Communication Objectives Model (COM): A Taxonomy of Face-to-Face Communication
Objectives to Inform Tele-Presence Technology Adoption

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Abstract

Computer-mediated communication (CMC) has become the new normal in the era of pandemic-induced physical distancing. CMC has dramatically reduced business travel and daily commuting for knowledge workers able to work from home, which in turn reduces carbon emissions and energy expenditure. CMC offers a different communication experience compared to in-person interactions, and its impact on the success of communication is complex. Here, we report the Communication Objectives Model (COM), a framework developed to: a) understand differences in the performance of communication objectives between CMC and face-to-face interactions, and b) guide future research on measurement of such communication objectives. Given that effective communication is essentially the result of a team activity, the psychosocial constructs that comprise our framework are derived from team research across multiple domains (e.g., social psychology, human-computer interaction, and computer supported cooperative work). Constructs of interest include trust, rapport, engagement, conflict management, collective efficacy, mental models, and shared situation awareness. For each construct, we provide a definition, empirical evidence, and theoretical bases for its observable behavioral markers, as well as potential measurement methods and analytical techniques. The contributions of this research include a framework for characterizing differences between different communication media, a hypothetical implementation demonstrating how the framework can inform the decision to travel in-person versus to deploy CMC (i.e., a travel replacement threshold), and an inventory of tools and techniques that can be used to measure and assess the psychosocial constructs involved in CMC.

Keywords: computer-mediated communication, remote collaboration, virtual teams, trust, rapport, engagement, conflict management, collective efficacy, mental models, shared situation awareness.

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1 Introduction

Geographically dispersed teams are groups of people with a common purpose who carry out interdependent tasks across locations and time. With the rise of globalization in business organizations, an increasing number of globally distributed teams must gauge when travelling is essential to mitigate the inherent problem of knowledge distribution through virtual means (Cramton, 2001). The COVID-19 global pandemic has intensified the need to clearly scrutinize travel needs in order to reduce the spread of viral infections. The decision to do so, however, is multifaceted and highly subjective. Effective computer-mediated communication (CMC) is essentially the result of an effective team activity. Team research attributes up to 42% of team performance variance to team behaviors (Sottolare et al., 2018). Choosing remote CMC with tools like Zoom, Webex, Microsoft Teams, Google Meet, etc., introduces challenging tradeoffs between the convenience and accessibility of CMC platforms with the ability to achieve communication objectives (e.g., developing interpersonal relationships) and team objectives (e.g., achieving performance goals). Here we seek to characterize the dimensions of interest when measuring whether CMC is comparable to in-person or face-to-face interactions with respect to achieving communication objectives within teams.

We aim to provide practice-oriented researchers and practitioners with a conceptual framework that can be leveraged in several ways. First, our framework can inform future empirical work comparing computer-mediated to face-to-face interactions and yield resulting system design recommendations. Second, an understanding of relevant communication objectives in team processes can guide the development of evidence-based recommendations for identifying when computer-mediated communications offer a reasonable alternative to physical travel. To that end, we excluded two scenarios from consideration: communication scenarios involving the physical exchange of goods or services, and travel scenarios primarily focused on personal goals (e.g., sight-seeing holidays, visits to family and friends).

Instead, we focus on business travel, where adoption of CMC can decrease energy consumption as well as provide economic incentive through cost savings (Olaison & Revang, 2017). Such tools should provide affordances enabling the expression of positive team behaviors.

Consequently, tools that do not enable positive team behaviors introduce barriers to CMC technology adoption. Instead of surveying the technical features of existing telecommunications tools, we conducted a literature review to inform a taxonomy of high-level psychosocial constructs and human communication objectives. We drew from prior work in computer supported cooperative work (CSCW), social psychology, management science, human computer interaction, and industrial/organizational psychology

2 Communication Objectives Model (COM): Psychosocial Dimensions of Interest and their Manifestations

Our goal in this paper is to create a conceptual framework of communication objectives that may deter individuals from choosing computer-mediated communication in lieu of face-to-face interactions. Two research questions guided our search:

1. What factors affect communication, regardless of the communication context?
2. How do you measure the likelihood that one will choose to adopt computer-mediated communication?

To address these questions, we first drew from research on teams (Sottilare et al., 2018) and organizational citizenship behavior (OCB; Robinson & Morrison, 1995) to create a list of constructs relevant to successful communication: trust, rapport, engagement, conflict management, collective efficacy, mental models, and shared situation awareness. Next, we conducted a semi-structured literature review to further elaborate on these constructs as well as to identify associated behavioral manifestations and computationally tractable metrics that are representative of each construct. We first identified empirical and conceptual work on each construct by conducting a keyword search in such databases as Web of Science, Scopus, and Google Scholar using the following search terms: “computer supported cooperative work,” “physical telepresence,” “video mediated communication,” “interpersonal communication encoding and decoding,” “trust,” “rapport,” “common ground,” “affinity,” “engagement,” “collective efficacy,” “conflict management,” “mental models,” “situation analysis,” and “situation awareness.” The resulting taxonomy, henceforth referred to as the Communication Objectives Model (COM), comprises high-level communication objectives that span across different situational contexts.

The situational context of interest plays a vital role in determining one's communication goals. COM, however, represents an overarching model of all possible communication objectives that speakers may aim to achieve, as opposed to being restricted to the specifics of a situational context. Further, given the present focus on CMC, it is important to note that technological capabilities can impose constraints that enable or hinder communication objectives. One intuitive example is that audio and visual streaming quality will directly impact the rate and fidelity of information conveyed. A less intuitive example is the impact of speaker images on participant engagement and presence. Nowak and Biocca (2003) discuss the influence of the quality of conversation partners' visual representation and conclude that a higher fidelity does not necessarily translate to higher perceived telepresence. In animatronics/robotics and computer graphics, a related phenomenon has been referred to as the "uncanny valley" (Mori et al., 2012). These nuanced effects relating to technological affordances of the medium may have downstream consequences on the likelihood of attaining communication success but lie outside the scope of the present work. For a review on the effects of verbal and nonverbal behavioral characteristics on communication outcomes between humans and various automated conversational agents, see Van Pinxteren et al. (2020).

The communication objectives described in the sections that follow are also subject to influence by moderating variables outside of the communication medium itself. For example, cultural differences significantly contribute to communication breakdown (Daim et al., 2011), and gender differences have been reported in the preference and frequency of CMC use (Kimbrough et al., 2013). A literature review on virtual teams has also delineated 16 moderating variables that may affect various communication objectives (Alaiad et al., 2019). Further, per the classic Shannon-Weaver model of communication (Shannon and Weaver, 1949), there are two necessary components to successfully achieving a communication objective. First, a speaker must be able to communicate their message effectively. Second, the listener must be able to adequately perceive the speaker's message. Therefore, both speaker and listener baseline capabilities can either enhance or hinder the delivery of a message. Individual differences in terms of empathy (i.e., the ability to objectively enter into another's experience and gain an appreciation of their experience and viewpoint; Neumann et al., 2015) may serve as a proxy for an individual's communication competence (Redmond, 1985). In summary, a variety of factors outside the communication medium can also affect communication.

However, despite the potential influence of situational contexts, technological capabilities, and moderating variables, the COM presents a comprehensive taxonomy of communication-related psychosocial constructs and their derivatives. In the sections that follow, the general structure of the COM is introduced and each component is described in greater detail. We then describe potential measurement and analytical strategies that stretch across multiple components of the COM. To conclude, we discuss a potential implementation of the COM for a business use case as well as directions for future research.

2.1 Team Research Frameworks and the COM

Taxonomies of teamwork and conceptual frameworks of virtual team communication, have previously been formulated (Alaiad et al., 2019; Marlow et al., 2017; Salas et al., 2014), enumerating the elements of communication and team outcomes in various frameworks, reviews, and other schema. While work (including Salas et al., 2014) has focused on determining the structure to teamwork and team performance, there is no cumulative framework by which researchers may align their measures and indicators of teamwork ability.

