The Influence of Virtuality on Social Networks Within and Across Work Groups: A Multilevel Approach

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The Influence of Virtuality on Social Networks Within and Across Work Groups: A Multilevel Approach

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ABSTRACT: We examine how the virtuality of work context influences individuals’ social networks within and across work groups. Given this purpose, we develop a multilevel research framework that explores the effects of different levels of virtuality on one’s intra-group tie strength and extra-group network range based on the computer-mediated communication theory, the proximity theory, and the social network theory. The results of the hierarchical linear modeling indicate that the individual-level virtuality (use of personal and communal communication technologies) significantly influences one’s intra-group tie strength and extra-group network range. Moreover, the results show that the effects of individual-level virtuality on social networks vary depending on the group-level virtuality, such as geographic/temporal dispersion and technological support. By illuminating how individuals’ social networks can be developed through the appropriate use of personal and communal communication technologies in the context of a virtual group, this study provides useful insights into the mechanics that underlie effective virtual work.

KEY WORDS AND PHRASES: computer-mediated communication, hierarchical linear modeling, multilevel analysis, social networks, virtuality.

As virtual collaborations become ubiquitous and unavoidable for organizations, many practitioners and researchers have focused on the potential of information and communication technologies to overcome the space and time constraints that plague face-to-face meetings [20, 49]. However, the lack of face-to-face cues engenders diverse managerial risks, such as communication depersonalization, process dissatisfaction, conflict, and low levels of closeness [35, 36, 61]. Some studies show that mediated work can lead to less satisfaction with peers [34] and a feeling of isolation [2, 57]. These studies also suggest that certain individuals are better able to work in virtual contexts than others [10]. Since the effectiveness of virtual groups is ultimately determined by how effectively employees adjust to virtual work [53], researchers and managers alike are struggling to maximize the opportunities provided by virtual collaboration, while they are eager to minimize the potentials for conflict and process losses [31, 36].

In this research, we address two specific challenges posed by virtual work. One key challenge relates to creating a feeling of closeness that makes the members feel connected to the group [2, 10, 31, 35]. It is important to examine how individuals can address their need for feeling a part of a group and for information sharing. A second challenge is overcoming the barriers in information processing in the presence of various aspects of virtuality. Research has shown that mediated communication is less effective for exchanging tacit information that is difficult to codify than face-to-face interactions [26, 56]. Therefore, individuals frequently have difficulties in accessing valuable information that is needed to perform group tasks in virtual settings [15, 51].

This research is founded on our position that the effective development of social networks can help individuals and groups address these challenges and that research on the antecedents and consequences of the development of such social networks
within and across groups can not only help to extend the research on virtuality but also have implications for the effectiveness of virtual workers in organizations. We posit that social networks with desirable characteristics can be developed through the effective use of personal and group communication technologies. In particular, using these technologies to enhance intra-group tie strength can increase group solidarity, cooperation, and information sharing [29, 63]. Second, these technologies can be utilized to enhance extra-group network range, which can open up access to a wider range of information, resources, and perspectives [8, 24, 25, 54].

Therefore, our goal is to examine how virtuality influences individuals’ social networks within and across work groups. Toward that end, we examine the effect of individual use of personal and group communication technologies in creating personal social networks within and across work groups. Then, we examine the moderating effect of group virtuality on these relationships. We propose that geographic and temporal dispersion, along with technological support, can influence the extent to which individual use of personal and group technologies affects these outcomes.

In addition to the above, this study contributes to research on virtuality in the following ways. The study distinguishes between individual and group levels of virtuality by adopting a multilevel approach, thus extending the research on virtuality. In doing so, we are able to develop cross-level hypotheses and examine the interaction effect between two different-level variables. This in turn helps to provide a more complete picture than would be possible by examining only one of these levels of analysis by itself. Most previous studies on computer-mediated interaction have relied on self-reported perception measures of group relationships. We add to this literature by employing objective social network measures based on actual interactions.

The paper proceeds as follows. We begin with a literature review of social networks and virtuality. Then, we present our research model, followed by the methodology utilized for testing the model. We then discuss our results and provide the implications of our findings.

Theoretical Background

In this section, we first discuss the theoretical underpinning for social network outcomes by employing the social network theory. Next, we conceptualize the dimensions of virtuality and link them with one’s social networks by taking a multilevel approach.

Social Networks and Individual Outcomes

The social network perspective has been suggested as an alternative approach for leveraging the benefit of technology provision and overcoming the challenges of virtual work [1, 27, 52, 56]. This approach is based on two important concepts. One focuses on intra-group tie strength to increase group solidarity and closeness, and to facilitate conformity to agreed-upon norms, cooperation, and information sharing [29, 63]. As group members have strong ties with one another, each member is more likely to have
strong attachments to the group, which may help to maintain fairness and trust in the relationship and build confidence that others’ actions will be beneficial or favorable; thus, shared information will not be appropriated or misused [27, 38, 53]. Therefore, strong ties characterize higher levels of intimacy, self-disclosure, and emotional as well as instrumental exchanges among group members [42].

The other concept focuses on extra-group network range that enables individuals to gain access to a wide range of information, resources, and perspectives that are distributed throughout an organization [8, 24, 25, 54]. The network range includes (1) network size and (2) the presence of structural holes. Network size refers to the number of nodes (contacts) linked in one’s network. A structural hole refers to a gap between disconnected people in a network. If one has social ties with A and B and those two people do not have social ties, then there exists a structural hole in one’s network. Individuals that lie between the two unconnected individuals can broker information between the two by linking or cutting across different groups [8, 9]. Therefore, an individual who has a large number of contacts and more structural holes in his or her network can access nonredundant information, ideas, and knowledge resources [24, 25] and can benefit from the structural position by controlling the information flow [8, 9].

Research on Virtuality

Research has shown that virtuality allows organizations to have more agile, flexible, and fluid structures through overcoming actual constraints, such as physical location, time zones, and organizational boundaries. This stream of research defines virtuality as “being virtual.” So, what does it mean to “be virtual”? While virtuality has received much attention, recent reviews have suggested that a finer-grained theoretical understanding of the concept of virtuality is needed [4, 12, 26, 66].

Group-Level Virtuality

One group of research describes virtuality by focusing on the group context, such as geographical and temporal dispersions, which have been considered to be the most critical and important features of virtual teams [4, p. 22]. In addition to spatial dispersion as an essential element of virtuality, recent research has provided another perspective on virtuality—the extent of technological support. This is also a group-level factor in that the technological support available to the team allows virtual collaboration through mediated communication by overcoming the physical distance among group members [12, 26]. For example, Watson-Manheim et al. [67] introduce the concept of discontinuities to capture distinctive aspects of the virtual collaboration environment and suggest geographic dispersion, temporal dispersion, organizational boundaries, and cultural differences as discontinuities. O’Leary and Cummings [46] focus on geographic dispersion by substantiating the concept of virtuality via three dimensions: spatial, temporal, and configurational dispersion.
Griffith et al. [26] provide a comprehensive framework for explaining virtuality at the group level along three dimensions: technological support, geographic dispersion, and percentage of time apart on task. After reviewing the previous literature, we conclude that the main components that make up virtual collaboration are geographic and temporal distribution of team members, as well as the technological support that enables electronic linkage between members. Those attributes provide a virtual group with distinct features, such as dynamic processes, fluid membership, permeable boundaries, and reconfigurable structures [20]. Accordingly, we conceptualize a virtuality index at the group level consisting of the following elements: (1) geographic dispersion, which refers to the extent to which group members are geographically distributed across different locations (e.g., different sites, offices, or countries); (2) temporal dispersion, which refers to the extent to which group members do not share overlapping work hours; and (3) technological support, which refers to the level of technological infrastructure of the group that supports cooperative work and communication among group members.

