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Efficacy in Technology–Mediated Distributed Teams

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Abstract

The concept of collective efficacy within virtual teams has yet to be studied. This study developed and rigorously validated a domain-specific measure of collective efficacy, entitled virtual team efficacy, within a comprehensive research framework. Over a two-year period we collected field study data from multiple samples of information systems project teams—in all, 52 virtual teams comprising 318 students from the United States, Great Britain, and Hong Kong. As we hypothesized, group potency and computer collective efficacy act as antecedents to virtual team efficacy, and virtual team efficacy is in turn predictive of perceptual and objective measures of performance. Further, consistent with efficacy theory, we also find that virtual team efficacy acts on performance outcomes through specific mediating processes. This paper contributes to the academic and practitioner communities by providing a comprehensive model of virtual team efficacy and performance and by providing validated instrumentation that can be immediately applied during further research in this area.

Introduction

The use of virtual teams to accomplish work objectives is becoming increasingly prevalent in today's organizations [26, 32, 33, 47-49, 53, 54]. This trend is expected to continue [46] for a variety of reasons, including reduced travel costs, increased organizational benefits from using the best talent regardless of location [10, 20, 22] and the greater availability of sophisticated technology to support such distributed work [8, 61, 73].

Given the growing use of virtual teams, understanding the factors that affect their performance is becoming increasingly important. Past information systems research has examined a variety of virtual team performance measures, including decision effectiveness [69], leadership effectiveness [38], and team performance [54, 68]. Researchers have also studied a variety of factors proposed to be at least partially responsible for observed performance differences in such teams. For example, information systems researchers have investigated how group characteristics such as trust [9, 32, 33, 62, 65], leadership [38, 63], and communication [32, 33, 68] can influence group outcomes. Further, researchers have also investigated how structural components influence group interactions, for example how factors such as temporal constraints [53] and the relative strength of subgroups [59] can influence virtual team productivity.

One area of investigation that may provide additional insights on virtual team performance involves team members' collective efficacy beliefs. Efficacy, the belief in one's ability to accomplish a particular behavior, has long been known to influence the behaviors [3, 4] and performance [4, 15-17, 35] of individuals. More recent research, however, has applied the concept of efficacy to groups [24, 74], finding that a group's beliefs about its ability to accomplish a particular behavior influence group outcomes such as effectiveness, satisfaction, and performance [23, 34, 37, 66]. Given that virtual teams must also function as groups, we should expect that team member beliefs in the team's ability to work in virtual environments may similarly influence virtual team outcomes; however, this relationship has not been previously investigated.

This study addresses the following research question: How does efficacy operate in the context of virtual teams? More specifically, this paper explores antecedents that influence the formation of efficacy, as well as the consequences of efficacy in terms of both mediating and ultimate outcome variables in distributed technology-mediated teams. In answering this question, this paper contributes to the information systems literature in a number of ways. First, we believe this study is the first application of collective efficacy to the context of virtual project teams operating in distance-based, technology-mediated environments. Such an application is significant to the academic and practitioner communities because it may identify an important component missing from existing models of virtual team performance. Second, developing and rigorously testing an instrument designed specifically to measure the efficacy perceptions of virtual team participants provides a measure that researchers interested in the performance of virtual teams can immediately apply. Third, our observations of virtual team efficacy within a comprehensive research model, using both perceptual and objective measures of performance, provide valuable insight into how collective efficacy operates in such environments.

This paper is organized as follows. First, a research model is presented as a foundation for the current study. Next, the virtual team and collective efficacy research is reviewed, and the concept of virtual team efficacy is developed. Then the virtual team efficacy instrument is developed and tested for its predictive properties at the group level of analysis using perceptual and actual performance measures. The paper concludes with a report of our results and discussion of the limitations, implications, and possibilities for future research related to this topic.

Research Model

Researchers have consistently shown that efficacy, an important component of social cognitive theory [3, 4], influences performance in a variety of contexts [24, 41, 60]. In this research, we develop the concept of virtual team efficacy and examine a select group of antecedents and consequences. Answering calls in the literature for studies that investigate the relationship between general and specific measures of efficacy [28], we examine the influence of two more general forms of efficacy—group potency and computer collective efficacy—as antecedents to the more context-specific virtual team efficacy. Group potency, consistent with past research [24], is *the belief in the general effectiveness of the group across multiple situations*. Computer collective efficacy is defined in the current study as *the belief in the group's general computer competency*. Both of these more general, but related, forms of efficacy should influence our more context-specific virtual team efficacy, which we define as *the belief in a team's ability to use communication technology to coordinate their activities across time and space*.

With regard to the specific consequences of virtual team efficacy, we examine the effect of virtual team efficacy both on perceptions of group outcomes through its influence on effort and on actual performance through its influence on communication level. The hypotheses for this research are reflected in the research model shown in Figure 1. Table 1 describes the research constructs.

[Insert Figure 1 Here]

[Insert Table 1 Here]

Theoretical Background

To gain a complete understanding of how efficacy operates in the context of virtual teams, we first discuss factors that past research has linked to virtual team performance. We then turn our attention to efficacy, discussing efficacy specifically within the context of groups, different conceptualizations of collective efficacy, and different methods for measuring it. Finally, we turn our attention to the concept of virtual team efficacy, discussing both antecedents and consequences within the context of our research model.

Virtual Team Research

A significant amount of research has been conducted in the areas of distributed work and virtual teams (for a reasonably extensive treatment of the subject, see Hinds and Kiesler [30] and Cohen and Gibson [14]). Although an exhaustive review of this literature is beyond the scope of the current study, it is important to discuss briefly how such research may apply to our study of efficacy in virtual teams.

