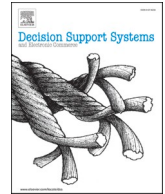




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Revisiting the effects of social networks on enterprise collaboration technology use: A fuzzy-set qualitative comparative analysis approach

Mengxiao Zhu^{a,b}, Lin Liu^{b,*}, Ruoxiao Su^a, Noshir Contractor^c

^a School of Humanities and Social Sciences, University of Science and Technology of China, 96 JinZhai Road, Hefei, Anhui 230026, China

^b School of Management, University of Science and Technology of China, 96 JinZhai Road, Hefei, Anhui 230026, China

^c School of Communication, Northwestern University, 2240 Campus Drive, Frances Searle Building, Evanston, IL 60208-2952, USA

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ABSTRACT

Enterprise collaboration technologies (ECTs) are increasingly recognized for supporting effective and efficient digital collaboration, such as decision-making activities, among employees. Given the social and collaborative nature of ECT use, social network theory offers important and helpful insights into how and why employees' social network relations facilitate their ECT use. However, existing research primarily examines the effects of a single social network relation or several social network relations separately, without applying a holistic approach to investigate the joint effect of multiple social network relations on ECT use. Drawing on a novel technique of fuzzy-set qualitative comparative analysis (fsQCA) and social network analysis, this study explores how multiple social network relations (i.e., advice, friendship, and communication) collectively influence ECT use. Using multi-source data from 178 employees in the human resources department of a global technology company, we identify several configurations of multiple social network relations associated with high ECT use and low ECT use. Our findings indicate that a single social network relation is insufficient to explain ECT use and should be considered alongside other social network relations. Overall, this study provides an integrative framework to unpack the complex and contingent effects of multiple social network relations on ECT use.

1. Introduction

Advanced information and communication technologies have revolutionized the ways in which information resources are exchanged between individuals. In organizations, enterprise collaboration technologies (ECTs) are valued for enabling multiple employees to collaborate on information processing without temporal and spatial barriers [21,51,61]. In addition, ECTs usually provide various functionalities (e.g., screen sharing and video sharing) that increase the effectiveness and efficiency of digital collaboration among employees [21,60]. Substantial evidence has affirmed the benefits of ECT use in the workplace, such as improving employees' collaboration capability and collaboration satisfaction [1], engagement in supportive work [51], and task performance [9]. Thus, exploring the factors associated with employees' ECT use is essential to ensure its most advantageous use.

ECT use is a socialized behavior that typically occurs among interdependent employees. Hence, social network theory, illustrating how the relations or interaction patterns among individuals influence their behaviors in the social context, can be a critical lens to explain ECT use

[48,60]. Previous studies have provided significant insights into how technology use is driven by social networks. However, most studies have focused on examining the role of a single social network relation or several social network relations separately [48,55,60], and only a few studies have explored the joint effects of different social networks on technology use. This issue deserves a more in-depth investigation because employees in the workplace are embedded in a variety of social networks [5,12,44], and the interplay between multiple social network relations in facilitating employees' ECT use remains unclear. Therefore, the overarching research question in this study is how multiple different social network relations interact to influence ECT use.

Drawing upon the literature on social networks, this study identified three interrelated but distinct types of social networks that are theoretically associated with technology use, including advice networks, friendship networks, and communication networks. Advice networks capture the relationships developed for the transfer of information, expertise, and assistance for accomplishing tasks [14,48]; friendship networks record the relationships developed for the sharing of social and emotional support [14,47]; communication networks are reflected by

* Corresponding author.

E-mail addresses: mxzhu@ustc.edu.cn (M. Zhu), SA6060@mail.ustc.edu.cn (L. Liu), srx6098@mail.ustc.edu.cn (R. Su), nosh@northwestern.edu (N. Contractor).

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the communication behaviors supporting interaction and collaboration among employees [25]. In this study, we view advice networks and friendship networks as relationship-based networks that provide employees access to or control of work-related and social-related resources and communication networks as behavior-based networks that reflect the actual communication activities among employees. Given the interconnections among advice, friendship, and communication networks, this study aims to take a system-level and holistic view to examine their joint effects on ECT use.

To unpack the complex interdependence among multiple social networks, this study applies a novel technique of fuzzy-set qualitative comparative analysis (fsQCA), which is grounded in set theory and the Boolean algebra algorithm that allows identifying the configurations (i.e., combinations of multiple conditions) associated with a given outcome [8,31]. Compared with traditional correlation-based approaches, fsQCA models the effects of different predictor variables holistically instead of examining the net effects of different factors [8]. By using fsQCA and social network analysis on multi-source data collected from 178 employees in the human resources (HR) department of a global technology company, this study reveals four configurations sufficient for high ECT use and five configurations sufficient for low ECT use. Our findings shed light on the necessity of considering multiple social network relations alongside each other in explaining ECT use. Overall, this study paves a new avenue to understanding the joint effects of multiple social network relations on technology use.

2. Literature review and research framework

2.1. Enterprise collaboration technology use

Enterprise collaboration technologies (ECTs) can be defined as a set of software applications that facilitate digital collaboration among employees in the workplace, such as information transfer, knowledge sharing, and idea fostering [1,21,28]. Facilitated by ECTs' comprehensive functions, employees can efficiently communicate and collaborate with coworkers from different physical locations [42,61]. By nature, ECT use requires the participation of multiple employees and enables them to work collectively on tasks without physical boundaries.