Individual-Level Virtuality

A second perspective on virtuality conceptualizes it as a task execution process performed by an individual rather than a group [12, 51]. Such individual-level virtuality (ILV) varies according to the degree to which an individual relies on computer-mediated communication (CMC) media for carrying out given tasks. In other words, although the context at the group level is applied equally to the members of a group, ILV can vary for each member of the group. For example, much online contact occurs between people who can see each other in person and work at the same place. In some cases, employees deliberately communicate using e-mail or instant messaging while they work silently side by side [4, 50]. Therefore, an individual who performs a significant portion of his or her work using CMC media operates at a high level of ILV, despite having a low level of group-level virtuality (GLV).

Generally, a virtual process is conducive to CMC modalities, including (1) personalized computer-mediated communication (PCMC) such as e-mail and instant messaging and (2) communal computer-mediated communication (CCMC) such as audio/video conferencing, threaded discussions, electronic group calendar/scheduling tools, and other group electronic support systems. PCMC and CCMC partly overlap in terms of functionality and utility, and both types of media provide additional capabilities for supporting enterprise-wide communications and collaborative work. However, the characteristics of each type of CMC modality differ from each other. First, they vary depending on whether they provide communal space to communicate collectively, such as brainstorming, group decision making, group scheduling, and collaborative modeling [39]. Second, they can vary in their ability to communicate two-way or multiple-way (i.e., e-mail to a specific person versus a message on a bulletin board) [62]. Accordingly, we classify CMC technologies into two categories: PCMC and CCMC.
Linking Social Networks and Virtuality

While the social network theory has mainly focused on explaining the outcomes of network structure, studies have rarely focused on the antecedents of social network properties. To go beyond this, we now consider how an individual’s social networks are affected by the different aspects of virtuality at different levels. Some previous studies have concerned the effects of information technology (IT) on social networks, arguing that IT tools may modify the mode of formation, expansion, and diversification of an individual’s social relationships [68]. However, most previous studies have limited their views to discrete units of analyses and have ignored the role of GLV, which may shape the effects of ILV on intra-group and extra-group social networks. Considering there has also been no empirical study on the interaction effects of GLV and ILV on social networks, the research questions included in this study, which link virtuality and social networks, are critical in helping information system (IS) developers and team leaders design more effective communication systems and manage individuals’ social networking.

Research Model and Hypotheses

As previously indicated, the overall objective of this study is to contribute to the understanding of virtuality at the individual and group levels by examining the joint effects of technology and geographical and temporal boundaries on one’s social networks. In this section, we develop a research model as shown in Figure 1. By including both group-level and individual-level variables within one research model, the model simultaneously examines how ILV influences individuals’ social networks within and across work groups and how GLV moderates these relationships.

Individual-Level Virtuality and Intra-Group Tie Strength

ILV refers to the extent to which an individual completes tasks via CMC media. CMC is defined as any communicative transaction that occurs through the use of two or more networked computers [44]. While the term has traditionally referred to communications that occur via computer-mediated formats (e.g., instant messaging, e-mail, chat rooms), it has also been applied to other forms of interactions, such as Internet-based social networking supported by social software. Researchers have categorized CMC media according to whether they are used synchronously or asynchronously (e.g., [47]). However, synchronous CMC media do not work synchronously in situations where people work across temporal boundaries. As synchronicity is subject to temporal boundaries, this study proposes a novel approach for CMC categorization: PCMC, which supports boundary-spanning activities, and CCMC, which supports collective communication.

With respect to the use of PCMC, conventional CMC theories, such as the media richness theory [18] and the social presence theory [59], commonly view PCMC as lean, having lower social presence and being relatively impersonal. Therefore, some researchers have considered PCMC to be effective for task-oriented communication.
but not suitable for socioemotional expression [61]. However, the hyperpersonal theory argues that PCMC is sometimes more effective in developing strong interpersonal ties because it breaks down perceived hierarchies and promotes a feeling of equality and centrality [65]. Indeed, empirical research has reported that PCMC users achieve high levels of positive communication outcomes in several relational dimensions of interpersonal communication, such as emotional closeness and high attraction [64, 65, 69].

While PCMC connects dyadic communications and supports boundary-spanning activities, CCMC provides a customized and communal space for group members to conduct task-related discussions, share information and electronic documents, and coordinate task activities [3, 36]. CCMC stimulates group members’ internal interaction and facilitates participation in a group’s communal communication [11], thereby helping group members can build rapport and strengthen emotional closeness. Thus, all else being equal, PCMC and CCMC will lead to an increase in intra-group closeness.

Hypothesis 1a: Use of PCMC is positively related to one’s intra-group tie strength.

Hypothesis 1b: Use of CCMC is positively related to one’s intra-group tie strength.

Individual-Level Virtuality and Extra-Group Network Range

PCMC is usually not restricted to a locally limited work group; rather, it expands connectivity to outside the work group. For example, e-mail users can include the lists of people outside their groups when they communicate with their group members, and
external lists that are related to the tasks can be shared within the group. In this case, people can easily recognize “who knows what” outside their teams and, consequently, can expand their contacts far beyond the local area. For instance, some functions of PCMC (e.g., instant messaging) enable people to connect and expand their “friend list” to other boundaries throughout the organization, even though they rarely meet each other offline. In addition, specific functions of PCMC, such as lateral/hierarchical linkage, ease of adding other people’s contact lists, and ease of searching contact points, allow individuals to expand their social networks outside their work groups. This discussion casts the same light on some of the arguments of social network theorists; namely, that increased connectivity via personal electronic media leads to increased weak ties [13, 50] in a social network.

The network range is, however, not only dependent on the size of a network but also the presence of structural holes. While network size emphasizes a “large” network, the concept of structural holes focuses on a “sparse” or “nonredundant” network [8]. If there are many structural holes in one’s social networks, this means that one has contacts that are more diverse and can take a more advantageous position in the network.

There is an argument that PCMC enables people to have a variety of partial relationships because it makes individuals interact with unfamiliar people and discover others with common interests in the online space [50]. As Watson-Manheim and Belanger [66] illustrate in their case study of how e-mail users gather information they need and extend their social networks, individuals may effectively span the range of social ties by eliminating boundaries and facilitating social interaction beyond their local areas by using PCMC. For instance, one person first sends an e-mail to another person who might possess information or have a specialty in order to get an answer, and the two parties can link up later either through an e-mail response or a scheduled meeting. Therefore, we can infer that as individuals have more virtual interactions, they are more likely to achieve diverse relationships through the functions provided by PCMC because they are more capable of addressing sparser networks:

Hypothesis 2a: Use of PCMC is positively related to one’s extra-group network size.

Hypothesis 2b: Use of PCMC is positively related to the presence of structural holes in one’s extra-group network.

The effect of CCMC would be different from the effect of PCMC on the extra-group network range. CCMC usually limits the boundary of online contacts to the intra-group members. If an individual spends intensive time interacting with other group members via CCMC, then he or she has few opportunities to expand social ties outside the group. Research has shown that there exists a trade-off between internal and external social interactions [16]; this is because developing social networks is constrained by factors like time and social distance. Since people invest time and effort to establish and maintain relationships with others, emotional intensity, intimacy (mutual confiding), and reciprocal services are constrained by the number of social ties involved. Likewise, there will be eventual competition between reinforcing intra-group closeness and
expanding external bridging ties. Therefore, we can infer that internal communication via CCMC limits an individual’s external social networking:

_Hypothesis 2c:_ Use of CCMC is negatively related to an individual’s extra-group network size.

_Hypothesis 2d:_ Use of CCMC is negatively related to the presence of structural holes in one’s extra-group network.

