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Article

Role Variability in Self-Organizing Teams Working in Crisis Management

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Abstract

Crisis management teams face situations characterized by high risk, time pressure, and uncertainty and must adapt to a wide range of circumstances. Self-organizing teams have been proposed as an alternative to more traditional functional teams as they are described as adaptive and promptly reconfigurable. This study investigated whether self-organizing teams display more role flexibility than functional teams and the impact on performance and coordination. Teams were assigned to either a functional or a self-organizing structure and completed scenarios in a functional simulation. Results revealed that self-organizing teams performed and coordinated better than functional teams. As expected, self-organizing teams showed more role variability across and within teams. However, greater variability in role allocation within teams was associated with poorer performance and coordination. We conclude that flexibility in roles can be beneficial but that too much variability can be associated with role ambiguity and negatively affect a team's ability to achieve its goals.

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Teamwork is ubiquitous in complex and dynamic work environments such as emergency rooms, power plants, and military operations. The uncertainty, high tempo, volatility, and high-risk characteristics of these situations compel teams to be very efficient and to adapt promptly and appropriately to events, whether anticipated or not (Brehmer, 2007). This is especially paramount in crisis management (CM) because the stakes and demands faced by these teams can be particularly severe. Crisis situations can be differentiated from other complex and dynamic situations because they involve an acute level of time pressure—or urgency—and uncertainty (Boin & Hart, 2007; Rosenthal, Boin, & Comfort, 2001). CM is defined as the direction of resources and activities with the aim of achieving specific goals in response to human-made or natural crisis events (e.g., earthquake, oil spill, health pandemic, terrorist attack; Curts & Campbell, 2006). Crises of diverse nature can require the involvement of public safety and/or the military, and these teams must come together to achieve their goals and combine skills, expertise, and knowledge to fulfill a variety of roles (e.g., resource management, search and rescue, and planning; Office of Emergency Services, 2012).

In the last 15 years, there has been an ever increasing push toward greater team flexibility in managing complex and dynamic situations such as CM, including the promotion of self-organizing teams as a way to increase team effectiveness. By nature, self-organizing team structures afford members greater flexibility to adapt to occurring and unanticipated events to maximize team effectiveness. This flexibility, if acted on, should manifest through greater variability in terms of various team behaviors when compared with functional teams, which have a more fixed structure and more constraints as to what roles and behaviors each team member can adopt. However, there is still a dearth of empirical evidence demonstrating whether and under what conditions such flexibility can be beneficial to team effectiveness. Therefore, the objective of the present study is to investigate the extent to which self-organizing teams exhibit more flexibility in their roles than functional teams and, if the case, whether that flexibility is associated with differences in team performance and coordination.

Team Structure in CM

CM teams often operate based on a functional, mostly centralized structure whereby team members are assigned specific well-defined and pre-determined roles (see Diedrich et al., 2002; Hutchins, Kleinman, Hocevar, Kemple, & Porter, 2001). FireScope, a commonly used crisis intervention plan developed in California (Office of Emergency Services, 2012) is a good example of such a structure. Role allocation usually derives from the expertise of the different team members and creates a system of complementary and highly interdependent tasks and activities that teams must coordinate to achieve their mission. Moreover, CM teams can also be *ad hoc* teams, which are teams that are composed as needed when a crisis occurs of members from different professions and organizational cultures, with limited experience in working together prior to the event (Schraagen, Veld, & De Koning, 2010). Therefore, the structure (i.e., each team member's function) is usually pre-established in CM teams, but who might be part of the team can often be decided *ad hoc*. However, owing to the unpredictable and complex nature of crisis situations, CM teams must strike a balance between allocating specific a priori roles and being responsive to changing demands and unexpected events (Bigley & Roberts, 2001). This requires flexibility in implementation of plans as well as in role and task allocation (Essens et al., 2009). Effective teams will be able to adapt to these changes and transitions and coordinate their activities efficiently while working toward achieving the mission goals (LePine, 2005; Rousseau, Aubé, & Savoie, 2006).

An expanding number of organizations and researchers have taken to exploring team or organizational structures that aim to achieve the flexibility required in complex and dynamic task environments such as CM and support reliability and effectiveness in these unstable and demanding situations (Alberts & Hayes, 2006; Bigley & Roberts, 2001; Stanton, Rothrock, Harvey, & Sorensen, 2015). As a result, more flexible and hybrid organizational forms have been put forward as strategies for coping more efficiently with complex and volatile task environments (Alberts & Hayes, 2003; Ilinitch, D'Aveni, & Lewin, 1996; Tu, Wang, & Tseng, 2009). Flexibility in that context refers to an organization's ability to respond to demands and changes in the environment by adapting the role, task, or workload allocation within or across teams involved in dealing with the situation (Alberts & Nissen, 2009; Thunholm et al., 2009). One alternative that has been put forward to limit the rigidity of a set structure and to increase team responsiveness is the concept of self-organizing teams (also called edge teams; Alberts & Hayes, 2003).

Self-Organizing Teams

Self-organizing teams represent an adaptive, flattened, rapidly reconfigurable, and distributed organizational structure compared with the more traditional hierarchical or functional structures (see Rosen, Fiore, Salas, Letsky, &

Warner, 2008). They take on many aspects of fluid, highly decentralized organizations and are assumed to allow increased empowerment, shared awareness and understanding, and freely flowing information, which are considered by many as key for more effective teams (Alberts, 2007; Alberts & Hayes, 2003; Bolia & Nelson, 2007). Implementation of self-organizing teams is often based on the assumption that no one team structure is optimal for all tasks and situations (Pennings, 1992). In the same vein, Balkema and Molleman (1999) argued that the level of self-organization should be "contingent on the level of environmental variety the organization has to deal with" (p. 137). This suggests that CM teams could benefit from a certain degree of self-organization or flexibility. Therefore, team structure, including allocation of roles and responsibilities, should be adapted to the demands and constraints of their task environments, especially when dealing with complex and volatile environments (Alberts & Nissen, 2009; Stanton et al., 2015; Stempfle, Hübner, & Badke-Schaub, 2001).

