Author: Haar, Selma van der
Title: Getting on the same page : team learning and team cognition in emergency management command-and-control teams
Issue Date: 2014-02-12

CHAPTER 6

Evolving team cognition: the impact of team situation models on team effectiveness[9]

Abstract

In a study of 32 real-life on-scene-command teams, we investigated how the early development of team situation models (TSM, i.e. a shared understanding in teams of which actions to take) influences final team effectiveness. We used both an inter-team longitudinal approach that examines TSM development at the sample level and an intra-team longitudinal approach that examines TSM development at the level of individual teams. We found that overall TSM change at the early stage of team functioning is positively related to team effectiveness at the end measured by quality of actions and goal achievement. Teams with increasing TSM similarity patterns tend to deliver higher team effectiveness than teams with stable TSM patterns but not than teams with decreasing TSM patterns. We discussed the theoretical and methodological contribution of the paper to team cognition research and the practical implications to real-life command-and-control teams.

This chapter is based on: Van der Haar, S., Li, J., Segers, M., Jehn, K.A., & Van den Bossche, P. Evolving team cognition: the impact of team situation models on team effectiveness. *Revised and resubmitted for publication in the European Journal for Work and Organizational Psychology.*

Well begun is half done. --- English proverb.

Team cognition refers to the manner in which knowledge important to team functioning is mentally organized, represented, and distributed in a team (Kozlowski & Ilgen, 2006). Emerging through the interplay between the individual cognition of each team member and team process behaviors (Cooke, Salas, Kiekel, & Bell, 2004), team cognition allows team members to anticipate and execute actions and hence exercises influence on team effectiveness (Cannon-Bowers, & Salas, 2001; DeChurch & Mesmer-Magnus, 2010; Kozlowski & Ilgen, 2006; Salas & Fiore, 2004).

A pivotal recent development in team cognition research is a shifting focus to the temporal dynamic nature of team cognition. Not only has team cognition been identified as an emergent state varying as a function of team context, inputs, processes, and outcomes over time (Kozlowski & Ilgen, 2006; Marks, Mathieu, & Zaccaro, 2001; Mohammed, Ferzandi, & Hamilton, 2010), but new team cognition concepts have also been introduced to address the temporal dynamic nature and to distinguish from established concepts. A notable example is team situation models (TSMs) that refers to "mental representations associated with a dynamic understanding of the current situation (i.e. environment, task, team) that is developed by team members moment by moment" (Rico, Sánchez-Manzanares, Gil, & Gibson, 2008, p.167). TSMs differ from more established team cognition concepts such as shared or team mental models that refer to collectively owned long-term knowledge structures that team members have developed during earlier team training, team experiences and team discussions (Mohammed, et al., 2010). TSMs contain short term-knowledge at one point of time. In empirical research, however, largely lacking is the evidence of how the dynamic TSM develops over time and, more importantly, how TSM development affects team effectiveness (DeChurch & Mesmer-Magnus, 2010; Mohammed et al., 2010).

Drawing upon the team cognition literature and team development literature, we aim to gain a deeper understanding of the influence of changing TSMs on team effectiveness. We build upon Marks and colleagues' (2001) team development model that suggests that most types of work teams (e.g. project teams and action/performing teams) alternate between transition and action phases over time. In transition phases, teams evaluate and/or plan activities to guide their accomplishment of a team goal or objective; in action phases, teams are engaged in acts that contribute directly to goal accomplishment. As a team goes through different transition and action phases, the TSM is changing accordingly. As a team goes through different transition and action phases, the TSM is likely to change accordingly. In other words, the level of similarity among individual team members' situation models is likely to change across team development phases. An increasing TSM means that team members gain more similarity in their situation models over time; a stable TSM indicates no change in the level of similarity; a decreasing TSM indicates less similarity in individual team members' situation models over time.

In this study, we focus on TSM development at the early stage of team functioning in a naturalistic setting. At this stage in which all different sorts of information emerge, team activities are highly dynamic. Team members need to quickly learn about their environment, tasks, and other members and they establish task procedures and social norms. The interaction patterns that a team working under such circumstances establishes in its early existence are related to eventual team effectiveness (Zijlstra, Waller, & Phillips, 2012). These patterns tend to be persistent (Feldman, 1984; Ginnett, 1987) and play a role in developing and building the trust that supports exchanging and sharing information (Uitdewilligen, Waller, & Zijlstra, 2010). Therefore, we expect that TSM development at the early stage plays a critical role in shaping TSMs and team members' interactions at the later stages and eventually affects team effectiveness. TSM development is likely to be path dependent (Cronin, Weingart, & Todorova, 2011) which means that a team's TSM at a particular time moment influences its TSM at a later moment and is influenced by its TSM of a previous moment.

We use both an inter-team and an intra-team longitudinal approach (c.f. Li & Roe, 2012) in the data analysis. The inter-team approach follows a sample-to-cases order of inference that first examines sample-level changes over time and then infers individual teams' changes over time from the sample-level estimations. It generates conclusions applicable at the sample level but might ignore important findings of individual teams' changes. The intra-team approach complements the inter-team approach and follows a reverse cases-to-sample order of inference. In this approach, individual teams' change patterns are first identified as increasing, stable, or decreasing over time. Then this categorical variable is entered into multivariate analyses to examine the effects of individual teams' change patterns. The intra-team approach generates conclusions applicable to teams with qualitatively different TSM change patterns. By simultaneously applying both approaches, we are able to gain novel insights and comprehensive knowledge pertaining to the impact of early TSM development on team effectiveness.