The Moderating Effects of Group-Level Virtuality

We consider the three subdimensions of GLV as contextual factors that shape individuals’ work processes and interactions. The first of these factors is geographic dispersion, which refers to the extent to which group members are situated across geographic boundaries. According to the proximity theory, geographic dispersion among group members negatively affects their social interactions and provides fewer opportunities for acquisition of group knowledge, thus significantly reducing the level of intra-group closeness [22]. Even though CMC technologies can, to an extent, mitigate such negative effects of geographic dispersion on group members’ interactions and allow them to develop interpersonal relationships through CMC [55], individuals in different places must be much more intentional in their efforts to develop strong ties because geographic dispersion reduces the likelihood of face-to-face contact and spontaneous communications, which enhance and support emotional closeness and high attraction.

Similarly, while CCMC can provide a communal space for group members to conduct task-related discussions, share information and electronic documents, and coordinate task activities [3], it is limited in its effectiveness under conditions of geographical dispersion because it is not supplemented by opportunities for group members to update other members on work progress and to develop mutual knowledge [17]. Therefore, we posit that, given the same levels of CCMC and PCMC, group members are less likely to form strong ties when they are more geographically dispersed than when they are less geographically dispersed:

_Hypothesis 3a:_ Use of PCMC will be more strongly associated with one’s intra-group tie strength when the group members are less geographically dispersed than when they are more geographically dispersed.

_Hypothesis 3b:_ Use of CCMC will be more strongly associated with one’s intra-group tie strength when the group members are less geographically dispersed than when they are more geographically dispersed.

The second dimension of GLV is temporal dispersion, which refers to the extent to which members do not share overlapping work hours because of differences in working hours, time zones, or working rhythms [17, 21]. A high level of temporal dispersion reduces the group’s capability to solve real-time problems [17, 21, 46] and to coordinate team conflicts [4, 36, 43]. This is mainly because temporal boundaries
among group members make it impossible to communicate synchronously and thus deteriorates interactivity of communication among group members. Synchronicity is suggested as one critical factor for CMC interactivity [39]. If there is a high degree of temporal dispersion among group members, the communication flow will be hindered [70] and the interpersonal interactivity will be significantly decreased. While the use of PCMC increases the frequency of dyadic communications and supports the personal exchange of socioemotional information among group members, and the use of CCMC supports intra-group closeness and collective activities, such positive outcomes of PCMC and CCMC will be more salient in a situation where some degree of interactivity and synchronicity can be guaranteed:

**Hypothesis 4a:** Use of PCMC will be more strongly associated with one’s intra-group tie strength when the group members are less temporally dispersed than when they are more temporally dispersed.

**Hypothesis 4b:** Use of CCMC will be more strongly associated with one’s intra-group tie strength when the group members are less temporally dispersed than when they are more temporally dispersed.

Individuals who do not share overlapping work hours with other members often have to invest their private time to communicate with them, which is necessary to coordinate or accomplish joint work. If group members are more temporally dispersed, then it is more difficult to have group discussions or online meetings simultaneously. For example, when some members utilize CCMC, such as video/audio conferencing, they sometimes have to be online outside of typical business hours (e.g., early in the morning or late at night). This can discourage members from using CCMC, such as a group collaboration system, to solicit feedback from others when they are not available [17], something they might otherwise do if they could achieve immediate responses. Conversely, if members are forced to use CCMC for synchronous communications with their partners who are in different time zones, this will require them to invest much more time and effort in using CCMC when group members are more temporally dispersed than when group members are less temporally dispersed. Consequently, temporal dispersion leads to reduced opportunities to expand one’s social ties outside the work group. Thus, we posit that the negative effects of CCMC on extra-group network range will be stronger when the group members are more temporally dispersed:

**Hypothesis 4c:** Use of CCMC will be more strongly associated with a decrease of one’s extra-group network size when group members are more temporally dispersed than when they are less temporally dispersed.

**Hypothesis 4d:** Use of CCMC will be more strongly associated with a decrease of one’s extra-group structural holes when group members are more temporally dispersed than when they are less temporally dispersed.

The third dimension of GLV is technological support, which refers to the extent to which technological infrastructure supports a team’s communication, documentation, and decision-making technologies. Research suggests that perceived IT support of a group positively affects contextualization [40], task coordination among group
members [36, 47], even distribution of information among team members [15, 41], and co-creation and manipulation of boundary objects [21]. Group-level technologies support group configuration management and coordination, including search and access to personnel profiles, shared calendars, event posting and scheduling, and meeting agenda planning and tracking, all of which enable group members to cooperate effectively and exchange information as well as maintain emotional interactions [3]. In this regard, technological support at the group level has a complementary relationship with individual use of CMC, thereby enabling group members to become productive members of the group very quickly and socialize more easily with other group members:

**Hypothesis 5a:** Use of PCMC will be more strongly associated with one’s intra-group tie strength when the group has a higher level of technological support than when it has a lower level of technological support.

**Hypothesis 5b:** Use of CCMC will be more strongly associated with one’s intra-group tie strength when the group has a higher level of technological support than when it has a lower level of technological support.

Notably, group-level technology not only supports task coordination among group members but also supports external connectivity. For example, a group’s repository connected to a corporate knowledge base, well-established electronic Who’s Who directories, and technical functions to facilitate notification of new corporate development allow workers to connect with external perspectives from remote sources, which consequently leads to the development of extended social ties [41]. To take another example, different levels of technology (e.g., broadband Internet access versus dial-up or mobile Internet access) may also influence individual members’ interactions with other employees, especially when they are apart from their companies or work in different countries because faster connectivity makes it more likely that members will reach out to others not only inside but also outside the team. Therefore, individuals who belong to a group where technology support is of a higher level (e.g., more diverse and advanced technologies to communicate effectively with others outside their work groups) are likely to acquire larger networks:

**Hypothesis 5c:** Use of PCMC will be more strongly associated with one’s extra-group network size when the group has a higher level of technological support than when it has a lower level of technological support.

**Hypothesis 5d:** Use of PCMC will be more strongly associated with one’s extra-group structural holes when the group has a higher level of technological support than when it has a lower level of technological support.

**Sampling and Data Collection**

This study selected the consultants and IS development project teams of five global business consulting firms in Korea that met the objectives of the study. Most of the teams we surveyed had members who worked in different physical spaces (different
sites or countries) or at different time zones and heavily relied on a variety of CMC media, including e-mail, instant messaging, group support systems, video/audio conferencing, group scheduling, and project management software. Therefore, we believe that the sample frame used in this study is appropriate to the proposed research questions.

After modifying the questionnaire based on pretesting feedback, we contacted the high-level executives of five business consulting firms and then solicited their support so that team managers would urge their team members to participate in the survey. This was possible because one of the authors had been working as an advisory professor in several consulting firms and had close relationships with the executives of the firms. Before conducting the survey, we asked the project managers to provide the roster of their teams. After receiving the roster of each project team, we then asked the team managers to distribute the assigned questionnaire to the team members.

For this study, 270 people were requested to fill out a questionnaire regarding their work environment and their relationships with both team members and others. A total of 211 surveys were collected; the response rate was 78 percent. To derive numerical values for diverse social network properties, we employed the social network analysis (SNA) method. SNA is useful in analyzing the structural tendencies of informal network forms [14]. For the SNA, the questionnaire should be administered to at least 80 percent of the team members [60]. Teams with a response rate below 80 percent should not be considered for further analysis. We discarded 39 questionnaires because they had a less than 80 percent response rate within their teams. Another 7 questionnaires were removed because of a low level of group agreement. The group-level variables (technological support and temporal dispersion) are the shared unit properties. Shared unit properties originate at lower levels but are manifest as higher-level phenomena [37, p. 29], so individual items should be aggregated only when individual judgments coincide [32]. We scrutinized the level of agreement of each team and found that two teams affected detrimentally the overall level of intraclass correlation. Therefore, these two teams were removed from the final analysis. Finally, 165 individuals and 40 project teams were used in the analysis.

