The "Double-Edged Sword" Effect of Team Virtuality: A Team Development Perspective

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Abstract

Team virtuality refers to the degree to which team members work in a distributed manner and collaborate through virtual communication tools. Enhancing team virtuality has become a crucial initiative for organizations to adapt to the development of the digital economy and respond to the impact of the pandemic. However, the academic community has yet to provide a definitive answer regarding whether team virtuality promotes or inhibits team performance. This not only creates deficiencies in theoretical understanding but also makes it difficult to offer effective guidance for organizations seeking to fully leverage the advantages of team virtuality to improve team performance. Based on a team development perspective, this project conducts three studies centered on questions such as "whether team virtuality is beneficial or detrimental to team performance and how to maximize its advantages while minimizing its disadvantages" : (1) introducing team development stage as a dynamic contingency factor to analyze the differential impact of team virtuality on team performance across different team development stages; (2) exploring the dual pathways through which team virtuality promotes and inhibits team performance, and elucidating which pathway plays a dominant role at different team development stages; (3) investigating how team leaders can enhance or weaken the positive and negative effects of team virtuality on team performance at different team development stages. This project constructs a new theoretical framework for analyzing the "double-edged sword" effect of team virtuality on team performance and can provide decision-making support for team leaders to match appropriate management intervention strategies according to team development stages.

Full Text

The Double-Edged Sword Effects of Team Virtuality: A Study from the Team Development Perspective

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Abstract

Team virtuality refers to the extent to which team members work in dispersed locations and collaborate through virtual communication tools. Enhancing team virtuality has become a critical organizational response to digital economic development and the COVID-19 pandemic. However, academic research has yet to provide a definitive answer regarding whether team virtuality promotes or inhibits team performance. This theoretical ambiguity not only creates a gap in scholarly understanding but also fails to offer effective guidance for organizations seeking to leverage team virtuality to enhance performance. Grounded in a team development perspective, this project addresses the question of whether team virtuality benefits or harms team performance and how to maximize its advantages while minimizing its drawbacks through three studies: (1) introducing team development stage as a dynamic contingency factor to analyze the differential effects of team virtuality on team performance across various developmental stages; (2) examining the dual pathways through which team virtuality promotes and inhibits team performance, and identifying which pathway dominates at different team development stages; and (3) exploring how team leaders can enhance the positive effects and mitigate the negative effects of team virtuality on team performance at different developmental stages. This project constructs a novel theoretical framework for analyzing the double-edged sword effects of team virtuality on team performance and provides decision-making support for team leaders to implement stage-matched management intervention strategies.

Keywords: team virtuality, team performance, team development stage, leader intervention

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On December 12, 2021, the State Council issued the "14th Five-Year Plan for Digital Economy Development" (Guofa [2021] No. 29), emphasizing that

the digital economy is driving profound transformations in production methods, lifestyles, and governance models, becoming a key force in reorganizing global factor resources, reshaping global economic structures, and changing global competition patterns. The notice also pointed out that to empower enterprise operations and support the Digital China strategy, organizations should further innovate digital management models. In light of this, management scholars should explore scientific principles and distill practical insights from management practices at all organizational levels to provide important guidance for enterprise digital management.

Virtual teams represent a highly contemporary and representative team operation model that aligns with digital economic development (张志学等, 2021). The core characteristic of virtual teams is team virtuality, which primarily manifests as the geographic dispersion of team members and the level of virtual communication tool usage (Gilson et al., 2015). Higher team virtuality means team members work in more dispersed locations and collaborate more frequently through virtual communication tools. According to statistics, after the COVID-19 outbreak, approximately 80% of global enterprises were forced to increase team virtuality to varying degrees to reduce infection risks (Meluso et al., 2020). This measure addressed urgent needs and kept team operations running during the pandemic. Some companies (such as Ctrip and Twitter) recognized the performance-enhancing benefits of team virtuality and even announced permanent adoption of virtual work arrangements. Moreover, many employees experienced the benefits of virtual work and hoped to continue this arrangement after the pandemic (Karl et al., 2022). However, other companies noted that increasing team virtuality during the pandemic was a reluctant measure rather than an optimal strategy, creating numerous management problems that hindered team performance goal achievement (Purvanova & Kenda, 2021). This raises a critical question: Is team virtuality beneficial or detrimental to team performance? And in the post-pandemic digital era, should organizations continue virtual team operations or return to traditional face-to-face arrangements?

