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# A meta-analytic investigation of virtuality and information sharing in teams

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ABSTRACT

We uncover new insights on the role of virtuality on team information sharing. A new two-dimensional conceptualization of information sharing (Mesmer-Magnus & DeChurch, 2009) enabled us to reconcile past inconsistencies in the virtual team literature. Recasting the findings of 94 studies (total number of groups = 5596; total *N* approximately = 19,702) into this framework reveals three key insights. First, virtuality improves the sharing of unique information, but hinders the openness of information sharing. Second, unique information sharing is more important to the performance of face-to-face teams than is open information sharing, whereas open information sharing is more important to the performance of virtual teams than is unique information sharing. Third, the effects of virtuality on information sharing are more curvilinear than linear – such that low levels of virtuality improve information sharing, but high levels hider it. Implications for research and practice are discussed.



## Introduction

Organizations are increasingly structuring work around teams due to their potential to excel in complex decision-making and problem-solving tasks. Two important aspects of teamwork are the knowledge-intensity of their tasks and the virtual arrangement of their members. Across the vast array of organizational teams, those designing products, developing software, treating patients, researching new drug treatments, and inventing solutions to mass oil spills, teams today are utilizing information distributed across multiple team members, and they are doing so with the aid of an ever-increasing variety of information technology. Virtual teams are comprised of "geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish an organizational task (Townsend, DeMarie, & Hendrickson, 1998, p. 17)." According to Lipsinger (2010), at least half of teams in today's organizations operate as virtual teams on a regular basis. In fact, even a decade ago, surveys revealed that 61% of employees in organizations with 500 or more employees worked as part of virtual project teams; nearly half of those surveyed indicated they completed virtual work at least once per week (Modalis Research Technologies, 2001).

This modern reality of teamwork creates a real need to understand the fundamental ways in which communicating through technology impacts (1) how much and what types of information are exchanged in teams, and (2) the value of the information exchanged to team performance. Though organizational scientists have been investigating the impact of virtual communication on team information sharing for nearly two decades (Baltes, Dickson, Sherman, Bauer, & LaGanke, 2002; Fjermestad, 2004; McLeod, 1992; Rains, 2005), theoretical shortcomings in defining virtuality and information sharing have impeded progress in this area (cf. Kirkman & Mathieu, 2005; Mesmer-Magnus & DeChurch, 2009). Towards this aim, we employ meta-analysis to uncover core relationships between team virtuality and information sharing.

Past findings and meta-analyses on the impact of virtual communication in teams have yielded no clear pattern of results. Depending on the source, we can either conclude that virtual communication is a benefit (Rains, 2005) or a detriment (Fjermestad, 2004) to team information sharing. A recent discovery in re-conceptualizing team information sharing may hold the key to resolving this apparent discrepancy. Mesmer-Magnus and DeChurch (2009) meta-analyzed the team information sharing literature and found essentially two different forms of information sharing, uniqueness and openness, that have different effects on team outcomes. Building on this distinction, perhaps we can better understand the impact of virtual communication in teams by adopting this multidimensional view. Furthermore, we adopt Kirkman and Mathieu's (2005) expanded definition of virtuality that captures the extent to which team interactions resemble those that would occur if mediating technologies were not employed (i.e., a combination of amount of tool use, informational value of tools, and synchronicity of tools

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which may yield varying degrees of similarity/dissimilarity with face-to-face interactions). We utilize these expanded views of virtuality and information sharing to address two critical questions. First, to what extent does virtuality affect information sharing uniqueness and openness in teams? Second, do the effects of information sharing uniqueness and openness on team performance depend on the means through which information is transmitted?

## Theoretical development

A number of reviews have examined the role of communication modalities on team communication, particularly informational processes (e.g., Baltes et al., 2002; Fjermestad, 2004; McLeod, 1992; Rains, 2005). These reviews link team communication mode (i.e., group support systems versus face-to-face) to a range of information-relevant outcomes including degree of task focus, decision quality, equality of participation, communication effectiveness, production of unique ideas, member dominance, member satisfaction, influence equality, normative influence, and decision shifts. However, these reviews have yielded mixed findings regarding how communication mode affects information sharing and other related outcomes in teams. Fjermestad (2004) found face-to-face teams reported better communication than Group Support System (GSS) teams, whereas Rains (2005) found the opposite, that groups using a GSS generated a larger amount of unique ideas than face-to-face groups. Baltes and colleagues (2002) meta-analytically concluded that computer-mediated teams were less effective decision-makers than face-to-face teams, while McLeod (1992) found the opposite, observing positive outcomes for groups using GSS, including improved decision quality and equality of participation.

Beyond the contradictory findings of past reviews, we submit that two important theoretical and practical extensions necessitate a new review to uncover these relationships. First, past reviews have compared the amount of information sharing in face-to-face and virtual teams, making no distinction in the degree of virtuality of these teams. The current meta-analysis moves toward a more theoretically-grounded approach to the study of virtuality by incorporating Kirkman and Mathieu's (2005) three-dimensional conceptualization of virtuality to examine key relationships along a continuum of virtuality. Second, a recent meta-analysis on team information sharing finds different predictors and outcomes of two dimensions of team information sharing: openness and uniqueness (Mesmer-Magnus & DeChurch, 2009). Our meta-analysis moves the study of virtuality forward by examining these dimensions of information sharing separately.

## Dimensions of virtuality

Various definitions of team virtuality exist in the extant literature, ranging from focusing on the extent to which teams are geographically distributed (e.g., Cohen & Gibson, 2003) to defining the extent to which teams make use of virtual media (e.g., Griffith, Sawyer, & Neale, 2003). Importantly, these definitions do not give a complete picture of how 'virtual' a team is, because they focus on only one aspect of virtuality (Bell & Kozlowski, 2002; Martins, Gilson, & Maynard, 2004). For example, although teams may make use of virtual tools to communicate, various aspects of the media they use may result in communication patterns that are not markedly different from traditional teams (i.e., those that meet face-to-face). Kirkman and Mathieu (2005) recently delineated three dimensions that comprise team virtuality; the combination of these dimensions defines a team's overall level of virtuality: (1) extent of reliance on virtual tools as well as the (2) informational value and (3) synchronicity afforded by the tools. The *most virtual* teams are highly reliant on tools which are both asynchronous and result in the transmission of information with low informational value. However, teams which make use of tools that more closely mimic face-to-face interactions (e.g., videoconferencing, which is both synchronous and high in informational value) are comparatively much less virtual. As such, there is an important distinction between teams which are fully virtual (making full use of virtual tools) and those that are highly virtual (making use of tools which do not result in similar communication patterns and advantages as found in face-to-face teams; i.e., high virtuality teams).

Drawing on Kirkman and Mathieu's (2005) taxonomy, we classify teams in terms of their levels of virtuality using a combination of these three important aspects of virtuality. The first dimension is the *use of virtual tools,* which describes the proportion of team interaction that occurs via virtual means. On one end of this continuum, teams make use of no virtual media, instead interacting exclusively face-to-face. On the other end of the continuum, teams interact solely through virtual means. The second dimension of team virtuality, *informational value*, refers to the extent to which virtual tools transmit data that is valuable for team effectiveness. Kirkman and Mathieu (2005) argue that when technologies convey rich, valuable information necessary for team performance, then the exchanges are less virtual; as the richness of information decreases, the level of virtuality increases. Finally, *synchronicity* is the extent to which team interactions occur in real time versus incurring a time lag. The closer to 'real time' the team's interactions, the more synchronous (and the less virtual) the team. Phone conferences and video conferences, for example, would both be highly synchronous virtual tools, whereas email and group blogs are more asynchronous given the time lag which typically occurs between communication attempts.