Virtual teams are often distinguished by a lack of collocation and by the use of technology to interact [20]. Lipnack and Stamps [46, p. 18] acknowledge these features by defining a virtual team as "a group of people who work interdependently with a shared purpose across space, time, and organizational boundaries using technology." Although this represents a general definition of virtual teams, other researchers have more precisely defined virtual teams in terms of their physical distance, level of technology support, and amount of time spent apart while working on a task [26]. Johnson, Suriya, Yoon, Berrett, and LaFleur [36] describe virtual team interactions as being "geographically unrestricted." This definition does not preclude some group members from having face-to-face interactions as the group goes about its work but rather implies that interactions can occur in a variety of ways over time. Similarly, Griffith, Mannix, and Neale [27] indicate that virtual teams may contain a mixture of co-located and virtual members [26]. In this sense, "virtuality" can be represented as a continuum rather than a dichotomy [56].

The use of distributed teams by organizations is not a new phenomenon [40]. In fact, if *virtual* means "geographic dispersion," some authors suggest that entities such as the Roman Empire and the early Catholic Church operated as virtual organizations [58]. Many factors important to the success of these early organizations remain important to that of current-day distributed teams [58]. For example, recent research has shown how communication [42], conflict management [50, 52, 72], leadership [38], and trust [33, 62] affect virtual team interactions, factors that were likely just as critical then as now. Further, evolutionary changes in the technology used to facilitate such teams may make the creation of shared social settings [39] even more complex. Thus, effective study of virtual teamwork demands examination of factors focused both on the group and on the technology that influences the group's interactions.

Because of the importance of such factors, a virtual team's collective belief in its ability to use technology to overcome geographic dispersion may help to explain its performance outcomes. Thus, the related concept of collective efficacy [24, 37, 74] may be an important factor missing from existing models of virtual team performance. Providing conceptual evidence in this regard, researchers have linked the efficacy of groups to factors known to influence virtual team performance [4, 50]. For example, Mannix, Griffith, and Neale [50] suggest that transactive memory may influence collective efficacy, and that collective efficacy should in turn influence the ability of teams to manage conflict, a factor previously shown to influence the performance of virtual teams [54].

Such conceptual linkages may allow future researchers to develop more comprehensive models of performance that involve the efficacy of virtual teams. Because of space limitations, however, the current study cannot fully address how these factors may interact with virtual team efficacy. We do, however, present a brief discussion of the possibility of such relationships in the future research section of this paper. We now turn our attention to a discussion of the efficacy of groups.

Background on Efficacy within Groups

Efficacy at the group level represents a team's belief in its interactive and coordinative abilities [4]. These dynamics are responsible for the emergent properties of the group beyond the capabilities of the individual members. Although collective efficacy and self-efficacy differ in their unit of agency, both have similar sources, serve similar functions, and operate through similar processes [4].

Prior research has established that numerous factors may contribute to efficacy formation. Early research established that four primary sources of information are instrumental in the development of efficacy beliefs, including enactive mastery, vicarious experience, verbal persuasion, and physiological and affective states [2, 3]. Later research extended our understanding of efficacy, illustrating that a relationship may exist between one form of efficacy and another. For example, in education, Zimmerman et al. [76] found that broader, more general self-efficacy beliefs related to students' ability to learn were predictive of more focused, specific self-efficacy beliefs about academic achievement. Likewise, Chen [11] found general self-efficacy beliefs to be predictive of exam self-efficacy in an academic setting. Within the computing domain, Agarwal et al. [1] reported similar results, finding that general computer self-efficacy beliefs are predictive of more task-specific computer beliefs. Given the recognized parallels between self- and group efficacy [28], general measures of group efficacy may similarly be predictive of more specific measures of group efficacy.

A significant amount of research has also explored the consequences of collective efficacy—in particular, the relationship between collective efficacy beliefs and performance [2, 3]—in a variety of contexts, including education [60], sports [41], and organizations [24]. Although these studies have generally shown a direct relationship between efficacy and performance, additional research has established that efficacy beliefs act on performance through cognitive, motivational, affective, and selective processes [2, 3]. For example, cognitive processes such as visualizing negative outcomes may undermine performance, while motivational processes may influence performance through causal attributions (e.g., effort), outcome expectancies (e.g., rewards), and goal setting [4]. Affective processes such as anxiety may also influence performance. Finally, selection processes—involving the team's choice of a working environment best suited to its perceptions of its abilities—may influence performance if the group misreads either its abilities or the characteristics of the task [4].

Evaluating Efficacy within the Context of Groups

The literature routinely reports investigations of the influence of efficacy on group performance [74], but the ways in which group efficacy is conceptualized and measured remain varied. An understanding of both the different conceptualizations and the different methods used to measure group efficacy is important in considering the development of a virtual team efficacy measure. Thus, we discuss these issues here.

Different Conceptualizations of Efficacy in Groups

Researchers have used the terms *group potency* and *collective efficacy* [24, 28, 37] when referring to the efficacy of groups. Although these terms have sometimes been incorrectly used interchangeably, it is more generally accepted that group potency measures a group's perceived general effectiveness, while collective efficacy measures a group's perceived conviction that it can be successful in a specific domain [37]. As such, group potency and collective efficacy are distinct concepts: Group potency is most often used to predict groups' perceptions of their abilities across multiple domains, and collective efficacy is used to predict specific group outcomes in a given domain. Such usage is consistent with findings establishing domain-specific efficacies as having greater predictive power within a respective domain [4].

Different Methods for Measuring the Efficacy of Groups

In addition to the different conceptualizations of the efficacy of groups, there are also different methods for measuring collective efficacy—which do not necessarily align with the different conceptualizations discussed in the previous section. Rather, a given conceptualization can be measured in multiple ways, depending on the study. The most common method for measuring collective efficacy is to gather individual member perceptions of the group's ability and then use the nonaggregated or aggregated responses, depending on whether the outcome of interest is an individual or group-level outcome.

Although the literature proposes additional methods for measuring collective efficacy [24], we measure the various forms of efficacy in the current research by eliciting individual virtual team members' perceptions of their respective team's abilities, consistent with Bandura's [4, 5] recommendations for collective efficacy assessment. As discussed above, such a method allows for the prediction of individual-level outcomes (using nonaggregated member perceptions) and group-level outcomes (using aggregated member perceptions), depending on the absence or presence of group-level effects.