In the last decades, notions similar to the concept of self-organization (e.g., empowered self-management, self-managing task groups, and autonomous work groups) have been examined in organizational and management sciences (Balkema & Molleman, 1999; Cooney, 2004, for a review). The concept of self-organization is akin to notions such as boundary systems (Simons, 1995) and Morgan's (1986) "minimal critical specification" principle in which teams or organizations are given minimal directions to allow them flexibility and initiative in how to achieve their task. Research efforts investigating self-organizing teams have been increasing. For example, Balkema and Molleman (1999) found that one of the greatest barriers to the development of self-organizing teams appeared to be an inability or unwillingness to delegate, particularly with more sophisticated tasks. Although interesting, these results were obtained by studying only three teams using questionnaires and observations. In 2001, Stempfle and colleagues proposed a theory capable of predicting the distribution of task roles in a team based on group members' skills and preferences. However, interpretation of these results is limited by the fact that they validated their theory using a single group, and skills and measurement methods used had not been subject to prior in-depth analysis. M. Duncan and Jobidon (2008) studied role allocation in a self-organizing team performing an intelligence analysis task. They reported that members of the team spontaneously adopted only a subset of the roles explicitly assigned to the functional team. Jobidon, Turcotte, Labrecque, Kramer, and Tremblay (2014) examined how self-organizing teams spontaneously adopt and organize roles in CM situations. Using cluster analysis, they found that self-organizing teams appear to allocate roles differently than functional teams, but for a given team that allocation remains relatively stable once established. One limitation of cluster analysis is that it is determined by the variable selected to be analyzed (i.e., the data being clustered). This means that a different behavioral indicator may yield another, distinct, clustering from the one described in this article.

Overall, however, a good portion of the research on self-organizing teams has been based on case studies and qualitative studies (observation and questionnaire-based) in diverse work environments (e.g., manufacturing, business, software development, or engineering), with some focusing on complex and dynamic environments such as CM (e.g., the studies mentioned above; see also Thunholm et al., 2009 and Tu et al., 2009). Nevertheless, empirical evidence remains somewhat inconclusive as to the benefits and limitations of self-organizing structures and as to whether such organizations can significantly improve team functioning and increase team effectiveness.

Role Allocation

Role allocation is closely linked to organizational team structure because the assignment of roles can be determined or constrained by the structure of the team. Indeed, the organizational structure expresses the division of tasks and roles within the structure, among team members (Hollenbeck, 2000). The various ways in which work can be allocated (and the organizational structures created) will be characterized by different requirements for coordination, communication, and the distribution of information (e.g., who needs access to which information; Waern, 1998). According to team literature, explicit role allocation (like in functional team structure) allows team members to develop knowledge of their own and others' roles and has been associated with improved team planning process and shared situation awareness and overall better team performance (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995). The knowledge that team members hold of their own and others' roles is part of the team competencies that are key to effective team performance (Cannon-Bowers et al., 1995). Team mental models are team members' shared, organized understanding, and mental representation of knowledge about key elements of the team's relevant environment (Klimoski & Mohammed, 1994). Their content includes shared representations of tasks, equipment, working relationships, and situations (Cannon-Bowers, Salas, & Converse, 1993; P. C. Duncan et al., 1996). Teams whose members share models of both accurate taskwork and teamwork are better positioned to anticipate the needs and actions of other members, thereby increasing team performance (Cannon-Bowers et al., 1993). However, Mohammed and Dumville (2001) suggested that the optimal degree of sharing across content domains will depend on factors such as the specific environment in which a team operates, the level of interdependence among members, the nature of the task, and where the team is in terms of development.

The new interactive team cognition theory suggests that without some prerequisite levels of knowledge, team members will not be effective, and this will likely have negative impacts on team performance (Cooke, Gorman, Myers, & Duran, 2013). This theory proposes that these interactions are cognitive processes that are more critically linked to team effectiveness than knowledge. That is, team members can have a suitable distribution of knowledge, but if team members do not interact or fail to coordinate effectively, it can lead to the team failing. This ecological perspective, contrary to the more traditional shared knowledge perspective, allows for more adaptability and flexibility within the team. Moreover, flexibility in role allocation has been identified conceptually as one of the mechanisms of expert teams, one that mediates team performance (Salas, Rosen, Burke, & Goodwin, 2009). In the self-organizing structure, there is no explicit allocation of roles, tasks, or resources. Team members must determine among themselves how to distribute resources and how to go about achieving their mission. This flexibility in role adoption enables a team to adapt to varying levels of workload by supporting each other's roles and shifting tasks (Huey & Wickens, 1993) or to respond to unexpected events by creating new roles or adapting existing ones (Araki, 1999; Wesensten, Belenky, & Balkin, 2005). However, the notion of role ambiguity in organizations—that is, the lack of clarity on team roles and responsibilities—can negatively impact the team's performance (Klein et al., 2009; LePine, LePine, & Jackson, 2004). In essence, as identified by Salas et al. (2009), ensuring that team members' roles are "clear but not overly rigid" (p. 67) contributes to more reliable and higher levels of performance (what Bigley & Roberts, 2001, describe as "appropriate improvisation"). Therefore, the questions remain as to whether flexible role adoption is beneficial, and, if so, under which conditions the benefits of flexibility outweigh the potential hindrance of role ambiguity (see Alberts & Nissen, 2009).

Variability in Role Allocation

Teams that are allowed flexibility in structure, like self-organizing teams, should demonstrate a certain degree of variability in the way their roles are allocated. This flexibility can be considered at two levels. On the first level, this flexibility can occur in the way teams are structured, or structure themselves, from the onset of a mission. At this level, variability would manifest itself mainly across (inter) teams. That is, teams that are afforded flexibility in the way they organize their roles and tasks would likely differ from one another, as each team would determine the structure or allocation that best suits their mission goals. On a second level, flexibility can lead to variability within (intra) teams, over time. The variability results from a team adapting to changing circumstances and demands in the environment by modifying the current allocation of roles and responsibilities, whether that allocation was pre-determined or self-determined. In this study, the variability due to the flexibility of the self-organizing team structure is not considered a moderating variable but a characteristic that allows the distinction between the more traditional functional and the self-organizing team structures.