Unfortunately, existing research offers contradictory and inconclusive answers to this pressing question. Some studies suggest that virtual team operations help overcome spatial and temporal constraints to integrate human and material resources, enhancing operational flexibility and reducing communication costs to improve efficiency. Consequently, team virtuality is viewed as a catalyst for team performance (e.g., Boh et al., 2007; Purvanova et al., 2020). Conversely, other research indicates that in highly virtual teams, geographic dispersion and lack of face-to-face communication often result in weak emotional connections, insufficient trust and mutual dependence among members, and ultimately poor collaboration. Therefore, team virtuality not only fails to improve but actually inhibits team performance (e.g., Gibson & Gibbs, 2006; Schmidtke & Cummings, 2017). Recent meta-analytic results even show no significant correlation between team virtuality and team performance (Purvanova & Kenda, 2021). In summary, the academic community has not yet provided a clear answer to whether team virtuality helps or harms team performance, indicating an incom-

plete understanding of its influence patterns and an inability to make reliable predictions about the team virtuality-performance relationship. This confusion also leads to contradictory management implications, leaving practitioners uncertain about whether to increase team virtuality and what strategies might enable it to enhance performance. Therefore, we need innovative theoretical perspectives and integrated, systematic, and distinctive theoretical paradigms to interpret the complex relationship between team virtuality and team performance, advance and guide research in this field, and provide scientific foundations for team management decisions.

Based on these considerations, this project explores the contingency factors, mechanisms, and intervention strategies through which team virtuality produces both positive and negative effects on team performance. It aims to provide a new, systematic theoretical framework explaining why team virtuality has both detrimental and beneficial effects, thereby advancing research frontiers. Practically, it provides scientific guidance for organizations selecting team operation models and improving efficiency, while offering innovative direction for team leaders to enhance their leadership effectiveness in virtual work environments.

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2. Research Framework

This project argues that contradictory findings regarding whether team virtuality is beneficial or harmful primarily stem from neglecting the dynamic nature of team development and overlooking how virtuality' s effects differ across developmental stages. Team Development Theory (Kozlowski et al., 1999) posits that teams progress through three stages—formation, development, and maturity—and that specific team characteristics (such as virtuality) have dynamic effects on performance that may vary or even reverse across these stages. Meta-analytic results also show that team virtuality significantly negatively correlates with performance in samples with short team development timeframes, but shows no significant relationship in samples with greater development time variation (Purvanova & Kenda, 2021). These theoretical and empirical insights suggest that team development stage may be a critical contingency factor causing the double-edged sword effects of team virtuality on performance, yet previous research has rarely examined this factor and its underlying mechanisms. This gap creates theoretical deficiencies and incomplete empirical findings, leaving practitioners unclear about whether and what stage-matched interventions can effectively manage virtuality' s effects.

Guided by Team Development Theory, this project explores how team virtuality influences team performance across different developmental stages, including its effects, mechanisms, and intervention strategies. Specifically, (1) it analyzes the differential effects of team virtuality on team performance at various development stages; (2) drawing on team information processing literature, it identifies the promoting and inhibiting mechanisms through which virtuality affects per-

formance and determines which mechanism dominates at each stage; and (3) it examines what strategies team leaders can employ at different stages to enhance virtuality' s positive effects while mitigating its negative consequences.

