, 2017). Technological advances have shifted many people from working inside formal organizations to working as loosely connected members of a larger community, such as the virtual office employees across major industries (Joshi, Lazarova, & Liao, 2009). Technological advances have given rise to the gig economy, where individuals sell their services directly to the market (Petriglieri, Ashford, & Wrzesniewski, 2019). Crowd workers contract their time and skills on an as-needed basis on e-commerce sites like Upwork, an online platform that "expertly matches professionals and agencies to businesses seeking specialized talent" (Upwork, 2019), and MTurk, a "crowdsourcing marketplace that makes it easier for individuals and businesses to outsource their processes and jobs to a distributed workforce who can perform these tasks virtually" (MTurk, 2018). There are many ways digital technologies are transforming the nature of work. The permeation of digital technologies is *not* changing the widespread organization of work into teams, but it is changing the nature of teamwork. Consider these examples:

- Organizations from Netflix to NASA regularly use online tournaments to source innovation (Dissanayake, Zhang, Yasar, & Nerur, 2018; Lifshitz-Assaf, 2018).
- Internet sites like Upwork allow Fortune 500 companies to hire freelancers from around the world to perform skilled and specialized work (Green, Walker, Alabulthtim, Smith, & Phillips, 2018).
- The free online encyclopedia Wikipedia is maintained by volunteers who produce a product with comparable accuracy to traditional encyclopedias (Giles, 2005).
- Robots now routinely assist physicians and nurses during a wide range of surgeries (Lanfranco, Castellanos, Desai, & Meyers, 2004).

Each example describes work that has been enhanced in some way through advances in computing. All four examples involve teams performing work that has and continues to change with advances in digital tools. In the cases of Upwork and Wikipedia, the internet has enabled a new kind of organization: the online community, where relationships are informal and participation is voluntary. Although contributions to Wikipedia are unpaid, contributions to Upwork are paid at a negotiated rate. On Upwork, individuals can create a team project (i.e., "enable teams") and staff the team with contractors located around the world. Traditional organizations like Netflix and NASA are leveraging these advances to help them innovate. All four examples demonstrate the exciting ways technology is transforming the basic nature of teamwork (Fan & Yen, 2004).

This fundamental transformation of teamwork vis a vis technology has important implications for leadership. Teams are using an

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increasingly sophisticated array of technologies to work together - relatively basic messaging and video conferencing systems have been joined by enterprise social media (e.g., Slack, GroupMe) and collaborative editing suites (e.g., Google Drive, Microsoft Teams). Though technologies have been shifting the landscape of teams for some time, these shifts are becoming more transformative. Technologies have, for some time, enabled individuals to collaborate in teams over great distances. They are now shaping who comes together in teams and allowing teams to scale up in much larger networks of teams. If the 20th century saw the rise of self-managing work teams (Stewart & Manz, 1995), the 21st century introduces us to teams with crowd workers, paid or unpaid workers who organize via the internet, operate outside formal organizations, and may never meet in person (Dow et al., 2011; Kittur et al., 2013).

Technologies are also creating new kinds of team members. Whereas most basic definitions of teams begin with "two or more individuals" (Kozlowski & Ilgen, 2006), the digital age invites organizational scholars to rethink what constitutes a team member. Rapid advances in robotics (Burke, Murphy, Rogers, Lumelsky, & Scholtz, 2004; Chui, Manyika, & Miremadi, 2016; Manyika et al., 2017) and Artificial Intelligence (AI; Chui et al., 2018; Yen et al., 2001) are introducing technologies to teams as autonomous team members. Although robots and algorithms have long been replacing some individuals (e.g., robots used in manufacturing) and augmenting the capabilities of others (e.g., surgical robots; Van Den Berg et al., 2010), we are fast approaching a time when autonomous agents are motivated beings working alongside their human counterparts.

The popular press is replete with futuristic thinking on the changing nature of work (i.e., Lund et al., 2019; Marr, 2019; Schwartz, Collins, Stockton, Wagner, & Walsh, 2017), and there is great demand for managerial training to equip leaders for the digital age. How managers leverage AI may well be the major differentiator between those who succeed and those who fail at leading in the age of AI: "the advances of brilliant machines will astound us, but they will transform the lives of senior executives *only* if managerial advances enable them to" (Dewhurst & Willmott, 2014). The success of teams in settings that span the many industries being transformed by technology - healthcare, entrepreneurship, space exploration, entertainment - hinges on concurrent advances in leadership.

The central premise of this review is that the digital transformation of work makes leadership even more critical to team effectiveness in a variety of ways. Furthermore, how we view technology's role in teams creates different implications for leadership. In order to more concretely understand the leadership implications of technologies, we reviewed the research on team leadership as it relates to digital technology. In doing so, we identified four perspectives on the role of technology in teams. These four perspectives are depicted in Fig. 1, along with an approximate timeline of when we started to see research reflective of each technology view. Each of these views makes a distinct core assertion about the role of leadership in supporting teamwork.

There have been a number of excellent recent reviews on team leadership (c.f., Burke, Diaz-Granados, & Salas, 2011; Kozlowski, Mak, & Chao, 2016), though there has not been a review explicitly focused on the implications of technology for team leadership. Given the changes in teamwork described in our opening, such a review is sorely needed to highlight the specific ways that technology can condition, create, and shape team leadership. The central aim of our review is to bring digital technology more clearly into focus in order to understand the leadership implications of leading in the digital age.

Our review juxtaposes technology and team leadership. We review key findings from technology-rich domains as they relate to team leadership in order to highlight the leadership implications stemming from each technology perspective. In doing so, we unveil new insights about leading teams in an age of unprecedented technological transformation. Our primary contributions are twofold.

Fig. 1 previews the key components of our review. In the center, we depict the four perspectives on digital technology we identified in our review, we label these: digital technology as a team context, digital technology as sociomaterial team practices, digital technology as team creation medium, and digital technology as a teammate. We also note the approximate timeframe when prominent theorizing about technologies began to adopt each of the four perspectives included in our review. Along the bottom of Fig. 1 we have listed some examples of the terms used in research examining the ways emerging technologies affect teams. Starting from the left, we list one of the earliest terms "computer-supported groups." Though we begin our review in earnest after the turn of the century, we included this term for completeness as this was a period that ignited interest in teams and technology. Around the turn of the century, substantial attention was paid to "virtual teams" whose members used technologies to collaborate remotely. On the bottom of Fig. 1 we have listed some examples of the focal technologies that scholars had in mind as they studied technology and teams. The far right of the figure denotes the leadership findings and implications that comprise the bulk of our review. For each technology perspective, we review the research that relates to team leadership, summarizing the leadership implications that come into focus when we take on each of the four technology perspectives. We present the timeline as a guide for understanding the loose temporal associations between theorizing on team leadership, technology, and emerging team forms. Though we note that our review of findings does not proceed chronologically; rather we organized findings according to the technology perspective reflected in the study. For each technology perspective, we review findings as they relate to team leadership.

Research on team leadership generally emphasizes two dimensions: leadership functions and leadership forms. The first dimension is *team leadership functions* (McGrath, 1962; Zaccaro, Rittman, & Marks, 2001). This dimension highlights the need for leaders to ensure the core needs of the team are satisfied "with the ultimate aim of fostering team effectiveness" (Morgeson, DeRue, & Karam, 2010). Though taxonomies differ, most encompass the need for teams to develop strong *affective emergent states* like trust and cohesion, the need to develop *cognitive emergent states* like shared mental models and transactive memory systems, and the need to enact *behavioral integration processes*. *Leadership forms* describe the pattern or topology of how leadership is carried out by the team. Some common team leadership forms include hierarchical, shared, distributed, and rotated leadership (Contractor, DeChurch, Carson, Carter, & Keegan, 2012). Research shows collective forms of leadership are more beneficial than hierarchical forms in promoting team effectiveness (D'Innocenzo, Mathieu, & Kukenberger, 2016; Nicolaides et al., 2014; Wang, Waldman, & Zhang, 2014).

Based on these two dimensions, *team leadership* can be thought of as actions taken by one or more team members to ensure that team needs are being met. Zaccaro et al. (2001) summarize a number of team leadership actions: recognizing and constructing team problems, generating, planning, and implementing solutions to those problems, and coordinating and monitoring the implementation of those solutions. Together, leadership functions and forms provide a useful framework for understanding leadership in the digital age.

We review the findings related to team leadership that explicitly focus on some aspect of digital technologies. We began our review by searching for articles with keywords such as "leader" and "technology". We knew that our literature search would need to take place across disciplines as the research on leadership and technology is cross-disciplinary and much of the human-technology interaction work is in fact occurring in disciplines other than the organizational sciences. Thus, we also skimmed the abstracts of articles with the terms "group", "team", "collective", and other group-related terms to see how other disciplines might be talking and thinking about team leadership and technology. In reviewing these studies, we saw evidence of four perspectives on technology that serve as the major categories of our review.

The first two perspectives are prevalent in technology studies. *Technology as context* views technology and social practices as distinct

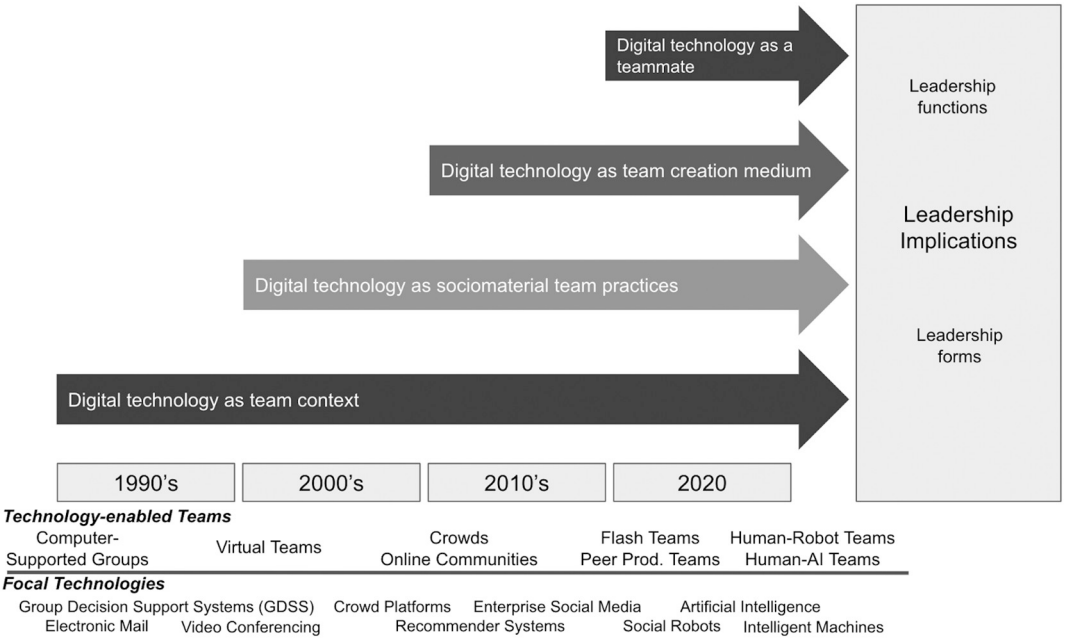

Fig. 1. Four perspectives on digital technology with implications for leading teams.

entities. The technology is a situational context that creates conditions that affect social practices. The second view, *technology as sociomaterial*, explores "the ways that [a technology's] physical and/or digital materials are arranged into particular forms that endure across differences in place and time" (Leonardi, 2012, p. 29), and views material aspects of technology and social practices as *mutually dependent ensembles* such that there is "an inherent inseparability between the technical and the social" (Orlikowski & Scott, 2008, p. 434). Most current work on team leadership takes one of these two perspectives on technology.

The third perspective, *technology as team creation medium*, explores the ways that technology platforms are shaping who forms teams and how they form them. Research in this area focuses on the role of technology in the initial formation and later reformation of teams. The prevalence of large online communities and new ways of organizing are expanding the role of team leaders, and in some cases, replacing leader activities with algorithmic control. A fourth perspective is emerging in which technology is a motivated social being: *technology as teammate*. With the rise in automation in our everyday lives, we are becoming dependent on our technological teammates at home and at the office. Intelligent machines are helping us pilot our airplanes, select new employees, and crunch numbers in order to make organizational steering decisions, just to name a few examples. This perspective will influence how leaders manage team members, both humans and intelligent agents, and has important ethical considerations for leaders as this perspective of teaming becomes increasingly prevalent in our organizations. In the next section, we review scholarship on digital technologies and team leadership in order to foster greater linkages between the two and to highlight the key leadership implications suggested by work in each domain.

A review of technology and team leadership

Table 1 provides a useful guide for the review that follows. We summarize each of the four technology perspectives and their implications for leadership. Table 1 allows us to compare and contrast the perspectives in terms of: (1) how digital technologies relate to teamwork and (2) the leadership needs created by technology when viewed from each perspective. We begin by considering research conducted from the first technology perspective.

Technology as context

The first area of research on technology and organizing considers *technology as team context*. This view holds that technology has fixed features that set up the context in which team processes take place (Table 1). According to this view, when teams use digital technologies to interact with one another, the technology is an important aspect of the leadership situation. According to this view, we would understand a distributed team convening via videoconference by looking separately at the team process behavior on the one hand and the features of the video conference system (e.g., clarity, refresh rate, pan-tilt-zoom, audio-video timing) on the other. In this view, technology is separate from the team; there are teams who use technology and those who do not. There are teams who use information-rich technologies and those who use less rich tools. Technology as context considers technology as having features that determine important aspects of the leadership situation.

The context perspective of technology in teams grows out of a long-standing view of teamwork and leadership as situated in context. Reviews of context in psychological leadership research (Liden & Antonakis, 2009; Maloney, Bresman, Zellmer-Bruhn, & Beaver, 2016) demonstrate a long history of context as a consideration in the study of teams and leadership. One area of research that took a technology as context perspective in its examination of leadership is that of E-leadership (Cascio & Shurygailo, 2003; Zaccaro & Bader, 2003). E-leadership theorizes the leadership needs of those "who conduct many of the processes of leadership largely through electronic channels" to begin to study leadership in virtually collaborating teams (also Avolio, Kahai, & Dodge, 2000; Avolio, Sosik, Kahai, & Baker, 2014; Hedlund, Ilgen, & Hollenbeck, 1998; Johnson, Suriya, Yoon, Berrett, & La Fleur, 2002; Sosik, Kahai, & Avolio, 1998; Tyran, Tyran, & Shepherd, 2003).

Other work advocates the need for greater attention to context in leadership research in general (Johns, 2006, 2017, 2018). Johns suggests that context is often mishandled in organizational behavior research and offers useful dimensions through which to understand leadership in context: the omnibus context and the discrete context. The omnibus context is the overarching context in which leadership occurs and represents the "who, where, when, and why" of the context. The discrete context represents the task, social, and physical context of the team. The omnibus context encompasses the discrete context. These

Table 1
Four Perspectives on technology and their implications for leading teams in the digital age.

Technology perspective	How digital technology relates to teamwork	Leadership needs created by technology
Technology as team context	Technology has mostly fixed features that place constraints on the team and constitute a meaningful aspect of the team's context.	Technology features determine important aspects of the leadership situation.
Technology as sociomaterial team practices	Technology practices come about when team needs meet material features of technology; technology and teamwork are mutually dependent ensembles.	Material features of technology and behavioral intentions jointly create affordances for leading and collaborating in teams.
Technology as creation medium	Technology enables teams to form in new ways within and outside of formal organizations.	Digital tools and platforms enable leadership processes enacted during team formation.
Technology as teammate	Technology is a member of the team, fulfilling a distinct role that directly contributes to team performance.	Leadership needs to facilitate relationships among human and synthetic team members.

two dimensions of context are proposed to help scholars think about how their study of context and the generalization of contextual findings can occur in a more rigorous and structured way. In thinking about teams in the digital age, new technologies influencing leadership processes are part of the larger, "omnibus" context, the "who, where, when, and why" of the context.