1. Team situation models

A TSM is a shared understanding and dynamic mental representation of a team pertaining to a current team functioning situation, including its environment and task, and the team itself (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Rico, et al., 2008). As a team cognitive structure, a TSM indicates to what extent the individual team members' situation models are similar (Cooke, Gorman, Duran, & Taylor, 2007; Mathieu, Maynard, Rapp, & Gilson, 2008; Rentsch, Small, & Hanges, 2008). This level of similarity is a team property. It relates to team cognition structures, such as team (or shared) mental models and shared situation awareness (Cooke, Stout, & Salas, 2001). Team mental models (TMMs) contain collectively owned long-term knowledge which team members have developed prior to the current team cooperation and bring to the new situation (Mohammed, et al., 2010). During task execution, team members assess the situation and develop a certain situation awareness which Endsley (1995, p. 36) defines as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". While sharing their individual situation assessments, they may develop shared situation awareness (Cooke, Stout, & Salas, 1997; Cooke, et al., 2001). The content of both the team mental models and the shared situation awareness add to a dynamic and continuously changing shared understanding of the momentary situation which is reflected in the TSM (Cooke, et al., 1997, 2001). While team mental models and other team cognition concepts contain a rather stable notion of teams’ cognitive structures over time (Rico, et al., 2008), the TSM contains dynamic and fleeting shared knowledge (Cooke, et al., 2004) and acknowledges the temporal dynamic nature of teams’ cognitive structures over time.

Therefore, the TSM is labeled as an emergent team state (Decuyper, Dochy, Van den Bossche, 2010; DeChurch & Mesmer-Magnus, 2010; Cooke, et al., 2007) which comes into existence through interactions between team members (Cooke, Kiekel, & Helm, 2001; Cooke, et al., 2004; Cronin, et al., 2011; Holland, 1998; Marks, et al., 2001; Morgeson & Hofmann, 1999). Cronin and colleagues (2011) note that the development of an emergent state is path dependent—what happens in a team now can determine what happens next. As for TSMs, team members’ shared understanding and mental representation of a current situation is influenced by how team members understand the previous situations. In other words, a TSM is a path-dependent and bottom-up emergent state (DeChurch & Mesmer-Magnus, 2010; Kozlowski & Klein, 2000).

At the empirical level, it has been found that team members’ similar cognitive structures, including their similar situation models, are beneficial to team effectiveness (e.g. DeChurch & Mesmer-Magnus, 2010; Lim & Klein, 2006; Mohammed, et al., 2010; Van den Bossche, Gijselaers, Segers, & Kirschner, 2006). However, most extant studies on TSMs examined it as a static phenomenon. Three studies are exceptions but yield mixed findings. On the one hand, Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) and Cooke, Kiekel, Salas, and Stout (2003) found that team taskwork knowledge does not differ over time. On the other hand, He, Butler, and King (2007) found that the emergence of teams’ shared task understanding over time is influenced by pre-existing team characteristics such as gender diversity and initial member familiarity, and by intra-project team interactions. Whereas these studies focus on TSM development and its antecedents and were conducted with student teams in laboratory experiments, our study focuses on the consequences of TSM development on the effectiveness of real-life work teams.

2. Team development over time

Team functioning and team members' interactions are intrinsically dynamic over time (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Kozlowski & Klein, 2000; Marks, Zaccaro, & Mathieu, 2000), particularly for teams that operate in a turbulent environment and under considerable time pressure, such as action teams and project teams. Moreover, the team development literature suggests that the early stage of team functioning is highly dynamic and contains constant changes. Arrow, Poole, Henry, Wheelan, and Moreland (2004) summarize five team development models, including sequential state models (e.g. Tuckman, 1965), repeating cycle models (e.g. Marks, et al., 2001), robust equilibrium models (Arrow, 1997), punctuated equilibrium models (e.g. Gersick, 1988, 1989, 1991), and adaptive response models (Arrow, 1997), all of which share this common feature. In particular, the repeating cycle models, punctuated equilibrium models, and robust equilibrium models explicitly address that *at the early stage*, members of a team are preoccupied with various activities that help them to form the team and start to operate soon. Team members need to quickly understand the team's mission, goals, tasks, resources, and operational environment. They also need to get acquainted with each other and establish task procedures for future taskwork and team norms for future teamwork. Consequently, team emergent states, such as TSMs, will change from moment to moment as team members keep learning about their tasks and about each other. After this stage, a team enters a rather stable plateau of task performance until this state is interrupted by internal or external forces.

Former empirical studies confirm the crucial influence of the early stage of team functioning on team effectiveness. For example, Ericksen and Dyer (2004) found that project teams' early mobilization strategies and launch meetings at the beginning of projects have substantial influence on team processes and team effectiveness at the end. Also Woolley (2009) evidenced in a study of knowledge work teams that early events in a team's life cycle are influential to its later development. Zijlstra and colleagues (2012) found that the interaction patterns that a team establishes in its early existence are related to eventual team effectiveness.

In the same vein, we expect that TSM development at this crucial early stage of team functioning, which is fostered by the content of both the team mental models and the shared situation awareness (Cooke, et al., 1997; Cooke, et al., 2001), will positively influence the eventual team effectiveness. The TSM results from interactions between team members (Cooke, et al., 2001; Cooke, et al., 2004; Cronin, et al., 2011; Holland, 1998; Marks, et al., 2001; Morgeson & Hofmann, 1999) and the team interaction pattern is often determined in the early stage of team functioning (Zijlstra, et al., 2012). This makes a TSM develop in a path dependent way over time (Cronin, et al., 2011). Therefore an initially convergent trend of individual team members' situation models (i.e. an increasingly similar TSM) is likely to continue to develop as such to the later stages. This would mean that a high level of similarity emerges which positively influences team effectiveness according to former research (e.g. DeChurch & Mesmer-Magnus, 2010; Lim & Klein, 2006; Mohammed, et al., 2010; Van den Bossche, et al., 2006). Hence

Hypothesis 1: TSM similarity development at the early stage of team functioning has a positive effect on team effectiveness. *(inter team approach)*