2.1 Study 1: The Effects of Team Virtuality on Team Performance Across Development Stages

Study 1 applies Team Development Theory, using team development stage as a contingency factor affecting the virtuality-performance relationship to analyze differential effects across stages. Team Development Theory conceptualizes teams as dynamic, adaptive systems that progress through formation, development, and maturity stages, with distinct key factors influencing performance at each stage (Kozlowski et al., 1999; Zander et al., 2013).

During the team formation stage, members lack understanding of the team and each other, experiencing high uncertainty and anxiety. They need information about the team and their roles to integrate effectively. Rapid integration and adaptation allow members to focus on task completion and enhance performance, whereas high uncertainty and anxiety may prevent work engagement (Dierdorff et al., 2011). In highly virtual teams, members work in dispersed locations, relying primarily on electronic media with limited face-to-face contact. This communication mode conveys less socio-emotional information, hindering accurate interpretation of behaviors and impeding member interaction (Hacker et al., 2019). Consequently, it obstructs rapid information acquisition, clear role cognition, and effective integration—critical factors for performance during formation (Dierdorff et al., 2011; Kozlowski & Bell, 2013).

During the team development stage, trust among members increases substantially. The primary focus shifts to mastering work skills through practice and establishing collaboration patterns through role interaction (Kozlowski et al., 1999; Zander et al., 2013). Key performance factors include whether members can exchange and learn information about work skills and role responsibilities to enhance task completion capabilities (Pearsall et al., 2010). Highly virtual teams rely more on information and communication technology (ICT), which reduces the salience of status-related individual characteristics, decreases hierarchical information transmission, and increases information openness, allowing members to access and share more relevant information (秦辉, 王瑜炜, 2016; Triana et al., 2012). Additionally, virtual communication records and preserves substantial information, enabling easy retrieval and transfer (Kanawattanachai & Yoo, 2007). With established trust, these features help members access rich information and resources to master skills and develop efficient collaboration patterns—the main determinants of performance during the development stage.

In the team maturity stage, members have established friendly, open, and highly interdependent norms, focusing intensively on task completion (Zander et al., 2013). Key performance factors become the team' s ability to efficiently leverage

existing knowledge and skills to solve problems and flexibly respond to internal and external demands (Kozlowski et al., 1999; Pearsall et al., 2010). Virtual work arrangements offer significant advantages, substantially enhancing flexibility. Virtual communication enables rapid, accurate information retrieval and distribution, helping members access task-relevant information anytime and improving information processing and problem-solving capabilities (Kanawattanachai & Yoo, 2007). Moreover, virtual operations allow collaboration across time and space, enhancing team flexibility (Gibson et al., 2015). Problem-solving ability and flexibility are crucial for performance at the maturity stage.

Based on this reasoning, we propose the following hypotheses:

Hypothesis 1-1: Team virtuality is negatively related to team performance during the team formation stage.

Hypothesis 1-2: Team virtuality is positively related to team performance during the team development stage.

Hypothesis 1-3: Team virtuality is positively related to team performance during the team maturity stage.

2.2 Study 2: Mechanisms of Team Virtuality's Effects on Performance Across Development Stages

The reasoning for Study 1' s hypotheses indicates that information acquisition, processing, and exchange are crucial for performance at all stages. However, Team Development Theory does not fully explain how team characteristics influence performance through these information processing mechanisms. Study 2 integrates Team Development Theory with team information processing perspectives (e.g., De Dreu et al., 2008; Hinsz et al., 1997) to identify the promoting and inhibiting mechanisms of team virtuality and examine their relative strength across development stages, providing deeper theoretical explanation for why virtuality produces opposite effects at different stages.

2.2.1 Promoting and Inhibiting Pathways of Team Virtuality' s Effects

We propose that team virtuality enhances team information transmission capability while simultaneously reducing members' information sharing willingness. Information transmission capability improves performance, whereas low sharing willingness decreases it, creating dual and potentially offsetting effects.