To explore the antecedents of ECT use by employees, researchers have considered various factors related to the technology, the task, and more importantly, the users. For instance, Brown, Dennis and Venkatesh [3] identified four sets of factors related to ECT use, including technological factors (e.g., social presence and immediacy), individual and group factors (e.g., collaboration technology experience and familiarity with others), task factors (e.g., idea generation and decision making), and situational factors (e.g., coworker conditions and environmental conditions). Maruping and Magni [21] suggested that exploring the antecedents of ECT use should go beyond the individual level and consider team compositions. Furthermore, since employees tend to establish digital collaboration with socially connected colleagues, researchers have also started to explore the role of social networks as antecedents of ECT use in recent years. For instance, in a study of 1441 employees in an organization, Zhang and Venkatesh [60] found that peer support ties can significantly foster employees' use of the features of large-scale collaboration systems. Since employees in the workplace are usually embedded in multiple social networks with distinct influence mechanisms [5,44], it is highly likely that ECT use would be driven by multiple social network ties. However, limited studies have explored the impact of multiple social network ties on ECT use. Thus, there is a need to revisit the effects of multiplex social networks on ECT use.

2.2. Different types of social networks and ECT use

A social network comprises a set of actors and social ties among them [16]. Given the limited existing studies on the effects of various types of social networks on ECT use, we slightly expanded the scope of our

literature review and summarized the existing studies focusing on the impact of social networks on technology use in general. A summary of key findings from recent years is presented in Table 1. In most of these studies, social ties on the positive side (e.g., advice ties) were found to be positively related to technology use [48,60]. However, certain nuanced network structures of positive social ties or relations on the negative side (e.g., hindrance ties) were found to be negatively related to technology use [20,52]. Although all studies considered at least one type of social network ties and a few studies started to explore the effects of multiple social network ties, there is a neglect of their joint effects on technology use. As the only exception in the reviewed studies, Sykes and Venkatesh [47] examined the interaction effects between two social networks on technology use and operationalized the interactions as the overlapping of social ties from different networks. Considering the lack of studies on multiple social networks, especially the interaction effects of different networks, several scholars have called for research to integrate multiple types of social networks within one research framework to explain technology use [48,58]. In addition, there is a lack of study on the use of ECT, and most technological systems considered in previous studies, such as enterprise content management systems and enterprise resource planning systems, involve just some or even no social interactions. Instead, ECT use may be more deeply interwoven with the various social networks in which all potential users of ECT are embedded.

To fill this gap, this study aims to examine how multiple social networks jointly affect ECT use. We considered three social networks, including advice, friendship, and communication networks, which were found to be closely associated with technology use [47,48,53]. In addition, these three networks are closely related to each other and distinct from each other. For instance, the advice network and the friendship network capture relatively stable work-related and social-related connections among individuals, which indicates whom employees considered their advisors or personal friends at work [5]. In contrast, the communication network arises from actual communication behaviors and reflects the flow of resources among employees [59]. As a result, certain communication activities may also be triggered by advice and friendship ties. The interconnections and differences between these three social networks make it important to explore their interaction effects on ECT use.

2.2.1. Advice networks

Advice networks comprise the relationships developed for the transfer of information, expertise, and assistance for accomplishing work-related tasks [14,37]. Given the directional nature of advice networks [14], this study distinguishes between advice-seeking and advice-sought ties from advice networks. For advice-seeking ties, employees who have a large number of advisors possess more sources of advice in the workplace [58] and are more likely to turn to colleagues for advice or help when facing problems [60]. As ECTs support collaboration without spatial constraints [21,42], we expect that employees with more advice-seeking ties also use ECTs more frequently to garner advice, which may reinforce the further use of ECTs [1,34,41]. Similarly, for advice-sought ties, employees who are approached by many colleagues for advice are considered experts [45], and they may also receive many requests digitally through ECTs. The experience of using ECTs would help them develop technical skills in using ECTs and encourage increased ECT use [58]. In addition, after using ECTs to provide advice, experts are more likely to receive positive feedback from the same channel, which encourages them to engage in ECT use more frequently [60]. In summary, advice-seeking and advice-sought ties are considered to be positively related to ECT use.

2.2.2. Friendship networks

Friendship networks comprise relationships involving the sharing of social and emotional support [37,50], which are often considered symmetric and mutually agreed upon [33]. Employees with a large number of friendship ties at work tend to be more enthusiastic in

Table 1
Key studies on the relationships between social networks and technology use.

Studies	Year	Network	Network Interaction	Technology	Main findings
Sykes, Venkatesh and Gosain [48]	2009	Help-giving network, Help-seeking network	No	Enterprise content management system	Help-giving ties and help-seeking ties are positively related to technology use.
Magni, Angst and Agarwal [20]	2012	Advice network	No	Customer relationship management system	Advice network closure and bridging have opposite effects on technology use.
Venkatesh and Sykes [55]; Venkatesh, Sykes, Rai and Setia [54]; Venkatesh, Sykes and Zhang [56]	2013; 2019; 2020	Advice network	No	Internet-enabled kiosk in a rural area	Advice network centrality has a positive effect on technology use. Strong and weak advice network centrality have opposite effects on technology use.
Venkatesh, Rai, Sykes and Aljafari [52]	2016	Advice network, Hindrance network	No	E-Health kiosk	Advice ties and hindrance ties have opposite effects on technology use.
Venkatesh, Shaw, Sykes, Wamba and Macharia [53]	2017	Communication network	No	Internet-enabled kiosk in a rural area	Communication ties to the family and community and communication ties to men in power have opposite effects on technology use.
Robert Jr. and Sykes [36]	2017	Advice network	No	Enterprise content management system	Advice network ties have positive effects on technology use.
Sykes and Venkatesh [47]	2017	Advice network, Impeding network, Friendship network, Acquaintance network	Yes	Enterprise resource planning system	Acquaintance-advice ties and friend-impeding ties have opposite effects on the deep structure use of technology.
Wu, Choi, Guo and Chang [58]	2017	Advice network	No	Electronic medical record system	Advice-seeking closure and advice-giving closure have opposite indirect effects on technology use.
Zhang and Venkatesh [60]	2017	Peer support network	No	Knowledge management system	Help-seeking and help-giving ties are positively related to technology use.