## Information sharing and virtuality

Information sharing is the primary process through which teams utilize their available informational resources (e.g., Bunderson & Sutcliffe, 2002; Jehn & Shah, 1997). If information is not effectively shared among team members, the team is not able to fully capitalize on the informational resources initially distributed throughout their team. However, there is more to information sharing than the quantity or frequency of the shared information. Stasser and Titus's (1985, 1987) biased information sampling model illustrates that, in general, groups spend more time discussing shared (commonly held) information that is already known by all group members than unshared information that is unique to individual team members. This is problematic given that Mesmer-Magnus and DeChurch (2009) recently meta-analytically demonstrated that information sharing enhances team performance most when teams shared unique, rather than commonly held, information. As such, the distinction between common and unique information sharing is critical when examining information sharing and its predictive effects.

The majority of existing empirical studies have examined what Mesmer-Magnus and DeChurch (2009) refer to as the uniqueness dimension of information sharing; or "variability in how many group members have access to a piece of information" (Hinsz, Tindale, & Vollrath, 1997, p. 54). These studies examine the extent to which teams are taking advantage of members' unique knowledge sets for the teams' benefit. A second subset of team information sharing studies has examined aspects of information exchange more broadly, including the volume of information shared independent of the initial distribution pattern of information among team members (Henry, 1995; Jehn & Shah, 1997). Mesmer-Magnus and DeChurch refer to these studies as investigations of the openness of information sharing. Simply stated,

openness refers to the extent to which a team is overtly sharing information, unique and common alike.

Importantly, the virtuality of a team's interaction may affect the amount and type of information that is shared in teams. Whereas face-to-face communication offers easier coordination (Ensher, Heun, & Blanchard, 2003), additional non-verbal information (Straus, 1996), and a greater opportunity to observe behavior and build trust (Aubert & Kelsey, 2003), communication via computer-mediated/virtual media has a number of advantages over face-to-face interaction, including conversation which is less inhibited by social norms and group pressures, reduced potential for production blocking and evaluation apprehension, more convenient/direct access to team members who have problem relevant information (e.g., via direct emails, instant messaging, phone calls), a record of communication/decisions, the opportunity to weigh, consider, and digest information shared by team members, and more time to consider and research contributions to team discussion (Ensher et al., 2003; Straus, 1996). Although virtual communication also has weaknesses not found in face-to-face meetings (e.g., increased potential for miscommunication, lack of warmth and non-verbal cues, potentially disjointed communication, and the need for some level of computer/technology proficiency), the advantages of virtual communication are just those which may permit greater information sharing to occur.

Compared with low virtuality and face-to-face teams, high virtuality teams have a greater opportunity to think through information shared by other members, think about responses before making them, and do research on questions posed by other members. This additional processing time created by the communication time lag enables individuals to process information deeper than they would "on the fly" in a face-to-face meeting, and to consider it from alternative perspectives. This asynchronous aspect of virtual interactions enhances the potential such teams will share unique information. Similarly, research has suggested that a primary advantage of highly virtual computer-mediated communication is social equalization (Siegel, Dubrovsky, Kiesler, & McGuire, 1986). In high virtuality environments, there are fewer cues indicating the status and position of team members; as such, minority and lower status group members feel they have more influence. This equalization of influence results in the reduction of conformity pressure as well as a reduction in fear of expressing divergent ideas (Pissarra & Jesuino, 2005), both of which increase the likelihood that team members will share unique information that they may have been hesitant to share in more interpersonally risky face-to-face situations. Consequently, we expect:

**Hypothesis 1.** High virtuality teams will share more unique information than either low virtuality or face-to-face teams.

Although virtual communication may well benefit unique information sharing by equalizing status differences, not all effects are likely to be beneficial. Specifically, virtuality may inhibit open information sharing as it is more cumbersome and media-poor than face-to-face interactions. Further, because high virtuality teams use media with less informational value and synchronicity, the overall volume of information sharing that can occur will be reduced compared to low virtuality and face-to-face teams. It takes longer to convey the same amount of information using high virtuality tools as compared with low virtuality tools or face-to-face interactions, likely due to the time-delayed nature of the communication threads and the relative time required to type rather than speak (e.g., Baltes et al., 2002; McLeod, 1992). Therefore, members of high virtuality teams may tend to reduce contributions of (1) redundant information and (2) the sorts of general relationship-building communications that more easily occur in synchronous mediums, limiting their messages to problem-relevant unique information. Further, highly virtual communication tools (e.g., email, information databases, group support systems) inherently create a record of information exchanged, reducing the tendency to and the necessity of repeating information in subsequent communications. In sum, because high virtuality teams have to exchange their information more succinctly and because their virtual tools serve as an external group memory, we expect:

**Hypothesis 2.** High virtuality teams will exhibit less open information sharing than either low virtuality or face-to-face teams.

## Virtuality as a moderator

Our first research question examined the direct impact of communication media on the amount and type of information sharing. Our second question examines the extent to which the value of team information sharing processes to team performance depend upon the communication medium through which information is shared. In their meta-analysis of the information sharing–team performance relationship, Mesmer-Magnus and DeChurch (2009) found the reliability-corrected mean correlation between information sharing and team performance to be .42, suggesting the extent to which a team effectively shares information plays a considerable role in team performance. In the same study, they also found the type of information shared (unique vs. open) moderates the information sharing–team performance relationship, such that the sharing of unique information more strongly relates to team problem solving and task performance, likely because it permits greater creativity and more fully informed solutions to problems than does the sheer openness of information sharing. Although unique information sharing may be a crucial component of quality performance and team creativity, it is not in and of itself a sufficient condition. Rather, a team's capacity to arrive at creative solutions to complex problems or to produce high quality products also relies upon effective coordination behaviors and other team process dynamics (Marks, Mathieu, & Zaccaro, 2001).

Research suggests open information sharing more strongly relates to team satisfaction and cohesion (Mesmer-Magnus & DeChurch, 2009) and sets the stage for more efficient interpersonal team process. Although there exist a variety of mechanisms in face-to-face teams which may support such team dynamics, information sharing is the primary means by which they are established and maintained in virtual contexts. Specifically, virtual teams experience the disadvantages of electronically-mediated communication, such as lack of warmth, reduced verbal and non-verbal cues, and increased possibilities of misunderstandings (Aubert & Kelsey, 2003; Ensher et al., 2003; Straus, 1996). As teams increase in their level of virtuality, they also likely spend less time developing the sorts of interpersonal relationships which underscore effective team process, in part because sharing information and connecting with team members on a personal level becomes more cumbersome and less socially required (Baltes et al., 2002). It is also more difficult for members of high virtuality teams to closely monitor their teammates' performance or engage in implicit coordination and backup behavior. Johnson, Bettenhausen, and Gibbons (2009) found that team members who use computer-mediated communication experience lower positive affect than face-to-face teams, and that this relationship was especially strong in hybrid teams that use virtual tools more than 90% of the time. Further, Kiesler, Siegel, and McGuire (1984) argue that virtual groups need affective bonds in order to be effective, and trust and personal engagement are critical for their development. Open information sharing likely mitigates the negative effects of computer-mediated communication on team affect in virtual

teams by allowing the team to develop the social structures necessary to maintain positive affect (e.g., psychological safety, trust, and cohesion among team members).