Team information transmission capability refers to members' ability to allocate, retrieve, and extract relevant information as needed (Kanawattanachai & Yoo, 2007). Information processing research (Hinsz et al., 1997) views individuals as information carriers whose interactions and media usage affect group transmission capability. Team virtuality reflects differences in interaction patterns and ICT dependence. In highly virtual teams, dispersed members rely primarily on ICT for interaction, enabling rapid information allocation (Marlow et al., 2017)

and preserving communication records that facilitate easy information search and extraction (Kanawattanachai & Yoo, 2007).

Enhanced information transmission capability positively affects team performance, defined as overall task completion efficiency and quality (Hu & Liden, 2015). Information processing research indicates that effective information storage, allocation, and extraction form the basis for group information integration, which critically influences group decision-making (De Dreu et al., 2008; Hinsz et al., 1997). Strong transmission capability enables rapid, effective information integration, clarifying problem solutions (郎艺, 尹俊, 2021; Schmidtke & Cummings, 2017), improving decision efficiency, and thereby enhancing performance.

Integrating this logic, we argue that high virtuality teams' heavy ICT reliance facilitates information allocation, search, and extraction, strengthening transmission capability, which in turn improves performance. Thus:

Hypothesis 2-1: Team information transmission capability mediates the positive relationship between team virtuality and team performance.

Conversely, motivated information processing research (De Dreu et al., 2008) extends information processing theory (Hinsz et al., 1997) by examining psychological motivations affecting information sharing (吴梦, 白新文, 2012). This research suggests sharing willingness depends on: (1) individuals' effort to develop comprehensive, deep, and accurate understanding of issues, and (2) the extent to which they prioritize group over personal goals and contribute to collective welfare.

We contend that higher team virtuality weakens members' information sharing willingness, particularly for tacit information. First, virtual communication generates massive information volumes (e.g., numerous messages and emails), much of which is irrelevant or unimportant, consuming memory capacity and causing cognitive overload (Marlow et al., 2017). Virtual communication also requires senders to reprocess information (e.g., converting speech to text), increasing time and effort costs. These factors reduce members' motivation to expend cognitive resources sharing tacit information for deep understanding. Second, virtual communication conveys less rich social information (Schmidtke & Cummings, 2017), hindering clear perception of others' personalities and behavioral traits and impeding collaboration. This weakens members' identification with the group, reducing their consideration of group goals and motivation to share important tacit information for team development.

Lower information sharing willingness subsequently reduces team performance. Information processing research (Hinsz et al., 1997) considers individual information sharing, especially of tacit information, essential for effective group processing and decision-making. When members share unique information, teams can make more comprehensive and accurate judgments and discover new work methods, skills, or tools (李倩等, 2019; Schmidtke & Cummings, 2017). Conversely, low sharing willingness hinders rapid, accurate environmental assessment and

innovative thinking, suppressing performance. Therefore, weak sharing willingness inhibits team performance.

In summary, virtual communication generates substantial redundant information, causing cognitive overload (Chamakiotis et al., 2021) and impeding close interpersonal relationships, which reduces members' motivation to share information, particularly tacit information, for team development. This prevents teams from leveraging diverse member information for rapid analysis, reaction, and problem-solving, thereby inhibiting performance. Thus:

Hypothesis 2-2: Team member information sharing willingness mediates the negative relationship between team virtuality and team performance.

2.2.2 Relative Strength of Promoting versus Inhibiting Effects Across Development Stages Having examined how team virtuality affects performance through information transmission capability and sharing willingness, we now consider how their relative strength varies across development stages.

During team formation, members'unfamiliarity with tasks and each other creates high uncertainty, anxiety, and psychological distance (Peralta et al., 2018; Zander et al., 2013). These psychological characteristics lead members to form abstract, decontextualized trait attributions about others' behaviors (Wilson et al., 2013). For example, members may attribute slow message responses to cold personality rather than busy schedules. In this context, dispersed work and highly virtual communication convey limited contextual and socio-emotional information, hindering observation of psychological states and behaviors (Chamakiotis et al., 2021) and increasing misunderstanding and conflict that impair effective interaction. Since effective interaction and collective identity formation drive information sharing motivation, team virtuality strongly negatively affects sharing willingness during formation.