The respondents’ ages ranged from 25 to 46 years (M = 34.10 years, SD = 3.984) and there were 32 women and 133 men. Job tenures ranged from 1 year to 23 years (M = 6.86, SD = 4.336). Number of project team members ranged from 3 members to 10 members (M = 4.71, SD = 1.6). Project tenure ranged from 1 month to 16 months (M = 6.98, SD = 3.59).

Measures

Independent Variables

Measurement items were developed based on the definitions provided by previous literature. All dimensions of ILV were measured using a five-point Likert scale (1 = “strongly disagree,” 5 = “strongly agree”). Group-level geographic dispersion was measured using a sociometric technique and derived numerical value from 0 to 1.
For the measurement of geographic dispersion, all team rosters were reported to be “complete” by all respondents. We asked every team member: “During the project period, to what extent did you work with this person [name] at the different location?” Their responses were valued on a five-point scale (1 = “never,” 5 = “almost always”). The links between two individuals were recorded in a square social network matrix, and we dichotomized the values using the sociometric technique. We placed a 1 in the cell if the value of the link was more than 4 (often); otherwise, we placed 0 in the cell. Finally, we made symmetries with the maximum value. To compute the degree of geographic dispersion of each team, we used UCINet, an SNA software program, by adopting the equation of network density. We used the following formula for density: 
\[ \frac{k}{n(n - 1)/2}, \]

where \( k \) is the number of lines present and \( n \) is the number of group members. The index of network density represents the degree of connectedness among people within a particular team. In this case, a fully connected network means that every team member works at a different place. To assess the degree of group-level technological support, we asked to what extent a team’s technological infrastructures supported team members’ communication, documentation, and decision making. To measure temporal dispersion, we asked to what extent group members do not share overlapping work hours. Operational definitions and each questionnaire item are provided in Appendix Table A1.

**Dependent Variables**

Tie strength refers to the depth of individual relations by measuring the emotional closeness [42]. For SNA, all team rosters were reported to be “complete” by all of the respondents. The respondents were asked to indicate the intensity of their connection in terms of emotional closeness. These network data were valued on a five-point scale (1 = “very distant,” 5 = “very close”). To compute one’s intra-group tie strength, we used the average value of the emotional closeness with other group members.

Each individual’s external network range was assessed using two network properties. One was an individual’s network size, and the other was an individual’s structural holes. Using egocentric networks, we measured the extra-group network variables. The central actor of concern in a relationship was termed “ego.” Respondents were asked to generate the names of people with whom they had frequent contacts for getting information and knowledge. It was noted that extra-group relations were limited to within their company. The number of external relations was limited to a maximum of 10 people. Next, respondents were asked to mark any ties in which they had a relationship between two other people (alters). In egocentric network research, there might be some perceptual biases because of the individual responses concerning possible interconnections between people to whom the ego is tied. The name generation method has been regarded as an appropriate way to measure an ego’s structural holes [8, 45].

To derive the numerical indices for extra-group network size and structural holes in each ego’s network, we adopted the procedure used in Burt’s work [8, 9]. As a measure of extra-group network size, we used the total number of contacts in an ego’s network. As a measure of structural holes, we used a network constraint index,
which describes the extent to which a person’s network is concentrated in redundant contacts. As Burt states, “more constraint means fewer structural holes” [9, p. 347]. The index of structural holes is measured by taking the form of 1 minus the sum of the constraint posed by each of the contacts in the network \((1 - \sum c_{ij})\). The constraint \(c_{ij}\) is computed as

\[
c_{ij} = (p_{ij} + \sum q p_{iq} p_{jq})^2, \quad q \neq i, j,
\]

where \(p_{ij}\) is the proportion of \(i\)’s relations invested in contact \(j\), \(\sum q p_{iq} p_{jq}\) is the proportion of \(i\)’s relations invested in contacts \(q\) who are in turn invested in contact \(j\). The sum of squared proportions, \(\sum c_{ij}\), is the network constraint.

Control Variables

There are several other characteristics of the individual and the context that have been or may be shown to influence individual social networks. Although it was not possible to include all these variables in this study, we did control for an individual’s age, gender, and job tenure, all of which have been suggested to affect an individual’s social network [23]. First, at the group level, we controlled for group size, which refers to the number of group members. Existing research has demonstrated that group size could affect intra-group processes and network structure [5]. Second, we controlled for the extent to which group members worked with one another in the previous projects (group members’ past work experience) at the group level. Research has suggested that the effect of geographic or temporal dispersion should be distinguished from the effect of prior familiarity among members to avoid introducing confounds due to past work experience [21, 46]. We calculated the index of past work experience by sociometric technique, which is the same way we calculated the index of geographic dispersion. We first assessed whether the respondent had work experience with every other team member; then we made a social network matrix in which every link of pairs was recorded. Next, to compute the degree of past work experience of each team, we used UCINet by adopting the equation of network density.

Validity of the Instruments

To test for the construct validity of virtuality, a principal axis factoring analysis was conducted using the direct oblimin method. All the items were loaded on each distinct factor, and the factor loadings for all the items were greater than 0.7, except one item, PCMC3 (0.527). This item relates to socioemotional aspect, rather than the task aspect as the other two items addressed. It is possible that the socioemotional content was embedded in the task-related messages and the respondents did not initiate messages that were solely socioemotional. Thus, the respondents may have regarded the socioemotional aspect as a part of task usage for PCMC because the main purpose of communication was task related, even if they exchanged socioemotional information via PCMC [51]. This would explain why the item did not contribute to the same factor. A factor loading is the correlation of the variable and the factor; the squared loading
is the amount of the variable’s total variance accounted for by the factor. Thus, the
loading must exceed 0.7 for the factor to account for 50 percent of the variance of a
variable [28, p. 127]. Accordingly, we removed PCMC3 from further analysis.

Eigenvalues of the four factors were 3.846, 2.129, 1.452, and 1.172, respectively.
These four factors explained 78.169 percent of the total variance. The four factors
emerged with no cross-construct loadings above 0.5, indicating a satisfactory level of
discriminant validity. This instrument also demonstrated high convergent validity with
all factor loading exceeding 0.7. Table 1 shows the results of the factor analysis.

For group-level technological support and temporal dispersion, we aggregated
individual response to the group level and used the mean to represent collective inter-
pretation. To determine whether they could be aggregated to the group level, interrater
agreement was estimated using two indices: within-group agreement ($r_{wg}$) and intraclass
correlation (ICC). We computed two ICC statistics: ICC(1) represents the proportion
of the total variance that can be explained by group membership, and ICC(2) provides
an estimate of the reliability of the group means [6]. The cutoff value 0.3 for ICC(1)
and 0.7 for ICC(2) were recommended in some cases. However, research suggests
that the index of ICC(1) and ICC(2) should not be judged by a single cutoff level, but
should be comprehensively interpreted by taking other contextual factors into account
because the value of 0.3 for ICC(1) and the value of 0.7 for ICC(2) represent very
large values encountered by researchers studying small, highly diverse groups [6, 7].
Bliese states: “I have never encountered ICC(1) values greater than .30; I typically see
values between .05 and .20. I would be surprised to find ICC(1) values greater than
.30 in most applied field research” [6, p. 361]. Furthermore, ICC(2) tends to increase
as the group size increases [6]. Accordingly, as shown in Table 2, all indices of $r_{wg}$,
ICC(1), and ICC(2) for group-level variables in our study indicated acceptable agree-
ment because $r_{wg}$ was greater than 0.7 and ICC(1) and ICC(2) were marginal. Those
ICC values were probably more realistic in applied settings and represented moderate
and moderately high ICC values [7].