Adaptability refers to the ability of teams to undertake effective actions as necessary, in response to unexpected events or circumstances, and effectively adjusting processes, plans, or courses of actions to take these changes into account with the goal to maintain or improve team effectiveness (Burke, Stagl, Salas, Pierce, & Kendall, 2006; Pulakos, Mueller-Hanson, O'Leary, & Meyrowitz, 2012; Stagl, Burke, Salas, & Pierce, 2006). Although there is some conceptual overlap between team adaptability and self-organization—in the sense that both notions imply the ability of teams to modify their structure in response to changes in the environment—team adaptability also refers to modifications unrelated to team structure (see Burke et al., 2006; Stagl et al., 2006). Therefore, adaptability can be conceived as a more encompassing concept than self-organization because it can manifest itself in various ways and at different scales. The adaptability concept does not inevitably equate with self-organizing, but the flexibility associated with this team structure suggests that it could be easier for team members to adapt to unexpected circumstances because they are free to make changes (contrary to more rigid team structures). Indeed, the flexibility potential associated with the self-organizing structure could allow teams to reconfigure roles or resources and therefore to better adapt to the complex environment of CM.

Objectives

The present study investigates whether self-organizing teams take advantage of the flexibility offered by their structure and therefore show variability in roles and resources allocation, and, if the case, whether this variability is associated with differences in team performance and coordination. Adaptability is considered a key teamwork competency (Rousseau et al., 2006; Salas, Rosen, & DiazGranados, 2010; Salas, Sims, & Burke, 2005), one that is particularly critical for teams working in unpredictable, dynamic, and complex environments (what Uitdewilligen, Waller, & Zijlstra, 2010, label *action teams*). Teams facing such conditions do not have the luxury to pause and take stock of unexpected circumstances and changing demands to determine how to best deal with them; rather, they need to adapt on the fly (LePine, 2005). These teams need to be responsive and adjust their roles to cope effectively with changing circumstances in their task environment

(Bigley & Roberts, 2001; Moon et al., 2004; Rousseau et al., 2006). As such, adaptability is associated with the temporal aspects of team functioning (Dyer, 1984) in the sense that teamwork occurs over time and implies taking advantage of or having to manage circumstances at time t that may not have existed at $t - 1$, while the situation continues to evolve. LePine (2005) noted that although the importance for teams to adapt to unforeseen changes was identified in the late 1960s (notably by Behling et al., 1967, as cited in LePine, 2003), research efforts on this topic only really began 30 years later (LePine, 2003; Marks, Zaccaro, & Mathieu, 2000; Zozlowski, Gully, Nason, & Smith, 1999; see Stagl et al., 2006, for a similar observation). For instance, Marks et al. (2000) investigated how team interaction training and leader briefings affect team adaptation to novel situations. Using a low fidelity war game simulation, they showed that both variables positively influence team communications and performance, through an impact on the development of team mental models. Kozlowski et al. (1999) focused on theoretical development by stressing the need to consider team functioning and performance dynamically rather than statically. According to their theory, team performance results from a process occurring across phases and time. They posit that teams adapt and evolve over time in response to the changing nature of the work environment and demands, and continuous improvement and team development. For his part, LePine (2003) studied team adaptation following unforeseen changes in the task environment. Specifically, he assessed the impact of team members' cognitive ability and personality on team performance and whether role structure adaptation mediated that relationship. LePine considered team adaptation as a behavior (i.e., a process) rather than a measure of performance (i.e., an outcome). His findings show that teams composed of members with higher cognitive ability, openness, and achievement, as well as lower dependability, performed better following unforeseen changes. That relationship was mediated by teams' effectiveness in adapting their roles in the face of these changes. Since then, theoretical and empirical efforts have aimed to better understand adaptability and its links to various aspects of team functioning and performance, such as team cognition (Uitdewilligen et al., 2010), leadership (Zaccaro, Banks, Kiechel-Koles, Kemp, & Bader, 2009), and training (Entin & Serfaty, 1999; Priest, Burke, Munim, & Salas, 2002), as well as role allocation and team structure (e.g., Bigley & Roberts, 2001; Dubé, Tremblay, Banbury, & Rousseau, 2010; Jobidon, Labrecque, Turcotte, Rousseau, & Tremblay, 2013).

We investigate the extent to which self-organizing teams take advantage of the flexibility offered by their team structure and whether this potential variability is associated with increased team performance and coordination. This study contributes to filling a dearth of empirical work investigating the contrast between the more traditional functional team structure in which roles and resources are allocated to team members versus the self-organizing structure in which flexibility is promoted and roles or resources are not pre-established. In addition, we wish to investigate if this greater flexibility is associated with better performance and coordination. To that end, the following hypotheses will be tested:

> **Hypothesis 1:** Self-organizing teams will display greater variability in their role allocation and behaviors than teams with the functional structure.
> **Hypothesis 2:** Self-organizing teams will perform better than teams with the functional structure.
> **Hypothesis 3:** In self-organizing teams, a greater variability in role allocation within teams (across scenarios) will be correlated with a better performance and a better coordination.
> **Hypothesis 4:** In self-organizing teams, a greater variability within roles (greater sharing of roles and resources between team members) will be correlated with a better performance and a better coordination.

Method

Participants

One hundred ninety-two volunteers were recruited on the Université Laval campus in Québec City, Canada, to participate in the study (114 women and 78 men; $M = 25.2$ years, $SD = 8.7$ years). Participants were randomly assigned to 48 four-person teams. Participants received a monetary compensation of Can$25 in exchange for their participation.

