TEAMS UNDER THREAT

Uncovering and Overcoming Rigidity Effects

Wim Kamphuis

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Teams under Threat
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Contents

Chapter 1

Caught in an Ambush or Bound by Rigidity?

Ar Rumaythah, a desert town in Iraq, around midnight. A unit of the Dutch Military Police (MP) is on its way back to their base. When they cross a bridge and enter the centre of the town, the streetlights turn off and the streets suddenly seem deserted. They continue driving. But then the sound of automatic rifles firing breaks the silence. One moment, the unit is completely stunned. Then the vehicles quickly accelerate and manage to escape by driving at full speed through the dark streets. A few kilometers further, one of the vehicles breaks down, and the unit comes to a halt. One of the servicemen has been deadly injured during the shooting, two others have been wounded. The unit contacts the command post of the Dutch base near Ar Rumaythah. Although it is not directly clear what happened, company command immediately sets emergency procedures in motion. A Quick Reaction Force (QRF) with an ambulance is mobilized and sent out to provide assistance. A Medevac (helicopter for medical evacuation) is requested from Tallil airbase, to evacuate the wounded. Battalion headquarters in As Samawah (30 kilometers south-east) is informed.

Half an hour after the first report from the stranded unit, the QRF arrives at the scene. They have chosen a different route than the MP unit, avoiding the town's centre. They have also been fired upon, but not as heavily as the MP unit, and at a different location. They secure the perimeter and contact company command to give a situation update. The company commander decides to send a second QRF, for additional medical aid and protection. The second QRF consists of unarmored vehicles, just as the first QRF. In the meantime, the battalion in As Samawah has also deployed a QRF, to provide assistance from the south. Company command, however, decides to call this QRF to a halt before they arrive at the location of the stranded MP unit.

As the second QRF enters the town's centre, it is again surprisingly silent on the streets. But then, all hell breaks loose. It starts with a heavy explosion, followed by the sound of guns firing and grenades exploding. The QRF receives heavy fire from both sides of the road. They return fire while increasing their speed to escape the shooting, but it lasts for several kilometers. When the convoy makes a turn left, the last vehicle goes off the road and is hit by a Rocket Propelled Grenade (RPG). It breaks down. The four passengers can barely leave the vehicle before a second RPG hits it. Their vehicle starts burning and the four servicemen have to abandon it while under heavy fire. They manage to get away from the car and find cover in a backyard. Three of them are wounded.

When the remaining vehicles of the second QRF arrive at the location of the stranded MP unit, several of the men are wounded. They contact company command and report that one of their vehicles is missing. The company commander decides to deploy a third QRF, this time with armored vehicles, to search and rescue the missing soldiers. This unit also encounters heavy opposition, but manages to push forward when Apache helicopters arrive at the scene. They finally find the four stranded men and return them back to the base. At the same time, the Medevac transports the wounded servicemen from the MP unit back to their base. About four hours after the start of the attack, all units have returned. Five of the servicemen have been seriously injured and several others suffered minor injuries. One serviceman of the Military Police lost his life.[1]

Research Question

This incident took place in the night of 14 to 15 August 2004, during the Dutch participation in Stabilisation Force Iraq (SFIR). It sets the scene for the topic of this dissertation: team performance under threat. In this dissertation I present research that aims to uncover how threat affects team performance during complex tasks and how teams can be protected against negative effects of threat.

Such knowledge has relevance for the military, because military teams face threats as part of their job. Teams in other safety critical work environments may

[1] This description of events is based on a case study including a series of interviews with servicemen involved in this incident (Delahaij, Kamphuis, Van Bezooijen, Vogelaar, Kramer, & Van Fenema, 2009).

face threats on a regular basis too. Think of aircrews, emergency medical teams, and crisis management teams. But even in non-safety critical work environments, teams may face threats, such as potential financial loss, hostile takeovers, or negative publicity.

These threats have the ability to negatively affect the performance of teams. Many tragedies in the military, aviation, and other safety critical work environments have been attributed to teams giving way under threat (e.g., Cannon-Bowers & Salas, 1998b; Flin, Slaven, & Stewart, 1996; Helmreich & Schaefer, 1994). In addition, many of the worst decisions made by top management teams and governments were made in the face of threat (e.g., Janis, 1972; Staw, Sandelands, & Dutton, 1981). Teams, consequently, appear to be vulnerable to the effects of threat.

Despite this apparent vulnerability, little is known about how threat exactly affects the performance of teams (e.g., Burke et al., 2004; Ellis, 2006; Turner & Horvitz, 2001), especially during complex tasks. Teams, however, increasingly have to deal with complex tasks, as the complexity of the workplace continues to grow (e.g., Salas, Cooke, & Rosen, 2008). Understanding which processes play a role in the reaction of teams to threats performing complex tasks is vital to improving their performance. Only when it is known how threat affects teams, it will be possible to develop adequate measures to protect them.

In the remainder of this chapter, I will define threat and discuss a theory that proposes how teams react to threat, using the incident as an illustration. Then, I will review the research that has been done in this area. Subsequently, I will describe the design of the present research and end with an overview of this dissertation.

Threat

Threat can be defined as a possible impending event perceived by a person or group of persons as potentially causing material or immaterial loss to, or the obstruction of goals of that person or group of persons (cf. Argote, Turner, & Fichman, 1989; Lazarus, 1966; Staw, Sandelands, & Dutton, 1981; Turner & Horvitz, 2001). In research, threat and stress are often mentioned in one breath. According to the transactional theory of stress (e.g., Lazarus, 1966, Lazarus & Folkman, 1984) threat is one of the major determinants of stress. A person experiences stress when the demands of the environment exceed his or her resources and endangers his or her well-being (Lazarus & Folkman, 1984). Thus, stress is the reaction of an individual to its environment, while threat can be the environmental event leading to this reaction.

The effects of threat as potential stressor have not been investigated much because threat is hard to manipulate in experimental settings (e.g., Turner & Horvitz, 2001). In the present research, however, we focus on threat, because of its key role in stressful appraisals. Moreover, rather than combining multiple stressors to maximize the stress response (e.g., Driskell, Salas, & Johnston, 1999), we chose to investigate threat as single potential stressor, because different stressors may lead via different mechanisms to distinct effects (e.g., Broadbent, 1963; Hancock & Warm, 1989). A combination of potential stressors therefore, might obscure the unique underlying processes (cf. Klein, 1996).

Theoretical Framework

Let us return for a moment to the incident described above. For it looks as if the way the Dutch troops handled this incident is an exception to the image drawn above of teams being vulnerable to the effects of threat. After all, the consequences of such an ambush could have been far worse. To some extent this may be true. The comparatively favorable outcome can be partly attributed to the professionalism of the Dutch servicemen. However, closer inspection shows that they also seemed to have had luck on their side. Imagine, for example, that the first rather than the last vehicle of the second QRF would have broken down during the ambush. It then would have obstructed the passage way for the other vehicles, which would have become easy targets for the attackers. In that case, the ambush could have resulted in far more casualties. Just looking at the outcome, therefore, is not enough to determine if and how threat affected team performance in this situation (cf. Smith-Jentsch, Johnston, & Payne, 1998).

If we take a closer look at the process instead, some questions arise. For example, why was a second QRF ordered to drive straight into the ambush? Why didn’t this second QRF avoid the town’s centre, just as the first QRF did? Why did this second QRF consist of unarmored vehicles? And why was the QRF of the battalion ordered to abort their action? To be able to find some answers to these questions, we first have to turn to the theory.

The most comprehensive theory addressing the effects of threat is the threat-rigidity thesis (Staw et al., 1981; see Figure 1.1).

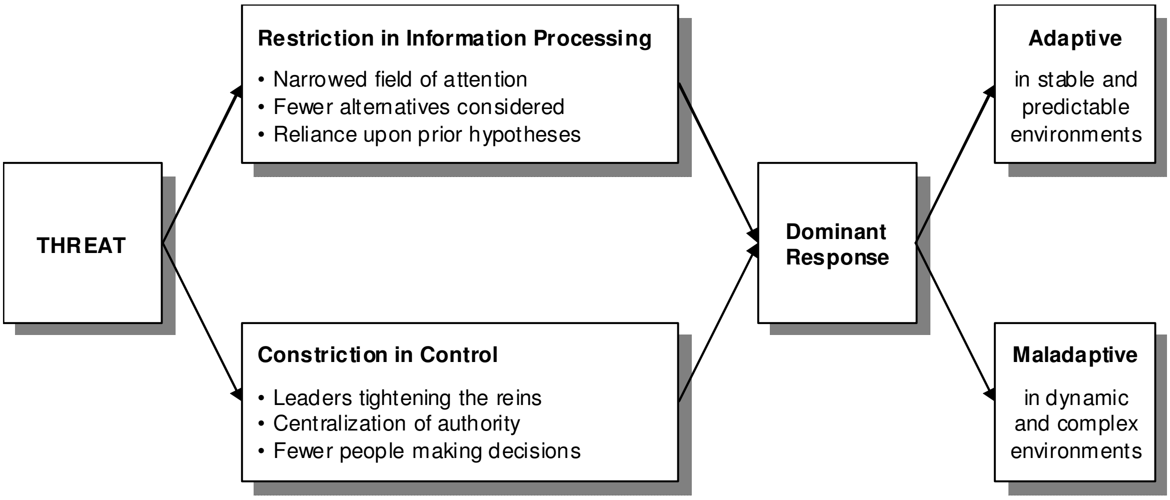

Figure 1.1
Schematic overview of the Threat-Rigidity Thesis

It states that there is a general tendency for individuals, groups, and organizations to behave rigidly in threatening situations. This rigidity consists of two types of effects: a *restriction in information processing* and a *constriction in control*. Examples of a restriction in information processing are a narrowed field of attention, a reduction in the number of alternatives considered, adherence to previously learned solutions, and reliance upon prior hypotheses. Constriction in control may be demonstrated by leaders tightening the reins on their subordinates, power and influence becoming concentrated in higher levels of a hierarchy, and fewer people making the decisions.

Together these effects cause a system's behavior to become less diverse and flexible. Instead, the system will emit its most well-learned or dominant response (Zajonc, 1966). This dominant response may be either adaptive or maladaptive, depending on the task environment in which it is produced. In stable and predictable environments, a dominant response can be successful. After all, it has been learned in the same environment and therefore should be appropriate. Conversely, in dynamic, complex, and unpredictable environments, a dominant response can be maladaptive, because in this environment the dominant response may no longer be appropriate and flexibility rather than rigidity is necessary to perform well (Staw et al., 1981, Weick, 1979). Looking at the incident in Ar Rumaythah again, we may try to answer the questions posed above, using the threat-rigidity thesis as an explanatory framework.

Analysis of the Incident[2]

Nature of the task environment

As described above, the threat-rigidity thesis predicts different outcomes of rigidity reactions depending on the nature of the task environment in which these reactions are produced. Therefore, it is important to understand the nature of the task environment the company command team found themselves positioned in. Although task complexity is difficult to define, researchers (e.g., Brown & Miller, 2000; Kelly, Futoran, & McGrath, 1990; Rasmussen; 1986; Staw et al., 1981; Volkema, 1988; Wood, 1986) have identified a number of attributes that contribute to the complexity of a task, including:

- information load (the sheer amount of information that must be processed to successfully complete the task, and the number of different information sources);
- number of subtasks (the number of acts requiring specific knowledge and skills that must be carried out to accomplish the task);
- unfamiliarity and non-repetitivity (the extent to which well-learned skills or procedures to perform the task are lacking);
- task uncertainty (the ambiguity of information in the task, the lack of knowledge concerning the relationship between processes and outcomes, and the novelty of potential outcomes);
- number of goals or pathways to goals (referring to how many goals must be attained and in how many different ways these goals can be reached);
- time-varying conditions (relating to the dynamic nature of the task environment, with changing circumstances and rules).

Looking at the task environment of the company command team, we may notice a number of things. As the incident unfolded, more and more parties were involved, each creating an information flow to company command, causing a high information load. In addition, company command was responsible for multiple subtasks, including gathering information, creating situation awareness, directing the QRFs, controlling medical and attack helicopters, reporting to battalion, and taking appropriate decisions. Although emergency procedures do exist for these kinds of situations, the task of company command can by no means be described as familiar

[2] The analysis of the incident is based on Kamphuis & Delahaij (2009).

or requiring well-learned, repetitive actions. In fact, this was the first time that this company encountered an incident of this scale. Lack of clarity about the nature of the incident, the location of the stranded MP unit, the location of the enemy, and the scale of the incident guaranteed a high level of task uncertainty. This uncertainty about the situation also resulted in multiple different pathways in which the stranded MP unit could be reached and supported (e.g., with armored or with unarmored QRFs, avoiding the town's centre or going through it, with or without help from the battalion, with or without close air support). Finally, the command team's task environment continually changed, due to new information becoming available, and due to the enemy's actions. Taken together, it seems reasonable to conclude that the company command team faced a complex task. The threat-rigidity thesis proposes that in such an environment rigidity in reactions will be maladaptive, and flexibility rather than rigidity is necessary to survive. But is there evidence for rigidity in reactions on the side of the company command team?