conveying their caring to colleagues in the workplace [22]. ECTs provide opportunities for them to provide social support to other colleagues in a timely way even when they are not at the same physical location [46]. In addition, friendship ties are often formed among employees with similar knowledge, interests, and values at work [37,47] and usually result in mutual trust and shared norms [57]. As a result, employees are more likely to collaborate with their friends on ECTs to augment face-to-face interaction when the latter is infeasible or inconvenient. Thus, friendship ties are considered to be positively related to ECT use.

2.2.3. Communication networks

Communication networks capture the overall communication patterns among employees represented by their daily communication activities [60], which is often treated as undirected since communication activities are often carried out mutually among employees. Considering that the frequency of communication activities varies widely between employees, we followed previous studies [10,12,56] and distinguished between strong and weak communication ties to gain a more fine-grained understanding of the role of communication networks in ECT use.

Strong communication ties are characterized by close and intense ties, while weak communication ties are characterized by infrequent and distant ties [4,59]. Strong communication ties are often developed between employees with a closer work arrangement, and employees are likely to feel more comfortable when collaborating with closely communicated colleagues [59]. Additionally, employees who have many strong communication ties generally have higher confidence and ability to communicate with colleagues; thus, they are more likely to embrace ECTs in the work environment [13,38,60]. On the other hand, weak communication ties often connect heterogeneous employees with different divisions of labor in the organization [4,59]. Through weak communication ties, employees can gain diverse information to broaden their horizons in the workplace [11,59]. Thus, employees with many weak communication ties are more likely to use ECTs to obtain resources. In summary, both strong and weak communication ties are considered to be positively related to ECT use.

2.3. Configurational approach to studying ECT use

This study aimed to thoroughly explore how advice, friendship, and communication networks jointly influence ECT use from a holistic configurational perspective, as depicted in Fig. 1. To handle the complex interaction relationships between these social networks, we adopted a configurational approach called qualitative comparative analysis (QCA). QCA focuses on the combined effects of multiple conditions, called “configurations”, on a given outcome, rather than isolating the net effects of independent variables as in correlation-based approaches [8,31,32]. QCA is grounded in set theory and Boolean algebra and features nonlinearity, equifinality, and asymmetry [8,31]. Nonlinearity means that the impact of a certain condition on an outcome may vary according to the presence or absence of other conditions. Equifinality means that there may be several valid and different configurations

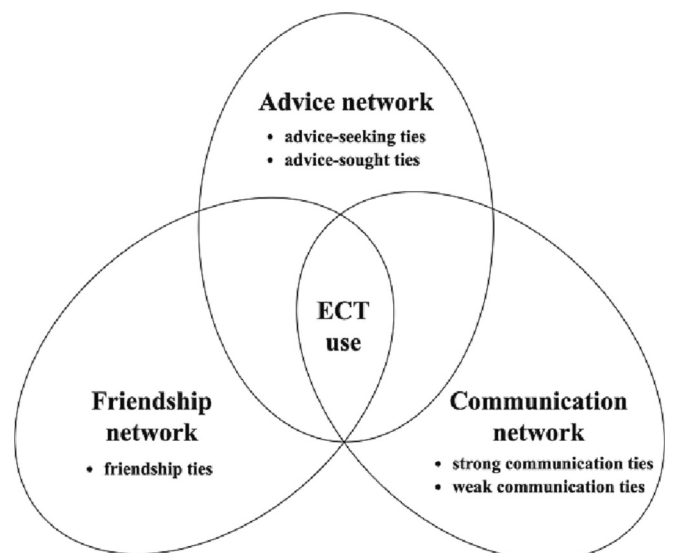


Fig. 1. The configurational model of ECT use.

leading to the same outcome. Finally, asymmetry means that the association between the presence of a condition and a given outcome (e.g., high ECT use) does not necessarily imply that the absence of this condition would lead to the opposite outcome (e.g., low ECT use). These unique features make QCA a suitable tool to explore the complex and intertwined relationships between multiple conditions and a given outcome, such as multiple social network ties and ECT use.

QCA can be categorized into crisp-set QCA, multi-value QCA, and fuzzy-set QCA according to the attributes of processed variables [35]. The techniques of crisp-set QCA and multi-value QCA are used for the analysis of dichotomized variables and multi-value variables, respectively. However, the transformation of continuous variables into categorical variables may lead to significant information loss. To address this limitation, fuzzy-set QCA (fsQCA) was developed by converting continuous variables into a continuum between “full nonmembership” and “full membership” [18,23], which greatly reduces the information loss in data transformations. In this study, fsQCA was chosen among the three methods to better maintain information in the observed data.