Essentially, past findings that information sharing uniqueness is more important to team performance than openness are based on the logic that the function of information exchange is to increase the overall amount of information that teams have available for use in decision-making (Stasser & Titus, 1985, 1987). Whereas the paradigm is logical for face-to-face teams, we submit that in high virtuality teams, open information sharing takes on new importance, compensating for the socio-emotive void of virtual communication modalities that are asynchronous and informationally poor. Past research consistently finds that unique information sharing is more important than open information sharing to team performance. However, the finding that open information sharing has stronger relations than unique information sharing to cohesion, trust and affect (Mesmer-Magnus & DeChurch, 2009), suggests that in virtual environments, when there are fewer ways to develop cohesion, trust, and affect, open information sharing will take on new importance and be more impactful to team performance than will unique information sharing. As such, *open* information sharing is likely more directly related to team effectiveness in virtual teams because (1) virtual teams have fewer alternative mechanisms for the development of important psycho-social mechanisms that contribute to team performance and (2) there are fewer "substitute" processes in operation that might make up for ineffective team information sharing in virtual teams. Thus, we expect:

**Hypothesis 3.** The relationship between information sharing and team performance will be moderated by both the type of information being shared and the degree of virtuality of the teams, such that for face-to-face teams, uniqueness will be more strongly related to team performance than openness, whereas for virtual teams, openness will be more strongly related to team performance than uniqueness.

## Method

### *Database*

Ninety-four independent studies reported in 90 manuscripts (total number of groups = 5596; total $N$ approximately[1] = 19,702) examining information sharing in teams were included in this meta-analysis. We compiled the relevant extant literature on team information sharing using a multi-faceted approach in an effort to include studies from a variety of disciplines (e.g., psychology, business, education, communication, information systems, information technology): (1) a computerized search of the PsycInfo, ABI Inform, Business Source Premier, Google Scholar, Emerald, Ebscohost, ScienceDirect, and ERIC databases using relevant keywords or phrases (e.g., group OR team AND information sharing, virtuality, computer-mediated, geographically dispersed, distributed, decision-making, discussion, critical information, unshared information, information exchange, hidden profile, and biased information sampling), (2) a search for studies that cited foundational work on team information sharing (e.g., those that cited Stasser's, Stewart's, or Titus's works, or Kirkman & Mathieu, 2005), (3) a manual search of references cited in recently published reviews (e.g., Baltes et al., 2002; Curseu, Schalk, & Wessel, 2008; Dennis, Wixom, & Vandenburg, 2001; Fjermestad, 2004; Hertel, Geister, & Konradt, 2005; Lin, Standing, & Liu, 2008; McLeod, 1992; Rains, 2005) as well as in studies included in this database, and (4) obtained related studies from recent conference presentations (i.e., Academy of Management, Society for Industrial and Organizational Psychology, and Hawaii International Conference on System Sciences).

As we examined virtuality as both an antecedent of information sharing and a moderator of the information sharing/team performance relationship, to be included in our database, a study must have reported a relationship between (1) virtuality and information sharing, or (2) information sharing and team performance. Studies were omitted from the database if sufficient information to compute a correlation between information sharing and either virtuality or performance was not reported. A subset of the studies included in the database did not report correlations but did report sufficient information to compute a point-biserial correlation between information sharing and either virtuality or performance (e.g., means and standard deviations for experimental and control groups, $t$ or $F$ statistics). As point-biserial correlations are attenuated (in this case, due to the dichotomization of information sharing), corrections were made to convert correlations to a full $+/-1$ scale. We also made adjustments to the sample sizes for the corrected correlations to avoid underestimating sample error variance using procedures described in Hunter and Schmidt (1990, 2004) and Ones, Viswesvaran, and Schmidt (1993). When authors reported multiple estimates of the same relationship from the same sample, a mean correlation was computed to maintain independence (Hunter & Schmidt, 1994, 2004).

### *Coding procedure and inter-coder agreement*

Each study was coded for (a) sample size, (b) number of teams, (c) operationalization of information sharing (i.e., as uniqueness or openness; Mesmer-Magnus & DeChurch, 2009), (d) degree of virtuality of the teams in the sample, (e) correlations between information sharing and virtuality and/or performance, and (f) reliability estimates for information sharing and team performance, if reported. To ensure coding consistency and construct validity, the authors jointly developed a coding scheme based upon the conceptual and operational definitions for relevant constructs within the primary studies. Two of the study's authors independently coded the 94 studies that met criteria for inclusion in this study. Initial inter-coder agreement by variable is reported in Table 1. Instances of disagreement were resolved through discussion.

### *Primary study characteristics*

The majority of the studies included in our meta-analytic database reported experiments (83%), were conducted in laboratory settings (87%), and used student samples (84%). The team tenure in studies ranged from less than 30 min of interaction time to as long as 6 months, with a median interaction time of 42.5 min. Consistent with the increase in research examining virtuality in the workplace, the majority (51%) were published in the past decade. Types of teams examined in the primary studies (according to the Sundstrom, McIntyre, Halfhill, & Richards, 2000 typology) included action/negotiation teams (6%; e.g., naval command and control team responsible for monitoring aircraft that entered the team's airspace), advice/involvement teams (60%; e.g., committees, review panels, boards), management teams (21%; e.g., corporate executive teams, regional steering committees), and project teams (11%; e.g., research groups, planning teams, architect teams, engineering teams, development teams, task forces). Tasks performed by these teams varied and included solving a murder mystery, providing recommendations regarding the employee hiring or promotion, solving an organizational problem, and playing a computer-based command and control simulation. The studies utilized a variety of technologies for communication: 56% used some form

[1] Some primary studies did not report a total sample size. These studies did report number of teams and average team size for the sample, thus enabling us to compute an approximate total sample size.

**Table 1**
Summary of coder reliabilities for key study variables.

| Variable | % Agreement | Kappa | 95% CI Kappa |
|---|---|---|---|
| Sample Size | 100 | 1.0 | 1.0/1.0 |
| Number of teams | 100 | 1.0 | 1.0/1.0 |
| Operationalization of information sharing | 100 | 1.0 | 1.0/1.0 |
| Use of virtual tools | 96.6 | .95 | .89/1.0 |
| Synchronicity | 97.7 | .96 | .92/1.0 |
| Informational value | 93.2 | .90 | .81/.98 |

*Note.* 95% CI Kappa refers to the 95% confidence interval around Kappa. Cohen's Kappa is a measure of inter-rater reliability often used in conjunction with percent agreement to index inter-coder consistency in meta-analyses (Lipsey & Wilson, 2001). All Kappa coefficients were significant at $p < .01$. Kappa coefficients greater than .80 are considered high/outstanding (Landis & Koch, 1977).

of computer conferencing system, 39% used a group decision support system, and 29% used email.

*Coding of information sharing*

Conceptualization of information sharing in the primary studies was coded as either (1) uniqueness or (2) openness using criteria detailed in Mesmer-Magnus and DeChurch (2009). Specifically, when authors examined the sharing of information that was originally uniquely held by a subset of the team (unshared/distributed information; e.g., biased information sampling), those studies were coded as *information sharing uniqueness*. When authors examined the breadth of information shared, independent of the original distribution of that information, those studies were coded as *information sharing openness*.