Restriction in information processing

The concept of a restriction in information processing directs our attention to the way the company command team dealt with incoming reports of the incident and how their image of the incident developed over time. It turns out that it took quite a while before company command had an accurate view of the scale of the incident. This may very well have been caused by the effects of threat.

Initially, after the reports of the unit of the Military Police, company command had the impression that the incident was a hit-and-run attack by local insurgents. This was their original hypothesis. The threat-rigidity thesis proposes that under threat, an entity will be inclined to adhere to this original hypothesis. New information will be perceived in terms of this hypothesis, or even be ignored if it does not fit. It seems that this is exactly what happened during the incident in Ar Rumaythah. This is apparent from the way company command dealt with information from the first QRF they sent out. This QRF reported that they had also been fired upon, but at a different location. Based on this report, company command could have drawn the conclusion that more insurgents were involved in the attack than initially thought. They also could have drawn the conclusion that these were the same people as those who fired at the MP unit, but that they had moved to a different location. With the threat-rigidity thesis in mind, the conclusion of the company commander is not surprising:

> *Then* (i.e., after the report of the shooting of the first QRF) *I drew this conclusion: the people that trapped the MP unit on this location (…) were retreating and then accidently stumbled upon (…) the first QRF, fired a few rounds at them as well and then left. In itself, that makes perfect sense.*

Company command thus adheres to its initial hypothesis and tries to make sense of new information by fitting it in to that image. The result is that company command, at this moment, has the point of view that there are at most a handful of insurgents, who have already left the scene, while in reality the centre of Ar Rumaythah is teeming with rebels. The inaccurate image of company command contributes to their decision to employ a second QRF and letting them use unarmored vehicles. It also contributes to the decision of the commander of the second QRF to drive through the centre of Ar Rumaythah, rather than avoiding it, just like the first QRF. Because the situation they are dealing with is not stable and predictable, but instead dynamic and complex, these standard routines are not appropriate. And thus, restricted information processing moves everything into position for a potentially catastrophic ambush. The fact that in the end every serviceman of the second QRF survived this ambush may be nothing short of a miracle.

Constriction in control

The second proposition of the threat-rigidity thesis, predicting a constriction in control under threat, turns our attention to the way the company command team directed the operation. On the one hand, they had to command their own troops. On the other hand, they had to report to their next-higher level, battalion command. In both these directions, the actions of the company command team show that they tried hard to maintain control (or a sense of control) over the situation. Again, the threatening nature of the circumstances may have been an important cause of this.

One instance that illustrates the way company command tried to withhold their next-higher level from interference in the situation, pertains to the deployment of a QRF by battalion command. As described above, battalion command deployed a QRF on their own initiative, to provide assistance from the south. When the company commander heard of this deployment, he immediately intervened and calls this QRF to a halt:

> *I remember having shouted: "Abort that operation! When I need something, I'll say so myself". So they* (i.e., the QRF of the battalion) *immediately hit the*

brakes and pulled over somewhere in the next hundred meters. Try to imagine: they would have driven in completely blind, while I'm in control of the situation here (…) At that moment, I have absolutely no use for a unit from outside. As long as I can handle it myself, as long as I have a cook that is still able to mount, I don't need you around here!

The company commander thus tries to stay in control by not letting other units enter his area of responsibility. Allowing this would have meant a loosening of control, whereas his aim is to maintain and constrict control, to keep the situation manageable. However, in doing so, company command shuts off useful resources. Although the battalion is 30 kilometers away, they can reach the location of the stranded MP unit without having to go through the town's centre, and they can do so in time, because battalion command sent out their QRF rapidly after the first reports of the attack on the MP unit.

Thus, the rigidity in reactions by company command again seems inappropriate in the current circumstances. However, the QRF of the battalion somehow does continue on its way, despite the orders of company command, and nevertheless arrives at the location of the stranded MP unit. At this location they are deployed by the on scene commander to secure the landing point of the Medevac. Hence, eventually the control exerted by company command in this case did not get the chance to exert its negative effects. Once again, it becomes clear that threat actually did negatively affect the performance of the command team, but that these effects somehow did not get the chance to have an effect on the operation as a whole.

Another instance illustrates how company command constricts control with regard to their own troops, although in a different manner. This happens when the incident seems to have come to an end. The wounded have been transported and it appears to have become quiet. At that moment, company command orders that all troops gather together inside the base, so they can be addressed by the company commander. But just when he is about to start speaking to the troops, the base is attacked with Rocket Propelled Grenades (RPGs). The troops have to run for cover and take up their positions again. They start shooting back with all means at their disposal until peace returns. Luckily, none of the RPGs hit the base and no one gets injured.

This constrictive action of company command aimed to regain a sense of control over the situation. The urge to bring everyone together to foster this sense of control made that the company cut itself off from the outside world. This made them blind to what happened outside the gates. Their enemies immediately exploited this weakness. Once more, it becomes apparent that in a situation that does not correspond to the original expectations, but rather proves to be complex and unpredictable, constriction in control may have disastrous consequences. In the words of the company commander:

> *That* (i.e., gathering everyone inside) *was wrong. That's something I have learned from this experience. You can't create a situation in which you're completely blind, directly after a combat situation. That's just not acceptable. Of course, it's only human (…) but after this incident, we have never done it this way again.*

Evidently, it is not possible to conclude with certainty that without threat, things would have unfolded differently. It is, after all, always difficult to deduce causal relations from single events. But it is not unlikely that without the effects of threat, company command would have sooner replaced their initial hypothesis of a hit-and-run attack with an alternative hypothesis. And they might also have felt more inclined to accept assistance from the battalion.

Although the analysis of a single incident may deliver valuable knowledge, more controlled research is useful to test the propositions of the threat-rigidity thesis and establish causal relationships between threat on the one hand, and team processes and performance on the other hand. Below we review previous research that has addressed the effects of threat on team performance in controlled settings.

Previous Research

Only a small number of studies tested propositions of the threat-rigidity thesis at the team level. Below, we review the results of these studies.

Gladstein and Reilly (1985) investigated how teams in a six day management simulation responded to threatening events. These simulated events consisted of incidents with potentially severe negative financial consequences (e.g., a strike). Participants reported to have restricted their information processing in response to these events, by using less information to make a decision. However, no evidence was found for a constriction in control.

Argote et al. (1989) investigated the effects of threat on the centralization of communication structures in teams using a simple laboratory team task (discovering which of five colors displayed on cards distributed to each team member was held in common). They manipulated threat by suggesting that participants would lose the opportunity to win additional money if they did not perform well and by creating time pressure. They found that higher levels of perceived threat were associated with more centralized communication structures, which is an indication of a constriction in control.

Driskell and Salas (1991) investigated the effects of threat on team decision making, using a simple team task too (choosing which of two patterns contained a greater area of white). Threat was manipulated by telling participants that during task performance a small amount of tear gas would be introduced into the room (which, in reality, did not happen). They found that high status team members under threat accepted *more* influence on their decisions from low status team members than high status team members under normal conditions did. The researchers interpreted this result as a loosening of control under threat rather than a constriction in control predicted by the threat-rigidity thesis.

Harrington, Lemak, and Kendall (2002) investigated how threat affected teams participating in a student team project. Threat was not manipulated, but assessed by the researchers on the basis of the importance and the complexity of the project, the level of competition, and time pressure. Participants facing higher levels of threat reported to have used a more rigid approach to the decision making process, indicating both a restriction in information processing and a constriction in control.

Two recent studies suggested that a restriction in information processing under threat may extend to team information as well (Driskell et al., 1999; Ellis, 2006). In other words, team members under threat might not only overlook or ignore important task information, but they might also ‘forget’ that they are part of a team and become self-focused rather than team-focused. Driskell et al. (1999) investigated how a combination of time pressure, task load, and auditory distraction affected team processes and performance during a tactical decision-making task. The authors concluded that stress resulted in a narrowing of team perspective (the extent to which members feel like a team and are oriented at team rather than individual activities during the task), which in turn led to impaired team performance.

In addition, Ellis (2006) investigated how this narrowing of team perspective under threat affected the transactive memory systems (TMSs) and performance of teams during a tactical decision-making task. A TMS is a set of distributed, individual memory systems for encoding, storing and retrieving information that combines the knowledge possessed by particular members with a shared awareness of who knows what (Wegner, 1995). Due to an effective TMS, team members can retrieve knowledge from each other, anticipate each other's actions and needs, and thus work together effectively (e.g., Moreland, 1999). Threat was manipulated by videotaping participants and telling them that if they would not perform well, the tape would be shown to their entire class as an example of ineffective teamwork. In addition, every 5 minutes these teams received warnings that they did not have much time left. Results of the study showed that threat negatively affected TMSs which mediated the relationship between threat and team performance.

Taken together, these studies provide initial support for the proposition of a restriction in information processing in teams under threat. The studies show that, under threat, teams use less information and adopt a more rigid approach in the decision-making process (Gladstein & Reilly, 1985; Harrington et al., 2002). Moreover, this narrowing of attention does not only pertain to task information but also causes team members to shift from a broader, team perspective, to a more narrow, individualistic focus (Driskell et al., 1999). This shift in focus negatively affects TMSs in teams, which in turn leads to deteriorated team performance (Ellis, 2006).

Results of the described studies regarding the proposition of a constriction in control, however, are less straightforward. Some studies reported findings in line with this proposition (Argote et al., 1989; Harrington et al., 2002), whereas other studies found no effects (Gladstein & Reilly, 1985) or even results indicating a loosening of control rather than a constriction in control (Driskell & Salas, 1991). Hence, it seems that on the basis of these studies, no definite conclusions regarding the exercise of control under threat can be drawn.

Although the studies reviewed above provide valuable initial insights into the effects of threat on the performance of teams, for a more thorough understanding several aspects that have not been adequately addressed by previous research need closer attention. First, most studies investigating the effects of threat on team performance used simple laboratory tasks, or tactical decision-making tasks. Although these tasks may deliver valuable knowledge, they are not suited to investigate some of the processes that characterize team performance in complex environments. Simple team tasks, for example, lack inherent role differentiation, as a result of which no real interdependence exists between team members. Team processes, such as coordination and supporting behavior, therefore can not be investigated with simple team tasks. In tactical decision-making tasks, team members typically do have different roles, but these roles are often so well-defined that they rule out the possibility of engaging in processes such as performance monitoring and supporting behavior (Weaver, Bowers, Salas, & Cannon-Bowers, 1995). In addition, the actions required from team members in these tasks are repetitive and rule-based as a result of which processes such as hypothesis generation, planning, and problem-solving cannot be investigated (Weaver et al., 1995).

Second, although a number of studies addressed the proposition of a constriction in control in teams under threat, in none of these studies, a formal leadership role was assigned to one of the team members. This is remarkable because in most organizational teams, one person does bear final responsibility and can be considered the leader. In the proposition of a constriction in control of the threat-rigidity thesis, leadership plays an important role. Therefore, it might be problematic to draw conclusions about the absence or presence of a constriction in control under threat on the basis of teams in which the leadership role is lacking.

Third, to our knowledge, no study has investigated the effects of physical threat on team performance during complex tasks. Instead, other kinds of threats were used (e.g., social or material). Previous research, however, has shown that physical threat (i.e., threat of electric shock) may have other effects than material threat (i.e., threat of small monetary loss; Klein, 1976). Therefore, it remains to be seen, to what extent results from experiments using non-physical threats can be generalized to physical threat situations.

Fourth, most studies mixed up time pressure with their threat manipulation. Although time pressure indeed may be a critical component of the environments in which many teams have to operate, using it in this way only serves to obscure the effects of threat. After all the effects of time pressure on information processing coincide for a large part with the effects of threat, because time pressure also causes team members to attend to a more restricted range of cues and engage in more heuristic information processing (cf. the Attentional Focus Model, Karau & Kelly, 1992; Kelly, Jackson, & Hutson-Comeaux, 1997; Kelly & Karau, 1999). Therefore, if one is interested in the effects of threat, time pressure should be held constant over the conditions.