One can consider communication in virtual teams through the lens of the framework proposed by Marlow et al (2017). This framework states, among other details, that the team process of communication and the team context, including the diversity of its members, lead to emergent team states (trust and cognition) and teamwork outputs (including viability, performance, and satisfaction). While we do not dispute this claim, we seek to delineate the emergent states of teamwork which are influenced by communication in virtual teams. Specifically, we identify trust, rapport, engagement, conflict management, collective efficacy, mental models, and shared situation awareness as emergent states that can be considered to be contained but not explicitly described in the framework proposed by Marlow et al (2017).

One of the most popular models for organizing research of teams is the Input-Mediator-Output-Input model, which originated within activity theory and is an extension of the Input-Process-Output model (Ilgen et al., 2005). The move from I-P-O to IMOI reflects the iterative nature of group activity, with the acknowledgement that outputs feedback to influence the inputs of subsequent work, and the use of mediators rather than processes alludes to the broad range of variables which impact the outcomes of teamwork.

The present work builds upon several existing I-P-O and IMOI models used to describe teams (Ilgen et al., 2005; Marlow et al., 2017; Alaiad et al., 2019; Lee and Paine, 2015) by elaborating upon and identifying additional emergent states and high-level psychosocial constructs that are important for performance. Figure 1 depicts the team, technology, and task contexts to groupwork, of which communication is a major component. The Inputs, including the boxes labeled “Inputs” and “Technology, Team, and Task Characteristics,” are mostly communication contexts (represented by white rectangles). These contexts are drawn from previous work (Ilgen et al., 2005; Marlow et al., 2017; Alaiad et al., 2019; Lee and Paine, 2015). The Outputs are also drawn from prior models (Marlow et al., 2017). The Processes and Emergent States boxes, which are drawn from the work of Ilgen and Marlow and colleagues (Ilgen et al., 2005; Marlow et al., 2017). Marlow et al. (2017), identify communication frequency, quality, and content as Team Processes, while trust and cognition are identified as Emergent States. Our taxonomy includes these but expands the mediators to include a more wholistic view of the processes involved in group activity, and updates the three communication processes to “communication,” “learning,” and “knowledge management,” which are variables in the broader models of teams proposed by Ilgen et al. (2005) and Alaiad et al. (2019).

From within the broader contextual representation of groupwork dynamics of Figure 1, Figure 2 is a schematic of the COM framework and depicts each of the relevant constructs to communication and the specific nature of our report. To provide utility and convenience for research practitioners, a brief review of each of these variables is presented, covering conceptual definitions and detailing how the constructs typically manifest, accompanied by an exploration into the options available for measuring them. These measurement options range from observable behaviors to self-report attitudinal or cognitive measures. Each construct can manifest in different categories of behaviors, broadly either verbal or nonverbal. Verbal cues are those that involve spoken or written language, including both what is said (i.e., the content of a message or statement) as well as *how* it is said (i.e., linguistic cues such as verb tense, the presence or absence of pronouns, etc.). Nonverbal cues are referred to by Bavelas and colleagues (1990) as vocal or paralinguistic cues (tone, emphasis, rhythm, rate, hesitation), and bodily cues (expressions, gestures, movement, direction of gaze). To facilitate the selection of detection technologies, we further divided verbal and nonverbal behaviors so that each manifestation is categorized as either linguistic, paralinguistic, non-verbal behavior, or complex behaviors.

Complex behaviors are defined as higher level behavioral manifestations that cut across multiple categories. Some constructs may have overlapping manifestations. For instance, both objectives of “Conflict Management” and “Mental Model” require turn-taking behaviors, thus turn-taking is listed under each of these objectives. In the following sections, we first present a definition of each psychosocial construct in the COM, review theoretical or empirically demonstrated links to behavioral markers as well as low-level metrics and measurement techniques that are conducive to observation by a human or automated coder.

2.2 Trust

The concept of trust has received much empirical and theoretical evaluation across disciplines. Trust is often defined as a psychological state comprising the intent to accept vulnerability based on positive expectations and the actions of the trustee (Mayer et al., 1995; Rousseau et al., 1998). Trust is thus divisible into two primary dimensions: the intention to accept vulnerability, and the maintenance of positive expectations with respect to the outcome. Within human machine teaming, trust has been theorized as having three components: analytical, analogical, and affective trust (Lee & See, 2004). Analytical trust is the result of a calculation of the capabilities of the trustee to perform the task. Analogical trust is related to affinity of the trustee to other trusted members, and affective trust describes influences of emotion and affect on the trustee’s perceived trustworthiness. The term *trust* is distinguishable from the related concept of *trustworthiness* (Colquitt et al., 2007). Where trust is considered the conscious intention to rely on another person (and thus assume vulnerability), trustworthiness involves portraying characteristics, such as benevolence and integrity, that can inform an interaction partner’s perception of the risk of assuming that vulnerability. For the purpose of the Communication Objectives Model, trust is defined as the willingness to accept vulnerability by allocating time or other resources to the trustee to achieve team objectives.

Cognitive processes, affective processes, and organizational norms and mechanisms all contribute to the development of interpersonal trust (McAllister, 1995). *Cognitive trust* is associated with one’s evaluation of another person’s competency and reliability, and these evaluations are informed by the success of prior interactions as well as the extent to which the parties can be considered in-group members. In contrast, *affective trust* is related to the emotional bonds that exist between individuals. Precursors to affective trust include behavior

that is self-initiated and behavior that demonstrates concern for another rather than self-interest. Relatedly, *organizational citizenship behavior* can be conceptualized as altruistic behavior that provides assistance outside of one's own role (Organ, 1997). Expectations of a continued relationship, flexibility to make adaptations, proactive information exchange, and encouragement of self-control are antecedents of trust (Aulakh et al., 1996). Contextual information, including professional designation, shared group membership, and team climate, can also be leveraged as a foundational heuristic to swiftly assess trust when team members have not yet developed personal experience through cooperative engagement (Dumitru & Mittelstadt, 2020). Of note, Costa et al. (2015) stress that trust levels are dynamic throughout time, continuing to calibrate in accordance with incoming feedback. A subject of ongoing contention regards whether interpersonal trust between work team members, as measured pairwise, should be considered conceptually distinct from collective trust of the team as an aggregate unit (Dumitru & Mittelstadt, 2020).

Trust has widespread use in situations where one must assume some level of risk, such as in negotiation tasks (Naquin & Paulson, 2003), team performance (Breuer et al., 2016; Henttonen & Blomqvist, 2005) and when relying on autonomous/automated systems (Lee & Moray, 1994; Israelsen & Ahmed 2019). In the context of negotiation, trust increases the provision of information by reducing the fear of exploitation (Kimmel et al., 1980; McAllister, 1995). A meta-analysis found an above average impact of both cognitive and affective trust on team performance after controlling for team trust in the leader and past team performance (De Jong et al., 2016). Importantly, virtual teams face unique challenges with regard to establishing and maintaining trust due to geographic, temporal, and social distance which can have a detrimental impact on collaboration (Morrison-Smith & Ruiz, 2020). Olson et al. (2002) recommend using rich media channels that convey body language cues, subtle voice inflections, and facial expressions, finding evidence that they facilitate the initial development of trust much more effectively than text-only mediums.