3. Methodology

3.1. Sample and data collection

The data used in this study were collected from a Fortune 150 international company’s branch offices in China. The company made a great effort to introduce and promote an internal enterprise collaboration technology, which had been implemented for several years by the time we collected the data. This ECT comprises comprehensive functions (e.g., screen sharing and video sharing) to support online conferencing among multiple employees. Additionally, this technology is the company’s only officially designated ECT, and all employees in this company are encouraged, but not mandated, to use it in the workplace, which provides an opportunity for us to better explore the associations between employees’ social ties and their elective use of ECTs.

This study targeted all employees in the HR department as a social unit because HR work requires employees to carry out extensive collaboration on a daily basis [7]. We collected social network data through an online survey, and ECT use data through the digital trace extracted from the system server’s logs. With independent and dependent variables collected from different sources, the common method bias was reduced [29]. To improve the response rate of the online survey, employees were allowed to fill out the survey during work time. The social network survey was distributed in December 2019, and the survey collection lasted for approximately one month, which provided sufficient time for the employees to complete the survey. There were 198 employees in the HR department of this company, and 183 employees completed the social network survey. Among the employees who completed the survey, five were removed because they had no ECT usage record in the digital trace data. As a result, we had 178 employees as the final sample. The response rate exceeded the threshold of 80% required for social network analysis [16]. Of these 178 employees in the HR department, 153 (85.96%) were women. Their ages ranged from 25 to 53 (mean = 37.20 years, s.d. = 6.86), and seniority ranged from 0 to 26 (mean = 7.67 years, s.d. = 5.95).

Digital trace data on ECT use were collected for six weeks, from December 10, 2019 to January 17, 2020, with the starting time later than the distribution of the social network survey. For privacy considerations, digital trace data did not include any specific communication content or the real identity of the participants from the online conferencing sessions. The system log recorded the ECT use in two files. The first file contained information on the coded employee ID and the session ID of the online conference attended by the employee. The second file recorded the details of the online conferencing sessions, including the session ID, the start time of the session, the number of participants, and the duration of the session. A combination of these two files provides a full picture of the employee’s ECT use records.

3.2. Measurement

3.2.1. Dependent variable

ECT use. This study used the frequency of participation in online conferencing sessions extracted from the digital trace data to measure ECT use [3], which is more objective than the self-reported measure and can effectively eliminate retrospective bias [26]. Before calculating the frequency of ECT use, we preprocessed the digital trace data based on the following rules. First, we removed the record of the online conferencing sessions held during the weekends or holidays. Second, we chose only sessions with no more than seven participants because a session with too many participants is more likely to be an information dissemination meeting for a larger group instead of a collaborative one [24]. Third, we removed sessions involving fewer than two HR employees, which had limited relevance to the social networks comprised of HR employees. Fourth, we combined multiple records generated for the same session because of the re-entering of the users to the same session or the restarting of a session after unexpected disconnection. After preprocessing, we calculated the frequency of ECT use by employees in collaboration with their HR colleagues.

3.2.2. Independent variables

We used a roster-based approach to collect social network data through online surveys. Every participant was provided a roster with the names of all employees in the HR department and was asked to identify all fellow employees with whom they had advice, friendship, and communication ties. Only one item was used to measure each social network to avoid placing too much burden on the participants [5]. Then, we used the *igraph* package in R (version 4.1.0) to separately construct three 178×178 matrices for the advice, friendship, and communication networks [6].

Advice-Seeking Ties and Advice-Sought Ties. We constructed the advice network by asking participants to indicate the colleagues they would go to for help or advice at work [14]. Specifically, we used out-degree centrality (i.e., the total number of nominations submitted by each employee) to measure employees’ advice-seeking ties and in-degree centrality (i.e., the total number of nominations received by each employee) to measure employees’ advice-sought ties.

Friendship Ties. We constructed the friendship network by asking participants to indicate the colleagues whom they considered personal friends [2]. To symmetrize the friendship network, if either one of the employees of a pair reported the other as a friend, the friendship tie between them would be counted [22]. Then, we used the degree centrality (i.e., the total number of friendship ties) to measure a person’s friendship ties.

Strong Communication Ties and Weak Communication Ties. The communication network was constructed by asking participants to indicate how much time they spent communicating with colleagues during a regular week on a 7-point Likert-type scale (from “1 = less than an hour” to “7 = more than 15 hours”) [50]. Participants were expected to leave the row blank if they did not communicate with a colleague. To symmetrize the communication network, the tie between employee A and employee B was assigned the higher strength of the tie from A to B and the tie from B to A. Then, we followed previous studies [38,56] and used the median of the tie strength (i.e., “4 = from 6 to 9 hours per week”) as the cutoff to distinguish between strong and weak communication ties. Then, we used the degree centralities to capture the numbers of strong and weak communication ties for each individual.

Fig. 2 visualizes the advice, friendship, and communication networks among the 178 employees in the HR department. To determine whether any two networks were significantly related, we conducted the quadratic assignment procedure (QAP) analysis [17], and the results can be interpreted in a similar way as in the Pearson correlation analysis. As shown in Table 2, the QAP correlations among the advice, friendship, and communication networks were all significant, with absolute values lower than 0.4. The results indicated that there existed certain overlaps

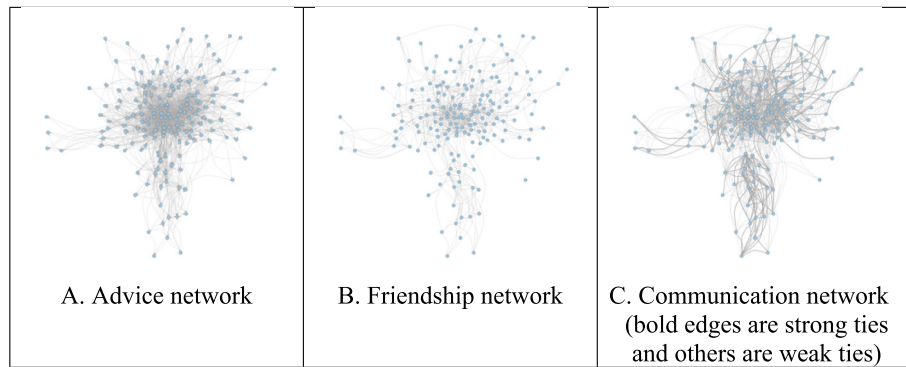


Fig. 2. Visualization of social networks.

