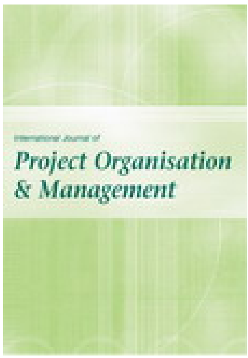



**International Journal of Project Organisation and Management**

ISSN online: 1740-2905 - ISSN print: 1740-2891
https://www.inderscience.com/ijpom

---

# Does temporal distance (still) affect the performance of virtual teams?

Idan Roth, Dov Te'eni

**DOI:** 10.1504/IJPOM.2024.10061744

**Article History:**

| | |
|---|---|
| Received: | 30 November 2021 |
| Last revised: | 18 August 2022 |
| Accepted: | 16 September 2022 |
| Published online: | 25 January 2024 |

# Does temporal distance (still) affect the performance of virtual teams?

## Idan Roth*

School of Information Systems,
The Academic College of Tel-Aviv,
Yaffo, Rabenu Yeruham St.,
P.O. Box 8401 Yaffo, 6818211, Israel
Email: idanro@mta.ac.il
*Corresponding author

## Dov Te'eni

Coller School of Management,
Tel Aviv University,
P.O. Box 39040 Ramat Aviv Tel Aviv, 69978, Israel
Email: teeni@tauex.tau.ac.il

**Abstract:** Many were optimistic that virtual collaboration in distributed projects would eliminate distance and, furthermore, enable work around the clock to achieve high performance. We ask whether this optimism has held up over the past two decades, in the face of changes in technology and changes in the workplace. Using an adjusted measure of temporal distance (ATD), the paper models the perceived decision quality in a project as a function of ATD, mediated by communication richness and moderated by project analysability. The model was tested in 2009 and again in 2019 with a combined quantitative and qualitative field study. The results suggest that the relationship between ATD and perceived decision quality is nonlinear and is mediated by communication richness. In 2019, projects engaged in significantly richer communication compared with 2009, yet temporal distance still made a difference. The results did not show an interaction effect between communication richness and project analysability. We argue that despite substantial IT progress, temporal distance is not dead and should be managed.

**Keywords:** virtual teams; communication richness; computer-mediated communication; CMC; project analysability; project management; perceived decision quality; time zone; temporal distance; adjusted temporal distance; ATD.

**Reference** to this paper should be made as follows: Roth, I. and Te'eni, D. (2024) 'Does temporal distance (still) affect the performance of virtual teams?', *Int. J. Project Organisation and Management*, Vol. 16, No. 1, pp.75–101.

**Biographical notes:** Idan Roth holds an MSc and PhD in Information Systems from Tel-Aviv University. He is a Senior Faculty member at the Academic College of Tel-Aviv, Yaffo, and Lecturer at the Coller School of Management, Tel Aviv University. His research interests include virtual teams, the practice of information systems, and technology-based training.

Dov Te'eni is a Professor Emeritus at the Coller School of Management. He studies visualisation and feedback, knowledge sharing for innovation, human-machine systems, and design of systems that support decision making and creativity. He has served as the President of the world-wide Association of Information Systems. He was awarded AIS Fellowship in 2008, Vision award in 2011, Danish Velux Fellowship in 2015 and the AIS LEO award in 2015.

## 1 Introduction

Virtual collaboration has become ubiquitous and often vital for organisations because of their need to work from a distance (Suh et al., 2011). It is now central to maintaining our increasingly globalised social and economic infrastructure (Morrison-Smith and Ruiz, 2020), and has evolved to a point where online collaboration is a way of working for national companies and, more naturally, for multinational or regional companies (Garro-Abarca et al., 2021). Yet, after decades of experience, questions about its effectiveness and broader impact on work life still remain unresolved. Indeed, only recently, large companies practicing virtual collaboration have called for returning to face-to-face work in the office. In particular, challenges to virtual collaboration in project management and project delivery have been noted in the past decade by researchers and practitioners alike, making it imperative to understand how the supporting communication technology should be managed to ensure effective collaboration (Martinic et al., 2012). Moreover, the growing reliance on virtual collaboration for project management in a global and dynamic economy has underscored the urgent need to understand the technical and social challenges of virtual collaboration, especially in hi-tech projects with significant virtual components such as software development projects. These challenges of working at a distance include facilitating effective communication and mutual understanding among team members, establishing trust among team members, and managing the team, as well as broader issues of the work environment and work culture (Morrison-Smith and Ruiz, 2020).

It appears, therefore, that it may have been too early to claim that (physical) 'distance is dead' (Cairncross, 1997) with regard to team work. Physical distance is in space and time. Although inter-related, geographical and temporal distance should be treated as separate dimensions, each with its specific impact on work and behaviour (Cummings, 2011; Espinosa et al., 2011). Geographical distance indicates the amount of effort needed to collaborate face to face; temporal distance indicates the time displacement that must be overcome to interact with each other (Ågerfalk et al., 2005). Our focus in this paper is temporal distance. While geographic distance was argued to be more important in the mid-1990s, temporal distance has become the principal obstacle to efficient coordination (Carmel and Espinosa, 2011), particularly due to the reduced overlap in work hours that results in coordination delays (Morrison-Smith and Ruiz, 2020).

One key disadvantage to high temporal distance is the reduced number of overlapping work hours between collaboration sites (Battin et al., 2001; Kiel and Eng, 2003). Virtual teams working at a temporal distance, face the challenge of having less opportunities for synchronous time necessary for coordination (Espinosa et al., 2007), and in any event, the technology used to support virtual collaboration is central to the question of whether virtual collaboration results in better or lower performance. If indeed temporal distance still matters, the design and management of technology will play a crucial role in overcoming distance through virtual collaboration.

We investigate the impact of temporal distance in the particular context of virtual teams working on developmental projects in hi-tech industries, which have pervasively adopted the practice of virtual project teams. In these virtual project teams, team members cooperate remotely regardless of the temporal distance within teams, and collaborate using various computer-mediated communication (CMC) tools (Lukić and Vračar, 2018). Thus, our research question is, specifically, how the use of CMC tools overcomes the impact of temporal distance on the performance of the virtual project team.

Temporal distance can be caused by both time shifts in work patterns and differences in time zones (Sarker and Sahay, 2004). It is often measured only by the difference in time zones (Sosa et al., 2002), but, as we argue below, this measure should be adapted to reflect time-shifts in work patterns too. In fact, time-zone differences and time shifts in work patterns can be manipulated to either decrease or increase the effect of temporal distance (Ågerfalk et al., 2005). We wish therefore to examine the role of technology in overcoming temporal distance in light of new versions of technologies and the continuous demand for faster cycles and response (Carmel and Espinosa, 2011).

Temporal distance has been investigated at length (Cheng et al., 2016; Espinosa et al., 2007, 2015; Nan et al., 2009). While some results reveal the negative effect of temporal distance on outcomes (Espinosa et al., 2007, 2015; Nan et al., 2009), others argue the opposite (Massey et al., 2003; Maznevski and Chudoba, 2000). Our current study extends the methodology of these studies in two respects. Firstly, temporal distance in dispersed teams is typically caused by external constraints, such as time-zone differences (Espinosa and Carmel, 2004), but may also arise from factors such as work schedule shifts (Espinosa et al., 2015), holidays (Conchuir et al., 2006), and different workweeks among team members. In some cases, different workweeks may imply only three overlapping workdays a week, for example, when team members from Muslim countries such as Algeria and Kuwait work from Saturday to Wednesday, while their American colleagues work from Monday to Friday. We therefore consider non-overlapping workweeks as part of temporal distance.

Secondly, we study the effect of distance in the field with virtual teams in hi-tech projects. Virtual collaboration in practice is complex and subject to different norms of work regarding team composition and work out of the office (Chase, 1999). This complexity, due in part to the long duration of virtual collaboration in projects, is hard to duplicate in the laboratory experiments, where most previous studies have been conducted. Exceptions that engaged in field studies are Cummings et al. (2009), Espinosa et al. (2011) and Herbsleb and Mockus (2003). Furthermore, studying the practice of virtual teams allowed us to duplicate our study ten years later to examine the results in a new work context. Our two-stage field study based on questionnaires complemented with comments by practitioners may explain some of the conflicting results found in laboratory experiments.

Section 2 advances the theory and hypotheses and Section 3 gives the study design. Sections 4 and 5 present, respectively, the results of the quantitative and qualitative studies. Section 6 discusses the implications for design and management of virtual collaboration in projects.

## 2 Theory and hypotheses

Teams are usually established to accomplish a specific goal and their performance is measured in terms of achieving that goal (Chase, 1999; Lipnack and Stamps, 1997). Virtual collaboration can be seen as a means of overcoming the difficulties posed by working at a distance to achieve the team's goals, using appropriate communication technologies (Chase, 1999). As noted in the introduction, how effective virtual collaboration is in overcoming distance to achieve high team performance is still an open question (Allen et al., 2015). The answer to this question is a moving target that changes as the communication technologies progress and practices of teamwork transform.

We concentrate on both the progress in CMC technologies that is reflected in the capacity or richness of the media to communicate effectively and the changes in the practice of using CMC. The particular practices of using CMC technologies to enable effective collaboration may depend on the context in which people communicate, coordinate and collaborate. Our work is focused on virtual collaboration in development teams that work in projects of at least three months, which implies that team members are expected to communicate throughout the project in different forms (e.g., synchronous and asynchronous, verbal and graphic) and with different technologies (e.g., e-mail, video conference). We therefore conceptualise communication richness (CR) as an attribute of the project's team members' pattern of *using* various CMC technologies throughout the project. Our goal is to model the relationship between temporal distance and performance as it is mediated by CR. As our arguments build on the effect of temporal distance on the communication and coordination necessary for effective virtual collaboration, we chose to concentrate on how temporal distance impacts the quality of team decisions, which is the most relevant aspect of team performance. Each of these three variables, namely temporal distance, CR and project decision quality, is discussed and the relationships between them are formalised as the first two hypotheses formed below.