2.2.1 Behavioral Markers of Trust within the Telecommunications Context

Behavioral manifestations of trust are comprised of markers associated with the trustee's behavior (i.e., trustworthiness) as well as with the behavior of the trustor (i.e., trust). Cooperation is an oft-used proxy for trust, given the assumption that one would not engage in cooperative behavior if trust were lacking. Behavioral markers of trust are shown in Figure 3, grouped by

categories of markers. Teleconferencing and computer-mediated communication present challenges for trust development. Trust building has been observed as a particular challenge in Global Virtual Teams (GVT; Daim et al., 2012). Specifically, the verbal and non-verbal correlates of trust-building strategies are much more difficult to both present and observe when using video conferencing platforms (Bordia, 1997). Theories with respect to social presence (e.g., Gunawardena, 1995; Short et al., 1976; Jarvenpaa and Leidner, 1998) and media richness (Daft et al., 1987) suggest that the lack of available communication cues hinders the development of trust between parties. However, despite starting off at a disadvantage compared to face-to-face contexts, trust in computer-mediated contexts improves when there is a sufficiently long interaction period (Wilson et al., 2006). Additionally, platforms that provide audio and/or audio-visual modalities serve to benefit social presence and the development of interpersonal trust (Bente et al., 2008).

2.2.2 Detection and Measurement of Trust

Linguistic markers indicative of team membership (e.g. the use of “we” versus “you and I”) can be leveraged to approximate the extent to which one considers an interaction partner to be in either a common or different group (Wu et al., 2013). Other behaviors such as requesting backup are manifestations of trust and acceptance of vulnerability, as is the absence of behaviors such as reminders for tasks or questioning competency of trustee (Sottolare et al., 2018). Such manifestations can be measured with Natural Language Processing (NLP). Linguistic data can be obtained and assessed by first submitting audio or audio-visual recordings to transcription software, and then analyzing the content of the produced transcripts with a computerized text analysis software such as Linguistic Inquiry and Word Count (LIWC; Pennebaker et al, 2001) or sentiment analysis (Giatsoglou et al., 2017). Paralinguistics such as variation in emphasis and intonation can be analyzed from an audio signal (Waber et al, 2015). Kinesics and nonverbal movements, for instance an open or forward leaning posture, are also indicators of trust (Lee et al., 2013). Computer vision can be employed for automatic gestural detection. Complex behaviors indicative of trust include task delegation, the withholding of information or knowledge-sharing, and seeking task-related opinions (Park & Lee, 2014) Self-report measures of trust can be obtained via surveys administered prior to and/or following a task or interaction (e.g., Goldberg, 1999; McAllister, 1995; Vignovic & Thompson, 2010). Feitosa et al. (2020) performed a meta-analytic review which found that the observed correlation between trust and

team performance was strongest in studies employing cross-sectional designs, while studies with a time-lag in between measurements found a weaker relationship overall. This finding suggested trust measurements should be administered within close proximity to the team event in order to maximize power. The authors further recommend sampling trust at multiple points longitudinally when feasible to capture the construct's dynamic temporal trajectory and, further, to select a scale which taps into both cognitive and affective components.

2.3 Rapport

Though there is much diversity in how it is defined, the concept of *rapport* can be thought of as a harmonious, positive interaction between individuals that evokes feelings of trust and inspires cooperation (e.g., Cappella, 1990). The COM leverages Tickle-Degnen & Rosenthal (1990)'s theoretical conceptualization of rapport which involves three fundamental components: *mutual attentiveness*, *positivity*, and *coordination*. Mutual attentiveness, or the degree to which the interaction partners are focused on or interested in each other, contributes to the formation of a unified, coherent interaction. Positivity involves the affective nature of the interaction, including one's perception of another's friendliness and caring. Coordination reflects the synchrony, balance, and harmony of the interaction between the individuals.

Related to the concept of rapport are *affinity*, which reflects a feeling of connection or one's openness to connection with another person (Nardi, 2005), and *common ground*, or mutual knowledge, beliefs, and assumptions shared by conversational partners (e.g., Kecskes & Zhang, 2009). Antecedents of affinity include nonverbal behaviors and activities, including touch and shared experiences. Incidental conversation about mundane topics (e.g., the weather, simple jokes, etc.) can sufficiently begin to evoke feelings of affinity (Argyle, 2017; Oren & Gilbert, 2012). Both affinity and common ground are important for increasing coordination and performance because of their potential to boost the effectiveness of mutual communication between interaction partners (Convertino et al., 2005). Building rapport is thus desirable in a myriad of social contexts, including law enforcement investigative interviews (Brimbal et al., 2019), in educational settings with teacher-learner relationships, and in virtual work teams (Muir et al., 2017).

2.3.1 Behavioral Markers of Rapport within the Telecommunications Context

Behavioral markers for the high-level construct of rapport are shown in Figure 3. As with trust, telecommunication systems and other forms of mediated communication can put conversation partners at a disadvantage for relationship development by decreasing the number of nonverbal cues available (e.g., Culnan & Markus, 1987). Intonations influence affect (Scherer et al., 1984), but they might be altered through the communication medium. Other cues such as mimicry can signal desired social distance (Farley, 2014), but these may again be difficult to detect. Richer modalities of mediated communication, such as those that include visual, audio, and verbal information, have been reported to increase closeness (Kirk et al., 2010) and can effectively match the information available in a face-to-face interaction (Sprecher, 2014). As a result, both interpersonal outcomes, such as liking and perceived intimacy, as well as task performance are improved relative to more “lean” forms of computer-mediated communication (Ramirez & Burgoon, 2004). However, despite technological capabilities, it is worthwhile to note that unstructured time and serendipitous “hallway” conversations tends to occur less frequently in telecommunications, thus providing fewer opportunities and venues to build rapport. Promisingly, Nicholson (2002) found that instant messaging was able serve this purpose, and it resulted in end users reporting communication-ease and feeling a greater sense of community. Further, CMC interactions are associated with an increased reliance on verbal behaviors (e.g., statements of positive affection, emoticons) to convey affinity, whereas the nonverbal cues available during an in-person, face-to-face interaction (e.g., direct body orientation, postural openness) tend to convey affinity (Walther et al., 2005).

2.3.2 Detection and Measurement of Rapport

Behavioral manifestations of rapport include linguistic markers, paralinguistic markers, nonverbal markers, and self-report measures. Linguistic markers can include “socializing” language, such as discussion of socializing outside of work contexts or sharing of personal stories (Sottilare et al., 2018). Ritual or mock impoliteness can be used to promote closeness (Hardaker, 2010). Paralinguistic signals of rapport include the amount and length of conversational turns (e.g., Sprecher & Treger, 2015), gestures and actions that are present when introductions are made (e.g., *touch* in the form of a handshake), as well as the ability to direct one’s attention to the intended interactant (e.g., eye gaze; Nardi, 2005). Additional nonverbal

markers of rapport include mutual smiling, gaze, and leaning forward between conversation partners, especially when occurring synchronously in time (Yu et al., 2013).

Linguistic data can be obtained and analyzed with the computerized text analysis software LIWC (Pennebaker et al., 2001; Tausczik & Pennebaker, 2009) or other discourse analyses (Graesser et al., 2003). Within LIWC, specific libraries can be used to assess different types of verbal content, such as the expression of plural pronouns (e.g., “we” and “us,” first person plural pronouns) and inclusive reference terms (e.g., “with” and “also”), reflecting the social and cognitive processes that are present during communication. Nonverbal and paralinguistic cues can be assessed via toolkits that use feature extraction such as openSMILE (Schuller et al., 2012), OpenFace 2.0 (Zadeh et al., 2018) or detect global body motion synchrony such as Motion Energy Analysis software (Ramseyer, 2020). One particular benefit of these nonverbal methods is that they capture time-series behavioral data such that synchrony and its developmental pattern over the course of an interaction can be evaluated. Survey measures can be used to assess peoples’ self-reported feelings of rapport during an interaction and/or with an interaction partner (e.g., Bernieri, 1988). These self-report measures of rapport are typically administered following the conclusion of an interaction.

