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A Complex Adaptive Systems Approach to Real-Life Team Interaction Patterns, Task Context, Information Sharing, and Effectiveness

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Abstract

Interaction dynamics are considered to be key characteristics of complex adaptive systems (CAS). Taking a CAS approach, this study examines how three team interaction patterns affect team effectiveness. Specifically, we analyze recurring, heterogeneous, and participative patterns of team interaction in routine and nonroutine team-task contexts. Fine-grained coding of video-based footage plus nonlinear dynamical systems (NDS) statistics are used to identify the interaction patterns in a sample of 96 real-life teams, comprising 1,395 team members. We establish that recurring patterns of team interaction reduce perceived team information sharing and, in turn, team effectiveness and that these harmful effects are more pronounced in teams doing nonroutine work than in those engaged in routine work. Participative team interaction was found to be positively related to a high level of perceived team information sharing and effectiveness. Heterogeneous team interaction was not associated with perceived team information sharing

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and effectiveness. Post hoc analyses, in which the behavioral content of the interaction patterns of the 15 most effective and least effective teams is compared, revealed primarily task-directed patterns in the most effective teams. We offer practical recommendations for team development and call for more CAS research on the communicative behaviors within teams of knowledge workers.

Keywords
team interaction patterns, complex adaptive systems, task context, perceived information sharing, team effectiveness

Introduction

Why are some teams more effective than others? One potential explanation, of interest to scholars since the earliest days of team research, lies in the way that team members interact in pursuit of their goals. Despite a general acceptance of the importance of team interaction patterns, our understanding of them remains limited. This is because team research to date has predominantly used "statistical approaches directly or indirectly grounded in the general linear model" to capture team interactions (Knight, Kennedy, & McComb, 2016, p. 223). Team interaction patterns, however, are decidedly *nonlinear* (e.g., Cronin, Weingart, & Todorova, 2011; Gorman, Cooke, Amazeen, & Fouse, 2012). More understanding of them is needed, especially in today's knowledge economy, which highlights the need for strong interaction skills (e.g., Greiner, 2002; Mathieu, Gallagher, Domingo, & Klock, 2019). A theory that underpins the explicit incorporation of the dynamics of team interaction in a given task context is complex adaptive systems (CAS) theory. CAS at the team level focuses on members interacting with each other in their team-task context (e.g., Arrow, Poole, Henry, Wheelan, & Moreland, 2004; McGrath, Arrow, & Berdahl, 2000). CAS deviates from team research which considers "teams as simple systems characterized by unidirectional cause–effect relationships, failing to take into account the context in which teams operate" (Ramos-Villagrasa, Navarro, & García-Izquierdo, 2012, p. 780). Teams may, indeed, tailor their interactions to the nature of the work at hand: Complex team tasks may require complex interactions among the team members. Thus, to explain why teams are effective, we must incorporate both the nonlinear nature of team interaction patterns and the contexts in which such patterns occur (Endedijk, Hoogeboom, Groenier, de Laat, & Van Sas, 2018; Kerr, 2017; Marks, Mathieu, & Zaccaro, 2001; Mathieu et al., 2019; Pentland, 1992; Ramos-Villagrasa, Marques-Quinteiro, Navarro, & Rico, 2018).

An important distinction of a team's task context is whether it operates in a routine or nonroutine manner (Kerr, 2017). A routine task context is characterized by higher levels of stability and predictability, whereas a nonroutine task context is defined by more complex and novel situations (e.g., Lei, Waller, Hagen, & Kaplan, 2016). To advance the CAS theory at the team level, we identified and examined patterns of team interaction and how they are related to team effectiveness in both task contexts. Our key research question is, "How do team interaction patterns impact team effectiveness, and does this vary in routine or nonroutine task contexts?"

In addition to examining team interaction patterns and how they may vary, given their contexts, the CAS theory advocates combining nonlinear and linear methods to expand our understanding of team effectiveness (Ramos-Villagrasa et al., 2018). Integrative frameworks of team effectiveness and CAS theory promote the inclusion of team processes as antecedents of team effectiveness and "products" of team interaction dynamics (Curşeu, 2006; Marks et al., 2001, p. 358). An influential team process that is known to "result from the dynamic process" of team interaction is information sharing (Curşeu, 2006, p. 252; Mesmer-Magnus & DeChurch, 2009); effective teams are considered to be information-sharing and, subsequently, adaptive entities (Marks et al., 2001). Prior studies on team interaction patterns have examined such patterns and team processes in isolation (e.g., Kanki, Folk, & Irwin, 1991; Kolbe et al., 2014; Stachowski, Kaplan, & Waller, 2009; Zijlstra, Waller, & Phillips, 2012). Some scholars (e.g., Kanki, Folk, & Irwin, 1991) have called for more comprehensive models that integrate team interaction patterns with important team processes as well as task contexts (or contextual dynamics) and effectiveness (see also, Curşeu, 2006; Green & Mitchell, 1979). Through recent advances in CAS theory (including its underlying nonlinear dynamical systems [NDS] approach), we can now examine in more integrative terms which team interaction patterns are associated with team information sharing and team effectiveness in different task contexts.

This article contributes to a better understanding of effective patterns of team interaction. Specifically, we investigate (a) the team-task *context* in which such interactions are enacted, that is, routine versus nonroutine, and (b) the downstream *outcomes* of different team interaction patterns, that is, their impact on perceived team information sharing and effectiveness. In addition to advancing CAS theory with these investigations, we exemplify how team pattern analysis can capture the "discontinuous bursts and lulls of interactivity" among team members (Gorman et al., 2012, p. 503). As opposed to static team snapshots, we incorporate temporality by zooming in on various team interaction patterns over time, using minute video-based coding of the behavior of all team members. We contribute to the team and

CAS literature by adding nuance to our understanding of how interaction dynamics translate into a crucial team process, in relation to team contexts, and how both team processes co-shape team effectiveness. In addition to offering empirical evidence of effective teams as CAS, our research responds to the call by Leenders, Contractor, and DeChurch (2015) that "current theoretical and operational formulations of team process require greater specificity if they are to truly afford a high-resolution understanding" (p. 1). In this article, the ephemeral behavioral patterns within teams are made visible and are coupled to team effectiveness.

Theory and Hypotheses

A CAS Approach to Team Interaction Patterns

Although management scholars have referred to teams as CAS, very few studies have empirically examined the dynamics of team interaction (Ramos-Villagrasa et al., 2012). To advance our understanding of why some teams are more effective than others, more team models need to incorporate these dynamics (McGrath & Tschan, 2007). An NDS approach (Ramos-Villagrasa et al., 2018; Ramos-Villagrasa et al., 2012) requires the modeling and measurement of temporal processes among several elements that interact (Pincus, Kiefer, & Beyer, 2018). Guastello and Liebovitch (2019) argue that "when combined with domain-specific knowledge about psychological phenomena, NDS constructs . . . reveal commonalities in dynamical structure among phenomena that might not have been compared or connected otherwise" (p. 1). To better understand the dynamics of team interaction, task context cannot be bypassed when viewing teams as CAS (Ramos-Villagrasa et al., 2012). In other words, the within-team dynamics can be assumed related to team contexts. As we capture nonlinear team interaction patterns in the present field study, we take an NDS approach and examine how three team patterns are linked to team effectiveness in two different task contexts.

Team interaction patterns are defined as sets of observable behaviors that evolve sequentially and occur at certain time intervals. These patterns are, thus, sequential sets of behavioral events which occur above and beyond chance, if they are all independently distributed (Magnusson, 2000; Magnusson, Burgoon, & Casarrubea, 2016; Waller & Kaplan, 2018). Over time, through successive iterations, team interactions can, thus, become discernible as discrete "patterns" of interaction. Particular interaction patterns may be required for teams to operate effectively (Stachowski et al., 2009). Gorman et al. (2012) argued that *recurring* team interaction patterns can indicate whether a team is in a more stable or adaptable mode. Kanki, Folk, and

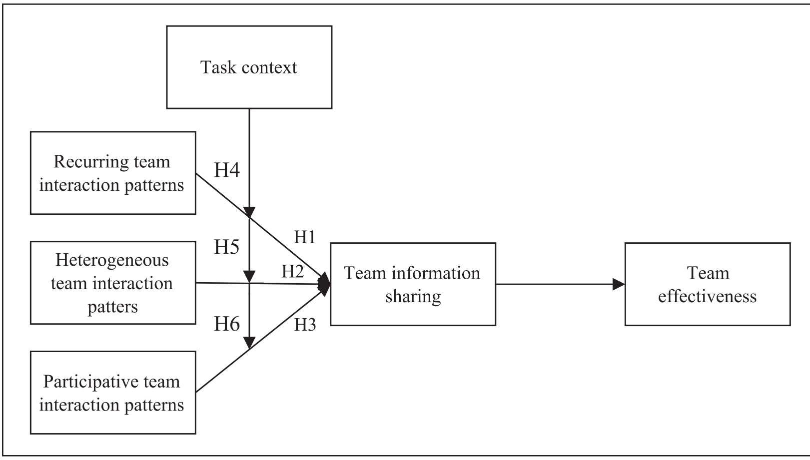

Figure 1. Research model.