Temporal distance is commonly gauged in terms of time zones (Morrison-Smith and Ruiz, 2020). The difficulties in team collaboration related to temporal distance may, however, be a function not only of the magnitude of time-zone difference but also the differences in working patterns among team members located in different time zones (Saunders et al., 2004). The problems associated with the use of time zones as a proxy for distance have been overlooked too often (Nan et al., 2009), and they may be especially relevant when investigating the feasibility of synchronous or instant communication (Cheng et al., 2016; Olson and Olson, 2000). As elaborated below in the method section, we adjust the traditional measure of temporal distance to reflect additionally the percentage of overlapping working hours between team members. Henceforth, we refer to *adjusted temporal distance* (ATD) in order to emphasise the broader implications of temporal distance that are not captured by the difference in hours between time zones.

The mediating variable between temporal distance and the project team's decision quality is CR, which builds on the idea in media richness theory (MRT) that different media enable different levels of richness in the communication (Daft and Lengel, 1986). MRT classifies media along a continuum of richness (Kock, 2005), where richness is composed of various elements, including the ability of media to carry non-verbal cues, support synchronisation and provide rapid feedback (Montoya-Weiss et al., 2001). For example, face-to-face communication may support faster feedback and a richer set of signals than, say, e-mail. MRT postulates that richer communication is needed to overcome communication complexity by conveying and contextualising the requisite information more effectively, thus improving comprehension (Te'eni, 2001). Moreover, MRT claims that the contingent choice of one medium over the other will result in better performance in comparison with using the same medium for all situations (e.g., using video conferencing for both simple and complex communication). Past research has singled out media richness as a factor that captures the main differences between media in their capacity to affect communication effectiveness.

Building on the idea of alternative media to overcome distance, past research has attempted to assess the media richness of various CMC technologies by looking at certain attributes such as synchronicity and a variety of signs (including non-verbal), forms and languages (Clark and Brennan, 1991; Olson and Olson, 2000). Clearly, the media used for collaboration has changed considerably in the past two decades. Already ten years ago, advanced communication technologies such as virtual meetings and conference calls were labelled 'super-rich' media (DeRosa et al., 2004). Furthermore, not only are specific technologies with greater richness being used, but the portfolio of technologies from which to choose contingently has expanded and continues to expand as new technologies are often adopted upon release, particularly by the younger generation. The last couple of years have demonstrated how synchronous tools can be adopted almost instantly when needed, although their effectiveness is yet to be proven. The media richness of newer tools has been increasing, when considering their synchronicity, the variety of modes and formats they support (pictures and videos), and their capabilities to manage and fit the message to the recipient and situation.

CR is conceptualised at the level of the project team as the way the project team members use the various CMC technologies in the project, a practice that may vary from one team to another. In determining CR for particular projects, we regard it as an aggregation of the project team members' use of the communication technologies available in their portfolio, each technology with its own level of media richness and with its usage.

As noted, the mediating role of CR between ATD and performance rests on its capacity to mitigate the difficulties caused by working virtually from a distance. The CMC technology can provide two functions to overcome two types of difficulties: it can provide richer communication to overcome difficulties in *understanding* messages that arise from distant as opposed to proximal communication, and it can provide the means to overcome difficulties in *coordinating* distant communication. On the one hand, as ATD grows, understanding is compromised because of different contexts and fewer opportunities for immediate feedback to clarify the message (Te'eni, 2001). On the other hand, ATD imposes further coordination activities among team members to enable synchronous communication that is feasible for some distances but not others; for example, a nine-hour time difference may make it difficult to find a common time unless at least one party is willing to participate outside working hours.

The relationship between CR and ATD is a result of technology's capacity to overcome difficulties induced by ATD both in understanding and in coordinating communication, but the relationship is not linear. At very low levels of ATD or none at all as in virtual collaboration within the same country or region, we assume that team members choose the seemingly appropriate medium that is available for a particular situation, which is not necessarily the medium with the highest richness (Katz and Te'eni, 2008).

At somewhat higher ATD, of 1–3 time-zone differences or workweek differences, ATD induces a need for higher CR to ensure effective communication, as long as coordination is not prohibitively difficult. When ATD differences further increase, coordination becomes difficult. When time-zone differences approach nine hours, the time gap becomes a chasm, with no overlap of working hours (Carmel and Espinosa, 2011), and synchronous media become challenging due to members' availability constraints, often driving team members to choose lean media despite their natural inclination to choose richer media (Burke and Chidambaram, 1999; O'Leary and Cummings, 2007). Thus, for a given portfolio of available communication technologies, there may be two competing forces at work: increasing richness to improve mutual understanding and avoiding richness to reduce coordination costs. When ATD is sufficiently high to create substantial communication gaps and misunderstandings, CR will be selected even at a higher cost of coordination, but eventually decrease at high ATD levels that prevent synchronous communication. Nevertheless, at less substantial distances, the cost of coordination may outweigh the benefits of more effective communication, and rely on leaner media alternatives. Thus, we hypothesise a nonlinear relationship between ATD and CR.

It is not clear how the last two decades have affected this relationship. The new norms of work with longer hours along with advances in the ease of using rich media may shift the curvilinear relationship between CR and ATD but not necessarily affect its shape. We tested the possible shift by examining the following hypothesis in two different periods, namely, 2009 and 2019 (and did the same for the other two hypotheses).

H1 The relationship between adapted temporal distance (ATD) and CR is nonlinear.

Effective communication in projects is needed to understand problems in order to make good decisions (Coughlan and Macredie, 2002). Collaborative decision making requires that the communicators understand each other, and receive the information, and explanations if needed, in a timely manner, through appropriate media (Coughlan and Macredie, 2002; Nasir and Sahibuddin, 2011; Patrashkova-Volzdoska et al., 2003). In particular, adding context and explanations to messages when communication is complex, as expected in development projects, increases the chances of comprehension (Cramton, 2001; Hinds and Bailey, 2003; Majchrzak et al., 2000; Maznevski and Chudoba, 2000). According to MRT, CR is needed for such team communication in order to produce high quality decisions (Baker, 2002; Cummings, 2007). Additionally, higher CR decreases the feelings of loneliness and ambiguity associated with using media (Workman et al., 2003) by supporting more nuances and social communication, and affecting the quality of decisions (Baker, 2002). Notably, it is the CR enabled by the entire portfolio that matters (Laufer et al., 2008).

To examine the effect of CR in the context of projects, we focus on the perceived quality of decisions made by the project team. The quality of decisions as an outcome of a collaborative decision process is associated with a sound process, one that is based on logical arguments and systematic procedures and that improves key aspects of the decision (Skinner, 1999). Hence, the following hypothesis:

H2 Greater CR is associated with higher perceived decision quality.

Rich communication is most needed when teams engage in making difficult decisions that require deliberations and explanations that are less needed in structured, known and routine decisions. In other words, the tasks the team performs in the project make a difference in terms of the richness of the requisite communication. Task has been an important factor in the study of workgroups (McGrath, 1984), and of computer-supported group work, in particular (Zigurs and Buckland, 1998). Dennis et al. (2008) define task in terms of the communication that is needed to generate a shared understanding among the team members in the face of the ambiguity and uncertainty associated with the task. We concentrate here on the salient dimension of task, namely, *analysability*, which refers to team members' knowledge of the procedures needed for accomplishing the task (Daft and Lengel, 1984; Te'eni, 2001), defining it as the extent to which a task can be broken down into small, well-defined components (Ahuja and Carley, 1999; Rice, 1992).

Analysable tasks are those for which the team has predetermined and structured responses to potential problems and understands the outcomes, while in tasks with low analysability, responses are more personal, less structured, more *ad hoc* and improvisational (Daft and Weick, 1984). Furthermore, in tasks that are low on analysability, the information processed may be equivocal because precise coding schemes do not fit extant practices (Daft and Macintosh, 1981), and decisions are made on the basis of judgement, intuition, creativity, and rules of thumb (Simon, 1965).

A virtual-team's project is basically a collection of various tasks, such as setting project objectives, setting technical specifications and comparing competing concepts, each task with its unique characteristics (Majchrzak et al., 2000). We assume here that the project can similarly be characterised as consisting of predominantly high analysability or low analysability tasks (Jin and Levitt, 1996). We therefore refer to project analysability as the team members' perceived analysability of tasks in the project overall. According to MRT, low analysability calls for richer media (Daft and Lengel, 1984) and, furthermore, low analysability calls for greater contextualisation and explanation, which also requires richer media (Katz and Te'eni, 2008).

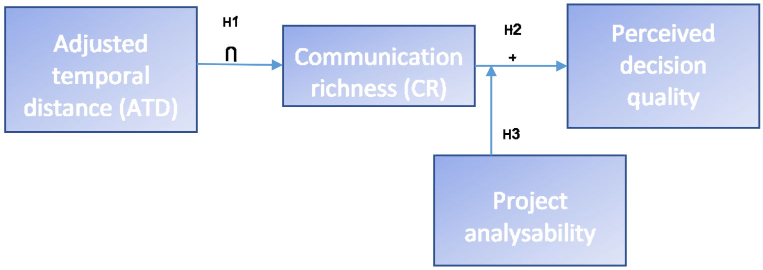
H3 The positive association between CR and perceived decision quality is greater for low project analysability.