Table 2
QAP results of different social networks.

Social networks	1	2	3.1	3.2
1. Advice network	–			
2. Friendship network	0.356***	–		
3.1. Strong communication network	0.253***	0.358***	–	
3.2. Weak communication network	0.366***	0.316***	–0.035	–

Note: *** $p < 0.001$.

between different social networks, but each still had its own distinct structure.

3.3. Analysis procedures

We followed the standard analytical procedure of fsQCA for data analysis [8]. First, we conducted the calibration process that converted the original values of all variables, including employees' degree centralities in different social networks and their ECT use frequencies, into fuzzy membership scores. For each variable, three anchors for “full membership”, “crossover point”, and “full nonmembership” were determined and used to generate the fuzzy membership scores. Values higher than the “full membership” threshold are coded as 1, values equal to the “crossover point” are coded as 0.5, values lower than the “full nonmembership” threshold are coded as 0, and all other values are coded as numbers between 0 and 1. In general, a value above 0.5 indicates the “presence” of a condition, and a value below 0.5 indicates the “absence” of a condition. The values represent the extent of presence or absence. Furthermore, the fuzzy membership score of 0.5 poses the maximum ambiguity and indicates the same probability of the presence or absence of a certain condition. Consequently, the fuzzy membership score of 0.5 cannot be processed in the fsQCA, and we followed previous studies and subtracted a small constant of 0.001 from all scores of 0.5 to prevent the exclusion of such cases because of the fuzzy membership score conversion [8]. In this study, to avoid introducing excessive subjective judgment, we used the direct method of calibration to decide the anchors based on the data distribution. In particular, we adopted a strict standard as proposed in Lee [18] and used the 95th, 50th, and 5th percentiles as the calibration anchors for “full membership”, “crossover point”, and “full nonmembership”. After indicating the calibration anchors in the fsQCA 3.0 software [31], the system transformed the raw values of each variable into fuzzy membership scores.

Second, we constructed a truth table with a list of all possible 2^k combinations of conditions (i.e., configurations), where k is the number of independent variables [8]. In our case, using five social network measures as independent variables, with the presence and absence of each network measure, there are $2^5 = 32$ possible configurations or combinations of conditions. For instance, the presence of all five network ties is one of the 32 possible configurations. All the observed cases are then sorted into one of these configurations based on fuzzy set

operations. As a result, some configurations may have more cases, and others may have fewer. The outcome variable ECT use was also converted into fuzzy membership scores and can be used to classify the high ECT use cases and the low ECT use cases using the cutoff score of 0.5. Because of the asymmetric feature of fsQCA [39], separate analyses need to be conducted to identify different configurations that led to high ECT use and low ECT use.

A configuration is considered “sufficient” for a certain outcome when its presence would be very likely to lead to the outcome [19]. To operationalize the discovery of sufficient configurations for an outcome (e.g., high ECT use), the consistency and frequency of configurations are defined, and configurations with consistency and frequency values higher than certain thresholds are considered sufficient. Consistency captures the percentage of cases with the specific configuration associated with a certain type of outcome, e.g., high ECT use [40]. Frequency captures the number of cases covered by the specific configuration. As suggested by previous studies [15,23], we set thresholds of 0.85 for consistency and 2 for frequency to ensure the robustness and generalizability of the results. For instance, a configuration that had at least two cases and $>85\%$ of the cases associated with high ECT use was identified as a sufficient configuration for high ECT use. In this step, all sufficient configurations were identified, and only these were kept in the truth table for further analysis. A similar procedure was conducted to identify sufficient configurations for low ECT use.

As the final step, the Boolean algebra algorithm was used to logically simplify the identified sufficient configurations by removing redundant conditions in the truth table to form the final configurational solutions. Again, separate configuration simplification procedures were conducted for high and low ECT use analyses, which concluded the analysis procedures.

4. Results

The fsQCA results are presented in Table 3. Each column represents one specific configurational solution formula for high or low ECT use. A solid circle (●) indicates the presence of a condition, a crossed-out circle (⊗) indicates the absence of a condition, and a blank cell indicates that the presence or absence of a condition does not matter [31]. Additionally, large circles refer to core conditions that have a strong influence on a given outcome, and small circles refer to peripheral conditions that are less important and have a weaker influence on the outcome [8,27]. Each solution is thus a combination of conditions that can be present, absent, or “does not matter” and core or peripheral.

Table 3 also includes the fit indicators, including consistency and coverage, of each solution and overall solution. Consistency captures the proportion of cases in the configuration that is consistent with the outcome, and coverage captures the proportion of total cases with the outcome covered by the configuration. All solutions exhibited high consistency scores that were >0.8 , and the overall consistency scores were also high, with 0.836 for high ECT use and 0.823 for low ECT use.

Table 3
Configurations sufficient for high and low ECT use.