Irwin (1991) focused on *heterogeneous* team interaction patterns: They found that the more variety or complexity there was in the patterns, the poorer the teams' effectiveness. Interaction patterns within teams can fluctuate also in terms of the degree of *participation* or collaboration (Lei et al., 2016). To date, no prior empirical study has compared these three types of interaction patterns.

The various patterns of team interaction can be detected with so-called T-pattern analysis (see, for example, Kolbe et al., 2014; Stachowski et al., 2009; Zijlstra et al., 2012), permitting the identification of interactive behavioral chains that are governed by structures of variable stability (Gorman et al., 2012; Magnusson et al., 2016). Herein, we will also use T-pattern analysis to detect team interaction patterns. Addressing how these team interactions are linked to team context and perceived information sharing, as well as to team effectiveness, aims to enhance our understanding of effective team interaction (Gorman, Amazeen, & Cooke, 2010; Gorman et al., 2012). In the text below, we describe how the three team interaction patterns are linked to perceived information sharing, which subsequently influences team effectiveness. We hypothesize also how team-task context may moderate the relation between the three types of interaction patterns and information sharing (see Figure 1).

Information Sharing

Team members' frequent sharing of task-relevant information is considered the bedrock of team effectiveness (Brodbeck, Kerschreiter, Mojzisch, & Schulz-Hardt, 2007; Mesmer-Magnus & DeChurch, 2009). The more information a team can share, analyze, store, and use, the greater the team's effectiveness, especially for knowledge-intensive teams (Schippers, Homan, & van Knippenberg, 2013; Tost, Gino, & Larrick, 2013). Team members' proactive sharing of information produces apt team knowledge, which improves coordination as well as decision-making (Klimoski & Mohammed, 1994; Marks, Zaccaro, & Mathieu, 2000; van Ginkel & van Knippenberg, 2009; Zaccaro, Rittman, & Marks, 2001). According to Phelps, Heidl, and Wadhwa (2012), higher degrees of perceived information sharing are associated with effective social interaction in a team. Hence, when interacting with each other, team members can make optimal use of each other's information and knowledge. Thus, team interaction patterns can be seen as a primary mechanism of how information gets shared and exchanged (Marks et al., 2000; Zellmer-Bruhn, Waller, & Ancona, 2004); they can either enable or inhibit perceived information sharing (Schippers, Edmondson, & West, 2014; Super, Li, Ishqaidef, & Guthrie, 2016).

A specific interaction pattern that is likely to influence both team information sharing and effectiveness is the so-called recurring team interaction pattern. In their taxonomy of information-processing failures, Schippers et al. (2014) highlight habitual team routines as being detrimental to team information sharing. Using habitual "scripts" that teams developed earlier on in their interactions might not spark information sharing any longer in the current moment. As opposed to "mindful" engagement or behavioral adaptation to the moment, recurring patterns of team interaction are likely to curb perceived information sharing. Thus, when a team engages in habitual routines (i.e., in repeatedly co-occurring actions or interactions), it may fail to allow an exchange of information among team members that represents changed situational dynamics. Conversely, teams that adapt quickly are more flexible or open toward each member's input, such as information and knowledge (Stachowski et al., 2009). Hence, recurring patterns of team interaction might inhibit the open, continuous sharing of opinions, ideas, and knowledge in a team. Recurring team interaction patterns are, thus, likely to create a sense of stability that may lead to rigidity in teams, which, in turn, might limit their effectiveness (LePine, 2003). When teams adhere to many recurring interactions, lower team effectiveness or even tragic team failures may come about as shown in post hoc accident investigations (Gersick & Hackman, 1990; Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012). Therefore, we can hypothesize that in teams with a high number of recurring team interaction patterns, within-team information sharing fails, leading to lower team effectiveness.

> **Hypothesis 1:** There is an indirect negative relationship between recurring team interaction patterns and team effectiveness, through team information sharing.

In addition to recurring patterns, heterogeneous team interaction patterns may also affect team effectiveness. When the heterogeneity of team interaction patterns is high, the total number of different interaction patterns in a team is high.[1] Such heterogeneity, thus, entails a relatively large range of different team interaction patterns (Kanki, Folk, & Irwin, 1991). Teams with heterogeneous patterns of interaction are assumed to share more information and knowledge among their members. A high degree of team members' sharing of information has been associated with high team performance because the information can be used to make sense of the team's task environment and then take proper action (e.g., Larson, Christensen, Abbott, & Franz, 1996). Although compositional heterogeneity in teams (e.g., in terms of diversity, tenure, or expertise) has been linked to diversity in information and expertise, sparking the interaction and exchange of ideas (Frigotto & Rossi, 2012), heterogeneity in team interaction patterns has not been frequently associated with team performance or information sharing. When teams engage in heterogeneous interaction patterns, team members interact in a more flexible, nonstandard, or prescribed manner with each other (Zijlstra et al., 2012). This greater variety of interaction is assumed, in turn, to lead to a higher level of team information sharing and performance, due to more information and knowledge exchange (Rico, Sánchez-Manzanares, Gil, & Gibson, 2008). Consistent with the idea that compositional heterogeneity is functional for team information sharing (Frigotto & Rossi, 2012), we hypothesize that more diversity in team interaction patterns stimulates team effectiveness through a higher degree of team members' information sharing.

> **Hypothesis 2:** There is an indirect positive relationship between heterogeneous team interaction patterns and team effectiveness, through team information sharing.

A third type of pattern, participative team interaction, is also assumed to co-occur with a high degree of perceived information sharing and subsequent team effectiveness. Earlier research on team interaction and communication dynamics has shown that greater amounts of communicative action or participation among leaders and followers nurture the revelation of new information

(Cotton, 1993). When team-level interaction patterns are more participative, in the sense that they include more frequent switches among team members, including the team leader, more possibilities to exchange and co-construct relevant information arise (Edmondson & Lei, 2014). Team members in team meetings characterized by highly participative or collaborative patterns are strongly involved in sharing and exchanging their ideas; a steady informational flow among the team members has been associated with collective team behavior (Bourbousson & Fortes-Bourbousson, 2016). This means that participative or collaborative relationships can enable the transfer of information among team members (Phelps et al., 2012). Hence, to perform team tasks effectively, interdependent action and interaction among team members may be required (e.g., Cheng, 1983). Such action or collaborative communication may be associated with a high degree of exchange of information and knowledge (Butchibabu, Sparano-Huiban, Sonenberg, & Shah, 2016). More participative team interaction patterns might, thus, enhance team performance. In addition, meetings have been perceived as more effective when active employee participation is warranted and relevant informational input is provided by the employees as well as their leader (Meinecke, Lehmann-Willenbrock, & Kauffeld, 2017). Based on the above, we hypothesize that participative team interaction patterns are positively related to team effectiveness, and that they are mediated by perceived team information sharing.

> **Hypothesis 3:** There is an indirect positive relationship between participative team interaction patterns and team effectiveness, through team information sharing.

Task Context

In team research, the difference between a routine and nonroutine task context has been highlighted as one of the most powerful moderators of team interaction and a contingent condition of information sharing (Chung & Jackson, 2013; Kerr, 2017; Unger-Aviram, Zwikael, & Restubog, 2013). Both task contexts vary in their degree of knowledge-intensiveness (Campbell, 1988). Routine team contexts include team tasks that are more predictable and are handled with standardized work procedures and efficient team interaction (e.g., Resick, Murase, Randall, & DeChurch, 2014). Nonroutine contexts, in contrast, involve team tasks that occur in less predictable situations, with frequent change, requiring relatively unique interactive team behaviors. In an experimental study, Rico et al. (2008) found that team members in a nonroutine or more novel task environment exchanged more information and ideas compared with teams in a routine environment. Although team interaction and effectiveness depend crucially upon the teams' task context, most prior empirical research focused on one type of task context only (Kerr, 2017). Our inclusion of more than one team-task context enables insight into how team interaction patterns may vary with this context.