To summarise our discussion so far, Table 1 lists the constructs used to build the three hypotheses and Figure 1 shows the relationships between them.

**Table 1** Constructs and corresponding measures

| *Constructs* | *Measures* |
|---|---|
| Adjusted temporal distance (ATD) | The team's overlapping working hours as a function of time-zone differences and different workweeks between team members |
| Communication richness (CR) | The team members' aggregated use of communication technologies, each technology with its attributed elements of richness and usage, targeted to convey and contextualise requisite information |
| Project analysability | The team members' knowledge needed for accomplishing tasks in the project |
| Perceived decision quality | The quality of the decision process leading to its decision outcome, characterised as a sound process based on logical arguments and systematic procedures, and improving key aspects of the decision |

**Figure 1** A model of ATD, CR, and perceived decision quality (see online version for colours)




## 3 Study design

To test our hypotheses, we used a field study, followed by qualitative study, administered in 2009 (stage I) and repeated in 2019 (stage II) (Roth and Te'eni, 2019). In both stages, we first collected data with a questionnaire and followed up with semi-structured interviews. Thus, our sequence of methods was quantitative, qualitative, quantitative and qualitative (Bazeley, 2011). The qualitative method was used to address unexpected and unexplained results in the preceding quantitative method.

Using our personal connections, we identified informants in global organisations that were willing to collaborate in obtaining access to project teams in their organisations. We sought virtual teams that consisted of three or more members working together for over four months. At least two of the team members worked remotely. The majority of the team projects were developmental projects in hi-tech companies. We supplied the informants with e-mail templates that contained links to web-based questionnaires, which they forwarded to the team members of one or more virtual teams in their own organisations.

The respondents were asked to complete the web questionnaire with the following information:

1 personal data and group characteristics that enabled us to compute the ATD

2 collaboration characteristics, including information about the virtual team member's habits in using the various communication technologies that enabled us to compute CR

3 perceived decision quality and project analysability (described below).

In stage I (2009), the e-mails were distributed by the local informants to 501 virtual team members of 62 virtual teams. Additionally, the informants were asked to provide information about each virtual team. To increase the response rate, respondents were offered financial incentives, as well as a report of the study's summarised results. One hundred and eighty-nine valid responses from 62 virtual teams were collected, representing a 38% response rate, which is considered acceptable (Eastin and LaRose, 2005; Mitchell and Nicholas, 2006). In stage II (2019), 178 valid responses from 55 virtual teams were received, representing a 34% response rate.

## *3.1 Measures*

To augment the temporal distance reflected by time-zone differences, ATD considers the reduction in overlapping working hours between team members by assessing the differences between workweeks. As in the computation of Euclidean distance, we compute for each pair of team members the absolute time-zone difference and then compute a weighted average of all the possible pairs in the team, where the weights are the differences in workweeks. Hence ATD is computed as the average of pairs of the absolute difference between *GMTi* and *GMTj* (the local times of team member *i* and of team member *j*, respectively) multiplied by the proportion of overlapping work days in a 5-day week for the pair of team members. The sum is over all pairs of the teams (O'Leary and Cummings, 2007; Monge and Kirste, 1980).

$$ATD = \frac{1}{(n-1)} \sum_{j=1}^{n} \left( WWij * \left| GMTi - GMTj \right| \right)$$

Hence, for a team of three, located in the UK with GMT 0, Germany with GMT 1 and Israel with GMT 2, the ATD for the German team member would be the average of the two pairs, Germany-UK with similar workweek and Germany-Israel with only four days a week overlap, Sunday → Thursday vs. Monday → Friday, and would be calculated as follows:

$$\frac{1*|1-0|+1.25*|1-2|}{2} = 1.125$$

- *Project analysability*, adopted from previous research (Ahuja and Carley, 1999; Daft and Macintosh, 1981), is measured with a 5-item questionnaire (see Appendix Table A1). It asks respondents to indicate the extent to which each of the 5 statements described their work in the virtual team, on a 5-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree, and 5 = strongly agree.
- *CR* is a weighted sum of the team members' use of all available communication tools, each tool with its richness. We build on previous work (Anandarajan et al., 2010; Bagley and Olson, 2016; Balaji and Chakrabarti, 2010; Olson and Olson, 2000) that grants points for each of the attributes associated with the communication tool; for example, telephone is characterised by four attributes, audibility, co-temporality, simultaneity and sequentiality, and thus, its richness score is 4. Newer communication technologies, such as, virtual meetings, bulletin boards and conference calls, were added according to the same scheme. Usage frequencies were measured with a 5-point Likert scale (Lee et al., 1999), where 1 = never, 2 = rarely, 3 = sometimes, 4 = often, and 5 = very often. The full list of communication tools is given in Figure 2.

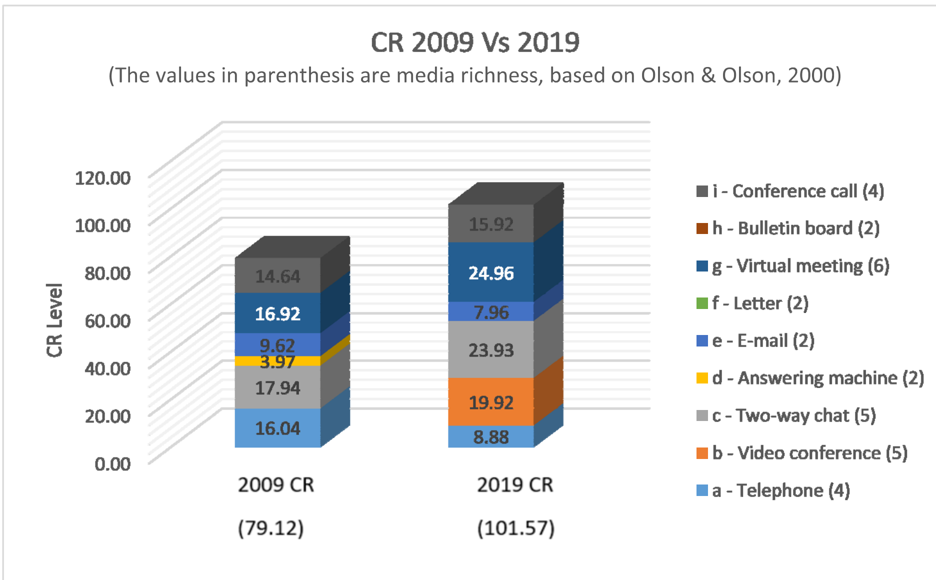
The accumulated CR of team member *i* was the sum of the products of the extent of usage of communication tool *j* and its richness, for all tools, *j* = 1...*n*. That is, the team member's CR was:

$$CR = \sum\nolimits_{j=1}^{n} \left( Medium's\ Richness_j * Usage_j \right)$$

Hence, for participant, *i* who very often used telephone, e-mail and two-way chat, sometimes used conference call, rarely used answering machine and never used virtual meeting, the cumulative CR would be: 5*4 + 5*5 + 5*2 + 3*4 + 2*2 + 1*6 = 77.

The measurement of a team member's *perceived decision quality* in the project is taken from previous work (Gouran et al., 1978; Huang et al., 2003; Pitt et al., 1994). The measure consisted of eight questions, using a 7-point Likert scale (the questionnaire appears in Appendix, Table A2).

**Figure 2** CR breakdown in 2009 versus 2019 (see online version for colours)




H1, H2 and H3 are tested using structural equation analysis (SEM) to examine the role of CR in mediating the relationships of ATD and ATD square with perceived decision quality. All analyses are conducted using AMOS, version 25 (SPSS Inc.) with the maximum likelihood estimation procedure.

The model fit is examined using five goodness of fit indices (Hoyle and Panter, 1995), namely two absolute indices – the $\chi^2$ statistic, and the root mean square error of approximation (RMSEA), and three incremental indices – the normed fit index (NFI), the comparative fit index (CFI) and the Tucker-Lewis index (TLI). The analysis is performed using multiple group analysis and includes data from the two studies, from 2009 and 2019. The model in each group includes an examination of the direct effect of ATD and its square on perceived decision quality as well as an examination of the mediating effect of CR between ATD and perceived decision quality while controlling for two covariates, team size and years of experience. In order to test the interaction effect of CR and project analysability on perceived decision quality (H3), the independent variables are centred, then CR, project analysability and the interaction between those variables are added to the model.

## 4 Quantitative analyses

This section presents the quantitative results from both stages and the next section presents the qualitative results. We integrate the quantitative and qualitative in the discussion section. In the 2009 stage, there were 62 teams, with an average team size of eight team members. The average overlap of a team member with the other team members was 69%. The sample consisted of 68% males and 32% females, the major mother tongues were Hebrew 33.7%, English 29.4% and Russian 7.5%, English level very good or native English speaker was 80.95%, major countries of residence were Israel (34.78%), USA (21.74%) and South Africa (16.85%), typical organisation types were software (56%), pharma (11%) and semiconductors (9%), major organisation sizes were 10,001+ (58%), 2,001–500 (13%), 51–200 (13%). The cumulative number of team members of these 62 teams was 502, and the 187 respondents represent 37% response rates, where in some cases the entire team cooperated with 9 team members out of nine answering, and in other cases, limited cooperation, recording one response from a team with six members.