Meanwhile, although high virtuality teams benefit from ICT advantages in information storage, search, and extraction, these benefits are less pronounced during formation. Members lack clear understanding of tasks, responsibilities, and virtual communication methods, and have not yet mastered information transmission tools (Kanawattanachai & Yoo, 2007). Therefore, virtuality' s positive effect on information transmission capability is weak during formation.

Team Development Theory also indicates that different factors drive performance at different stages (Kozlowski et al., 1999). During formation, key activities involve forming team cognition and integrating oneself into the team, which determine performance (Dierdorff et al., 2011). High sharing willingness facilitates exchange of tacit team information, enabling clear cognition and integration, thus strongly positively affecting formation-stage performance. Although information transmission capability may promote performance, this effect is weak because tasks are just beginning and members lack deep task and role understanding. Overall, during formation, virtuality' s negative effect on sharing willingness is strong, its positive effect on transmission capability is

weak, and sharing willingness has a stronger positive impact on performance than transmission capability. Integrating this logic:

Hypothesis 2-3: During the team formation stage, the negative indirect effect of team virtuality on team performance through reduced member information sharing willingness is stronger than the positive indirect effect through enhanced team information transmission capability.

Team collaboration evolves dynamically. During the team development stage, members acquire work-related skills through practice and establish interaction patterns through role relationships (Kozlowski et al., 1999; Kozlowski & Bell, 2013). Uncertainty and psychological distance decrease significantly (Peralta et al., 2018; Zander et al., 2013). Consequently, even with extensive ICT-mediated remote communication, virtuality causes less misunderstanding and weaker negative effects on interaction and sharing motivation. Thus, virtuality' s negative effect on sharing willingness is weak during development. Moreover, as members focus more on skill mastery (Pearsall et al., 2010) and become more familiar with ICT, tasks, and roles, they better leverage ICT for information allocation, search, and extraction, strengthening virtuality' s positive effect on transmission capability.

During this stage, the performance impact of transmission capability and sharing willingness are comparable. Mastering work skills, understanding role positioning, and applying these to complete tasks are key performance determinants (Pearsall et al., 2010). Strong sharing willingness stimulates more exchange about tasks and roles, while strong transmission capability provides the necessary conditions for such exchange. Both play important roles in enhancing development-stage performance. Given that virtuality' s positive effect on transmission is strong while its negative effect on sharing willingness is weak:

Hypothesis 2-4: During the team development stage, the positive indirect effect of team virtuality on team performance through enhanced team information transmission capability is stronger than the negative indirect effect through reduced member information sharing willingness.

In the team maturity stage, collaboration reaches the team level with highly trusting and interdependent patterns, focusing primarily on task completion (Panteli et al., 2019). Virtual team members have highly adapted to virtual communication and expect to use these technologies to improve efficiency and flexibly respond to environmental changes. Smooth member interaction also helps identify problems and improvement solutions in virtual communication, strengthening virtuality' s positive effect on transmission capability. Additionally, since task completion requires extensive information sharing for solution development, members are less likely to reduce sharing willingness despite dispersed work and virtual communication challenges. Thus, virtuality' s negative effect on sharing willingness is weak during maturity.

During this stage, transmission capability has a stronger performance impact than sharing willingness. The ability to form systematic cognitive structures,

focus intensively on task completion, and coordinate to adapt to complex environments becomes central to performance (Kozlowski et al., 1999; Pearsall et al., 2010). Transmission capability significantly influences cognitive structures and collaboration capacity, making it highly impactful. Meanwhile, after extensive development, teams have already accumulated substantial task and role-related skills and information, weakening the positive impact of sharing willingness on performance. Therefore, in the maturity stage, virtuality' s positive effect on information processing capability exceeds its negative effect on sharing willingness, and transmission capability better promotes performance than sharing willingness. Integrating these factors:

Hypothesis 2-5: During the team maturity stage, the positive indirect effect of team virtuality on team performance through enhanced team information transmission capability is stronger than the negative indirect effect through reduced member information sharing willingness.