Variables	High ECT use				Low ECT use				
	Solution A1	Solution A2	Solution A3	Solution A4	Solution B1	Solution B2	Solution B3	Solution B4	Solution B5
	Communicative consultant	Communicative newcomer	Friendless task-focused employee	Well-rounded star	Marginalized employee	Lone ranger	Dedicated advisor	Egocentric help-seeker	Silent friend
Advice-seeking ties		⊗	●	●		⊗	⊗	●	
Advice-sought ties	●		●	●	⊗		●	⊗	
Friendship ties		⊗	⊗	●		⊗	⊗	⊗	●
Strong communication ties	●	●		●			⊗	⊗	⊗
Weak communication ties	●	●	●		⊗	⊗			⊗
Consistency	0.867	0.866	0.854	0.887	0.846	0.873	0.871	0.899	0.871
Raw coverage	0.541	0.375	0.338	0.429	0.693	0.614	0.321	0.289	0.347
Unique coverage	0.051	0.042	0.048	0.023	0.072	0.018	0.028	0.008	0.006
Overall consistency	0.836				0.828				
Overall coverage	0.653				0.781				

The high consistency scores indicated that the cases in each solution or the overall solution were consistently associated with a certain outcome [30]. In addition, most solutions in this study performed well in terms of raw coverage and unique coverage. The solution coverage is similar to the R-squared in regression analysis, which indicates the extent to which a solution contains the cases that lead to a given outcome, and a higher value is generally preferred [31]. Since different solutions may contain overlap cases, fsQCA distinguishes between raw and unique coverage, where the former considers all contained cases in a solution and the latter focuses on those cases that can only be explained by this solution [27]. The overall coverage captures the percentage of cases that lead to a given outcome covered by the combination of all discovered solutions. In our analysis, for high ECT use, all identified solutions jointly covered 65.3% of the cases, and for low ECT use, all identified solutions jointly covered 78.2% of the cases.

An overview of the solutions for high ECT use and low ECT use clearly proves the asymmetric nature of the effects of different network ties. For instance, the presence of advice-sought ties and both strong and weak communication ties lead to high ECT use (as in solution A1), but the mirror opposite solution with all three types of ties absent is not a sufficient solution for low ECT use. In fact, none of the solutions mirror each other for high and low ECT use. In addition, it is counterintuitive that the presence of advice-seeking ties, advice-sought ties, and friendship ties are associated with both low ECT use (as in solutions B3, B4, and B5) and high ECT use (as in solutions A1, A3, and A4). In other words, the impacts of these conditions vary according to the presence or absence of other conditions, which highlights the nonlinear nature of the joint effects of different social network ties on ECT use. Both observations justify our decision to explore the complex effects of different social network ties using the configurational approach. Next, we provide interpretations for each of the configurational solutions.

4.1. Configurations for high ECT use

Solution A1 is characterized by the peripheral presence of advice-sought ties and the core presence of strong communication ties and weak communication ties. This solution describes those employees who have superior expertise and actively communicate with colleagues in their daily work, and we label this solution the communicative consultant. These employees are more likely to transfer information and expertise to their colleagues and thus use ECT more frequently.

Solution A2 is similar to solution A1 in the presence of both strong

and weak communication ties but is also characterized by the absence of advice-seeking ties and friendship ties. We traced down all six employees in this solution and found that four of them were relatively new to the organization and were employed for less than two years. At least for them, the lack of advice-seeking ties and friendship could potentially be explained by their limited tenure in the organization. Given this observation, we label this solution the communicative newcomer. Despite the lack of connections with experts and friends at work, active communication needs prompt them to use ECT frequently.

Solution A3 is characterized by the presence of advice-sought ties, advice-seeking ties, and weak communication ties along with the absence of friendship ties. These employees are very popular in the advice network but lack friendship ties, and we label this solution the friendless task-focused employee. In this solution, the lack of friendship ties and the strong presence of advice ties jointly facilitate ECT use.

Solution A4 is similar to solution A3 in its core presence of advice ties but also has the presence of friendship and strong communication ties. We labeled this solution the well-rounded star. By holding central positions in multiple social networks, these employees are more likely to use ECT frequently to maintain their structural advantages in social networks.

Across the above four solutions, two broad solutions emerge for high ECT use. The first one includes both strong and weak communication ties as core conditions (as in solutions A1 and A2), and the second one includes both advice-seeking and advice-sought ties as core conditions (as in solutions A3 and A4). These two broad solutions underscore the critical roles of communication networks and advice networks in facilitating ECT use. However, the presence of ties from these two networks did not yield sufficient solutions. Instead, the presence of communication ties needs to be combined with the presence of advice-sought ties in solution A1 and the absence of advice-seeking ties and friendship ties in solution A2 to guarantee high ECT use. In solutions A3 and A4, the presence of advice ties needs to be combined with either the absence of friendship ties and the presence of weak communication ties or the presence of both friendship ties and strong communication ties to produce sufficient solutions for high ECT use. These two solutions also displayed the dynamics in the roles of communication ties when combined with either the presence or absence of friendship ties.

4.2. Configurations for low ECT use

For low ECT use, five sufficient solutions were identified, as shown in

Table 3. Solution B1 is characterized by the absence of both advice-sought ties and weak communication ties. This solution portrays employees who are rarely the source of advice in the workplace and are barely connected with colleagues via weak communication ties, and we label this solution the marginalized employee. The lack of contact with colleagues in serving as advisors and the lack of communication jointly lead to low ECT use.