Drawing upon the structural contingency approach (Drach-Zahavy & Freund, 2007), which stresses that the optimal course of action is dependent upon the situation, it is likely that the effectiveness of different team interaction patterns is contingent upon the task context (Agliati, Vescovo, & Anolli, 2006; L. A. Perlow, Gittell, & Katz, 2004). Knowledge-intensive teams tend to work on more ambiguous or nonroutine team tasks. Therefore, they need to gather and share information to adapt adequately or adroitly to changing circumstances (Raes, Heijltjes, Glunk, & Roe, 2011). When a team's task is knowledge-intensive, the team members "experience greater changes and exceptions to their task and hence, are likely to become less familiar with their task" (Wong, 2004, p. 647). Complex issues are also less likely to have standard solutions (Cummings & Cross, 2003; Jehn, 1997). Such issues call for anticipation of dynamic behavioral adjustment by the team (Gardner, Gino, & Staats, 2012; Kozlowski, Gully, Nason, & Smith, 1999). Thus, vigorous, interactive work contexts call for members to behave flexibly, to adapt to continually changing demands and objectives (Gardner et al., 2012).

When a team displays recurring interaction patterns, it relies on a habitual mode of interaction. Kozlowski and colleagues (1999) theorized about the opposite: To be effective, teams undertaking complex or rapidly changing work must integrate their members' knowledge in an ongoing process of mutual adjustment (Chung & Jackson, 2013; Thompson, 1967; Van de Ven, Delbecq, & Koenig, 1976). Drawing upon CAS theorizing, the wider the variety of interaction patterns that are being displayed by teams, the more this enables them to effectively exchange information and adapt to unpredictable situations (Ramos-Villagrasa et al., 2012). The effect of more recurring interaction patterns on team information sharing may, thus, be negative in knowledge-intensive teams, as this context requires more dynamic anticipation and a less habitual form of interaction. Recurring modes of interaction patterns are likely to occur more in teams with routine tasks (Kerr, 2017; Resick et al., 2014). Because routine tasks are less knowledge-intensive, they can be properly handled with standard or more recurring team interaction patterns and with considerably less information sharing. We hypothesize, therefore, that if recurring team interaction patterns occur in knowledge-intensive teams, they inhibit information sharing and consequently team effectiveness.

Hypothesis 4: Team-task context moderates the relation between recurring patterns of team interaction and information sharing, such that the negative relation is stronger when the team-task context is nonroutine.

Viewing teams as CAS, one could argue that nonroutine team tasks require proactive anticipation or continuous adaptation by team members: In such task contexts, a wide variety of content must be reflected in the team's interaction patterns (Ramos-Villagrasa et al., 2012). Hence, team interaction patterns that are more varied (i.e., more heterogeneous) might have an impact on how well the team can anticipate a complex task context. Whereas nonroutine situations require continuous monitoring of complex systems and quick adaption to novel situations (e.g., Waller, Gupta, & Giambatista, 2004), routine team tasks require more conventional forms of interaction with lower variety in their content. In line with this, Kanki, Folk, and Irwin (1991) found that in a realistic flight scenario, requiring prescribed sequences of action and communication, highly effective aviation teams exhibited more homogeneous (or protocolized) interaction patterns. Hence, only in routine-type task contexts that require conventional forms of interaction can team members predict each other's behavior (Kanki, Folk, & Irwin, 1991). In nonroutine or more knowledge-intensive task contexts, constant adaptation and coordination is seen as an important source of team performance (LeBaron, Christianson, Garrett, & Ilan, 2016). When team members in such task contexts show high behavioral conformity, they are unable to address the dynamic demands typical of nonroutine task contexts (Uitdewilligen, Waller, & Zijlstra, 2010). Thus, in nonroutine team-task contexts, homogeneous interaction patterns might reduce information sharing. Nonroutine task contexts call for more "nonscripted" team interactions (LePine, 2003). We surmise, therefore, that in nonroutine task environments, heterogeneous team interaction patterns are beneficial for perceived information sharing.

> **Hypothesis 5:** Team-task context moderates the relation between heterogeneous patterns of team interaction and information sharing, such that the positive relation is stronger when the team-task context is nonroutine.

Teams in nonroutine task environments tend to be confronted with new and changing task elements. To perform well, these teams are required to alter or modify their knowledge or information frequently (Chen, Thomas, & Wallace, 2005). Thus, knowledge-intensive team tasks seem to require continuous exchange, sharing, and interpretation of complex information among team members (Kozlowski & Bell, 2013). In such contexts, in which continuous sharing of member expertise and coordination is important, leaders and followers exchange ideas and develop a shared understanding of their changing task environment (Lei et al., 2016). Kanki, Palmer, and Veinott (1991) found that swift-starting teams, which were constantly facing unpredictable, challenging, and new situations, were more effective when they showed more participative interaction patterns. Curşeu (2006) also took a CAS perspective to better understand the emergence of important team processes and interaction in teams. He suggested that efficient use of information technology creates higher levels of team participation and interaction between virtual team members, which is crucial for high performance. As virtual teams tend to operate mostly in the context of knowledge-intensive tasks (Castellano, Davidson, & Khelladi, 2017) and can, thus, be considered as working in a nonroutine-type task context, highly participative team interaction in such teams enhances the transfer of knowledge and information. Therefore, we expect that in such nonroutine contexts, participative team interaction patterns enhance perceived information sharing.

> **Hypothesis 6:** Team-task context moderates the relation between participative patterns of team interaction and information sharing, such that the positive relation is stronger when the team-task context is nonroutine.

Method

Sample

A stratified random sample of 150 teams was drawn from one large public-sector organization in the Netherlands; 96 teams, or 64%, accepted our invitation to be videotaped during one randomly selected, regular staff meeting. A total of 1,395 members participated, including the 96 formally appointed team leaders. There was freedom and variety in how the team meetings were conducted, so that possible agenda-setting effects are likely to have been randomly distributed across the teams. In terms of the teams' tasks, they processed financial-administrative data (in various degrees of knowledge-intensiveness) or created the infrastructure to increase efficiency while complying with regulative, normative, and cultural forces. An example of a nonroutine task context in our sample is a team of software developers; an example of a team operating in a routine task context in our sample is a call center for internal clients. During the videotaped meetings, more than 80% of the team members were present. Immediately following these meetings, they all completed a hard-copy survey to rate the degree of perceived information sharing of their own team. Later, 167 expert ratings of team effectiveness were collected: an average of 1.8 ratings per team. These experts held managerial positions senior to the focal team leaders and were well acquainted with each team.

The team leaders averaged 50.94 years of age (ranging from 27 to 64: $SD = 7.70$), with employment tenure ranging from 0.5 to 46 years ($M = 24.98$, $SD = 13.24$), and with an average of 13.18 years of experience in leadership positions (ranging from 1 to 36: $SD = 9.02$). Of these leaders, 23.70% was female. Among the nonmanagerial team members in the sample, 34.80% was female. Team members were, on average, 49.19 years old ($SD = 10.68$), with an average tenure of 24.16 years (ranging from 0 to 48: $SD = 13.77$), and had worked for an average of 3.88 years (ranging from 0 to 38: $SD = 5.26$) in their current teams. The average team comprised 13 members (minimum = 4; maximum = 33).

Measures

Team effectiveness. The Gibson, Cooper, and Conger (2009) scale, consisting of four items, was used to capture the overall idea of team effectiveness, rather than whether specific goals were accomplished. A high level of team effectiveness implies that a team accomplishes its assigned tasks very satisfactorily (Gibson et al., 2009). Scores were given by the experts on a Likert-type scale ranging from 1 (*very inaccurate*) to 7 (*very accurate*). A sample item is "This team is consistently a high performing team." The Cronbach's alpha was .94. There was sufficient within-group agreement among the experts of each team (M $R_{wg} = .64$, ranging from .22 to .91; Bliese, 2000; Lance, Butts, & Michels, 2006; LeBreton & Senter, 2008). Because 39 teams only had one expert rater, we correlated this score with team effectiveness ratings obtained from the followers.[2] A significant association was found between the expert scores and follower perceptions on team effectiveness ($r = 37$, $p < .01$). This indicates that we could validly use the expert ratings on team effectiveness.

Team information sharing. Using the four items developed by Bunderson and Sutcliffe (2002), team information sharing was rated by the team members on a survey scale from 1 (*very inaccurate*) to 7 (*very accurate*). A sample item is "When a member of this team gets information that affects the team, they are quick to share it." We obtained a Cronbach's alpha of .95. The intraclass correlation coefficient (ICC1; .14, $p < .01$), ICC2 (.70, $p < .01$), and the R_{wg} ($M = .63$, ranging from .18 to .91) values indicated that the data could be aggregated to the team level.

Team interaction patterns. We analyzed behavioral patterns in regular team staff meetings (Hoogeboom & Wilderom, 2015; Lehmann-Willenbrock, Meinecke, Rowold, & Kauffeld, 2015; Meinecke & Lehmann-Willenbrock, 2015). Such meetings can provide rich insights into interaction patterns between team members (see also, Agliati et al., 2006; Gardner et al., 2012). They have often served as a prime context for ethnographic-type workplace studies (e.g., Svennevig, 2008; Vine, Holmes, Marra, Pfeifer, & Jackson, 2008). Lehmann-Willenbrock, Chiu, Lei, and Kauffeld (2017) highlighted that interactions during regular staff meetings mirror the social interactions outside the meeting context.