Similar to Johns' dimensions of organizational context, Morgeson and colleagues suggest a model for understanding team leadership functions in which one must understand the context of the team, the organization, and the environment in order to understand leadership processes and subsequent team effectiveness (Morgeson, Lindoerfer, & Loring, 2010). Oc (2018) builds directly on the Johns (2006) framework for understanding organizational context and proposes a framework for understanding leadership and team context. Oc proposes that the omnibus and discrete contexts interact with leadership influencing processes (i.e., leader behaviors, follower attributions, leader-member exchange, etc.) and leadership outcomes (i.e., effectiveness, cognition, attitude, and behavior). In sum, technology as context stems from a popular and well-developed perspective of research on the context of leadership in general.

Much of this work on technology as context uses the notion of team virtuality. Team *virtuality* is comprised of: "(a) the extent to which team members use virtual tools to coordinate and execute team processes… (b) the amount of informational value provided by such tools, and (c) the synchronicity of team member virtual interaction" (Kirkman & Mathieu, 2005, p. 702). Another definition of *virtuality* includes geographic dispersion, electronic dependence, structural dynamism, and national diversity (Gibson & Gibbs, 2006). Scholarship on virtuality holds technology as having fixed objective properties that constitute the context in which leadership occurs. These definitions of virtuality serve to underscore the emphasis of technology as a piece of the environment in which organizing occurs, which is core to work taking viewing technology as a context for teamwork.

Work examining technology as a context in teams began with the study of computer-supported work groups in the 1990's (i.e., Constant, Sproull, & Kiesler, 1996; Zack & McKenney, 1995). The work on computer-supported work groups morphed into what we know of today as "virtual teams" (Bell & Kozlowski, 2002; Dulebohn & Hoch, 2017), also sometimes referred to as global virtual or globally-distributed teams as well (Gajendran & Joshi, 2012; Kayworth & Leidner, 2002; Kotlarsky & Oshri, 2005; Oshri, Van Fenema, & Kotlarsky, 2008). Virtual teams are defined as "groups of geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task" (Townsend, DeMarie, & Hendrickson, 1998, p. 17). As a guide, Table 2 includes a list of definitions for some of the various labels applied to technology-enabled teams.

From a technology as context perspective, we see that leadership requires unique considerations on the part of the leader in technologically-enabled contexts (Dulebohn & Hoch, 2017; Meyer, 2010). There is a "consensus among scholars that virtual teams are more difficult to lead than face-to-face teams" (Hoch & Kozlowski, 2014, p. 391). Team leadership needs to compensate for the challenges created by virtual collaboration. Difficulties in leading such teams relate to both leadership functions and leadership forms.

A large body of research has examined leadership functions in teams with technology taken as a context. Specifically, research has focused on the challenges leaders face specific to team affective processes, such as relationship-building, which fosters team states such as team cohesion and team trust (Powell, Piccoli, & Ives, 2004). Face-to-face teams have been shown to have higher levels of cohesion than virtual teams (Straus & McGrath, 1994; Warkentin, Sayeed, & Hightower, 1997), and teams using chat have lower levels of cohesion compared to face-to-face teams and videoconferencing teams (Hambley, O'Neill, & Kline, 2007). Computer-mediated teams are also generally less satisfied in their team interactions than face-to-face teams (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002). Trust is integral to virtual team functioning, but is also difficult to form virtually (Jarvenpaa & Leidner, 1999; Paul & McDaniel Jr, 2004).

Research has also tackled the issue of team behavioral processes in technology as a context, including communication and coordination (Powell et al., 2004). Communication in virtual teams can be challenging (Hambley et al., 2007). Virtual teams communicate through multiple different channels, often including both instant messaging through an enterprise social media platform and video conferencing. Sometimes virtual team members can actually see the faces of their team members, and other times, virtual team members only have text to go off of to interpret a team member's meaning behind their words. Nonverbal communication is a primary challenge for communication in virtual teams (Sproull & Kiesler, 1991). Likewise, utilizing technology for coordination of virtual team members can pose a challenge. Virtual team members may come from different time zones so the physical coordination of work can become asynchronous from one another, making coordination challenging (Montoya-Weiss, Massey, & Song, 2001). Virtual team members also may encounter cultural differences, especially global virtual teams, which may mean team members have different preferences and work styles (Maznevski & Chudoba, 2000; Meyer, 2015).

Finally, research has investigated team cognitive processes in technology as a context. Cognitive processes are especially difficult to develop in teams whose members rarely if ever meet in person. However, formation of transactive memory systems in virtual teams is essential to effective team task performance. Research on knowledge coordination in virtual teams has shown that virtual teams form mental maps of member's knowledge, but that these mental maps, "transactive memory systems", take a considerable amount of time to form (Kanawattanachai & Yoo, 2007).

Research has found that leaders play an integral role in virtual team functioning, and virtual team leaders can help to tackle challenges caused by the virtuality of their teams through a few different means (Gibson & Gibbs, 2006; Gilson, Maynard, Jones Young, Vartiainen, & Hakonen, 2015). Research has demonstrated that leaders in virtual teams are critical in encouraging positive team interactions and reducing negative team interactions, such as team conflict (Wakefield,

Table 2
Definitions of exemplar technology-enabled team types.

Entity	Definition	Exemplar citation(s)
Computer-supported work groups	Two or more people who communicate and make decisions using specialized computer hardware and software.	DeSanctis & Gallupe, 1987
Virtual teams	Virtual teams are groups of people connected by a shared goal that use technology in order to interact with each other.	Martins, Gilson, & Maynard, 2004
Online community	A virtual space where people come together with others to converse, or to exchange information or other resources.	Resnick & Kraut, 2011
Crowd	People who self-organize online around a common purpose; typically that purpose was "once performed by employees and is now outsourced to a network" of people through an "open call" for participation.	Howe, 2006
Peer production group	Individuals who come together to "harness the collaborative efforts of many individuals in order to create artifacts of lasting value"	Kittur et al., 2009
Flash team	A team that is dynamically assembled with paid experts drawn from a crowd.	Retelny et al., 2014
Human-robot team	Team comprised of humans and *embodied* intelligent agents working interdependently in pursuit of a common goal.	DeCostanza et al., 2018
Human-AI team	Team comprised of humans and intelligent agents working interdependently in pursuit of a common goal.	DeCostanza et al., 2018

Leidner, & Garrison, 2008). Virtual team leaders can help facilitate team norms for how the team will go about communicating and coordinating with one another (Malhotra, Majchrzak, & Rosen, 2007). Clearly establishing norms for communication and coordination can help to establish trust among team members by providing clear expectations for themselves and others. Fostering high quality communication can help increase trust in virtual teams (Marlow, Lacerenza, & Salas, 2017). High quality communication has been shown to be predictive of who emerges as a leader in virtual teams (Gilson et al., 2015; Gluckler & Schrott, 2007). Leaders that help to foster interpersonal communication as opposed to more task-focused communication can help increase cohesion and trust in virtual teams (Gupta & Govindarajan, 2000). When virtual teams support more social communication among team members, virtual teams report higher levels of trust (Jarvenpaa & Leidner, 1999) and interpersonal relationships (Robey, Khoo, & Powers, 2000). Interestingly, one study found that if virtual team member actions are made more visible to the rest of the team, then the effects of virtuality on trust may be lessened compared to teams with less visible team member actions (Goh & Wasko, 2012).

Leaders can also help to overcome the challenges of virtual teaming through cultivating psychological safety among team members. Psychological safety is the shared belief that the team is an accepting place for taking interpersonal risks. Making mistakes is an accepted part of learning, and team members encourage each other to speak up (Edmondson, 1999). High levels of psychological safety have been shown to help mitigate the challenges of working and leading in virtual teams such that communication and coordination is less challenging in a psychologically safe environment (Gibson & Gibbs, 2006).

Finally, some styles of leadership are more conducive than others in fostering productive teamwork in virtual teams. Transformational leadership in virtual teams was associated with higher team performance, team satisfaction, and team motivation (Andressen, Konradt, & Neck, 2012; Gilson et al., 2015; Purvanova & Bono, 2009; Whitford & Moss, 2009).

In sum, leaders may be able to help virtual teams overcome the challenges of virtuality by encouraging visible, high quality, socially-oriented communication in order to help build trust and cohesion among virtual team members. Leaders can also help to encourage psychological safety among team members to help with virtual team communication and coordination. Finally, transformational leadership behaviors may be more beneficial than transactional behaviors in overcoming the challenges faced by virtual teams.

Taken together, these findings summarize ways that team leadership meets team needs when team members are working remotely largely through and with digital technologies. The key assumption about leading teams from this technology perspective is that technology features determine important aspects of the leadership situation. We summarize the findings reviewed in this section as suggesting the following leadership implication:

Leadership Implication #1. *Team leaders need to compensate for the challenges that virtual teams face in developing affective and cognitive states and enacting team processes, challenges that are created by virtual collaboration (remote communication through digital tools, diversity, etc.).*

A second area for leadership research related to our review of research examining technology as a context examines leadership forms. Extant research on leadership in teams from the technology as context perspective suggests that team leadership benefits from sharing leadership among team members. Research on leadership forms in virtual teams suggests that distributing leadership across multiple members of the virtual team rather than a single member is a more effective and efficient leadership structure in many virtual team settings (Bell & Kozlowski, 2002). This is because placing all leadership responsibility on a single virtual team member requires more time and effort than your average face-to-face team due to the technological tools that must be used in order to complete typical leadership activities, such as motivation and direction-setting (Purvanova & Bono, 2009). In fact, multiple studies have observed that the inherent structures and collaborative tendencies within virtual teams cause leadership behaviors to emerge informally from a number of team members rather than from any officially appointed leader (Avolio, 1999; Carte, Chidambaram, & Becker, 2006; Charlier, Stewart, Greco, & Reeves, 2016; Yukl, 1998). The observation from these studies is that shared leadership is better than hierarchical leadership for helping virtual teams develop needed affective and cognitive states and enact team processes.

Leadership Implication #2. *Shared leadership forms are better than vertical forms for helping virtual teams develop functional affective and cognitive states and enact team processes.*

Technology as sociomaterial

A second body of work takes a different view of technology. Work that adopts a *technology as sociomaterial team practices* perspective considers the technology practices that teams develop as they encounter material aspects of digital technologies (Table 1). Technology practices come about when team members' intentions, a desire to do something, meet features of digital technologies, an ability to do something using a feature of technology. The earliest work on teams to reflect this technology perspective emerged from structuration which is a concept that "acknowledges the active role of human agency in social systems" (Poole & DeSanctis, 1992, p. 6). The idea of structuration evolved into the area of research examining *adaptive structuration theory*. Adaptive structuration theory is proposed as a "framework for studying variations in organization change that occur as advanced

technologies are used" (DeSanctis & Poole, 1994, p. 122). Adaptive structuration explains that a technology's features can serve very different functions to a team. Team members develop practices and use technologies in ways that meet their needs. The same team may use the same technology differently at different times as their needs change. Likewise, different teams might use the same technology in different ways. In this way, the sociomaterial perspective examines technology and teams as mutually dependent ensembles (Orlikowski, 2007) and leads us to explore "the *development or use of* materials and forms" in teams (Leonardi, 2012, p. 34).

The view of technology as mutually intertwined with social practices is often examined from a technology affordance perspective. The core idea of affordances originated from James Gibson's Gestalt psychology thinking that objects do not have inherent functions (Gibson, 1977); rather a function is what comes about when an individual realizes that an object can be used for something. It is neither the person nor the object, separately, that explains the pleasure of resting on a tree stump, rather it is the moment when the *tired* person sees the *flatness* of the stump and decides to sit. In this example, fatigue creates the person's motivation to rest and the stump's flatness is a material property that can enable rest. Flatness has *afforded* the weary hiker a means to rest. Though not always tactile, digital technologies nonetheless have properties that inspire uses as well. Many of these have been described and characterized as technology affordances.

Consider the *association affordance* (Treem & Leonardi, 2013). Many team processes require that team members form a mental understanding of who holds what viewpoint, who creates which products or ideas, or who supports or opposes whom. The team process of monitoring and backup behavior (Marks, Mathieu, & Zaccaro, 2001) implies that team members can observe one another's work and intervene when the work is subpar in order to ensure that team performance does not suffer. Many programmed features that are built into digital technologies afford team members the ability to make these associations. As an example, consider any project management software (e.g., Slack, Asana, Basecamp) that has members create a profile with their name and photo. When the member posts something, the post appears next to their name and photo. A team member who wants to go back and review what has been posted related to a particular deliverable could use the search function to see who has contributed what.

"An affordance perspective recognizes how the materiality of an object favors, shapes, or invites, and at the same time constrains, a set of specific uses" (Zammuto, Griffith, Majchrzak, Dougherty, & Faraj, 2007, p. 752). Zammuto and colleagues use the concept of affordances to "capture the interplay between IT and organization" to represent the idea that "new combinations of technology and organizational features continually create possibilities that affect organizational form and function" (p. 750). Zammuto et al. (2007) suggested five possible affordances offered by organizational technologies: work processes visualization, real-time product and service innovation, virtual collaboration, collaboration with many people at once, and virtual reality.

As an example of how the sociomaterial view considers the joint confluence of human intentions and material aspects of technology, consider a technology called Ambit. Ambit (Ambit, 2019) is a software tool that monitors team conversations in realtime and provides instant feedback on the percentage of air time captured by each team member during a discussion. This feature may serve as a shared leadership affordance, enabling the group to adjust and rebalance conversation to gain input from soft spoken members. Another group may see this information differently, instead using the tool to determine the deviant whose pattern of communication is blocking the passage of an important initiative. Importantly, the technology has features, but the way these features are perceived and appropriated by the team can vary widely.

With the exception of Poole and DeSanctis' adaptive structuration theory, work viewing technology from a sociomaterial lens proliferated in the 2000's alongside the spread of online communities (i.e., Barrett, Oborn, & Orlikowski, 2016; Faraj, Jarvenpaa, & Majchrzak, 2011) and crowds (i.e., Orlikowski & Scott, 2015; Osterlund, Mugar, Jackson, Hassman, & Crowston, 2014). Online communities and crowds are interrelated terms. The former is used to describe a virtual space "where people come together with others to converse, or to exchange information or other resources" (Resnick & Kraut, 2011, p. 1). Organizational scholars exploring online communities study the shared identity that develops and connect members. Crowds, on the other hand, are more deliberative and closer to resembling work teams. Crowds include people who self-organize online around a common purpose; typically that purpose was "once performed by employees and is now outsourced to a network" of people through an "open call" for participation (Howe, 2006). Crowds often form within online communities. Online communities and crowds can form within traditional organizations or outside formal organizations. An example of the latter is InnoCentive (InnoCentive, 2019), an open innovation platform where organizations post challenges offering rewards to solvers who need not be employees of the sponsoring organization.

If we adopt a technology as sociomaterial view then we see the ways in which team leadership comes about and is enacted as team needs meet technological materiality. Leaders and team members have agency in determining how technologies are used to meet team needs. Research has explored the ways in which the "imbrication of humans and material agencies" (Leonardi, 2011, p. 147) can explain leadership functions and forms.