On the contrary, when a team's TSM similarity decreases at the beginning, it indicates that the team members are not fully capable of getting on the same page right away. As change in teams is usually path-dependent (Cronin, et al., 2011), an increasingly dissimilar TSM pattern at the starting point might become even more dissimilar in the next phase and create difficult in communication and cooperation in the team. In other words, it takes more effort for this team to get on the same page in the second phase than a team that starts with an increasingly similar TSM pattern. Therefore we assume that a decreasing TSM has a negative effect on the team effectiveness. Hence

Hypothesis 2: Teams with increasing TSM similarity patterns at the early stage of team functioning outperform those with decreasing TSM similarity patterns. (intra team approach)

We contrast the teams with a changing TSM, increasing or decreasing, with teams in which the level of sharedness of the members' situation models does not change at all. We follow the suggestion of Roe, Gockel, and Meyer (2012) that "stability is a special case of change [in temporal research]" (p. 644). As for the TSM development, a stable TSM pattern implies a lack of change in the sharedness of team members' individual situation models. In other words, team members might not timely and adequately process and exchange information in accordance to a team's ever-changing task situations. This lack of learning or knowledge adaptation can be detrimental to team effectiveness in a dynamic task situation, particularly in comparison with an increasingly similar TSM. Hence

Hypothesis 3: Teams with increasing TSM similarity patterns at the early stage of team functioning outperform those with stable TSM similarity patterns. (intra team approach)

3. Context: Command-and-control teams

We expect that TSM development at the early stage of team functioning is especially relevant for the effectiveness of teams that operate in dynamic and uncertain environments and perform complex and interdependent tasks. Especially when these are temporary swift-starting teams (i.e. "ad hoc teams formed teams for immediate task performance, with highly trained members who have generally not previously worked together as a team", Zijlstra, et al., 2012, p. 1). Therefore we investigated our hypotheses in command-and-control teams. Command-and-control teams consist of individuals who have high levels of skills and abilities, are specialized in their respective duties, and come together for a short period of time to work interdependently towards a common valued goal (Salas, Burke, & Samman, 2001). Used mostly in military and civil emergency situations and occasionally in non-emergency events such as major conferences, command-and-control teams function over time in a manner of repeating cycles of action and transition phases (Marks, et al., 2001). Members of a team act at the scene (i.e. action phases) and interact with each other during team meetings (i.e. transition phases).

There is no universal early stage of a team (Morgan, Salas, & Glickman, 1993) in terms of time. Each team type and accompanying team task determines what can be best approached as the first stage in team development (Morgan, et al., 1993). In swift-starting command-and-control teams operating in a dynamic environment we consider the first two cycles of action and transition phases to be the early stage of team development since it is in this phase that the team forms, explores the team and the situation, takes the first decision, monitors the initial performance at the scene including the consequences of initial decisions, and evaluates and redirects this first performance in meeting 2 (Morgan, et al. 1993).

In this study, we investigated one type of command-and-control team: the on-scene-command team (OSCT). This team coordinates the interdisciplinary aid efforts of the fire department, the police, and disaster medicine in case of natural or manmade emergencies, such as floods, fire breakouts, or car accidents. Consisting of representative officers from the different aid units, an OSCT is aimed to prevent (further) death and damage on the scene of emergent incidents through coordinated and safe interdisciplinary efforts. The assistance at the scene is executed by units of the fire department, the police, and disaster medicine and not by the OSCT. Together these units and the OSCT thus function as a multi team system ("two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals" (Marks, et al., 2001, p. 290) in which the teams are interdependent (Marks, DeChurch, Mathieu, Panzer, Alonso, 2005). This implies that teams gain new information from other teams during action phases (Healey, Hodgkinson, & Teo, 2009). In this study we investigate the TSM of the OSCT, the team that coordinates the cooperation in this multi team system, and not of the different disciplines acting at the scene.

During the first action phase at the onset of an emergent incident, aid units and their on-duty officers are called out to respond to and manage the incident. The OSCT-officers receive initial information about the incident from the emergency control center on the way to the scene. At arrival on the scene, the officers consult members of the own units who have already started the assistance process, and have bilateral information exchanges with officers from other units. After this first action phase, the officers organize their first short OSCT-meeting on the scene in which they succinctly share information, assess the current situation, and plan and decide upon actions in the next phase (Salas, et al., 2001). This is the first transition phase. After the meeting, the officers go back to their own units and coordinate tasks within the units according to what have been agreed and decided upon in the OSCT meeting (action phase two). In the second meeting they follow the same procedure as in the first, yet, they will often have more information and emerging issues that need a multidisciplinary approach. By the end of the first two cycles, a command-and-control team has formed an initial impression of the incident and a rough plan for the upcoming actions. Generally, command-and-control teams meet three to five times on average during emergency incidents and hence will go through three to five cycles of action-transition phases.

4. Method

4.1 Setting and sample

Since incidents fortunately are rare and OSCT members need to be prepared, they are obliged to take part in regular emergency management exercises designed to simulate real-life emergencies. During such exercises which were developed and organized in a cooperation between the fire department, the police, and disaster management, we collected data. Our study included thirty-two actual OSCTs (152 individuals) that participated in a regular exercise with one out of nine different scenarios, organized in five of the 25 different safety regions in the Netherlands. Participants were employees in the fire department, police, disaster medicine, and possible other organizations that were responsible for managing emergencies. Each team had three to seven members with an average team size of five persons. The mean age of the 152 participants was 45 years old (*SD* = 7.8); 63% of them held a bachelor or higher degree. Twenty percent of the participants were women. The average experience of working in real-life emergencies was 13 times (*SD* = 19.04), and of being in emergency management exercises was 17 times (*SD* = 16.21). In the first meeting, the team members allocated one of them to be the informal leader to chair the meeting. In twenty teams the scenario of the exercise included that this informal leader was replaced by a formal team leader with a higher rank from the second meeting.