Three separate video cameras were used to record each of the 96 regular staff meetings. To minimize obtrusiveness, all three cameras were set up before each meeting began. The postmeeting surveys found both the videotaped meetings (M = 5.59, SD = 1.36) and the behaviors displayed by the team members (M = 5.90, SD = 1.08) to be representative of similar nonvideotaped meetings. This indicated that habituation occurred quickly after the start of the meetings (e.g., Smith, McPhail, & Pickens, 1975). The meetings' duration varied considerably, from 30 to 191 min (M = 85, SD = 31), depending on the length of the agenda and the amount of discussion. The total number of minutes coded in this study was 8,194.

Each recording was sent directly to the university and was systematically coded by two members of a rotating panel of 14 trained and supervised MSc and BSc students majoring in Business Administration, Psychology, or Communication Science. They used a 15-page validated codebook and specialized coding software ("The Observer XT": Noldus, 1991; Noldus, Trienes, Hendriksen, Jansen, & Jansen, 2000; Spiers, 2004). The codebook was developed and refined during earlier behavioral studies (Hoogeboom & Wilderom, 2015). The basis of the codebook was developed in a prior PhD study with a set of mutually exclusive behavioral categories, allowing for exhaustive coding of a full range of leader–follower interactions (Bakeman & Quera, 2011). It was later refined and further detailed on the basis of existing behavioral taxonomies and team communication research. Since then, the codebook has been validly used in other studies (Hoogeboom & Wilderom, 2015).

In total, 18 mutually exclusive micro-behaviors were coded (Table 1: interrater reliability [IRR] = 82.53, kappa = .81, indicating "almost perfect agreement"; Landis & Koch, 1977, p. 165). The unit of analysis when systematically coding the videos was a speech segment that reflected a completed statement (Bales, 1950; Borgatta, 1962). For example, when a team member says, "Yes, exactly," in reaction to an opinion of another member, this is coded as *agreement* (i.e., one of the behavioral codes: see Table 1). Sometimes a code comprises only a single word, but mostly a single sentence, reflecting an independent sequence of interaction (Waller & Kaplan, 2018). With the preset codebook, we assigned a code to every speech segment from each entire meeting. Most of these micro-behaviors were grouped into four behavioral meta-categories on the basis of current leadership theory (i.e., transactional, transformational, initiating structure, and counterproductive behavior). Six additional micro-behaviors in our codebook were not

Table 1. Examples of the Video-Coded Behaviors.

Coded behavior		Definition	Examples
1. Providing negative feedback	(TA)	Criticizing the behavior or actions of other team members	"I do not think that this is a good solution" "In August I've send an e-mail with amendments, and I find it regrettable that at least half of the attendees does not know the content of this e-mail"
2. Task monitoring	(TA)	Asking team members for clarification and confirmation about (the progress on) their tasks	"How is the project progressing" "Do you also have a specific role in that process, since there might be possibilities for a follow-up project"
3. Correcting	(TA)	Imposing of disciplinary actions; Presenting team members with a "fait accompli"	"Yes, but that is the wrong decision" "Now you are talking about a failure fine, however this is a different type of fine"
4. Individualized consideration	(TF)	Paying attention to each individual's need for achievement and growth by acting as a coach or mentor and creating a supportive climate	"We offer a training course in August, which might be helpful for your career planning" "You can make a note of that request, I am willing to help you with it"
5. Intellectual stimulation	(TF)	Asking for ideas, stimulating team members to critically think about team tasks, opportunities, and so on, including the questioning of assumptions; thinking about old situations in new ways	"Yes, if you have any ideas put them together and discuss it with me or Jan"
6. Idealized influence behavior/Inspirational motivation	(TF)	Talking about an important collective sense of vision; Talking about important values and beliefs	"I find it important that we all work in unison towards this shared objective" "Until Vision 2020 is more clearly specified we will be operating under these standards; it is important to follow this agreed line"
7. Showing disinterest	(CP)	Not taking any action (when expected)	Not listening actively
8. Defending one's own position	(CP)	Emphasizing one's leadership position; Emphasizing self-importance	"I am the manager within this organization" "We do it my way, because I am the manager"

(continued)

Table 1. (continued)

Coded behavior		Definition	Examples
9. Interrupting	(CP)	Interfering or disturbing when other team members are talking	Disrupting other team members when they did not finish their sentence
10. Directing	(IS)	Dividing tasks among team members (without enforcing them); Determining the current direction	"John, I'd like you to take care of that" "Jack, I want you to . . ."
11. Informing	(IS)	Giving factual information	"The budget for this project is . . ." "The sick-leave figure is relatively low"
12. Structuring	(IS)	Structuring the meetings; Changing the topic; Shifting toward the next agenda point	"We will end this meeting at 2pm" "Maybe, we need to discuss this point after you are finished"
13. Providing positive feedback	(O)	Positively evaluating and rewarding the behavior and actions of team members	"How you approach the project is much better than 3 months ago" "I am delighted to see that you did not passively waited, but rather pro-actively came with a proposal"
14. Giving own opinion	(O)	Giving one's own opinion about what course of action needs to be followed for the organization, department, or the team	"We already discussed this, let's talk especially about how we can avoid these things in the future" "I my opinion, we should . . ."
15. Agreeing	(O)	Agreeing with something; consenting with something	"This also reflects how I personally think about the matter" "Yes, I agree with you"
16. Disagreeing	(O)	Contradicting with team members	"That is not correct" "I have to disagree with you on this point"
17. Humor	(O)	Making jokes or funny statements	Often jokes are made within the context of the interaction. When three or more members laugh, the code "humor" is assigned.
18. Giving personal information	(O)	Sharing personal information (e.g., about the family situation)	"We had a lovely holiday" "My mother is doing better now, thank you"

Note. TA = transaction behavior; TF = transformational behavior; CP = counterproductive behavior; IS = initiating structure behavior; O = other behavior which is not placed in one of these four meta-categories of coded micro-behaviors.

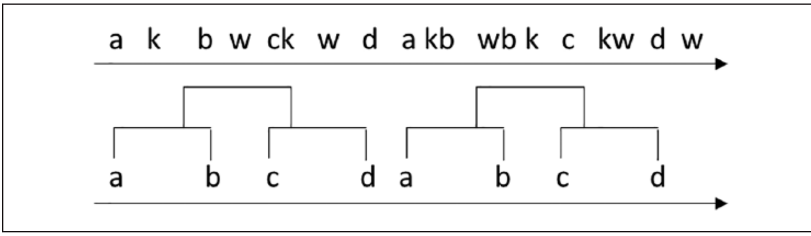

Figure 2. Schematic illustration of team interaction patterns.

Note. Above the upper horizontal line, random examples of "behavioral events" of individuals (such as w, a, k) are displayed. Below this line, four behaviors of team members (*a, b, c, d*) are presented that the software detected as part of a pattern of team interaction. An actual team interaction pattern found in the data is, for example, "Leader Counterproductive behavior (*a*) – Leader Transformational behavior (*b*) – Leader Transactional behavior (*c*) – Leader Initiating Structure behavior (*d*)." More examples of patterns of team interaction can be found in Table 6. Smaller patterns (*ab* or *cd*) are combined into more complex patterns that are longer and/or with more levels. The software automatically ensures that the smaller patterns (e.g., *ab*) that are also part of larger patterns (e.g., *abcd*) are included. The team interaction patterns themselves are detected on the basis of critical intervals. For example, in the above figure, behavioral event *b* occurs later than event *a* and is part of the later pattern at *t*. This interval $([t + d1, t + d2](d2\ ^{3}\ d1\ ^{3}\ 0))$ (Magnusson, 2000) should include minimally one (1) more incident of *b* than what would be expected by chance. The search for team interaction patterns stops when no more critical intervals are detected.

classifiable into one of these four categories (entries 13-18 in Table 1). Team interaction patterns were identified here with these four behavioral meta-categories and the six additional micro-behaviors.

Next, pattern recognition algorithms were employed using Theme software (Magnusson, 2000; Magnusson et al., 2016). Theme is capable of discovering behavioral patterns in a temporal order. The program predicts whether the occurrence of sets of sequential behavioral events within a specific time period appear significantly more often than by chance (i.e., when the data are randomized). A so-called T-pattern reflects a sequence of temporal behaviors (see Figure 2). The behavioral input is aggregated by Theme into time sequences of multiple behaviors, based on statistically significant thresholds. First, Theme detects patterns involving two sequential behaviors that occur significantly more often than by chance (e.g., *ab*). Then, Theme searches and "builds" patterns that are more complex (i.e., involving more behaviors: e.g., *abcd* or *abdc*). It should be noted that the less complex and smaller initial patterns (identified in Step 1: e.g., *ab* or *cd*) are then discarded because they are considered to be less complete. A visual representation including more information about the pattern detection algorithm in Theme is provided in Figure 2. We strove to detect the most important types of patterns.