Research taking a sociomaterial view of technology has explored the ways in which leadership functions come about in tandem with material aspects of digital technologies (Oborn, Barrett, & Dawson, 2013). Studies have identified practices that meet affective team needs. For instance, in a study of three virtual investing-related communities, members with no formal role took on the role of *conflict mediators* "when a disagreement between two individuals became personal and destructive" (Gu, Konana, Rajagopalan, & Chen, 2007; Faraj et al., 2011, p. 1232). Members also stepped forward to motivate and direct the group. Though rarely the initiator of the idea, *idea champions* "ensure that the kernel of the idea was maintained and evolved through the discussion" (Kane, Majchrzak, Johnson, & Chen, 2009). A final example of how informal leadership is used to build affective attachment is *metavoicing*, which occurs when online community members react to one another's presence in the online community, their profile, contributed content, or other activities (Majchrzak, Faraj, Kane, & Azad, 2013).

Studies also suggest leaders help online communities and crowds to meet their cognitive process-related group needs. For example, qualitative studies observed the role of the *shaper* in an online community. The shaper is someone who helps to organize diverse contributions into a coherent message (Majchrzak et al., 2007; Yates, Wagner, & Majchrzak, 2010). The shaper self-nominates to take on the work of intellectually integrating contributions. Another leadership act aimed at team cognition is called *channeling participation*. Channeling participation occurs when members "create a narrative that helps keep fluid participants informed of the state of the knowledge, with this narrative having a necessary duality between a front narrative for general public consumption and a back narrative to air the differences and emotions created by the tensions" (Faraj et al., 2011, p. 1231).

Quite a few studies have explored leadership that behaviorally integrates team members' ideas and actions. One set of activities is labeled *engendering roles in the moment*. This occurs when observing "a perceived state of the community, coupled with a perceived self-efficacy that a particular contribution might be helpful to the community… These roles are not enacted because the participant is a member of a core group or asserts leadership authority…Instead, … the participant appears to be enacting a self-defined role as a mediator, 'unmasker,' organizer, or supporter…" that sustains collaboration (Faraj et al., 2011, p. 1231). Another leadership act enabling behavioral integration in online communities is *dynamically changing boundaries*, a strategy

used by online community members to "discourage or encourage certain resources into and out of the communities at certain times" (Faraj et al., 2011, p. 1231).

Lastly, leaders in online communities enable adaptive behavioral responses among contributors. Members of online communities *evolve technology affordances* in ways that are embedded by, and become embedded into, iteratively enhanced social norms. "These iterations help the OC to socially and technically automate responses to tensions so that the community does not unravel" (Faraj et al., 2011, p. 1231). Evolving technology affordances is a strategy for teams to remain adaptive in response to changes.

Taken together, the work on leadership functions taking a sociomaterial view of technology suggests ways that features of technology can enable team members to lead the development of needed affective and cognitive team states and behavioral team processes. The key assumption about leading teams from this technology perspective is that material features of technology and behavioral intentions jointly create affordances for leading and collaborating in teams. The findings reviewed in this section can be summarized with the following leadership implication:

Leadership Implication #3. *Team leaders can shape technology practices in order to foster the development of functional affective and cognitive states and enactment of team processes.*

Research adopting a technology as sociomaterial perspective also speaks to the second dimension of team leadership: forms. DeSanctis and Poole (1994) pointed out that technology plays an important role in shaping team status hierarchies. Material aspects of technological tools can determine "the likelihood of leadership emerging when the technology is used, whether a leader is more likely or less likely to emerge, or whether there will be equal participation versus domination by some members" (p. 127).

Research on online communities and crowds emphasizes the importance of emergent, informal leadership that is often shared or rotated among community members. Leadership in online communities and crowds tends to shift among members, and leadership authority has been observed as "fleeting in such communities" (Faraj et al., 2011, p. 1231). In fact, online communities have even been seen as resisting formal leadership from those developing and maintaining the platforms (Brabham, 2008). Overall, the inherent structure of online communities and crowds lends to a more shared, informally emergent leadership structure in terms of the form in which leadership takes in such teaming types. These findings emphasize that technological affordances can affect the form of leadership that emerges in teams, and also the degree to which leadership is stable or fluid. This suggests the following leadership implication:

Leadership Implication #4. *Team technology practices can shape the emergence of team leadership structures, and the stability versus fluidity of team leadership structures.*

Technology as creation medium

A third area of research takes another perspective of technology. Work adopting a *technology as team creation medium* perspective explores the ways that technology platforms are shaping who forms teams and how they do it (Table 1). This research explicitly focuses on the role of technology in the initial formation and later reformation of teams through boundary management practices. The technology as creation medium perspective views technology as creating new opportunities for team leadership, expanding the ways leaders can lead teams. Studies conducted from a technology as creation medium perspective also mark a shift in thinking about technologies and teams insofar as studies illustrate ways that the technologies themselves can serve all or at least parts of the leadership role.

The context and sociomaterial perspectives have in common that they both explain how technology meets traditional team leadership functions like supporting affective and cognitive states and team process behavior. The context view highlights ways that technology makes each of these team needs more pressing, requiring leaders to compensate for technology-induced challenges. The sociomaterial view explores technology practices in teams and suggests the kinds of practices that can provide needed leadership functions and the ways technology features shape team leadership forms. In the technology as creation medium perspective, the focus shifts to new leadership functions and leadership behaviors that are made possible with emerging technologies, and in some cases, to ways in which these functions can be accomplished by the technology as a leadership substitute. This perspective has flourished in the 21st century as the internet has become widely accessible to larger audiences around the world. The larger the population of internet users, the larger the pool becomes that could potentially contribute to projects created through technology that was not possible prior to the availability of large, diverse populations of potential contributors.

One group of studies on technology as a creation medium is work on peer production groups, the quintessential example being the teams who come together to curate pages in the online encyclopedia Wikipedia. *Peer production groups* are "large-scale, collaborative and primarily voluntary models of production in some of the most innovative and competitive sectors of information and technology" (Algan, Benkler, Fuster Morell, & Hergueux, 2013, p. 2). Some examples of peer production groups include open source software teams who rapidly self-assemble online in response to bugs in computer code (Crowston & Howison, 2006), citizen science teams who self-assemble to help classify and label stars in the galaxy (Iacovides, Jennett, Cornish-Trestrail, & Cox, 2013), and open innovation teams, where "people from different organizations work together to develop new products, services, or markets" (Du Chatenier, Verstegen, Biemans, Mulder, & Omta, 2009, p. 350). Most of the pages on the online encyclopedia Wikipedia.com are written and maintained by a fluid core team of individuals who monitor and update the content. Peer production groups, like those managing Wikipedia articles (Giles, 2005), consist of individuals who come together to "harness the collaborative efforts of many individuals in order to create artifacts of lasting value" (Kittur, Pendleton, & Kraut, 2009). In peer production examples such as the creation and maintenance of the online open encyclopedia Wikipedia or the Linux operating system (Weber, 2004), individuals voluntarily join a cause or project because of some intrinsic value of the project toward that person (Raymond, 1999). Team collaboration processes among the groups working on the peer production project are not organized in any particular way and are often only acknowledged through peer production-related forums or chat boards.

Another group of studies comes from work on flash teams. Flash teams come together on portals like Upwork.com that allow individuals to lead the formation and maintenance of a team of experts to accomplish specific goals. Upwork is a marketplace for professional workers that allows individuals to rapidly hire experts and supports their collaboration to accomplish a defined task. Flash teams provide a technological "framework for dynamically assembling and managing paid experts from the crowd" (Retelny et al., 2014, p. 75). For example, one might decide to convene a "flash team" using the software platform Upwork (Retelny, Bernstein, & Valentine, 2017). Flash teams provide an effective way to accomplish a variety of tasks ranging from creative design to engineering projects (Retelny et al., 2014). Individuals who participate in these teams have specialized skills and see new opportunities for flexible work on their own terms without a formal connection to traditional organizations. In these types of groups, individuals have the choice to opt in to or out of projects based on their own best interests.

The third set of studies in this subdomain explores team formation systems. These studies use digital platforms to create teams, albeit in very different ways. There are a variety of specific technologies, for

example Huddler or MyDreamTeam, that allow teams to self-organize online based on algorithms that recommend teammates to one another. With peer-production teams it is the platform that lays out the work, and then teams form organically based on mutual attraction to the work itself. With flash teams, a leader uses a platform to design the work and then chooses a set of paid experts to carry out the work. The leader of the flash team is designing the team. In contrast to the way teams form with peer-production or flash team platforms, with team formation systems members self-organize, but it's not the attraction to the work that brings them together. It is the attraction to each other.

As an example of this distinction, on Wikipedia a peer-production team came together to curate the page on "Florentine Painting" because of their shared expertise and interest in accurately conveying the most notable painters, paintings, techniques, and influences on Florentine painting. The team formed because its members were all drawn to the same task. In contrast, those who join teams in team formation systems do so on the basis of personal bases of attraction. They choose who to work with, and the task follows. One example of a team formation system is the online tool *Huddler* that "utilizes a dynamic programming algorithm to optimize for highly familiar teammates" (Salehi, McCabe, Valentine, & Bernstein, 2017, p. 1700). Another is a tool called *MyDreamTeam* (Gomez-Zara et al., 2019) which is an online searchable tool where those joining project teams can run queries to search for teammates matching those of their ideal teammates. All of these studies explore new leadership capabilities invited by technologies.

If we adopt a technology as a team creation medium perspective, then we see the ways that technology is expanding the purview of team leadership. Research from this perspective has taken as a starting point the introduction of a new technology, and then investigated the ways the technology creates leadership needs that take effect during the process of team formation, and then as the team develops and needs to reconfigure itself. As we review research on technology as a creation medium, we see how this genre of work invites leadership researchers to expand the functional lens to place greater emphasis on leadership during team formation. Work in this area expands the focus of leadership, illustrating ways that leadership dynamics are set in motion during the team formation process aided by digital platforms. To illustrate this point, consider the leadership processes involved in online peer production teams.

The leadership that occurs within peer production teams is self-governing. There is often a person or group of people who act as administrators ensuring that the technical infrastructure is set up and maintained (Butler, Sproull, Kiesler, & Kraut, 2002). Besides the one layer of leadership defined by the platform's organizational structure, the bulk of the leadership in peer production is emergent. Many of the active contributors of peer production teams, who are the individuals who do the bulk of the content creation in a platform like Wikipedia, are also often identified as taking on a leadership role and are often not compensated for their work (Zhu, Kraut, & Kittur, 2012, 2013). As peer production is a voluntary activity, team leaders must find non-monetary ways to motivate others to contribute. This means leaders must provide intrinsic rewards for contributors such as creating a community that contributors can embed themselves within and derive meaning from (Deaux & Stark, 1996; Penner & Finkelstein, 1998). Recruiting members to the team and erecting a meaningful boundary that serves as a basis for positive social categorizations is especially important in these groups that form outside of any formal organizational structure.

From a leadership perspective, these teams are formed by those with project needs or vision, or workers can join a pre-existing cause, started and maintained by individuals they may never meet in person. In these situations, many of the leadership processes are occurring before team members even join the team. Leadership involves recruiting team members, monitoring progress, and determining when new members need to be added or existing members disenfranchised.

Research taking a technology as creation medium perspective has explored the ways in which traditional and emerging leadership functions are carried out in online platforms. Starting with the traditional function of meeting team affective needs, a number of studies have explored how technologies can play a role in meeting the leadership needs of teams as they form. These studies do not study how team leaders use technology (sociomaterial perspective) or are affected by technology (context perspective), but rather, investigate a new function of forming teams, and some studies reflect a technology performing the leadership function even without the awareness of the team. For example, Salehi et al. (2017) show that their tool *Huddler* enables teams with greater familiarity to form faster than they can without the tool and that familiarity doubles the performance of crowd worker teams. Another example is work done by Luther and Bruckman (2008) which observes that one of the functions of leaders in online creative collaboration is to design a collaborative project for the team to form around.

In a set of studies wherein digital technology oversees a *team dating* process, team members work with the technology to form teams (Curseu, Kenis, Raab, & Brandes, 2010). Team dating uses a technology to allow people to meet a variety of potential teammates quickly for short encounters, rating them, and then being matched with higher-rated teammates. Another study demonstrates how technology can take on leadership functions using a personality matching algorithm (Lykourentzou, Antoniou, Naudet, & Dow, 2016). The technology used an algorithm to form teams with balanced personality types. Crowd worker teams whose members have different personality types experienced less conflict and greater satisfaction than more homogenous teams. Interestingly, when given a choice of being matched based on their own ratings or the average ratings of people provided by everyone participating, people prefer their own ratings (Lykourentzou, Kraut, & Dow, 2017; Lykourentzou, Wang, Kraut, & Dow, 2016). Although not explicitly labeled team dating, other researchers have investigated the use of a community-wide deliberation process prior to team formation, and researchers found that this process prior to team formation resulted in higher team performance after team formation (Wen, Maki, Dow, Herbsleb, & Rose, 2017).

Also on the topic of leading team affect, it is interesting to note that a set of platforms is cropping up to allow individuals who work in paid crowdsourcing environments and on peer-production and flash teams to discuss their experiences and rate the "employers". Four of them supporting the Amazon Mechanical Turk workforce are: TurkerNation, MTurk Forum, MTurkGrind, and MTurk Crowd. Workers come here to decide which projects to participate in and which to avoid (LaPlante, Silberman, & Metall, 2016). Although crowdsourcing research often takes a technology as sociomaterial view, the work on these kinds of groups pre-formation falls within our technology as creation medium perspective, since this work examines the groups and technology before and as they are being created rather than after they are created. For individuals who regularly organize and lead flash teams, these forums provide an important source of reputational capital that affects their ability to lead projects by attracting top talent in the future.

Research taking a technology as creation medium view has also explored the ways in which technologies play a role in supporting team cognition as teams form. Specifically, research on crowd teams has examined the role of technology in team cognition such as team familiarity, mental scaffolding, and collective intelligence. Overall, leadership functions have also been preliminarily found to affect team cognitive processes. For example, crowd teams high in interpersonal familiarity have been shown to outperform crowd teams low in interpersonal familiarity, which is believed to be because of team cognition (Salehi et al., 2017). Also, differences in expertise levels can impede crowd workers' collaborative effectiveness. Specifically, a crowd worker team's use of modifiable shared artifacts to scaffold ideas between team members and crowd workers was shown to improve collaboration (Lee et al., 2018). Research has found that peer production group members use other's history of project activity to form impressions of other's expertise (Marlow, Dabbish, & Herbsleb, 2013). An expert leader in a

crowd worker team can also be helpful in leading non-experts to successfully accomplish data analysis tasks (Feldman, Anastasiu, & Bernstein, 2018). Finally, collective intelligence systems can help organizations to create optimal teams from crowds to fit specific organizational needs (Malone, Laubacher, & Dellarocas, 2010). Together, these results suggest preliminary evidence for the role of leader behaviors influencing team cognitive processes in teams using technology as a creation medium. In crowd worker teams and peer production teams, leaders must be particularly careful about clarifying team boundaries so that team members can form productive cognitive models about one another.