Fifth, although a number of studies investigated the effects of threat on team processes, few studies investigated how these effects influenced team performance, and none of these studies simultaneously addressed the total set of relevant mediating processes in the relationship between threat and team performance. Knowledge concerning the mediational properties of these processes, and the way they relate to each other, however, is relevant, since some of these processes might be far more important in causing deterioration of team performance than other processes. Interventions aimed at mitigating the effects of threat on team performance should target those processes that are responsible for the performance deterioration.

Finally, hardly any research has addressed the question of how to mitigate the effects of threat on team performance. Knowledge of the specific effects threat has on team processes could be very useful in developing interventions aimed at reducing the negative effects of threat. Organizations could greatly benefit from such interventions in preparing teams for operations in dangerous environments.

Present Research

The present research thus investigates how threat affects team performance during complex tasks, and what can be done to protect teams against these effects. The design of this research aims to address the aspects that have not received sufficient attention in previous research.

To test the propositions from the threat-rigidity thesis in a controlled way, an experimental approach was adopted. In this approach, teams had to perform an experimental team task that embodied the complexity many present-day teams face. Since none of the existing tasks used in team research fully satisfied the requirements of both, complexity and controllability, we decided to develop a new task environment. This task environment had to permit controlled experimental research into team planning, problem-solving, and decision-making behavior in a complex world.

The resulting flexible research platform, called PLATT (PLAnning Task for Teams; Kamphuis, Essens, Houttuin, & Gaillard, 2009; Kamphuis & Houttuin, 2007), allowed the controlled investigation of team processes characteristic of teams operating in complex environments, while offering a broad range of automated and embedded team process measurement possibilities. PLATT consists of a modular software architecture in which research-specific scenarios can be run. The scenarios developed for the present research were planning and problem-solving scenarios in a military context. Team members occupied different roles with unique responsibilities, expertise, and tasks. One of the team members occupied the leadership role, and was responsible for directing the activities of the other team members.

The task environment in combination with the specific scenarios made it possible to investigate all relevant processes pertaining to the constructs of interest: information processing, exercise of control, and team perspective. The use of the PLATT task environment in the present study thus addressed the above described overemphasis on simple laboratory tasks and rule-based decision making tasks, while maintaining sufficient experimental control. Because all relevant processes could be studied simultaneously and linked to team performance in a meaningful manner, we were able to investigate the full complexity of the threat rigidity thesis. In doing so, we also could attend to the relative importance of the different threat-rigidity effects as mediating variables in the relationship between threat and team performance, a subject that had been largely ignored by previous research.

In addition, the developed scenarios addressed the lack of a formal leadership role in previous studies that tested propositions from the threat-rigidity theory at the team level. This made it possible to investigate constrictions in control in line with the original proposition of the threat-rigidity thesis. This helped to shed some light on the seemingly contradictory results that have been found for the effects of threat on the exercise of control in teams.

Furthermore, in the present research, we manipulated physical threat. In doing so we aimed to fill the research gap that existed because no research previously investigated the effects of physical threat on complex team performance. We also manipulated social threat, making it possible to compare results of both threat manipulations with each other. Because we did not aim to maximize the stress response, but rather set out to determine the specific effects of threat, we did not combine threat with other potential stressors, such as time pressure, or auditory distraction. Because of this, threat effects could not be attributed to, or obscured by, other potential stressors, making it possible to determine the effects unique to threat.

Finally, the knowledge gained in this research about the effects of threat on team processes was used to develop a training intervention aimed at protecting teams against the negative effects of threat. This training intervention was tested experimentally. Given the vulnerability of teams to the effects of threat, and the signaled lack of research addressing methods to mitigate these effects, this intervention could be of considerable value to the domain.

Overview of this Dissertation

As outlined above, the objective of the present dissertation is to uncover how threat affects team performance during complex tasks and in what way teams can be protected against the negative effects of threat. The following chapters describe the development of a suitable research environment and the empirical research that has been conducted in this environment to answer these research questions. These chapters have been written as individual papers, intended to be read separately. As a consequence, there is some overlap between these chapters. See Figure 1.2 for a schematic overview of the chapters.

Chapter 2 describes PLATT, the task environment we developed for controlled research on team processes in complex environments. In this chapter, we sketch the complexity present-day teams face and present an overview of previously used tasks for team research. Then we formulate requirements for an environment that enables controlled research on team performance in a complex world. We describe the software architecture of PLATT, the military evacuation scenario that has been developed for the present research, and the range of measurement possibilities this environment offers. In addition, we describe some potential research applications of this environment and illustrate its possibilities by describing a number of experiments that have used PLATT for a variety of research questions.

Chapter 3 describes an experimental test of the reactions proposed by the threat-rigidity thesis in teams under physical threat. We investigated whether physical threat lead to a restriction in information processing, a constriction in control, and a narrowing of team perspective in teams performing a complex planning and problem-solving scenario in PLATT. Participants were civilians, recruited from a pool of volunteers of the research institute. Physical threat was manipulated in a between-teams design by letting participants in the threat condition believe that they would possibly be subjected to reduced oxygen levels during task execution. In reality, no reduction of oxygen level occurred. Team processes (information processing, leadership, communication, coordination, and supporting behavior) were measured by automated behavior recordings and questionnaires, and team performance was determined on the basis of the final plan the team delivered.

Chapter 4 extends the findings of Chapter 3 by examining the appropriateness of threat-rigidity reactions for team performance in a complex environment. We tested a multiple-mediation model to investigate whether threat

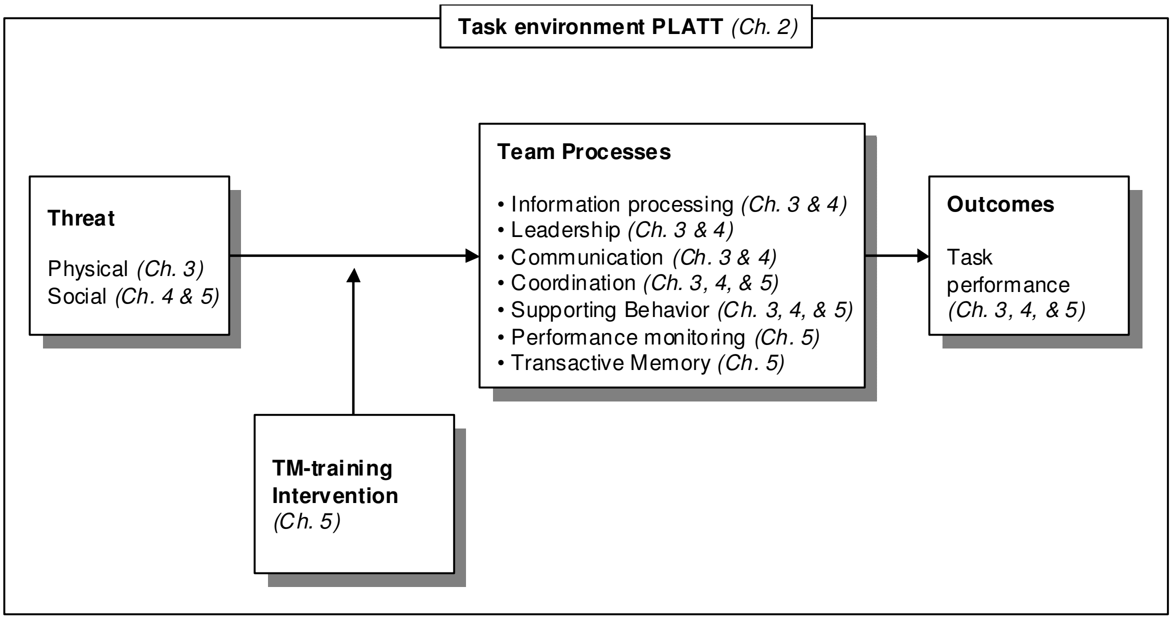

Figure 1.2
Schematic overview of the chapters

negatively affected team performance through restricted information processing, constricted control, and a narrowed team perspective. Participants were officer cadets of the Netherlands Defence Academy. We used a similar PLATT-scenario as in Chapter 3, but this time we manipulated a social threat in a between-teams design. This threat consisted of creating an evaluative situation with potentially negative social consequences in case of poor performance. Again, relevant team processes were measured through behavioral recordings and questionnaires, and team performance was assessed on the basis of the plan the team delivered.

Chapter 5 describes the development and experimental testing of a training intervention aimed at protecting teams from the negative effects of threat. This training intervention was built on the knowledge we developed regarding the effects of threat on team processes. It aimed to reinforce team perspective by enhancing transactive memory in teams. This Transactive Memory training intervention (TM-training) combined a focus on sharedness of knowledge, with a focus on distribution and compatibility. The TM-training intervention was tested in a study with officer cadets of the Netherlands Defence Academy engaging in a complex planning and problem-solving scenario in PLATT, with social threat and TM-training as between-teams factors. Behavioral and self-report measures were collected to assess transactive memory, transactive memory systems, performance monitoring, and supporting behavior. Team performance was determined on the basis of the plan the team delivered.

Finally, Chapter 6 provides an overview of the main findings of the present research, and discusses theoretical and practical implications. Strengths and limitations of the presented research are identified and avenues for future research are outlined.

Chapter 2

PLATT: A Flexible Platform for Experimental Research on Team Performance in Complex Environments[1]

This chapter introduces PLATT, a recently developed task environment for controlled experimental research on team performance in complex environments. PLATT was developed to meet the research demands posed by the complexity present-day teams face. It consists of a flexible, modular software architecture and research-specific scenarios. The scenarios can target various types of tasks in different operational contexts. Different software configurations can be used to investigate questions pertaining to team structure, team virtuality, and multiteam systems. In this chapter, we describe the software architecture, one of the scenarios, and the broad range of automated and embedded measurement possibilities PLATT offers. To illustrate PLATT's possibilities, we describe a number of experiments that have used PLATT for a variety of research questions. We conclude that PLATT meets the formulated demands and provides researchers with a flexible platform to investigate the complex issues present-day teams face.

Teams are everywhere. They can accomplish tasks that exceed the capabilities of single individuals. In our age of information, teams have to be able to cope with an

[1] This chapter is based on Kamphuis, Essens, Houttuin, & Gaillard (2009).

increasingly complex world. Large amounts of information, with an often ambiguous and contradictory nature, tax the abilities of teams. They have to be effective in dynamic and unpredictable environments. To complicate matters even more, team members may be geographically dispersed, necessitating the use of technology to communicate with each other.

The complexity present-day teams have to meet, requires scientific understanding (cf. Salas, Cooke, & Rosen, 2008). Research is needed that aims to gain more insight into the present-day factors affecting team effectiveness, in order to contribute to the development of training methods, interventions, and technology to improve team effectiveness. Studies with existing teams in field settings can provide initial understanding of the conditional factors of teamwork. To test predictions derived from these field studies systematically and establish causal relationships, more controlled experimentation is necessary. For these studies, experimental team tasks are necessary. On the one hand, these tasks have to embody the complexity present-day teams face. Only then relevant processes emerge and can be measured. On the other hand, these tasks have to allow a good degree of control. Only then processes of interest can be measured in a systematic way. Hence, there is a complexity-control trade-off. This chapter describes a recently developed task environment that facilitates controlled experimental research on team performance in complex environments: PLATT[2].

Previous Research

Team researchers have conducted research on both ends of the simplicity-complexity continuum. They have used either simple tasks in highly controllable laboratory experiments, or complex tasks in realistic, high-fidelity simulations. As an example of a simple task that has been used for the study of team performance consider the "Winter Survival Exercise" (Johnson & Johnson, 1987), in which participants have to reach a consensus concerning the ranking of 12 items salvaged from a crashed plane, according to their relative survival value (see, for example, Durham, Locke, Poon, & McLeod, 2000). High-fidelity simulations to study team performance are, for example, business management simulations like "Tycoon",

[2] PLATT is an acronym for PLAnning Task for Teams. This name had its origin in the first scenarios developed for the task environment, which were planning scenarios. In developing the environment, flexibility increased as a result of which more types of tasks could be simulated. Nonetheless, we decided to adhere to the original name, since it had already been established.

developed by the Amos Tuck School of Business Administration in 1973 (see, for example, Gladstein & Reilly, 1985), or the “Management Game” (MCC, 1993; see, for example, Van der Vegt & Van de Vliert, 2005).