In the 2019 stage, there were 55 teams, with an average team size of 9.4 team members. The average overlap of a team member with the other team members was 75%. The sample consisted of 61% males and 39% females, the major mother tongues were Hebrew 46.6%, English 15.7% and Russian 11.2%, English level very good or native English speaker was 82.60%, major countries of residence were Israel (50.0%), Ukraine (16.85%) and USA (7.3%), typical organisation types were SW (93%), consulting (5%) and communication (2%), major organisation sizes were 1,001-5000 (63%), 51-200 (21%), 201-500 (6%). The cumulative number of team members of these 55 teams was 502, and the 187 respondents represent a 34% response rate, where in some cases the entire team cooperated, with four team members out of four answering, and in other cases, cooperation was limited, with four responses from a team with 30 members.

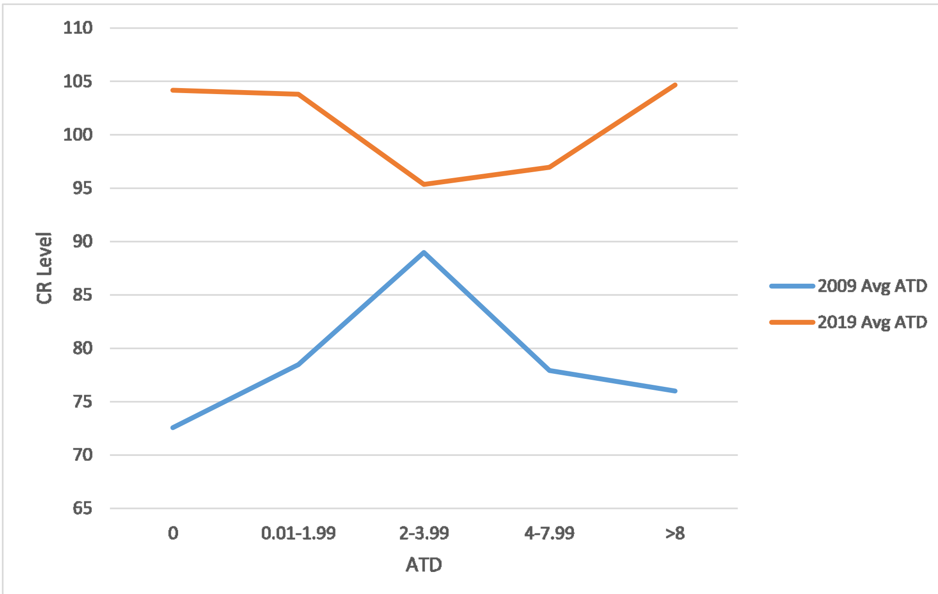
Table 2 summarises the descriptive statistics of the four variables in the study. Figure 2 depicts the cumulative media usage in 2009 and in 2019, showing the changes in CR. In particular, telephone usage was cut by half in 2019, while video conferencing, two-way chats and virtual meetings, which account for approximately 70% of the 2019 cumulative CR, increased significantly. Overall, the cumulative CR score in 2019 (101.57) increased by about 25% versus 2009 (79.12).

**Table 2** Descriptive statistics of model constructs for both stages

| *Constructs* | *ATD* | | *CR* | | *Project analysability* | | *Decision quality* | |
|---|---|---|---|---|---|---|---|---|
| | *2009* | *2019* | *2009* | *2019* | *2009* | *2019* | *2009* | *2019* |
| Mean | 2.96 | 2.03 | 79.11 | 101.57 | 3.80 | 3.74 | 5.32 | 5.58 |
| Std. dev. | 3.08 | 2.39 | 18.28 | 15.08 | 0.33 | 0.46 | 0.90 | 0.66 |
| Minimum | 0 | 0 | 37 | 57 | 2.75 | 2.53 | 1.00 | 4.00 |
| Maximum | 12.50 | 9.62 | 115 | 130 | 4.40 | 4.8 | 7.00 | 7.00 |

Figure 3 presents CR usage at different ATD levels across the two periods, in five different settings: the first represents identical GMTs and workweek, resulting in zero ATD, the second represents close GMTs of up to one hour, the third represents GMTs with two to three hour gaps, the fourth represents more substantial gaps, and the last setting includes cases with the highest GMT gaps. Apparently, 2019 is characterised by increased CR usage for all the ATD levels. While CR usage is lower in 2009 at the highest ATD level with minimum overlap, in 2019 the highest ATD level is characterised by an increase to the highest CR usage.

**Figure 3** Relationship between CR and ATD, plotted for both stages (see online version for colours)




Note: *The data presented in Figure 3 does not reflect the impact of the control variables

## 4.1 Structural model

An initial analysis showed that the interaction effect was not significant (2009 – beta = –.08, p>.05; 2019 – beta = .014, p > .05), which means project analysability does not moderate the relationship between CR and perceived decision quality. Based on Bentler and Mooijaart (1989), we arrived at the most parsimonious model by omitting the non-significant structural paths. Path coefficients were unconstrained, except for the coefficient of the relationship between CR and perceived decision quality. All fit indices of the final model, across the two groups, indicated an excellent fit of the model to the data: $\chi^2$ (5) = 2.09 ns; RMSEA = .00; NFI = .99; CFI = 1.0; TLI = 1.0. The relationship strength (standardised coefficient), t-values for each relationship and chi-square and its significance for each comparison across both groups (when that specific relationship is constrained) are presented in Table 3.

Table 4 summarises the hypotheses analyses. The effect of ATD on CR (H1): A linear ATD effect on CR was found in the two stages, (β = –2.51, p = .005) in 2009, and (β = .292, p = .008) in 2019, as well as a curvilinear effect of ATD on CR, (β = –.207, p = .020) in 2009, and (β = .265, p = .016) in 2019. The effect of CR on perceived decision quality (H2): A linear ATD effect of CR on decision quality was found as expected in the two stages, (β = .151, p = .037) in 2009, and (β = .172, p = .020) in 2019.

Finally, the results presented in Table 4 confirmed our hypothesis that CR partially or fully mediates the effect of ATD on perceived decision quality.

**Table 3** Two group difference test

| *Hypothesised relationships* | | | *Study1 (2009) Standardised estimates (t-values)* | *Study2 (2019) Standardised estimates (t-values)* | *Group differences* $\Delta\ \chi 2/1df$ |
|---|---|---|---|---|---|
| ATD | → | Perceived decision quality | –.19 (–2.09) | .10 (0.94) | 4.24* |
| ATD square | → | Perceived decision quality | –.14 (–1.53) | –.001 (–0.01) | 0.955 n.s. |
| ATD | → | CR | –.25 (–2.82) | .29 (2.66) | 14.69*** |
| ATD square | → | CR | –.21 (–2.33) | .26 (2.41) | 11.09** |
| CR | → | Perceived decision quality | .15 (2.09) | .17 (2.32) | 0.11 n.s. |

**Table 4** Summary of the hypotheses

| *Year* | | *Effect* | | | *B* | *β* | *S.E.* | *C.R.* | *P* |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | H1 | ATD | → | CR | –16.052 | –.251 | 5.685 | –2.824 | .005 |
| | H1 | ATD square | → | CR | –30.970 | –.207 | 13.276 | –2.333 | .020 |
| | H2 | CR | → | Decision quality | .007 | .151 | .004 | 2.090 | .037 |
| 2019 | H1 | ATD | → | CR | 16.299 | .292 | 6.123 | 2.662 | .008 |
| | H1 | ATD square | → | CR | 34.778 | .265 | 14.414 | 2.413 | .016 |
| | H2 | CR | → | Decision quality | .009 | .172 | .004 | 2.320 | .020 |

**Table 5** Test for mediation using a bootstrap analysis with a 95% confidence interval

| *Study 1 (2009)* | | | | | | |
|---|---|---|---|---|---|---|
| *Relationships* | *Direct effect* | *Indirect effect* | *Confidence interval* | | *P* | *Conclusion* |
| | | | *Low* | *High* | | |
| ATD → communication richness → perceived decision quality | –.188* | –.042 | –.09 | –.01 | <.01 | Partial mediation |
| ATD square → communication richness → perceived decision quality | –.137 | –.035 | –.08 | –.01 | <.01 | Full mediation |
| *Study 2 (2019)* | | | | | | |
| *Relationships* | *Direct effect* | *Indirect effect* | *Confidence interval* | | *P* | *Results* |
| | | | *Low* | *High* | | |
| ATD → CR → perceived decision quality | .104 | .045 | .014 | .107 | <.01 | Full mediation |
| ATD square → CR → perceived decision quality | –.001 | .041 | .011 | .103 | <.05 | Full mediation |

## 5 Qualitative analyses

We used qualitative research methods to complement the quantitative questionnaires of both the 2009 and the 2019 studies with insights from practitioners' views of working in virtual teams and using communication tools. This sequence allowed us to adapt the data collection and integrate the analyses (Bazeley, 2011). Here we report the qualitative results of both stages and the discussion section integrates them with the quantitative results.

Information was gathered from two different sources. One source was the textual comments made as part of the web questionnaire, and the other was a set of 20 semi-structured interviews, conducted with a sample of virtual team members and team leaders, and with content specialists who were familiar with virtual collaboration in the industry.

The interviewees were recruited through convenience and snowball sampling, beginning with one or more contacts within a given population and asking participants to nominate others (Goldenberg, 1992). The selection of interviewees was designed to get maximum feedback from various experts and organisational players in a variety of organisations in the public and private sectors, including software and hardware, semiconductor, pharmaceutical, and financial companies. A range of key informants were sought, including integration and verification managers, engineering architects, software engineers, HR managers, CEOs, and project managers. The duration of each interview was 60-90 minutes, and it was supported with a template which was specially designed for the purpose, so that each participant was asked the same set of questions. The interview began with general questions, and then turned to more specific questions about the model's variables, where the interviewees were asked to describe the role of these variables, for example, the role of communication in virtual teams. Afterwards, interviewees were asked to address the possible relations between the quantitative variables. Throughout the interviews, interviewees were encouraged to raise any issue which they perceived as having any effect on their virtual teams.