Next, we performed a correlation analysis. Tables 3 and 4 show the results of the
simple correlation among all the research variables in the individual-level and group-
level properties, respectively. The results of the Pearson correlation showed that there
was a high correlation between extra-group network size and structural holes (0.73).
In general, network size was highly correlated with structural holes. If network size
was large, structural holes had a tendency to increase. However, each network property
was different in nature [8]. Thus, we included both network size and structural holes,
as dependent variables, in our research by using different models.

Analysis and Results

Multilevel Modeling

Since the hypotheses of the present research required testing for cross-level effects,
we used an analytical technique—hierarchical linear modeling (HLM), which is gain-
ing increased acceptance in the management literature [33]. This technique allows
Table 1. Factor Analysis Results for Virtuality

<table>
<thead>
<tr>
<th>Items</th>
<th>Cronbach’s α</th>
<th>Factor 1</th>
<th>Factor 2</th>
<th>Factor 3</th>
<th>Factor 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCMC2</td>
<td>0.882</td>
<td>0.931</td>
<td>0.117</td>
<td>0.185</td>
<td>0.360</td>
</tr>
<tr>
<td>CCMC1</td>
<td>0.915</td>
<td></td>
<td>0.142</td>
<td>0.233</td>
<td>0.358</td>
</tr>
<tr>
<td>CCMC3</td>
<td>0.848</td>
<td></td>
<td>0.054</td>
<td>0.115</td>
<td>0.536</td>
</tr>
<tr>
<td>TEMP2</td>
<td>0.822</td>
<td>0.161</td>
<td></td>
<td>0.225</td>
<td>0.140</td>
</tr>
<tr>
<td>TEMP1</td>
<td>0.108</td>
<td></td>
<td>0.882</td>
<td></td>
<td>0.107</td>
</tr>
<tr>
<td>TEMP3</td>
<td>0.048</td>
<td>0.827</td>
<td></td>
<td>0.068</td>
<td>0.076</td>
</tr>
<tr>
<td>PCMC1</td>
<td>0.756</td>
<td>0.203</td>
<td>0.102</td>
<td></td>
<td>0.896</td>
</tr>
<tr>
<td>PCMC2</td>
<td>0.167</td>
<td>0.140</td>
<td></td>
<td></td>
<td>0.893</td>
</tr>
<tr>
<td>TECH1</td>
<td>0.824</td>
<td>0.412</td>
<td>0.095</td>
<td>0.271</td>
<td></td>
</tr>
<tr>
<td>TECH2</td>
<td>0.404</td>
<td>0.027</td>
<td>0.227</td>
<td>0.933</td>
<td></td>
</tr>
<tr>
<td>TECH3</td>
<td>0.333</td>
<td>0.215</td>
<td>0.280</td>
<td>0.726</td>
<td></td>
</tr>
<tr>
<td>Eigenvalue</td>
<td></td>
<td>3.846</td>
<td>2.129</td>
<td>1.452</td>
<td>1.172</td>
</tr>
<tr>
<td>Percentage of variance</td>
<td>34.965</td>
<td>19.355</td>
<td>13.199</td>
<td>10.650</td>
<td></td>
</tr>
<tr>
<td>Cumulative percentage</td>
<td>34.965</td>
<td>54.320</td>
<td>67.519</td>
<td>78.169</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Boldface figures correspond to items that load highly on the factor. Intra-group average tie strength, extra-group network size and structural holes, geographic dispersion, and past work experience are not included in the factor analysis because we calculated a single value for those variables by using sociometric technique.
researchers to analyze data from two or more levels of analysis while accounting for the nonindependence in observations that the nested structure of multilevel data tends to produce [30, 32, 33].

**Individual-Level Model (Level 1)**

Because an individual’s network building is the dependent variable of interest in this study, we denoted each network property (i.e., intra-group tie strength, extra-group network size, and structural holes) of person \(i\) in group \(j\) as \(Y_{ij}\). This outcome is represented as a function of \(X_{ij}\), which is the value on the predictor for individual \(i\) in group \(j\). The micro-level model is formulated as follows:

\[
Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + r_{ij},
\]

where \(\beta_{0j}\) and \(\beta_{1j}\) are intercepts and slopes estimated separately for each group (as noted by the subscript \(j\)), and \(r_{ij}\) represents the residual at the individual level.

**Group-Level Model (Level 2)**

After the formulation of the level 1 model, it is necessary to construct a level 2 model. In this study, the level 2 model explains the impact of group-level virtuality on the mean level of individuals’ network properties on each group. The level 2 analysis uses the intercepts and slopes from the level 1 analysis as dependent variables. Thus, the macro-level model takes the following form:

\[
\begin{align*}
\beta_{0j} & = \gamma_{00} + \gamma_{01} W_j + u_{0j} \\
\beta_{1j} & = \gamma_{10} + \gamma_{11} W_j + u_{1j},
\end{align*}
\]
Table 3. Correlation Analysis Between the Individual-Level Research Variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 1. Use of CCMC</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Use of PCMC</td>
<td>0.21***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B 3. Age</td>
<td>-0.03</td>
<td>0.02</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Job tenure</td>
<td>0.02</td>
<td>-0.02</td>
<td>0.76***</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Gender</td>
<td>0.06</td>
<td>0.12</td>
<td>-0.34***</td>
<td>-0.13</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C 6. Intra-group tie strength</td>
<td>0.17**</td>
<td>-0.08</td>
<td>-0.30***</td>
<td>-0.20**</td>
<td>-0.09</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>7. Extra-group network size</td>
<td>0.04</td>
<td>0.16**</td>
<td>-0.08</td>
<td>-0.13</td>
<td>0.06</td>
<td>0.11</td>
<td>1.00</td>
</tr>
<tr>
<td>8. Extra-group structural holes</td>
<td>0.01</td>
<td>0.14*</td>
<td>-0.14*</td>
<td>-0.18**</td>
<td>0.05</td>
<td>0.11</td>
<td>0.73***</td>
</tr>
</tbody>
</table>

Notes: We assessed multicollinearity between job tenure and age using the variance inflation factor (VIF) value. Our results showed that the VIF scores are 2.528 for intra-group tie strength, 2.536 for extra-group network size, and 2.387 for extra-group structural holes. These scores were well below the threshold value of 10, thus indicating that high correlation between job tenure and age was not a problem in this study. A = individual-level virtuality; B = individual-level control variable; job tenure (unit: year), gender (male: 0, female: 1); C = individual-level network properties (dependent variables). N = 165; * p < 0.1; ** p < 0.05; *** p < 0.01.
where $W_j$ is a group-level variable, and $\gamma_{10}$ and $\gamma_{00}$ are the second-stage intercept terms. $\gamma_{01}$ is the coefficient that captures the effect of $W_j$ on the within-group levels represented by $\beta_{0j}$. $\gamma_{11}$ is the slope relating $W_j$ to the slope terms from the level 1 equation, and $u_{0j}$ and $u_{1j}$ are residuals at the group level. Using variable labels instead of algebraic symbols, this study uses the following equations to test our hypotheses:

\[
Y_{ij} = \beta_{0j} + \beta_{1j}(\text{Use of PCMC}_{ij}) + \beta_{2j}(\text{Use of CCMC}_{ij}) + \beta_{3j}(\text{Gender}_{ij}) + \beta_{4j}(\text{Age}_{ij}) + \beta_{5j}(\text{Job Tenure}_{ij}) + r_{ij}
\]

\[
\beta_{0j} = \gamma_{00} + \gamma_{10}(\text{Technology Support}_{j}) + \gamma_{02}(\text{Geographical Dispersion}_{j}) + \gamma_{03}(\text{Temporal Dispersion}_{j}) + \gamma_{04}(\text{Past Work Experience}_{j}) + u_{0j}
\]

\[
\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Technology Support}_{j}) + \gamma_{12}(\text{Geographical Dispersion}_{j}) + \gamma_{13}(\text{Temporal Dispersion}_{j}) + u_{1j}
\]

\[
\beta_{2j} = \gamma_{20} + \gamma_{21}(\text{Technology Support}_{j}) + \gamma_{22}(\text{Geographical Dispersion}_{j}) + \gamma_{23}(\text{Temporal Dispersion}_{j}) + u_{2j}
\]

\[
\beta_{3j} = \gamma_{30}
\]

\[
\beta_{4j} = \gamma_{40}
\]

\[
\beta_{5j} = \gamma_{50}.
\]