Although both types of research can deliver valuable knowledge, the tasks used seem to be less useful in light of the mentioned team research needs of complexity and controllability. With the simple team tasks the complexity present-day teams face cannot be investigated. In addition, many of the processes characteristic of teams are absent in these tasks due to a lack of inherent role differentiation. The high-fidelity simulations elicit real team behavior, but do not provide enough experimental control.

A more recent approach positioned between these two ends, is the use of low-fidelity simulations: networked multi-player computer games that reflect reality to a certain degree, but still offer control (Weaver, Bowers, Salas, & Cannon-Bowers, 1995). The past quarter century produced a wealth of low-fidelity networked computer simulations. Consider, for example, DDD (Distributed Dynamic Decision-Making Simulation; Kleinman, Serfaty & Luh, 1984), TIDE[2] (Team Interactive Decision Exercise for Teams Incorporating Distributed Expertise; Hollenbeck, Sego, Ilgen & Major, 1991), TANDEM (Tactical Navy Decision Making task; Weaver et al., 1995), TPAB (Team Performance Assessment Battery; see Weaver et al., 1995), Team-Track (Jentsch, Bowers, Compton, Navarro, & Tait, 1996), ARGUS (Schoelles & Gray, 2001), C3Fire (Granlund, 2002), and FFTT (Fire Fighting Team Task; Rasker, 2002). All these tasks are in essence monitoring tasks in which targets have to be monitored or detected, and subsequently correctly dealt with. Team members repeatedly have to bring together distributed information about these targets, take decisions concerning these targets, and take appropriate actions.

This category of tasks makes it possible to investigate real team behavior under controlled conditions. The focus of these tasks, however, is on the action aspects of team performance. Since judgments and decisions in these tasks are rule-based and become routine, little higher-level, non-routine, problem-solving processes are demanded. Weaver et al. (1995) already noted that although these simulations appear quite dynamic, in reality they do not allow for much complexity since the actions required from the team members are repetitive in nature and their roles are too well-defined. Consequently, these low-fidelity simulations do not fully satisfy the mentioned team research needs, as these needs also pertain to higher-level, complex problem-solving aspects of team performance (cf. Salas et al., 2008).

Purpose and Requirements

Since none of the above approaches seemed to be able to fully address the complexity present-day teams face in a controlled setting, we decided to develop a new task environment. This task environment had to initiate a research program on team performance in a complex, networked world. The environment had to permit controlled experimental team research on complex planning and problem-solving behavior. In terms of the described approaches, the environment was to be positioned between the low- and high-fidelity simulations.

Specifically, we formulated six requirements the task environment had to fulfill (also see Kamphuis & Houttuin, 2007). First, participants performing the task should exhibit *real team behavior*. In line with Salas, Dickinson, Converse, and Tannenbaum (1992), we defined teams as distinguishable sets of individuals who have each been assigned specific roles or tasks to perform and who work interdependently toward a common goal. The most important necessity stemming from this definition is that the task should have a division of roles with different specializations leading to interdependence among team members to reach the common goal.

Second, the task environment should be suited to study the *higher-level team processes that surface in complex environments*, in addition to processes that are necessary to accomplish rule-based tasks. The latter include processes such as decision making, information exchange, communication, supporting behavior, and team initiative (e.g., Smith-Jentsch, Johnston, & Payne, 1998), whereas higher-level team processes comprise processes such as information search and selection, hypothesis generation, planning and replanning, priority setting, and problem solving. To be able to measure these processes, the task should be constructed in such a way that teams need to demonstrate these processes to accomplish their goal. The task environment therefore should allow the possibility of a high information load to necessitate information selection; the use of different media to impose active information searching; new information becoming available during the task to necessitate adjusting and replanning; and complex problems that demand problem-solving behavior.

Third, the task environment should offer a *good degree of experimental control*. It should be possible to keep all circumstances constant across teams, including the events in the task. The task therefore should only be dynamic with respect to scripted changes, not with respect to participants' actions. In this way, differences in processes and effectiveness can be attributed solely to experimental manipulations.

Fourth, the task environment should allow *relatively efficient data collection*. More precisely, it should be possible to perform the task without specific foreknowledge and without extensive training in a relatively short amount of time. The task should be capable of being constructed in multiple comparable versions (to enable within team designs and practice rounds).

Fifth, the task environment should offer a broad range of *team process measurement possibilities*, both behavioral and self-report. It should be capable of taking unobtrusive, real-time automated behavioral measures (cf. Salas et al., 2008) and collect these in a single log file. In addition, it should offer the possibility of online, embedded questionnaires that have to be filled out during task performance. The task environment should allow the measurement of team cognition (e.g., Canon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994).

Finally, the software should allow a high degree of *flexibility*. Much of the existing software for investigating teams is intended for investigating specific research questions and does not leave much room for alterations in configuration (e.g., Kerr, Aronoff, & Messé, 2000). As a result of this, experimenters frequently have to develop their own software to be able to investigate a specific research question. The present task environment should address this problem and have a generic structure that can be tailored to specific research questions. It should be possible to investigate a wide array of research questions within the same task environment. The task environment should, for example, be suitable for Multi Team Systems research (Mathieu, Marks, & Zaccaro, 2001), and allow larger numbers of players, the configuration of multiple teams and multiple hierarchical levels.

PLATT

In response to these requirements we developed PLATT, a flexible software platform for controlled experimental research on team performance in complex environments. PLATT consists of a modular software architecture in which research-specific scenarios can be run. The software architecture is research question independent and guarantees a large degree of flexibility. The scenarios are developed on the basis of a theory-based research model, in response to specific research questions. Participants playing the scenarios receive messages, search for information on web sites, interact with a shared workspace and communicate with each other via e-mail. The scenarios can target different types of tasks, like planning, problem solving, and decision making. Moreover, the scenarios can take place in different operational contexts, for example, the military, organizational settings, or crisis management contexts. There is no limit to the number of participants that can join in a scenario.

Software Architecture

The PLATT software architecture (see Figure 2.1) is a distributed application. It consists of a Scenario Player, a Web Agent, and a Participant Interface with different components. In addition, there is a separate Data Analysis Tool. PLATT has been created using the *JADE agent platform*. JADE (Bellifemine, Caire, Poggi, & Rimassa, 2003) is a widespread agent-oriented middleware system, distributed as open source software under LGPL license. All distributed parts of PLATT (i.e., Scenario Player, Web Agent, and Participant Interface) are implemented as JADE agents that communicate using the JADE communication infrastructure.

The *Scenario Player* reads the configuration file and the scenario file. During an experiment, the Scenario Player sends scenario events to the team members and defines changes on the web sites they can visit. It also creates a log file with detailed information of all scenario events and all actions participants perform during task execution (i.e., sending, opening, and receiving e-mails, selecting web browser or shared workspace tabs, opening web pages, etc.).

The *Web Agent* keeps track of the access rights of different participants to web pages and registers the current version of a web page. Information on web pages can be made dynamic (i.e., changing over time) by creating different versions of the same web page, and having the scenario define which version of a web page should be available at what moment. When the web server receives a page request from a participant (via the web browser), it consults the Web Agent and handles the request in accordance with the access rights and the version information of the web page. If the participant has the proper access rights, the web browser shows the requested page in return.

Finally, the *Participant Interface* shows the different applications participants can use during the scenario. It consists of multiple windows positioned on top of each other. In the standard PLATT set-up, the Participant Interface contains three windows: an e-mail window, a web browser window, and a shared workspace window.

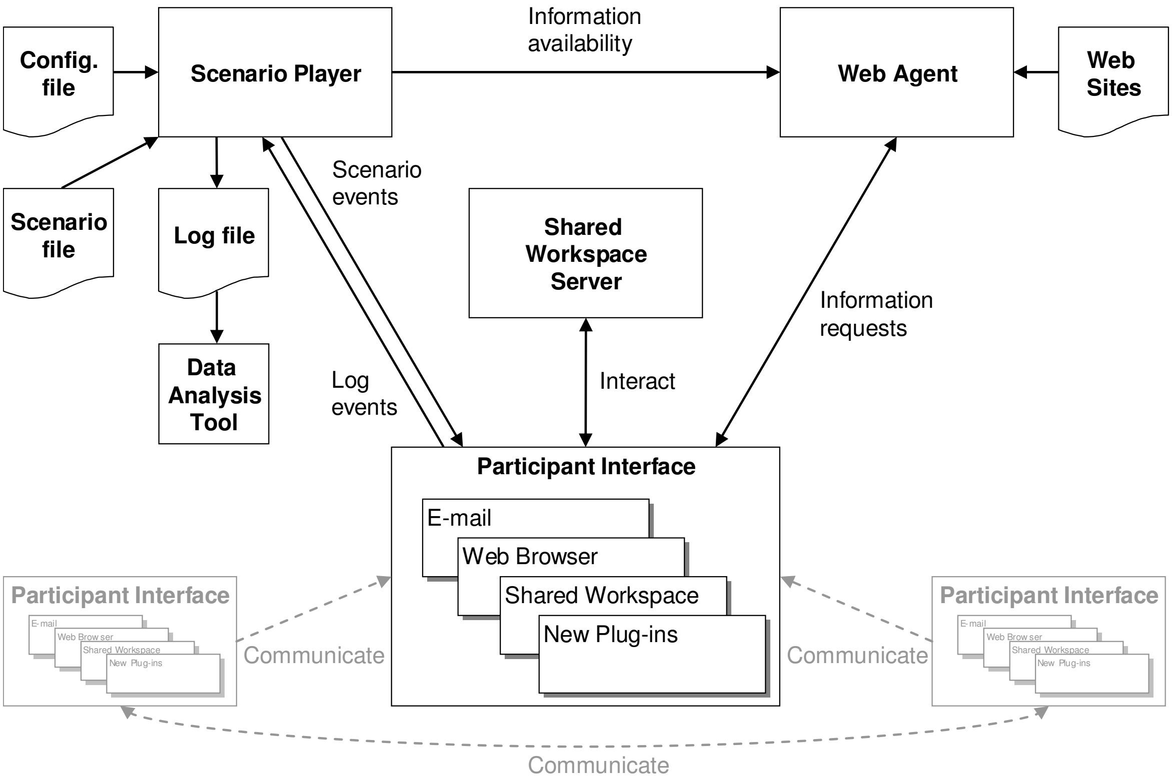

Figure 2.1
Schematic overview of the PLATT software architecture

When participants open their *e-mail* window, they can use an e-mail application to communicate with each other (via text messages). In this e-mail application team members also receive the scripted events sent by the Scenario Player. The events they receive can have different formats. An event can be a text message, an audio message, a video message, or a hyperlink to a web page.

In the *web browser* window, participants can search for additional information. This information is part of the scenario, and the scenario controls which information is available at what moment. The web browser allows for the presentation of virtually any textual, visual and multimedia content. Because of this, the scenario content can be as rich as the content that can be found on the internet.

The last window is the *shared workspace* window. The shared workspace is a digital area that allows for parallel viewing and editing by team members with the appropriate authorization. In this space, team members may work jointly on certain team tasks, or it may act as a common operational picture that is constantly being updated according to changes in the situation.

The client software has a modular design that has been established using a component framework. All participant applications (e.g., e-mail, web browser, shared workspace) are independent PLATT components that can be plugged into the framework and configured in the central configuration file. Every component is loaded on a new tab in the Participant Interface. This plug-in architecture makes it relatively easy for researchers to extend PLATT with new PLATT components using the framework software interface. Different kinds of shared workspaces have already been implemented and used in experiments (e.g., a digital editable map, a bulletin board for sharing e-mails, and a shared whiteboard). Similarly, different kinds of communication media could be plugged in (e.g., chat or video-conferencing), and different web browsers could be used. This modular design contributes to the flexibility of the PLATT software platform.

The *Data Analysis Tool* converts the log file of an experimental run into meaningful measures (e.g., total number of unopened e-mails as a measure of information selection). It uses the directory with log files as input and delivers one Excel sheet with team summaries and total summaries as output.

The complete configuration of an experiment is captured in a single file. This file defines the roles of participants, the communication structure of the team (or teams), and the interface components each participant receives. The file also defines what computer is assigned to what role. Using this information, the Scenario Player controls the starting, running, and stopping of all remote clients, making it no longer necessary to perform these actions at every separate participant workstation during the experiment.

Scenarios

The scenarios that run in the software architecture are composed of a scenario file, web sites, and content for the shared workspace (e.g., a map of the area). Scenarios can be written by experimenters for their own specific question. No programming knowledge is required, as the scenario files can be written in Excel format (spreadsheets). Scenarios can be tested by using the *accelerate* function of the Scenario Player. In this modus, the scenario unfolds at 10 times normal speed. This allows the experimenter to ensure that all events occur at the expected time, that hyperlinks direct to the right pages, that questionnaires automatically pop up, and so forth.