The Concept of Virtual Team Efficacy

Collective efficacy, like other forms of efficacy, is typically considered to be a domain-specific construct, meaning that the collective efficacy beliefs most closely aligned with the specific context will influence performance the most [28]. The specific context of interest in the current research is virtual teams; thus, the contextual measure of collective efficacy we are interested in is virtual team efficacy.

In the current study we are concerned with virtual teams whose members are not collocated and who must rely on technology to interact and are unable to meet physically as a complete team at any time during the project. This added complexity from using technology to overcome differences in space and time motivates our development of a context-specific measure of virtual team efficacy in this study. Building on past definitions of efficacy and examining collective efficacy in the context of the group's need to use technology to communicate over space and time, we define virtual team efficacy as *a group's belief in its ability to work together successfully in a noncollocated, technology-mediated environment*.

The Antecedents of Virtual Team Efficacy

The sources of efficacy information proposed by Bandura [3, 4] have been investigated as antecedents in models of collective efficacy [66] as outlined above. However, additional factors may provide valuable insight into the development of collective efficacy in virtual teams. Consistent with past research that has examined the relationship between more general forms of efficacy and more context-specific forms [1, 76], in this study we investigate two related but distinct general measures of collective efficacy as antecedents to virtual team efficacy.

We propose these specific relationships with the goal of providing an additional contribution to the academic literature by investigating the relationship between general and specific forms of efficacy [51] in the context of virtual teams. Specifically, we propose that group potency, a measure of the team's belief in its general effectiveness, will influence that same team's belief in its ability to perform in a virtual setting. Further, we propose that computer collective efficacy, a measure of the group's belief in its effectiveness using computers, will also influence the more contextually specific, but related, concept of virtual team efficacy. It should be noted, however, that we do not imply that these two antecedents are the only ones that may influence virtual efficacy formation. Rather we believe these are two important factors that allow us to examine the formation of virtual team efficacy in the current context.

Group Potency

Researchers interested in the performance of groups [24, 37, 74] have frequently used the group potency construct, defined as "a belief in a group about its general effectiveness across multiple tasks" [24]. Pursuant to our goals in this research, we develop a research model surrounding the concept of virtual team efficacy. To begin this process, we investigate the relationship between group potency, a general measure of a group's belief in its effectiveness, and virtual team efficacy, a context-specific belief in the group's ability to function as a virtual team. Consistent both with studies finding general self-efficacy beliefs to be predictive of more specific beliefs [1, 35] and with those acknowledging the similarities between self- and collective efficacy [4, 29], we propose that a team's belief in its general effectiveness should influence that same team's belief in its ability to perform in a more specific context (e.g., as a virtual team).

H1: Group potency has a direct, positive effect on virtual team efficacy.

General Computer Collective Efficacy

Similar to Bandura's conception of collective efficacy as an extension of self-efficacy [4], we see computer collective efficacy as a natural extension of computer self-efficacy to the group level of analysis. Computer self-efficacy (CSE) has been defined as "a judgment of one's capability to use a computer" [17]. Although computer self-efficacy has often been studied within the IS literature, we have found no attempt to measure computer efficacy at the collective level. Like general computer self-efficacy [16], computer collective efficacy is focused not on the efficacy related to a specific technology (e.g., efficacy related to using computer-mediated communications technology) but rather on proficiency with computers in general. Therefore, remaining consistent with the literature proposing a general to specific progression of efficacy [1, 11, 76], we propose that a group's belief in its ability to use computers will directly influence its belief in its ability to use technology to work together as a virtual team.

H2: Computer collective efficacy has a direct, positive effect on virtual team efficacy.

The Consequences of Virtual Team Efficacy

Virtual team efficacy may play an important role in predicting a variety of factors related to virtual team performance. Although the direct effects of efficacy on performance outcomes have often been studied, Bandura suggests that the influence of efficacy on performance outcomes often depends on various mediating processes [2, 4]. For the purposes of this study, we limit our discussion to the effect of virtual team efficacy on perceptual and actual group performance through the two mediating factors of effort and communication level, for both have been established as important in previous efficacy [6, 45] and virtual team research [33].

Perceptual Mediating Processes: Effect of Group Effort on Outcome Perceptions

Specific examples of the predictive powers of collective efficacy on group outcome perceptions include research by Gibson et al. [24], who found a positive relationship between collective efficacy and outcomes such as time to completion, group agreement, process effectiveness, and perceived effectiveness of the group's solution. Other studies [23, 37, 64] have also found a positive relationship between collective efficacy and group outcomes. As an example, in a study of group performance and development, Pescosolido [23, 37, 64] found collective efficacy to be positively correlated with several outcome variables, including willingness to continue as a group and perceived learning. Similarly, in a meta-analysis of the collective efficacy and group potency constructs, Gully et al. [28] found an overall effect size of .35 between collective efficacy and group outcomes.

In a survey of the self-efficacy and computer self-efficacy literature, Marakas, Yi, and Johnson [51] identified the importance of mediating processes in the efficacy–outcomes relationship and further urged that future efficacy research consider these mediating factors. In addition, Bandura [4] has suggested that while many studies of self-efficacy acknowledge the mediating processes through which self-efficacy acts on group outcomes, most fail to directly test such relationships and therefore provide only a weak test of efficacy theory. As stated earlier, it has been suggested that collective efficacy influences outcomes through a variety of socio-cognitive mediators in a manner similar to self-efficacy [4], and therefore we include one such mediator in our current research. Specifically, we include perceptions of effort, a motivational process [4], as a mediator between virtual team efficacy and group outcome perceptions because effort has been established as an important variable within self-efficacy research [6, 51] and identified as a potential mediating process within models of collective efficacy and team performance [28, 45]. We therefore propose and test:

H3: Virtual team efficacy has an indirect, positive effect on group outcome perceptions through its influence on team effort

Objective Mediating Processes: Effect of Communication Level on Actual Performance

In any study that relies on perceptual measures, common method variance may become a concern. Therefore, to alleviate these concerns, we further investigated the predictive validity of the virtual team efficacy measure using two objective measures: communication level and actual team performance. Communication level [33], measuring the frequency of communication, is one possible proxy for the communication effort that group members exerted during the group process, and is one possible dimension of the overall effort expended in the virtual team's interactions. The communication-level measure is consistent with the mediating processes suggested by Bandura [3, 4], as teams with higher efficacy should communicate more often [4], thus affecting their performance outcomes [2, 4, 51]. Given this relationship, and previous reports that communication level influences the outcomes of virtual teams [33], we propose and test:

H4: Virtual team efficacy has an indirect, positive effect on actual performance through its influence on communication level

Methodology

Data for this study was collected during a series of virtual team projects led by universities in the United States and Hong Kong using a multiwave field survey methodology. The use of such a methodology has certain advantages. Specifically, when the desired result is to develop a general model applicable across various tasks and team compositions, using a field survey methodology, given its lack of focus on specific controls (as used in experimental research), is especially suitable. Given the use of this methodology, however, it is important that the model be developed in accordance with existing theory. Dennis et al. [19] acknowledge the importance of results when using such a methodology: “If the processes of interest are still observed in an uncontrolled environment with all of its extraneous influences, this bespeaks of the power of those processes” (p. 186).

Study Context

Four projects involved teams of students from universities located in the United States and Hong Kong; one additional project involved teams of students from the United States, Hong Kong, and the United Kingdom; and a final project consisted of teams formed from students enrolled in the distance learning and on-campus versions of a project management course at a U.S. university. Students were randomly assigned to the various teams; however, because of differences in the respective class enrollments, as well as our deliberate intention to vary the composition of the teams, team size and makeup were not controlled. Overall, approximately 400 students were involved in the projects, of whom 318 (52 project teams) provided usable responses to all three survey questionnaires.

Technology

WebCT, a web-based learning environment, was used to facilitate the projects.[1] Deliverable instructions and submission areas were made available using the web-based learning tool. In addition, each team was provided with its own private group discussion area, which served as a central hub for facilitating asynchronous communication and transferring of documents. Additional discussion areas were provided for communication with the instructors. Project deliverables were graded and returned in the same web-based learning environment.

Tasks

Projects were varied across the different semesters and courses. However, all of the tasks involved business problems to be solved by the respective teams, consistent with the "choose" quadrant of the McGrath [54] circumplex, a well-established taxonomy of group task types. This quadrant includes solving problems with correct answers (intellective tasks) and deciding issues with no right answer (decision-making tasks). In the case of this research, the focus was on the group reaching agreement over a preferred answer or alternative, and thus the group projects are classified as decision-making tasks. Business problems to be solved generally included the development of a project plan based on project management principles; in some cases they required the development of an e-commerce-based web site. Further, all the projects had a substantial impact on the students' course grades.

[1] One project was conducted using Blackboard hosted at the UK university.

Survey Administration

During the course of each project, a series of electronic surveys were administered. The first survey was designed to collect demographic information. The second survey, administered after the teams' introductory deliverables were graded and returned, was designed to measure members' perceptions of their team's group potency, computer collective efficacy, and virtual team efficacy. The final survey, administered at the end of the project, was designed to measure team outcome perceptions. Consistent with our earlier discussion of collective efficacy measurement methods, nonaggregated individual perceptions of the teams' abilities and performance were collected and used to conduct exploratory and confirmatory factor analyses at the individual level [21, 60, 75]. Following the validation process, tests for intergroup agreement were conducted, and after this requirement was satisfied, group-level analyses were then conducted using the aggregated member perceptions.

Measures

The latent constructs used in the current study, consistent with the recommendations of Bandura [4], were all measured using the individual member perceptions of the respective virtual teams' abilities. Following instrument development procedures at the individual level of analysis, intergroup agreement was then established, and the measures were aggregated for use at the group level of analysis.

Exogenous Measures

The exogenous measures used in the current study include group potency and computer collective efficacy.

Group Potency

The group potency measure developed by Guzzo et al. [29] was used to measure the individual members' perceptions of their team's general effectiveness. Group efficacy researchers [24] often use the group potency measure, which has consistently been shown to predict general group outcomes [24, 28, 45]. Reliability for the group potency measure was found to be .86, above the .7 level specified as an acceptable level of reliability [57].

Computer Collective Efficacy

Computer collective efficacy was measured using items adapted from a validated, general measure of computer self-efficacy [55]. Consideration was given to adapting Compeau and Higgins's [17] measure of computer self-efficacy for this purpose, another common measure of this construct, but the authors believed that for two reasons the measure provided by Murphy et al. [55] would better suit the needs of the current research. First, the measure developed by Compeau and Higgins [17] relies on individuals assessing their competency relative to the software of their choice. In the current context, it is likely that if such a scale were used, individual virtual team members would evaluate their team's general computer efficacy using different software packages as a referent, which could result in rating inconsistencies among members of the same virtual team. Given that the current research involves individuals assessing their *team's* abilities, we believed that having the participants rate their efficacy toward objectively consistent skills, in agreement with the Murphy et al. [55] measure, was more appropriate. Second, while the Compeau and Higgins [17] measure is focused on software efficacy, the authors believed that a more general measure of computer efficacy, capturing both software and hardware skills (again consistent with Murphy et al. [55]), was more appropriate as an antecedent of virtual team efficacy.

The Murphy et al. [55] measure consists of three levels of items. For the purposes of this research we adopted only the level-two items; the level-one items reflected skills so rudimentary that ceiling effects were likely to be observed, and the level-three items reflected mainframe skills that were not relevant to the current study.

Endogenous Measures

The current study identifies three endogenous measures: virtual team efficacy, effort, and group outcome perceptions.

Virtual Team Efficacy

The authors developed the virtual team efficacy measure for the current study. While creating the measurement items, we gave consideration to social-cognitive theory, collective efficacy, and the virtual team literature. We used established instrument development procedures to validate the virtual team efficacy measure [12] that are outlined in the instrument development section below. Reliability for the virtual team efficacy measure was .93.

Effort

While developing our effort measure, we gave specific consideration to the measure developed by Lester et al. [45]. This measure, however, was designed to measure perceptions of both effort and persistence, two distinct constructs within the social cognitive theory framework [4]. Therefore, we chose to represent effort as an independent construct measuring the individual team members' perceptions of their respective team's effort, and avoided using items that were anchored by persistence. Reliability for the effort measure was .87.