2.4 Engagement

Depending on the research context, the definition and behaviors indicative of “engagement” vary. For instance, the concept of engagement has been associated with behaviors that are in line with a person’s motivation to perform a task (Cannell et al., 1981; Reeve et al., 2004; Skinner & Belmont, 1993). Regarding an interpersonal interaction, engagement has been conceptualized as the process by which people start, maintain, and end their perceived connection to one another (Sidner et al., 2005), and may be indicated by behaviors that reflect positive or negative evaluations of an interaction partner (Tickle-Degnen & Rosenthal, 1990). Three fundamental components of engagement are thus attentional involvement (e.g., to a stimulus or interaction partner), emotional involvement (that is afforded by sustained attention; Peters et al., 2009) and behavioral engagement (active participation; Johnston, 2018). An important component to engagement is a feeling of connection between two people (i.e., copresence; Nowak & Biocca, 2003), regardless of whether communication is occurring face-to-face or via computer-mediated platforms. For the purposes of this paper, engagement is defined

as directing one's attention, acknowledging other participants, and demonstrating a readiness to interact with other participants, whether positively or negatively. Note that with this definition, there can be a feeling of presence or a lack of engagement whether in face-to-face or CMC. The affordances of select communication environments and platforms have especially pronounced implications for participant engagement and that engagement's behavioral or expressive manifestations. Modern CMC applications such as Slack, Discord, Clubhouse, and Zoom each offer varying degrees of focus tailored toward specific communicative modalities. The positive and negative downstream effects of utilizing each of these exemplary technologies on social or performance-related outcomes tied to engagement are important to consider for educational, industrial, and leisurely pursuits. For an illustrative example, massive open online courses retain an average of only 5-10% of registered learners (Robal et al., 2018), thus providing a clear incentive for the study and identification of factors which influence markers of engagement.

2.4.1 Behavioral Markers of Engagement within the Telecommunications Context

Behavioral markers for the high-level construct of engagement are shown in Figure 5. Engagement in the telecommunication context may be particularly difficult to measure because the technologies themselves can present many distractions from engaging with a fellow participant. Desktop CMC applications invite multi-tasking, but the multi-tasking can be due to engagement (e.g., searching for materials relevant to the current conversation to present to other participants) or can be due to a complete lack of engagement (e.g., performing completely unrelated tasks). Detection of the multitasker's intent is difficult; thus, one cannot unilaterally rely on ambiguous metrics such as how much time a participant is spent looking at a shared screen. Lack of engagement can be characterized as attention shifting away from a target task to unrelated thoughts (i.e., mind-wandering; Schooler et al., 2011). Engagement, or disengagement, can be reflected in one's appearance and facial expressions. For instance, in a learning context, movement in the region of the upper face (e.g., eyebrow raising, eyelid tightening) has been shown to reliably predict engagement, frustration, and learning (Grafsgaard et al., 2013). Disengagement has also been associated with increased frequency of blinking and decreased frequency of task-relevant visual fixation (Smilek et al., 2010).

2.4.2 Detection and Measurement of Engagement

Both verbal and nonverbal cues can serve as indicators of engagement. For instance, eye contact and gestural information often reflect acknowledgement. Additionally, the presence and consistency of reactions can indicate a willingness to interact. Nowak and Biocca (2003) developed two measures to assess perceptions of an interaction partner's involvement (perceived other's copresence) as well as their own involvement in the interaction (self-reported copresence). Analyzing one's post-hoc knowledge about the interaction may provide objective measures of a participant's attention. Of note, the presence of a dialogical exchange itself is a cursory indication of engagement (Taylor & Kent, 2014). Further, the quality of a conversation and an interactant's skill in communication can be assessed with a self-report measure (such as the Conversation Quality and Engagement Checklist, or CQEC; van der Merwe et al., 2007).

Nonverbal correlates of engagement include having a directed gaze, a direct body orientation, nodding, raising eye-brows, leaning forward, and mirroring another's posture (Tickel-Degnen & Rosenthal, 1990). Automated systems (e.g., the Nonverbal Behavior Analyzer or NovA system) have been developed to detect gestural and postural information from audiovisual recordings of interactions that indicate social attraction and engagement, such complex behaviors like mimicry (Lakin et al., 2003) and other constructs (Baur et al., 2013). One of the most straightforward examples from computer vision involves simply detecting whether or not there is a face present in a webcam video stream (Robal et al., 2018). Further, a multimodal approach using information from facial expressions, eye activity, acoustics, linguistics, and paralinguistics can reliably predict a person's level of interest in a conversation (Schuller et al., 2009). Several self-report measures have been created to assess users' experiences of presence and immersive tendencies (e.g., Witmer & Singer, 1998; for review, see Oh et al., 2018). Kopp and Krämer (2021) have considered whether these signals, originated in human-human analyses, apply well to human-agent communication.

2.5 Collective Efficacy

Efficacy is defined as one's confidence of one's capabilities to execute an action to produce a level of performance (Lee & Bobko, 1994). Those with high self-efficacy tend to exert more workload by setting more challenges for oneself whereas those with low self-efficacy exert less (Bandura, 1993). Similarly, *collective efficacy* describes a team's shared perception of its

ability to successfully perform a task (Bandura, 1997). A team experiences collective efficacy when they are confident that the team members have the ability to fulfill their responsibilities in relation to a task (Sottolare, 2018). Collective efficacy influences teams in a similar manner as self-efficacy influences individuals (Tasa et al., 2007) and as a result can influence the team's performance (Bandura, 1997; Bandura & Locke, 2003; Gully et al., 2002). Collective efficacy develops not only on the individual level, but at the team level through information exchange and teamwork behaviors (Gibson, 1999; Tasa et al., 2007).

The relationship between a team member's perceived ability and suitability for a task may be moderated by interpersonal factors (Sottolare, 2018). For example, when personal conflict among team members is high, the team may feel a loss of collective efficacy due to the impact of interpersonal factors on task execution. Teams that take a cooperative approach and have a shared perception of the team's ability to organize and execute courses of action are more confident in their abilities to manage conflict, have a higher level of collective efficacy, and are able to operate more productively (Alper et al., 2000). Furthermore, Khong and colleagues (2017) found that high levels of self-efficacy at the individual level hindered performance in a small group exercise, while their tasks were completed more successfully by those teams with high collective efficacy, demonstrating the special importance of collective efficacy resulting from effective communication. Social cognitive theory and some previous research suggests collective efficacy is the most pivotal state by which team inputs modulate team performance (Li et al., 2020).

2.5.1 Behavioral Markers of Collective Efficacy within the Telecommunications

Context

Behavioral markers for the high-level construct of collective efficacy can be found in Figure 6. Geographically dispersed teams are especially susceptible to communication breakdowns (Daim et al., 2012), which affect objective measures such as project timelines, as well as the subjective perception of collective efficacy. Collective efficacy is directly related to perceived team member ability and the task at hand. Therefore, behavioral markers for collective efficacy reflect this dichotomy: ability and task context (Sottolare, 2018). Ability markers are those that focus on communication among team members and help-seeking behaviors (e.g., requesting assistance from team members), whereas contextual markers focus on interpersonal

relationships among team members in relation to a task (e.g., confidence in ability to resolve conflicts about how to approach a task).

As with other components of communication, collective efficacy may be challenging to foster within the telecommunications context. For example, many ability markers of collective efficacy take the form of non-verbal cues (e.g., nodding, positive facial expressions) that are often lost in an audio-only system. However, the use of mediated communication platforms that includes both audio and visual information allow for these cues to be present (Sprecher, 2014).