*Coding of virtuality*

Degree of virtuality (the extent to which communication modalities mimic face-to-face interactions) of the focal teams in each primary study was coded so virtuality could be examined as both an antecedent of team information sharing as well as a moderator of the information sharing–team performance relationship. Primary studies were coded along three points of this continuum: face-to-face, low virtuality, and high virtuality. Face-to-face interactions permit a highly synchronous exchange of information that is high in informational value (Kirkman & Mathieu, 2005), so these sorts of interactions are the least virtual. Virtual tools like videoconferencing, teleconferencing, and instant messaging permit more valuable and synchronous information to be exchanged than do tools like email and group information databases, which are arguably lower in both informational value and synchronicity. As such, teams that made use of virtual tools wherein informational value and synchronicity were high (e.g., videoconferencing, teleconferencing, instant messaging) were coded as "low virtuality" teams because the nature of communication in these teams was more similar to face-to-face interactions (and thus less "virtual") than was communication in teams that made use of virtual tools wherein informational value and synchronicity were low (e.g., email, informational databases; i.e., "high virtuality" teams).

To permit exploratory moderator analyses, the nature of virtuality of the teams in the primary studies was also coded using Kirkman and Mathieu's (2005) three-dimensional framework of virtuality. Specifically, *use of virtual tools* was coded as (1) none (when no virtual tools were used by the team; e.g., face-to-face teams), (2) hybrid (when teams made use of both virtual tools and face-to-face meetings), and (3) full (when teams communicated only via virtual means). *Synchronicity* was coded as (1) low (when primarily asynchronous communication occurred; e.g., email), (2) moderate (when a combination of synchronous and asynchronous tools were used; e.g., email and telephone), and (3) high (when primarily synchronous communication occurred; e.g., telephone, instant messaging, face-to-face). *Informational value* was coded as (1) low (when less rich media are used resulting in the value of information communicated being far less than could be communicated in face-to-face discussions; e.g., email and information databases because only verbal and no non-verbal information can be communicated), (2) medium (when somewhat rich media are used; e.g., teleconferencing, instant messaging), and (3) high (when the richest forms of media are used such that the informational value was as rich or nearly as rich as that which would be communicated in face-to-face discussions; e.g., videoconferencing).

*Analysis*

The meta-analytic methods outlined by Hunter and Schmidt (2004) were used to analyze this data. Corrections were made for sampling error, measure reliability, and, when necessary, attenuation of observed correlations due to the dichotomization of information sharing. Corrections were made for measure reliability using artifact distribution meta-analysis as reliability estimates were not consistently reported in primary studies. Given the possibility of a file-drawer effect wherein significant findings are more likely to be published than non-significant findings (Rosenthal, 1979), we conducted a file-drawer analysis (Hunter & Schmidt, 2004) to estimate the number of studies reporting null effects that would be required to reduce the reliability-corrected correlations to a specified lower value (we used $\rho = .05$).

## Results

Tables 2–5 report results of the meta-analyses of focal study relationships. In each table, we report the total number of independent studies included in each meta-analysis ($k$), the total number of groups ($N$), the sample size weighted mean observed correlation ($r$), the sample size weighted standard deviation of the observed correlations ($SD_r$), the sample size weighted mean observed correlation corrected for unreliability in both measures ($SD_\rho$), the standard deviation of $\rho$, the 80% credibility interval around $\rho$ (80% CV), the 90% confidence interval around $\rho$ (90% CI), the percent variance due to sampling error (%SEV), the percent variance due to all corrected artifacts (%ARTV), and the file drawer $k$ ($FD_k$) representing the number of "lost" studies reporting null findings necessary to reduce $\rho$ to .05.[2]

Hypotheses 1–2 posited virtuality as an antecedent of team information sharing uniqueness and openness. Table 2 reports the results of meta-analyses bearing on these relationships. In general, negative rhos indicate more information sharing occurs in less virtual teams (i.e., face-to-face, low virtuality teams); positive rhos indicate more information sharing occurs in more virtual teams (i.e., high virtuality teams). Hypothesis 1 predicted high virtuality teams would share more unique information than either low virtuality or face-to-face teams. Results support this hypothesis. Specifically, as can be seen in Table 2, high virtuality teams share more unique information than low virtuality ($r = .10$) or face-to-face

[2] We report both the credibility intervals (CV) and confidence intervals (CI) around $\rho$ because each provides unique information about the nature of $\rho$ (Hunter & Schmidt, 2004; Whitener, 1990). Specifically, the CV provides an estimate of the variability of corrected correlations across studies. Wide CVs or those that include zero suggest the presence of a moderator. An 80% CV that excludes zero indicates that more than 90% of the corrected correlations are different from zero (10% lie beyond the upper bound of the interval). The CI provides an estimate of the accuracy of our estimation of $\rho$ (Whitener, 1990); in other words, the CI estimates the variability around $\rho$ due to sampling error. A 90% CI that excludes zero indicates that if our estimation procedures were repeated many times, 95% of the estimates of $\rho$ would be a larger than zero (5% would fall beyond the upper limit of the interval).

**Table 2**
Virtuality as an antecedent of team information sharing (IS).

| Meta-analysis | *k* | *N* | *r* | $SD_r$ | $\rho$ | $SD_\rho$ | 80% CV | 90% CI | %SEV | %ARTV | $FD_k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Face-to-face vs. virtual communication (IS overall) | 38 | 1098 | .08 | .49 | .08 | .49 | −.54/.71 | −.05/.21 | 15.75 | 15.77 | 23 |
| Face-to-face vs. virtual teams | 35 | 989 | .09 | .49 | .09 | .45 | −.49/.66 | −.05/.23 | 16.63 | 16.64 | 28 |
| Face-to-face vs. low virtuality teams | 22 | 533 | .01 | .52 | .02 | .48 | −.60/.63 | −.34/.38 | 17.18 | 17.18 | – |
| Face-to-face vs. high virtuality teams | 13 | 456 | .17 | .43 | .17 | .40 | −.34/.68 | −.03/.37 | 16.54 | 16.55 | 31 |
| Low virtuality vs. high virtuality teams | 3 | 79 | −.30 | .22 | −.31 | .12 | −.46/−.16 | −.53/−.09 | 71.27 | 71.58 | 16 |
| Information sharing uniqueness | 18 | 549 | .13 | .48 | .14 | .48 | −.46/.73 | −.06/.34 | 15.63 | 15.69 | 32 |
| Face-to-face vs. virtual teams | 17 | 509 | .13 | .49 | .14 | .48 | −.47/.75 | −.07/.35 | 14.84 | 14.88 | 31 |
| Face-to-face vs. low virtuality teams | 11 | 269 | −.13 | .48 | −.13 | .44 | −.70/.44 | −.11/.37 | 18.95 | 19.01 | 18 |
| Face-to-face vs. high virtuality teams | 6 | 240 | .41 | .34 | .43 | .31 | .02/.83 | .19/.67 | 18.03 | 18.22 | 46 |
| Low virtuality vs. high virtuality teams | 1 | 40 | .10 | – | – | – | – | – | – | – | – |
| Information sharing openness | 30 | 749 | .15 | .52 | .16 | .48 | −.46/.77 | −.01/.33 | 15.93 | 15.93 | 66 |
| Face-to-face vs. virtual teams | 27 | 670 | .22 | .50 | .23 | .47 | −.37/.82 | .06/.40 | 16.15 | 16.17 | 97 |
| Face-to-face vs. low virtuality teams | 17 | 338 | .25 | .51 | .25 | .46 | −.33/.84 | .05/.45 | 19.35 | 19.36 | 68 |
| Face-to-face vs. high virtuality teams | 10 | 332 | .19 | .49 | .19 | .46 | −.40/.78 | −.06/.44 | 12.43 | 12.44 | 28 |
| Low virtuality vs. high virtuality teams | 3 | 79 | −.42 | .15 | −.42 | .00 | −.42/−.42 | −.56/−.28 | 100 | 100 | 22 |

*Note*. Positive correlations indicate greater virtuality resulted in more information sharing; negative correlations indicate face-to-face teams shared more information. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; $SD_r$ = sample size weighted standard deviation of the observed correlations; $\rho$ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_\rho$ = standard deviation of $\rho$; 80% CV = 80% credibility interval around $\rho$; 90% CI = 90% confidence interval around $\rho$; %SEV = percent variance due to sampling error; %ARTV = percent variance due to all corrected artifacts; $FD_k$ = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce $\rho$ to .05.