Group Outcomes Perceptions

Group outcome perceptions is an endogenous construct represented in the model as a second-order construct composed of the three separate, yet correlated, individual-level measures: satisfaction with the team, satisfaction with team outcomes, and perceptions of team outcome quality. Previous studies of collective efficacy have used similar perceptual outcome variables [24, 75]. Reliabilities for the first-order measures of group satisfaction, outcome satisfaction, and outcome quality, were .95, .93, and .95 respectively.

Communication Level

Communication level, an endogenous variable, was measured by summing the number of discussion postings within the respective group discussion areas. This measure is similar to the communication-level measure used by Jarvenpaa [33], where the e-mails among the respective teams sent through the listserv were summed.

Actual Performance

Team performance was measured using the respective team project grades. As both communication level and actual performance were single-item actual performance measures, reliabilities were not computed.

Instrument Development

To facilitate the testing of the virtual team efficacy model, it was necessary to develop an instrument that could measure the individual member's perceptions of her/his virtual team's efficacy [4, 5]. Given the very nature of collective efficacy measurement as proposed by Bandura [4], items necessarily refer to individual-level perceptions of the group. Such measures do not apply to the group until after aggregation, and aggregation is only conducted if sufficient group-level agreement exists. In cases where such agreement does not exist, individual analyses are often then conducted.

The first step in the process involved developing the virtual team efficacy items based on past research in the areas of social-cognitive theory, collective efficacy, and virtual teams. During item development, researchers familiar with both virtual team research and social-cognitive theory were called on to review the items for content validity. The second step involved the exploratory examination of the virtual team efficacy factor structure using principal components analysis (PCA). During this phase, the virtual team efficacy items were tested in an exploratory manner to determine their factor structure. The third step consisted of testing the construct in a confirmatory manner. The confirmatory phase consisted of two processes. The first process was to confirm the factor structure of the virtual team efficacy measure using confirmatory factor analysis. The second process was to test the virtual team efficacy construct's predictive validity within the nomological net of the research model at the group level of analysis.

Step 1—Item development

Development of the virtual team efficacy measurement items was based on an extensive review of the social-cognitive theory, collective efficacy, and virtual team literature. The unit of analysis was also considered. Given these criteria, the authors developed eight items that would reflect a respondent's belief in his/her team's ability to work in a virtual team context, which naturally included a reference to performing as a virtual group using communication technology. Additionally, to reflect the collective focus of the analysis [4, 5], items were worded as "I believe my group has the ability…" rather than "I believe I have the ability…." For example, item 1 is worded: "I believe my group has the ability to use communications software to collaborate with remote group members." Wording the items in this manner serves two purposes. First, such wording allows the items to be used to examine downstream individual-level member perceptions of group outcomes. Second, these same items can be easily aggregated and used for predicting group-level outcomes [3, 4, 37, 64, 74, 75].

Consideration was also given to Bandura's prescriptions about developing efficacy measures in terms of their generality, strength, and level [4, 5]. In terms of generality, Bandura argues that most domain-specific measures are more predictive than general efficacy measures [4]. However, Bandura also argues that the appropriate level of generality may vary between domains [4]. Other authors have also noted that designing efficacy measures too narrowly may result in a loss of both external validity and practical relevance [44]. In the current context it was difficult to predict all the specific dimensions relevant to virtual team efficacy; further, we believed that developing a narrowly defined measure would be of limited value to the academic and practitioner communities. Therefore, the virtual team efficacy measure used in this research was designed to be useful in predicting performance across multiple tasks within the virtual team domain.

Efficacy beliefs also vary in strength, and efficacy strength is generally captured by the structure of the efficacy scale. The scale used to measure the virtual team efficacy items in the current study is consistent with previously validated efficacy scales [4, 5], and therefore addresses this issue.

The third prescription—level of efficacy belief—was not directly employed in the current research. That is, no attempt was made to predict group outcomes using a specific cut-off value in terms of the efficacy level held by team members. Rather, level of efficacy belief was captured through the continuous measure of efficacy strength [4, 5].

Step 2—Exploratory Factor Analysis

During step 2, the eight virtual team efficacy items were subjected to a principal components analysis (PCA) using SPSS v.11. A single-factor solution was observed during the EFA, and therefore rotation was unnecessary. Table 2 depicts the results of the PCA.

[Insert Table 2 Here]

Step 3—Confirmatory Testing

Confirmatory testing was carried out in a two-step process consisting of a CFA and a test of the constructs within the nomological network of the research model. Using AMOS v. 4, the virtual team efficacy measure was subjected to a CFA along with the Computer Collective Efficacy, group potency, and effort constructs using the nonaggregated member responses (*n* = 318) collected during the series of virtual team projects. Preliminary results showed unacceptable fit measures. Upon examination of the modification indices, it became evident that several error terms were highly correlated within their respective latent constructs. Eliminating the correlated error terms and their associated items resulted in a more parsimonious model (i.e., three items for Computer Collective Efficacy, three for group potency, three for Effort, and four for virtual team efficacy) that provided an excellent fit to the data. Table 3 reflects the research constructs and their respective items. Fit measures for the final model were GFI .952; NFI .964; CFI .983; and RMSEA .037. All factors loaded above the .6 level on each of their respective latent constructs, an indication of convergent validity [67].

[Insert Table 3 Here]

To test the discriminant validity of the virtual team efficacy construct, we conducted a chi-square differences test, following the procedure outlined by Chin et al. [12]. Specifically, we conducted four sets of confirmatory factor analyses in which the chi-square associated with the model, where the correlation between the construct of interest and virtual team efficacy was free to vary, was compared with the chi-square associated with the model, where the correlation was fixed to 1. If the constructs are truly different, the resultant chi-square difference should be significant. Table 4 shows the results of the chi-square differences test.

[Insert Table 4 Here]

To complete the development of the virtual team efficacy instrument, we examined the construct within the research model to test for predictive validity. We tested the research model at the group level using the aggregated team member responses following the establishment of sufficient intergroup agreement.