Material

The task environment used was the C³Fire microworld, a computer-based simulation of forest firefighting (Granlund, 1998, 2003; Tremblay, Lafond, Gagnon, Rousseau, & Granlund, 2010; Tremblay, Lafond, Jobidon, & Breton, 2008). The fire model in the simulation is based on research on actual forest fires, and the C³ context is based on case studies of emergency coordination centers (Brehmer, 2004). For these reasons, the ecological validity of the simulation is deemed to be at a high level (Tremblay et al., 2010). C³Fire is a command, control, and communication (C³) simulation environment that can be used as a valid research tool for studies of decision making and as a network-based training tool for training core team collaboration skills (Granlund,

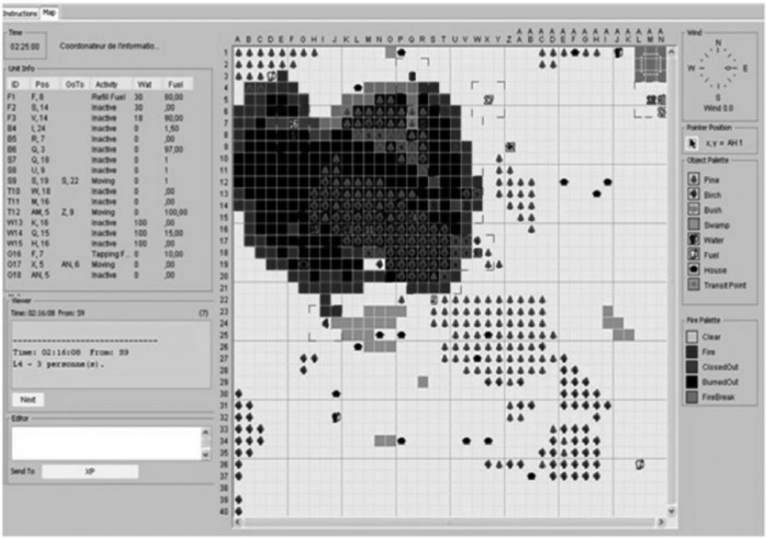

Figure 1. C3Fire interface.

2003). It has been widely used for research and training purposes in a range of work domains such as emergency response, military, homeland security, and health care. A study with professional military officers showed that participants quickly adopted analogies to their own field of expertise. Furthermore, many of the teams clearly stated that they found the simulation valuable, and that it reflects some of the crucial aspects of teamwork in dynamic settings (Granlund, 2003). Like real-life CM situations, the simulated task requires dynamic team decision making and involves regulating a dynamic system in which (a) a series of activities are required to reach and maintain the overall goal, (b) activities depend on the outcome of previous activities, (c) task parameters are continuously varying in response to changes, and (d) tasks are accomplished in real time.

The C3Fire interface contained a geospatial map, displayed on a 40 × 40 cell grid, built up by a set of four interacting simulation layers: fire, geographical objects, weather, and intervention units (see Figure 1).

The first two layers defined the dynamics of the environment. The *fire* layer outlined five different states for each cell of the map: clear, built with a firebreak, on fire, extinguished, or burnt out. A clear cell corresponded to a cell in which no fire has started yet, but that could be ignited if a bordering cell was on fire. A cell became red when it was ignited and was burning and brown when extinguished by FFs. If a cell was not extinguished within a set time period after ignition, it burnt out and turned black. A burnt-out cell could not be extinguished or reignited. If a firebreak was built on a clear cell, that cell turned grey and could no longer catch fire. The *weather* layer determined the strength and direction of the wind, which directly influenced the spread of the fire. The stronger the wind, the faster the fire spread to adjacent cells in the same direction as the wind blew.

The other two layers characterized the content of the geospatial map. The *geographical objects* layer defined the various physical objects or features displayed on the map (e.g., houses, transit point, water tanks, fuel tanks, types of trees, and swamps). The content of a cell determined the time it took to ignite (e.g., trees can be set to catch fire more quickly than houses). In this study, swamps, transit points, water tanks, and fuel tanks could not ignite. The *unit* layer outlined the types of intervention units controlled by the participants. There were six types of units: firefighters (FF), firebreakers (FB), water tankers (WT), fuel tankers (FT), search units (S), and rescue units (R). Each unit was represented on the map by a numbered icon. Each type of unit was color coded and fulfilled a specific role: FF extinguished fire, FB created firebreaks to control the spread of fire, WT and FT supplied water and fuel to the other units, S explored the map to find new fires and survivors, and R collected the survivors and brought them to safety at a transit point.

To move a unit on the map, a participant had to click on the unit and drag it to the desired location. FF extinguished fire by moving to a burning cell, which emptied their reservoir at a pre-determined rate. Their reservoir contained a limited quantity of water, and they could be refilled by moving a WT to a cell adjacent to the FF. Similarly, FF, FB, WT, and R had a limited fuel tank, which was refilled by moving a FT to an adjacent cell. Finally, both WT and FT had a limited reservoir to hold their respective resource and had to be refilled by moving the unit to water and fuel tanks, respectively, distributed on the map.

For each C^3Fire scenario teams completed as part of this experiment, every event in the microworld (e.g., a cell igniting or burning out, keystrokes) as well as continuous screen capture was recorded using the Morae software (TechSmith, Okemos, MI). Team members communicated verbally with each other via headsets, by holding down the control key on the keyboard. Teamspeak (TeamSpeak Systems, Krün, Germany) was used to transmit and record all communications.

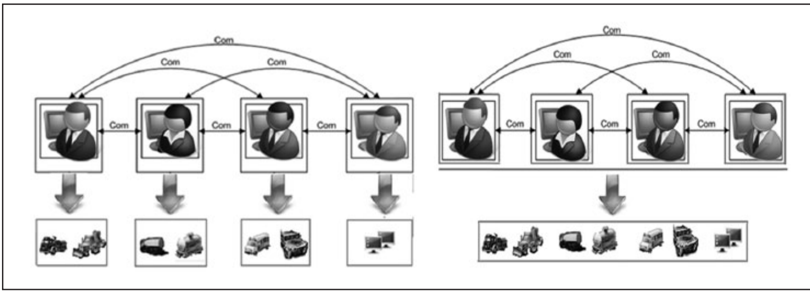

Figure 2. Illustration of the two conditions of team structure.
Note. The functional structure is displayed on the left, and the self-organizing structure is displayed on the right. In the functional structure, each team member controls a specific unit, and roles are specialized and interdependent. In the self-organizing structure, each team member can control any unit.

Procedure

Teams were assigned randomly to one of two team structure conditions: functional or self-organizing. In the functional structure, participants were randomly assigned one of four roles, each one with specific units. As illustrated in Figure 2, participants had access only to the units associated with their role: *operations chief*, responsible for three FF and three FB; *search and rescue chief*, in charge of three R and three S; *resources management chief*, responsible for three WT and three FT; and *planning chief*, who did not control any units but saw the position and the information about the other team members' units and had the overall view of the situation. Thus, the planning chief was responsible for communicating all relevant information to the other team members to achieve the task goals. This role also required assessing the fire propagation, monitoring the rescue of civilians, and communicating this information—via typed messages—to the "media" once every 2 min. Interpersonal dependencies in terms of information, resources, and subtask management task had to be satisfied to complete the collective task (Wageman, 1995). For instance, team members had to be highly interdependent and work together as each unit needs water and/or fuel to function.