**Table 3**
Dimensions of virtuality as antecedents of team information sharing (IS).

| Meta-analysis | *k* | *N* | *r* | $SD_r$ | $\rho$ | $SD_\rho$ | 80% CV | 90% CI | %SEV | %ARTV | $FD_k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Use of virtual tools (VT)* | | | | | | | | | | | |
| None vs. full use of VT | 33 | 1000 | .12 | .52 | .13 | .51 | −.52/.78 | −.03/.29 | 13.15 | 13.20 | 53 |
| None vs. hybrid use of VT | 2 | 50 | .27 | .08 | .28 | .00 | .28/.28 | .18/.38 | 100 | 100 | 9 |
| Hybrid vs. full use of VT | 3 | 79 | −.30 | .22 | −.33 | .12 | −.48/−.17 | −.56/−.10 | 71.27 | 73.05 | 17 |
| *Informational value (IV)* | | | | | | | | | | | |
| High IV (no VT) vs. high IV (full VT) | 3 | 56 | .33 | .19 | .34 | .00 | .34/.34 | .15/.53 | 100 | 100 | 17 |
| High IV (no VT) vs. moderate IV (Full VT) | 20 | 565 | .20 | .46 | .21 | .44 | −.35/.78 | .03/.39 | 17.17 | 17.37 | 64 |
| High IV (no VT) vs. low IV (full VT) | 11 | 362 | .10 | .57 | .10 | .54 | −.59/.80 | −.18/.38 | 9.87 | 9.87 | 11 |
| *Synchronicity (sync.)* | | | | | | | | | | | |
| High sync. (no VT) vs. high sync. (Full VT) | 20 | 507 | .03 | .55 | .03 | .53 | −.66/.71 | −.17/.23 | 14.48 | 14.48 | 0 |
| High sync. (hybrid VT) vs. high sync. (Full VT) | 2 | 62 | −.32 | .24 | −.32 | .17 | −.54/−.10 | −.60/−.04 | 47.25 | 47.25 | 11 |
| High sync. (No VT) vs. high sync. (hybrid VT) | 2 | 50 | .27 | .08 | .28 | .00 | .28/.28 | .18/.38 | 100 | 100 | 9 |
| High sync. (no VT) vs. moderate sync. (full VT) | 7 | 358 | .40 | .29 | .41 | .28 | .06/.76 | .23/.59 | 16.39 | 16.61 | 50 |
| High sync. (no VT) vs. low sync. (full VT) | 7 | 152 | −.24 | .46 | −.24 | .41 | −.76/.29 | −.53/.05 | 21.05 | 21.05 | 27 |

*Note*. Positive correlations indicate greater virtuality resulted in more information sharing; negative correlations indicate face-to-face teams shared more information. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; $SD_r$ = sample size weighted standard deviation of the observed correlations; $\rho$ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_\rho$ = standard deviation of $\rho$; 80% CV = 80% credibility interval around $\rho$; 90% CI = 90% confidence interval around $\rho$; %SEV = percent variance due to sampling error; %ARTV = percent variance due to all corrected artifacts; $FD_k$ = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce $\rho$ to .05.

**Table 4**
Virtuality as a moderator of the team information sharing–performance relationship.

| Meta-analysis | *k* | *N* | *r* | $SD_r$ | $\rho$ | $SD_\rho$ | 80% CV | 90% CI | %SEV | %ARTV | $FD_k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Information sharing (overall) | 59 | 4029 | .37 | .18 | .40 | .15 | .21/.59 | .36/.44 | 36.31 | 38.03 | 413 |
| Face-to-face | 41 | 2027 | .35 | .18 | .37 | .14 | .19/.54 | .32/.42 | 48.45 | 49.68 | 262 |
| Virtual teams | 14 | 1688 | .40 | .17 | .44 | .16 | .23/.64 | .36/.52 | 20.61 | 22.79 | 109 |
| Low virtuality | 10 | 1537 | .41 | .18 | .45 | .18 | .23/.68 | .35/.55 | 14.41 | 15.93 | 80 |
| High virtuality | 4 | 151 | .33 | .06 | .37 | .00 | .37/.37 | .31/.43 | 100 | 100 | 26 |
| Information sharing uniqueness | 32 | 1726 | .38 | .16 | .39 | .12 | .25/.54 | .34/.44 | 53.63 | 55.55 | 218 |
| Face-to-face | 26 | 1199 | .40 | .17 | .43 | .12 | .27/.58 | .37/.49 | 52.23 | 53.74 | 198 |
| Virtual teams | 4 | 306 | .31 | .02 | .33 | .00 | .33/.33 | .31/.35 | 100 | 100 | 25 |
| Low virtuality teams | 2 | 196 | .31 | .03 | .34 | .00 | .34/.34 | .30/.38 | 100 | 100 | 12 |
| High virtuality teams | 2 | 110 | .30 | .00 | .30 | .00 | .30/.30 | .30/.30 | 100 | 100 | 10 |
| Information sharing openness | 35 | 2807 | .35 | .19 | .39 | .18 | .16/.62 | .33/.45 | 26.58 | 27.86 | 238 |
| Face-to-face | 21 | 1067 | .26 | .20 | .28 | .15 | .09/.47 | .20/.36 | 46.13 | 46.76 | 97 |
| Virtual teams | 11 | 1550 | .41 | .18 | .46 | .18 | .23/.68 | .36/.56 | 16.47 | 18.53 | 90 |
| Low virtuality teams | 9 | 1509 | .41 | .18 | .45 | .18 | .22/.68 | .34/.56 | 12.95 | 14.55 | 72 |
| High virtuality teams | 2 | 41 | .40 | .07 | .46 | .00 | .46/.46 | .37/.55 | 100 | 100 | 16 |

*Note*. *k* = number of correlations meta-analyzed; *N* = total number of groups; *r* = sample size weighted mean observed correlation; $SD_r$ = sample size weighted standard deviation of the observed correlations; $\rho$ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_\rho$ = standard deviation of $\rho$; 80% CV = 80% credibility interval around $\rho$; 90% CI = 90% confidence interval around $\rho$; % SEV = percent variance due to sampling error; %ARTV = percent variance due to all corrected artifacts; $FD_k$ = file drawer *k* representing the number of "lost" studies reporting null findings necessary to reduce $\rho$ to .05.