Research taking a technology as creation medium view has also explored the ways in which technologies play a role in supporting team behavioral processes as teams form. In order to illustrate what we mean by this, consider a flash team. When a leader decides to create a flash team, and recruit team members to join, the leader designs a workflow in the platform. Creating *workflows* in flash teams is the act of dividing up crowdsourcing jobs into smaller tasks. The workflow largely dictates who communicates with whom in the course of coordinating the work. Once the leader determines the workflow, the technology largely governs team behavioral processes; team interactions travel where the tracks were laid down by the flash team leader and then are continually reinforced by the technology. Research finds these workflows provide a useful coordination artifact, but also prevent team members from being able to adapt personal work plans when needed (Retelny et al., 2017).

Taken together, the work on leadership functions taking a creation medium view of technology suggests unique ways that technologies are shaping team formation within and outside formal organizations. These technologies shape who comes together in teams in the first place or at all, and also sets team dynamics in motion. The key assumption about leading teams from this technology perspective is that team leaders can leverage technologies during the team formation stage to foster the development and maintenance of needed team states and process. As such, we summarize the following leadership implication supported by our review of this work.

Leadership Implication #5. *Team leaders can use team formation technologies in order to foster the development of functional affective and cognitive states and enactment of team processes.*

In reviewing these studies, we note a key shift in thinking about leadership that needs to be mentioned. Most of these studies look at how team members can use technologies during team formation. The idea being that how individuals use technology during team formation can be pivotal in supporting teamwork later on. Other studies look at how the technology can be programmed in such a way as to take the team members out of the leadership loop during team formation. These studies move toward using the technology in team formation as an alternative or substitute for leadership. As a case in point, *Huddler* (Salehi et al., 2017) and related studies (i.e., Rahman, Roy, Thirumuruganathan, Amer-Yahia, & Das, 2018) in the genre seek to codify into an algorithm the choices and actions of team leadership during the team formation process. Based on this, we summarize the following additional leadership implication that arises from the technology as creation medium perspective:

Leadership Implication #6. *Digital technologies used during team formation can serve a team leadership role by fostering the development of functional affective and cognitive states and enactment of team processes.*

Not only does the creation medium perspective have implications for leadership of the most commonly studied teamwork states and processes, but research conducted with this view in mind suggest additional leadership functions as well. Boundary work has long been an important aspect of team leadership and presents as particularly critical to leading wherein technology is a creation medium. A boundary defines who is on a team and who is not (Hackman, 2012). Examples of boundaries that may be drawn in organizations are vertical boundaries, horizontal boundaries, demographic boundaries, and geographic boundaries (Yip, Ernst, & Campbell, 2011). Vertical boundaries occur across levels of hierarchy whereas horizontal boundaries occur across function or expertise level. Demographic boundaries occur across group diversities such as gender, age, or cultural background, and geographic boundaries occur between those located in different locations. Boundaries provide teams with needed entitativity, a perception of group similarity and interconnectedness (Campbell, 1958; Gaertner & Schopler, 1998). Hackman (2012) suggests that “real teams” require boundaries that distinguish those on the team from those who are not. Meaningful boundaries serve as a basis for positive social categorization processes, define ingroups and outgroups, and inspire, motivate, and promote collaboration within boundaries (Arrow & McGrath, 1995; Ernst & Yip, 2009; Lau & Murnighan, 2005).

Technological advances raise the importance of boundary management work in technologically-enabled environments, but also the challenges of dynamic boundary management work in such contexts (Hwang, Singh, & Argote, 2015; Mortenson & Haas, 2018). Team boundary spanning, or team boundary management, is “a team's efforts to establish and manage external linkages” that can occur within and between teams and organizations (Marrone, 2010). We adapt the classic definition of team boundary management for a technologically-enabled definition that better suits the boundary complexities that leaders face within teams that use technology as a creation medium, like flash teams or peer production groups. In these teams that form entirely through online platforms, leader boundary management will be critical to gaining participation, creating functional norms, and sustaining member motivation to contribute to the team.

Research taking a technology as creation medium view has uncovered a new leadership function needed by teams in informal online environments. With flash teams, the team leaders need to continuously reevaluate who stays on the team. The fluidity of flash teams requires teams to balance conflict with cohesion, constantly defining and redefining the boundary of the collective project in order to socialize newcomers and extradite members who no longer advance the shared vision (Luther, Fiesler, & Bruckman, 2013).

Team boundaries, or a lack of clear team boundaries, is especially salient in teams in which technology is being utilized as a creation medium. To give some context, the bulk of work contributed in peer production communities, such as a Wikipedia page, is typically completed by a small group of contributors who claim leadership in creating that particular page (Kittur & Kraut, 2008, 2010). However, unlike in a typical organization, there are no organizational or hierarchical structures in place to guide contributors in who leads whom. Technically, in an open-source, peer production project, anyone can contribute to the project. How does the core of contributors regulate the creation and quality of output on the page? The core group of contributors must navigate the fluid boundaries of the peer production project through whatever means of communication and coordination are available to them in the platform. These forms of organizing are also increasingly being used inside formal organizations in open innovation projects (Chesbrough & Appleyard, 2007). Although team-boundary spanning is a well-known leadership behavior, what do leaders do when there is a clear lack of boundaries to span? Setting up and managing team boundaries through effective leader boundary management is critical to the overall performance and viability of those working in the peer production group. Fluid boundaries are a particular challenge for leaders of teams using technology as a creation medium. Based on this work emphasizing the increasing challenges related to boundary management, we suggest the following leadership implication:

Leadership Implication #7. *Team leaders can use team formation technologies to manage team boundaries both during team formation, determining who's on the team, and also during subsequent team phases through the periodic reevaluation of team membership.*

Not only are digital technologies playing a role in team leadership functions, they are also shaping the form leadership takes on in the team. Distributed leadership is where multiple team members take part in leading the team (Gronn, 2008; Thorpe, Gold, & Lawler, 2011), and was examined in flash teams using a tool called *Pipeline* (Luther et al., 2013). Pipeline was designed to "support and transform leadership, with the goal of easing the burden on leaders of online creative projects" (Luther et al., 2013). The *Pipeline* tool "redistributes" leadership to spread the burden of leadership across multiple team members, which was theorized to improve team effectiveness. Another study on leadership forms in Wikipedia finds strong evidence for the presence of shared leadership among the online encyclopedia groups (Zhu, Kraut, Wang, & Kittur, 2011). Studies like these show how a digital technology can shape the leadership form that comes about. Other studies show how individuals' behavior with these technologies can shape their own fate as team leaders.

As a case in point, studies using the *MyDreamTeam* (Gomez-Zara et al., 2019) tool found significant disparities in the number of team invitations individuals sent out. This disparity was important because the study also found that being central in the team invitation network, i.e., being the one who invites everyone to the team, predicted leader emergence once the team began to work together (Twyman, 2019). Hence, those who are most active in using technologies to assemble teams may also have an outsized role in leading them once formed.

Reflecting the technology as team creation medium lens, these studies find consequential leadership dynamics are playing out in online digital platforms as teams are forming and are shaping the leadership functions and forms involved in teamwork later on. The studies of tools like Pipeline highlight the ways digital tools are shaping leadership structures in teams. Studies like Twyman (2019) show actions taken during team formation can shape team leadership emergence later on as the team executes taskwork. Accordingly, we note the following leadership implications that relate to team leadership forms:

Leadership Implication #8. *Digital technologies can shape the leadership structures that emerge in teams.*

Leadership Implication #9. *Team members actions and interactions during team formation within digital technologies can play a role in who emerges as a team leader.*

Technology as a teammate

The fourth area of research takes yet another perspective of technology. Work adopting a *technology as teammate* perspective explores the ways that digital technologies are advancing to the point of fulfilling a distinct role on the team (Table 1). As the long history of work on digital technologies and teams clearly suggests, technologies have long been important to teams. The role of technology in the other three perspectives has been to understand how technology affects teamwork. In the context view, it constrains teamwork. In the sociomaterial view, it gives rise to work practices. In the creation medium view, it creates new opportunities to lead during the formation process. In the teammate view, technology is not viewed as it constrains or augments what team members are doing, technology is viewed as a motivated social being operating as a co-equal member of the team.

We are quickly approaching a time when digital technologies are as agentic as are human counterparts. Historically, humans have worked alongside machines in many forms, such as in automobile assembly lines or cracking codes in World War 2. Today, many airplanes have an autopiloting system consisting of code that works as a teammate alongside human pilots. The future promises even more automation in our day-to-day lives with innovations in autonomous transportation, like self-driving Ubers and autonomous ground transportation. Moreover, autonomous agents will become more embedded in organizational life, as organizations begin to use AI in nearly every corner of their organizations, from human resources (Bokelberg et al., 2017), selection (Strohmeier & Piazza, 2015) and training (Taylor, 2017), to steering and investment decisions (Strier, 2017).

The extant literature on leadership in teams has focused on leadership of teams of humans. However, as we just listed in the previous paragraph, technology is becoming increasingly prevalent within our teams, taking on team roles and functions that used to be occupied by humans (Bourton, Lavoie, & Vogel, 2018; Nass, Fogg, & Moon, 1996). Important work in the human-computer interaction literature has started to push the boundaries of this work to not only think about the best possible design of technologies for human use, but also consideration of how to create technologies that can best take on team roles or functions so that they can also collaborate well with their human teammates (Ajoudani et al., 2018; Breazeal, Kidd, Thomaz, Hoffman, & Berlin, 2005; Groom & Nass, 2007). In contrast to our previous perspectives wherein technology was being used by humans or augmenting human behavior, our review of the literature invites us to acknowledge a new perspective on leadership and technology: technology as a teammate.

Although clearly relevant to organizational scholars, work examining technology as a teammate has primarily lived in areas other than organizational behavior. Kellogg, Valentine, and Christin (2019) proclaim "organizational scholarship has not kept pace with the ways that algorithmic technologies have the potential to transform organizational control in profound ways, with significant implications for workers" (p. 2). Thus, we find much of the work on technology as teammate originating from the area of human-computer interaction and other technology-related areas, rather than in the organization sciences. Human-robot teams have been the subject of study in these areas for much of the 20th century in the form of assembly line teams, for example. Although the study of the interaction between humans and robots is not new, only within the past decade or so has the scholarly research been able to actually study human interaction with intelligent agents. This is due to the fact that the intelligent technologies have only recently become "intelligent", with the creation of artificially intelligent agents such as IBM's Watson. Thus, the human-AI team has only come about in the 21st century.

At this point, it is useful to distinguish the terms agent, technology, robot, and AI. DeCostanza et al. (2018) distinguish a *technology* from an *agent* when it comes to teams: "we reserve the term technology for those devices, software, protocols, and other interventions that target the members of the team with the goal of improving team processes. It is entirely possible that a technology will also be a team member, which we refer to as an agent. We use the term technology when referring to its role as assisting in team performance as opposed to satisfying its role in the team" (DeCostanza et al., 2018, p. 4). A robot can be either a technology or an agent, depending on its role in the team. If the robot merely augments a human, making no unique contributions to the team apart from making a human more effective, then it is a technology. If, on the other hand, the robot is a team member fulfilling a distinct role in the team and making a unique contribution to performance, then it is an agent. For the purposes of our review, we use the term robot to refer to the latter meaning, where robots are a type of agent, serving as a member of the team. Thus, the perspective of technology as teammate deals with technology that acts as an agent, not just a technology.

Next, it is necessary to distinguish the difference between robots and AI to better define human-robot teams from human-AI teams. *Robots* are embodied agents with physical features roughly resembling human characteristics. Not all agents are embodied, and disembodied computational systems can also be a teammate, which introduces the notion of Artificial Intelligence (AI) to teams. *AI* is defined as the use of a computer to "perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages" (Artificial intelligence, 2019). The most critical aspect of this definition being "tasks normally requiring human intelligence," since this distinguishes AI from automation which also

involves technology performing human tasks, but typically more behavioral tasks. We use the term agent in human-agent teams to refer to cases where a technology serves as a team member broadly. This umbrella term then captures two types of human-agent teams: human-robot teams and human-AI teams. The primary distinction between the two being the physical embodiment of the robot. Both are computerized, employ computational algorithms, and occupy a role on the team. However, the robot is physically embodied while the AI teammate is not. The distinction is useful because prior work on robot embodiment is important for leading human-robot teams, but not for leading human-AI teams.

Human-robot teams are composed of humans and embodied intelligent agents working interdependently in pursuit of a common goal (DeCostanza et al., 2018). Human-robot teams include teams of humans and robots working on assembly lines together and teams of human cooks and touch screens working as order-takers in a fast food restaurant. Human-AI teams are composed of humans and disembodied intelligent agents working interdependently in pursuit of a common goal (DeCostanza et al., 2018; Wilson & Daugherty, 2018). Examples of AI include machine learning or deep learning computational techniques used in the corporate world to predict market changes or human behavior (Pyle & San Jose, 2015; Wellers, Elliott, & Noga, 2017). Machine learning algorithms "detect patterns and learn how to make predictions and recommendations by processing data and experiences, rather than by receiving explicit programming instruction" (Chui, Kamalnath, & McCarthy, 2018). One could imagine AI being used in teams to run risk-analyses for team decisions or help with retaining and sharing relevant team information (Wilson & Daugherty, 2018).

Extant research on humans working in teams with agents is still in its infancy, but one major point stressed in the extant literature on the topic is that human-agent teaming of the future will present a range of challenges (Chakraborti, Kambhampati, Scheutz, & Zhang, 2017; Talamadupula, Briggs, Chakraborti, Scheutz, & Kambhampati, 2014). Humans have been working alongside some form of automation for decades, and there have obviously been leaders of such teams. However, in the past, a leader's consideration of such technologies was to ensure that there was a person on the team that was equipped to manage or operate the technology and to step in if something malfunctioned. However, we are now moving into a new era of robotics and automation where agents are taking on more advanced executive functions, like choosing the team, providing feedback on team processes, or intervening to stimulate controversy over team decisions.

Though more nascent than the other three perspectives, this perspective represents one of the most exciting new frontiers for team leadership research. Though there are far fewer studies, particularly empirical ones to summarize in this domain, we synthesize existing conceptual perspectives with the lens applied thus far in our review in order to outline three leadership implications suggested by this early thinking on technology as teammate.

A first set of thinking in this area relates to affective and cognitive leadership needs. A major issue in human-agent teamwork is getting humans and technology to have productive affective processes. Researchers have begun to investigate issues like trust in human-robot interaction (Billings, Schaefer, Chen, & Hancock, 2012; Freedy, de Visser, Weltman, & Coeyman, 2007; Lee & See, 2004). In particular, research has found that humans' trust in robots was highly dependent on the robot's performance and perceived competence (Hancock et al., 2011). Another study found that team members preferred to cede control to a robot rather than a human teammate (Gombolay, Gutierrez, Clarke, Sturla, & Shah, 2015). Teams have also been shown to perform better when they were emotionally attached to a robot teammate (You & Robert, 2018). Researchers have even looked into anxiety detecting systems in human-robot collaboration (Rani, Sarkar, Smith, & Kirby, 2004). However, little empirical research has been done on a leader's considerations in leading teams with modern-day robotics working alongside human teammates.

This research suggests that leaders must not only manage the interaction between humans and robots, but they must also consider the way introducing robots to teams might change human-human relationships (Jung, 2017; Jung & Hinds, 2018). Introducing robots to social settings has been found to shape the interactions that occur among humans. For example, in a study introducing a snack delivery robot to the workplace, employees were later found to be more polite because they were paying close attention to how one another was treating the robot (Lee, Kiesler, Forlizzi, & Rybski, 2012). Another example is research examining the ability of a robot teammate to mend team conflicts. Researchers had the robot interject with statements like: "Dude, what the heck! Let stay positive" (Table 2, p. 232). The study found that robots using conflict repairing strategies were able to influence human-human conflict interactions (Jung, Martelaro, & Hinds, 2015).