Scenario files consist of predefined events on a linear timeline. In the scenario file, every line is one event. The events fall into three categories. The first category of events consists of the messages that are sent to the participants. These messages can have text, audio, or video formats, and they may contain hyperlinks to web pages. For each event, the experimenter defines in the scenario file: the *time* at which the event should start; the *sender* of the message; the *recipient* of the event; the *subject* of the message; the *message* content; and, if applicable, the *hyperlink* that comes with the message.

The second category consists of changes in the information that can be found on the (scenario-specific) web sites. In the scenario file, the experimenter can define which version of a web page has to be accessible at what moment. In this way, the same web page can show different information at different moments. For these events, the experimenter has to define the *time*, the *recipient* (who is allowed to visit this webpage), the *hyperlink* to the web page, and the *version* of this web page.

The last category of events in the scenario file consists of hyperlinks that open automatically when the participant receives the link. This category is used for the online questionnaires participants have to fill out during the task. For these events, the experimenter has to define the *time*, the *recipient*, and the *hyperlink*.

Research Model

The development of a scenario is guided by the research model. The purpose of this model is to secure that the intended research will be about real team behavior, that it will be possible to measure relevant team processes, and that there will be a meaningful link between these processes and the team's performance. First, to measure real team behavior, there has to be task and goal interdependence between participants (for a taxonomy of different classes of interdependence, see Saavedra, Earley, & Van Dyne, 1993). In a scenario, the experimenter has to realize this by creating different roles, with different responsibilities, expertise, and tasks, for each of the team's members. In addition, the quality of the output of the team's performance on the scenario has to be dependent upon the input from every team member. The preconditions for team processes to emerge are fulfilled when the expertise from all team members is necessary to accomplish the task, and when team members are motivated to perform well as a team.

Second, the experimenter has to determine what team and task processes are of interest, given the research question, and how these processes can be elicited by the scenario. For example, if one is interested in supporting behavior, the scenario should incorporate situations or events in which there is an opportunity for team members to assist fellow team members with their task. This opportunity could be created by overloading one of the roles with information at a certain moment, while giving a fellow team member at that same moment the time and means to step in and help out. In addition, engaging in these processes needs to be relevant in view of the overall goal, because otherwise team members would not be required to demonstrate them.

Finally, the experimenter has to think about ways to make the relevant processes measurable. This can be done at the behavioral level, by, for example, designing critical events (events that need to be dealt with in a specified way), and investigating how participants dealt with these events on the basis of the log file. It can also be done at the cognitive level, by integrating online measurement techniques.

Scenario Example

As an example of a scenario that has been developed for PLATT, we describe a military evacuation scenario that has been used in a series of studies with military personnel and with civilians (e.g., Kamphuis, Gaillard, & Vogelaar, 2008, 2009c).

Task

In this scenario, participants have the assignment to develop a plan to evacuate a group of people from a hostile area to a safe place. More than a dozen routes can be used for the evacuation. The team has to determine the fastest route and plan how they will employ their transportation, engineer, and infantry units. Whether a route is appropriate does not only depend on the length of the roads, but also on the condition of these roads, and whether there are enemy activities on these roads.

Roles

The scenario contains three roles, each of which has its own responsibilities, expertise, and tasks: Operations, Intelligence, and Logistics. Operations has the leadership role and is responsible for coordinating the activities of the other team members. Operations is the only team member who is allowed to edit the shared map of the area in which the evacuation has to take place. Intelligence is responsible for all safety information and has unique expertise concerning determining the reliability of all information sources in the scenario. Logistics is responsible for personnel and materiel, and for the condition of the roads. Logistics has unique expertise concerning calculating the duration of the various routes. Every team member receives role-specific training.

Instruction

Teams receive approximately 30 minutes of instruction. This instruction consists of a 20-minute standard video with information about the team’s assignment and the use of the participant interface. Afterwards, team members receive a written instruction containing information about their own roles in the scenario. Every team member receives a different instruction, with role-specific knowledge and information.

Events

During the scenario, the team receives a large amount of information concerning road conditions, enemy activities, delays due to different causes, the position of their units, personnel and materiel problems, weather conditions, unrelated events, and so forth. This information varies in relevance and is sent by many sources differing in reliability. The information can be ambiguous, or in contradiction with information the team received earlier. The events in the scenario are constructed in such a way that at different moments different routes are optimal, so the team has to adjust initial plans and adapt to circumstances.

Websites

Both Intelligence and Logistics have access to web sites. Intelligence can search this web site for information concerning the safety of the roads in the area. Logistics has a web site containing information about the availability and the capacity of the units, and the condition of the roads. The scenario file controls changes in information on these web sites.

Shared workspace

The shared workspace in this scenario consists of a digital, editable map of the area in which the evacuation has to take place (see Figure 2.2). All three roles can view this map, but only Operations is allowed to edit it. Operations can put symbols in the map to indicate, for example, enemy activities, locations of units, and road conditions. In addition, Operations can use text to ‘write’ information in the map. These map-updates are visible to Intelligence and Logistics.

Potential Research Applications

Because PLATT makes it possible to write new scenarios for every specific research question, the opportunities to investigate team performance in complex environments are numerous. Already, scenarios have been developed for investigating team processes in complex problem-solving tasks, networked decision-making tasks, and crisis management tasks. In addition to having the capability to write different scenarios, or adjust existing scenarios for different research questions, experimenters also have the ability to choose different software

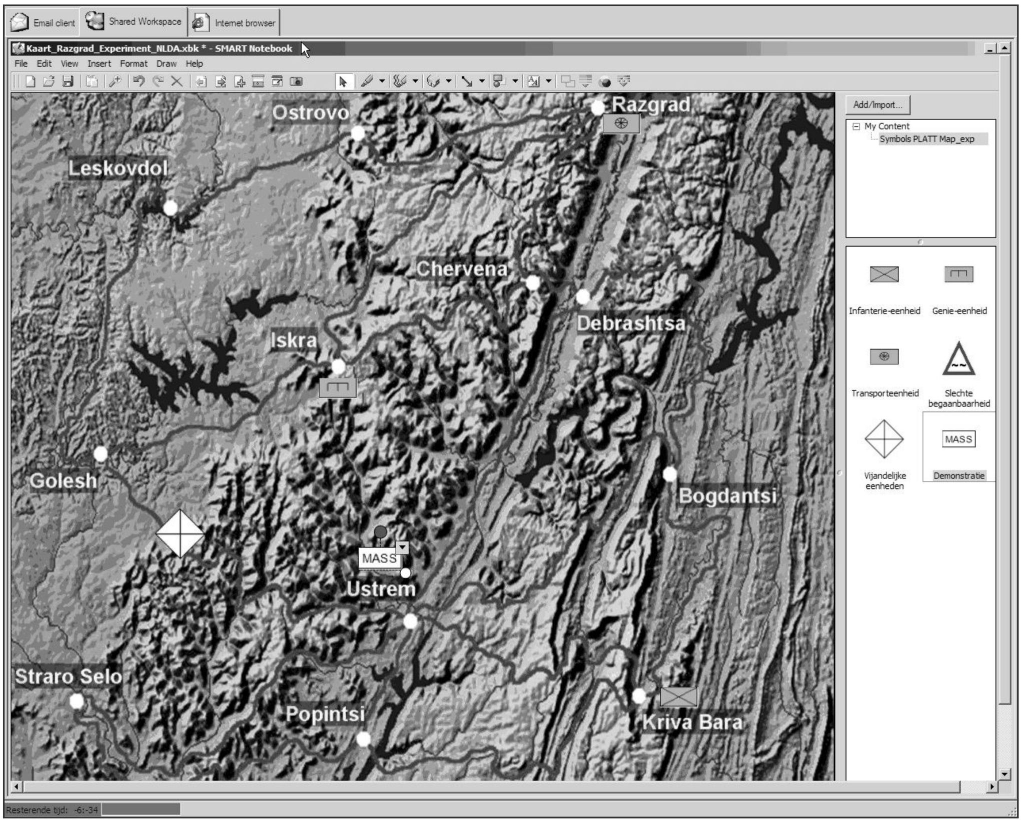

Figure 2.2

Participant interface showing the shared workspace of the military evacuation scenario. The symbols on the right hand side can be used to represent specific information in the map. The other two applications (e-mail and web browser) can be opened by clicking the tabs in the upper left corner.

configurations to investigate certain research questions. Below we give three examples of theoretically and practically relevant manipulations based on the software configuration.

Team Structure

In PLATT, it is possible to manipulate the team's structure by defining who can communicate with whom. In this way, different team structures can be compared to each other. In a team with three roles, for example, the experimenter could create a centralized team structure in which only one of the roles can communicate with both other roles, and both of the other roles can communicate only with this one role and not with each other. This could be compared to a decentralized situation in which every role is able to communicate with both other roles. Such a manipulation has relevance in light of the possibilities created by current information and communication technologies. Currently, lower levels in organizations ('the edges') can easily have all of the information necessary to make their own decisions at their disposal. Power and decision rights therefore could be given to these edges of the organization (Alberts & Hayes, 2003), leading to decentralized organization structures. By simulating these circumstances in PLATT, decision speed, accuracy, and effectiveness as well as other team measures (e.g., trust, shared awareness, and leadership) in self-organizing, edge team structures could be compared to traditional hierarchical team structures.

This functionality of PLATT is comparable to the characteristics of another recently developed software environment for team research called ELICIT (Experimental Laboratory for Investigating Collaboration, Information-sharing and Trust; Ruddy, 2006, 2007). ELICIT has been developed to compare traditional command and control, hierarchical organizational structures with networked, self-organizing, edge organizational forms in decision-making tasks (Ruddy, 2007). ELICIT requires teams of 17 members to collaborate in a network-centric environment to identify the who, what, where, and when of an adversary attack. In order to solve this puzzle, participants receive information elements (called factoids) containing information corresponding to the four kinds of information required. As standard experimental manipulation, participants receive instructions about the nature of their organizational structure (either hierarchical or edge) and the ways they can exchange information with team members. Team members exchange information by posting factoids on common screens, or sending factoids directly to one another. No other communication is possible. Eventually, team members individually have to indicate their solution to the problem.

ELICIT certainly appears to be an interesting environment to investigate differences between hierarchical and edge organizations in a controlled, experimental manner. Similar research questions can be addressed in PLATT too. However, PLATT has the advantage that fewer participants are required for experimental runs. In addition, researchers can configure the PLATT software themselves in many ways, and consequently any organizational form can be created and investigated. Moreover, in PLATT, participants are allowed to communicate with each other via e-mail, ensuring more realistic teamwork processes. Because of this, and because of other PLATT features (e.g., the individual web sites) more diverse process and outcome variables can be measured using PLATT.

Information Sharing and Team Virtuality

Another software-based manipulation, related to the one above, pertains to the distribution of information within the team. The experimenter has the ability to define which role has access to which information on the web sites. In addition, the experimenter determines who can view the shared workspace and who cannot. With these manipulations it is possible to investigate the effects of shared information (information held by all group members) versus unshared information (information only held by one group member) on decision making in groups. Since the introduction of the biased sampling model of group discussion by Stasser and Titus (1985), an extensive line of research has investigated information pooling behaviors in groups. Many studies have shown that teams perform suboptimally because they spend more time discussing shared information than unshared information. In so doing, teams are not employing the informational advantage they should have over individuals (see for a recent meta-analysis Mesmer-Magnus & DeChurch, 2009).

The great majority of studies in this domain has used hidden profile tasks (e.g., select the best candidate), in which shared information supports an inferior alternative, whereas unshared information supports a superior option (Stasser & Titus, 1985). The external validity of these tasks has been questioned (Mohammed & Dumville, 2001) and the Mesmer-Magnus and DeChurch (2009) meta-analysis showed that the relationship between information sharing and team performance is partly caused by the use of these hidden profile tasks. In addition, in this paradigm the primary dependent variables of interest have been the number of times particular information is mentioned and the quality of the decision made. Other team processes and team cognition have received far less attention. Researchers therefore have called for new directions within this research domain (e.g., Mesmer-Magnus & DeChurch, 2009). PLATT could be a useful platform to facilitate this research, because scenarios can be made more realistic, and a broad range of process and outcome measurement possibilities are available (see below). In addition, in PLATT different software-based manipulations are possible that make research in new directions feasible. One of the new proposed research directions, for example, pertains to virtual teams (Mesmer-Magnus & DeChurch, 2009). This research should examine information sharing under various configurations of team virtuality (as determined by the team's use of virtual tools, the informational value of these tools, and the synchronicity of team member interactions; Kirkman & Mathieu, 2005). PLATT can be configured to conduct this kind of research, because the experimenter can manipulate the level of team virtuality by, for example, varying communication media (e.g., e-mail, voice-, and video-conferencing), the access to the digital shared workspace, and the nature of this digital shared workspace (e.g., a map of the area or a postings board).