Procedures—Group Level

To assess the predictive validity of the virtual team efficacy measure at the group level of analysis, we next evaluated the research model as hypothesized using the aggregated team member responses. The evaluation of the group-level model involved three separate steps. The first step was to evaluate intergroup agreement among the respective virtual teams. The second step was to test the measurement model portion of the group-level model. The final step was to evaluate the structural portion of the group-level model. Steps two and three were repeated to facilitate the testing of the respective mediating hypotheses (i.e., H3 and H4).

Within-Group Agreement

Before individual collective efficacy responses are aggregated, intergroup agreement must first be established [37]. One widely accepted method for demonstrating such agreement is by calculating the rwg(j) coefficient [31]. The rwg(j) is especially suitable for studies involving multi-item latent constructs because it overcomes the "all-or-nothing" proposition of many common methods of establishing agreement when single-item measures are used [31]. In this study, the rwg(j) formula was applied to the group potency, Computer Collective Efficacy, virtual team efficacy, effort, team satisfaction, outcome satisfaction, and outcome quality measures. Results revealed that the average rwg(j) coefficient across the constructs was .83, ranging from a low of .74 to a high of .96, above the .7 value suggested as sufficient for establishing intergroup agreement [71]. Based on these results, data were then aggregated to the group level.

Model Tests

To test the model at the group level of analyses, it was necessary to move from covariance-based MLE to principal components–based partial least squares (PLS), an estimation method more suitable for small samples [13]. Unlike covariance-based SEM estimation methods, however, PLS relies on the explanation of variance and the significance of the regression paths for evaluating model fit [13]. We conducted two separate analyses to evaluate the research hypotheses. The first evaluated hypotheses 1 through 3 using a sample of 52 project teams. The second evaluated hypothesis 4 using a sample of 31 project teams.

Analysis 1

Although the convergent and discriminant validity of the virtual team efficacy instrument was evaluated at the individual level, the measure must be reevaluated for its properties at the group level once aggregation has occurred [24]. We examined the measurement portion of the virtual team efficacy model as hypothesized using PLS-Graph v 3.0. Results from the measurement model analysis revealed that all items loaded above .6 on their respective constructs, an indication of convergent validity [12]. We then established discriminant validity by verifying that the square root of the average variance extracted (AVE) exceeded the respective constructs' correlation with any other variable in the model [13]. Table 5 depicts these results.

[Insert Table 5 Here]

The second step was to evaluate the structural model. During the first model run, we tested Hypotheses 1 and 2, and they were supported as expected. Next, we evaluated the mediating relationships of Hypothesis 3 using the three-step process recommended by Baron and Kenny [7]. The first estimation established the significant direct effect of virtual team efficacy on group outcomes. Next, the significance of the paths from virtual team efficacy to effort and from effort to group outcomes was established. Finally, we reevaluated the direct path from virtual team efficacy to group outcomes with the virtual team efficacy to effort and effort to group outcome paths retained in the model. In support of Hypothesis 3, and consistent with the recommendations of Baron and Kenny [7], all model paths were significant except for the direct path from virtual team efficacy to group outcomes. Although the work of Baron and Kenny [7] on mediation testing is well-known, more recent research has called for additional testing to empirically establish the strength of hypothesized mediating relationships. Specifically, Shrout and Bolger [70] recommend the calculation of an effect proportion mediated ratio as a measure of the strength of mediating effects. Such a test is advocated because it allows for the reporting of partial mediating effects rather than only findings of full mediation. In the case of Hypothesis 3, the effect proportion mediated relationship was calculated as .89, with 1 representing total mediation.

Given this information, we conducted a final model run reflecting the optimal model, which included effort but no longer specified the direct path from virtual team efficacy to group outcomes. The fit for the optimal model was excellent in that all regression paths were significant as hypothesized and ~72% of the variance in group outcomes was accounted for. Table 6 reflects the model test results for the group-level analyses.

[Insert Table 6 Here]

Analysis 2

Using PLS-Graph v 3.0, we conducted the second analysis to test the mediating effect of communication level on actual performance during a similar two-step process. First, we examined the results of the measurement model, which revealed that all items loaded above .6 on the virtual team efficacy construct, establishing its convergent validity [12]. As communication level and actual performance were both single-item objective measures, it was not necessary to establish their convergent validity. Discriminant validity was established by verifying that the square root of the average variance extracted (AVE) exceeded the respective constructs' correlation with any other variable in the model [13]. Table 7 depicts these results.

[Insert Table 7 Here]

Next, we examined the structural model, and as expected, virtual team efficacy had a significant positive effect on actual performance without communication level specified in the model. Further, just over 32% of the variance in actual performance was accounted for. Inconsistent with Hypothesis 4, however, communication level did not fully mediate the relationship of virtual team efficacy on actual performance. Although the beta associated with the path from virtual team efficacy to actual performance was reduced when the paths from virtual team efficacy to communication level and communication level to actual performance were included in the model, the direct path of virtual team efficacy to actual performance retained its significance. The effect proportion mediated ratio recommended by Shrout and Bolger [70] was calculated as .28. Such findings are indicative of a partial mediating effect as discussed by Shrout and Bolger [70], and thus only partial support for Hypothesis 4 was demonstrated. Table 8 depicts the model test results for the actual outcomes model.

[Insert Table 8 Here]

Discussion

This study addressed the research question: How does efficacy operate in the context of virtual teams? In doing so, it made several contributions to the information systems literature on virtual teams. First, we applied the concept of efficacy within virtual information systems project teams—to our knowledge the first test of this concept within a distance-based, technology-mediated environment. Second, we developed and rigorously tested an instrument designed specifically to measure the efficacy perceptions of virtual team participants that researchers interested in the performance of virtual teams can immediately apply. Third, we observed virtual team efficacy within a comprehensive research framework at the group level of analysis, using both perceptual and objective measures of the mediators and outcomes in our model. These contributions are significant to both the academic and practitioner communities because they provide a cumulative body of empirical evidence about the importance of virtual team efficacy in diagnosing the performance of such teams.