Research also highlights the leadership need related to team cognition. One obstacle acknowledged in expert reports is that a leader's job is to help team members better understand the technology (McAfee, Brynjolfsson, Goldbloom, & Howard, 2014, September). Experts claim that human-robot teaming of the future will be primarily more of a cognitively intensive challenge rather than a physical challenge because of the implicit expectations that humans have of their teammates, whether they are human or otherwise (Chakraborti et al., 2017; Hoffman, 2013). Related to cognitive team processes, a leader's job is two-fold. First, leaders are and will continue to be pivotal in the development of productive teaming with intelligent agents. An extensive knowledge of teamwork and human interaction is crucial for designing technologies that work well with human team members. On the other hand, leaders must be able to help human team members adopt new technology teammates, including understanding the role of the technology and how the technology is preprogrammed to perform that role on the team.

Taken together, early work on leadership functions taking a technology as teammate view emphasizes the need for leadership to develop functional affective and cognitive states. Interestingly, these states have two foci: the interface between humans and machines, and the interface among human teammates who are working in the presence of machines. The key assumption about leading teams from this technology perspective is that the addition of intelligent machines as full-fledged team members with their own programmed and evolving motivations creates a leadership need of facilitating productive relationships among human and synthetic team members. The findings reviewed in this section can be summarized with the following leadership implication:

Leadership Implication #10. *Team leaders need to foster functional affective and cognitive states and behavioral processes among human and synthetic team members so that human-agent teams can perform effectively.*

Adding intelligent machines as teammates creates additional leadership needs. AI is quickly becoming a source of competitive advantage across industries and levels of organizations, and many industrious organizational leaders are driving this trend. However, there are limits to the technology. The C-Suites of major technology firms - Amazon, Google, Apple, and Netflix, to name a few - routinely leverage AI, often in the form of machine learning, to help with pattern recognition and analysis to make organizational steering decisions (Pyle & San Jose, 2015). Rather than human-created rules that are pre-programmed into the algorithm, machine learning generates algorithms from data. These approaches first train on massive data sets, creating rules from patterns in the data set and are then refined through an iterative process of applying the rules to data, learning, adjusting rules, and so forth. Organizations are beginning to rely on such algorithms in order to steer decision making processes, but there are limits. One major theme of concerns for leaders in using AI is the ethics behind the technology. Some ethical considerations come from the data that is used to train the algorithms. The data used in training and making

Table 3
Summary of leadership implications stemming from four technology perspectives.

Technology as team context
Leadership Implication #1. *Team leaders need to compensate for the challenges that virtual teams face in developing functional affective and cognitive states and enacting team processes, challenges that are created by virtual collaboration (remote communication through digital tools, diversity, etc.).*
Leadership Implication #2. *Shared leadership forms are better than vertical forms for helping virtual teams develop functional affective and cognitive states and enact team processes.*
Technology as sociomaterial team practices
Leadership Implication #3. *Team leaders can shape technology practices in order to foster the development of functional affective and cognitive states and enactment of team processes.*
Leadership Implication #4. *Team technology practices can shape the emergence of team leadership structures, and the stability versus fluidity of team leadership structures.*
Technology as team creation medium
Leadership Implication #5. *Team leaders can use team formation technologies in order to foster the development of functional affective and cognitive states and enactment of team processes.*
Leadership Implication #6. *Digital technologies used during team formation can serve a team leadership role by fostering the development of functional affective and cognitive states and enactment of team processes.*
Leadership Implication #7. *Team leaders can use team formation technologies to manage team boundaries both during team formation, determining who's on the team, and also during subsequent team phases through the periodic reevaluation of team membership.*
Leadership Implication #8. *Digital technologies can shape the leadership structures that emerge in teams.*
Leadership Implication #9. *Team members' actions and interactions during team formation within digital technologies can play a role in who emerges as a team leader.*
Technology as a teammate
Leadership Implication #10. *Team leaders need to foster functional affective and cognitive states and behavioral processes among human and synthetic team members so that human-agent teams can perform effectively.*
Leadership Implication #11. *Team leaders need to ensure that team members have a shared understanding of the limits of technology and when control needs to be taken back by human team members.*
Leadership Implication #12. *Team members' interactions with synthetic teammates can play a role in shaping who emerges as a leader, and the overall leadership structure that emerges in human-agent teams.*

predictions might come from a data set that is biased, misinforming the team. Until ethical standards are developed at an industry level, leaders must decide how to navigate the ethical questions of AI.

Leaders must navigate their human team members' acceptance of the technology used as teammate. The leader must learn about and stay up to date on the constant innovations occurring in the technology as well as clearly communicate the technology and its capabilities to the humans on the team in order to build team efficacy and trust around the technology. Furthermore, the leader must communicate the necessary pieces of information about the technology acting as teammate so that humans understand the strengths and limitations of the technology. Artificially intelligent machines tend to not advertise their limitations, so is an important responsibility for team leaders. One example where this mutual understanding of the technology's limitations is critical can be seen in the Boeing 737-Max crashes in early 2019 (Beech & Suhartono, 2019). Pilots in these incidents were unaware of the limitations of a new update in the navigation systems, so the pilots did not know to take control from the navigation system at the appropriate time. Although an extreme example, the Boeing 737-Max incidents underscore the importance of having everyone on the same page, both humans and technologies. A leader's intricate knowledge of all teammates, human and otherwise, is critical in teams wherein technology is perceived as a teammate.

Leadership Implication #11. *Team leaders need to ensure that team members have a shared understanding of the limits of technology and when control needs to be taken back by human team members.*

Not only does the prospect of synthetic teammates shape needed team leadership functions, it also has important implications for leadership forms. Several studies find humans appreciate ceding some leadership responsibility over to robots. In a study by Gombolay and colleagues mentioned earlier, human team members preferred to cede control to the robot as compared to a human teammate. This has implications for shared leadership more generally. If humans prefer sharing leadership with technologies, this may make it more difficult for humans to share leadership with one another. Also speaking to this issue is work by Lee et al. (2012) on a study of the snackbot robot that brought snacks to offices over a period of 4 months. This employee's quote is telling about how bonds between humans and robots can later spill into human relationships: “One time I told Snackbot–I think Snackbot asked me if there was maybe a tour of [building] or something, which room should Snackbot take me up to, and I just told Snackbot that probably someone would program it. It's a robot. It's probably not going to make those choices. And then my office mate was like, ‘Oh. Now you've gone and made Snackbot feel bad.’ So I think part of it is about how my relationship with Snackbot is not just about Snackbot but about other people who are around and kind of see us” (Lee et al., 2012, p. 700). When human relationships are shaped in part by how humans relate to technology, we would expect these interactions to shape leadership emergence in teams. Those whose interactions are more positive toward and effective in interacting with technological teammates (robots or algorithms) are themselves likely to be seen as more capable leaders. This leads to our final leadership implication:

Leadership Implication #12. *Team members' interactions with synthetic teammates can play a role in shaping who emerges as a leader, and the overall leadership structure that emerges in human-agent teams.*

Discussion

In reviewing the research on teams using digital technologies, we distinguished four perspectives on technology that were not labeled as such, but at closer inspection suggest the authors adopted somewhat differing assumptions about the role of technology in teamwork. Then, as we summarized the findings from each view using the two dimensions of leadership, functions and forms, we identified a set of leadership implications that arise from each perspective. Some of these implications are close to those found in other reviews, particularly those in the technology as context domain, but others offer exciting new directions for team leadership research. In this closing section, we highlight the novel implications suggested by our review and the future directions they imply for the research and practice of leading teams.

New directions for leading teams in the digital age

In reviewing research on team leadership from a technology vantage point, we identified twelve leadership implications suggested from this work. As we look across the leadership implications arising from these perspectives, summarized in Table 3, we would like to highlight three opportunities ripe for future leadership theory and research. These include: (1) leading technology practices, (2) leading teams across an expanded set of functions, and (3) collaboratively leading teams along with technology.

The first new direction suggested by our review is increased attention to the various ways team leaders shape technology practices. A leadership function discussed above and brought about by new technologies is that leaders must be aware that they help create team context and shape how teams utilize various types of technology, a process called *team technology appropriation.* This particular leadership function applies in particular to leaders in online communities/crowds, peer production groups, and flash teams. For example, Wikipedia, the peer-produced online encyclopedia, was founded by Jimmy Wales, who was the first leader within the Wikipedia platform. As such, Jimmy Wales created context and helped to shape team technology

appropriation at the beginning of Wikipedia's life. Once Wikipedia shifted to a more democratically-run system, Wikipedia page editors in good standing could run for positions in Wikipedia administration (Wikipedia contributors, 2019, October 7). Today, Wikipedia is led by decisions made by those elected administrators. On a more micro-level, there are page editors who take responsibility for certain pages or topic areas. Both administrators and page editors alike now decide how to move forward with the context and technology appropriation, such as with the formation and use of comment sections within Wikipedia through which editors may communicate.

The second new direction suggested by our review is an expanded set of leadership functions. Specifically, our review suggests that leadership actually begins before a team even forms. Our review took us into the team formation literature and brought up a few implications of leadership responsibilities in team formation. Another new function from the technology as teammate perspective is the need for team leaders to ensure that team members hold a shared understanding of when authority that has been shared with synthetic teammates needs to shift to human teammates. Issues of control get to the heart of how humans and autonomous agents interact. *Control* is the basic mechanism by which human team members monitor AI at key points in time, with the ability to intervene if deemed necessary. In thinking about how leaders manage AI-control, the concept of a team interaction mental model is useful (Lim & Klein, 2006). A team interaction mental model is a mental representation among team members about how members interact in performing taskwork. Leading teams with synthetic teammates will require the development of effective human-agent interaction models. These mental representations will need to be shared by human teammates and programmed into the AI by technology developers that ensure control mechanisms that are clear to all team members, human and synthetic.

The third new direction suggested by our review is collaboratively leading teams along with technology. This direction came out of the technology as team creation medium perspective when we found studies designing algorithms that would essentially take over the team leader's role in staffing. We also saw this suggested in the technology as teammate domain when robots were given control of task allocation processes (Gombolay et al., 2015) or programmed to diffuse interpersonal tension (Jung et al., 2015). Discussions of how AI will affect managers often focus on two things: 1) AI can reduce the amount of time leaders spend doing administrative work, and 2) AI will take on more and higher level decision making (Kolbjørnsrud, Amico, & Thomas, 2016; Parry, Cohen, & Bhattacharya, 2016). As advances in AI render intelligent agents better able to take on much of the direct administration, scheduling, and coordinating work in teams, human leaders can be more effective to the extent that they develop ways to share this work with their synthetic teammates. Similarly, as deep learning algorithms prove their value in making important decisions, leaders can work alongside these algorithms, adding their distinctive expertise on social and interpersonal issues that need to be considered in tandem with algorithmic judgement. The notion of ceding some responsibility for leadership of team formation to intelligent machines opens up a new research direction. What are the different forms of sharing leadership with intelligent machines? Which aspects of leadership are team members more and less willing to share with synthetic teammates? And in terms of performance, which structures best promote effective teamwork in human-agent teams?

These three themes apparent from examining team leadership from a technology perspective suggest new and interesting directions for leading teams. New sets of leadership activities come about when we focus on sociomaterial practices or technology as a creation medium. New sets of functions come about when we probe the technology as creation medium or technology as teammate perspectives. Lastly, from the technology as creation medium and technology as teammate vistas, we are invited to consider the ways leadership can be effectively shared between human and synthetic teammates. Whereas the preceding discussion highlights new directions for leading teams revealed by our review, it is also important to point out the enduring aspects of team leadership.

Enduring aspects of leading teams

Across the four perspectives, functional aspects of team leadership are as important as ever for supporting teamwork across the many technology-enabled teams explored in our review. Leadership activities that promote the emergence of affective states in teams came up as important across areas. Trust was a common need across studies viewing technology as a context (Gilson et al., 2015; Joshi et al., 2009; Tyran et al., 2003), as a creation medium (Luther et al., 2013), and as a teammate (Hancock et al., 2011). Cognitive team needs also cut across technology viewpoints. Studies viewing technology as context point out the need for leaders to address the lack of shared meaning across distributed team members (Bjørn & Ngwenyama, 2009), studies viewing technology as sociomaterial call out team roles like the “shaper” who organizes diverse contributions into a coherent product (Majchrzak et al., 2007; Wagner & Majchrzak, 2006; Yates et al., 2010), and studies in the technology as teammate genre emphasize that leaders need to enable human and synthetic team members to understand and predict others' thoughts (i.e., Chakraborti et al., 2017; Talamadupula et al., 2014).

While the functional needs were present across studies conducted with different technologies in mind, another observation looking across these studies is the importance of contextualizing leadership functions to the technology. For example, team behavioral processes are needed by all teams, and yet the four technology views highlight interesting differences in the kinds of behaviors required to align team member contributions. For example, many studies of virtual teams focus generally on the need for communication (Gilson et al., 2015; Gluckler & Schrott, 2007) whereas studies of teams on large online platforms take a far more nuanced view of the behaviors that align members' contributions like engendering roles or evolving technology practices (Faraj et al., 2011). Even more detailed and contextualized in the technology are behaviors described in studies of human-agent teams. Consider this description of backchanneling behavior: “a set of mostly nonverbal behaviors by a listener in a conversation, which signals to the speaker that the listener is actively engaged in the interaction. It includes behaviors such as ‘mm-hmm’ vocalizations, slight nodding, eye contact, and orientation toward the speaker” (Jung et al., 2013, p. 1556). These kinds of technology-contextualized processes will continue to be essential in developing leadership theory and practice in the digital age.

Our review also highlights that leadership forms continue to be an important aspect of leadership, and one that is likely to be shaped by digital technologies. Whereas leadership functions are a more tangible and observable aspect of teams, leadership forms are less visible to team members. Conceptual and meta-analytic works point to the importance of leadership structures in enabling team performance (c.f., Pearce & Conger, 2003; D'Innocenzo et al., 2016). A theme evident in the technology as creation medium and technology as sociomaterial perspective is that technology can be pivotal in shaping team leadership structures (see Leadership Implications 4 and 8).

We can see from the preceding discussion that leadership functions and forms continue to be meaningful aspects of leading teams across technology perspectives. However, by examining the ways these two dimensions of team leadership are theorized across perspectives, we can better understand how these functions are met differently in different technology environments. Having taken stock of three ways that technology opens up new possibilities for leadership theory and research, and the continued utility of the dimensions of functions and forms of leadership, we conclude by considering some of the implications of technological advances for leadership development.

Leadership development in the digital age

The four perspectives of technology in teams highlighted in this review point to new directions in leadership development. As organizations continue to structure work around teams, relying more on informal relationships and less on formal hierarchy, leadership development has evolved to emphasize the importance of relationship building. Accordingly, the targets of leadership development efforts focus on the need to build social capital, rely on relational competence, and leverage social awareness and social skills (Day, 2000). Leading teams in the digital age suggests two directions for leadership development: (1) extending the relational focus to include technologies and (2) exploring ways that emerging AI tools can augment leader relational competencies.

In the technology as context view, leadership development frameworks (Day & Dragoni, 2015; Zaccaro, Ardison, & Orvis, 2003) emphasize the role of context in more technologically-enabled teams and the need for leaders to build important intra- and inter-team relationships given this context (Cullen-Lester, Maupin, & Carter, 2017). Work in this domain guides research and theory in leadership development (Day, Fleenor, Atwater, Sturm, & McKee, 2014). The other three views of technology and teams invite us to consider additional directions for leadership development.