There may also be implications for workload in teamwork performed through telecommunications. Media richness theory (Daft & Lengel, 1986) suggests that face-to-face should be preferred over CMC because the latter lacks the richness of multi-channel multi-modality throughput. Reduced richness in communication can be interpreted as fewer cues available and therefore decreased information throughput. Based on multiple resource theory (Wickens, 1980), a reasonable consequence of this reduced richness may be increased participant workload because the participant must perform additional, cognitively-taxing meaning-level processing to compensate for the lack of cues. However, Kock's (2005) Compensatory Adaptation Theory (CAT) postulates that increased workload does not necessarily decrease task performance. Kock (2005) found that when comparing face-to-face vs. web-based discussions for a collaborative re-design task, cognitive effort, communication ambiguity, perceived message preparation, and fluency tended to increase in virtual teams. However, there was no effect on the quality of team outcomes. Therefore, though workload needed to overcome technology challenges can influence the selection of face-to-face vs. CMC, its relation to the team's work quality is not well established. Kock cites multiple examples where obstacles in group effectiveness actually cause voluntary and involuntary compensation behaviors, resulting in the same and even better outcomes than situations without said obstacles. Although Kock did not evaluate individual nor collective efficacy, such positive outcomes may also be related to high collective efficacy and the team's willingness to expend greater workload to achieve higher performance. In fact, it may be the case that greater collective efficacy may mitigate participant workload by increasing motivation to perform well (Bedwell et al., 2014).

2.5.2 Detection and Measurement of Collective Efficacy

Measurement of collective efficacy tends to be focused on a specific task as well as interpersonal factors that may affect team performance. These measures generally follow one of

two approaches: aggregating the individual members' perceptions of their capabilities to perform their role in the group and aggregating members' perceptions of their group's capability as a whole (Bandura, 2000). One standardized measure to assess task workload is the NASA-TLX (Hart & Staveland, 1988). As the measurement of collective efficacy tends to be task specific, scales tailored to a task or team are common. However, despite the tailored nature of many measures of collective efficacy, Bandura (1997) recommends that measures assess both magnitude and strength of team performance. For example, Tasa and colleagues (2007) measured magnitude with the item "I believe [yes/no] that the team can finish the simulation in at least the top 10 teams [out of 50 teams]" and strength with a continuous 100-point scale where 0 was "no confidence at all" and 100 was "complete confidence." As such, these authors recommend following this lead in structure and tailoring or adapting survey items to the research and task context, as demonstrated in Salanova et al. (2003), for example. Moreover, human coders could document task and performance related behaviors in a similar context specific manner, for instance, wherein a team member may request backup or assistance. The use of inclusive or positive language could also serve as positive signals of collective efficacy. Similarly, breakdowns in communication and performance such as argumentation or personalized verbal attacks would be reverse coded, contraindicative manifestations for this construct (Podsakoff et al., 2003). Nonverbal acknowledgement cues such as nodding and gesturing are well known marks of collective efficacy in competitive team sports and may generalize to broader contexts of group activity (Seiler et al., 2017). Previous work in classroom settings demonstrates a link between the paralinguistic construct of fluency and collective efficacy and could be a metric worth consideration for researchers in education or related fields (Lewis, 2011). Salas et al. (2015) provide a review of the collective efficacy field's operationalization and measurement techniques, including innovative, unobtrusive methods.

2.6 Conflict Management

Mitigating conflict is a necessary function of high performing teams (Alper et al., 2000). Conflict management is a process through which team members engage in strategies to effectively address tension due to real or perceived differences (de Dreu & Weingart, 2003), or activities that obstruct or interfere with effective behavior of another (Deutsch, 1973). This process includes identifying and acknowledging conflict, solution seeking, and coming to

consensus on methods to address the conflict (Sottolare et al., 2018). Caputo et al. (2019) and Zhang et al. (2018) each offer broader reviews of conflict management literature. Conflict within teams can be due to interpersonal incompatibilities, contrasting viewpoints and opinions pertaining to the task at hand or due to differences with respect to how a task should be accomplished (Jehn & Mannix, 2001). A cooperative style of conflict management views conflict as a shared problem that calls for a mutually beneficial solution. In contrast, a competitive style of conflict management views conflict as an adversarial, win-lose situation wherein intimidation and pressure lead to conformity (Tjosvold, 1988). Cooperative conflict management strategies may be particularly conducive for achieving collective efficacy (Alper et al., 2000). Emotional intelligence and emotion recognition skills of supervisors and employees alike are important predictors of conflict management success and resolution in workplace settings (Way et al., 2020; Winardi et al., 2021).

2.6.1 Behavioral Markers of Conflict Management within the Telecommunications Context

Behavioral markers for the high-level construct of conflict management are shown in Figure 7. Effective conflict management requires keen observations of participant emotions as well as checking one's own expressions. This presents both a challenge and a potential advantage for the use of telecommunications. On the one hand, current telecommunications, even video-enabled, often make it more difficult to pick up other team members' emotions and subtleties that might be more readily observed in face-to-face (Walther et al., 2005). On the other hand, one can more easily conceal anger or other negative emotions when using CMC, which can facilitate conflict management.

Conflict management behaviors can be differentiated based on whether they aid or hinder group performance (Bottger & Yetton, 1988). For instance, positive conflict management behaviors include examining competing knowledge bases, considering alternatives, and providing logical arguments and explanations for one's point of view. In contrast, negative conflict management behaviors include zero-sum resolutions, "I win/you lose" dominance games, and may be characterized by reluctance to argue one's opinions. In-person interactions tend to foster positive conflict management behaviors, whereas CMC produces higher levels of negative conflict management behaviors (Zornoza et al., 2002).

Best practices in conflict management favor cooperative and confirming approaches over competitive and avoiding behaviors (Barker et al., 1988). Conflict management includes group oriented and individual manifestations. Positive group behavioral markers include discouraging signs of anger, identifying and addressing conflict, and seeking and encouraging an inclusive, collective attitude such as “seeking a solution for all” and encouraging a “we’re in it together” attitude. Positive individual behaviors revolve around emotional intelligence such as being respectful of other opinions and refraining from overt negative expressions of emotion (Sottolare, 2018).

2.6.2 Detection and Measurement of Conflict Management

Some manifestations of conflict management, such as showing respect, can be difficult to evaluate objectively due to cultural and individual differences. However, other behaviors that are more universal, such as demonstrations of anger, are more easily observable by automated means. Linguistic analysis can be used to detect verbal expressions of emotion and attitudes (Van Swol & Kane, 2019). As with trust, evaluating the relative frequency of in- and out-group language can be indicative of group affiliation strength (Wu et al., 2013). Computer vision methods can be leveraged to detect facial expressions and other potentially threatening poses or postures that are indicative of anger. Paralinguistic markers, which can include turn-taking and the number of interruptions, could possibly be used to quantify whether an inclusive, egalitarian attitude exists within the group. Other complex behaviors could be coded by a human researcher.

In addition to behavioral measures, self-report surveys can be used to assess participant perceptions on whether the team took cooperative or competitive approaches to conflict management (Alper et al., 2000). Further, the Dutch Test for Conflict Handling (DUTCH; De Dreu et al., 2001) has been validated as a measurement tool to assess preferences for and actual performance of conflict management strategies.

2.7 Mental Models

The term “mental model” has been used to describe theories of how things work (e.g., how a refrigerator works; Norman, 1988) as well as how information is mapped between perceived stimuli and words to conceptual structures (e.g., one’s spatial model of London or the rules of a game; Johnson-Laird, 1983; Larkin & Simon, 1987). With respect to

telecommunications, there are three types of mental models that are useful to consider. First, high-performing teams may have *shared* mental models about elements of a task environment, such as available tools or skills of individual team (Cannon-Bowers et al., 1993; for review see Mohammed et al., 2010). Having such mutually shared descriptions enables team members to coordinate and communicate effectively (Mathieu et al., 2000).

Second, people may have mental models of the people with whom they communicate. In the context of both face-to-face and computer-mediated communication, mental models will be informed by the person's social and cultural context (Mantovani, 1996; for review, see Lee & Malcein, 2020). The unconscious categorization of others into social categories may also contribute to the formation of mental models based on a persons' previous experience with other demographically similar individuals or based on an accurate estimation of personality traits from brief video clips (i.e., person perception; for review, see Brooks & Freeman, 2018). Often only a few seconds in length, video clips showing "thin slices" of behavior offer cues such as facial expressions, voice cues, and body pose that influence categorization (Weisbuch & Ambady, 2011). The notion of person perception has also been extended from how individuals are perceived to how *groups* of individuals are perceived (i.e., *people* perception; Phillips et al., 2014).