Content analysis (Berg, 1989) was used to code the interview transcripts and the web questionnaires' textual responses. The unit of analysis was at the statement or phrase level, and the categorising method adopted (Hambley et al., 2007) consisted of three levels. At the lowest level, the statement or phrase referred to a theme (e.g., strategic location of remote employee). When applicable, themes were grouped into sub-categories (e.g., team's diversity). The highest level of analysis was the category (e.g., diversity).

In stage I (2009), 15 of the 20 interviews were conducted face-to-face, while the other five were conducted using a virtual meeting tool. In all, 52 respondents' comments were gathered. In stage II (2019), an identical number of interviews took place and they followed the same semi-structured questions, with five of the 20 interviews being conducted face to face, while the other 15 were conducted using a virtual meeting tool.

A quantitative record was kept by tracking the number of participants who mentioned each theme as a basis for the content analysis, which generated factors that may affect the constructs of our research model. (The model's constructs and relationships are not represented in the list of themes and categories.) The content analysis yielded four major categories that affect virtual collaboration: CMC (technology), management, individual characteristics, and team diversity. CMC refers to characteristics of the technology that affected its use such as usability, training and external support. Management refers to managing the collaboration process, including setting up the team and the ongoing work and meetings, monitoring and conducting the team work, and attending to individual workers. Individual characteristics of team members that affected virtual collaboration included experience, capabilities, motivation, preferences and more. Diversity referred to all relevant aspects such as language, culture, experience, collaboration history and more. We noticed that diversity applied both to the diversity within the team and diversity in the organisation at large.

Using the repertory-grid technique, we formed a matrix of categories, sub-categories and themes that mapped the themes in the texts to the four conceptual categories (see Appendix Table A3). We then used the grid to examine the possible effects of the themes and categories on the model's constructs and relationships. We constructed a table of such effects, using arrows to indicate the direction of each of the themes. For example, we found that highly self-motivated team members, compared with less self-motivated members, experienced low project analysability and expressed a stronger association between CR and perceived decision quality.

We use the four categories that emerged from the textual comments and interviews, namely, CMC technology, management, individual characteristics, and team diversity, as a context for understanding the model depicted in Figure 1. While the categories do not relate directly to temporal distance, they can be used to understand effects on virtual collaboration that either contradicted the predicted impact of temporal distance on CR and decision quality, or were found to differ, *a posteriori,* from year 2009 to 2019. Our goal in this analysis of the context captured by the four categories is to provide new insights not articulated in the model.

In our model, CR is affected by ATD. The qualitative analysis indicates other factors that affect CR, providing a deeper understanding of how ATD affects richness. A point that came up frequently in the comments and interviews was the discretionary choice of media, which depends on feasibility, urgency and preference. Communication technology reflects the feasibility of using the media available in the portfolio, depending, for example, on the quality of the audio, the usability of the software, and the technical support. For instance, respondents in the 2009 stage complained that the audio communication was often disrupted, forcing them to communicate via leaner media, and remote employees located out of their office with limited bandwidth were sometimes driven to use leaner media despite their preference for richer media when dealing with low analysability, possibly reducing decision quality. Management, individual characteristics and team diversity also affected the team member's preference for a particular medium for a given conversation; for example, the combination of the technology's usability and the individual's experience with the technology was found to influence the choice of media. Moreover, insofar as urgent tasks benefit from synchronous and richer communication tools regardless of the nature of the task, it is the combination of feasibility, urgency and preference that dictates media choice. We return to this issue in the next section when we combine our quantitative results with the qualitative insights.

The choice of media was not always left to the individual but was often a group or management decision. In particular, we learned that management sometimes imposed certain media by demanding records of meetings (reviewability and auditability), even though the individual's preference was to avoid recordings. In addition, managerial capabilities to moderate discussions also affected the preference for certain communication tools. Similarly, diversity in the team raised certain difficulties that affected the feasibility of communication and its effect on decision quality. Different mother tongues and different accents prompted team members to use written communication to avoid the need to ask people to repeat vocal messages, despite the need for higher synchronicity for low analysability. On the other hand, usage of richer communication tools regardless of diversity challenges is unlikely to lead to improved decisions. These, too, are effects on virtual collaboration that are not included in our model but should be. In fact, we realise that the context in which we attempt to understand the impact of ATD on virtual collaboration not only affects the feasibility and preference in media choice, but the context itself may be affected directly by ATD. We found incidents in which temporal distance increases the plausibility of language differences, decreases the availability of certain communication technologies, and increases the likelihood of management intervention. The analysis suggests that the relationships between ATD and CR, and between CR and perceived decision quality, may be more complicated than specified in our model: there may be two separate effects of ATD, one direct and one via the context (the four categories).

## 6 Discussion

Project management in many organisations has come to rely on virtual collaboration. In the face of progress in the communication technologies available and changes in work practices, it is important to reexamine periodically the impact of virtual collaboration on team members' performance. Our attempt to model the effect of temporal distance on virtual collaboration focused on the curvilinear relationship between ATD and CR, based on two competing forces, namely the communication quality (understanding) and coordination costs. We now discuss this relationship in light of the integrated quantitative and qualitative analyses. We show that this relationship is more complicated than we initially thought. The subsequent relationship between CR and decision quality was hypothesised on the basis of previous research (Workman et al., 2003) and reconfirmed in both stages. The interaction effect of project analysability was not found to be statistically significant. The conclusion, nevertheless, of our quantitative analysis is that temporal distance still plays an important role in virtual collaboration and still makes a difference to the quality of team decision making. At the same time, the significant role of CR opens the possibility of using new communication technologies to manage virtual collaboration contingently, as we discuss below.

The curvilinear relationship between temporal distance and CR is depicted in Figure 3. In both stages, 2009 and 2019, there is a turning point on the graph in the middle ATD interval, which is consistent with our rationale of two interplaying forces. One force is the need for richer communication to overcome misunderstandings associated with temporal distance, which has been a cornerstone of the extensive research based on MRT (Daft and Lengel, 1984). The second force is the tendency to avoid the coordination costs of rich media, and as Jack Welch, former CEO of general electric, asserted, 'speed is everything'. Indeed, the new culture of work emphasises the importance of fast cycle and fast response (Carmel and Espinosa, 2011), though, research is inconclusive about the relationship between temporal distance and coordination costs (Morrison-Smith and Ruiz, 2020). Our qualitative analysis indicated that practitioners pay attention to the latter, sometimes at the expense of the former. In other words, when talking about discretionary choice of media, the explicit reasons the practitioners gave referred to coordinating, monitoring, reviewing and reusing conversations. The need for richer media to improve understanding was rarely mentioned in the responses we collected.

Previous work reported a positive impact of virtual collaboration on performance, suggesting that effective virtual collaboration helped to avoid misunderstandings and conflicts (Tan et al., 2019). Our work reconfirms this effect of virtual project teams on decision quality, but, based on respondents' interviews, questions the importance of mutual understanding in comparison to that of coordination costs in determining how teams use CMC tools.

We can offer two explanations for why respondents neglected the theoretical argument for improving mutual understanding among team member by engaging in richer communication. One explanation is that people attend to the pragmatic rather than the abstract (Vallacher and Wegner, 1987); they not only consider the complexity or ambiguity of communication when selecting the media but also concentrate on the more pragmatic issue of coordinating the communication. This argument aligns with the criticism of MRT that it fails to consider contextual environment and considers technology as the primary explanatory variable. It is possible that team members consider the value of rich media in specific cases that require a special feature, such as sharing a screen during a team meeting, in which case they focus on the screen-sharing functionality rather than the more abstract need to promote mutual understanding. A second explanation is that, in comparison with earlier days of communication, the current context of virtual collaboration magnifies the challenges of coordination and diminishes the need to ensure mutual understanding. In our qualitative analysis, we re-categorised the context as four contextual factors: communication technology, management, individual characteristics and team diversity. These four contextual factors were seen to affect primarily the need to coordinate and manage the process of virtual collaboration, while mutual understanding may have been taken for granted.

The changing context of virtual collaboration critically affects project management, which has come to rely on information technology, to employ global and diverse project teams, and to require contingent and adaptive management (Martinic et al., 2012). The changes made between 2009 and 2019 in all four contextual factors are remarkable. Most clearly, the technology has changed substantially, with new functionalities that are broadband internet and smartphone based, pervasive, and often enhanced by AI. These technological advances that allow new forms of team work bring about new challenges, such as issues of security and privacy that require management interventions. In one of the large gaming companies in our sample, management left little discretion to employees in selecting media. This is only one instance of tighter control on virtual collaboration that managements exercise nowadays. Nevertheless, and in opposition to management interventions, individual team members, especially in hi-tech companies, strive towards individualistic work with maximum freedom and discretion. Coupled with the ever-growing erosion of the traditional work-home boundaries, individuals choose, contingently and at their own discretion, the media with which they communicate and when they do so. The growing diversity within teams also intensifies both the need to ensure mutual understanding within the group and the need to coordinate the collaboration. Given individuals' possible insensitivity to the need for ensuring mutual understanding, management may need to regulate and guide the use of richer communication. In terms of Figure 3, management may need to intervene so as to erase the dip in CR displayed in 2019.