In the self-organizing condition, no specific roles or units were assigned to the participants. Information on the different units was provided to them. They also had to report—via typed messages—to the "media" once every 2 min. All team members had access to all units, and they had to determine how to distribute the roles and resources among themselves as they saw fit to accomplish the task efficiently (see Figure 2). Although participants could choose to work somewhat more independently than in the functional structure (i.e., by allotting units so that each team member could coordinate water and fuel refills with their own FF and WT units), they still needed to work together to manage every aspect of the task. C³Fire has been designed to be complex and to require teamwork, so participants still needed to work as a team, share information, and coordinate the different subtasks (e.g., rescue civilians, extinguish houses on fire).

Teams in both conditions shared the same set of goals: (a) to save civilians in houses from the fire, (b) to prevent houses from burning, and (c) to limit fire spread by extinguishing cells on fire. Each test scenario began with a fire on the map. Two critical changes occurred during the course of each trial to simulate a realistic and unexpected CM situation; either a new fire started somewhere on the map or the wind increased in speed and changed direction. Participants had to detect these changes, communicate them to their teammates, and adjust their behavior accordingly.

The overall study lasted between 2.5 and 3 hr. Figure 3 depicts the timeline of the experiment. First, participants read a tutorial describing the C³Fire simulation and the goals of their mission, and they watched a demonstration of C³Fire. The tutorial describing the C³Fire simulation and the goals of the mission differed slightly for each team structure. For the functional condition, the tutorial presented each role and its assigned units. For the self-organizing condition, no specific roles were presented, only the different units and their functions. After the tutorial, participants completed two familiarization scenarios. The first familiarization scenario lasted 15 min and was played individually to allow participants to familiarize themselves with the basic functionalities of C³Fire. The second familiarization scenario, lasting 10 min, was performed with the other team members allowing them to learn to play C³Fire as a team. In the functional structure, each participant played his or her role and had only access to his or her units. In the self-organizing structure, participants had access to all units. Then, each team completed a 5-min unsupervised planning session (which was recorded). During this planning session, team members had the opportunity to discuss their strategy. This was also the time for the participants in the self-organizing structure to determine how to distribute the units. Following this planning session, all teams completed four 10-min test scenarios, each followed by a set of questionnaires (post-scenario questionnaires took 5-7 min to complete). The order in which the scenarios were completed was counterbalanced. The experiment ended with a final set of questionnaires that addressed the overall experiment, which took participants between 20 and 30 min to complete.

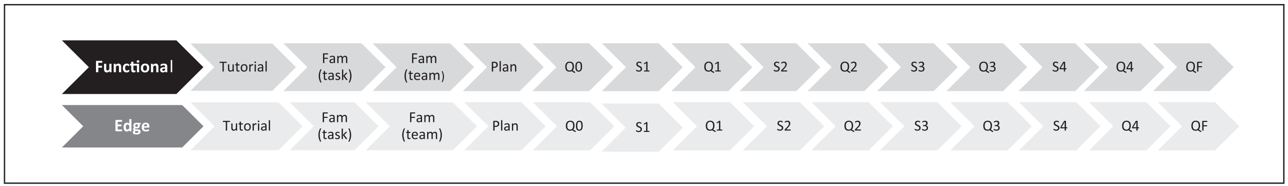

Figure 3. Experiment timeline.
Note. Fam = familiarization, Qx = questionnaires, Sx = scenarios.

Metrics

The key challenges in C^{3}Fire are to locate and prioritize the fires, protect houses and survivors, ensure that FFs are refilled in water and fuel in a timely manner, and re-supply WTs and FTs at appropriate times. C^{3}Fire involves time pressure, uncertainty, and teamwork: three key considerations in CM. C^{3}Fire logs yield a considerable set of data. For the purpose of this article, we focused on a subset of the data pertaining to a behavioral indicator of role adoption in self-organizing teams to compare the roles adopted in these teams with the roles allocated in functional teams (i.e., planning, operations, search and rescue, and resources management). Specifically, the behavioral indicator we used to operationalize the various roles was the proportion of use of each type of unit (i.e., water, fuel, transportation, search, rescue, firefighters, and firebreaks). That is, during a C^{3}Fire scenario, team members use the various units to reach their goals (i.e., controlling the fires, protecting the houses, and saving civilians). The type of units used by a given team member is indicative of what role this person is fulfilling (e.g., a person using WT and FT indicates that this person is fulfilling a role of resources management; see M. Duncan & Jobidon, 2008, for a similar approach). From this measure, a set of metrics were derived to investigate variability of roles in self-organizing teams compared with functional teams. Sending messages, which was a key action of the planning chief role, was considered as a unit though there were no actual units attached to that role. This action was logged by C^{3}Fire and could therefore be tracked (e.g., who, when, how often) over the course of a scenario. Metrics of performance and coordination were also computed.

Performance. Performance was assessed by measuring teams' success in managing both the defensive and offensive objectives of the task. The three objectives that teams had to achieve were, in order of importance, (a) saving civilians in houses from the fire, (b) protecting the houses from the fire, and (c) extinguishing as many burning cells as possible to limit fire propagation. For each scenario, the actual performance of a team was compared with the worst possible performance (i.e., the outcome of the scenario if there was no intervention at all). This metric, termed *process gain*, represents the number of civilians, houses, and cells saved during a scenario, weighted by the priority of each objective. Participants were advised that the achievement of each of these sub-objectives would be weighted according to importance, taking into account the pre-established order of priority to compute a final team performance score for each team. Please note that these weights were chosen to retain equal intervals between each of the three goals (i.e., 0.2) and to keep the impact of the weight minimal, hence, the use of decimals. We also tested to make sure that these determined weights did not change the pattern of significance of the results. Therefore, mean team performance was computed as follows:

$$\frac{1.5\,x\,\%\,of\ \ people\,saved\ \ from\ \ fire + 1.3\,x\,\%\,of\ \ houses\,saved\ \ from\ \ fire + 1.1\,x\,\%\,cells\,saved\ \ from\ \ fire}{3.9}$$