Finally, people may have mental models of the communication channel and its affordances. As noted previously, people within CMC contexts will adopt new behaviors to compensate for missing affordances (Kock, 2001; 2007). These new behaviors may actually lead to the same or better communication than expected from the CMC channel because of overcompensation (Kock & DeLuca, 2007; Oren & Gilbert, 2012; Riche et al., 2010). Cultural differences can also affect not only the perception of the communication context, as mentioned above, but also the perception of affordances of CMC tools themselves (Setlock & Fussell, 2010).

2.7.1 Behavioral Markers of Mental Models within the Telecommunications Context

Behavioral markers for the high-level construct of mental models are shown in Figure 8. Despite differing operationalizations of the construct, behavioral markers of shared mental models involve the extent to which there is overlapping or similar content between team members' models (DeChurch & Mesmer-Magnus, 2010). For instance, similarity of team members' mental models may manifest as correlated ratings of task attributes (e.g., Mathieu et

al., 2000) or as clusters of groupings following a card-sorting procedure (e.g., Smith-Jentsch et al., 2001). Team behaviors such as coordination and backup behavior (i.e., one member doing another member's task when the other member is overloaded) may also factor into the calculation of whether the mental models are shared. Mutual understanding and mutual attention between individuals tend to suffer in CMC, relative to face-to-face communication (Biocca et al., 2001).

Regarding mental models of others, researchers have shown that a larger face width-to-height ratio is correlated with perception of people as deceptive and aggressive (Carré et al., 2009; Haselhuhn & Wong, 2012). Face "averageness," on the other hand, has been shown to increase judgments of trustworthiness (Sofer et al., 2015). Brooks and Freeman (2018) also review previous research on vocal cues for mental models of others, noting that very short voice samples can lead to accurate predictions of body size, affect, age, gender, and race. Listeners also feel confident in making judgments about trustworthiness based on voice, whether or not they are correct.

In addition, eye behaviors can serve as markers of relationships during communication. A person's gaze facilitates conversational flow and turn-taking (Knapp et al., 2013). Most importantly for mental models of other people, eye gaze patterns can serve to communicate status and dominance as well as desire for intimacy. It is worth noting that while popular culture suggests that eye gaze can be used to detect lying or deception, research results demonstrate that not to be the case (Hartwig & Bond, 2011). Pupil dilation as a consistent behavioral marker has a mixed history but has experienced a more recent resurgence as a measure of mental workload (van der Wel & van Steenbergen, 2018).

Some of the behavioral markers in studies evaluating mental models of the communication medium itself have included: number of contributions to an online discussion forum, word counts per post, time to reply, percentage agreement on team process changes (Kock & Deluca, 2007), knowledge sharing of privileged information between collaborators (Oren & Gilbert, 2012), reduced mouse movements in a collaborative system with four simultaneous mouse users, and increased communication about the collaborative system itself (Riche et al., 2010).

2.7.2 Detection and Measurement of Mental Models

Most efforts to measure shared mental models have involved elicitation techniques such as post-task surveys, ratings, or concept maps (e.g., Biocca et al., 2001; Mohammed et al., 2000). A

method that moves closer to an automated process is the Mental Model Acquisition Tool (MMAT; Delugach et al., 2016). While the MMAT still requires human intervention with group members, the humans facilitating its use do not need to know anything about the team task or the team composition. The MMAT uses simplified conceptual graphs (nodes and links) as its representation of knowledge; each team member uses the tool to construct a model of the team's process. Members might construct the models individually or as a team, and they can do so before or after an activity, or both. Furthermore, Scheutz and colleagues (2017) propose computational formalism to be used to describe shared mental models. More recently, researchers have attempted to measure components of team members' mental models by linguistic markers during communication (Wu et al., 2013) or in real-time via embedded or "stealth" assessment based on complex actions taken in a simulation or game (Shute & Ventura, 2013).

Regarding facial analysis, a manual process with static photographs that have had hair removed and been normalized to the same overall size may be used to measure potential judgments based on facial width-to-height ratio (e.g., Carré et al., 2009). This method could potentially be automated based on extracting appropriate head-on frames from video. Existing computer vision software (e.g., Littlewort et al., 2011) has been used successfully to recognize emotional facial expressions such as surprise, happiness, anger, etc., and facial electromyography (fEMG) has been used successfully to measure confusion (Durso et al., 2012). In order to distinguish moments of interpersonal eye-gaze during in person and teleconferencing interactions, Tran and colleagues (2020) leveraged OpenFace and a novel clustering algorithm that quantified the duration of time interactants spent visually attending to their conversational partner. Additionally, Tchanou and colleagues (2020) describe and test an index that identifies moments when dyads' gaze converge on the same objects during the collaborative use of information technologies. High proportions of joint attention over time corresponded with superior task performance, suggesting the development of shared mental models (Sharma et al., 2020). To evaluate people's mental processes of social categorization or bias during stimulus perception, several researchers have used a mouse-tracking paradigm (e.g., Freeman & Ambady, 2010) in which the participant must use a mouse to choose between two options on screen. Easily distinguishable stimuli lead to simpler mouse paths than stimuli that present conflicting cues, e.g., an androgynous face when asked to choose male or female. While this approach might

be useful to compare avatars in a pre-communication setting, it would be difficult to implement during live communication.

2.8 Shared Situation Awareness

Similar to shared mental models, shared situation awareness is related to the participants' understanding of the environment. However, researchers suggest that analyzing shared mental models alone is not sufficient for assessing team communication during coordinated activity and that situational awareness must be taken into account (Carroll et al., 2006). Motivated initially by the design of human interfaces for avionics and flight control systems, the concept of situation awareness emerged in the late 1980s. The seminal work by Endsley (1988 May) defines situation awareness (SA) as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (p. 792). In the intervening years, SA has become a substantial topic in the general human factors research community with applications as diverse as air traffic control, power systems operation, emergency management and robotic teleoperation for health care, oil and gas exploration, hazardous environments, and mining, among others (see Kedia et al., 2020, Rockwood et al., 2018, and Stanton et al., 2017 for reviews). SA research has even extended to measure the collaborative performance of teams (Gorman et al., 2006; Salas, et al., 1995) and to guide the design of groupware, such as CMC (Gutwin & Greenberg, 2002) and telepresence (Cidota et al., 2016) systems. With respect to shared situation awareness (SSA) in teams, the SA of the individuals involved is important. However, some researchers have noted that not only must there be similarity between individual's SA, but also the individuals' SA must be *accurate* (Saner et al., 2009).

2.8.1 Behavioral Markers of Shared Situation Awareness within the Telecommunications Context

Behavioral markers for the high-level construct of shared situation awareness are shown in Figure 9. When using telecommunications, participants are likely not sharing the same physical space. Therefore, achieving shared situation awareness may be particularly challenging if and when there is greater communication distance between individuals (Carroll et al. 2006; Saner et al., 2009). If the environment of the participants is relevant to the task at hand, individuals

communicating via telecommunications may be disadvantaged because they lack agency in the remote space and cannot easily access information embedded in the remote environment of team members (Gutwin et al., 1996). Wuertz et al. (2018) analyzed how this issue manifests in multiplayer games, for example. Streaming body worn cameras or “see what I see” features try to address this challenge, but individuals watching the streaming video still lack agency because they are not able to direct their own attention (Cidota et al., 2016). By limiting the remote participant to the local participant’s point of view, self-directed exploration is restricted. Although this is a key difference between those employing face-to-face versus CMC, it is unclear whether it is a factor in achieving shared situation awareness. Wang and colleagues (2014) provided an augmented reality telepresence system called TeleAR which enhanced mutual awareness, distributed cognition, and trust by supporting gaze awareness, facial expressions, and gestures. Cidota et al. (2016) similarly focused on a framework for enhancing situation awareness between co-workers by facilitating AR cues. Intuitively, behaviors such as following eye gaze to an object of interest based on a teammate’s description may show a level of situation awareness. Other markers such as an expression of confusion may also provide clues about whether a participant understands elements in his/her environment.