4.2 Procedure

All exercises were instructed and constructed in a similar way by the local trainers (see Appendix A for a description). Each team participated in one of the exercises which were as realistic as possible. First, the exercise included at least two cycles of action and transition phases. Second, team members were not informed of team composition or the emergent incident before the start. Third, the time frame was similar to the real-life situation. Fourth, the incident scene was projected in virtual reality and could thus be explored by each team member individually (with a joy stick). Fifth, team members could communicate with each other either face-to-face or with a walkie-talkie outside the virtual world. Sixth, during the exercise, the team members received additional standardized information based on a script about the development of the incident and about the consequences to their actions. This information was provided by response trainers that simulated to be a member of one of the assistance units (e.g. the nurse of the first ambulance or the commander of the fire department unit that had arrived first at the scene) or the dispatcher of the central emergency control room.. These response trainers were provided with the scripts and the time schedule for when to give what kind of information (e.g. “the number of victims is unclear”, “it is possible that there are chemicals in the burning building”, “there is a traffic jam in the city center”).

During the exercises, we froze the task for about a minute (Cooke, et al., 2001) immediately after each team meeting to collect data concerning the team situation model of the OSCT. Every individual could get back to work immediately after finishing the questionnaire. As we were interested in understanding the impact of TSM development at the early stage of team functioning, we focused on the TSM developed in the first two team meetings (i.e. Meeting 1 and Meeting 2). Since the representatives of the fire department, police, and medical assistant unit were present at both meetings, we investigated the change of their TSM and excluded the TSM of team members that were only present from the second meeting. After finishing the exercise, we measured team effectiveness. Nineteen teams had three team meetings and thus four measurement moments and 13 teams had two meetings and thus three measurement moments.

4.3 Measures

Team situation models (TSMs). We used team member similarity ratings of predefined categories of emergency management processes (e.g. rescue and technical support, traffic control, medical assistance; see Appendix A) by the Dutch government (Geveke, Huizing, Stijger, Sybrandi, & Temme, 2008) for the measure of the TSM (DeChurch & Mesmer-Magnus, 2010). This is a dynamic and context-driven key area of the team’s work (Rico, et al., 2008). These processes can be approached as a category of main activities that could be executed by the fire department, the police, or the medical assistant unit. The OSCT members were familiar with these processes since these are commonly used in reality and training situations. Their function is that all members know which assistance unit has what responsibilities in general and, accordingly, which discipline has what expertise and needs what information.

We asked each individual team member to indicate from a checklist of at least 15 choices[10] what emergency management processes were needed at the scene at that particular time moment. This measure tapped the individual situation model of each member containing the processes that were and would be going on at the scene. These models were a result of collective situation assessment and decision making about actions during the meetings. The task-specific and task-embedded measure was short enough to minimize fatigue or boredom effects and to prevent disturbing the flow of the highly dynamic emergency management task (Cooke, et al., 2004, Mohammed et al., 2010).

Our measure is an approximate team cognition measure since we measure individual cognition which we "scale up" to team cognition (Cooke, et al., 2007). In this approach, a team is seen as a group of individuals and their individual responses are compared to get an overview of what information or ideas are shared among them and which not (Cooke, et al., 2007). We aggregated the individual data (situation models) by determining the level of dispersion (Cooke, et al., 2004). To this end, we investigated to what extent members of a team marked the same emergency management processes as relevant. To calculate the similarity scores, we first transformed individual team members' selected processes into a dichotomous matrix (1 indicated "given priority", and 0 indicated "not given priority"). Since the set of emergency management processes in the mind of each individual can be qualitatively distinct the type of diversity is variety (Harrison & Klein, 2007). In the second step we therefore used the Blau's Index to calculate the diversity scores per process at the team level as this is the most commonly employed measure for diversity-as-variety (Harrison, & Klein, 2007). We reversed the results to gain similarity scores. Third, we summed the similarity scores of all processes per team and transformed these scores into percentages of the possible maximum similarity score (a score of 100% indicated that all team members indicated the exact same processes having priority on the scene at a particular moment). Our TSM measure thus indicates to what extent the members of a team had a TSM reflecting the processes they thought had priority and they expected to be executed on the scene in the action phase following the team meeting.

Team effectiveness. In this field study, team effectiveness was externally rated by the response trainers that each represented a different role during a particular exercise, for instance fire brigade commander, or first ambulance nurse. Hence, each rater observed team effectiveness from a different perspective. Teams were scored by different sets of raters so we did not have a crossed design. The raters were expected to have a professional opinion about emergency management due to at least one year of experience in emergency management as team members, team leaders, or trainers of OSCTs (tenure ranged from 1 – 34 years, M = 13.96, SD = 10.76). Moreover, they knew

[10] Whether a team receives a checklist of 15, 16, or 17 choices depends on its safety region. We present the checklist and measures of the other variables in Appendix A.

the script of the scenario before the exercise. Nine teams were judged by one rater. These raters varied in tenure from 6 to 33 years and thus were expected to have enough experience to have a professional and reliable opinion about the team effectiveness. They vary in education level (56% academic and higher professional education), gender (7% women), age (range 31 – 58, *M* = 46,72, *SD* = 7.90), and organization (40% fire department, 24% medical assistance unit, 14% police, 14% government, 4% safety region, 4% other e.g. consultancy).

Team effectiveness was measured by a validated effectiveness scale customized to OSCTs (Van der Haar, Segers, & Jehn, 2013). This seven-point Likert scale included thirteen items such as “The actions on the scene are adequate” and “The crisis is controlled” and contained three dimensions (see Appendix A), that is, quality of actions ($M = 5.71$, $SD = .75$, $\alpha = .93$), goal achievement ($M = 5.39$, $SD = .85$, $\alpha = .93$), and error rate ($M = 5.13$, $SD = .84$, $\alpha = .75$). Each team had one to five different raters ($M = 2.5$). Nine teams had one rater. We aggregated the individual judges’ ratings into team scores if there was more than one rater. This decision was supported by sufficient *Rwg* scores (Table 1) which indicated high inter-rater agreement (James, Demaree, & Wolf, 1984, 1993), and high ICC(1) values for unequal group sizes (Bliese & Halverson, 1998) which are interpreted as large effect sizes (LeBreton & Senter, 2005). The ICC(2) values tended to be moderate (LeBreton & Senter, 2005) which may be caused by the intentionally different rater perspectives, a tendency to high scores, and therefore a restriction of range, and the fact that raters were not trained (Hallgren, 2012).