We began using a null model (baseline model), examining whether groups varied significantly on average for an individual’s network properties [32]. The percentage of total variance that resides between groups was significant for intra-group tie strength. Using this variance, we can define the intraclass correlation $\rho$ illustrated below [33], which is calculated from a random coefficient model. It should be noted that this $\rho$ is different from the ICC (1), which is calculated from an analysis of variance (ANOVA) model to assess group agreement [6, p. 355]. The equation for the $\rho$ is as follows:

\[
\rho = \frac{\sigma_{w}^2}{\sigma_{w}^2 + \sigma_{i}^2},
\]

where $\sigma_{w}^2$ is the variance of the individual-level errors $r_{ij}$, and $\sigma_{w}^2$ is the variance of the group-level errors $u_{0j}$. In this study, $\rho$ of intra-group tie strength is $0.358/(0.358 + 0.226)$, which equals 0.613. Thus, 61.3 percent of the variance of the intra-group tie strength
is at the group level. Yet both the $\rho$ of extra-group network size and the $\rho$ of extra-group structural holes were close to zero. This means that there might be no significant direct effects of group-level variables. However, multilevel modeling can elucidate the cross-level effects between the individual level and the group level, even when the $\rho$ is near zero [30].

Table 5 shows the results of the HLM analysis. We controlled for gender, age, and job tenure at the individual level. The results show that male consultants are more likely to have strong ties with other group members than female consultants, and age is negatively associated with intra-group tie strength. The results also reveal that job tenure is negatively associated with one’s extra-group network size and structural holes. At the group level, the results show that past work experience has a positive influence on intra-group tie strength, while the group size has no direct effect on intra-group tie strength as well as extra-group network size and structural holes.

H1 addressed the relationship between ILV and intra-group tie strength. The results of this study showed that the use of PCMC did not influence intra-group tie strength, whereas the use of CCMC significantly increased intra-group tie strength, regardless of group contexts ($\gamma_{20} = 0.098$, SE [standard error] = 0.047, $p < 0.05$ in Model 1). Accordingly, H1a was not supported, while H1b was supported.

H2 addressed the relationship between ILV and extra-group network range. As we expected, use of PCMC positively influenced extra-group network size ($\gamma_{10} = 0.562$, SE = 0.280, $p < 0.05$ in Model 2) and structural holes ($\gamma_{10} = 0.056$, SE = 0.025, $p < 0.05$ in Model 3), supporting H2a and H2b. However, contrary to our expectations, use of CCMC did not decrease an individual’s extra-group network size as well as structural holes; thus, H2c and H2d were not supported.

H3 addressed the moderating effect of geographic dispersion. Contrary to our expectations, the results showed that individuals were more likely to form strong ties by using PCMC under a higher level of geographic dispersion ($\gamma_{12} = 0.608$, SE = 0.231, $p < 0.01$ in Model 1). Figure 2 shows that every group has a different slope, which represents the relationship between PCMC and intra-group tie strength. Figure 3 demonstrates the subgroup analysis along with the levels of geographic dispersion. At the same time, the results showed that there was no significant moderating effect of geographic dispersion on the relationship between the use of CCMC and intra-group tie strength. Therefore, H3a and H3b were not supported.

H4 addressed the moderating effects of temporal dispersion. The results showed that the effects of CCMC and PCMC on intra-group tie strength were not changed by the degree of temporal dispersion. On the contrary, we found that the relationship between the use of CCMC and extra-group network range was significantly moderated by the degree of temporal dispersion. More specifically, the use of CCMC decreased extra-group network size ($\gamma_{23} = -0.846$, SE = 0.349, $p < 0.05$ in Model 2) (see Figures 4 and 5) and structural holes ($\gamma_{23} = -0.100$, SE = 0.046, $p < 0.05$ in Model 3) (see Figures 6 and 7) when the group members were more temporally dispersed. Accordingly, H4a and H4b were not supported, while H4c and H4d were supported.

H5 addressed the moderating effects of technological support. With respect to the effects of PCMC and CCMC on intra-group tie strength, technological support did
Table 5. The Results of Hierarchical Linear Modeling Analysis

<table>
<thead>
<tr>
<th>Fixed Effect</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Intra-group tie strength</td>
<td>Extra-group network size</td>
<td>Extra-group structural holes</td>
</tr>
<tr>
<td></td>
<td>Coefficient</td>
<td>Standard error</td>
<td>Coefficient</td>
</tr>
<tr>
<td>Individual level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>$\gamma_{00}$</td>
<td>3.641***</td>
<td>0.079</td>
</tr>
<tr>
<td>Use of PCMC</td>
<td>$\gamma_{10}$</td>
<td>-0.029</td>
<td>0.051</td>
</tr>
<tr>
<td>Use of CCMC</td>
<td>$\gamma_{20}$</td>
<td>0.098**</td>
<td>0.047</td>
</tr>
<tr>
<td>Gender</td>
<td>$\gamma_{30}$</td>
<td>-0.187*</td>
<td>0.107</td>
</tr>
<tr>
<td>Age</td>
<td>$\gamma_{40}$</td>
<td>-0.040**</td>
<td>0.020</td>
</tr>
<tr>
<td>Job Tenure</td>
<td>$\gamma_{50}$</td>
<td>0.007</td>
<td>0.018</td>
</tr>
<tr>
<td>Group level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technological Support</td>
<td>$\gamma_{01}$</td>
<td>0.001</td>
<td>0.134</td>
</tr>
<tr>
<td>Geographical Dispersion</td>
<td>$\gamma_{02}$</td>
<td>-0.994***</td>
<td>0.355</td>
</tr>
<tr>
<td>Temporal Dispersion</td>
<td>$\gamma_{03}$</td>
<td>-0.091</td>
<td>0.130</td>
</tr>
<tr>
<td>Past Work Experience</td>
<td>$\gamma_{04}$</td>
<td>0.562***</td>
<td>0.210</td>
</tr>
<tr>
<td>Group Size</td>
<td>$\gamma_{05}$</td>
<td>-0.035</td>
<td>0.041</td>
</tr>
</tbody>
</table>

(continues)
Table 5. Continued

<table>
<thead>
<tr>
<th>Cross level</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of PCMC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× Technological Support</td>
<td>(\gamma_{11})</td>
<td>0.010</td>
<td>0.084</td>
</tr>
<tr>
<td>× Geographical Dispersion</td>
<td>(\gamma_{12})</td>
<td>0.608***</td>
<td>0.231</td>
</tr>
<tr>
<td>× Temporal Dispersion</td>
<td>(\gamma_{13})</td>
<td>–0.014</td>
<td>0.101</td>
</tr>
<tr>
<td>Use of CCMC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>× Technological Support</td>
<td>(\gamma_{21})</td>
<td>0.014</td>
<td>0.094</td>
</tr>
<tr>
<td>× Geographical Dispersion</td>
<td>(\gamma_{22})</td>
<td>–0.014</td>
<td>0.260</td>
</tr>
<tr>
<td>× Temporal Dispersion</td>
<td>(\gamma_{23})</td>
<td>–0.017</td>
<td>0.124</td>
</tr>
</tbody>
</table>

\(R^2\) within group | 0.133 |
\(R^2\) between groups | 0.284 |
\(R^2\) total | 0.226 | 0.113 | 0.089 |

Notes: * \(p < 0.1\); ** \(p < 0.05\); *** \(p < 0.01\).