2.8.2 Detection and Measurement of Shared Situation Awareness

Endsley (1988 May, 1988 October) introduced an objective measure of SA called the Situation Awareness Global Assessment Technique (SAGAT). This approach involves essentially freezing a simulation or task at a random point in time to assess the subject’s current and future state understanding, typically via simple queries related to information required by the operator to successfully complete the task. Traditional SAGAT queries to assess individual SA for multiple team members can also be transformed to account for shared SA within teams (Saner et al., 2009). Other SAGAT-like “freeze-probe” techniques have been proposed for other domains and they all share the advantages of avoiding post-trial data collection and the subjective nature of self-rating techniques. However, these methods depend necessarily on interruptions which make them difficult to implement in real-world situations. A subjective measure of SA has also been developed. This tool, termed the Situational Awareness Rating Technique (SART), provides information related to perceived SA, which may not always be related to objective assessments of SA (Endsley et al.; 1998).

Recently Nguyen, et al. (2019) published a thorough literature review of contemporary SA measurement techniques and describes them in terms of the following six categories: Freeze-probe, Real-time probe, Post-trial self-rating, Observer-rating, Performance measures, and Process indices. The advantages and disadvantages of each are described as well as how they map onto three theoretic types of SA models, namely: Individual SA; Team and Shared SA; and System and distributed SA. The latter, System SA, is characterized as distinct from Team SA via the integration of humans with technical elements to support organizational activities. Typical domains for System SA are complex, safety-critical systems in which the emphasis is on the interactions between team members rather than each individual's SA. While SA has been well described in CSCW work, as it relates to the shared workspace in real-time groupware (Gutwin & Greenberg, 2002, 1996), few studies seek to measure the quality of the awareness provided by the system, as noted by Cidota et al (2016). Whereas human factors definitions of System SA focus on the interactions, in CSCW, the system refers to the technological set up used by a pair or group. The volume and frequency of transactional exchanges may also be used as a proxy measurement for distributed situational awareness, whereby the number of task-relevant interactions is especially important (Sorensen & Stanton, 2016).

3 Measurement and Analysis Technologies

An objective of this research is to evaluate differences in achieving communication objectives through face-to-face interaction as opposed to CMC. The prior section provided communication objective definitions and described behavioral and physiological manifestations of those objectives. This section identifies technologies that can measure behavioral manifestations. Measurement technologies are typically related to a specific modality (e.g., computer vision, audio recording analyses, proxemics etc.), while manifestations of each high-level construct may span multiple modalities. Some high-level constructs also have similar or overlapping manifestations and thus the same detection methods may be used for multiple constructs. Below are brief descriptions of each category of manifestations.

3.1 Linguistic Behaviors

Linguistic behaviors involve the use of language through spoken and/or written means. Data may be acquired through manual transcription or speech recognition (i.e., speech to text)

technologies. Analytic tools use the Natural Language Processing (NLP) technique and range from relatively transparent methods, such as bag-of-words, word matching and word count, which disregard grammar and word order, to more computationally complex approaches, such as Latent Semantic Analysis (LSA; see Landauer et al., 2013).

3.2 Paralinguistic Behaviors

Whereas linguistics is concerned with the lexical elements of communication, paralinguistic behaviors can be thought of as the style with which words are expressed. Measures include volume, pitch, intonation, timing, and other patterns in speech that can contribute to conveying emotion (see Mozziconacci & Hermes, 1999). To evaluate social dynamics, speaker detection (e.g. Wyatt et al., 2007), turn taking, the distribution of speaking duration, and the number of interruptions may also be included. Analysis methods range from manual coding using software such as BORIS (Friard & Gamba, 2016) to computational methods (e.g., Xu, 2013).

3.3 Nonverbal Behaviors

Nonverbal behaviors span across eye contact, facial expressions, gestures, pose, and other forms of body language. Intuitively, eye contact is an indicator of attention, and can be measured using commercially available eye tracking devices. At a social level, shared eye contact may also indicate shared attention. The universality of facial expressions suggests that they span cultural norms (Ekman, 1973). Further, the automaticity or inability to inhibit natural facial expressions (Kappas et al., 2000) suggests that these manifestations are beyond the individual's conscious control and may more accurately reveal an individual's underlying emotion than self-reports. Similar to other behaviors mentioned above, manual coding has traditionally been used for detection of facial expressions and gestures. Electromyography (EMG) can be employed to detect microexpressions indicative of emotional states, even beyond the subject's conscious awareness (Wexler et al., 1992).

Other novel computational methods have become increasingly available. Since Viola and Jones' (2001) seminal work using Haar feature-based cascade classifiers to train a convolutional neural network to detect faces in an image, several open-source toolkits have been developed to reliably recognize facial expressions representing emotion. For example, the computer emotion

recognition toolbox or CERT predicts the expression of one of seven possible emotions (i.e., anger, disgust, fear, happiness, sadness, surprise and neutral; Littlewort et al., 2011). OpenFace and OpenFace 2.0 are powerful open-source software tools that enable head pose estimation, facial action unit recognition (emotion), and eye-gaze estimation using regular webcams (Baltrusaitis et al., 2016; 2018). While some gestures are culturally informed (e.g., nodding one's head in Europe carries a similar agreeable sentiment as shaking one's head in India), other forms of body language may also provide insights about an individual's underlying emotions and motivations. Proxemics have been studied in physical environments by instrumenting participants with wearable sensors (Pentland, 2010) as well as through studying their movement patterns in virtual environments (Börner & Penumarthy, 2003).

3.4 Complex Behaviors

We define complex behaviors as those with multi-modality displays at an individual level, or multi-participant displays at a social level. An example of an individual level complex behavior is sarcasm where the combination of linguistic, paralinguistic, and facial expressions is used for display and detection (Caucci & Kreuz, 2012). An example of a complex behavior at the social level is mimicry between individuals for displaying affect (Farley, 2014). In a study examining the nonverbal movement synchrony between dyadic collaborators in virtual reality, Sun and colleagues (2019) found that increased rates of postural mimicry positively correlated with self-reported measures of social closeness, confirming classic findings from face-to-face interactions using embodied CMC (LaFrance, 1979).

3.5 Surveys

Self-reports may be limited in their ability to objectively draw insights from participants compared to behavioral analysis, given that they are subject to the participant's own biases, perceptions, and level of self-awareness. For example, Hazlett and Hazlett (1999) found EMG to be more discriminatory than self-reports for emotional responses to television commercials. Yet, surveys are widely used as they provide a method to measure some constructs where there is a lack of alternatives, or they serve as a catch-all for participant opinions that may otherwise not be captured. For these reasons we have included validated surveys as measurement methods.

4 Implications for Practice

The presented framework showcases the components that can be considered important to coordinated action, whether that happens locally or remotely. Coordinated action incorporates an inclusive conceptualization of “working together” and “shared goal” into the definition of collaboration, acknowledging that group work may span many siloed contexts and can encompass multiple (related or seemingly disparate) goals (Lee & Paine, 2015). The COM may thus serve two functions. First, given a specific communication objective, a researcher can identify the types of behaviors a subject is likely to exhibit when attempting that objective. In this case, COM provides a pragmatic decision aide for selecting behaviors to observe and tools for making those observations. The next logical step is to apply the model to a use case.