Solution B2 is characterized by the absence of advice-seeking ties, friendship ties, and weak communication ties. This solution depicts those employees who rarely rely on colleagues for work-related advice and social support and hardly connect with colleagues through weak communication ties, and we label this solution the lone ranger. These employees may be less motivated to collaborate with colleagues, which may lead to low ECT use at work.

Solution B3 and solution B4 comprise the same elements of advice-seeking ties, advice-sought ties, friendship ties, and strong communication ties, where only advice-seeking ties are present in solution B3 and only advice-sought ties are present in solution B4, while others are absent for both solutions. Employees who fall into both solutions lack connections with other colleagues in terms of friendship and strong communication. In addition, employees in solution B3 are rarely advice seekers but often serve as advice givers. In comparison, employees in solution B4 are rarely advice givers but often serve as advice seekers. Given these characteristics, we label solution B3 the dedicated advisor and solution B4 the egocentric help-seeker. The lack of close bonds with colleagues in friendship and strong communication together with the limited exchange of advice is likely to result in less ECT use in the workplace.

Solution B5 describes cases with the presence of friendship ties but the absence of both strong and weak communication ties. These employees are well connected with friends but are not actively involved in communication activities, and we label this solution the silent friend. Despite the existence of connections with personal friends at work, limited activities in both strong and weak communication still result in low ECT use.

Overall, one pattern shared by all five solutions for low ECT use is the absence of communication ties appearing in all solutions, such as either strong or weak communication ties or both. In comparison, the presence and absence of advice ties and friendship ties can both be associated with low ECT use when combined with other conditions. This finding suggests that encouraging communication with colleagues could be an effective intervention to reverse low ECT use.

4.3. Robustness tests

Following previous studies [19,43], we further conduct several robustness tests to validate the stability of the solutions. Since our analysis used stricter thresholds whenever possible, we tried to relax these subjective choices in the first two robustness tests. We also tested the results by changing the operationalization of the outcome variable in the last test. Taking high ECT use analysis as an example, we first relaxed the requirements and used the 85th, 50th, and 15th percentiles as the calibration anchors in generating fuzzy membership scores. The solutions sufficient for high ECT use remained the same. Second, we adopted different thresholds for frequency and consistency to generate the truth table. With the less demanding threshold of one for frequency, solutions A1, A3, and A4 for high ECT use were recovered, together with two more new solutions very similar to A2. After lowering the threshold of the consistency level from 0.85 to 0.8, all solutions were also recovered with only minor differences. Third, we measured ECT use using the total durations of online conferencing sessions instead of the frequencies. With this dramatic change in the outcome variable, solutions A1 and A3 were still recovered as sufficient for high ECT use. Similar procedures were conducted to examine the robustness of solutions for low ECT use, and the generated solutions were also similar to the ones in Table 3, thus supporting the overall robustness of our findings.

5. Discussion

This study aims to investigate how multiple social networks, including advice, friendship, and communication networks, collectively influence ECT use. Using the technique of fuzzy-set qualitative comparative analysis (fsQCA) and social network analysis (SNA), this study identifies multiple equifinal solutions sufficient for high ECT use and for low ECT use. Our findings indicate that a single type of social network tie is not enough to predict high or low ECT use, and there were rich insights gained by considering the combined effects of multiple types of social network ties. More specifically, on the one hand, the presence of a single type of social tie can lead to opposite outcomes (i.e., high and low ECT use) when combined with other types of social ties. For instance, the presence of advice-sought ties was found to be part of the configurations for both high ECT use (as in solution A1) and low ECT use (as in solution B3). On the other hand, the absence of certain types of social ties (i.e., friendship ties and advice-seeking ties) might also be associated with high ECT use in the presence of other social ties, as in solutions A2 and A3. Furthermore, our findings revealed that the configurations sufficient for high ECT use and low ECT use are not the opposite, and such asymmetry indicates that the configurations for promoting high ECT use may not be appropriate for preventing low ECT use.

5.1. Implications for theory

Our research offers several important theoretical implications. First, we incorporate multiple social network ties within an integrated framework and provide theoretical insights regarding their complex joint effects on ECT use. Prior relevant studies primarily examined the roles of different social network ties in technology use separately [48,58,60], and the understanding of how multiple social network ties collectively and structurally influence ECT use was limited. To address this limitation, our study identified three interrelated but distinct types of social networks, including advice, friendship, and communication networks, and investigated how multiple social ties from these networks collectively influence ECT use. This study reveals several configurational patterns of these social ties for engendering high and low ECT use and elaborates on the complementary relationships among advice, friendship, and communication network ties. Overall, this study provides in-depth and rich insights into the combined effects of multiple social network ties on ECT use.

Second, by applying a configurational perspective, this study further our understanding of the roles of advice, friendship, and communication networks in facilitating ECT use. For advice networks, this study suggests that advice-sought ties and advice-seeking ties in the configurational model might induce more limited positive effects than suggested by previous studies on ECT use [48,55]. In particular, the presence of advice-sought ties and advice-seeking ties only appear as core conditions in two of the four configurations sufficient for high ECT use. Furthermore, the presence of advice-seeking ties or advice-sought ties also appears in the configuration associated with low ECT use. For friendship networks, this study responds to previous calls for gaining deeper insights into the role of friendship networks in technology use [55,58]. Our results showed that friendship ties appeared in three of the four configurations for high ECT use. These findings highlight the importance of friendship networks in shaping employees' ECT use. For communication networks, this study sheds light on the different roles between strong and weak communication ties. More importantly, our findings reveal that the need for either strong communication ties, weak communication ties, or both to promote ECT use depends on the combinations of other social network ties.