2.3 Study 3: Leader Intervention Strategies for Team Virtuality Across Development Stages

Building on Studies 1 and 2, Study 3 examines what strategies team leaders can employ at different development stages to strengthen virtuality' s positive effects while buffering its negative effects, thereby maximizing benefits and minimizing drawbacks. Research from a team development perspective indicates that leadership roles should vary across stages (Kozlowski et al., 2009). During formation, leaders should shape work routines to help members understand norms and integrate into team work. During development, leaders should focus on understanding work processes and interaction patterns to ensure healthy task and relationship development. In maturity, when member capabilities and interactions reach optimal levels, leaders' primary task is providing task-relevant information, helping identify problems and improvements, and enhancing flexibility and efficiency to achieve team goals. Guided by Team Development Theory, Study 3 explores three effective intervention strategies: team-ICT matching during formation, process monitoring during development, and performance feedback during maturity.

First, we propose that leaders' focus on enhancing team-ICT fit during formation can strengthen the positive effect of virtuality on information transmission capability while buffering its negative effect on sharing willingness. ICT (information and communication technology) encompasses information and communication technologies (Ayyagari et al., 2011). Team-ICT fit refers to the degree to which adopted ICT matches team task requirements and interpersonal interaction needs (Malhotra & Majchrzak, 2014).

As previously argued, virtuality enhances information transmission capability because high virtuality teams can use ICT to efficiently allocate and extract information. Based on Team Development Theory and information processing

logic (Hinsz et al., 1997; Kozlowski et al., 1999; Zander et al., 2013), this effect during formation depends partly on whether ICT matches task requirements. When ICT-task fit is high, members adapt and effectively use these technologies more quickly (Malhotra & Majchrzak, 2014), fully realizing ICT' s advantages in information allocation and extraction. Thus, the more teams work through ICT (i.e., higher virtuality), the stronger their information transmission capability. Leaders can therefore shape technology-task matching routines during formation to strengthen virtuality' s positive effect on transmission capability. Conversely, virtuality reduces sharing willingness because virtual communication decreases cognitive resources and increases cognitive biases. However, if leaders create matching interpersonal interaction channels based on interaction patterns during formation, members can communicate more effectively (Peralta et al., 2018), reducing cognitive resource depletion and interaction frequency and quality, thereby decreasing cognitive biases (Eisenberg & DiTomaso, 2019). Thus, leaders can enhance team-ICT fit to weaken the negative impact of dispersed work and virtual communication (i.e., team virtuality) on sharing willingness.

During formation, team-ICT matching not only strengthens virtuality' s positive effect on transmission capability and weakens its negative effect on sharing willingness but also moderates the relationships between these mechanisms and performance. Team-ICT matching improves communication efficiency based on existing transmission capability (Malhotra & Majchrzak, 2014), converting capability into team output. Therefore, it strengthens the positive effect of transmission capability on performance. Additionally, appropriate ICT channels can help members access information and solve problems even when sharing willingness is low (Malhotra & Majchrzak, 2014), partially substituting for sharing willingness' s positive effect on performance. Thus, team-ICT matching can weaken the relationship between sharing willingness and performance. Integrating Study 2' s mediation logic:

Hypothesis 3-1: During the team formation stage, leaders' team-ICT matching strategy strengthens the positive indirect effect of team virtuality on team performance through information transmission capability by enhancing both the virtuality-transmission capability relationship and the transmission capability-performance relationship.

Hypothesis 3-2: During the team formation stage, leaders' team-ICT matching strategy weakens the negative indirect effect of team virtuality on team performance through member information sharing willingness by reducing both the virtuality-sharing willingness relationship and the sharing willingness-performance relationship.