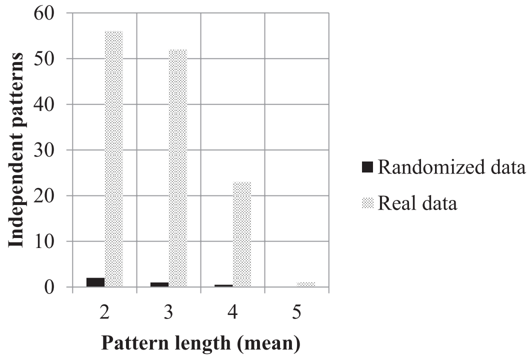

Figure 3. Randomized versus real data.
Note. The video-coded, actual data are compared with a randomized set of behaviors to test whether the real data set contains meaningful patterns. In this figure, pattern length was taken as the exemplar parameter. The randomization procedure is performed 5 times, by the Theme software, on the basis of which means are computed. This figure shows that the data contain meaningful patterns of team interaction; when randomizing the data, team interaction patterns are no longer found.

Theme provides the following information about the detected T-patterns: (a) recurring team interaction patterns (i.e., the total number of times patterns of team interaction occurred), (b) heterogeneous team interaction patterns or the number of unique patterns,[3] and (c) participative team interaction patterns, as represented by the number of actor switches in a pattern (i.e., the number of times that another actor–leader or follower–starts to speak in the patterns). Participative team interaction patterns are, thus, represented by interaction sequences of the same set of actors.

In this study, a total of 110,635 separate behavioral events were coded, and Theme detected 7,879 behavioral patterns. By comparing the average number of detected patterns in the randomized data with the actual number of patterns, we verified that the generated patterns were due neither to chance nor to the presence of many data points (Figure 3). Here, the randomly distributed data produced significantly fewer patterns. This means that the patterns of behavior found during the team meetings had a statistically valid basis for interpretation. All earlier available team pattern studies (Kanki, Folk, & Irwin, 1991; Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012) had smaller sample sizes and focused on pattern length, complexity, and number of actor switches. The focus of the present study is on the context, effects, and behavioral content of team interaction patterns.

Across all Theme analyses, the default of pattern occurrences was set at “3”; based on the minimum meeting time of 30 min, a pattern had to occur at least once every 10 min. A similar default was used by Zijlstra et al. (2012). Figure 3, demonstrating that meaningful patterns were detected, also shows that, in terms of the patterns’ length, fewer patterns were detected that consisted of four or five behaviors. Hence, the figure also reveals that complex patterns (consisting of more than three behaviors) are less likely to be repeated within short time intervals. Although the figure combines two distinct “parameters (i.e., pattern occurrence and pattern length),” it implies that if a threshold of 4 would have been used (i.e., a pattern had to occur every 7 min), the more complex patterns would not have been captured by the analysis. Note that the number of patterns was standardized to the shortest video time to control for variability in the staff meeting duration.

T-pattern analysis has been used in several domains, including animal research (Casarrubea, Sorbera, Magnusson, & Crescimanno, 2011), sports science (e.g., Bloomfield, Jonsson, Polman, Houlahan, & O’Donoghue, 2005), child psychology (e.g., Merten & Schwab, 2005), psychiatry, psychopharmacology, ethology, and, only recently, team research (Lei et al., 2016; Stachowski et al., 2009; Zijlstra et al., 2012). The software reveals patterns that would be difficult to observe with the naked eye and are, therefore, easily overlooked.

Task context. The organization distinguishes between teams working in a routine versus nonroutine task context. This classification of teams is a longstanding tradition in public-sector organizations in the Netherlands. The same distinction was adopted here. The teams that work in a routine task context are described as doing comparatively more of the same, repetitive tasks. They do work that includes strong procedural guidelines, including protocols on what to do when deviations occur. Teams that operate in a nonroutine task context are constantly facing new situations and have to continuously adapt their way of working to fit the changing task context. Hence, the level of task complexity varies between the teams that operate in routine versus nonroutine task contexts. In total, 40% of the teams in our sample worked in routine task contexts, and the rest in nonroutine task contexts.

Control variables. Prior studies that examined both information sharing and the nature of team interactions noted that these dynamics are affected by the gender and age of the group members as well as by team tenure and size (e.g., Chang, Bordia, & Duck, 2003; Gardner et al., 2012; Gersick & Hackman, 1990; Stasser, Taylor, & Hanna, 1989). Compared with team members who had spent a long time working together, those team members who had spent less time working together showed more adaptive interaction dynamics (Gorman et al., 2010). Throughout the analyses, individual responses about gender, age, and tenure in the team were aggregated to the team level. Team size was measured by the total number of employees.

Data Analysis

To test the hypotheses, hierarchical multiple regression analyses were conducted. All the reported agreement and reliability indices, for the variables for which more than one rater was present, justify aggregation to the team level (James, Demaree, & Wolf, 1984). The variables and our theorizing were all pitched at the team level. Hence, we did not perform a multilevel analysis (Gooty & Yammarino, 2011). Although we tested the mediation hypothesis with Baron and Kenny's (1986) four well-known conditions,[4] we strengthened the examination of the moderated-mediation effects by following Edwards and Lambert (2007). Previous tests of moderated mediation, such as splitting the data into subgroups (e.g., Fabrigar & Wegener, 2011), the moderated causal steps procedure for mediation (Baron & Kenny, 1986), or the piecemeal approach to test mediation and moderation, have limitations: They do not reveal which of the dependent, independent, or mediator paths vary as a function of the moderator; or they lower the statistical power by splitting up the sample. Using the path-analytical approach, in addition to Baron and Kenny's (1986) procedure, provides several important benefits and overcomes the issues associated with these earlier analytical approaches.

Results

Descriptive Statistics

Means and standard deviations of the variables in the hypothesized model, as well as their zero-order correlations, are shown in Table 2. Tables 3 to 5 present the results of the hierarchical regression and moderated path analyses of the proposed moderated-mediation model.

Hypotheses Testing

Support was found for Hypothesis 1, which proposed that the relationship between recurring patterns of team interaction and team effectiveness is mediated by information sharing. The hierarchical regression analysis shows that (a) recurring team interaction patterns were negatively related to team effectiveness ($\beta = -.34$, $p < .01$: Model 2 for team effectiveness); (b) recurring

Table 2. Means, Standard Deviations, and Correlations.

	M	*SD*	Minimum	Maximum	1	2	3	4	5	6	7	8	9
1. Team effectiveness	6.95	0.64	5.00	8.00									
2. Team information sharing	5.19	0.49	4.13	6.50	.48***	—							
3. Recurring team interaction patterns	82.07	119.19	3.00	434.00	−.33**	−.30**	—						
4. Heterogeneous team interaction patterns	18.67	26.64	1.00	105.00	−.05	−.03	−.23*	—					
5. Participative team interaction patterns	1.18	0.52	0.29	2.33	.27**	.31**	−.25*	.04	—				
6. Team gender	1.33	0.19	—	—	−.02	−.18	−.01	.02	.08	—			
7. Team age	49.25	5.11	33.95	59.83	−.02	−.04	.04	−.04	.03	−.37***	—		
8. Team tenure	3.73	3.12	0.63	17.03	.02	−.04	.15	−.09	.09	−.31**	.34**	—	
9. Team size	13.32	5.89	4.00	33.00	.01	−.17	.03	−.06	−.09	.17	.04	.02	—
10. Task context	1.60	0.49	—	—	.06	−.00	−.27**	.07	.22*	−.14	.12	−.07	−.14

Note. $N = 96$. Gender was coded “1” = Male and “2” = Female. Task context was coded “1” = Routine and “2” = Nonroutine. Team tenure was measured in years.
$*p < .05$. $**p < .01$. $***p < .001$.

Table 3. Results of Hierarchical Regression Analyses ($N = 96$).