Regarding our first contribution, the application of collective efficacy to virtual teams was successful in that the virtual team efficacy measure was shown to be predictive of both perceptual and objective group outcomes. Such a finding is significant in identifying virtual team efficacy as an important construct missing from existing models of virtual team performance.

Regarding our second contribution, our measure of virtual team efficacy was shown to be highly reliable across a variety of group contexts, including differences in group composition, group size, task duration, and task complexity. The reliability of the virtual team efficacy measure was established to be .93, and the factor loadings were all found to be .8 or higher. In addition, through the use of the chi-square differences test, we showed that the virtual team efficacy measure exhibits discriminant validity from the previously validated general measure, group potency. We also established the convergent and discriminant validity of the virtual team efficacy measure using group-level aggregated responses.

Regarding our third contribution, we examined virtual team efficacy within a comprehensive research framework. We evaluated two general forms of efficacy as antecedents to virtual team efficacy: group potency and computer collective efficacy. The positive relationship between group potency and virtual team efficacy supported Hypothesis 1. Hypothesis 2, which explored the relationship between computer collective efficacy and virtual team efficacy, was supported as expected.

Hypotheses related to the consequences of virtual team efficacy were also supported. For Hypothesis 3, effort was found to mediate the relationship between virtual team efficacy and group outcome perceptions, demonstrating consistency with efficacy theory [4]. This finding is especially interesting given that the mediating processes in efficacy–performance research are generally less researched and thus less well understood [4, 51]. Finally, the virtual team efficacy measure was examined for its predictive properties using objective measures. Contrary to expectations, H4 was only partially supported in that we observed a partial mediating effect of communication level on actual performance. However, the variance accounted for in actual performance increased from 32% to 46% with communication level specified in the model. This partial mediating effect is not all that surprising in hindsight. Although a perceptual measure of effort may be more comprehensive (perhaps capturing such factors as persistence), communication level (while reflecting one objective dimension of effort) is certainly not the only such mediator, and thus we would not necessarily expect a fully mediated result.

Implications, Limitations, and Future Research

This research has important implications for researchers and practitioners interested in developing and studying virtual teamwork. For researchers, developing a robust measure of virtual team efficacy should allow for downstream research on how efficacy is formed in the virtual team context. As mentioned in the paper, virtual teams are different from traditional teams in their use of technology-mediated communication to overcome noncollocation. This is an important distinction, which should have substantial implications on how efficacy beliefs are built or eroded in this context.

As discussed earlier, efficacy research has identified at least four sources of efficacy information that may influence the formation of efficacy beliefs. These sources include enactive mastery (i.e., prior performance), vicarious experience (imagining oneself or watching others perform an activity), verbal persuasion (encouragement from others), and physiological and affective states (e.g., excitement or anxiety). Studies on computer-mediated communication have shown that technology features influence interpersonal communication [18, 39, 42, 50]. In the current context of virtual teams, we would expect these same technology features to influence the sources of efficacy information. As an example, vicarious experience information in virtual teams could be gained by observing other members of the team performing particular behaviors. However, the fact that intergroup interactions must occur via technology may change the group member's perceptions of such behaviors. Likewise, given that different types of communication technology allow for different types of information to be conveyed [30, 52], technology choice may influence the effectiveness of such factors as verbal persuasion and affective processes in building virtual team efficacy. In other words, the ability of the group to "pump itself up" for task accomplishment may be quite different in the virtual team environment. Future research should explore how technology-mediated communication affects the formation of efficacy in such groups.

There may also be a conceptual linkage between collective efficacy and virtual team success factors such as trust, leadership, communication, and structure. Future research should investigate the interactive effects of virtual team efficacy and such established virtual team success factors. For example, leadership [64] and conflict management [50] have been empirically linked to the collective efficacy of groups, and therefore similar linkages may be observed in virtual teams.

For practitioners, establishing virtual team efficacy as an important variable in the success of virtual teams provides an additional tool they may use to diagnose the outcomes of such teams. For example, when a virtual team is diagnosed with low collective efficacy, interventions (e.g., vicarious experience) may be implemented to raise virtual team efficacy. Based on our findings, some of the potential antecedents and consequences of virtual team efficacy should also be useful. Given the knowledge that virtual team efficacy beliefs are related to other forms of efficacy, such as group potency and computer collective efficacy, organizational development specialists can suggest and develop interventions that might influence not only virtual team efficacy but also group potency and Computer Collective Efficacy. Specifically, our results indicate that in the case of Computer Collective Efficacy, computer training related to more advanced skills sets may be useful in building virtual team efficacy. Alternatively, group process training may be beneficial to enhance group potency. In addition, knowing that virtual team efficacy's effect on performance is mediated by factors such as effort and communication level allows those responsible for assessing performance in the workplace to go beyond looking at just final results. Intermediary factors such as team persistence, anxiety, and group goal setting may also be important to observe to improve future team performance.

Although virtual team research has previously been conducted using student teams [32, 33, 68], the use of student teams may be considered a limitation of this research [25]. To minimize this limitation, this research involved teams of students performing information systems development and management activities who had a substantial stake in their group's performance. Although additional research certainly needs to be done in other organizational settings, the intent of the current research was not to generalize from student teams to organizational teams but rather to develop a model that can be investigated for its generalizability to other settings (e.g., organizations) in future studies [43].

Although the goal of this research was to develop and test our model of virtual team efficacy in a robust environment, involving different team compositions, team sizes, project deliverables, and project durations, we also realize this methodology does not control for extraneous variables. However, we believe the strength of the theoretically based relationships among the variables, the significance of the regression paths, and the large amount of variance that was accounted for provide testimonial to the strength of the model as specified [19] and enhances our confidence regarding the model's generalizability. Future research should be conducted in both the lab and field to further verify the robustness of our findings.