Multiteam Systems

Another new direction in information sharing research proposed by Mesmer-Magnus and DeChurch (2009) concerns the area of multiteam systems. Recently, organizations have begun to employ this new form of work arrangement. In a multiteam system two or more teams work interdependently toward the accomplishment of at least one collective distal goal, while at the same time pursuing different proximal goals (Mathieu et al., 2001). Team researchers have stressed the need for research in this area (e.g., Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005; Mesmer-Magnus & DeChurch, 2009). In PLATT, it is possible to conduct this kind of research. Multiple teams can be defined, each with their own website and shared workspace. In addition, these teams may also have a workspace and website that is shared across teams. The experimenter can define which role within a team has the rights to communicate with members of other teams. This makes it possible to define different hierarchical levels: one level where two or more teams primarily work to attain their own proximal goals and a higher level where representatives of these teams work towards accomplishment of the common, more distal goal. All kinds of variations are imaginable, with different roles responsible for maintaining contact with the other teams, different ways of framing the goal hierarchy, and different hierarchical structures.

Measures

PLATT offers the experimenter a broad range of measurement possibilities, both behavioral and self-report. In line with the plea of Cooke, Salas, Kiekel, and Bell (2004), these measurement possibilities are both automated and embedded. Automated behavioral measurement takes place as a result of logging by the Scenario Player, and online embedded questionnaires can be integrated in the scenario, enabling the measurement of team cognition. In this way, task disruptions due to measurement are reduced, experimenter measurement errors are minimized, and experimenter costs are lowered. Additionally, these real-time measurement possibilities allow for the measurement of the more dynamic aspects of team processes and team cognition (e.g., Cooke, Salas, Cannon-Bowers, & Stout, 2000).

Behavioral

As we mentioned above, the scenario player creates a log file with detailed information of all scenario events and all actions participants perform during task execution. On basis of this information different real-time unobtrusive measures can be constructed with help of the data analysis tool. The experimenter can, for example, construct measures concerning information processing (e.g., number of web site visits, selective attention to information, and time spent on shared workspace) and communication (e.g., number of e-mails, use of subjects in headings, and content of communication). In addition, it is possible to measure behavioral indicators of relevant cognitive constructs (e.g., Cooke et al., 2000).

As an example, consider the use of behavioral indicators to measure the functioning of *transactive memory systems* (TMSs). A TMS consists of a set of distributed, individual memory systems that combines the knowledge possessed by particular members with shared awareness of who knows what (Wegner, 1995). At the behavioral level, a TMS is indicated by directory updating, information allocation, and retrieval coordination (Wegner, 1995). Through directory updating, team members learn about each other’s areas of expertise. Through information allocation and retrieval coordination, information is communicated to and retrieved from the teammate with the relevant area of expertise (e.g., Ellis, 2006; Hollingshead, 1998).

Whereas directory updating only depends on the content of the communication, information allocation and retrieval coordination depend on both communication content and communication flow. In PLATT, both communication content and communication flow are automatically recorded in the log files. As a result, to generate the behavioral indicators of a TMS, only communication content has to be coded. Subsequently, these codes can be inserted in the log file and the data analysis tool can calculate the percentage of e-mails in which information was allocated to or retrieved from the team member with the relevant area of expertise. These measures then constitute the behavioral indicators of information allocation and retrieval coordination (cf. Ellis, 2006).

Online Embedded Questionnaires

The experimenter has the possibility to integrate hyperlinks to online questionnaires in the scenario. When the scenario reaches the specified time, these questionnaires are sent to the participants and opened automatically, forcing them to fill out the questionnaire before they can continue with the task. Because the questionnaires are embedded, it is possible to get measures from different team members and measures across teams at precisely the same time. The timing and content of these questionnaires can be tuned to the events in the scenario.

This facility poses numerous possibilities. For example, to assess the team members' situation awareness (SA), one could use the embedded questionnaires to administer SAGAT (situation awareness global assessment technique; Endsley, 1995) type measures. In the military evacuation scenario, this could be realized by asking participants about their awareness of, for example, enemy activities, road conditions, and positions of the units, and about the ways in which this influences different evacuation routes. Depending on the scenario, it is also possible to take implicit measures of SA, by querying the participants at different moments during the scenario which solution would be best at that moment. To answer this question correctly, participants need to be aware of the relevant elements in the situation, comprehend how they affect different solutions, and how they will to develop over time. With this kind of measures, the accuracy of individual SA can be assessed, but also the degree to which team members are in agreement with regard to the relevant aspects of the situation (Shared Situation Awareness).

Other applications would include workload measurements, mental model measurements, and mood measurements, for example. Of course, this functionality of PLATT can also be used to administer questionnaires after teams have completed the scenario, to measure more static constructs and team outcomes like satisfaction and cohesion.

Outcome Measures

The outcome measures are scenario-specific. The experimenter has to develop a method to measure team performance objectively. In addition, the performance measures should logically relate to the assignment the team received and the processes the experimenter is interested in (e.g., Smith-Jentsch et al., 1998).

As an example, consider the performance measures in the military evacuation scenario. These measures consist of the quality of the route the team has chosen and the number of errors the team has made in planning the route. In order to arrive at these measures, the experimenter has to score a standardized form that the team has to fill out at the end of the scenario. On this form, teams have to (a) indicate via which route they plan to evacuate the group of people; (b) mark on three separate timelines how they plan to make use of their infantry, engineer, and transportation units; and (c) specify how much time the evacuation will take, considering the chosen route and the planned employment of units.

The scenario has been constructed in such a way, that all possible routes can be put in order from fastest to slowest, to make objective comparison of routes in line with the assignment of the team possible. Due to events in the scenario the most obvious routes eventually turn out to be the slowest ones and the less obvious routes turn out to be the fastest. As a result, the better teams process the events, the better the routes they will choose. The events are distributed in such a way that independent of the route teams choose, they always need to employ all their units. This guarantees a similar possibility of making errors across different routes.

Experiments Using PLATT

To date, PLATT has been used in four different research programs, to investigate (a) the effects of threat on the performance of teams during complex problem-solving tasks, (b) self-synchronization in teams, (c) the effects of a serious gaming intervention on the performance of ad hoc teams, and (d) the effects of team structure on team decision making. Below, we briefly describe the scenarios that have been developed for these studies, and the results that have been obtained. The results of these studies are described in more detail elsewhere (i.e., Kamphuis, Gaillard, & Vogelaar, 2008, 2009c; Van Bezooijen, Vogelaar, & Essens, 2009a, 2009b; Langelaan & Keeris, 2008; Schraagen, Huis in 't Veld, & Koning, 2009).

Team Performance under Threat

The above described military evacuation scenario has been developed to investigate the effects of threat on the performance of teams during complex problem-solving tasks. In this research, special attention was paid to effects on information processing, communication, supporting behavior, leadership, and transactive memory. Two studies were conducted. In the first study, threat was manipulated external to the task, as a between teams variable (Kamphuis et al., 2008). The second study used a 2 × 2 between-teams design, and investigated to what extent a brief transactive memory training intervention prior to task performance could mitigate the effects of threat on team performance (Kamphuis et al., 2009c). Results of these studies showed that in complex problem-solving environments, threat leads to a restriction in information processing and more controlling leadership. In addition, threat leads team members to shift from a team perspective to an individualistic focus, affecting transactive memory and teamwork processes. A brief transactive memory training intervention has the ability to moderate the negative effects of threat on team perspective, eventually resulting in better team performance (Kamphuis et al., 2008, 2009c).

Self-synchronization in Teams

Different military evacuation scenarios have been developed for research on self-synchronization (the undirected alignment of team members' actions with those of others in a network in light of overall objectives). Two studies were conducted in this line of research. The first study investigated the effects of leadership style on team situation models, self-synchronization, and coordination processes in teams (Van Bezooijen et al., 2009b). Results indicated that participative leadership resulted in higher similarity of the team situation model when task complexity was low, whereas directive leadership resulted in higher similarity when task complexity was high. The second experiment investigated the effects of the presence or absence of synchronous groupware (i.e., the shared workspace) on self-synchronization in teams. Preliminary results of this study indicated that the use of synchronous groupware in teams not necessarily improves synchronization and coordination processes (Van Bezooijen et al., 2009a).

Preparation of Ad Hoc Teams

For research on the preparation of ad hoc expert teams, a crisis management scenario has been developed. The goal of this research was to develop and test a game environment that can be used to enhance collaboration of professional ad hoc teams, in a short amount of time. For this purpose, an alternate reality game-like scenario has been developed in PLATT, in which participants are confronted with a breakdown in the water supply, and have to find out via all kinds of media what caused this breakdown and solve the problem. In a pilot study, ad hoc teams who had participated in this scenario were compared to ad hoc teams who had played different board games (e.g., Trivial Pursuit) together for the same length of time, on their performance on a second, unrelated team task (Langelaan & Keeris, 2008). Results of this study indicated that the scenario approach, in which participants are forced to work together, seems to be a promising method to improve collaboration in ad hoc teams and enhance the building of trust between team members, in a short amount of time.

Team Structure and Team Decision Making

For research on the differences in decision making between hierarchical teams and networked teams, a scenario was created about an explosion in a tunnel were a group of high-ranking politicians was about to pass through. Teams had to decide as quickly and as accurately as possible what the likely cause of the incident was: an attack by Al Qaeda, an attack by anti-globalists, or an accident. In order to do this, each team member had received role-specific training in one of these areas, to be able to identify incidents linked to their area of expertise. The experimental manipulation aimed to simulate the differences between hierarchical and networked teams and consisted of differences in team composition and task division, different decision rights, different communication media, and different information sharing facilities (Schraagen et al., 2009). The results showed that networked teams were overall faster and more accurate in their decisions than hierarchical teams. Networked teams also shared more knowledge with each other.

Conclusion

As the complexity of the workplace continually grows, teams increasingly will be confronted with complex cognitive tasks. More and more, they will have to perform these tasks as virtual teams in networked structures in close collaboration with other teams. Theories of teamwork and methods of measurement must keep pace with these developments to meet the demands from organizations for guidance on management and structuring of teamwork (cf. Salas et al., 2008). In response to these developments, we created a flexible software platform for research on team performance in complex environments, called PLATT.

PLATT should enable controlled experimental research into team planning, problem-solving and decision-making behavior in a complex, networked world. The development was guided by a set of six requirements we thought were pertinent to be able to conduct such research. The application of PLATT in a broad range of experiments in different research programs has shown that PLATT has the ability to meet each of these requirements. Because of the chosen approach of creating a scenario-independent, flexible software architecture in which different research-specific scenarios can be run, some requirements are met in the software architecture, and others are met in the specific scenarios. In all cases, however, the PLATT software architecture offers the possibility to fulfill the specified requirements.

First of all, PLATT allows researchers to investigate *real team behavior*. The formulated research model that guides the development of the scenarios for PLATT delineates that the experimenter has to create task and goal interdependence in the scenario. This can be done by creating different roles with different responsibilities, expertise, and tasks, for each of the team's members, and making the team's performance dependent upon input from every team member. The software platform is flexible to such an extent, that no matter how interdependence has been created in the scenarios, it can be run in PLATT.

Second, PLATT is suited to investigate *planning, problem-solving and decision-making processes of teams in complex environments*. The scenario-driven nature of PLATT makes it possible to create dynamism by constantly changing the existing situation through letting new information become available. It is also possible to overload participants with information. In addition, the modular set-up allows the use of different media as sources of information (i.e., e-mails, audio messages, video messages, and web sites), to add to the complexity. Again, the specific design of this complexity and the nature of the task depend on the scenario. In the scenario, the different roles are defined, the problem is created, wrong tracks are set out, and the clues for solving the problem are concealed.

Third, PLATT offers a *good degree of experimental control*. All circumstances and events can be held constant, and the experimenter has the possibility to manipulate the variables of interest. Because scenarios do not change in response to participants' actions, all teams have to deal with exactly the same circumstances, as a result of which measures across teams can easily be compared. PLATT also offers excellent ways of controlled measurement. Behavioral measures are automatically collected by logging all participants' actions. This precludes measurement errors due to observer failures. In addition, PLATT allows the administering of embedded, online questionnaires. This possibility assures that questions can be asked at the right moment and that the questionnaires can be administered at precisely the same time across team members.