Third, our work also contributes to the methods by integrating social network analysis (SNA) and fsQCA to explicitly capture the complex interaction effects among multiple social networks. There is a great deal of social network research exploring the interaction effects of different

social networks to gain more valuable insights [49,59]. As the variety of social networks increases, it will become especially vital to explore the joint effects among multiple social networks. Grounded in set theory and the Boolean algebra algorithm, QCA enables us to embody the nonlinear, equifinal, and asymmetric effects of multiple social networks. As such, the integration of SNA and QCA provides a distinctive lens through which to explore the joint effect of multiple interdependent social networks.

5.2. Implications for practice

This study also provides practical implications for managing social network ties in the workplace. Our findings indicate that the presence of social ties appears more often in the solutions that lead to high ECT use, while the absence of social ties often leads to the opposite; thus, there is a need to cultivate social ties between employees within the organization to promote ECT use. More importantly, employees in the workplace are embedded in multiplex social networks; thus, it is suggested that managers pay more attention to the synergy between different social network ties to promote ECT use. Our work identifies several combinations of multiple common social network ties in the workplace that are associated with high ECT use that managers can use as references for forming employees' social ties. As an example, for employees who already have many advice-seeking and advice-sought ties but lack friendship ties, developing weak communication ties rather than strong communication ties would better help promote their ECT use. Thus, managers are expected to carry out targeted strategies for different employees regarding the development of social ties. In summary, understanding configurational patterns of social network ties associated with high and low ECT use can bring actionable and practical insights into promoting ECT use and digital collaboration between employees within the organization.

5.3. Limitations and future research

This study, like others, inevitably has some limitations. First, because of the social nature of ECT use [21], this study only focused on social network ties as the antecedents of ECT use. Additional factors, such as personal characteristics (e.g., demographics and computer self-efficacy) and technical characteristics (e.g., usefulness and ease of use), and their joint effects on ECT use must be explored in future research. Second, this study implemented a lean measure of ECT use, but future research should incorporate richer measures of ECT use, such as deep use and exploratory use of ECTs [47], to yield other interesting insights. Third, we encourage future studies to take a more nuanced treatment of social networks. In particular, the communication network in this study includes overall communication activities among employees, and future studies can further distinguish between work-related and social-related communication networks based on the communication content or purpose. Additionally, the advice network in this study refers specifically to the advice-seeking network, future studies can collect both advice-seeking and advice-giving network data to gain a more complete measurement of advice network ties. Finally, this study only considers three social networks that were common in previous social network studies, and we expect future studies to integrate more types of social networks, such as hindrance networks and acquaintance networks, to gain a more detailed understanding.

6. Conclusion

By integrating the fsQCA and social network analysis approach, this study identifies several specific configurations of advice, friendship, and communication network ties associated with high and low ECT use. Our findings highlight the importance of incorporating multiple social network ties to jointly explain ECT use and provide sufficient evidence on the asymmetry between the configurations for high and low ECT use.

Overall, our work paves a new avenue to unpack the complex relationships among multiple social network ties in facilitating ECT use, and we encourage more future research to apply a configurational perspective to advance knowledge on the influence of social networks on technology use.

CRedit authorship contribution statement

Mengxiao Zhu: Conceptualization, Validation, Formal analysis, Data curation, Funding acquisition, Writing – original draft, Writing – review & editing. **Lin Liu:** Conceptualization, Methodology, Software, Formal analysis, Validation, Writing – original draft, Writing – review & editing. **Ruoxiao Su:** Software, Formal analysis, Investigation, Visualization. **Noshir Contractor:** Data curation, Investigation, Resources, Supervision, Writing – review & editing.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Data availability

Data will be made available on request.

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Dr. Mengxiao Zhu is a Distinguished Research Professor in the School of Humanities and Social Sciences at the University of Science and Technology of China (USTC). She earned her Ph.D. Degree in Industrial Engineering and Management Sciences from Northwestern University. Her current research focuses on computational social science, team process, and digital collaboration. She has published in Social Networks, and Computers and Education.

Lin Liu is a Ph.D. student in the School of Management at the University of Science and Technology of China. He received his B-S in Information Management and Information Systems from Dongbei University of Finance and Economics. His research interests focus on leveraging social networks to understand technology diffusion in the organization.

Ruoxiao Su is a master student in Journalism and Communication at the University of Science and Technology of China. She received her BE in Polymer Materials and Engineering and BA in Communication from the University of Science and Technology of China. Her research interests focus on organizational communication, social network, and computational social science.

Noshir Contractor is the Jane S. & William J. White Professor of Behavioral Sciences in the McCormick School of Engineering, the School of Communication, and the Kellogg School of Management at Northwestern University. He received the Distinguished Alumnus Award from the Indian Institute of Technology, Madras where he received a Bachelor's degree in Electrical Engineering. He has a Ph.D. from the Annenberg School of Communication at the University of Southern California. He investigates how social and knowledge networks form and perform. He is the President-Elect of the International Communication Association. He is also a Distinguished Scholar of the National Communication Association and a Fellow of the American Association for the Advancement of Science, the Association for Computing Machinery, and the International Communication Association. He received the Lifetime Service Award from the Organizational Communication & Information Systems Division of the Academy of Management. His research has been published in various academic journals including Science, Nature, Proceedings of the National Academy of Sciences of the United States of America, Academy of Management Journal, Organization Science, Journal of Applied Psychology, and Academy of Management Review.