During the team development stage, leader process monitoring can strengthen virtuality's positive effect on transmission capability and buffer its negative effect on sharing willingness. In development, members' core work involves learning information and knowledge to master skills and establishing interaction patterns through role relationships (Kozlowski et al., 2009). Process monitoring involves

leaders observing or interacting to understand task and relationship conditions (Liao & Chun, 2016). During development, process monitoring enables leaders to timely understand members' skill mastery, including ICT adaptation and usage (Zander et al., 2013), allowing them to support information extraction and sharing through ICT, thereby strengthening ICT' s effect on transmission capability. Thus, process monitoring strengthens the positive relationship between virtuality and transmission capability. Additionally, process monitoring helps leaders identify interpersonal interaction issues (Liao & Chun, 2016; Mishra & Ghosh, 2020), assisting members in overcoming virtual collaboration difficulties and coordinating interactions to maintain healthy operations (梁阜等, 2022; Zander et al., 2013). This compensates for virtuality' s negative interpersonal effects, reducing its impact on sharing willingness. Therefore, process monitoring weakens the negative relationship between virtuality and sharing willingness.

Furthermore, during development, process monitoring affects the relationships between transmission capability/sharing willingness and performance. Monitoring enables leaders to identify whether capabilities are being used to improve performance and provide guidance (Zhou, 2003), making transmission capability more likely to address critical problems and enhance performance. Thus, process monitoring positively moderates the transmission capability-performance relationship. Process monitoring also helps leaders identify needed information and knowledge (Zander et al., 2013), partially substituting for sharing willingness' s positive effect and reducing its negative impact when willingness is low. Integrating Study 2' s mediation logic:

Hypothesis 3-3: During the team development stage, leader process monitoring strengthens the positive indirect effect of team virtuality on team performance through information transmission capability by enhancing both the virtuality-transmission capability relationship and the transmission capability-performance relationship.

Hypothesis 3-4: During the team development stage, leader process monitoring weakens the negative indirect effect of team virtuality on team performance through member information sharing willingness by reducing both the virtuality-sharing willingness relationship and the sharing willingness-performance relationship.

During the team maturity stage, leader performance feedback can strengthen virtuality' s positive effect on transmission capability and weaken its negative effect on sharing willingness. In maturity, members focus on efficient task completion (Zander et al., 2013). Performance feedback involves leaders providing information about prior team performance (Gonzalez-Mule et al., 2014). In this stage, performance feedback motivates members to reflect on work methods, including ICT usage, to complete tasks more efficiently (Hoever et al., 2018), potentially optimizing ICT use and strengthening its effect on information allocation and exchange efficiency. Thus, performance feedback strengthens virtuality' s positive effect on transmission capability. Additionally, performance feedback directs members' attention toward task completion and away from neg-

ative interpersonal factors (Zander et al., 2013), reducing virtuality' s negative impact on interaction, trust, and sharing willingness. Therefore, performance feedback weakens virtuality' s negative effect on sharing willingness.

Moreover, in maturity, performance feedback moderates the relationships between transmission capability/sharing willingness and performance. Effective feedback motivates members to integrate existing knowledge and capabilities to complete tasks (Hoever et al., 2018), making transmission capability more likely to achieve high performance. Even when sharing willingness is low, performance feedback can inspire and motivate members to work harder (Zander et al., 2013), partially substituting for sharing willingness' s positive effect. Integrating Study 2' s mediation logic:

Hypothesis 3-5: During the team maturity stage, leader performance feedback strengthens the positive indirect effect of team virtuality on team performance through information transmission capability by enhancing both the virtuality-transmission capability relationship and the transmission capability-performance relationship.

Hypothesis 3-6: During the team maturity stage, leader performance feedback weakens the negative indirect effect of team virtuality on team performance through member information sharing willingness by reducing both the virtuality-sharing willingness relationship and the sharing willingness-performance relationship.