Fourth, PLATT allows *relatively convenient data collection*. All scenarios that have been developed thus far, could be played by participants without specific foreknowledge and without extensive training. Typically, teams would receive an instruction of about 30 minutes (partly by video). This instruction would contain information concerning the use of the participant interface and information pertaining to the specific task they had to perform. The scenarios that have been developed for experimental data collection on average take about half an hour to three quarters of an hour to play. Evidently, it would also be possible to create longer or shorter scenarios. Overall, a complete experimental run including reception of participants, instruction, actual task performance, questionnaires and debriefing would take, on average, two hours. In addition, it is possible to construct multiple comparable scenarios to enable within team designs. This could further reduce the time spent on data collection. For a complete experimental run, only one experimenter is necessary. There is no need for observers because all relevant behaviors are collected automatically and there is no need for supporting players in the scenario, because all events are scripted in advance.

Fifth, PLATT offers a broad range of *team process measurement possibilities*. As we elaborated above, the scenario-player in PLATT creates a log file with all actions participants performed. On basis of this log file, the experimenter can construct real-time behavioral measures with help of the data analysis tool. In addition, the experimenter has the possibility to use online, embedded questionnaires to measure processes of interest. As outlined above, both types of measures can also be used to measure team cognition (either as an externalized process, or as self-reported knowledge).

Finally, the PLATT software allows a high degree of *flexibility*. This flexibility stems from the fact that (a) the software architecture is scenario-independent, (b) the software itself has a modular set-up, and (c) different configurations can be defined regarding communication possibilities and access rights. Because the software architecture is scenario-independent, every experimenter can develop his or her own scenario that is ideally suited to investigate a specific research question. Because the software-architecture has a modular set-up, experimenters can choose which parts of the software they want to use for their own research. For example, one could choose to use only the e-mail application, because the web-server and the shared workspace do not have to be used in a scenario. In addition, due to this set-up it is relatively convenient to add other components to the software, for example, to allow for video-conferencing or to test different shared workspaces against each other. Because of the possibilities to define who can communicate with whom and who has access to what, PLATT also has the flexibility to configure for multiple teams and multiple hierarchical levels.

There are some considerations for researchers intending to use PLATT. First, development of a scenario takes time. The development of a basic scenario, for a research question that does not necessitate much complexity, could be a matter of hours. Researchers who want to make use of the full array of possibilities PLATT has to offer, on the other hand, should expect a greater time investment. This is an inherent consequence of the complexity that can be incorporated in PLATT and the flexibility it allows for. Writing a 4-hour scenario for multiple teams, with lower-level and higher-level goals, using text-, audio-, and video-events, dynamic web sites, and different kinds of shared workspaces, will be more a matter of weeks than days. However, different scenarios have already been developed, and as the use of PLATT as a team research platform grows, more and more scenarios will be added to this collection. Researchers could draw existing scenarios from this pool, and adapt these scenarios to their specific wishes.

Another issue, which surfaced during the first studies that used PLATT, is the process-outcome relationship. It proved to be difficult to establish a strong relationship between team processes and team performance. In organizational settings, this problem is not uncommon, because team performance may for a large part be determined by external circumstances and coincidence (cf. Smith-Jentsch, et al., 1998). In controlled, experimental studies, establishing this relationship is normally less complicated. Because PLATT scenarios can be quite complex, however, the first studies using PLATT suffered from the same problems as studies in applied settings. To overcome these problems we developed the research model described above, which stimulates researchers to think of the scenario in terms of team processes. This model stipulates that a scenario should be constructed in such a way that it elicits the processes the researcher is interested in. For the team, engaging in these processes should be relevant in view of their overall goal. The performance measure chosen, in turn, should be an appropriate operationalization of this goal. This operationalization should be proximal to the teams' processes rather than distal to it. When researchers approach scenario development in this way, the process-outcome relationship will be established more easily (see, for example, Kamphuis et al., 2009c).

Finally, as described, the log files make it possible to construct a variety of measures of participants' behaviors. Although this possibility has a number of advantages, as we described above, it should be used heedfully. Researchers constructing measures on the basis of the log files are likely to regard these measures as behavioral indicators of some latent construct. However, it might be difficult to determine the validity of such a measure, when it has not been used before. In such cases, it might be advisable to combine these behavioral measures with other (validated) measures, to determine the validity of the behavioral measure.

All things considered, PLATT has already proven to be a flexible platform that facilitates research into a wide array of team related research questions. It provides researchers with an environment to investigate the complex issues present-day teams face and has the ability to meet the demands of the future of team research.

Hardware/ Software Requirements and Availability

To be able to run PLATT, one PC for the scenario server and separate PCs or laptops for each participant are necessary. The PLATT software runs on computers with the Microsoft Windows XP operating system. Other software required is Windows XP Service pack 2, the Microsoft .NET 3 framework, and the Visual J# redistributable package. The computers must be connected by a network connection. Although the hardware demands of the software are not particularly high, it is recommended to use systems that smoothly run the Windows XP operating system and standard applications like Microsoft Office. The software is expected to run on Microsoft Vista and newer versions of the .NET framework. PLATT is available to interested researchers. Requests should be addressed to the author of this thesis.

Chapter 3

The Effects of Physical Threat on Team Processes During Complex Task Performance[1]

Teams have become the norm for operating in dangerous and complex situations. To investigate how physical threat affects team performance, 27 three-person teams engaged in a complex planning and problem-solving task, either under threat or under normal conditions. Threat consisted of the possibility that during task performance the oxygen level would be reduced (which, in reality, did not occur). Team processes were measured by automated behavior recordings and questionnaires. Results confirmed that threat caused restrictions in information management, more controlling leadership, less group discussions, and a reduction in coordination and supporting behavior. These results support the propositions of the threat-rigidity thesis and extend previous research by establishing these results for physical threat and demonstrating effects on coordination and supporting behavior as well.

The use of teams in dangerous and complex environments poses a paradox. On the one hand, teams seem to be perfectly suited to deal with these situations, because of the wide variety of capabilities individual team members may have. This makes a team a highly flexible, adaptable, and resilient system. On the other hand, teams can be vulnerable in these situations, because the interdependency between team

[1] This chapter is based on Kamphuis, Gaillard, & Vogelaar (2009d).

members results in a need for information exchange, coordination, and communication. Even a small weakness somewhere along the line may have disastrous consequences. Despite this vulnerability, teams are often the preferred choice when it comes to dealing with complicated problems in hazardous settings.

It is essential to understand in what way threats affect the processes in teams during these complex tasks. Only then will organizations be able to develop adequate measures to arm their teams against the potentially negative effects of these threats. Several researchers have noted that we are only beginning to understand how threat affects the performance of teams (e.g., Burke et al., 2004; Turner & Horvitz, 2001). For a more thorough understanding, research is necessary that adequately addresses the kinds of threats these teams face, takes into account the complexity of the tasks they have to perform, and objectively captures the relevant processes. As far as we know, up till now no research has experimentally investigated the effects of physical threat on team processes during complex tasks. Previous research either did not manipulate physical threats, or investigated team performance on less complex tasks, or both (e.g., Argote, Turner, & Fichman, 1989; Cannon-Bowers & Salas, 1998b; Driskell, Salas, & Johnston, 1999; Driskell & Salas, 1991; Ellis, 2006; Gladstein & Reilly, 1985; Harrington, Lemak, & Kendall, 2002).

Therefore, we conducted an experiment to gain more insight into the effects of physical threat on complex team processes. Three-person teams were examined while working on a planning and problem-solving task under physical threat. We focused on the processes of information management, leadership, communication, coordination, and supporting behavior (e.g., Smith-Jentsch, Johnston, & Payne, 1998). We measured these constructs in two ways: objectively at the behavioral level and with self-report data. Here, we will demonstrate how a physical threat affects the manner in which teams search for and share information, how leadership is exercised, and how the team members coordinate their actions and support each other while performing a complex task.

Theory and Hypotheses

Team Performance in Demanding Environments

In the past decades, organizations have shifted from individual-based to team-based work structures. Nowadays, organizations rely on teams to operate equipment, to produce goods, to solve problems, to manage projects, and to make decisions. Teams have also become the norm to operate in complex and potentially dangerous environments, where small mistakes may have disastrous consequences. Consider, for example, flight crews, military teams, and teams in high hazard industries. Numerous incidents with these teams have shown that they can not always cope with the demands placed on them. Researchers therefore have started to study team performance in demanding environments (e.g., Cannon-Bowers & Salas, 1998b; Driskell & Salas, 1991; Driskell et al., 1999; Ellis, 2006). The focus of these studies has been the question of how stress influences the performance of teams and how the problems stress poses can be mitigated.

Most of the above mentioned studies manipulated task-related stressors like time pressure and workload to create stress (e.g., Cannon-Bowers & Salas, 1998a; Gladstein & Reilly, 1985). Some studies also used threat (either social or material) as an additional stressor (e.g., Argote et al., 1989, Ellis, 2006). According to Lazarus and Folkman (1984), threat is one of the major determinants of stressful appraisals. Threat can be defined as a possible impending event perceived by a person or group of persons as potentially causing material or immaterial loss to, or the obstruction of goals of that person or group of persons (cf. Argote et al., 1989; Lazarus, 1966; Staw, Sandelands, & Dutton, 1981; Turner & Horvitz, 2001). Turner and Horvitz (2001) stated that our understanding of the performance of teams under threat is still in its infancy. They attributed this to the difficulties of manipulating threat in experimental settings. This applies a fortiori to physical threat. Physical threat, however, is an integral part of the environments in which, for example, fire fighting, police and military teams have to operate. In addition, in many other professions too, teams increasingly have to deal with physical threat and violence (e.g., ambulance crews, emergency response teams, and security personnel).

Moreover, the effects of physical threat on team performance may be different from stressors like time pressure and workload, because these latter stressors are dependent on performance of the task (cf. Driskell & Salas, 1991; Turner & Horvitz, 2001). Time pressure, for example, demands speed of response. As such, it causes team members to attend to a more restricted range of cues and engage in more heuristic information processing (cf. the *Attentional Focus Model*, Karau & Kelly, 1992; Kelly, Jackson, & Hutson-Comeaux, 1997; Kelly & Karau, 1999). A physical threat per se has no implications for the manner in which one has to perform his or her job, and therefore might have other effects than task-related stressors. Often, the physical threats these teams encounter may not be controllable. As such, they are likely to cause severe effects on performance (see, for a review of the effects of the controllability of threat: Thompson, 1981; also see

Blascovich & Tomaka, 1996). Since threat plays an important role in stressful appraisals, and because physical threat is a daily reality for teams that have to operate in hazardous settings, in this study we investigated the effects of an uncontrollable, physical threat on team performance. Specifically, we examined how a physical threat affected five important team processes.

Threat-Rigidity in Teams

Important team processes that have been identified in most models of team performance are information management, leadership, communication, coordination, and supporting behavior (e.g., Cannon-Bowers & Salas, 1997; Essens et al., 2005; Smith-Jentsch et al., 1998). In the present study, we investigated these five critical team processes. Previous research indicates that team processes under threat are characterized by rigidity. The most comprehensive theory addressing these effects is the threat-rigidity thesis (Staw et al., 1981).

The threat-rigidity thesis states that a system reacts to a threat with two types of rigidity: a restriction in information processing and a constriction in control. Restriction in information processing may manifest itself in a narrowed field of attention (attention to dominant cues and away from peripheral cues), reduction in the number of alternatives considered, and reliance upon internal hypotheses and prior expectations. Constriction in control is demonstrated by authority becoming more centralized, with fewer people making the decisions. Together these effects cause a system to emit its most well learned or dominant response (Zajonc, 1966). This dominant response may either be adaptive or maladaptive, depending on the environment in which it is produced. In an unchanged, stable and predictable environment, a dominant response that was previously successful can be successful again. Conversely, in a changing, ambiguous, and unpredictable environment, a dominant response can be maladaptive, because in this environment the dominant response may no longer be appropriate and flexibility rather than rigidity is necessary to survive (Staw et al., 1981).

On the basis of the threat-rigidity thesis, propositions can be formulated directly for the team processes of information management, leadership, and communication, and indirectly for coordination and supporting behavior. It appears that only four studies have explicitly tested the threat-rigidity thesis at the team level (Argote et al., 1989; Driskell & Salas, 1991; Gladstein & Reilly, 1985; Harrington et al., 2002). Below we review the results of these studies.