	Team information sharing											Team effectiveness							
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 1	Model 2	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4
Control variables																			
Team gender	−.21	−.22	−.22	−.25*	−.21	−.15**	−.20†	−.20†	−.24*	−.21†	−.23*	−.03	−.02	.08	.08	−.03	.08	−.06	.06
Team age	−.09	−.11	−.09	−.13	−.11	−.07	−.07	−.07	−.10	−.09	−.11	−.04	−.04	.01	.01	−.04	.01	−.07	−.01
Team tenure	−.03	.07	−.08	−.05	.05	−.03	−.08	−.07	−.05	−.01	.03	.03	.08	.07	.09	.02	.06	.05	.07
Team size	−.15	−.22*	−.15	−.10	−.20	−.31	−.14	−.13	−.10	−.10	−.10	.02	.02	.09	.09	.02	.09	.05	.10
Independent variable																			
Recurring team interaction patterns		−.31**			−.40***	−.28*					.21†		−.34**		−.20				
Heterogeneous team interaction patterns			−.05				−.05	−.09			.12					−.05	−.02		
Participative team interaction patterns				.33*					.38***	.28**	.23*								
																		.29**	.13
Moderator																			
Task context					−.18	−.13	−.06	−.05	−.15	−.15	−.17								
Interaction																			
Recurring Team Interaction Patterns × Task Context						−.23*					−.20*								
Heterogeneous Team Interaction Patterns × Task Context								.06			−.02								
Participative Team Interaction Patterns × Task Context										.28**	.19†								
Mediator																			
Team information sharing														.52***	.46***		.52***		.48***
R^2	.07	.15	.08	.18	.15	.24	.07	.07	.20	.26	.36	.00	.12	.26	.29	.00	.26	.08	.27
F	1.64	3.04*	1.44	3.82**	3.52**	3.73**	.98	.86	3.39**	4.16**	3.98***	0.05	2.28*	6.13***	6.01***	0.08	5.06***	1.57	5.43***

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

team interaction patterns were negatively related to team information sharing ($\beta = -.31$, $p < .01$: Model 2 for team information sharing); and (c) when controlling for recurring team interaction patterns in the regression equation, the relationship between information sharing and team effectiveness remained significant ($\beta = .46$, $p < .001$: Model 4 for team effectiveness).

No support was found for Hypothesis 2, which stated that heterogeneous team interaction patterns are positively related to team effectiveness through information sharing. Heterogeneous team interaction patterns did not significantly predict team effectiveness ($\beta = -.05$, *ns*: Model 5 for team effectiveness) nor team information sharing ($\beta = -.05$, *ns*: Model 3 for team information sharing).

Hypothesis 3, stating that the relationship between participative team interaction patterns and team effectiveness would be mediated by information sharing, was supported. Participative team interaction patterns were significantly related to team effectiveness ($\beta = .29$, $p < .01$: Model 7 for team effectiveness), fulfilling the first condition for mediation. They were significantly and positively related to information sharing ($\beta = .31$, $p < .05$: Model 4 for team information sharing), fulfilling the second mediation condition. Finally, while holding participative team interaction patterns constant, information sharing significantly predicted team effectiveness ($\beta = .48$, $p < .001$: Model 8 for team effectiveness).

The results support Hypothesis 4, which posited that task context moderates the relation between recurring team interaction patterns and team information sharing ($\beta = -.23$, $p < .05$: Model 6 for team information sharing; see Figure 4). Further support for the hypothesized indirect effect was obtained using moderated path analysis (Table 4). Differences in the effects of routine versus nonroutine task contexts show that the first stage of the indirect effect was stronger for the nonroutine task context (.14 – .07 = .07, $p < .05$). In the second stage, the indirect effect was slightly stronger in routine task contexts (.12 – .11 = .01, *ns*). The differences in the first stage contribute especially to a significantly stronger indirect effect in knowledge-intensive team-task contexts. The negative relationship between recurring patterns of team interaction and team information sharing was significant in nonroutine task contexts (simple slope = −.31, $t = -3.47$, $p < .01$), but not in routine task contexts (simple slope = −.16, $t = -1.91$, *ns*).

No support was found for Hypothesis 5, which stated that a task context moderates the relation between heterogeneous team interaction patterns and team information sharing ($\beta = .06$, *ns*: Model 8 for team information sharing).

Support was found for Hypothesis 6, which posited that task context moderates the relationship between participative team interaction patterns and

Table 4. Results of the Moderated Path Analysis for Recurring Team Interaction Patterns ($N = 96$).

	Recurring team interaction patterns (X) → Team information sharing (M) → Team effectiveness (Y)				
	Stage		Effect		
	First	Second	Direct effects	Indirect effects	Total effects
Moderator	PMX[a]	PYM[b]	PYX[c]	PMX × PYM	PYX + (PMX × PYM)
Routine task context	−.07 [–.24, .11]	−.12* [–.22, –.05]	−.20 [–.45, .04]	−.08 [–.27, .11]	−.19 [–.45, .05]
Nonroutine task context	−.14* [–.25, –.07]	−.11* [–.21, –.03]	−.11 [–.28, .07]	−.14* [–.29, –.04]	−.11 [–.30, .08]

[a]PMX: path from recurring team interaction patterns to team information sharing.
[b]PYM: path from team information sharing to team effectiveness.
[c]PYX: path from recurring team interaction patterns to team effectiveness.
*$p < .05$.

information sharing ($\beta = .28$, $p < .01$: Model 10 for team information sharing). We also found further support for the moderated-mediation effect in the results of the moderated path analysis (see Table 5). When comparing the differences in the effects of the nonroutine versus the routine task contexts, the results show that the first stage of the indirect effect was stronger for the nonroutine task context (.37 – .09 = .28, $p < .05$). The indirect effect was somewhat stronger in routine task contexts in the second stage of the model (.21 – .19 = .03, *ns*). The big differences in the first stage of the model are in line with our prediction of a stronger effect of participative team interaction patterns in a nonroutine task context. This moderation effect is visualized in Figure 5, including the simple slope for the nonroutine task context (simple slope = .43, $t = 4.53$, $p < .001$) and the routine task context (simple slope = .27, $t = 2.57$, $p < .05$).

When analyzing the control variables that were included in our hierarchical regression analyses, team age and tenure yielded no significant effects on information sharing and team effectiveness. In some models on team information sharing, a significant negative relationship between team gender and team information sharing appeared (see, for example, $\beta = -.23$, $p < .05$: Model 11 for team information sharing): If more females were part of the team, lower perceptions on information sharing were obtained. If the team

Table 5. Results of the Moderated Path Analysis for Participative Patterns of Interaction ($N = 96$).

	Participative team interaction patterns (X) → Team information sharing (M) → Team effectiveness (Y)				
	Stage		Effect		
	First	Second	Direct effects	Indirect effects	Total effects
Moderator	PMX[a]	PYM[b]	PYX[c]	PMX × PYM	PYX + (PMX × PYM)
Routine task context	.07 [−.24, .11]	.12* [−.22, −.05]	.20 [−.45, .04]	.08 [−.27, .11]	.19 [−.45, .05]
Nonroutine task context	.14* [−.25, −.07]	.11* [−.21, −.03]	.11 [−.28, .07]	.14* [−.29, −.04]	.11 [−.30, .08]

[a]PMX: path from participative team interaction patterns to team information sharing.
[b]PYM: path from team information sharing to team effectiveness.
[c]PYX: path from participative team interaction patterns to team effectiveness.
*$p < .05$.

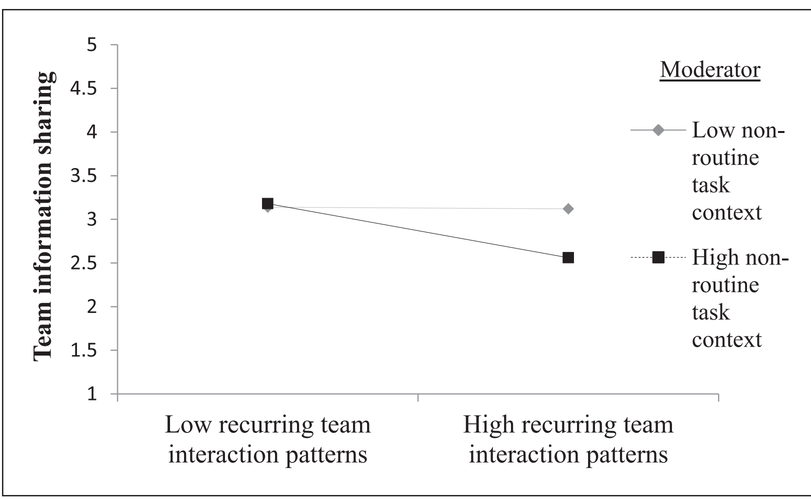

Figure 4. Moderating effect of task context between recurring team interaction and team information sharing.