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3. Theoretical Contribution and Innovation

In summary, this project examines the contingency factors, opposing mechanisms, and interventions underlying the double-edged sword effects of team virtuality on team performance from a team development perspective, constructing the theoretical model shown in Figure 1 [Figure 1: see original paper]. First, inspired by frontier team development theory and meta-analytic results (e.g., Kozlowski et al., 1999; Purvanova & Kenda, 2021; Zander et al., 2013), this project identifies team development stage as a critical dynamic contingency factor. Team virtuality produces different or even opposite effects on performance across stages: negative during formation but positive during development and maturity. Second, drawing on team information processing theory, this study identifies team information processing capability and motivation as opposing mechanisms: virtuality may enhance team information transmission capability (promoting pathway) while reducing member information sharing willingness (inhibiting pathway), creating divergent effects on performance. The inhibiting pathway dominates during formation, while the promoting pathway dominates during development and maturity. Finally, this project demonstrates that leaders can enhance virtuality' s positive effects and reduce its negative effects through team-ICT matching during formation, process monitoring during development, and performance feedback during maturity.

Figure 1. Theoretical Framework Model

This project represents an important extension of team virtuality research and provides crucial insights for team management model selection and efficiency improvement in the digital economy and post-pandemic era. Theoretically, first, introducing team development stage as a dynamic contingency factor to explain why team virtuality produces both positive and negative effects provides an important theoretical explanation for whether virtuality helps or harms performance. Existing research has independently examined positive and negative effects (e.g., Boh et al., 2007; Schmidtke & Cummings, 2017) but rarely investigated contingency factors producing opposite effects, making it difficult to answer this critical scientific and practical question. By proposing team development stage as a key dynamic contingency and analyzing its differential effects, this project integrates positive and negative effects within a unified theoretical framework, substantially deepening and expanding this research domain.

Second, revealing the promoting and inhibiting pathways and identifying which dominates at different stages constructs a new, systematic theoretical framework for analyzing the double-edged sword effects. Previous research has examined mechanisms linking virtuality to performance from various theoretical perspectives (e.g., Purvanova et al., 2020; Tzabbar & Vestal, 2015) but has not identified opposing mechanisms from a unified analytical perspective, hindering systematic understanding. This project demonstrates that the inhibiting pathway dominates during formation while the promoting pathway dominates during development and maturity, deepening understanding of virtuality's mechanisms and providing an integrated, systematic theoretical lens for examining its positive and negative effects.

Finally, analyzing how leaders can enhance positive effects and reduce negative effects across development stages importantly extends intervention strategy research. Existing virtual team intervention research has focused primarily on team climate and interpersonal interaction (e.g., Gibson & Gibbs, 2006; Tzabbar & Vestal, 2015), rarely examining leadership's role in the virtuality-performance relationship. This overemphasis on member interaction neglects leadership' s crucial role in virtual team operations. This project analyzes what stage-specific strategies leaders can use to strengthen/buffer virtuality' s positive/negative effects, further expanding theoretical understanding and providing new directions for intervention research.

Practically, first, this project reveals that team virtuality does more harm than good during formation but more good than harm during development and maturity. Organizations should consider continuing virtual team operations but must intervene differently across stages, particularly during formation, to enjoy benefits while overcoming drawbacks. Second, this project helps organizations improve virtual team efficiency through leader selection and training by identifying stage-specific behaviors that enhance virtuality' s positive effects and reduce negative ones. Organizations should assess these behavioral capabilities when selecting virtual team leaders and develop them through training, pointing to

new directions for personnel selection and human resource development. Third, this project provides important guidance for leaders to enhance virtual leadership. Through deep examination of virtuality' s mechanisms and stage-specific characteristics, it dynamically articulates different intervention strategies across development stages, helping leaders shift from static to dynamic contingency thinking and improve their virtual leadership effectiveness.

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Note: Figure translations are in progress. See original paper for figures.