Table 1. Mean within group agreement (rWG(j)) and Intraclass correlation coefficients ICC(1) and ICC(2) for the team effectiveness dimensions

Team effectiveness dimensions	rWG(j)	ICC(1)	ICC(2)	F	P
Quality of actions	.94	.29	.51	2.030	.013
Goal achievement	.88	.36	.59	2.415	.003
Error rate	.79	.24	.44	1.779	.035

Note. rWG(j) is calculated with the multi-item formula of James, Demaree, and Wolf (1984, 1993)

4.4 Control variables

In the sample, teams differed in several features that might potentially affect team effectiveness, including team size, presence of a team leader, and number of team meetings. We then added these three variables as control variables in the main analyses. In addition, teams differed in the exercise that they participated in which might have led to differential effectiveness levels across teams. Therefore, we measured team members’ perceived levels of stress, responsibility, and risk of their exercises on a context-specific 10-item seven-point Likert scale that we developed in communication with field practitioners (see Appendix A). Participants were asked to what extent they agreed with such statements as “I experienced as much stress as I would have if the incident was real" and "The responsibility I had in this exercise was realistic" ranging from 1 ("strongly disagree") to 7 ("strongly agree"). The *F*-scores (stress: $F = 1.271$, $p = .182$; responsibility: $F = 1.468$, $p = .076$; risk: $F = .854$, $p = .686$) revealed that teams participating in different exercises did not differ significantly in each of the three variables. Therefore, we concluded that there are no differential effectiveness levels across teams participating in the nine different exercises.

5. Analyses

We analyzed the impact of early TSM development on team effectiveness using an inter-team longitudinal approach and an intra-team longitudinal approach (c.f. Li & Roe, 2012). The inter-team approach assumes that individual teams' change patterns are either identical to or randomly variant from the change pattern of the sample mean (e.g. as in repeated-measures MANOVA, random coefficient models) and primarily concerns sample-level change. It first identifies the sample-level change pattern, then infers individual teams' change patterns, and lastly estimates the relationship of change with its predictors and consequences. In other words, the inter-team approach follows a sample-to-cases order of examination of "change over time".

In contrast, the intra-team approach assumes that individual teams' change patterns exist its own right (i.e. one pattern neither depends on nor is associated with any other patterns) and therefore can qualitatively differ from each other. With this assumption, the intra-team approach first identifies individual teams' change patterns according to one change characteristic (c.f. Li & Roe, 2012), then categorizes teams based on the similarity and dissimilarity of their change patterns, and finally examines whether and how teams with different change patterns show systematic differences in the level of a predictor or a consequence. The intra-team approach follows a cases-to-sample order of examination of "change over time".

As Li and Roe (2012) argue, these two longitudinal approaches have their own merits and weaknesses, address different theoretical questions, and together provide complementary and comprehensive knowledge of temporal changes. Whereas the inter-team approach draws conclusions regarding aggregated change at the sample level, the intra-team approach can reveal evidence that would otherwise be disguised in the inter-team approach and generate conclusions more applicable to changes in individual teams.

In the inter-team approach, we first computed a variable of change ratio to measure the relative change in a team's TSM level between the end of Meeting 1 and the end of Meeting 2. The variable was calculated as the difference in the TSM level between the two moments divided by the TSM level in Meeting 1. It indicates *to what percent* a team's TSM level had changed relative to the initial TSM level in Meeting 1. The standard deviation of the TSM is .08 in Meeting 1 and .11 in Meeting 2, suggesting rather stable variances in the sample for the unidimensional TSM construct. The average TSM change ratio is -0.0287 indicating a -2.87% change on average in the TSM level between the end of the two meetings. We then performed a hierarchical regression to examine the effect of the TSM change ratio on team effectiveness, controlling for presence of a team leader, team size, and number of meetings.

In the intra-team approach, we first computed a categorical variable to indicate whether a team's TSM development or change between the end of Meeting 1 and Meeting 2 was an increasing (coded as 1), a stable (coded as 0), or a decreasing pattern (coded as -1). If a team's TSM level is higher at the end of Meeting 2 than at the end of Meeting 1, it indicates that the team's TSM has become more similar between the two time moments and is coded as an increasing pattern. If a team's TSM level remains the same at the end of both meetings, it shows a stable TSM pattern over time. If a team's TSM level is lower at the end of Meeting 2 than at the end of Meeting 1, it indicates that the team's TSM has become more dissimilar over time and is coded as a decreasing pattern. Among the 32 teams, eleven teams demonstrated an increasing TSM pattern, four teams a stable pattern, and 17 teams a decreasing pattern. As the number of teams across the three categories is uneven, Levene's test was first performed for each dependent variable. The tests showed non-significant results (quality of actions F (1,29) = .262, p = .634; goal achievement: F (2,29) = .844, p = .440) which means that there is no difference between the variances of the teams with an increasing, a stable or a decreasing TSM pattern. We then performed an ANOVA with the categorical variable as the independent variable and team size, presence of a team leader, and number of team meetings as the control variables for team effectiveness. This procedure examines how teams with differential TSM development patterns between the ends of the two team meetings differ in team effectiveness.

6. Results

In Table 2, we present the descriptive statistics and correlations of the included variables. The team situation model (TSM) developed in meeting 1 (M1) correlates with team quality of actions (r = .36, p = .04).

Results from the hierarchical regressions (i.e. the inter-team approach, see Table 3) show a significant positive effect of early TSM development on quality of actions (B= 2.81, p= .004) and on goal achievement (B= 2.27, p= .044). This supports Hypothesis 1. A one-percent increase of the TSM from the end of Meeting 1 to the end of Meeting 2 can result in a 2.81 points higher quality of actions and a 2.27 points higher goal achievement on a 1-to-7 scale. Overall, the model explains 35% of the variances in quality of actions (R^2=.35) and 38% of the variances in goal achievement (R^2=.38). We did not find any significant results for the error rate dimension.