**Table 5**
Dimensions of virtuality as moderators of the team information sharing–performance relationship.

| Meta-analysis | $k$ | $N$ | $r$ | $SD_r$ | $\rho$ | $SD_\rho$ | 80% CV | 90% CI | %SEV | %ARTV | $FD_k$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Use of virtual tools* | | | | | | | | | | | |
| None | 42 | 2107 | .34 | .18 | .36 | .13 | .20/.53 | .31/.41 | 49.63 | 50.79 | 260 |
| Hybrid | 8 | 1515 | .42 | .16 | .46 | .16 | .25/.67 | .36/.56 | 13.80 | 15.90 | 66 |
| Full | 6 | 195 | .28 | .19 | .31 | .08 | .20/.41 | .17/.45 | 83.22 | 84.18 | 31 |
| *Informational value* | | | | | | | | | | | |
| Low | 3 | 148 | .33 | .05 | .34 | .00 | .34/.34 | .29/.39 | 100 | 100 | 17 |
| Moderate | 9 | 1361 | .42 | .18 | .46 | .18 | .22/.70 | .35/.57 | 14.39 | 16.05 | 74 |
| High | 44 | 2308 | .34 | .17 | .36 | .13 | .20/.53 | .32/.40 | 50.21 | 51.51 | 273 |
| *Synchronicity* | | | | | | | | | | | |
| Low | 1 | 38 | .42 | – | – | – | – | – | – | – | – |
| Moderate | 8 | 1347 | .42 | .17 | .46 | .16 | .25/.67 | .35/.57 | 15.47 | 17.85 | 66 |
| High | 46 | 2401 | .34 | .18 | .36 | .13 | .19/.53 | .31/.41 | 48.45 | 49.71 | 285 |

*Note.* $k$ = number of correlations meta-analyzed; $N$ = total number of groups; $r$ = sample size weighted mean observed correlation; $SD_r$ = sample size weighted standard deviation of the observed correlations; $\rho$ = sample size weighted mean observed correlation corrected for unreliability in both measures; $SD_\rho$ = standard deviation of $\rho$; 80% CV = 80% credibility interval around $\rho$; 90% CI = 90% confidence interval around $\rho$; %SEV = percent variance due to sampling error; %ARTV = percent variance due to all corrected artifacts; $FD_k$ = file drawer $k$ representing the number of "lost" studies reporting null findings necessary to reduce $\rho$ to .05.

teams ($\rho$ = .43, $k$ = 6); further, there is no difference in amount of unique information sharing between face-to-face and low virtuality teams ($\rho$ = −.13, $k$ = 11; the credibility interval includes zero).

Hypothesis 2 predicted open information sharing would be greatest in low virtuality and face-to-face teams as compared with high virtuality teams. Results are consistent with this hypothesis. Specifically, low virtuality teams more openly share information than high virtuality teams ($\rho$ = −.42, $k$ = 3), and no difference is found between face-to-face and low virtuality teams in open information sharing ($\rho$ = .25, $k$ = 17; the credibility interval includes zero). Importantly, results also suggest there is no difference between face-to-face and virtual teams overall in the amount of open information sharing ($\rho$ = .23, $k$ = 27; the credibility interval includes zero); rather, the effect is in the level of virtuality, not the distinction between face-to-face and virtual teams. Taken together, results related to Hypotheses 1 and 2 suggest that while low virtuality teams engage in more open information sharing than do high virtuality teams, the opposite pattern holds for unique information sharing; high virtuality teams engage in more unique information sharing than do low virtuality teams.

Although we made no specific hypotheses regarding Kirkman and Mathieu's (2005) three dimensions of virtuality as antecedents of team information sharing, Table 3 reports the results of analyses exploring the extent to which these aspects of virtuality may moderate the virtuality-information sharing (overall) relationship. Interestingly, results suggest that hybrid teams may share more information overall than either face-to-face or fully virtual teams. As can be seen in Table 3, we found no difference between face-to-face and fully virtual teams in levels of information sharing ($\rho$ = .13, $k$ = 33, credibility interval includes zero), but results suggest hybrid teams shared more information than either face-to-face ($\rho$ = .28, $k$ = 2) or fully virtual teams ($\rho$ = −.33, $k$ = 3; the confidence intervals do not overlap). Further, although no differences in information sharing are seen between face-to-face teams and virtual teams using tools of low and moderate informational value ($\rho$ = .10, $k$ = 11 and $\rho$ = .21, $k$ = 20, respectively; both credibility intervals include zero), results suggest virtual teams using tools of high informational value engage in more information sharing than face-to-face teams ($\rho$ = .34, $k$ = 3), thus suggesting that low virtuality tools may promote more information sharing than either face-to-face or high virtuality interactions. With regards to synchronicity, results suggest no differences between face-to-face teams and virtual teams using tools of high or low synchronicity ($\rho$ = .03, $k$ = 20 and $\rho$ = −.24, $k$ = 7, respectively; both credibility intervals include zero). However, virtual teams making use of tools of moderate synchronicity (i.e., using a variety of virtual tools) engage in more information sharing than face-to-face teams ($\rho$ = .41, $k$ = 7).

Hypothesis 3 looked at the role of virtuality as a moderator of the information sharing–team performance relationship, predicting this relationship would be moderated both by virtuality and type of information sharing, such that (1) unique information sharing would be more strongly related to team performance in face-to-face teams and (2) open information sharing would be more strongly related to team performance in virtual teams. As can be seen in Table 4, results support the hypothesized interaction between virtuality and type of information sharing. Specifically, for *face-to-face teams*, the information sharing uniqueness–team performance relationship is stronger than is the information sharing openness–team performance relationship ($\rho$ = .43, $k$ = 26 vs. $\rho$ = .28, $k$ = 21, respectively; the confidence intervals do not overlap). Conversely, for *virtual teams*, the information sharing openness–team performance relationship is stronger than is the information sharing uniqueness–team performance relationship ($\rho$ = .46, $k$ = 11 vs. $\rho$ = .33, $k$ = 4, respectively; the confidence intervals do not overlap). The pattern of findings is depicted in Fig. 1.

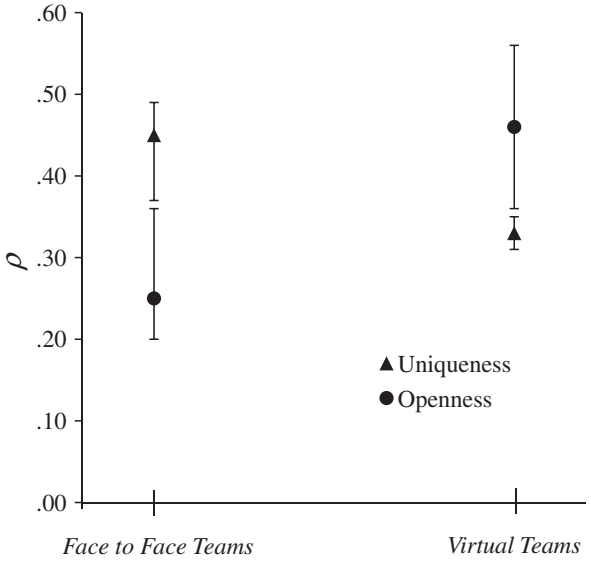


**Fig. 1.** Relationship between information sharing and team performance by type of information sharing and virtuality of team.

Table 5 reports the results of exploratory moderator analyses examining the extent to which Kirkman and Mathieu's (2005) three dimensions of virtuality moderate the information sharing–team performance relationship. Results suggest the information sharing (overall)–team performance relationship is strongest for hybrid teams and for teams using virtual tools moderate in informational value and synchronicity. Specifically, with regard to use of virtual tools dimension, the information sharing (overall)–team performance relationship is similar for face-to-face and fully virtual teams ($\rho = .36$, $k = 42$ and $\rho = .31$, $k = 6$, respectively; the confidence intervals overlap considerably), and both relationships were weaker than for hybrid teams ($\rho = .46$, $k = 8$). Similarly, with regard to informational value dimension, the information sharing (overall)–team performance relationship is similar for teams making use of virtual tools of low and high informational value ($\rho = .34$, $k = 3$ and $\rho = .36$, $k = 44$, respectively; the confidence intervals overlap considerably), and both relationships are weaker than for teams using tools of moderate informational value ($\rho = .46$, $k = 9$; the effect is not included within the confidence intervals of the compared effects). With regard to the synchronicity dimension, results suggest the information sharing (overall)–team performance relationship is stronger in teams using a variety of tools (moderate synchronicity; $\rho = .46$, $k = 8$) than in teams with highly synchronous interactions ($\rho = .36$, $k = 46$).