Conclusion

This study provided a comprehensive model of virtual team efficacy and performance as well as validated instrumentation that can immediately be applied in future research on virtual teams. Specifically, the study provided a new measure of virtual team efficacy, which was validated within a comprehensive research framework at the group level of analysis. The measure was found to be influenced by antecedents such as group potency and computer collective efficacy, and predictive of both perceptual and objective virtual team performance. These findings provide an important step in studying how virtual team efficacy is formed and what its consequences are in the context of virtual teams. Likewise, this research may provide practitioners with insights on how to improve virtual team performance within their organization. Given the organizational and economic advantages in using such teams, in combination with the ever-increasing sophistication of technology to support distributed teamwork, the continued growth in virtual teamwork seems assured.

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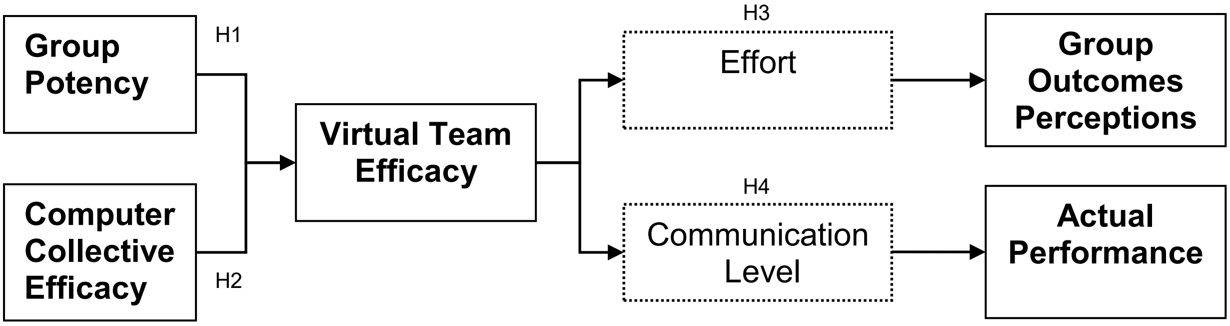

Figure 1: Research Model

Construct	**Description**
Group Potency (GP)	Used to assess the virtual team's belief in its general effectiveness across multiple situations and tasks
Computer Collective Efficacy (CCE)	Used to assess the virtual team's belief in its ability to perform more advanced and conceptual computer tasks such as troubleshooting computer-related problems
Virtual Team Efficacy (VTE)	Used to assess the virtual team's belief in its ability to work together successfully in a noncollocated, technology-mediated environment
Effort	Used to assess perceptions of the virtual team's effort toward completing the team project
Group Outcome Perceptions (GOP)	Used to assess perceptions of outcome satisfaction, team satisfaction, and outcome quality
Communication Level (CL)	Summation of postings within the respective virtual team discussion areas
Actual Performance (AP)	Team project grades

Table 1: Research constructs

Virtual Team Efficacy Component Matrix								
Item	VTE1	VTE2	VTE3	VTE4	VTE5	VTE6	VTE7	VTE8
Loading	0.88	0.87	0.88	0.90	0.89	0.83	0.84	0.91
Principal Component Analysis (No Rotation) *n* = 318								

Table 2: EFA results

Computer Collective Efficacy	
CCE6	I believe my group has the ability to understand terms/words relating to computer software.
CCE9	I believe my group has the ability to troubleshoot computer problems
CCE10	I believe my group has the ability to explain why a program (software) will or will not run on a given computer
Group Potency	
GP1	My group has confidence in itself.
GP3	My group expects to be known as a high-performing team.
GP6	My group can get a lot done when it works hard.
Virtual Team Efficacy	
VTE1	I believe my group has the ability to use communications software to collaborate with remote group members.
VTE4	I believe my group has the ability to do teamwork in a distributed environment if we have access to appropriate technology.
VTE5	I believe my group has the ability to share information using technology with remote group members.
VTE8	I believe my group has the ability to use communication technology to do work with people who can't physically get together to meet.
Effort	
Effort 1	My group worked hard on the project
Effort 3	My team exerted substantial effort on the project
Effort 4	My group did a significant amount of work on the project
Group Outcome Perceptions	
Outsat1	I am satisfied with the project outcome produced by my team
Outsat2	I am pleased with the quality of work we did in my team
Outsat3	I am satisfied with the final project deliverable submitted by my team
Grpsat1	I was satisfied with my group members
Grpsat2	I was pleased with the way my teammates and I worked together
Grpsat3	I was very satisfied working with this team
Outqual1	The work produced by my team was high quality
Outqual2	The project outcome produced by my team was excellent
Outqual3	The deliverables of my team were outstanding

Table 3: Survey items

	VTE-CCE	VTE-GP	VTE-Effort	VTE-GrpOut	Critical Value
Chi-Square (Free to Vary)	17.7	24	20.1	84.1	
Chi-Square (Path Set to 1)	140.6	206.6	73.3	137	
Difference	122.9	182.6	53.2	52.9	3.84 (α = 0.05)
Significance	Yes	Yes	Yes	Yes	

Table 4: Chi-Square differences test results

Construct	GP	CCE	VTE	Effort	GrpOut
GP	**0.899**				
CCE	0.708	**0.877**			
VTE	0.745	0.670	**0.929**		
Effort	0.579	0.402	0.648	**0.897**	
GOP	0.483	0.321	0.603	0.849	**0.880**

Bold = Square Root of the average variance extracted

Table 5: Group-level measurement model results

Hypothesis	**Beta**	**Supported**
H1 (GP-VTE)	0.546***	Yes
H2 (CCE-VTE)	0.300**	Yes
H3 (VTE-GOP)	0.621***	Yes
… (VTE-Effort)	0.625***	
… (Effort-GOP)	0.851***	
… (VTE-GOP with effort)	0.093ns	

Table 6: Group-level model structural results

*** $p < .001$

** $p < .05$

Construct	VTE	ComLevel	Performance
VTE	**0.922**		
CL	0.392	**1**	
AP	0.568	0.569	**1**
Bold = Square Root of the average variance extracted			

Table 7: Objective outcomes measurement model results

Hypothesis	**Beta**	**Supported**
H4 (VTE-AP)	0.569***	Partially
… (VTE-CL)	0.396***	
… (CL to AP)	0.497***	
… VTE-AP (with CL)	0.408***	

Table 8: Actual outcomes model results

*** $p < .001$