In the technology as sociomaterial view, we might consider functional and structural leadership affordances. For example, affordances like association explain how material aspects of technology and human intentions jointly enable knowledge sharing in organizations (Treem & Leonardi, 2013). The *association affordance* describes the ways technologies can signal "established connections between individuals, between individuals and content, or between an actor and a presentation" (Treem & Leonardi, 2013, p. 162). Similarly, leadership affordances can explain the ways in which materiality and motives constitutively shape leadership emergence and effectiveness in teams. As an illustration, we may consider a *shared leadership affordance* as the use of technological features to signal the distribution of leadership across team members, needed team roles, and over time. For example, when teams have access to a communication mapping tool (Pentland, 2012), this may enable team leadership focused on equal participation in the team. Leadership development efforts are increasingly expanding the toolkit to leverage network-enhancing practices that focus on one of three aims: help individuals build social competence, help individuals shape networks, or help collectives co-create networks (Cullen-Lester et al., 2017; Leonardi & Contractor, 2018). The technology affordance perspective may offer a way forward to enable a greater emphasis on network-based interventions that target the structure of groups. Previous research calls for leadership development efforts that target teams (Day, Gronn, & Salas, 2004) and use insights from shared leadership research (e.g., Friedrich, Vessey, Schuelke, Ruark, & Mumford, 2009; Pearce & Conger, 2003) with prescriptive advice for designing team interactions. The notion of leadership affordances is ripe for future theory and research and represents a novel approach to leadership development.

In the technology as team creation medium perspective, we might consider the role of relationship-building activities carried out prior to and during team formation as an additional area for leadership development. Research in this area suggests activities related to forming teams (Harris, Gomez-Zara, DeChurch, & Contractor, 2019) and monitoring team production using technologies (Faraj & Sambamurthy, 2006) are additional aspects of leadership.

In the technology as teammate view, leadership development needs to expand focus to understand the leadership imperatives of building effective relationships among human and synthetic teammates, among human teammates as they interact with synthetic teammates, and among multiple synthetic teammates.

The second implication for leadership development concerns exploring how AI tools, such as cognitive assistants, can augment leader relational competencies. A cognitive assistant "helps its user with various tasks" (Ebling, 2016, p. 4). Prevalent examples of cognitive assistants include Amazon's Alexa and Google Home (Kepuska & Bohouta, 2018) or IBM's Watson for Oncology which will "review all of the data and recommend treatment options based on the latest evidence and guidelines" (AOCNP, 2015, p. 31). Cognitive assistants have the potential to augment current leadership development practices, such as 360-degree feedback, coaching, mentoring, or action learning (Day, 2000). Cognitive assistants can work one-on-one with organizational members to target individualized learning, development, and self-regulation. Alternatively, cognitive assistants can work as teammates to help the team learn and develop together. The cognitive assistant may "see things" that team leaders might miss, like the structure of leadership, manifesting in subtle speech patterns otherwise undetectable to humans. Intelligent cognitive assistants represent a fascinating future direction for leadership development.

Conclusion

Instead of handing out a book at the next leadership development seminar, might attendees receive a shiny new device called Google Teamwork instead? Could such a speaker, that observes work patterns and makes personalized recommendations, ultimately replace executive coaches? Perhaps insights gleaned from listening in the workday background will be used to auto-generate a highly customized podcast delivered during an executive's daily gym workout. Rapid advances in technology and organizing invite a new genre of leadership scholarship. Age old questions of who emerges as influential, how leadership transitions and/or comes to be shared, and the leadership processes best promoting effectiveness take on new meaning when we envision crowds and intelligent robots, or "cobots" (Gillespie, Colgate, & Peshkin, 2001), working alongside humans in teams. As computer scientists push the technological frontier, leadership scholars must consider the implications of these advances for organizing. In our review, we have channeled some of the exciting developments of the digital age that relate to the field of leadership.

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References

Ajoudani, A., Zanchettin, A. M., Ivaldi, S., Albu-Schäffer, A., Kosuge, K., & Khatib, O. (2018). Progress and prospects of the human–robot collaboration. *Autonomous Robots, 42*(5), 957–975.

Algan, Y., Benkler, Y., Fuster Morell, M., & Hergueux, J. (2013). Cooperation in a peer production economy experimental evidence from Wikipedia. *Available at SSRN https://ssrn.com/abstract=2843518*.

Ambit (2019). Retrieved from https://www.ambit.ai/.

Andressen, P., Konradt, U., & Neck, C. P. (2012). The relation between self-leadership and transformational leadership: Competing models and the moderating role of virtuality. *Journal of Leadership and Organizational Studies, 19*(1), 68–82.

AOCNP, D (2015). Watson will see you now: A supercomputer to help clinicians make

informed treatment decisions. *Clinical Journal of Oncology Nursing, 19*(1), 31–32.
Arrow, H., & McGrath, J. E. (1995). Membership dynamics in groups at work: A theoretical framework. *Research in Organizational Behavior, 17*, 373–411.
Artificial intelligence (2019). In Oxford online reference. Retrieved from https://www.oxfordreference.com/view/10.1093/oi/authority.20110803095426960.
Avolio, B. J. (1999). *Full leadership development: Building the vital forces in organizations.* Thousand Oaks, CA: Sage Publications.
Avolio, B. J., Kahai, S., & Dodge, G. E. (2000). E-leadership: Implications for theory, research, and practice. *The Leadership Quarterly, 11*(4), 615–668.
Avolio, B. J., Sosik, J. J., Kahai, S. S., & Baker, B. (2014). E-leadership: Re-examining transformations in leadership source and transmission. *The Leadership Quarterly, 25*(1), 105–131.
Baltes, B. B., Dickson, M. W., Sherman, M. P., Bauer, C. C., & LaGanke, J. S. (2002). Computer-mediated communication and group decision making: A meta-analysis. *Organizational Behavior and Human Decision Processes, 87*(1), 156–179.
Barley, S. R., Bechky, B. A., & Milliken, F. J. (2017). The changing nature of work: Careers, identities, and work lives in the 21st century. *Academy of Management Discoveries, 3*(2), 111–115.
Barrett, M., Oborn, E., & Orlikowski, W. (2016). Creating value in online communities: The sociomaterial configuring of strategy, platform, and stakeholder engagement. *Information Systems Research, 27*(4), 704–723.
Beech, H., & Suhartono, M. (2019, April 2). Between two Boeing crashes, days of silence and mistrust. *New York Times*. Retrieved from https://www.nytimes.com/2019/04/02/world/asia/boeing-max-8-lion-air.html.
Bell, B. S., & Kozlowski, S. W. (2002). A typology of virtual teams: Implications for effective leadership. *Group & Organization Management, 27*(1), 14–49.
Billings, D. R., Schaefer, K. E., Chen, J. Y., & Hancock, P. A. (2012, March). Human-robot interaction: Developing trust in robots. *Proceedings of the 7th annual ACM/IEEE international conference on human-robot interaction* (pp. 109–110). ACM.
Bjørn, P., & Ngwenyama, O. (2009). Virtual team collaboration: Building shared meaning, resolving breakdowns and creating translucence. *Information Systems Journal, 19*(3), 227–253.
Bokelberg, E., Doral, C., Feinzig, S., Guenole, N., Lesser, E., Mertens, J., & Steele, S. (2017). Extending expertise: How cognitive computing is transforming HR and the employee experience. Retrieved from https://www.ibm.com/downloads/cas/QVPR1K7D.
Bourton, S., Lavoie, J., & Vogel, T. (2018). Will artificial intelligence make you a better leader? *The McKinsey Quarterly, 2018*(2), 72–75.
Brabham, D. C. (2008). Crowdsourcing as a model for problem solving: An introduction and cases. *Convergence, 14*(1), 75–90.
Breazeal, C., Kidd, C. D., Thomaz, A. L., Hoffman, G., & Berlin, M. (2005). Effects of nonverbal communication on efficiency and robustness in human-robot teamwork. *Proceedings of 2005 IEEE/RSJ international conference on intelligent robots and systems* (pp. 708–713). .
Burke, C. S., Diaz-Granados, D., & Salas, E. (2011). Team leadership: A review and look ahead. In A. Bryman (Ed.). *The sage handbook of leadership* (pp. 338–351). Los Angeles, CA: Sage.
Burke, J. L., Murphy, R. R., Rogers, E., Lumelsky, V. J., & Scholtz, J. (2004). Final report for the DARPA/NSF interdisciplinary study on human-robot interaction. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews), 34*(2), 103–112.
Butler, B., Sproull, L., Kiesler, S., & Kraut, R. (2002). Community effort in online groups: Who does the work and why. In S. Weisband (Ed.). *Leadership at a distance: Research in technologically supported work* (pp. 171–194). New York, NY: Taylor & Francis Group.
Campbell, D. T. (1958). Common fate, similarity, and other indices of the status of aggregates of persons as social entities. *Behavioral Science, 3*(1), 14–25.
Carte, T. A., Chidambaram, L., & Becker, A. (2006). Emergent leadership in self-managed virtual teams. *Group Decision and Negotiation, 15*(4), 323–343.
Cascio, W. F., & Shurygailo, S. (2003). E-leadership and virtual teams. *Organizational Dynamics, 31*(4), 362–376.
Chakraborti, T., Kambhampati, S., Scheutz, M., & Zhang, Y. (2017). AI challenges in human-robot cognitive teaming. [PDF file]. Retrieved from https://arxiv.org/pdf/1707.04775.pdf.
Charlier, S. D., Stewart, G. L., Greco, L. M., & Reeves, C. J. (2016). Emergent leadership in virtual teams: A multilevel investigation of individual communication and team dispersion antecedents. *The Leadership Quarterly, 27*(5), 745–764.
Chesbrough, H. W., & Appleyard, M. M. (2007). Open innovation and strategy. *California Management Review, 50*(1), 57–76.
Chui, M., Kamalnath, V., & McCarthy, B. (2018). An executive's guide to AI. *McKinsey analytics*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/McKinsey%20Analytics/Our%20Insights/An%20executives%20guide%20to%20AI/Executives-guide-to-AI.
Chui, M., Manyika, J., & Miremadi, M. (2016, July). Where machines could replace humans—and where they can't (yet). Retrieved from https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/where-machines-could-replace-humans-and-where-they-cant-yet.
Chui, M., Manyika, J., Miremadi, M., Henke, N., Chung, R., Nel, P., & Malhotra, S. (2018, April). Notes from the AI frontier: Applications and value of deep learning. Retrieved from https://www.mckinsey.com/featured-insights/artificial-intelligence/notes-from-the-ai-frontier-applications-and-value-of-deep-learning.
Constant, D., Sproull, L., & Kiesler, S. (1996). The kindness of strangers: The usefulness of electronic weak ties for technical advice. *Organization Science, 7*(2), 119–135.
Contractor, N. S., DeChurch, L. A., Carson, J., Carter, D. R., & Keegan, B. (2012). The topology of collective leadership. *The Leadership Quarterly, 23*(6), 994–1011.
Crowston, K., & Howison, J. (2006). Hierarchy and centralization in free and open source software team communications. *Knowledge, Technology, and Policy, 18*(4), 65–85.
Cullen-Lester, K. L., Maupin, C. K., & Carter, D. R. (2017). Incorporating social networks into leadership development: A conceptual model and evaluation of research and practice. *The Leadership Quarterly, 28*(1), 130–152.
Curseu, P. L., Kenis, P., Raab, J., & Brandes, U. (2010). Composing effective teams through team dating. *Organization Studies, 31*(7), 873–894.
Day, D. V. (2000). Leadership development: A review in context. *The Leadership Quarterly, 11*(4), 581–613.
Day, D. V., & Dragoni, L. (2015). Leadership development: An outcome-oriented review based on time and levels of analyses. *Annual Review of Organizational Psychology and Organizational Behavior, 2*(1), 133–156.
Day, D. V., Fleenor, J. W., Atwater, L. E., Sturm, R. E., & McKee, R. A. (2014). Advances in leader and leadership development: A review of 25 years of research and theory. *The Leadership Quarterly, 25*(1), 63–82.
Day, D. V., Gronn, P., & Salas, E. (2004). Leadership capacity in teams. *The Leadership Quarterly, 15*(6), 857–880.
Deaux, K., & Stark, B. E. (1996, May). *Identity and motive: An integrated theory of volunteerism. Paper presented at the annual meeting of the Society for the Psychological Study of Social Issues, Ann Arbor, MI*.
DeCostanza, A. H., Marathe, A. R., Bohannon, A., Evans, A. W., Palazzolo, E. T., Metcalfe, J. S., & McDowell, K. (2018). *Enhancing human agent teaming with individualized, adaptive technologies: A discussion of critical scientific questions (no. ARL-TR-8359)*. US Army Research Laboratory Aberdeen Proving Ground United States.
DeSanctis, G., & Gallupe, R. B. (1987). A foundation for the study of group decision support systems. *Management Science, 33*(5), 589–609.
DeSanctis, G., & Poole, M. S. (1994). Capturing the complexity in advanced technology use: Adaptive structuration theory. *Organization Science, 5*(2), 121–147.
Dewhurst, M., & Willmott, P. (2014). Manager and machine: The new leadership equation. *The McKinsey Quarterly, 4*(3), 76–86.
D'Innocenzo, L., Mathieu, J. E., & Kukenberger, M. R. (2016). A meta-analysis of different forms of shared leadership–team performance relations. *Journal of Management, 42*(7), 1964–1991.
Dissanayake, I., Zhang, J., Yasar, M., & Nerur, S. P. (2018). Strategic effort allocation in online innovation tournaments. *Information & Management, 55*(3), 396–406.
Dow, S., Kulkarni, A., Bunge, B., Nguyen, T., Klemmer, S., & Hartmann, B. (2011, May). Shepherding the crowd: Managing and providing feedback to crowd workers. *CHI'11 extended abstracts on human factors in computing systems* (pp. 1669–1674). .
Du Chatenier, E., Verstegen, J. A., Biemans, H. J., Mulder, M., & Omta, O. (2009). The challenges of collaborative knowledge creation in open innovation teams. *Human Resource Development Review, 8*(3), 350–381.
Dulebohn, J. H., & Hoch, J. E. (2017). Virtual teams in organizations. *Human Resource Management Review, 27*, 569–574.
Ebling, M. R. (2016). Can cognitive assistants disappear? *IEEE Pervasive Computing, 15*(3), 4–6.
Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*(2), 350–383.
Ernst, C., & Yip, J. (2009). Boundary spanning leadership: Tactics for bridging social boundaries in organization. In T. Pittinsky (Ed.). *Crossing the divide: Intergroup leadership in a world of difference*. Boston, MA: Harvard Business School Press.
Fan, X., & Yen, J. (2004). Modeling and simulating human teamwork behaviors using intelligent agents. *Physics of Life Reviews, 1*(3), 173–201.
Faraj, S., Jarvenpaa, S. L., & Majchrzak, A. (2011). Knowledge collaboration in online communities. *Organization Science, 22*(5), 1224–1239.
Faraj, S., & Sambamurthy, V. (2006). Leadership of information systems development projects. *IEEE Transactions on Engineering Management, 53*(2), 238–249.
Feldman, M., Anastasiu, C., & Bernstein, A. (2018, June). Towards collaborative data analysis with diverse crowds–a design science approach. *International conference on design science research in information systems and technology* (pp. 218–235). Cham: Springer.
Freedy, A., de Visser, E., Weltman, G., & Coeyman, N. (2007). Measurement of trust in human-robot collaboration. *Proceedings of the 2007 international conference on collaborative technologies and systems* (pp. 106–114). Orlando, FL: IEEE.
Friedrich, T. L., Vessey, W. B., Schuelke, M. J., Ruark, G. A., & Mumford, M. D. (2009). A framework for understanding collective leadership: The selective utilization of leader and team expertise within networks. *The Leadership Quarterly, 20*(6), 933–958.
Gaertner, L., & Schopler, J. (1998). Perceived ingroup entitativity and intergroup bias: An interconnection of self and others. *European Journal of Social Psychology, 28*(6), 963–980.
Gajendran, R. S., & Joshi, A. (2012). Innovation in globally distributed teams: The role of LMX, communication frequency, and member influence on team decisions. *Journal of Applied Psychology, 97*(6), 1252–1261.
Gibson, C. B., & Gibbs, J. L. (2006). Unpacking the concept of virtuality: The effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity on team innovation. *Administrative Science Quarterly, 51*(3), 451–495.
Gibson, J. (1977). The theory of affordances. In R. E. Shaw, & J. Bransford (Eds.). *Perceiving, acting, and knowing* (pp. 67–82). Hillsdale, NJ: Lawrence Erlbaum Association.
Giles, J. (2005). Internet encyclopaedias go head to head. *Nature, 438*, 900–901.
Gillespie, R. B., Colgate, J. E., & Peshkin, M. A. (2001). A general framework for robot control. *IEEE Transactions on Robotics and Automation, 17*(4), 391–401.
Gilson, L. L., Maynard, M. T., Jones Young, N. C., Vartiainen, M., & Hakonen, M. (2015). Virtual teams research: 10 years, 10 themes, and 10 opportunities. *Journal of Management, 41*(5), 1313–1337.
Gluckler, J., & Schrott, G. (2007). Leadership and performance in virtual teams: Exploring brokerage in electronic communication. *International Journal of e-Collaboration, 3*, 31–52.
Goh, S., & Wasko, M. (2012). The effects of leader-member exchange on member