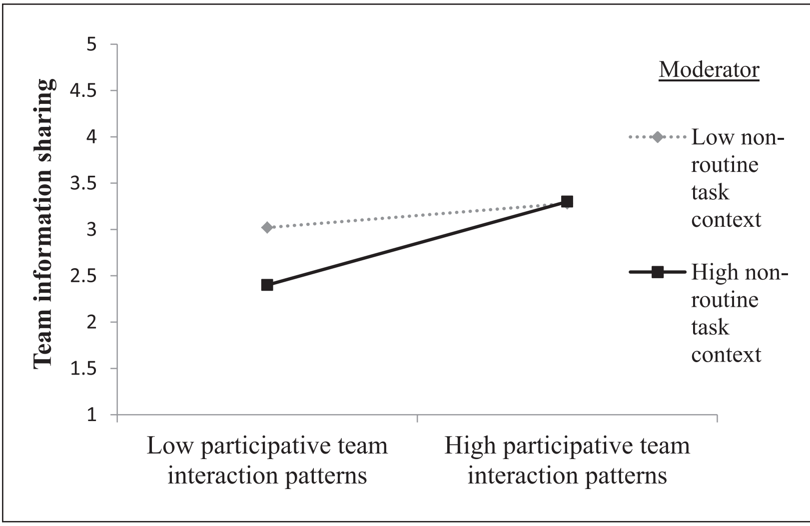

Figure 5. Moderating effect of task context between participative team interaction and team information sharing.

consisted of more males, higher levels of perceived information sharing were attained.

Post Hoc Analysis

No effects were found for the heterogeneous team interaction patterns; this type of pattern was not associated with information sharing or effectiveness. To better understand how all three patterns are linked to perceived information sharing and team effectiveness, we conducted post hoc content analysis of the behaviors involved in the patterns. Table 6 illustrates the most frequently occurring patterns within the 15 most effective and the 15 least effective teams. These teams were selected on the basis of an extreme scores analysis in which the most effective teams had effectiveness scores above 7.5 and the least effective teams had scores below 6.25 (on a scale of 1 to 10, which is the most customary performance rating scale in the Netherlands). The number of frequently occurring patterns was 258 for the most effective teams and 263 for the least effective teams. The pattern characteristics were visualized by the software program but were counted manually.[5] By doing this, we overcame the limitation noted by Gorman et al. (2012) of looking only at mean results; we also engaged in a detailed behavioral content analysis.

Table 6. Post Hoc Analysis: Differences in the Behavioral Content Between the Most and Least Effective Teams.

	Most effective teams ($N = 15$)			Least effective teams ($N = 15$)		
	Observed number of interaction patterns	Number of teams in which the interaction pattern was displayed	Pattern	Observed number of interaction patterns	Number of teams in which the interaction pattern was displayed	Pattern
1	33	5	Leader TA–Follower IS–Follower TA	27	5	*Leader TA–Follower IS–Leader IS*
2	32	5	Leader TF–Leader TA–Leader IS	19	4	Follower TA–Leader IS–Follower IS
3	32	5	*Leader TA–Follower IS–Leader IS*	19	3	Follower TA–Leader IS–Leader TF
4	31	4	Follower IS–Follower TA–Leader IS	15	2	Follower IS–Follower TA–Follower CP
5	25	3	Leader TA–Leader TF–Leader IS	15	3	Follower IS–Follower TA–Follower CP
6	23	6	Leader TA–Follower IS–Leader TF	14	3	Follower TA–Leader CP–Follower CP
7	22	4	Leader TA–Follower TA–Leader IS	13	3	Follower TA–Leader IS–Follower CP
8	21	4	Leader TA–Follower IS–Follower TA	12	2	Follower IS–Leader TA–Leader IS
9	20	4	Follower humor–Leader humor–Leader IS	11	3	Leader TA–Follower IS–Leader IS
10	19	4	Follower TA–Follower CP–Follower IS	10	3	Follower TA–Leader TA–Follower IS
11				10	3	Follower TA–Follower CP–Leader IS
12				10	2	Follower TA–Leader IS–Follower CP
13				9	3	Follower CP–Leader TF–Leader TA–Leader IS
14				9	2	Follower TA–Leader IS–Leader TA
15				8	2	Follower TA–Follower humor–Leader IS
16				8	2	Follower TA–Leader TF–Leader IS
17				8	2	Follower TA–Follower IS–Leader IS
18				8	2	Follower TA–Leader TA–Leader IS
19				8	2	Follower TF–Leader IS–Leader TF
20				8	2	Follower TF–Follower TA–Leader IS
21				8	2	Leader CP–Follower CP–Leader IS
22				7	2	Follower CP–Follower TA–Leader CP
23				7	2	Leader TA–Follower TF–Leader IS
Total	258			263		

Note. This "extreme teams" analysis is only made for illustrative purposes. In total, 678 team interaction patterns were detected in the 15 most effective teams versus 1,603 in the 15 least effective teams. The 15 most effective teams scored above 7.50 on team effectiveness (on a scale of 1 to 10, 10 meaning extremely highly effective); eight of them were knowledge-intensive teams. The 15 least effective teams scored lower than 6.25 on team effectiveness; eight of them were knowledge-intensive teams. In terms of the behavioral categories: TA = transaction behavior; IS = initiating structure behavior; TF = transformational behavior; CP = counterproductive behavior. The patterns in italics occur both in the most effective and least effective teams. See Table 1 for an overview of the video-coded behaviors.

Table 6 shows that even the most effective teams showed recurring behavioral patterns, but much less so than the least effective teams. In terms of the content of the interaction patterns of the most effective teams, task-oriented behavior prevails; in the most effective teams, many patterns consist entirely of task-oriented behaviors, such as transactional or initiating structure behavior (e.g., leader transactional–follower initiating structure–follower transactional; see Table 6, row 1). This task-directedness was observed in 54% (i.e., from rows 1, 3, 4, 7, and 8, we add up (33 + 32 + 31 + 22 + 21)/258) of the most effective teams, compared with just 40% in the least effective teams. It is noteworthy that the task-oriented "transactional" and "initiating structure" behaviors were the most dominant type of behaviors in the identified team interaction patterns (Judge & Piccolo, 2004). Surprisingly, transformational behavior hardly played a part in the patterns presented in Table 6. The least effective teams demonstrated much more counterproductive behavior within their interactions; this behavior occurred in 38% of their patterns, compared with 7% in the highly effective teams (Table 6).

Another differentiator between the most effective and least effective teams was the type of team member who initiated a team interaction pattern. In the least effective teams, followers initiated interaction patterns more often than the leaders (80% of the patterns in the least effective teams vs. 27% in the most effective teams). Conversely, more leader-only patterns were visible in the most effective teams; in such patterns, the leader appraised, inspired, and steered his or her team.

Discussion

This CAS study identified three team interaction patterns in two types of real-life task contexts and examined how the patterns relate to perceived team information sharing and team effectiveness. Multimethod/source data on the 96 videotaped teams, involving the micro-behaviors of 1,395 team members, were used to link the patterns to both perceived team information sharing and effectiveness. By combining linear and nonlinear statistical methods, we established that a high frequency of recurring team interaction patterns reduces the sharing of information among team members, especially in nonroutine task contexts, thereby lowering team effectiveness. In both nonroutine and routine task contexts, participative team interaction patterns are shown to be beneficial for perceived information sharing and team effectiveness. No effects were found for the heterogeneous team interaction patterns; this type of team interaction pattern appears not to be associated with team information sharing or effectiveness. Potentially divergent effects of the possibly related team interactive and compositional heterogeneity may have masked the hypothesized effects. Through content analysis, we illustrated that even the highly effective teams show recurring patterns. As noted by Gersick and Hackman (1990), a certain low degree of recurring team interaction is needed to accomplish team goals. The most effective teams appear to have predominantly task-based interaction patterns that only recur occasionally. The least effective teams manifest many more counterproductive behaviors.

We have shown that team dynamics captured with nonlinear techniques might be coupled to important team processes, such as perceived team information sharing. Having identified how this key process may be reached (through nonrecurring, participative team interaction), by viewing teams as CAS and incorporating nonlinear techniques, we extend the linear team research tradition (Ramos-Villagrasa et al., 2018). In addition to establishing that both nonrecurring and participative team interaction patterns are associated with information sharing and effectiveness, our study shows that the effects of those patterns can depend on the team task context. Thus, we empirically support the idea that the task context is a key aspect of teams as CAS (Kerr, 2017; Ramos-Villagrasa et al., 2018; Stevens & Galloway, 2014); highly knowledge-intensive teams are more vulnerable to the negative effects of recurring team interaction patterns, as this limits their information sharing. A greater variety of informational sources, such as those from various external and internal stakeholders, must then be integrated to make high-quality team decisions (Cummings & Cross, 2003). To perform well as a team, members of knowledge-intensive teams must bring together disparate bodies of information and knowledge for robust team sharing of information (Hau, Kim, Lee, & Kim, 2013). Based on our results, this can be accomplished with a high degree of participative deliberation within these teams. More generally, to improve their information sharing capacity and effectiveness, both types of teams should become more participative in their patterns of team interaction. But because little information exchange and elaboration are usually needed in effective routine team-task execution (Resick et al., 2014), many recurring interaction patterns are less detrimental for routine types of team work (see the moderation effect in Figure 4).