Coordination. We used the coordination latency to assess the time each unit spent without critical resources (i.e., water for FFs or fuel for WTs) to function. This type of coordination refers to processes that serve primarily to manage dependencies between activities or resource dependencies (Crowston, 1997). It provides an excellent indicator of the efficiency in performing the water or fuel refill process, which requires coordination between two types of units. The coordination metric is a true representation of a behavioral event because participants were only able to use their resources (units) if they collaborated and managed to coordinate their actions with other team members. Indeed, coordination activities between teammates are critical in C^3Fire due to the interdependency of the units controlled by team members. The coordination metric is based on the assumption that a better coordination process will lead to less delays in performing the refill process. It was measured objectively by calculating the time each unit spent without a critical resource; that is, water or fuel. This coordination metric has been used before (Jobidon et al., 2013; Lafond, Jobidon, Aubé, & Tremblay, 2011); however, it has been modified to better reflect active and efficient coordination. Previous use of the metric did not take into account whether the participant had an empty unit that needed to be refilled but was not using it, leaving it behind, and using other units instead (i.e., ineffective coordination). Therefore, the formula was changed to refer to latency of coordination and to include how long a unit that needed to be refilled was left empty. For this measure, a score of 0 represents optimal coordination effectiveness, as a unit would never have an empty water or fuel tank during the period of interest. It was calculated as follows:

$$\frac{Total\,time\,spent\,without\,water\,or\ \ fuel}{Total\,number\,of\ \ refills}$$

Variability. We used variability indices to investigate whether self-organizing teams took advantage of the potential for role and resources flexibility provided by their team structure. Overall, three indices allowed assessing variability from different perspectives: across teams (i.e., the extent to which a team allocates roles differently from other teams), within teams (i.e., the extent to which role allocation within a team varies over time or across scenarios), and monopolization (i.e., the extent to which a type of unit is shared; i.e., used by different people or monopolized by a team member). As described earlier, in the functional team structure, roles were defined by which units were attributed to each team members. For example, the operations chief was attributed the FF and FB units since this person was responsible for the operations (i.e., extinguishing and controlling fires), while the resources management chief was attributed the WT and FT units to fulfill the responsibility of managing the resources (i.e., keep other units filled with water and fuel so they can function). Therefore, how a unit was used and by whom (i.e., how interdependencies in resources and activities are managed, see Crowston, 1997) is very telling of how roles and responsibilities were allocated in this team structure.

At the end of each scenario, it is possible to extract a C^3Fire log detailing every event that happened in the simulation. Therefore, information such as the number of times each unit was used and by whom was available in the C^3Fire log. To integrate the task of sending messages about the progression of tasks (associated with the role of planning chief in the functional structure but that also needed to be performed in the self-organizing condition) the number of sent messages and who sent them was computed from the information available in the C^3Fire log.

To investigate the hypothesis that self-organizing teams display more variability in their structure and allocation of roles than functional teams, the proportion of use of each type of unit was calculated by taking the number of times a type of unit was used by a participant over the total number of times this type of unit was used by the team. This calculation was done for each team for each scenario and was at the basis of the three variability indices. As mentioned above, sending messages (a key action of the planning chief role in functional teams) was considered as a type of unit: The number of messages sent and by whom (i.e., who adopted or was allocated that role) was computed and included in the calculation of variability. It was also possible to calculate a within (intra) role variability index from this behavioral indicator. The third index, the monopolization of units, refers to the degree to which a type of unit was monopolized by a team member during a scenario.

Results

Performance

The four scenarios were collapsed for the analyses. A *t* test for independent samples was computed to assess functional and self-organizing teams' performance, as measured by process gain, $t(46) = -4.09$, $p < .001$, $d = 1.18$. The results revealed that as expected, self-organizing teams ($M = 0.83$, $SD = 0.12$) performed significantly better than functional teams ($M = 0.64$, $SD = 0.19$), thus supporting our second hypothesis.

Coordination

The results demonstrated that coordination was better for self-organizing teams, $t(46) = 2.44$, $p = .02$, $d = 0.71$, than functional teams. Indeed, self-organizing teams had a shorter coordination latency ($M = 35.88$, $SD = 17.07$) while functional teams took longer on average to re-supply ($M = 50.39$, $SD = 23.55$).

Variability

Inter-team variability. To validate the assumption that self-organizing teams could exhibit more flexibility, and hence, more variability, than functional teams, inter-team variability was computed using the proportion of unit usage. This index indicates, for each team structure, the extent to which the distribution of units and roles varies across teams. As expected, the results showed that self-organizing teams varied significantly more in their organization of roles ($M = 0.39$, $SD = 0.04$) than functional teams ($M = 0.00$, $SD = 0.02$)[1], $t(150) = -66.94$, $p < .001$, $d = 12.21$.

Intra-team variability. Role variability was also analyzed more specifically within self-organizing teams, across experimental scenarios ($M = 0.059$, $SD = 0.028$). This metric was then correlated with metrics of performance and coordination to assess the extent to which variability affects team effectiveness. The results of Pearson's correlations demonstrated that although variability was not significantly correlated with the coordination measure, they indicated that greater variability was significantly associated with poorer performance, $r = -.511$, $p = .011$.

Monopolization of units. Analyses were also run to assess the within (intra) role variability for the self-organizing teams ($M = 0.060$, $SD = 0.037$) that was calculated by using the monopolization of units within teams index. This metric consisted in a within-scenario variability index, indicating the extent to which the units of a given type (e.g., FF) were monopolized by a team member or shared across team members during a scenario. The results show that in a given scenario, the greater sharing of a type of unit was negatively correlated with performance, $r = -.435$, $p = .034$, and positively correlated

Table 1. Means and Standard Deviations of the Two Self-Organizing Clusters of Teams and Functional Teams.