performance in virtual world teams. *Journal of the Association for Information Systems, 13*(10), 861–885.
Gombolay, M. C., Gutierrez, R. A., Clarke, S. G., Sturla, G. F., & Shah, J. A. (2015). Decision-making authority, team efficiency and human worker satisfaction in mixed human–robot teams. *Autonomous Robots, 39*(3), 293–312.
Gomez-Zara, D., Paras, M., Twyman, M., Lane, J. N., DeChurch, L. A., & Contractor, N. S. (2019, April). Who would you like to work with? *Proceedings of the 2019 CHI conference on human factors in computing systems* (pp. 659). ACM.
Green, D. D., Walker, C., Alabulththim, Smith, D., & Phillips, M. (2018). Fueling the gig economy: A case study evaluation of Upwork.com. *Management Economics Research Journal, 4*(2018), 104–112.
Gronn, P. (2008). The future of distributed leadership. *Journal of Educational Administration, 46*(2), 141–158.
Groom, V., & Nass, C. (2007). Can robots be teammates? Benchmarks in human–robot teams. *Interaction Studies, 8*(3), 483–500.
Gu, B., Konana, P., Rajagopalan, B., & Chen, H. W. M. (2007). Competition among virtual communities and user valuation: The case of investing-related communities. *Information Systems Research, 18*(1), 68–85.
Gupta, A. K., & Govindarajan, V. (2000). Knowledge flows within multinational corporations. *Strategic Management Journal, 21*(4), 473–496.
Hackman, J. R. (2012). From causes to conditions in group research. *Journal of Organizational Behavior, 33*(3), 428–444.
Hambley, L. A., O'Neill, T. A., & Kline, T. J. (2007). Virtual team leadership: The effects of leadership style and communication medium on team interaction styles and outcomes. *Organizational Behavior and Human Decision Processes, 103*(1), 1–20.
Hancock, P. A., Billings, D. R., Schaefer, K. E., Chen, J. Y., De Visser, E. J., & Parasuraman, R. (2011). A meta-analysis of factors affecting trust in human-robot interaction. *Human Factors, 53*(5), 517–527.
Harris, A. M., Gomez-Zara, D., DeChurch, L. A., & Contractor, N. S. (2019). Joining together online: The trajectory of CSCW scholarship on group formation. *Proceedings of ACM on Human-Computer Interaction, 3*(CSCW).
Hedlund, J., Ilgen, D. R., & Hollenbeck, J. R. (1998). Decision accuracy in computer-mediated versus face-to-face decision-making teams. *Organizational Behavior and Human Decision Processes, 76*(1), 30–47.
Hoch, J. E., & Kozlowski, S. W. (2014). Leading virtual teams: Hierarchical leadership, structural supports, and shared team leadership. *Journal of Applied Psychology, 99*(3), 390–403.
Hoffman, G. (2013, June). Evaluating fluency in human-robot collaboration. *International conference on human-robot interaction (HRI), workshop on human robot collaboration. Vol. 381. International conference on human-robot interaction (HRI), workshop on human robot collaboration* (pp. 1–8).
Howe, J. (2006, 2 June). Crowdsourcing: A definition [weblog]. Retrieved from http://crowdsourcing.typepad.com/cs/2006/06/crowdsourcing_a.html.
Hwang, E. H., Singh, P. V., & Argote, L. (2015). Knowledge sharing in online communities: Learning to cross geographic and hierarchical boundaries. *Organization Science, 26*(6), 1593–1611.
Iacovides, I., Jennett, C., Cornish-Trestrail, C., & Cox, A. L. (2013, April). Do games attract or sustain engagement in citizen science?: A study of volunteer motivations. *CHI'13 extended abstracts on human factors in computing systems* (pp. 1101–1106). ACM.
InnoCentive (2019). Retrieved from https://www.innocentive.com/.
Jarvenpaa, S. L., & Leidner, D. E. (1999). Communication and trust in global virtual teams. *Organization Science, 10*(6), 791–815.
Johns, G. (2006). The essential impact of context on organizational behavior. *Academy of Management Review, 31*(2), 386–408.
Johns, G. (2017). Reflections on the 2016 decade award: Incorporating context in organizational research. *Academy of Management Review, 42*(4), 577–595.
Johns, G. (2018). Advances in the treatment of context in organizational research. *Annual Review of Organizational Psychology and Organizational Behavior, 5*, 21–46.
Johnson, S. D., Suriya, C., Yoon, S. W., Berrett, J. V., & La Fleur, J. (2002). Team development and group processes of virtual learning teams. *Computers & Education, 39*(4), 379–393.
Joshi, A., Lazarova, M. B., & Liao, H. (2009). Getting everyone on board: The role of inspirational leadership in geographically dispersed teams. *Organization Science, 20*(1), 240–252.
Jung, M., & Hinds, P. (2018). Robots in the wild: A time for more robust theories of human-robot interaction. *ACM Transactions on Human-Robot Interaction (THRI), 7*(1) (2:1-2:5).
Jung, M. F. (2017, March). Affective grounding in human-robot interaction. *2017 12th ACM/IEEE international conference on human-robot interaction (HRI)* (pp. 263–273). IEEE.
Jung, M. F., Lee, J. J., DePalma, N., Adalgeirsson, S. O., Hinds, P. J., & Breazeal, C. (2013, February). Engaging robots: Easing complex human-robot teamwork using backchanneling. *Proceedings of the 2013 conference on computer supported cooperative work* (pp. 1555–1566). ACM.
Jung, M. F., Martelaro, N., & Hinds, P. J. (2015, March). Using robots to moderate team conflict: The case of repairing violations. *Proceedings of the tenth annual ACM/IEEE international conference on human-robot interaction* (pp. 229–236). ACM.
Kanawattanachai, P., & Yoo, Y. (2007). The impact of knowledge coordination on virtual team performance over time. *MIS Quarterly, 31*(4), 783–808.
Kane, G. C., Majchrzak, A., Johnson, J., & Chen, G. (2009). A longitudinal model of perspective making and perspective taking within fluid online collectives. *Proceedings of the international conference on information systems (ICIS)*Phoenix, AZ: AIS Electronic Library (Paper 10).
Kayworth, T. R., & Leidner, D. E. (2002). Leadership effectiveness in global virtual teams. *Journal of Management Information Systems, 18*(3), 7–40.
Kellogg, K., Valentine, M., & Christin, A. (2019). Algorithms at work: The new contested terrain of control. *Academy of Management Annals*. https://doi.org/10.5465/annals.2018.0174 Retrieved from.
Kepuska, V., & Bohouta, G. (2018, January). Next-generation of virtual personal assistants (microsoft cortana, apple siri, amazon alexa and google home). *2018 IEEE 8th annual computing and communication workshop and conference (CCWC)* (pp. 99–103). IEEE.
Kirkman, B. L., & Mathieu, J. E. (2005). The dimensions and antecedents of team virtuality. *Journal of Management, 31*(5), 700–718.
Kittur, A., & Kraut, R. E. (2008, November). Harnessing the wisdom of crowds in wikipedia: Quality through coordination. *Proceedings of the 2008 ACM conference on computer supported cooperative work* (pp. 37–46). ACM.
Kittur, A., & Kraut, R. E. (2010, February). Beyond Wikipedia: Coordination and conflict in online production groups. *Proceedings of the 2010 ACM conference on computer supported cooperative work* (pp. 215–224). ACM.
Kittur, A., Nickerson, J. V., Bernstein, M., Gerber, E., Shaw, A., Zimmerman, J., ... Horton, J. (2013, February). The future of crowd work. *Proceedings of the 2013 conference on computer supported cooperative work* (pp. 1301–1318). ACM.
Kittur, A., Pendleton, B., & Kraut, R. E. (2009, October). Herding the cats: The influence of groups in coordinating peer production. *Proceedings of the 5th international symposium on wikis and open collaboration* (pp. 7). ACM.
Kolbjørnsrud, V., Amico, R., & Thomas, R. J. (2016). How artificial intelligence will redefine management [PDF]. Retrieved from https://www.pega.com/system/files/resources/2018-05/hbr-how-ai-will-redefine-management.pdf.
Kotlarsky, J., & Oshri, I. (2005). Social ties, knowledge sharing and successful collaboration in globally distributed system development projects. *European Journal of Information Systems, 14*(1), 37–48.
Kozlowski, S. W., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. *Psychological Science in the Public Interest, 7*(3), 77–124.
Kozlowski, S. W., Mak, S., & Chao, G. T. (2016). Team-centric leadership: An integrative review. *Annual Review of Organizational Psychology and Organizational Behavior, 3*, 21–54.
Lanfranco, A. R., Castellanos, A. E., Desai, J. P., & Meyers, W. C. (2004). Robotic surgery: A current perspective. *Annals of Surgery, 239*(1), 14.
LaPlante, R., Silberman, M. S., & Metall, I. (2016). Building trust in crowd worker forums: Worker ownership, governance, and work outcomes. *Proceedings of WebSci16*. ACM.
Lau, D. C., & Murnighan, J. K. (2005). Interactions within groups and subgroups: The effects of demographic faultlines. *Academy of Management Journal, 48*(4), 645–659.
Lee, J. D., & See, K. A. (2004). Trust in automation: Designing for appropriate reliance. *Human Factors, 46*(1), 50–80.
Lee, M. K., Kiesler, S., Forlizzi, J., & Rybski, P. (2012). Ripple effects of an embedded social agent: A field study of a social robot in the workplace. *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 695–704). ACM May.
Lee, S. W., Krosnick, R., Park, S. Y., Keelean, B., Vaidya, S., O'Keefe, S. D., & Lasecki, W. S. (2018). Exploring real-time collaboration in crowd-powered systems through a UI design tool. *Proceedings of the ACM on Human-Computer Interaction, 2*(CSCW), 104.
Leonardi, P., & Contractor, N. (2018). Better people analytics. *Harvard Business Review, 96*(6), 70–81.
Leonardi, P. M. (2011). When flexible routines meet flexible technologies: Affordance, constraint, and the imbrication of human and material agencies. *MIS Quarterly, 35*(1), 147–167.
Leonardi, P. M. (2012). Materiality, sociomateriality, and socio-technical systems: What do these terms mean? How are they related? Do we need them? In P. M. Leonardi, B. A. Nardi, & J. Kallinikos (Eds.). *Materiality and organizing: Social interaction in a technological world* (pp. 25–48). Oxford: Oxford University Press.
Liden, R. C., & Antonakis, J. (2009). Considering context in psychological leadership research. *Human Relations, 62*(11), 1587–1605.
Lifshitz-Assaf, H. (2018). Dismantling knowledge boundaries at NASA: The critical role of professional identity in open innovation. *Administrative Science Quarterly, 63*(4), 746–782.
Lim, B. C., & Klein, K. J. (2006). Team mental models and team performance: A field study of the effects of team mental model similarity and accuracy. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 27*(4), 403–418.
Luther, K., & Bruckman, A. (2008, November). Leadership in online creative collaboration. *Proceedings of the 2008 ACM conference on computer supported cooperative work* (pp. 343–352). ACM.
Luther, K., Fiesler, C., & Bruckman, A. (2013, February). Redistributing leadership in online creative collaboration. *Proceedings of the 2013 conference on computer supported cooperative work* (pp. 1007–1022). ACM.
Lund, S., Manyika, J., Segel, L., Dua, A., Hancock, B., Rutherford, S., & Macon, B. (2019, July). The future of work in America: People and places, today and tomorrow. Retrieved from https://www.mckinsey.com/featured-insights/future-of-work/the-future-of-work-in-america-people-and-places-today-and-tomorrow.
Lykourentzou, I., Antoniou, A., Naudet, Y., & Dow, S. P. (2016, February). Personality matters: Balancing for personality types leads to better outcomes for crowd teams. *Proceedings of the 19th ACM conference on computer-supported cooperative work & social computing* (pp. 260–273). ACM.
Lykourentzou, I., Kraut, R. E., & Dow, S. P. (2017). Team dating leads to better online ad hoc collaborations. *Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing* (pp. 2330–2343). ACM February.
Lykourentzou, I., Wang, S., Kraut, R. E., & Dow, S. P. (2016). Team dating: A self-organized team formation strategy for collaborative crowdsourcing. *Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems* (pp. 1243–1249). ACM May.
Majchrzak, A., Faraj, S., Kane, G. C., & Azad, B. (2013). The contradictory influence of social media affordances on online communal knowledge sharing. *Journal of Computer-Mediated Communication, 19*(1), 38–55.