\(R^2\) total = \(R^2\) within group \(\times (1 - \rho) + R^2\) between groups \(\times \rho\)

Intraclass correlation \(\rho = 0.613\)

\(R^2\) total for intra-group tie strength = 0.133 \(\times (1 - 0.613) + 0.284 \times 0.613 = 0.226\)

The percentage of total variance that resides between groups was not significant for extra-group network size and structural holes. Thus, \(R^2\) total is equal to \(R^2\) within group.
Figure 2. The Moderating Effect of Geographic Dispersion on Intra-Group Tie Strength (All Groups)

Figure 3. The Moderating Effect of Geographic Dispersion on Intra-Group Tie Strength (High/Low Groups)
Figure 4. The Moderating Effect of Temporal Dispersion on Extra-Group Network Size (All Groups)

Figure 5. The Moderating Effect of Temporal Dispersion on Extra-Group Network Size (High/Low Groups)
Figure 6. The Moderating Effect of Temporal Dispersion on Extra-Group Structural Holes (All Groups)

Figure 7. The Moderating Effect of Temporal Dispersion on Extra-Group Structural Holes (High/Low Groups)
not moderate the relationships. However, as we expected, use of PCMC had more positive effects on extra-group network size ($\gamma_{11} = 1.109$, $SE = 0.430$, $p < 0.01$ in Model 2) and structural holes ($\gamma_{11} = 0.116$, $SE = 0.044$, $p < 0.01$ in Model 3) when a group had a higher level of technological support (see Figures 8 and 9). The pattern for the moderating effect of technological support on the relationship between use of PCMC and structural holes is almost similar to Figures 8 and 9. Accordingly, H5a and H5b were not supported, but H5c and H5d were supported.

Discussion and Implications
The objective of this study was to examine how virtuality influences individuals’ social network within and across their work groups. The results of this study show that individual use of PCMC and CCMC have different effects on one’s intra-group tie strength and extra-group network range, given the group’s context, such as geographical and temporal dispersion and technological support. More details will be discussed in the following sections, broken down by the types of CMC technologies.

The Roles of PCMC

Research on organizational communication has generated seemingly contradictory findings indicating that the use of PCMC may reduce the level of interpersonal tie strength [18, 19] and that PCMC may be sufficiently “rich” to facilitate interpersonal ties [48, 64, 65]. These inconsistent results could be attributed to the following reasons. First, most prior studies did not isolate the effects of PCMC from the confounding effects of group members’ geographic dispersion. Second, previous research often focused on the PCMC effects on a single dyadic relationship and was not concerned with the average tie strength within a work group.

This study elaborates on the relationship between the use of PCMC and intra-group tie strength based on the results of multilevel analysis, showing that the effect of individual use of PCMC on one’s intra-group tie strength is moderated by the degree of a group’s geographic dispersion. The result of our analysis is consistent with the previous studies in that use of PCMC—which usually supports individualized communication—may effectively compensate for lack of face-to-face meetings, leading to a higher level of closeness among group members when the group is highly geographically dispersed. By contrast, it is notable that use of PCMC decreases one’s intra-group tie strength when group members are geographically close. One possible explanation can be drawn from the previous studies, which reported that PCMC is often used to record interactions for defensive documentation in groups with low levels of geographic dispersion [66]. In other words, when group members are close in terms of geographic proximity, individual use of PCMC tends to be impersonal, task oriented, and used for defensive documentation, thus leading to a decrease of internal tie strength. As Schultze and Orlikowski [58] suggest, it is important to understand how PCMC is being used, for what purpose, and within what context.
Figure 8. The Moderating Effect of Technological Support on Extra-Group Network Size (All Groups)

Figure 9. The Moderating Effect of Technological Support on Extra-Group Network Size (High/Low Groups)
We found that individual use of PCMC had a positive influence on extra-group network range, regardless of group context. This implies that the use of PCMC helps individuals develop a bigger and sparser (nonredundant) social network through which they can get more diverse, relevant, and timely information and knowledge. In addition, the results showed that the use of PCMC has a more positive influence on individuals’ extra-group network range when the degree of group-level technological support is high. Group-level technology may provide additional functionality in enabling bridging of people via electronic networks.

The Roles of CCMC

The results of this study showed that individual use of CCMC had a significant effect on intra-group tie strength regardless of group context, such as geographical or temporal dispersion. This result empirically supports the notion that a virtual workspace for a group is required to increase intra-group tie strength. The result also indicates that the use of CCMC is beneficial even for a collocated team because it may provide additional functions to the entire group and encourage individual members to share their information and facilitate group socialization, which could otherwise be achieved only with high costs in face-to-face settings.

We also found that individual use of CCMC did not restrict, but even increased one’s ability to expand extra-group network range in the groups with low levels of temporal dispersion. This result contradicts the traditional view of social networks, that there is a trade-off relationship between intra-group network closure and extra-group network range. One possible explanation is that the two forms of social network mechanisms are not in tension with one another when group members are less temporally dispersed. This result is consistent with a previous study in which Reagans et al. [54] argue that there is a positive association between one’s external range and internal average tie strength. The positive association suggests differences among individuals in terms of their sociability, or propensity to develop network connections across work groups, with a greater propensity increasing both intra-group tie strength and extra-group network range [54].

It is noteworthy that the use of CCMC is negatively related to the extra-group network range when members are more temporally dispersed. Because group-level temporal dispersion deteriorates the interactivity of communication and may require more costs in maintaining intra-group tie strength, people have to invest greater efforts in intra-group communication when group members are more temporally dispersed. A recent study argued that it is more difficult for group members to communicate when there are temporal boundaries than when there are geographic boundaries [17]. Therefore, the use of CCMC for intra-group communication hinders opportunities to expand social networks outside of work groups. Another possible explanation for this finding is that the results might be caused by the characteristics of individuals who might be shift workers or work in different time zones. Such individuals have a relatively smaller social network than they had in the past and are more likely to feel that they are isolated from other group members. Considering the positive effect of
CCMC on intra-group tie strength, use of CCMC is essential for the groups with high levels of temporal dispersion. However, this study cautions that individual members who work across different time zones may lose benefits from expanding their external networks when they are forced to use CCMC for group collaboration.

Implications for Research

To our knowledge, this is the first empirical study to analyze the effects of virtuality on human relationships by integrating previously separate strands of the CMC theory, the proximity theory, and the social network theory. Although a number of studies have investigated the effects of IT on the management information systems (MIS) field, there have been insufficient empirical attempts to examine how IT influences one’s internal and external social networks. For these reasons, we separated the effects of geographic and temporal boundaries from the use of technology and removed the confounding effects on social networks. The significance of this study, therefore, lies in the fact that it proposes a theoretical foundation regarding human interaction in the technology-mediated virtual environment and the interaction effects of this environment.

Another contribution of our research is that we fill the gap currently existing in IS literature by categorizing two different types of CMC tools. Most previous studies have focused on the effects of one single CMC medium and have compared the properties between different CMC tools. As this research suggests, media tools are evolving rapidly by adding new capabilities or functions; thus, it is better to refer to the set of features that the medium offers, rather than a specific medium [66]. In this regard, our categorization will provide a further step toward understanding different roles of CMC tools in different contexts; this approach will offer valuable insight into extant research on virtual work.