	Cluster 1 (n = 11)	Cluster 2 (n = 13)	Functional (n = 24)
	M ± *SD*	*M* ± *SD*	*M* ± *SD*
Intra-team variability	0.035 ± 0.014	0.080 ± 0.018	0.001 ± 0.005
Monopolization of units	0.035 ± 0.014	0.081 ± 0.029	0.002 ± 0.007
Performance	0.897 ± 0.064	0.771 ± 0.119	0.640 ± 0.195
Coordination	31.663 ± 16.419	46.627 ± 22.573	55.766 ± 23.294

with coordination latency, $r = .447$, $p = .029$. That is, teams in which a given type of unit was shared (and not monopolized) among team members performed significantly worse and coordinated less efficiently than teams in which participants monopolized the various types of units.

Cluster analysis. This analysis was used to partition data into meaningful groupings or clusters that exist in the data set (Fraley & Raftery, 1998). Cluster analysis was run on variability data from self-organizing teams to determine whether patterns emerge; that is, if some groups of teams behave similarly or differently from other groups of teams. The analysis revealed two separate clusters consisting of 11 (Cluster 1) and 13 self-organizing teams (Cluster 2), respectively (see Table 1 for means and standard deviations). The first cluster was characterized by significantly less variability, both intra-team, $t(22) = -6.78$, $p < .001$, $d = 2.89$, and with regard to the monopolization of units, $t(22) = -4.76$, $p < .001$, $d = 2.03$. Teams in this cluster demonstrated significantly better performance, $t(22) = 3.13$, $p = .005$, $d = 1.33$, and tended to have a shorter coordination latency, $t(22) = -1.83$, $p = .074$, $d = 0.78$, than teams in the second cluster (see Figure 4).

Discussion

The purpose of this study was to investigate, in the context of CM scenarios, the extent to which self-organizing teams display more flexibility in their roles than functional teams and whether that flexibility is associated with differences in coordination and performance. Variability within and across teams was assessed through the proportion of use of each type of unit. This metric was selected as a behavioral indicator of roles in C^3Fire, as the various units are closely related to the tasks needed to be accomplished during mission

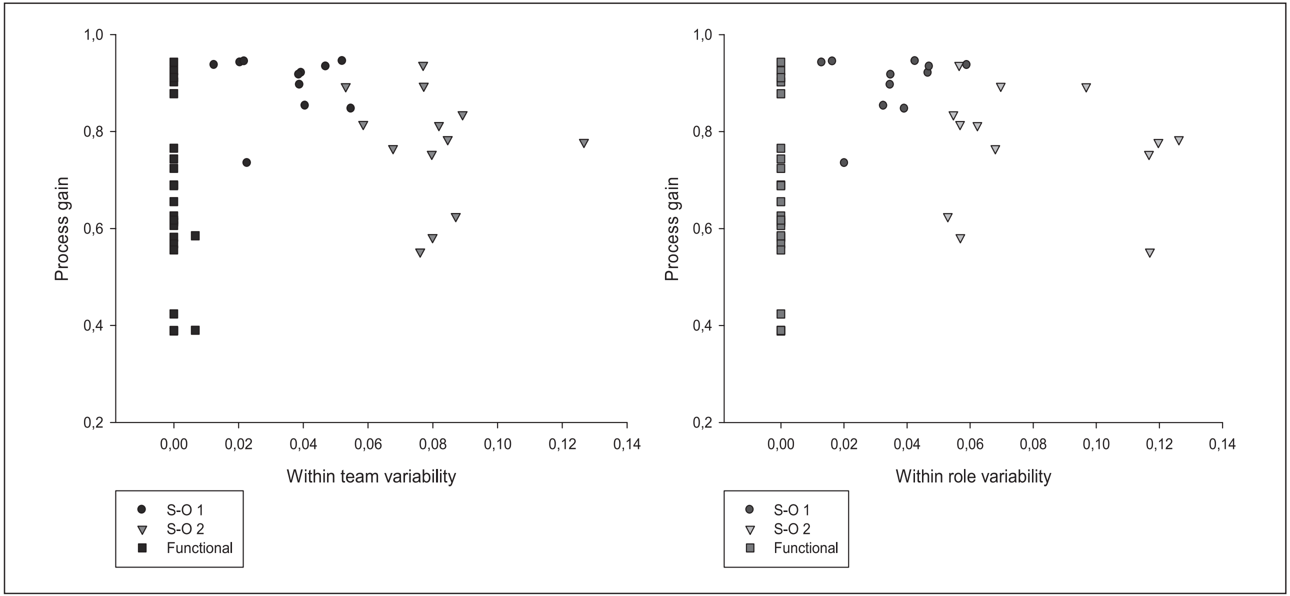

Figure 4. Performance of the two clusters of self-organizing teams (S-O 1, S-O 2) and of the functional teams as a function of variability.

scenarios (e.g., operations, resources management, search, and rescue). Hypothesis 2 was confirmed as the findings reveal an advantage for self-organizing teams; that is, they performed better than functional teams, and they also coordinated better overall, as indicated by shorter coordination latency.

Analyses of role variability yielded two main findings. First, as expected, inter-team variability was greater in self-organizing teams than in functional teams, which suggests that various self-organizing teams took advantage of the flexibility afforded to them and allocated roles differently from each other, and from functional teams. This confirms Hypothesis 1 and echoes the findings of M. Duncan and Jobidon (2008) in the context of an intelligence analysis task. Second, within self-organizing teams, a greater variability in role allocation across scenarios (i.e., over time) was associated with poorer performance. Similarly, a greater sharing of units among team members within a scenario was associated with poorer performance and coordination. These results contradict Hypotheses 3 and 4, respectively. An alternative, and potentially complementary, explanation is that poorly performing self-organizing teams may have opted to adjust their behaviors and roles, thus displaying greater variability, in an attempt to improve their performance. This would require them being aware of their less-than-optimal performance and would reflect two types of teamwork behaviors described by Rousseau et al. (2006) in their model, namely, work assessment behaviors (i.e., performance monitoring) and team adjustment behaviors, where adjustments are made in response to the monitoring and assessment of the team and its environment throughout the task.