Majchrzak, A., Wagner, C., Riehle, D., Thoeny, P., Shah, S., & Cunningham, W. (2007). The role of shapers in knowledge-sharing. *Virtuality and virtualization* (pp. 383–386). Boston, MA: Springer.
Malhotra, A., Majchrzak, A., & Rosen, B. (2007). Leading virtual teams. *Academy of Management Perspectives, 21*(1), 60–70.
Malone, T. W., Laubacher, R., & Dellarocas, C. (2010). The collective intelligence genome. *MIT Sloan Management Review, 51*(3), 21–31.
Maloney, M. M., Bresman, H., Zellmer-Bruhn, M. E., & Beaver, G. R. (2016). Contextualization and context theorizing in teams research: A look back and a path forward. *Academy of Management Annals, 10*(1), 891–942.
Manyika, J., Chui, M., Miremadi, M., Bughin, J., Willmott, P., & Dewhurst, M. (2017, January). Harnessing automation for a future that works. Retrieved from https://www.mckinsey.com/featured-insights/digital-disruption/harnessing-automation-for-a-future-that-works.
Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of Management Review, 26*(3), 356–376.
Marlow, J., Dabbish, L., & Herbsleb, J. (2013). Impression formation in online peer production: Activity traces and personal profiles in github. *Proceedings of the 2013 conference on computer supported cooperative work* (pp. 117–128). ACM February.
Marlow, S. L., Lacerenza, C. N., & Salas, E. (2017). Communication in virtual teams: A conceptual framework and research agenda. *Human Resource Management Review, 27*(4), 575–589.
Marr, B. (2019). The future of work: 5 important ways jobs will change in the 4th industrial revolution. Retrieved from https://www.forbes.com/sites/bernardmarr/2019/07/15/the-future-of-work-5-important-ways-jobs-will-change-in-the-4th-industrial-revolution/#5364944454c7.
Marrone, J. A. (2010). Team boundary spanning: A multilevel review of past research and proposals for the future. *Journal of Management, 36*(4), 911–940.
Martins, L. L., Gilson, L. L., & Maynard, M. T. (2004). Virtual teams: What do we know and where do we go from here? *Journal of Management, 30*(6), 805–835.
Maznevski, M. L., & Chudoba, K. M. (2000). Bridging space over time: Global virtual team dynamics and effectiveness. *Organization Science, 11*(5), 473–492.
McAfee, A., Brynjolfsson, E., Goldbloom, A., & Howard, J. (2014, September). Artificial intelligence meets the C-suite [interview by R. Kirkland]. Retrieved from https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/artificial-intelligence-meets-the-c-suite.
McGrath, J. E. (1962). *Leadership behavior: Some requirements for leadership training.* Washington, DC: U.S. Civil Service Commission, Office of Career Development.
Meyer, E. (2010). The four keys to success with virtual teams. Retrieved from http://www.forbes.com/2010/08/19/virtual-teams-meetings-leadership-managing-cooperation.html.
Meyer, E. (2015). When culture doesn't translate. *Harvard Business Review, 93*(10), 66–72.
Montoya-Weiss, M. M., Massey, A. P., & Song, M. (2001). Getting it together: Temporal coordination and conflict management in global virtual teams. *Academy of Management Journal, 44*(6), 1251–1262.
Morgeson, F. P., DeRue, D. S., & Karam, E. P. (2010). Leadership in teams: A functional approach to understanding leadership structures and processes. *Journal of Management, 36*(1), 5–39.
Morgeson, F. P., Lindoerfer, D., & Loring, D. J. (2010). Developing team leadership capability. In E. V. Velsor, C. D. McCauley, & M. N. Ruderman (Eds.). *The center for creative leadership handbook of leadership development* (pp. 285–312). (3rd ed.). San Francisco, CA: Jossey-Bass.
Mortenson, M., & Haas, M. R. (2018). Rethinking teams: From bounded membership to dynamic participation. *Organization Science, 29*(2), 341–355.
MTurk (2018). Retrieved from https://www.mturk.com/.
Nass, C., Fogg, B. J., & Moon, Y. (1996). Can computers be teammates? *International Journal of Human-Computer Studies, 45*(6), 669–678.
Nicolaides, V. C., LaPort, K. A., Chen, T. R., Tomassetti, A. J., Weis, E. J., Zaccaro, S. J., & Cortina, J. M. (2014). The shared leadership of teams: A meta-analysis of proximal, distal, and moderating relationships. *The Leadership Quarterly, 25*(5), 923–942.
Oborn, E., Barrett, M., & Dawson, S. (2013). Distributed leadership in policy formulation: A sociomaterial perspective. *Organization Studies, 34*(2), 253–276.
Oc, B. (2018). Contextual leadership: A systematic review of how contextual factors shape leadership and its outcomes. *The Leadership Quarterly, 29*(1), 218–235.
Orlikowski, W., & Scott, S. (2015). The algorithm and the crowd: Considering the materiality of service innovation. *MIS Quarterly, 39*(1), 201–216.
Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies, 28*(9), 1435–1448.
Orlikowski, W. J., & Scott, S. V. (2008). 10 sociomateriality: Challenging the separation of technology, work and organization. *The Academy of Management Annals, 2*(1), 433–474.
Oshri, I., Van Fenema, P., & Kotlarsky, J. (2008). Knowledge transfer in globally distributed teams: The role of transactive memory. *Information Systems Journal, 18*(6), 593–616.
Osterlund, C., Mugar, G., Jackson, C. B., Hassman, K. D., & Crowston, K. (2014). Socializing the crowd: Learning to talk in citizen science. *Academy of management annual meeting*Philadelphia, PA: OCIS Division January.
Parry, K., Cohen, M., & Bhattacharya, S. (2016). Rise of the machines: A critical consideration of automated leadership decision making in organizations. *Group & Organization Management, 41*(5), 571–594.
Paul, D. L., & McDaniel, R. R., Jr. (2004). A field study of the effect of interpersonal trust on virtual collaborative relationship performance. *MIS Quarterly, 28*(2), 183–227.
Pearce, C. L., & Conger, J. A. (2003). *Shared leadership: Reframing the hows and whys of leadership.* Thousand Oaks, CA: Sage Publications.
Penner, L. A., & Finkelstein, M. A. (1998). Dispositional and structural determinants of volunteerism. *Journal of Personality and Social Psychology, 74*(2), 525–537.
Pentland, A. S. (2012). The new science of building great teams. *Harvard Business Review, 90*(4), 60–69.
Petriglieri, G., Ashford, S. J., & Wrzesniewski, A. (2019). Agony and ecstasy in the gig economy: Cultivating holding environments for precarious and personalized work identities. *Administrative Science Quarterly, 64*(1), 124–170.
Poole, M. S., & DeSanctis, G. (1992). Microlevel structuration in computer-supported group decision making. *Human Communication Research, 19*(1), 5–49.
Powell, A., Piccoli, G., & Ives, B. (2004). Virtual teams: A review of current literature and directions for future research. *ACM SIGMIS Database: the DATABASE for Advances in Information Systems, 35*(1), 6–36.
Purvanova, R. K., & Bono, J. E. (2009). Transformational leadership in context: Face-to-face and virtual teams. *The Leadership Quarterly, 20*(3), 343–357.
Pyle, D., & San Jose, C. (2015). An executive's guide to machine learning. *The McKinsey Quarterly, 3*, 44–53.
Rahman, H., Roy, S. B., Thirumuruganathan, S., Amer-Yahia, S., & Das, G. (2018). Optimized group formation for solving collaborative tasks. *The VLDB Journal, 28*(1), 1–23.
Rani, P., Sarkar, N., Smith, C. A., & Kirby, L. D. (2004). Anxiety detecting robotic system–towards implicit human-robot collaboration. *Robotica, 22*(1), 85–95.
Raymond, E. (1999). The cathedral and the bazaar. *Knowledge, Technology, and Policy, 12*(3), 23–49.
Resnick, P., & Kraut, R. (2011). Introduction. In R. E. Kraut, & P. Resnick (Eds.). *Evidence-based social design: Mining the social sciences to build online communities*. Cambridge, MA: MIT Press.
Retelny, D., Bernstein, M. S., & Valentine, M. A. (2017). *No workflow can ever be enough: How crowdsourcing workflows constrain complex work.* New York, NY, USA: ACM.
Retelny, D., Robaszkiewicz, S., To, A., Lasecki, W. S., Patel, J., Rahmati, N., ... Bernstein, M. S. (2014, October). Expert crowdsourcing with flash teams. *Proceedings of the 27th annual ACM symposium on user interface software and technology* (pp. 75–85). ACM.
Robey, D., Khoo, H., & Powers, C. (2000). Situated learning in cross-functional virtual teams. *Technical Communication, 47*(1), 51–66.
Salehi, N., McCabe, A., Valentine, M., & Bernstein, M. (2017). Huddler: Convening stable and familiar crowd teams despite unpredictable availability. *Proceedings of the 2017 ACM conference on computer supported cooperative work and social computing* (pp. 1700–1713). ACM.
Schwartz, J., Collins, L., Stockton, H., Wagner, D., & Walsh, B. (2017). The future of work: The augmented workforce. Retrieved from https://www2.deloitte.com/us/en/insights/focus/human-capital-trends/2017/future-workforce-changing-nature-of-work.html.
Sosik, J. J., Kahai, S. S., & Avolio, B. J. (1998). Transformational leadership and dimensions of creativity: Motivating idea generation in computer-mediated groups. *Creativity Research Journal, 11*(2), 111–121.
Sproull, L., & Kiesler, S. (1991). *Connections: New ways of working in the networked organization.* Cambridge, MA: MIT Press.
Stewart, G. L., & Manz, C. C. (1995). Leadership for self-managing work teams: A typology and integrative model. *Human Relations, 48*(7), 747–770.
Straus, S. G., & McGrath, J. E. (1994). Does the medium matter? The interaction of task type and technology on group performance and member reactions. *Journal of Applied Psychology, 79*(1), 87–97.
Strier, K. (2017). How do you run the business when AI is steering the ship? *EY*. Retrieved from https://consulting.ey.com/steer-business-ai-running-ship/.
Strohmeier, S., & Piazza, F. (2015). Artificial intelligence techniques in human resource management—A conceptual exploration. *Intelligent techniques in engineering management* (pp. 149–172). Cham: Springer.
Talamadupula, K., Briggs, G., Chakraborti, T., Scheutz, M., & Kambhampati, S. (2014, September). Coordination in human-robot teams using mental modeling and plan recognition. *2014 IEEE/RSJ international conference on intelligent robots and systems* (pp. 2957–2962). IEEE.
Taylor, K. (2017). The future of corporate learning: Stepping into another dimension. *Training industry magazine*. Jul/Aug. Retrieved from https://trainingindustry.com/magazine/july-aug-2017/the-future-of-corporate-learning-stepping-into-another-dimension/.
Thorpe, R., Gold, J., & Lawler, J. (2011). Locating distributed leadership. *International Journal of Management Reviews, 13*(3), 239–250.
Townsend, A. M., DeMarie, S. M., & Hendrickson, A. R. (1998). Virtual teams: Technology and the workplace of the future. *Academy of Management Perspectives, 12*(3), 17–29.
Treem, J. W., & Leonardi, P. M. (2013). Social media use in organizations: Exploring the affordances of visibility, editability, persistence, and association. *Annals of the International Communication Association, 36*(1), 143–189.
Twyman, M. (2019). *Relational mechanisms in team self-assembly: A network and computational approach.* Unpublished doctoral dissertationNorthwestern University.
Tyran, K. L., Tyran, C. K., & Shepherd, M. (2003). Exploring emerging leadership in virtual teams. *Virtual teams that work: Creating conditions for virtual team effectiveness* (pp. 183–195). .
Upwork (2019). Retrieved from https://www.upwork.com/.
Van Den Berg, J., Miller, S., Duckworth, D., Hu, H., Wan, A., Fu, X. Y., ... Abbeel, P. (2010, May). Superhuman performance of surgical tasks by robots using iterative learning from human-guided demonstrations. *2010 IEEE international conference on robotics and automation* (pp. 2074–2081). IEEE.
Wagner, C., & Majchrzak, A. (2006). Enabling customer-centricity using wikis and the wiki way. *Journal of Management Information Systems, 23*(3), 17–43.
Wakefield, R. L., Leidner, D. E., & Garrison, G. (2008). Research note—A model of conflict, leadership, and performance in virtual teams. *Information Systems Research, 19*(4), 434–455.
Wang, D., Waldman, D. A., & Zhang, Z. (2014). A meta-analysis of shared leadership and team effectiveness. *Journal of Applied Psychology, 99*(2), 181–198.

Warkentin, M. E., Sayeed, L., & Hightower, R. (1997). Virtual teams versus face-to-face teams: An exploratory study of a web-based conference system. *Decision Sciences, 28*(4), 975–996.
Weber, S. (2004). *The success of open source.* Cambridge, MA: Harvard University Press.
Wellers, D., Elliott, T., & Noga, M. (2017). 8 ways machine learning is improving companies' work processes [PDF]. Retrieved from https://starlab-alliance.com/wp-content/uploads/2017/09/Machine-Learning-HBR.pdf.
Wen, M., Maki, K., Dow, S., Herbsleb, J. D., & Rose, C. (2017). Supporting virtual team formation through community-wide deliberation. *Proceedings of the ACM on Human-Computer Interaction, 1*(CSCW), 109.
Whitford, T., & Moss, S. A. (2009). Transformational leadership in distributed work groups: The moderating role of follower regulatory focus and goal orientation. *Communication Research, 36*(6), 810–837.
Wikipedia contributors (2019, October 7). Wikipedia. *Wikipedia, the free encyclopedia*. Retrieved October 7, 2019, from https://en.wikipedia.org/w/index.php?title=Wikipedia&oldid=920002728.
Wilson, H. J., & Daugherty, P. R. (2018). Collaborative intelligence: Humans and AI are joining forces. *Harvard Business Review, 96*(5), 20–21.
Yates, D., Wagner, C., & Majchrzak, A. (2010). Factors affecting shapers of organizational wikis. *Journal of the American Society for Information Science and Technology, 61*(3), 543–554.
Yen, J., Yin, J., Ioerger, T. R., Miller, M. S., Xu, D., & Volz, R. A. (2001). Cast: Collaborative agents for simulating teamwork. *International joint conference on artificial intelligence. Vol. 17, No. 1. International joint conference on artificial intelligence* (pp. 1135–1144). Lawrence Earlbaum Associates Ltd August.
Yip, J., Ernst, C., & Campbell, M. (2011). *Boundary spanning leadership.* Center for Creative Leadership.
You, S., & Robert, L. P. (2018). Emotional attachment, performance, and viability in teams collaborating with embodied physical action (EPA) robots. *Journal of the Association for Information Systems, 19*(5), 377–407.
Yukl, G. (1998). *Leadership in organizations* (4th ed.). Upper Saddle River, NJ: Prentice Hall.
Zaccaro, S. J., Ardison, S. D., & Orvis, K. L. (2003). Leadership in virtual teams. In D. V. Day, S. J. Zaccaro, & S. M. Halpin (Eds.). *Leadership development for transforming organizations: Growing leadership for tomorrow* (pp. 267–292). Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc.
Zaccaro, S. J., & Bader, P. (2003). E-leadership and the challenges of leading e-teams: Minimizing the bad and maximizing the good. *Organizational Dynamics, 31*(4), 377–387.
Zaccaro, S. J., Rittman, A. L., & Marks, M. A. (2001). Team leadership. *The Leadership Quarterly, 12*(4), 451–483.
Zack, M. H., & McKenney, J. L. (1995). Social context and interaction in ongoing computer-supported management groups. *Organization Science, 6*(4), 394–422.
Zammuto, R. F., Griffith, T. L., Majchrzak, A., Dougherty, D. J., & Faraj, S. (2007). Information technology and the changing fabric of organization. *Organization Science, 18*(5), 749–762.
Zhu, H., Kraut, R., & Kittur, A. (2012, February). Effectiveness of shared leadership in online communities. *Proceedings of the ACM 2012 conference on computer supported cooperative work* (pp. 407–416). ACM.
Zhu, H., Kraut, R. E., & Kittur, A. (2013). Effectiveness of shared leadership in Wikipedia. *Human Factors, 55*(6), 1021–1043.
Zhu, H., Kraut, R. E., Wang, Y. C., & Kittur, A. (2011). Identifying shared leadership in Wikipedia. *Proceedings of the SIGCHI conference on human factors in computing systems* (pp. 3431–3434). ACM May.