Thus, the changing context of virtual collaboration is not merely *technological* but *social* too (Morrison-Smith and Ruiz, 2020), and it translates into the different expectations and the different norms of collaboration we find in 2019 that we did not see in 2009. While it has been reported that in emerging or developing countries, norms of working from home, scattertime and nomadism weren't popular (Carmel and Espinosa, 2011), the expectations for speed (Carmel et al., 2009) and the enhanced IT infrastructure solutions may explain the increase in CR found in the later stage. The changes in the context of virtual collaboration on both dimensions, technological and social, affect the relationship between temporal distance and CR and will have implications for the development and management of communication technologies in future project management.

Our formalisation of ATD exemplifies the need to consider the technological and social changes in the context of virtual collaboration in projects. Time-zone distances have not changed, but the overlapping working hours between team members have changed dramatically. The new norms of work, especially in hi-tech industries, that have developed in the past two decades, including longer hours, out of the office work and flexible hour programs, namely time-shifting (Carmel and Espinosa, 2011), have increased the potentially overlapping hours between team members. Therefore, our proposed ATD may need to be adjusted further to accommodate the new norms of work, which would have to be examined empirically. Going back to Figure 3, such an adjustment would shift the line graph so that the dip in CR in 2019 would be smaller, while the overall shape of the graph would remain the same. The two dimensions, technological and social, have implications for the design and management of virtual collaboration.

This paper discusses the perceived changes between the two stages, though interviews also imply that certain communication issues did not change. One issue that was raised in the two stages was the importance of usage of a diversity of communication tools, according to the task's characteristics and its urgency.

The expectation to speed up outcomes may explain why employees accept adopting more flexible working hours, working outside their workweeks, working outside their company premises, often continuing work from their homes, and emphasises the importance of well predefined procedures, in an attempt to efficiently overcome misunderstanding and delays. Diversity may be the source for that, and was repeatedly mentioned by interviewees in the context of decision-making processes, management practices, usage of different communication tools, holidays, experience, type of tasks. In more routine tasks, the team's distribution easily enabled extension of the workweek to six days, while in other tasks, a limited overlapping workweek together with significant ATD had the opposite effect.

Another salient issue was that despite the importance of speed and the acknowledged practice of follow-the-sun work (Carmel and Espinosa, 2011), the interviewees from the two stages did not report adopting this practice. Only limited use of the practice of round-the-clock work was reported, and it focused solely on support activities. This phenomenon implies that despite the importance of speed, the coordination challenge is still unsolved, and although communication is an important ingredient, it is not the only ingredient of the virtual teams' recipe, and future work exploring CR in conjunction with concepts such as managerial practices and diversity dimensions is needed.

## 6.1 Implications and limitations

The implications of our findings for the management of virtual collaboration and the design and choice of the technologies employed for virtual team work are limited to virtual collaboration in hi-tech (mainly software) development projects, which is the sample we investigated. The ineffective use of virtual meetings in schools during the pandemic underscores the need to study virtual collaboration in different contexts. Moreover, we selected teams that had at least one remote team member, and usually more, which made it necessary to engage in virtual collaboration. The choices of technologies may be different when face-to-face meetings are a feasible option. Another methodological limitation is the elicitation of participants' considerations in using communication. The revealed preferences of team members were deduced from an analysis of free-form interviews and comments. A more invasive technique or a controlled manipulation may be needed to learn and measure the role of mutual understanding versus coordination by forcing the participants to explicate their ability to recognise when mutual understanding may be a threat to project success and their willingness to pay the price to improve communication.

Previous work (O'Leary and Cummings, 2007) attempted to offer formulae for the calculation of dispersion indices, including a time zone index. This paper moves one step further, and ATD is enhanced with a workweeks overlap dimension. A more profound construct that will capture additional differences such as holidays and hidden holidays (Carmel and Espinosa, 2011) may provide a more accurate perception of the ATD effect. The interaction effect of project analysability was not found to be statistically significant, perhaps because project analysability in software development projects is generally low so that differences in the effect of richness on decision quality are not significant, or, perhaps because of the nature of projects, which include multiple tasks of varying analysability.

The potential tradeoff between improving team members' mutual understanding and increasing the efficiency of coordination implies that the technology must ensure an effective balance between them, in addition to supporting each separately. As we noted, the dramatic technological and social changes in communication seem to have created a bias in practice towards coordination so that teams may not select richer media even if it is needed. By management guidance or by technological design, the selection of media to ensure mutual understanding must be encouraged and maintained. The functionality of most virtual meeting software is substantially richer than that of previous generations of communication technologies, including synchronous meetings with high quality audio-visual and sharing capabilities. Moreover, these presentation capabilities can be linked to knowledge repositories to support more effective knowledge sharing needed for collaboration. Today product lifecycle management (PLM) systems, for example, integrate product design knowledge with coordination systems based on a single logical database (Merminod and Rowe, 2012). We believe that future communication technologies will help identify high communication complexity to prompt users to use richer media when task analysability is low (Katz and Te'eni, 2008). Several software companies already analyse discussions and provide automated feedback and could leverage their capabilities to indicate how to improve communication in real time. Furthermore, communication complexity is also a function of emotional tensions that may also require rich media (Te'eni, 2001). In parallel to the technological aspects of improving communication, management will need to engage in guidance and training to encourage rich communication when communication complexity is expected. Contingent management of virtual collaboration is key to successful and innovative projects (Chamakiotis et al., 2020).

A further implication is the need to provide communication technologies that integrate the functionality geared toward mutual understanding when sharing knowledge with the functionality that helps coordinate meetings. Tools for setting a meeting time, inviting participants to the meeting and managing the session, linked to the effective selection of the technologies to share and present materials, should be available to the user through one unified interface that ultimately ensures effective team decision making and project management. Moreover, intelligent systems can ensure effective configurations according to temporal distance, and bearing in mind the context of virtual collaboration, for example, the diversity of the team, could tailor the configuration of tools to consider language differences. Communication technologies should help manage the process and quality of virtual collaboration.

In conclusion, we have argued that temporal distance still makes a difference in the form and quality of virtual collaboration, as seen in the case of development projects in the hi-tech industry. Our study calls for project managers to manage virtual collaboration in order to ensure quality decision making. The context of virtual collaboration has changed substantially in recent decades, and the requirements of flexible communication technologies and of management practices have changed accordingly.

## References

Ågerfalk, P., Fitzgerald, B., Olsson, H., Lings, B., Lundell, B. and Conchúir, E.Ó. (2005) 'A framework for considering opportunities and threats in distributed software development', *Proceedings of the International Workshop on Distributed Software Development*, Paris, 29 August, Austrian Computer Society.

Ahuja, M.K. and Carley, K.M. (1999) 'Network structure in virtual organizations', *Organization Science*, Vol. 10, No. 6, pp.741–757.

Allen, T., Golden, D.T. and Shockley, K. (2015) 'How effective is telecommuting? Assessing the status of our scientific findings', *Psychological Science in the Public Interest*, Vol. 16, No. 2, pp.40–68.

Anandarajan, M., Zaman, M., Dai, Q. and Arinze, B. (2010) 'Generation Y adoption of instant messaging: An examination of the impact of social usefulness and media richness on use richness', *IEEE Transactions on Professional Communication*, Vol. 53, No. 2, pp.132–143.

Bagley, C. and Olsen, J. (2016) 'Implications of media richness and ICT's on online course design/implementation in higher education', *Proceedings of E-Learn: World Conference on E-Learning*, Association for the Advancement of Computing in Education (AACE), Washington, DC, USA, pp.311–319.

Baker, G. (2002) 'The effects of synchronous collaborative technologies on decision making: a study of virtual teams', *Information Resources Management Journal*, Vol. 15, No. 4, pp.79–93.

Balaji, M.S. and Chakrabarti, D. (2010) 'Student interactions in online discussion forum: empirical research from 'media richness theory' perspective', *Journal of Interactive Online Learning*, Vol. 9, No. 1, pp.1–22.

Battin, R.D., Crocker, R., Kreidler, J. and Subramanian, K. (2001) 'Leveraging resources in global software development', *IEEE Software*, Vol. 18, No. 2, pp.70–77, doi: 10.1109/52.914750.

Bazeley, P. (2011) 'Integrative analysis strategies for mixed data sources', *American Behavioral Scientist*, Vol. 56, No. 6, pp.814–828, doi: 10.1177/0002764211426330.

Bentler, P.M. and Mooijaart, A. (1989) 'Choice of structural model via parsimony: a rationale based on precision', *Psychological Bulletin*, Vol. 106, No. 2, pp.315–317, doi: 10.1037/0033-2909.106.2.315.

Berg, B.L. (1989) *Qualitative Research Methods for the Social Sciences*, Allyn and Bacon, Boston, MA.

Burke, K. and Chidambaram, L. (1999) 'How much bandwidth is enough? A longitudinal examination of media characteristics and group outcomes', *MIS Quarterly*, Vol. 23, No. 4, pp.557–579, doi: 10.2307/249489.

Cairncross, F. (1997) *The Death of Distance: How the Communications Revolution will Change Our Lives*, Harvard Business School Press, Boston, MA.

Carmel, E. and Espinosa, J.A. (2011) *I'm Working while They're Sleeping: Time Zone Separation Challenges and Solutions*, Nedder Stream Press, USA.

Carmel, E., Espinosa, J.A. and Dubinsky, Y. (2009) 'Follow the sun workflow in global software development: theory, modeling and quasi-experiment to explore its feasibility', paper presented at the *Third Global Sourcing Workshop: The Impacts of Global IS Sourcing on Engineering, Technology and Innovation Management*, Key-stone, CO, USA.