Our findings support a key element of the team information sharing theory (Stasser & Titus, 1985). Team information sharing implies adaptive coordination, which, in turn, can explain why teams with participative interaction patterns contribute to a higher level of team effectiveness, and why teams with mainly recurring team interaction patterns contribute so little. Our results show that team information sharing is especially inhibited when teams engage in recurring interaction patterns. In other words, recurring interaction patterns can be seen as signs of team "information processing failure"

(Schippers et al., 2014, p. 731). Full utilization of the potentially available informational resources of all team members leads to a high level of team effectiveness. This research outcome points to the potential value of examining leadership *relationally*, that is, examining leaders and followers together, "in interaction," rather than separately, which is particularly relevant for teams that are knowledge-intensive or involved in nonroutine tasks. New CAS studies of teams should explain how effective team interaction patterns are established, that is, under what sort of team conditions? We must then also trace actual versus perceived team information sharing and interaction patterns over time. Multilevel-type data collection would be needed to complement such promising longitudinal team analyses. Indeed, adopting an NDS approach has consequences for both theory and research design (Kozlowski & Chao, 2012; Roe, Gockel, & Meyer, 2012).

Practical Implications

One of the fundamental characteristics that make a team "a team," and more than just a collection of individuals, involves the interactions that occur between and among its members. The present study found that team interaction patterns need to match their task environment; an adequate match, in essence, leads to effectiveness. We show evidence in this study that participative team interaction patterns are associated with a team's extensive sharing of information and, in turn, with team effectiveness in both routine and nonroutine task contexts. Especially in nonroutine task contexts, recurring team interaction patterns are undesirable, because then little information is exchanged among the members of a team, which makes the team ineffective. Thus, to be effective as a team, its members need to become aware of the patterns in their team interactions so that they can move to or stay in a mode in which they can optimally share and use each other's information.

Especially leaders of teams must become aware of the effectiveness benefits of various interaction patterns; to achieve team effectiveness, high participative and few recurring interaction patterns among the members must be ensured. Team coaches must also be able to detect the two team interaction patterns with the demonstrated opposing effects. Such coaches are increasingly charged with "getting teams out of a rut" or with helping team members and leaders to adapt better to the realities of their task environment (Hackman & Wageman, 2005). On the basis of our results, coaching guidance seems especially important for restoring the effectiveness of knowledge-intensive work teams. A final, more classical strategy to reduce the debilitating recurrent team interaction patterns is changing the composition of a team; how to do that well during an important team assignment is a practically relevant topic deserving future quasi-experimental field research into the degree to which and when certain members of teams are more inclined to engage in recurring team interaction patterns than other members.

Strengths, Limitations, and Future Research

The examination of real-time, behavioral data to understand team effectiveness better has been on the research agenda for at least a decade (Arrow et al., 2004; Cronin et al., 2011; Humphrey & Aime, 2014; Leenders et al., 2015; Mathieu, Maynard, Rapp, & Gilson, 2008; Salas, Cooke, & Rosen, 2008). To the best of our knowledge, no other large-scale, time-based study has coupled various team interaction patterns—derived from real-life organizational team member behaviors—to different team-task contexts. This CAS study has also limitations that must be acknowledged.

First, the study was carried out within a single organization in the Netherlands. Different patterns of team behavior may exist in other national and organizational cultures (Erez & Earley, 1993; M. Perlow, 2003), especially because the Netherlands is known as a low power-distance country. In the Netherlands, participation in a team's affairs during regularly scheduled team meetings is the norm. Similar research in a high power-distance country must examine whether or not comparable results of participative team interaction patterns on team information sharing and effectiveness can be retrieved. Future studies will, thus, need to examine whether the results are generalizable across nations or cultures.

Second, although our hypothesized relationship between heterogeneous interaction patterns, information sharing, and subsequent team effectiveness yielded no results, other studies did find an effect of heterogeneous interaction patterns on team performance. Kanki, Folk, and Irwin (1991) established that team performance is inhibited in aviation teams when the interaction patterns are more heterogeneous. Aviation teams need to perform in highly standardized and formalized work contexts, with predefined protocols for information sharing. Heterogeneous interaction patterns might inhibit effective information sharing in crisis contexts because, to respond quickly to a rapidly changing situation, the members must share the most crucial information efficiently so as to resolve the situation. Hence, although the suggested relationship could not be confirmed empirically in this study, it was found to be crucial in another context.

Third, the data include one video recording per team of one randomly selected, regularly held team meeting. Nevertheless, all behaviors of the 1,395 team members in those 96 team meetings, including 96 leaders, were reliably coded with a predeveloped behavioral observation scheme. To date, fine-grained analytical techniques have been cumbersome, and team processes have been typically studied as aggregated, perceptual measures, without considering the time-based patterns of team interaction (Leenders et al., 2015). Even though Note 5 shows that the nonlinear software in use still needs improvement, future team-effectiveness research can be greatly enriched with continuous-time data from real-life patterns of team interaction.

Fourth, even though the methods used in this study enable the mapping of three different patterns of real-time team interactions, the field data are cross-sectional. Due to our use of various methods and sources, common-source/method bias is not an issue, and, moreover, the order in which we collected the data for the variables is correctly reflected in our analyses. More research on the antecedents and content of team interaction patterns is recommended so that leaders and coaches are enabled even better to prevent or correct detrimental patterns (Bolger & Laurenceau, 2013). Qualitative examinations of how team interaction patterns unfold over time (e.g., Harrison & Rouse, 2015) could result in a more complete understanding of the development of such patterns.

Fifth, in this study, we rely on a perceptual measure of information sharing. Hence, by using this measure to assess information sharing, we were not able to delineate whether the shared information is either unique or common knowledge (Stasser & Titus, 1985). Moreover, information can take different forms (see, for example, Uitdewilligen & Waller, 2018, who distinguished between fact, interpretation, and projection sharing). Future empirical research on the team dynamics of information sharing must focus on the different types of information sharing needed in various task contexts. Most prior studies on the relationship between information sharing and team effectiveness have relied on the perceptions of team members. Also, using more objective measures of information sharing within teams has become desirable.

Conclusion

We took a CAS approach to better understand how real-life interaction patterns within teams are associated with team effectiveness in different task contexts. As hypothesized, when a large number of recurring team interaction patterns are present, this is negatively related to team effectiveness, through limited team information sharing. Instead, the more teams engage in participative patterns of interaction, the more they engage in information sharing, which, in turn, is associated with higher levels of team effectiveness. Knowledge-intensive teams, in particular, are advised to avoid frequently *recurring* patterns of team interaction. Teams working on routine tasks can be less concerned with recurring patterns of interaction, because their work requires less information sharing. Nonetheless, both types of teams, their leaders, members, and coaches should learn how to reduce recurring team interaction patterns and, instead, promote participative or collaborative patterns of team interaction. Given that the world is increasingly affected by the outcomes of knowledge-intensive teams, and nonlinear research methods are progressively available, we suggest that future research on work teams consider the use of more video-based CAS investigations to complement traditional methods.

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Notes

1. Whereas *recurring* patterns denote the total sum of interaction patterns shown by a team (e.g., it engages in the "*abc*" pattern 10 times), *heterogeneous* patterns refer to the number of different patterns that are being displayed (e.g., the interaction pattern "*abc*" is different from another occurring behavioral pattern, such as, for instance, "*ade*").
2. Intraclass correlation coefficients (ICCs) and R_{wg} were calculated to assess the within-group agreement and reliability of the team members' ratings of team effectiveness (i.e., indexing group-level dispersion or diversity in ratings: Newman & Sin, 2009). ICC1 (.17, $p < .01$) and the ICC2 (.76, $p < .01$) values showed sufficient levels of agreement.
3. For example, the pattern *abc* occurs 5 times, whereas the pattern *ade* occurs 4 times. The total number of unique patterns does not take into account how many times such a pattern occurs; only how many unique patterns can be identified. The patterns, *abc* and *ade*, would be both given a count of 1 as they are both unique patterns.

4. The first step is to test the relation between the independent and the dependent variable. When this effect is significant, in Step 2, the effect between the independent variable and the mediator must also be significant. In the final, third step, the relationship between the meditator variable and dependent variable should be significant while controlling for the independent variable.
5. An option to retrieve a summary of the different interaction patterns was missing in the software program. Therefore, the content analysis and counting of the different behavioral patterns were done manually. In total, 678 and 1,603 patterns were found for the most effective and least effective teams, respectively. Given the total number of 7,879 patterns, we analyzed about 33% of the total number of patterns of the most effective and about 16% of the least effective teams.

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