Table 2. Descriptive statistics and correlations of the aggregated variables

	Mean	*SD*	1	2	3	4	5	6	7	8	9
1. Leader presence	1.64	0.49	--								
2. Team size	4.76	1.17	.77**	--							
3. Number of team meetings	1.61	0.50	.15	-.12	--						
4. Team Situation Model (M1)	0.82	0.76	-.20	-.40*	.44*	--					
5. Team Situation Model change	-0.03	0.13	.04	.07	-.16	-.27	--				
6. Team Situation Model change (pattern)	-0.15	0.94	.26	.33	-.17	-.34	.71**	--			
7. Quality on actions	5.71	0.75	-.24	-.11	-.03	.36*	.34	.17	(.93)		
8. Goal achievement	5.39	0.85	-.30	-.08	-.07	.28	.23	.10	.86**	(.93)	
9. Error rate	5.13	0.84	-.30	-.19	-.06	.30	.08	-.10	.76**	.84**	(.75)

Notes. Cronbach's Alpha of the individual team effectiveness measure is n parentheses along the main diagonal; * p< .05 (two-tailed); ** p<.01 (two-tailed).

ANOVA results with Bonferroni corrections (i.e. the intra-team approach, Table 4) suggest that teams with an increasing, decreasing, or stable TSM development pattern differ in the level of quality of actions ($F_{(2, 25)}$=4.632, p=.019) and goal achievement ($F_{(2, 25)}$=3.755, p=.037) in the end, but not error rate ($F_{(2, 25)}$=2.177, p=.134). The result of Levene's test is not significant (quality of actions: $F_{(2,29)}$= .462, p= .634; goal achievement: $F_{(2,29)}$= .844, p= .440), which justifies the comparison across the three groups of teams. Pairwise comparisons predict no significant differences in the quality of actions (p = .083) nor goal achievement (p = .317) between teams with increasing and decreasing TSM patterns. Hypothesis 2 is not supported. But pairwise comparisons predict that teams with increasing TSM patterns (M=6.04) have significantly higher quality of actions than teams with stable TSM development patterns (M=4.84, p=.039). Teams with increasing TSM patterns (M=5.69) also have significantly higher goal achievement than teams with stable TSM development patterns (M=4.40, p=.043) as well. This supports Hypothesis 3. Thus, teams with increasing TSM patterns outperform teams with stable patterns in terms of the quality of actions and goal achievement, but not teams with decreasing patterns.

Table 3. Results of hierarchical regressions with quality of actions as dependent variable (inter-team approach)

	Step 1			**Step 2**			**Step 3**		
	B	***SE***	**β**	***B***	***SE***	**β**	***B***	***SE***	**β**
Constant	5.92	.77		1.81	1.82		.76	1.61	
Leader presence	-.67	.47	-.44	-.70	.43	-.46	-.75	.38	-.49
Team size	.15	.19	.24	.27	.19	.43	.30	.16	.47
Number of team meetings	.10	.30	.06	-.19	.30	-.13	-.14	.26	-.10
TSM (M1)				4.93	2.00	.50*	6.17	1.77	.62**
TSM change							2.81	.89	.48**
R^2	.079			.137			.354		
R^2 change	.079			.169*			.210**		
F	.789			2.228			4.391		
P	.505			.093			.005		

Note: * *p* < .05, ** *p* < .01

Table 4. Pairwise comparisons results of ANOVA for quality of actions and goal achievement

Variable	**Quality of actions**	**Goal achievement**
TSM Change		
Increase	6.04[a]	5.69 [a]
Stable	4.84[b]	4.40[b]
Decrease	5.70[ab]	5.43 [ab]
F-statistics	4.63*	3.75*

Notes. Team size, presence of a team leader, number of meetings, and TSM of meeting 1 are controlled. Bonferroni adjustment is applied for multiple comparisons. * *p* < .05, ** *p* < .01
There is no significant difference between the pattern with the same letter. The mean difference in quality of actions between the increase and stable pattern is at the significance level .039; that between the increase and decrease pattern is at .083; that between decrease and stable is .650. The mean difference in goal achievement between the increase and stable pattern is at the significance level .043; that between the increase and decrease pattern is at .317; that between decrease and stable is .335.

7. Discussion

The aim of this study is to gain a deeper understanding of the temporal dynamic nature of the team situation model (TSM) and its influence on team effectiveness. By studying 32 command-and-control teams with a coordinating task in a multi team system over time, we found that in teams that perform in a turbulent environment and under considerable time pressure, changing TSMs at the early stage of team functioning benefit the eventual team effectiveness in terms of quality of actions and goal achievement.

More specifically, teams with increasing TSM development patterns outperform those with stable patterns but do not differ from teams with decreasing patterns in their quality of actions and goal achievement. In other words, teams whose members' individual situation models become more similar at the early stage of team functioning are likely to outperform teams whose members' situation models remain unchanged but not teams whose members' situation models become more dissimilar. Below we discuss our findings in detail and the theoretical and methodological contributions of the paper to team cognition and team development research. We conclude the paper with suggestions for future research.