Chamakiotis, P., Boukis, A., Panteli, N. and Papadopoulos, T. (2020) 'The role of temporal coordination for the fuzzy front-end of innovation in virtual teams', *International Journal of Information Management*, Vol. 50, pp.182–190, doi: https://doi.org/10.1016/j.ijinfomgt .2019.04.015.

Chase, N. (1999) 'Learning to lead a virtual team', *Quality*, Vol. 38, No. 9, p.76.

Cheng, X., Fu, S. and Druckenmiller, D. (2016) 'Trust development in globally distributed collaboration: a case of U.S. and Chinese mixed teams', *Journal of Management Information Systems*, Vol. 33, No. 4, pp.978–1007, doi: 10.1080/07421222.2016.1267521.

Clark, H.H. and Brennan, S.E. (1991) 'Grounding in communication', in Resnick, J.M.L.L.B. and Teasley, S.D. (Eds.): *Perspectives on Socially Shared Cognition*, pp.127–149, American Psychological Association, Washington, DC.

Conchuir, E.O., Holmstrom, H., Agerfalk, P.J. and Fitzgerald, B. (2006) 'Exploring the assumed benefits of global software development', paper presented at the *2006 IEEE International Conference on Global Software Engineering (ICGSE'06)*, 16–19 October.

Coughlan, J. and Macredie, R.D. (2002) 'Effective communication in requirements elicitation: a comparison of methodologies', *Requirements Engineering*, Vol. 7, No. 2, pp.47–60, doi: 10.1007/s007660200004.

Cramton, C.D. (2001) 'The mutual knowledge problem and its consequences for dispersed collaboration', *Organization Science*, Vol. 12, No. 3, pp.346–371.

Cummings, J.N. (2007) 'Leading groups from a distance: How to mitigate consequences of geographic dispersion', in Weisband, S.P. (Ed.): *Leadership at a Distance*, Lawrence Erlbaum Publishers, Inc., Mahwah, NJ.

Cummings, J.N. (2011) 'Geography is alive and well in virtual teams', *Commun. ACM*, Vol. 54, No. 8, pp.24–26, doi: 10.1145/1978542.1978551.

Cummings, J.N., Espinosa, J.A. and Pickering, C. (2009) 'Crossing spatial and temporal boundaries in globally distributed projects: a relational model of coordination delay', *Information Systems Research*, Vol. 20, No. 3, pp.420–439, doi: 10.1287/isre.1090.0239.

Daft, R.L. and Lengel, R. (1986) 'Organizational information requirements, media richness and structural design', *Management Science*, Vol. 32, No. 5, pp.554–571.

Daft, R.L. and Lengel, R.H. (1984) 'Information richness: a new approach to managerial behavior and organization design', in Staw, B.M. and Cummings, L.L. (Eds.): *Research in Organizational Behavior*, JAI Press, Homewood, IL.

Daft, R.L. and Macintosh, N.B. (1981) 'A tentative exploration into the amount and equivocality of information processing in organizational work units', *Administrative Science Quarterly*, Vol. 26, No. 2, pp.207–224.

Daft, R.L. and Weick, K.E. (1984) 'Toward a model of organizations as interpretation systems', *The Academy of Management Review*, Vol. 9, No. 2, pp.284–295, doi: 10.2307/258441.

Dennis, A.R., Fuller, R.M. and Valacich, J.S. (2008) 'Media, tasks, and communication processes: a theory of media synchronicity', *MIS Quarterly*, Vol. 32, No. 3, pp.575–600.

DeRosa, D.M., Hantula, D.A., Kock, N. and D'Arcy, J. (2004) 'Trust and leadership in virtual teamwork: a media naturalness perspective', *Human Resource Management*, Vol. 43, Nos. 2–3, pp.219–232.

Eastin, M.S. and LaRose, R. (2005) 'Alt.support: modeling social support online', *Computers in Human Behavior*, Vol. 21, No. 6, pp.977–992.

Espinosa, J.A. and Carmel, E. (2004) 'The effect of time separation on coordination costs in global software teams: a dyad model', paper presented at the *37th Annual Hawaii International Conference on System Sciences (HICSS'04)*, Track 1 – Volume 1.

Espinosa, J.A., Cummings, J.N. and Pickering, C. (2011) 'Time separation, coordination, and performance in technical teams', *IEEE Transactions on Engineering Management*, Vol. 59, No. 1, pp.91–103.

Espinosa, J.A., Nan, N. and Carmel, E. (2007) 'Do gradations of time zone separation make a difference in performance? A first laboratory study', paper presented at the *International Conference on Global Software Engineering (ICGSE 2007)*, Munich, Germany, 27–30 August.

Espinosa, J.A., Nan, N. and Carmel, E. (2015) 'Temporal distance, communication patterns, and task performance in teams', *Journal of Management Information Systems*, Vol. 32, No. 1, pp.151–191, doi: 10.1080/07421222.2015.1029390.

Garro-Abarca, V., Palos-Sanchez, P. and Aguayo-Camacho, M. (2021) 'Virtual teams in times of pandemic: Factors that influence performance', *Frontiers in Psychology*, Vol. 12, p.624637.

Goldenberg, S. (1992) *Thinking Methodologically*, 2nd ed., HarperCollins, New York, NY.

Gouran, D.S., Brown, C. and Henry, D.R. (1978) 'Behavioral correlates of perceptions of quality in decision-making discussions', *Communication Monographs*, Vol. 45, No. 1, pp.51–63.

Hambley, L.A., O'Neill, T.A. and Kline, T.J.B. (2007) 'Virtual team leadership: perspectives from the field', *International Journal of E-Collaboration*, Vol. 3, No. 1, pp.40–64.

Herbsleb, J.D. and Mockus, A. (2003) 'An empirical study of speed and communication in globally distributed software development', *IEEE Transactions on Software Engineering*, Vol. 29, No. 6, pp.481–494.

Hinds, P.J. and Bailey, D.E. (2003) 'Out of sight, out of sync: understanding conflict in distributed teams', *Organization Science*, Vol. 14, No. 6, pp.615–632, doi: http://dx.doi.org/10.1287/orsc.14.6.615.24872.

Hoyle, R. and Panter, A. (1995) *Writing about Structural Equation Models. Structural Equation Modeling: Concepts, Issues, and Applications*, pp.158–176, Sage, Thousand Oaks, CA.

Huang, W.W., Wei, K-K., Watson, R.T. and Tan, B.C.Y. (2003) 'Supporting virtual team-building with a GSS: an empirical investigation', *Decision Support Systems*, Vol. 34, No. 4, pp.359–367.

Jin, Y. and Levitt, R. (1996) 'The virtual design team: a computational model of project organizations', *Computational and Mathematical Organization Theory*, Vol. 2, pp.171–195, doi: 10.1007/BF00127273.

Katz, A. and Te'eni, D. (2008) 'The contingent impact of contextualization on computer-mediated collaboration', *Organization Science*, Vol. 18, No. 2, pp.261–279, doi: 10.1287/orsc.1060.0237.

Kiel, L. and Eng, P. (2003) 'Experiences in distributed development: a case study', paper presented at the *GSD'03 The International Workshop on Global Software Development*.

Kock, N. (2005) 'Media richness or media naturalness? The evolution of our biological communication apparatus and its influence on our behavior toward E-communication tools', *Professional Communication, IEEE Transactions on*, Vol. 48, No. 2, pp.117–130.

Laufer, A., Shapira, A. and Telem, D. (2008) 'Communicating in dynamic conditions: how do on-site construction project managers do it?', *Journal of Management in Engineering*, Vol. 24, No. 2, pp.75–86, doi: doi:10.1061/(ASCE)0742-597X(2008)24:2(75).

Lee, H., Mayer, B., Yang, J., Chen, K-L. and Lee, C. (1999) 'College students' perception of electronic commerce and internet purchasing', *Allied Academies International Conference. Academy of Information and Management Sciences, Proceedings*, Vol. 3, No. 1, p.46.

Lipnack, J. and Stamps, J. (1997) *Virtual Teams: Reaching Across Space, Time, and Organizations with Technology*, John Wiley & Sons, Inc., New York.

Lukić, J. and Vračar, M. (2018) 'Building and nurturing trust among members in virtual project teams', *Strategic Management*, Vol. 23, pp.10–16, doi: 10.5937/StraMan1803010L.

Majchrzak, A., Rice, R.E., King, N., Malhotra, A. and Ba, S. (2000) 'Computer-mediated inter-organizational knowledge-sharing: Insights from a virtual team innovating using a collaborative tool', *Information Resources Management Journal*, Vol. 13, No. 1, pp.44–53.

Martinic, A., Fertalj, K. and Kalpic, D. (2012) 'Methodological framework for virtual team project management', *International Journal of Innovation, Management and Technology*, Vol. 3, pp.702–707, doi: DOI:10.7763/IJIMT.2012.V3.323.

Massey, A.P., Weiss, M.M.M. and Hung, Y-T. (2003) 'Because time matters: temporal coordination in global virtual project teams', *Journal of Management Information Systems*, Vol. 19, No. 4, pp.129–155.

Maznevski, M.L. and Chudoba, K.M. (2000) 'Bridging space over time: Global virtual team dynamics and effectiveness', *Organization Science*, Vol. 11, No. 5, pp.473–492.

McGrath, J.E. (1984) *Groups: Interaction and Performance*, Prentice-Hall, Englewood Cliffs, NJ.

Merminod, V. and Rowe, F. (2012) 'How does PLM technology support knowledge transfer and translation in new product development? Transparency and boundary spanners in an international context', *Information and Organization*, Vol. 22, No. 4, pp.295–322, doi: https://doi.org/10.1016/j.infoandorg.2012.07.002.