Overall, these findings suggest that a certain degree of variability and self-organization is valuable, but only to a certain extent, as too much variability appears to be detrimental to team functioning and team effectiveness. Results from the cluster analysis support this assertion. Indeed, the cluster regrouping the least variable, or more stable, self-organizing teams is characterized by significantly better performance and shorter coordination latency than the more variable cluster. This is in line with the assumption that flexibility in role and organizational structure can be beneficial in complex and dynamic environments such as CM (Alberts & Nissen, 2009; Bigley & Roberts, 2001; Tu et al., 2009), but that too much variability can lead to role ambiguity and negatively impact a team's ability to successfully achieve its goal (Klein et al., 2009; Thunholm et al., 2009). The poorer performance and coordination observed with more variable teams in the present study gives credence to this notion. Stachowski, Kaplan, and Waller (2009) came to a similar conclusion in an exploratory study investigating the response of nuclear power plant crews to simulated crisis situations. They observed that better performing teams were less rigid while also exhibiting less complex interaction patterns (e.g., coordination actions) than less effective teams. Therefore, as argued by Salas et al. (2009) in their review of teamwork competencies, clear but flexible roles represent one of the key mechanisms contributing to high-performing teams. The concept of self-organizing teams has been increasingly popular in the last 15 or so years. Many authors and practitioners have promoted the flexibility associated with this structure as a contribution to better efficiency and productivity and have encouraged organizations to adopt overall flatter and, theoretically, more adaptable work structures. However, from a practical perspective, the findings indicate that a controlled level of flexibility is more beneficial in certain types of situations, and provide insight into what conditions might benefit or not from flexibility. While self-organizing teams can be thriving in organizations such as Google, the characteristics associated with CM environments (e.g., complexity, uncertainty, and time pressure) seem to require a controlled flexibility. Therefore, a nuanced perspective should be adopted. In addition to selecting an appropriate team structure or allowing a level of flexibility based on the situation, training could also be adapted to prepare team members for the context (e.g., in terms of role flexibility) in which they will have to work.

While we recognize the limits associated with having a sample of participants comprised of students, the control available in laboratory experiments enables researchers to maximize experimental realism, especially when using a functional simulation. Being a functional simulation emulating key elements, C^3Fire does not require technical expertise to operate the system, allowing researchers to obtain larger samples that are typically necessary for hypothesis testing (Tremblay et al., 2010). This study is based on functional behaviors; therefore, having a sample comprised of students still allows for some generalization of the results. Novices can become "experts" in a relatively short span of time when playing C^3Fire. Although the task is a simplified simulation of real forest fires, the participants use their epistemic competence to solve it (Johansson, Persson, Granlund, & Mattsson, 2003). In addition, students can often verbalize and provide more information that is independent of expertise level than professionals, who have usually received prior training and can present potential biases related to their training or experience. It is one step in the process of empirically investigating the impact of flexibility of team structures and should be explored further with professionals in future research.

One limitation of the present work is that C^3Fire remains a simplification of real CM situations, and one should remember that computerized tasking is an initial step in the study of team structure. These findings should be reproduced in field studies and with more realistic tasks. The potential advantages of a more flexible team organization could then be confirmed and further understood. However, field studies are costly; they require a lot more resources, and CM is restricted by methodological barriers because of its great complexity. In functional simulation studies, this complexity is provided in a controlled and tractable manner (Johansson et al., 2003). The C^{3}Fire simulation can be useful for training and experimentation, such as the study of distributed decision making, situation awareness, and cognitive processes linked to team cognition (e.g., coordination, communication).

A line of further theoretical and empirical inquiry would be to determine what such flexibility, as a positive characteristic of team functioning, means; that is, within what boundaries and under which circumstances is flexibility and variability a positive tool and attribute of teams operating in complex and dynamic environments such as CM? Flexibility and adaptability can take different forms, from complete role re-allocation to more specific, as-needed, modifications such as online task balancing or back-up behaviors (Jobidon, Tremblay, Lafond, & Breton, 2006; Porter et al., 2003). These functions fall under what Rousseau et al. (2006) label *team adjustment behaviors*, and can be enabled by team members' knowledge of each other's roles. Indeed, while CM teams are usually created ad hoc, mechanisms like cross-training (Marks, Sabella, Burke, & Zaccaro, 2002; McCann, Baranski, Thompson, & Pigeau, 2000) and emergency protocols (Bigley & Roberts, 2001; Office of Emergency Services, 2012) can contribute to provide shared foundation knowledge of the various roles involved, even if the individuals have not worked together before.

Teams composed of team members that have been cross-trained together (Entin & Serfaty, 1999) and worked together for some time (Cooke, Gorman, Duran, & Taylor, 2007) show a better performance and more similar shared mental models than ad hoc teams. However, teams who participated in the present study only worked together for a few hours. It would be interesting to try and replicate these findings with real-life teams that have been working together for months or years and whose members would likely know each other's strengths and weaknesses. That knowledge might be associated with even better team functioning under conditions of flexibility and variability. However, as mentioned above, it is likely that teams put together to deal with a crisis will often include members that do not know each other personally, but that have a knowledge of the types of roles performed by the team (e.g., planning, search, and rescue). This type of situation corresponds to that examined in the present study.

Conclusion

Teams and organizations must be able to adapt to a wide range of circumstances in dealing with situations characterized notably by high risk, time pressure, and uncertainty. The present study contributes to better understanding the benefits and constraints of self-organizing teams and team effectiveness in complex and dynamic situations such as CM. We showed that self-organizing teams tend to take advantage of the flexibility they are allowed in role allocation and that a certain degree of variability can benefit teams working in such environments. Overall, when compared with the functional team structure, self-organizing teams achieved higher performance and better coordination. However, it appears that too much variability within teams can lead to role ambiguity and negatively impact performance and coordination. Indeed, too much variability in roles can be detrimental to team efficiency. Considering the challenges and the stakes of crisis situations, it is paramount to further our knowledge that will help find the optimal balance of role clarity and flexibility to bolster team effectiveness in various situations.

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Note

1. Although one would expect variability in functional teams to be nil, the .004 value results from the fact that in some scenarios, certain units were not used at all. For instance, it happened that an operations chief used only three of the four FF units available, hence, creating a value of 0 for the use of this unit for this particular scenario rather than a value of 1 as expected. It is these few exceptions that lead to the small variability observed with functional teams.

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