## Discussion

Although virtual interactions are clearly the norm in most organizations (e.g., Cramton, 2001; Lipsinger, 2010), there is still much to learn regarding how team virtuality affects team interaction and performance. Prior reviews have yielded mixed conclusions regarding the impact of virtuality on team informational processes (e.g., Baltes et al., 2002; Fjermestad, 2004; McLeod, 1992; Rains, 2005). We reorganized prior research on the association between team virtuality and team information sharing according to recent advancements in theory regarding team information sharing (e.g., Mesmer-Magnus & DeChurch, 2009) and virtual teams (e.g., Kirkman & Mathieu, 2005) to explore the extent to which level of virtuality affects different types of team information sharing as well as the extent to which degree of virtuality and type of information sharing set important boundary conditions for the information sharing–team performance relationship. Results reveal new insights on these relationships and highlight moderators which likely explain discrepant findings from prior reviews.

### *Theoretical contributions*

The overarching theoretical contribution of this work is that understanding the nuances of how communication modalities affect team processes requires attention to dimensions of team informational process as well as to where a team falls along the virtuality continuum. Both the direct and moderated relationships differ by level of team virtuality, and by type of information sharing. In examining the direct effects of virtuality on information sharing, we find the role of virtuality in team information sharing is moderated by type of information sharing such that more unique and less open information sharing occurs in high virtuality teams as compared with low virtuality and face-to-face teams. Examining the team virtuality–information sharing relationship from this multi-dimensional theoretical perspective sheds light on previously discrepant findings. For example, some studies have reported virtuality enhances information sharing (e.g., Jessup & Tansik, 1991; Lam & Schaubroeck, 2000) whereas others have found virtuality negatively affects it (e.g., Cramton, 2001; Hollingshead, 1996a, 1996b). Similarly, while Fjermestad (2004) found face-to-face teams reported better communication than Group Support System (GSS) teams, Rains (2005) found that groups using a GSS generated a larger amount of unique ideas than face-to-face groups. The explanation for these apparently discrepant findings lies in both the nature of information sharing and the nature of virtuality examined in each review. Specifically, Fjermestad and Rains focused on different levels of interacting moderators within the virtuality-information sharing relationship: Fjermestad focused on open information sharing while Rains focused on unique information sharing. Further, both compared face-to-face teams with teams higher on the virtuality continuum. When reframed into the multidimensional framework examined here, both results make more sense: high virtuality teams exchange more unique information whereas face-to-face teams exchange information more openly.

Another key insight resulting from our meta-analytic reorganization of the primary research on the role of virtuality in team informational process, is that both virtuality and type of information sharing set important boundary conditions on the information sharing–team performance relationship. Mesmer-Magnus and DeChurch (2009) concluded that unique information sharing is more strongly predictive of team performance than is open information sharing, though our results suggest this conclusion only holds for face-to-face teams. Specifically, only by examining both moderators (i.e., type of information sharing and the distinction between face-to-face and virtual teams) in concert do we see that the information sharing–team performance relationship is somewhat more complex: (1) unique information sharing promotes greater team performance than open information sharing in face-to-face teams whereas (2) open information sharing promotes greater team performance than unique information sharing in virtual teams. A likely explanation for this difference is that open information sharing promotes the affective outcomes, such as team satisfaction, cohesion, and trust, known to improve team process and performance, outcomes which are arguably more difficult to develop in high virtuality teams (Jarvenpaa & Leidner, 1999). Another compounding factor is that the type of information that tends to be shared in face-to-face as compared with virtual teams is exactly opposite that which is likely to promote the highest levels of performance in these teams. Specifically, although virtual teams do well with unique information sharing, it is actually open information sharing that is most strongly predictive of their performance. Conversely, although face-to-face teams are predisposed to openly share information, it is unique information sharing that will promote their performance.

### *Directions and Implications for future research*

Importantly, where a team falls along the virtuality continuum reflects a combination of factors associated with the virtual media they use. Kirkman and Mathieu (2005) recently delineated three dimensions that comprise team virtuality; the combination of these dimensions defines a team's overall level of virtuality: (1) extent of reliance on virtual tools as well as the (2) informational value (the extent to which teams exchange information that is valuable for team effectiveness) and (3) synchronicity (the extent to which the team's communications occur in real time versus incurring a time lag) afforded by the tools. Along the virtuality continuum, the most virtual teams are highly reliant on asynchronous virtual tools that permit the transmission of information low in informational value. Although Kirkman and Mathieu conceptualized the three dimensions of virtuality as being orthogonal, the practical reality is that the dimensions of virtuality are confounded in the types of virtual media employed by today's teams and examined in primary research, and thus do not permit us to easily tease apart the unique affects of each dimension of virtuality on different

types of information sharing nor to conduct a fully factorial moderator analysis exploring the interaction between multiple dimensions of information sharing and virtuality in the information sharing–team performance relationship. Nonetheless, we were able to conduct exploratory moderator analyses examining the impact on overall team information sharing of the three dimensions of virtuality, and to explore the extent to which they may moderate the team information sharing–performance relationship.

Two key insights emerged from these analyses, suggesting important avenues for future research wherein the dimensions of virtuality of the various communication tools used by today's teams may be examined in relation to their role in different types of team information sharing. First, the extent to which teams make use of virtual tools exhibits a curvilinear relationship with information sharing (overall) such that more information sharing appears to occur in hybrid teams than in either face-to-face or fully virtual teams. As face-to-face and virtual communications offer unique advantages to communication process, teams that are able to engage in both face-to-face and virtual interaction are getting the "best of both worlds" since they receive the advantages of both communication modes. For example, a project team that regularly meets face-to-face and supplements that communication with the use of virtual tools in the interim has the opportunity to coordinate work, ensure all are on the same page, and resolve issues quickly (advantages of face-to-face team meetings) as well as pose follow-up questions, do additional problem-relevant research, and weigh/integrate information provided by other team members (advantages of virtual team communication).

Second, interestingly, our results also suggest the information sharing (overall)–team performance relationship may be stronger in hybrid teams. Although hybrid teams have the advantages of both face-to-face and virtual teams (and the nature of both forms of interactions increase opportunities to share information), they also possess the disadvantages of both face-to-face (e.g., production blocking, evaluation apprehension) and virtual communication (e.g., lack of warmth, reduced verbal and non-verbal cues, increased possibilities of misunderstandings; Aubert & Kelsey, 2003; Ensher et al., 2003; Straus, 1996). In the face of such process losses, the effective sharing of information becomes even more important to a team's success. Future research might explore the comparative impact of each type of information sharing (uniqueness and openness) on performance in hybrid teams.

A key implication for future research is virtuality exists along a continuum, rather than at two artificial extremes (face-to-face versus virtual). The various dimensions of Kirkman and Mathieu's (2005) taxonomy of virtuality might be combined to plot points along this continuum. Unfortunately, given the constraint of what was available in the extant literature, we were only able to examine virtuality at three points along this continuum: face-to-face, low virtuality, and high virtuality. As the advantages and disadvantages of virtual tools vary by form, in order to make meaningful conclusions regarding the role of virtuality in team functioning, researchers must consider how the communication media used by today's teams fit within the broader continuum of virtuality.