Mitchell, R. and Nicholas, S. (2006) 'Knowledge creation in groups: the value of cognitive diversity, transactive memory and open-mindedness norms', *Electronic Journal of Knowledge Management*, Vol. 4, No. 1, pp.67–74.

Monge, P.R. and Kirste, K.K. (1980) 'Measuring proximity in human organizations', *Social Psychology Quarterly*, Vol. 43, No. 1, pp.110–115.

Montoya-Weiss, M.M., Massey, A.P. and Song, M. (2001) 'Getting it together: temporal coordination and conflict management in global virtual teams', *Academy of Management Journal*, Vol. 44, No. 6, pp.1251–1262.

Morrison-Smith, S. and Ruiz, J. (2020) 'Challenges and barriers in virtual teams: a literature review', *SN Applied Sciences*, Vol. 2, doi: 10.1007/s42452-020-2801-5.

Nan, N., Espinosa, J.A. and Carmel, E. (2009) 'Communication and performance across time zones: a laboratory experiment', paper presented at the *ICIS 2009*, Phoenix, Arizona.

Nasir, M.H.N.M. and Sahibuddin, S. (2011) 'Addressing a critical success factor for software projects: A multi-round delphi study of TSP', *International Journal of Physical Sciences*, Vol. 6, No. 5, pp.1213–1232.

O'Leary, M.B. and Cummings, J.N. (2007) 'The spatial, temporal, and configurational characteristics of geographic dispersion in teams', *MIS Quarterly*, Vol. 31, No. 3, pp.433–452.

Olson, G. and Olson, J. (2000) 'Distance matters', *Human-Computer Interaction*, Vol. 15, Nos. 2/3, p.139.

Patrashkova-Volzdoska, R., McComb, S., Green, S. and Compton, W. (2003) 'Examining a curvilinear relationship between communication frequency and team performance in cross-functional project teams', *Engineering Management, IEEE Transactions on*, Vol. 50, pp.262–269, doi: 10.1109/TEM.2003.817298.

Pitt, L.F., Tynan, C.A. and Nel, D. (1994) 'Discourse and deed: perceptions of discussion quality and group performance in marketing decision making', *Journal of Managerial Psychology*, Vol. 9, No. 5, pp.28–36.

Rice, R.E. (1992) 'Task analyzability, use of new media, and effectiveness: a multi-site exploration of media richness', *Organization Science*, Vol. 3, No. 4, pp.475–500, doi: 10.1287 /orsc.3.4.475.

Roth, I. and Te'eni, D. (2019) 'Do time zone differences affect the performance of a virtual team?', paper presented at *The 13th annual ILAIS*, Tel Aviv.

Sarker, S. and Sahay, S. (2004) 'Implications of space and time for distributed work: an interpretive study of US-Norwegian systems development teams', *European Journal of Information Systems*, Vol. 13, No. 1, pp.3–20.

Saunders, C.S., Slyke, C.V. and Vogel, D. (2004) 'My time or yours? Managing time visions in global virtual teams', *The Academy of Management Executive*, Vol. 18, No. 1, pp.19–31.

Simon, H.A. (1965) *The Shape of Automation for Men and Management*, Vol. 13, New York:

Skinner, D.C. (1999) *Introduction to Decision Analysis: A Practitioner's Guide to Improving Decision Quality*, 2nd ed., Gainesville, FL: Probabilistic.

Sosa, M.E., Eppinger, S.D., Pich, M., McKendrick, D.G. and Stout, S.K. (2002) 'Factors that influence technical communication in distributed product development: an empirical study in the telecommunications industry', *IEEE Transactions on Engineering Management*, Vol. 49, No. 1, pp.45–58.

Suh, A., Shin, K-S., Manj, A. and Kim, M.S. (2011) 'The influence of virtuality on social networks within and across work groups: a multilevel approach', *Journal of Management Information Systems*, Vol. 28, No. 1, pp.351–386, doi: 10.2753/MIS0742-1222280111.

Tan, C.K., Ramayah, T., Teoh, A.P. and Cheah, J.H. (2019) 'Factors influencing virtual team performance in Malaysia', *Kybernetes*, Vol. 48, No. 9, pp.2065–2092, https://doi.org/10.1108 /K-01-2018-0031.

Te'eni, D. (2001) 'Review: a cognitive-affective model of organizational communication for designing IT', *MIS Quarterly*, Vol. 25, No. 2, pp.251–312.

Vallacher, R.R. and Wegner, M.D. (1987) 'What do people think they're doing? Action identification and human behavior', *Psychological Review*, Vol. 94, No. 1, pp.3–15.

Workman, M., Kahnweiler, W. and Bommer, W. (2003) 'The effects of cognitive style and media richness on commitment to telework and virtual teams', *Journal of Vocational Behavior*, Vol. 63, No. 2, pp.199–219.

Zigurs, I. and Buckland, B.K. (1998) 'A theory of task/technology fit and group support systems effectiveness', *MIS Quarterly*, Vol. 22, No. 3, pp.313–334.

## Appendix

**Table A1** Task analyzability

| | |
|---|---|
| 1 | Normal work activities guided by standard procedures, directives, rules, etc. |
| 2 | Know a lot of procedures and standard practices to do the work well |
| 3 | Understandable sequence of steps that can be followed in carrying out the work |
| 4 | People actually rely on established procedures and practices |
| 5 | Established materials (manuals, standards, directives, statutes, technical and professional books, and the like) cover the work |

*Source:* Ahuja and Carley (1999) and Daft and Macintosh (1981)

**Table A2** Perceived decision quality

| | |
|---|---|
| 1 | The overall quality of the discussions was: (1) poor to (7) good |
| 2 | The discussions, on the whole, were: (1) ineffective to (7) effective |
| 3 | The outcomes of the discussions were: (1) unsatisfactory to (7) satisfactory |
| 4 | The discussions were: (1) incompletely executed to (7) completely executed |
| 5 | The issues explored in the discussions were: (1) trivial to (7) substantial |
| 6 | The content of the discussions were: (1) carelessly developed to (7) carefully developed |
| 7 | The manner in which participants examined issues was: (1) non-constructive to (7) constructive |
| 8 | The team's progress toward reaching conclusions on discussions was: (1) insignificant to (7) significant |

*Source:* Gouran et al. (1978)

**Table A3** Category-theme grid of content analysis

| *Category* | | *Management* | | | *CMC* | | *Individual* | *Diversity* | |
|---|---|---|---|---|---|---|---|---|---|
| # | *theme* | *Initial setting* | *Indiv.* | *Team* | *Internal* | *External* | | *Team diversity* | *Organisation diversity* |
| 1 | Asymmetric dispersion | | | | | | | X √ | |
| 2 | Self-motivated | | | | | | X √ | | |
| 3 | Professionalism | | | | | | X √ | | |
| 4 | Subordination difficulties | | | | | | | X √ | |
| 5 | Cultural differences | | | | | | | X √ | |
| 6 | Prior experience with team members | | | | | | | X √ | |
| 7 | Strategic location of remote employees | | | | | | | X √ | |
| 8 | Different employment condition | | | | | | | | X √ |
| 9 | Job security | | | | | | | | X √ |
| 10 | Organisational culture differences | | | | | | | | X √ |
| 11 | Autonomously work level (required) | | | | | | | X √ | |
| 12 | Media choice according to peers' preferences | | | | | | X √ | | |
| 13 | Technological problems | | | | | X √ | | | |
| 14 | Guidelines re communication use | | | | | X √ | | | |
| 15 | Communication constraint (customer's site) | | | | | X √ | | | |
| 16 | Communication moderation quality | | | | X √ | | | | |
| 17 | Employee's communication preferences | | | | X √ | | | | |
| 18 | Signal urgency/immediacy | | | | | | X √ | | |
| 19 | Monitoring | | | X √ | | | | | |
| 20 | Conflicts/tight schedule | | | | | X √ | | | |
| 21 | Setting long-term goals | X √ | | | | | | | |
| 22 | Procedures' completeness | X √ | | | | | | | |

Notes: X – 2009; √ – 2019

**Table A3** Category-theme grid of content analysis (continued)

| *Category* | *Management* | | | *CMC* | | *Individual* | *Diversity* | |
|---|---|---|---|---|---|---|---|---|
| *# theme* | *Initial setting* | *Indiv.* | *Team* | *Internal* | *External* | | *Team diversity* | *Organisation diversity* |
| 23 High detailed procedures | X √ | | | | | | | |
| 24 Information availability | | | X √ | | | | | |
| 25 Coordination (efficiency) | | | X √ | | | | | |
| 26 Cohesion | | | X √ | | | | | |
| 27 Motivate | | X √ | | | | | | |
| 28 Roles and responsibilities | X √ | | | | | | | |
| 29 Empower | | X √ | | | | | | |
| 30 Managerial personal attention | | X √ | | | | | | |
| 31 Prioritise | | | X √ | | | | | |
| 32 Multitasking | | | | | | X √ | | |
| 33 Face-to-face meeting | | | | | | | X √ | |
| 34 Be part of a community (informal comm.) | | | X √ | | | | | |
| 35 Misunderstandings | | | X √ | | | | | |
| 36 Team work (willingness to cooperate) | | | X √ | | | | | |
| 37 Language difficulties | | | | | | | X √ | |
| 38 Personal preferences for VT | | | | | | X √ | | |
| 39 Recruitment | X √ | | | | | | | |
| 40 Training – team | | | | | | | X √ | |
| 41 Training – CMC | | | | | | X | | |
| 42 Responsibility | | | | | | | X | |
| 43 Energy level (due to time zone) | | | | | | | X | |

Notes: X – 2009; √ – 2019