The first contribution of the paper is that it extends the general conclusions of the benefits of team members' similar mental models from a cross-sectional context to a longitudinal context. Our results show that, in addition to the actual similarity (e.g. Cooke, Kiekel, & Helm, 2001; Lim & Klein, 2006; Smith-Jentsch, Mathieu, & Kraiger, 2005), the *changing process* of team members' situation models matters for team effectiveness in teams; neither a stable pattern of high TSM similarity nor a stable pattern of low TSM similarity appears to be beneficial to eventual team effectiveness in terms of quality of actions and goal achievement. Stable TSM patterns, particularly if teams are operating in a dynamic and complex environment, may signal team members' obstructions and even failure in renewing their collective information repertoire and improving their shared knowledge structure in the ever-changing environment. The members of teams with a stable TSM may share the information that all members have already known but not the information that is yet unshared, a phenomenon referred to as the information sampling bias (Stasser & Titus, 1985, Mesmer-Magnus & DeChurch, 2009). It could also be that, as time passes by, the acquisition and processing of biased information in teams is further worsened by a confirmation bias, that is, an inclination of team members to overemphasize information that confirms the original interpretation of an ambiguous situation and to discount information inconsistent with it (Perrin, Barnett, Walrath, & Grossman, 2001). Over time, these cognitive biases prevent teams from incorporating new information and developing the TSM, which will in turn result in inadequate decisions, inaccurate judgment, and insufficient adaptation (Burke, Stagl, Salas, Pierce, Kendall, 2006; Nickerson, 1998; Wittenbaum, Hollingshead, Botero, 2004) and finally lead to low team effectiveness.

A change in the similarity of team members' situation models during the early phase of the team's life is thus beneficial to team effectiveness in the context of a turbulent environment, time pressure, and the necessity of acute action. As a team goes through cycles of action-transition phases over time, the ever-evolving task situation requires team members to continuously update their shared understanding of the situation and what needs to be done from phase to phase in order to perform well.

An increasing TSM development pattern indicates that members of a team have *temporally-converging* situation models. They are able to achieve more similar situation models and to create a more shared knowledge structure, even if the team is presented with constantly renewed information about the tasks, the team, and the environment. Team members' increasingly similar situation models over time allow team members to coordinate and communicate with each other (Marks, Sabella, Burke, & Zaccaro, 2002; Marks, et al., 2000) in an increasingly effective way and to interpret changes in the team's functioning situation (Marks, et al., 2000) in an increasingly cohesive manner, all of which lead to high team effectiveness at the end.

Unexpectedly yet interestingly, our study reveals a lack of significant difference in team effectiveness between teams with increasing and decreasing TSM development patterns. This evidence conveys potential benefits of team members' temporally-diverging situation models on team effectiveness, a finding largely different from the general conclusion from voluminous cross-sectional studies (e.g. Mohammed, et al., 2010; Salas & Fiore, 2004; Salas, Cooke, & Rosen, 2008). In other words, as long as members of a team have reached a certain level of shared understanding of the team's relevant situation, potential diverging changes of team members' situation models at the early stage do not necessarily incur negative influence on team effectiveness in the dynamic context we studied. We see different possible explanations for this result.

First, as long as the crucial elements are shared and these are accurate, team effectiveness will be supported even if the TSM similarity is decreasing. An accurate TSM indicates that the shared understanding is based on the right facts (Mathieu, et al., 2000). The relation between the accuracy of cognitive structures and performance is evidenced by some researchers (e.g. Cooke et al., 2001; Edwards, Day, Arthur, & Bell, 2006; Lim & Klein, 2006; Mathieu, Heffner, Goodwin, Cannon-Bowers, & Salas, 2005), but could not be confirmed in other studies (Mohammed et al., 2010; Webber, Chen, Payne, Marsh, & Zaccaro, 2000). We assume that when in the context of emergency management command-and-control the crucial elements are shared and these are accurate, the decreasing similarity of other elements is less important for the eventual team effectiveness. So it may not be a problem if people have different ideas about which emergency management processes are executed, as long as they all have the crucial and correct ones in mind. Future research should reveal whether this assumption holds.

A second possible explanation is that the team members may have reached a shared understanding of the very basic facts of the overall situation and the most crucial actions to take during the first team meeting (the first transition phase). After that, the team may face increasingly complex situations with constant new information. Team members need to not only share the most relevant and important information but also to activate and utilize their unique discipline-specific knowledge to perform their tasks. This may decrease the similarity of their situation models and result in a decreasing TSM similarity, but may nevertheless be necessary in order to achieve high team effectiveness. This is often referred to as a distributed situation model (Stanton, Salmon, Walker, & Jenkins, 2009). In such case, the danger of 'groupthink' (Janis, 1972) in which similarity discourages critical thinking and leads to an incomplete and flawed

TSM (Houghton, Simon, Aquino, & Goldberg, 2000) is prevented. The presence of a distributed situation model or the absence of groupthink can explain the positive effect of a decreasing similarity pattern on team effectiveness.

The second contribution of the paper is that it highlights the importance of early TSM development for team effectiveness. Drawing upon the phase model of team development (Marks, et al, 2001) and path dependency of team emergent states (Cronin, et al., 2011), we have found a positive effect of TSM changes at the early stage of team functioning on team effectiveness and particularly that both increasing and decreasing TSM patterns seem to bring benefits to team effectiveness in comparison with stable TSM patterns. These findings illustrate that, in addition to team processes or team members' interactions and activities such as strategic planning and team launch meetings (Ericksen & Dyer, 2004), emergent team states also play an important role at the beginning of team functioning. At this stage, it is crucial for teams to obtain certain shared understandings of their task situations and at the same time revise and adjust these shared understandings according to the constantly evolving situations.

The third contribution of the paper is at the methodological level, which shows the importance to distinguish between variances-based models in the differential paradigm and process-based models in the temporal paradigm (Roe, Gockel, & Meyer, 2012; Van de Ven, 2007; Van de Ven & Poole, 2005) in the study of team cognition development over time, particularly in dynamic task situations. Using an inter-team longitudinal approach (i.e. by nature a variances-based model) that focuses on *sample-level* change patterns (Li & Roe, 2012) we found that TSM change has a positive impact on team effectiveness. With this finding, one is very likely to infer that teams with *increasing* TSM development patterns tend to be more effective than teams with *stable* patterns, and teams with stable patterns more effective than teams with *decreasing* patterns. However, results from the intra-team longitudinal approach (i.e. by nature a processes-based model) pertaining to individual teams' changes show that the positive effect of TSM change on team effectiveness suggested by the inter-team approach is not "linear": The effectiveness rankings from high to low are found from teams with *increasing* to teams with *decreasing* to teams with *stable* TSM patterns.