Another potentially fruitful avenue for research would be to examine the extent to which different virtual tools effectively support different group processes. Such research would enable recommendations for team leaders regarding the appropriate mix of tools for specific teamwork/project requirements. Similarly, future research might work to clearly delineate the strengths/weaknesses of various virtual tools as such knowledge would help managers weigh cost/feasibility of these tools with their associated performance implications.

Given our results suggesting greater information sharing may occur in hybrid teams, future research might attempt to determine the ideal mix of various virtual media and frequency of face-to-face interactions. Such an exploration should certainly consider virtual tools occupying various points along the virtuality continuum (Gajendran & Harrison, 2010; Kirkman & Mathieu, 2005).

Future research might also explore the extent to which virtuality affects team performance. We explored the extent to which virtuality affected information sharing and moderated the information sharing–team performance relationship, but it would very useful to know the extent to which different virtual tools and different levels of virtuality affected a team's performance, and whether these relationships differed across various team types and tasks.

Finally, future research might explore the potential impacts of team heterogeneity and identity on the relationship between virtuality and information sharing. Much of the reason for increased virtuality is the globalization of organizations (Baba, Gluesing, Ratner, & Wagner, 2004). Indeed, Connaughton and Shuffler (2007) identify multinational and multicultural issues as a critical area of research in relation to virtuality, as many virtual teams are comprised of team members from a range of backgrounds. For example, Mesmer-Magnus and DeChurch (2009) found team heterogeneity negatively affected information sharing, but their findings were based on mainly face-to-face teams. The use of certain virtual tools may moderate this relationship, such that certain tools may reduce the apparent discomfort associated with sharing information with unlike others. Similarly, team identity may vary as a function of both a team's virtuality and its heterogeneity, affecting the nature of team information sharing.

### *Managerial implications*

Our results suggest managers should encourage open information sharing in virtual teams, because although unique information sharing is more strongly predictive of performance in face-to-face teams than is open information sharing (cf. Mesmer-Magnus & DeChurch, 2009), open information sharing appears to have greater importance than unique information in virtual teams. This is likely due to the fact that open information sharing facilitates team processes/outcomes that are arguably more challenging to handle in virtual than in face-to-face settings but are nonetheless important to team functioning (e.g., cohesion building, cooperation, trust). Managers can encourage such openness in information sharing by setting norms for frequent/on-going communications within the team, reminding team members they bring unique/important insights to the teams and that they should share that information, providing teams access to a variety of tools (e.g., teleconferencing, email, shared databases, videoconferencing, teleconferencing), structuring information exchange such that a record of team communications/decisions is available for all team members, and encouraging team norms that support high performance (e.g., avoiding "satisficing" in favor of creating high quality outputs).

The results of our exploratory moderator analyses based on the Kirkman and Mathieu (2005) taxonomy suggest that teams share more information when using a mix of face-to-face and virtual interactions (hybrid teams). This supports previous research which has suggested that it is important for virtual teams to get together occasionally during projects as occasional in-person meetings permit more efficient team development, faster and more effective conflict resolution, and greater team cohesion and satisfaction (Alge, Wiethoff, & Klein, 2003; Martins, Gilson, & Maynard, 2004; Strauss, 1996). Further, it may be that different forms of interaction are more conducive to supporting different team processes (i.e., transition versus action; Marks et al., 2001). Specifically, face-to-face interaction (as well as the low virtuality tools that attempt to simulate it) may facilitate team transition processes like planning and goal specification, whereas high virtuality tools may be more conducive to action team processes like coordination, backup behavior, and team monitoring. For example, project teams may

meet face-to-face or via low virtuality tools (e.g., teleconferencing and videoconferencing) to strategize about a project, but then use high virtuality tools (e.g., shared databases, email exchanges) between face-to-face meetings to actually coordinate and implement team work. Or, it may just be that use of both forms of interaction offers more opportunities for team members to communicate, thus increasing team information sharing. Teasing apart this story is a promising direction for future research. These data suggest managers of virtual teams ought to create opportunities for teams to meet in-person periodically and/or provide access to a variety of virtual tools representing various points along the virtuality continuum (Alge et al., 2003; Martins, Gilson, and Maynard, 2004; Strauss, 1996). Fortunately, the hybrid team is rapidly becoming the norm in the virtual organizations of today.

### Limitations

By recasting the 94 independent studies examined in this meta-analysis within a multidimensional view of information sharing (Mesmer-Magnus & DeChurch, 2009) as well as along a continuum of virtuality (informed by Gajendran & Harrison, 2010; Kirkman & Mathieu, 2005), the current findings shed new light on the manner in which virtuality affects distinct informational processes in teams. Importantly, several limitations exist that may qualify the current conclusions. Although we know of no criteria regarding the minimum number of studies required to conduct meta-analysis, we recognize the small number of primary studies available for some of our analyses are subject to second-order sampling error bias (Hunter & Schmidt, 2004). Importantly, second-order sampling error tends to affect standard deviations more than rhos (Hunter & Schmidt, 2004). Further, as our aim with these small *k* meta-analyses was not so much to estimate the size of the virtuality effect, but more to assess its direction, this limitation is less of an issue in our study. Nonetheless, our findings should be used to guide future research aimed at teasing apart the role of virtuality in team information sharing and performance, and effect sizes based upon small *k* meta-analyses should be interpreted with caution.

A second limitation of the current research involves the impact of temporal issues. With regard to virtuality there are two notable omissions relevant to time. The first is the possibility that the strength and direction of effects have changed over the past two decades. The technology has changed rapidly, as have its transparency to organizational members, thus it is possible that our estimates of effects over the full empirical record are masking different (i.e., stronger or weaker) effects at different points in historical time.

The second temporal issue concerns time as clocked by team development. It is logical to consider that virtual communication would have different effects on newly formed and well established teams (Walther, 1992; Wilson, Straus, & McEvily, 2006). We were unable to pose this as a moderator variable, as very few studies enabled such comparisons. Table 6 provides descriptive information about the current database of studies. The majority of studies examining these relationships have done so using student samples (84%). Further, most studies have been conducted in laboratory settings (87%). Thus, it is likely that an important qualification of the current findings is that they are largely based on teams in early stages of team development. Future research is needed that explores these relationships in applied organizational settings, tracking the effects of multiple dimensions of virtuality on both unique and open information sharing, across the stages of team lifecycles.

**Table 6**
Summary of database team characteristics table ($N = 94$).

| | *N* | Percent |
|---|---|---|
| *Sample type* | | |
| Student | 79 | 84 |
| Other | 15 | 16 |
| *Team type* | | |
| Management | 20 | 21 |
| Project/development, task forces | 10 | 11 |
| Action/negotiation | 6 | 6 |
| Advice/involvement, parallel groups | 56 | 60 |
| Varied | 2 | 2 |
| *Design* | | |
| Experimental | 78 | 83 |
| Other (Quasi-experimental and survey) | 16 | 17 |
| Setting | | |
| Field | 12 | 13 |
| Lab | 82 | 87 |

## Conclusion

Two decades ago, increased technology utilization prompted organizational researchers to systematically explore the impact of computer-mediated communication on information exchange in teams. A decade ago, it was proclaimed that virtual interactions were quickly becoming the norm in many organizations (Cramton, 2001). We submit that today, the fundamental issue for organizational scientists has changed. We no longer need to understand the impact of virtual communication in order to prefer one method to another, or even to prefer one method to another for certain types of communication at certain times, but rather, we need to understand these impacts so that we may ultimately understand how different subsets of team members can optimize communication flows through the variety of media-enabled virtual interactions they are already engaging in.

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