The COM is intended as a tool for experimenters to measure constructs which are important in communication and, more broadly in coordinated action. The COM can be used to characterize the domain of telemedicine, which has proven vital to patient care during the COVID-19 pandemic (Greenhalgh et al., 2020). Telemedicine can be reasonably expected to have similar requirements for online care to be just as effective as face-to-face appointments. Though patients report overall favorability toward telemedicine consultations because of their convenient delivery and the reduction in total time spent, several studies have found decreased engagement and the relative inability to develop trust and rapport between the patient and physician (Gordon et al., 2020; Shaw et al., 2018). This increase in access must be balanced with the degradation in ability to meet communication objectives (see Abimbola et al., 2019), and so the COM presented here provides a taxonomy and series of standardized metrics that could benefit research conducted in the field of telemedicine.

More importantly, how might the COM be useful to distributed business teams? By examining the importance of an individual objective to the overall goals of a group encounter, the effectiveness of CMC technology for supporting the objective can be compared. In comparing the effectiveness of the available technology, one can decide whether they must travel to have the most valid outcomes from a meeting.

4.1 Example of Using the COM: Communication Needs of a Mechanic

The job of mechanic is important across many industries and in the armed forces. While much of the training process can be accomplished by introducing the new mechanic to the device that they will be servicing, allowing them to practice diagnosing and fixing problems with the device may not always be feasible. For example, hands-on training requires access to the device, which may be as small as a circuit breadboard or as large as a C-130 aircraft. When considering training C-130 mechanics, access to the device (a transportation aircraft) means pulling resources from functional operations (Correll, 2020). Aside from optimizing the distribution of physical resources, training a mechanic may require the presence of an expert who can guide them through the process. Acquiring such an expert is often costly in terms of time, travel, energy, and monetary expenditure.

Fixing malfunctioning circuits in a yet unfamiliar device requires a mechanic be trained to recognize relevant problem states, diagnose potential root causes, properly fix or replace offending electronic components, and verify the successful return to a functional status. It may be reasonably assumed that an instructor and mechanic trainee should be co-located for in-person training sessions; however, that may not be necessary and, indeed, an expert may not be easily accessible for any number of reasons. By considering the communication objectives of training on physical tasks, such as establishing trust between interactants, engagement with one another and with the task, and shared visual situational awareness, we can investigate whether various CMC tools may actually afford outcomes competitive with those of the in-person benchmarks (e.g., Dianiska et al., 2020). While there are more constructs than are described here which are important to achieving communication objectives, for simplicity, only trust, engagement, and shared situational awareness are followed in this example. The mechanic must be able to trust the expert and their instructions, and they need to engage with the training material. Keeping a trainee engaged and ensuring they understand the material requires maintenance of shared situational awareness, both in the expert's understanding of the trainee's attentional focus and the trainee's continued awareness of how the expert's information aligns with the problem space.

To evaluate the effectiveness of CMC solutions compared to in-person communication, in future research, the authors will compare learning and communication outcomes mediated by videoconferencing tools and mixed reality platforms with standard face-to-face circuit maintenance training. The measurement methods described in detail above provide empirical means to validate which CMC technologies could be selected or whether one should book a

flight or reserve a VR HMD. These types of further studies are needed to determine which CMC technologies are best at supporting the individual components of COM. As a result of such research, there are two paths to generating recommendations: (1) probabilistic models of the communication format's support for the various aforementioned objectives and (2) empirically-defined travel replacement thresholds by which the ability of a particular mediation of communication to support the communication objectives may be scored for various forms of coordinated activity.

Probabilistic models are the most straightforward path to applying this research to the question of when coordinated activity requires face-to-face interaction. Through carefully designed experiments, the effects of various characteristics of communication formats (such as face-to-face, videoconferencing, and VR telepresence) can be compared by their impacts on components of COM. The characteristics in question include the technology's affordances for agency, fluidity, embodiment, and media richness, in addition to other contexts, including social factors and task requirements. For each of these contexts, there is an expected impact on the communication outcomes, and the impacts on the various COM elements outlined in this paper can be modeled for use in predicting the effectiveness of a given communication medium for a given coordinated activity (for example, training, business meetings, or telemedicine). These predictive models would require the user to make value judgements as to which communication objectives are most important to their specific context. Additionally, the user would need to evaluate the expected outcome in terms of the probability that it may be successful for effective communication – a task that is more difficult than it seems at surface level.

Arguably a more user-friendly approach to supporting decision making about the replacement of travel with CMC would be thresholds that are delineated through testing of the impacts of various contexts for communication (e.g., affordances, social factor, and task requirements). These results would give clear recommendations about the effectiveness of a given format for a specific use case. To understand whether a person should meet with a therapist or pursue telehealth, for example, the new patient would not need to know what portions of COM are most important to accomplishing their goal of receiving quality mental health care, they would simply need to know their overall context (receiving mental health care), their familiarity with the therapist provider, and maybe a specific challenge they wish to overcome (for instance, different requirements may be expected for treatment of PTSD than for

boundary work). By entering these variables, this threshold system would integrate knowledge from analyses of various CMC technology and face-to-face communication, weighted by evidence of the importance of the COM components to various contexts of use and of the comparative advantage of the technological and naturalistic solutions to communication. However, knowing the optimal thresholds will require further research into the technologies and the contexts of use.

Also, the COM may be used from the bottom up to infer a speaker's underlying communication objectives by observing their behaviors. This is potentially useful for creating socially intelligent agents that must infer higher level human goals from behavioral observations. Consider, for example, a listener's eye gaze behavior. A listener tracking and following the speaker's eye gaze onto an object is more likely to be associated with the objective of building a shared mental model as opposed to the objective of assessing the speaker's emotion (Tchanou et al., 2020), which is often associated with gaze upon facial and gestural features.

Moving between layers in the model, from construct to marker to metric, may not always be a simple process because there may be features of an interaction that rely on multiple simultaneous cues. For instance, if one desired to detect moments when two people “find common ground,” a known important factor in communication (Kecskes & Zhang, 2009), it might be important to identify a specific combination of metrics, e.g., nodding, smiling, directed gaze, and shared mental models. Aggregating multiple lower level metrics into higher level features such as “common ground found” is non-trivial and may require machine learning classification of patterns and an enriched state representation (Ostrander et al., 2019).

5 Conclusions

CWC has had a growing appeal as a replacement for business travel due to its convenience and lower cost, and it has now become a global public health tool after COVID-19. However, CMC presents new challenges beyond those inherent in face-to-face communication (FtF). One's intuition is that due to the reduced richness in a telecommunications medium compared to FtF, “high touch” social goals such as building rapport may be more challenging. These challenges must be substantiated and addressed in order to make CMC a feasible alternative to FtF at scale. The Communication Objectives Model (COM) has been introduced in this paper to describe

high-level communications objectives (i.e., trust, rapport, and engagement), how they manifest as behaviors (i.e., gaze, gestures, and speech), and how those behaviors can be measured. The COM is motivated by the idea that effective communication is due to effective team activity; consequently, the COM references psychosocial objectives that are linked to effective teams and connects them to observable behaviors, empirically linked metrics, and measurement methods.

In future work, it is worth exploring whether the COM could also be applied to the relationships described in the domains of human-agent teaming, human-robot interaction, and their related cousins, human-machine interaction, human-robot collaboration, and other similar terms. Although the behavioral markers the COM constructs may need to be adjusted, it is likely that much of the COM could still apply and be used as an evaluation framework for the quality of a human-machine relationship.

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Figure 1

A synthesis of team research frameworks, drawing on I-P-O, IMOI and others.

Figure 2

Schematic of the Communication Objectives Model (COM): Behavioral types and markers exist for each high-level construct. Metrics exist for each behavioral type and marker.

Figure 3*Behavioral Markers of Trust*

Figure 4*Behavioral Markers of Rapport*

Figure 5*Behavioral Markers of Engagement*

Figure 6*Behavioral Markers of Collective Efficacy*

Figure 7*Behavioral Markers of Conflict Management*

Figure 8*Behavioral Markers of Mental Models*

Figure 9*Behavioral Markers of Shared Situation Awareness*