Team effectiveness significantly differs only between teams with increasing and stable TSM patterns. In other words, the intra-team approach reveals important evidence of individual teams' TSM development patterns, which is disguised in the results of the inter-team approach. It also provides a novel implication that a diverging trend of TSMs within teams over time may yield benefits for team effectiveness in a highly dynamic environment. These findings and implications are revealed through a combinative application of the inter- and intra-team longitudinal approaches and together provide a comprehensive understanding of early TSM development and its influences on team effectiveness, which cannot be identified in the context of cross-sectional research. They also support organizational theorists and methodologists' argument for distinguishing between and combining variances-based models and processes-based models to generate comprehensive knowledge of changes in organizations (including changes in teams and individuals, Li & Roe, 2012; Roe, 2008, 2009; Van de Ven, 2007; Van de Ven & Poole, 2005).

8. Limitations and future research

Our findings show that a changing TSM does influence the team effectiveness dimensions quality of actions and goal achievement, but not error rate that refers to the extent to which the number of victims and damage could have been prevented and whether press could be positive about the emergency response. The reason for this may be that these factors highly dependent on the actions executed by the assistance units at the scene and thus the multi-team system as a whole. The OSCT can have decided on justified actions (i.e. the dimension quality of actions), but whether they were executed properly and led to only the inevitable number of victims and damage highly depends on the assistance units. In this way, error rate is a more concrete scale than goal achievement (example item: 'the crisis is controlled'). In future studies the relation between the three dimensions should be further studied in the context of a multi-team system.

A limitation of our study is that our measure does not capture the full TSM content (i.e., the information in the situation model, the specific facts and rules relevant to mental models, the informational cues in the environment, and the processes involved in interpreting this information, Cooke, et al., 2001). We used only one aspect, namely the eventual outcome of the team meeting in terms of what processes to stop, start, or continue. Future research should further investigate the TSM content and its changes over time in the context of emergency management and the decision making about what processes to activate on the scene. This research should also take into account the TSM of the other teams that function in the multi-team system (i.e. the assistance units). Especially in situations where the teams in this system have high cross-team interdependence (Marks, et al., 2005) it is the collective effort of these teams that eventually leads to a quality of actions at the scene and to goal achievement.

The second limitation is that we examine TSM similarity (i.e. the similarity of individual team members' situation models) but not TSM accuracy. TSM accuracy refers to what degree team members' common vision of evolving situations is based on the right facts (Mathieu, et al., 2000). TSM accuracy may account for the detrimental effect of stable TSM development patterns, as in dynamic environments, stable TSM development patterns are likely to indicate teams' inaccurate collective understanding of their task situations. As explained earlier, measuring TSM accuracy may also give insight in the reason why a decreasing TSM may be valuable. The importance of accuracy is proven in some studies (e.g. Cooke, et al., 2001; Edwards, et al., 2006; Lim & Klein, 2006; Mathieu, et al., 2005), but could not be confirmed in other studies (Mohammed, et al., 2010; Webber, et al., 2000). This means that in future research the measurement of the accuracy of the individual situation models and the team situation model should be included. Following the suggestions of Mathieu and colleagues (2000), this measure could be based on an expert model. Experts need to point out what emergency management processes are crucial at the different stages of the emergency response, so that the individual and team situation model scan be compared with the expert model. TSM accuracy is thus an interesting angle for future research about TSM patterns and their influence on team effectiveness (Cooke, et al., 2001).

In addition, to fully capture TSM development over time, it is necessary to measure TSM development at later stages of team functioning as well, examine its influence on team effectiveness, and compare the influence of TSM development between the early and later stages on team effectiveness. Moreover, as each action phase in a team's life includes certain actions and thus a certain quality of actions and contribution to goal achievement, it can be argued that team effectiveness changes over time as well and can thus also be conceived as a temporal-dynamic concept. Researchers can measure both TSMs and team effectiveness repeatedly throughout multiple action-transition cycles and improve our understanding of the interrelation between patterns of TSM development and team effectiveness over time. For future research it would be advisable to train teams of raters to judge team effectiveness to further increase the level of inter rater reliability (Hallgren, 2012).

Our study shows the relevance of TSM change in the early phase of teams that are multidisciplinary, ad hoc composed, and operate under turbulent circumstances that require immediate action. Future research needs to reveal whether our results can be replicated with teams operating under different circumstances. Doing so, our insight in the role time pressure and risk play for the development of the TSM may be broadened. To end with, although it is rather difficult to gain access to teams in a naturalistic setting, including a large number of teams increases the robustness of the findings.

9. Practical implications

This study shows that members of a command-and-control team need to be aware that in the first stage of their cooperation, they should put energy into developing similar situation models regarding what each assistance unit is going to do. This requires the team members to know by heart which assistance unit has what responsibilities as described in the emergency management processes. If this awareness is lacking, team members need to be informed about the processes and afterwards trained in using them as references to what assistance is offered at the scene. It could be a suggestion if OSCT members change roles during a rather simple exercise so that they can experience the different kind of responsibilities, problems, information, and resources they have. A team leader can support team members in making explicit which emergency management processes they will start or continue by simply asking them to share this at the end of a team meeting. The availability of and familiarity with a checklist of optional tasks and responsibilities of team members can support the development of shared knowledge about the division of tasks among team members.

In addition, team members and their team leaders need to acknowledge all available relevant information and explore different possible visions to avoid an information or confirmation bias. A critical attitude towards the teams' early ideas is necessary to avoid having stagnant team cognition and sticking to ideas that may not reflect the changing situation. Being critical may not be appreciated in each team. The team leader needs to invite and support the team members in sharing both their thoughts and doubts. If a team member dares to speak up, this should be rewarded by taking the comments seriously. This attitude should be monitored and evaluated during team exercises.