Finally, this study has contributed to the social network theory in that it provides antecedent elements for forming social networks. So far, microscopic phenomena within an organization have frequently been used as dependent variables in studies on social networks. In other words, whereas the social network theory has focused on the benefits created by a network, there have been few studies that explore the antecedent variables of a network. This study extends our understanding of how individuals can develop their social networks in a technology-mediated communication environment.

Implications for Practice

The overarching practical implication of this study is that CMC technologies can bridge geographic and temporal boundaries of a virtual group. A critical aspect of using CMC technologies, however, involves understanding when and where they may be appropriate. In this regard, our indices for virtuality will be useful for managers to precisely assess the group’s contexts where individual members use CMC technologies. This has important implications for practitioners because it can help them not only design more effective communication systems to support individuals’ social networking,
but also make better decisions regarding geographic and temporal configurations of virtual groups. Based on the results of this study, we offer several ways for managing virtual groups as follows.

First, managers should encourage group members to use CCMC so that all group members share task contexts and common ground for creating mutual knowledge about what the team members are doing [15]. Our results show that the use of CCMC leads to higher levels of intra-group closeness and thus may prevent members from feeling isolated. The more advanced functions related to voting or conferencing, where all members can get together and reach a group consensus, might help members build rapport and form a stronger common identity.

Second, this study shows that geographic dispersion has a direct negative influence on intra-group tie strength, whereas past work experience offsets the negative effect of geographic dispersion to some extent. This indicates that intra-group tie strength can be increased not only by changing current members’ behaviors and patterns in CMC usage but also by altering group composition to include members who have past work experience with others in a case where a group’s geographic dispersion is high.

Third, it should be noted that the use of CCMC negatively influences one’s extra-group network range when group members are highly temporally dispersed. This also has important practical implications because managers can intervene to reduce the negative outcomes by analyzing the group’s temporal context. If there are group members who do not share the overlapping work hours with other members, managers should pay careful attention to whether these individuals are struggling to provide feedback via CCMC even if they are not available. It is also important to identify other types of collaboration strategies to help members develop intra- and extra-group social networks simultaneously. Business social networking sites such as LinkedIn or XING, which include both PCMC and CCMC, would be good channels for managers to deploy their communication systems, as well as for individual members to develop effective communication strategies to increase their achievement. However, this study highlights that technology itself does not fully address the challenges posed by virtual work. In particular, a temporal boundary is more difficult to overcome because it significantly limits the synchronicity of CMC technologies. Thus, we suggest that researchers and practitioners should focus on how individuals can better collaborate without sacrificing one dimension of intra-group closeness and extra-group connectivity in a situation where group members are temporally dispersed.

Limitations

Despite some intriguing findings, the results of this study should be interpreted with caution due to the following limitations. First, we collected data from global business consulting firms. Business consulting firms are known as highly knowledge-intensive organizations. Although these samples are adequate for our study and provide valuable insight for the future of these organizations, such knowledge-intensive characteristics of the surveyed teams might have influenced the results of this study. There might
be differences in social networking, underlying values, and drivers when it comes to other industries or other business environments. Future research should explore the relationship between virtuality and social networks over a wider range of teams, including teams in less knowledge-intensive firms than in this sample.

Second, we used a name generation method to measure extra-group network size and structural holes. This might have caused perceptual biases, as we noted before. Because network size and structural holes represent the capability to form bridges to external knowledge resources for the work group, using direct measurement of extra-group bridging capability would be an alternative for future research.

Another limitation of this study is that we did not examine the link between social networks and team performance. Because previous network research has consistently demonstrated the causality between social networks and team performance, our effort in this study was focused on exploring the relationship between virtuality and social networks. Future research should examine the link that an individual’s social networks within and outside a virtual team leads to more effective team processes, which then leads to better performance. Such a study would also provide the opportunity to explore how virtual groups maximize their team performance by correcting individual usage patterns of CMC technologies in compliance with the team context.

Conclusion

The effects of IT on interpersonal relationships are considered to be critical in the research area of virtual work, as technology mediation often correlates with geographic and temporal boundaries. This study disentangled the mixed effects of technology mediation and geographic and temporal boundaries by capturing multidimensional and multilevel virtuality and illuminated how those different aspects of virtuality shape one’s social networks within and across work groups. Ignoring the different effects of CMC technologies and different group contexts on the development of one’s social networks might negatively affect the virtual group’s effectiveness. Our findings provide an important step in studying how a virtual group is managed in using CMC technologies to increase intra-group closeness and extra-group connectivity. From a theoretical perspective, this study has refined the concept of virtuality. Reconceptualizing and operationalizing virtuality at multiple levels enables researchers to examine diverse causal relationships linking the multidimensions of virtuality and outcome variables. From a methodological perspective, this study adopted SNA to assess one’s intra-group and extra-group social networks and demonstrated the usefulness of HLM to address the multilevel nature of research questions. We hope that the theory, method, and results of this study will catalyze further research to enhance the understanding of virtuality and social networks, an issue that has become vital for the success of virtual groups.

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### Appendix Table A1. Operational Definitions and Measurement Items

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<tr>
<th>Construct/Reference</th>
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| **Use of PCMC**     | The degree of use of personal electronic media, such as e-mail or instant messaging, to support individuals’ communication and information exchange.  
PCMC1. I frequently use personal communication technologies to conduct my tasks.  
PCMC2. I frequently use personal communication technologies to exchange task-related information.  
PCMC3. I frequently use personal communication technologies to exchange socioemotional information. |
| **Use of CCMC**     | The degree of use of group support technology or collaboration tools (e.g., video/audio conferencing, group scheduling or other group collaboration software) for idea generation, problem solving, and group decision making.  
CCMC1. I frequently use group support technologies for decision making.  
CCMC2. I frequently use group support technologies for idea generation.  
CCMC3. I frequently use group support technologies for problem solving. |
| **Technological support** | The extent to which technological infrastructures support the team’s communication, documentation, and decision making.  
G_TECH1. Our team has a solid technological infrastructure to support our task-related communication.  
G_TECH2. Our team has a solid technological infrastructure to support our documentation needs.  
G_TECH3. Our team has a solid technological infrastructure to support our decision-making capability. |
| **Geographic dispersion** | The extent to which group members are distributed over different geographical areas.  
During the project period, to what extent did you work with this person [name] at the different location? (1) never, (2) rarely, (3) occasionally, (4) often, (5) almost always |
| **Temporal dispersion** | The extent to which group members do not share overlapping work hours.  
G_TEMPO1. Our team often collaborates with members across different time zones.  
G_TEMPO2. Our team often works extended days in order to communicate with remote team members.  
G_TEMPO3. Our team rarely communicates all together at the same time. |
| **Intra-group tie strength** | Perceived emotional closeness  
How emotionally close are you to this person [name]? (1) very distant, (2) less than close, (3) normal, (4) close, (5) very close |
| **Extra-group network size** | Total number of each individual’s direct links with other actors outside the group. |

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Appendix Table A1. Continued

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| Extra-group structural holes [8] | The extent to which each individual occupies a structurally advantageous position, connecting otherwise unconnected people in one's extra-group social network.  
1. Please list the names of people with whom you maintain a friendship. These people should be outside the project team but within the company you work for.  
2. On the list below, please mark on the ties to indicate instances in which both people have friendship relations.* |

Notes: The scale used for each item measures “strongly disagree” to “strongly agree,” unless otherwise stated in the above table. * For this survey, we developed a special Web site that was dynamic and automated, especially for the name generation method. For example, as soon as a respondent typed his or her extra-group friend list into the Web site, the next screen automatically showed all possible pairs to the respondent. We gathered data about social relations with regard to friendship relations as well as task-advice relations. In this paper we reported the results of friendship networks because the results showed quite a similar pattern in task-advice networks.