Information management

Information management concerns the process of scanning the environment in search for relevant information, gathering this information and employing it for specific purposes, such as planning or decision-making. Staw et al. (1981) proposed that under threat teams react with a restriction in information processing, for example by ignoring new or peripheral information and deviating opinions (cf. Janis's, 1972, concept of groupthink). Two studies addressed this proposition at the team level and supported it. Gladstein and Reilly (1985) found that team members participating in a management simulation reported having used less information to make a decision when they were faced with a financial threat. Furthermore, Harrington et al. (2002), investigating rigidity in decision making in a student team project found that teams under high threat (assessed on the basis of the relative weight of the project on the students' grades, the level of competition, time pressure, and the complexity of the project) reported to have used a more rigid approach to the decision making process. However, they measured rigidity with a single measure, consisting of both restrictions in information processing and constrictions in control, as a result of which conclusions for each of the concepts separately should be drawn with caution.

Both these studies showed that under non-physical threats, team members restricted their information processing. To investigate how a physical threat affects the manner in which teams manage information, we assessed the way teams dealt with peripheral information and the extent to which they were able to keep an overview of the situation. We hypothesized that in teams performing a complex task, physical threat leads to a restriction in information processing such that:

Hypothesis 1a. *Teams under threat will show less attention to peripheral information than teams under normal conditions.*

Hypothesis 1b. *Teams under threat will experience more problems in maintaining an overview of the situation than teams under normal conditions.*

Leadership and communication

The threat-rigidity thesis states that under threat there will be a constriction in control. When teams face a threat situation, power will become centralized and leaders will become more likely to make decisions on their own, without consulting their teammates (Staw et al., 1981). This component of the threat rigidity thesis has implications for both leadership (i.e., directing, controlling, setting priorities, and keeping track of the team's progress) and the structure and content of communication (i.e., providing and requesting information, and discussing strategies and decisions) within the team. Results of studies explicitly testing this proposition from the threat-rigidity thesis are equivocal. Two studies found evidence for its occurrence. Argote et al. (1989), in an experimental study using a simple laboratory team task, found that higher levels of perceived (material) threat were associated with more centralized communication structures, which is an indication of a constriction in control. Furthermore, Harrington et al. (2002) found a general rigidity effect in teams experiencing high levels of threat. This effect encompassed the notion of a constriction in control. Though, as was mentioned above, they only obtained a single measure for restriction in information processing and constriction in control.

However, two other studies failed to find evidence for a constriction in control. Gladstein and Reilly (1985) did not find an increase in centralization of authority under a high level of threat in their management simulation study. Moreover, Driskell and Salas (1991) found that both low and high status participants in a laboratory study on decision making in dyads became more receptive to information provided by their partner when under physical threat of tear gas. This result indicates a loosening of control rather than a constriction in control under threat.

To summarize, these four studies provide no clear answer as to whether threat leads to a constriction in control. In fact, other studies not explicitly addressing the propositions from the threat-rigidity thesis, also found apparently contradictory results. For example, Brown and Miller (2000) found no effects for time pressure on the degree of centralization of communication in decision-making groups. Similarly, Lanzetta (1955) found that stress resulted in more collaborative, mediating and cooperating behaviors and a more democratic approach to problem-solving in groups. On the other hand, Foushee and Helmreich (1988) observed that crew members of airline flight crews depended more on their crew captain under high stress conditions, providing less task information and placing responsibility for decisions in the hands of their captain. Also, Klein (1976) found that team members saw their leaders as more competent as stress increased, and attributed more responsibility to them if they acted in a leader-like fashion in a stress situation. Similarly, Janis (1954) and Hamblin (1958) found that members of groups were more likely to accept directions from their leaders in situations of stress. In addition, Halverson, Murphy, and Riggio (2004) showed that leaders in three-person groups behaved more charismatically under stress, which in turn enhances the likelihood of team members becoming more susceptible to their influence (e.g., Shamir, House, & Arthur, 1993).

The above mentioned findings for the effects of threat and stress on leadership in teams seem irreconcilable. However, one important factor could probably explain these mixed results: the presence (or absence) of formal leadership in the teams investigated. It seems that in all the studies that failed to find evidence for a centralization of authority under stress, no formal leader was present from the start (i.e., Brown & Miller, 2000; Driskell & Salas, 1991; Gladstein & Reilly, 1985; Lanzetta, 1955). Group members in these studies all had similar roles or, at the most, differed in status (i.e., Driskell & Salas, 1991). However, every study that did have formal leaders from the start reported results in line with the idea of a centralization of authority (i.e., Foushee & Helmreich, 1988; Halverson et al., 2004; Hamblin, 1958; Janis; 1954; Klein; 1976). Therefore, it might be that only when a team has a formal leader who has been assigned the final responsibility for the team's performance, constriction in control under threat and stress emerges.

The present study contributes to the debate by investigating the effects of a physical threat on leadership style in teams with an assigned, formal leader. In addition, we examined how much team members deliberated, since in strictly controlled teams the members are less frequently consulted and participate less in the decision-making process (e.g., Borkowski, 2005; Hermann, 1963). On the basis of the above line of reasoning, we proposed that in teams with formal leadership, physical threat leads to a constriction in control such that:

> Hypothesis 2a. *Leaders under threat will exert more control than leaders under normal conditions.*
> Hypothesis 2b. *Leaders under threat will be less participative than leaders under normal conditions.*
> Hypothesis 3. *Teams under threat will engage in less deliberation than teams under normal conditions.*

Coordination and supporting behavior

The threat-rigidity thesis makes no explicit predictions regarding the critical team processes of coordination and supporting behavior. In addition, to our knowledge there is no research to date that explicitly addressed the effects of threat on coordination and supporting behavior in teams. However, two recent studies into the effects of stress on the performance of teams in tactical decision-making tasks suggest that a restriction in information processing (as proposed by the threat-rigidity thesis) may have consequences for these interpersonal activities as well (i.e., Driskell et al., 1999; Ellis, 2006). Driskell et al. (1999) proposed that group members under stress might become more self-focused and less group-focused. They found that stress indeed resulted in a narrowing of team perspective as measured by the extent to which members felt like a team and were oriented at team versus individual activities during the task. These results may have consequences for supporting behavior, because supporting behavior requires team members to have a broad team perspective. Team members with a narrow, individualistic focus will be less inclined to monitor the performance of their fellow team members and provide them with assistance when needed.

Furthering this line of research, Ellis (2006) proposed that a narrowing of the team members' breadth of attention under acute stress would disrupt information encoding, storage, and retrieval capabilities, which in turn would negatively affect the team's transactive memory system (TMS; Wegner, 1987). A TMS is a set of distributed, individual memory systems for encoding, storing and retrieving information that combines the knowledge possessed by particular members with a shared awareness of who knows what (Wegner, 1995). Due to an effective TMS, team members with different expertise can retrieve knowledge from each other and anticipate each other's actions and needs (e.g., Moreland, 1999). Hence, a TMS is an important antecedent of coordination in teams. Ellis (2006) did indeed find that the narrowing of the team member's attention under acute stress negatively affected TMSs. He measured TMS by investigating to what extent team members engaged in directory updating, information allocation, and retrieval coordination, which are considered behavioral indicators of a TMS (Ellis, 2006). These actions respectively refer to learning what others are likely to know, and communication of information to and requesting of information from team members with relevant areas of expertise (Wegner, 1995). As coordination refers to activities carried out by team members when managing dependencies (e.g., Espinosa, Lerch, & Kraut, 2004), these behavioral indicators can be considered coordinating activities that result from a well-functioning TMS.

The present study investigated to what extent a physical threat affects coordination and supporting behavior, by investigating communication content and communication flow. Building on Driskell et al. (1999) and Ellis (2006), who found that a restriction in information processing resulting from stress negatively affected team perspective and TMSs, we expected that a physical threat would lead to problems in the coordination of activities and the mutual supporting behavior of team members. Specifically, we expected that in teams performing a complex task, physical threat leads to a narrowed team perspective such that:

Hypothesis 4. *Teams under threat will coordinate their actions less well than teams under normal conditions.*

Hypothesis 5. *Teams under threat will engage less in supporting behavior than teams under normal conditions.*

Present Study

Previous research on teams in demanding environments has resulted in valuable knowledge of the possibly debilitating effects of these environments on the performance of teams. In the present study, we aimed to get a deeper understanding of complex team processes under physical threat. We used a planning and problem-solving task characterized by high complexity and measured dynamic team processes real-time by means of automated behavior recording. The contributions of this study to the domain are threefold. First, few studies have used complex tasks. Instead, simple laboratory tasks (e.g., Argote et al., 1989; Driskell & Salas, 1991), or tactical decision-making tasks (e.g., Driskell et al., 1999; Ellis, 2006) were used. In these tasks, role differentiation was either lacking, or the different roles were so well-defined that they ruled out the possibility of engaging in important team processes such as supporting behavior (cf. Weaver, Bowers, Salas, & Cannon-Bowers, 1995). Moreover, actions required from team members in tactical decision-making tasks are repetitive and rule-based as a result of which complex processes such as problem-solving cannot be investigated (Weaver et al., 1995). Second, most of these studies, including the two studies that did use more complex tasks (i.e., Gladstein & Reilly, 1985; Harrington et al., 2002) measured team processes collecting only self-report measures following task performance, and did not measure the processes directly, like in the present study. Third, to our knowledge, no study has investigated the effects of *physical* threat on team performance during complex tasks. Results from studies using other kinds of threats (e.g., social or material), however, can not automatically be generalized to these physical threat situations, since Klein (1976) found that physical threats lead to different processes in teams than material threats do.

In this study, we measured the effects of an uncontrollable, physical threat on five critical team processes: information management, leadership, communication, coordination, and supporting behavior. We expected the physical threat to cause a restriction in the team's information processing abilities, a constriction in control, and a reduction of activities aimed at coordination and mutual support.

Method

Participants and Design

Participants were 81 individuals (34 women and 47 men; mean age = 23.2 years), recruited from a pool of volunteers of the research institute. They volunteered to participate in a four-hour long 'Team performance at high altitudes'-study. They were paid 40 Euro for their participation. The participants were divided into 27 three-person teams, which were randomly assigned to either the threat condition (n = 14) or the no-threat condition (n = 13).[2]

Physical Threat Manipulation

The physical threat manipulation consisted of letting participants believe that they were possibly (going to be) subjected to reduced oxygen levels during task execution.[3] At various points during recruitment and the actual experiment participants were confronted with information designed to reinforce this idea. No reduction of oxygen level actually occurred. The potential event of a reduction of oxygen level during task execution causing the risk of physical side effects made up the threat manipulation. The exact procedure containing the different parts of the manipulation is described below.

Procedure

All participants signed in to take part in a study called 'Team performance at high altitudes', investigating the effects of thin air on team performance. After having signed in, participants received information about the study by mail. This information gave a description of the study, the climatic chamber in which the study would take place and the possible side effects (i.e., dizziness, tiredness, tightness of the chest, and headache) of the experimental manipulation. The participants were divided into triads, based on their scheduling preferences. Participants who knew each other

[2] One team was excluded from all the analyses. Members of this team accidentally overheard the physician talking about the instructions she just gave them, wondering whether they had believed her, as a result of which these team members did not believe the threat manipulation.
[3] This manipulation was approved by the institute's ethical review board.

where assigned to different teams. Hereafter, we describe the procedure for the two conditions separately.

Threat condition

Teams in the threat condition were told upon arrival that they could not be informed to which condition they were assigned. This was meant to create ambiguity and uncertainty as to under what circumstances they would have to work, since ambiguity reduces controllability and accordingly intensifies the stress response (e.g., Lazarus & Folkman, 1984). In addition, in case they eventually would conclude that there was no reduction in oxygen levels, this would not be problematic because of the possibility that they were assigned to the control condition. They first had to fill out an anamnesis form, which was checked by a physician, as they were told to make sure that they were healthy enough to take part in this study. For the sake of credibility, the physician spoke separately to those participants who had mentioned health issues that could cause problems in an environment with reduced oxygen levels, and decided in every case that the mentioned health issues would not cause problems in this study. This decision was communicated to the participant in question.

Following this, the three participants were randomly assigned to the three different roles for the team task (one of which was the leadership role) and received a 45-minute instruction for this task. Next, teams were taken to the climatic chamber in which the experiment would take place. The experimenter again told the participants that they could not be informed which condition they were assigned to, and that in the experimental condition a mixed gas would be introduced into the chamber, which would reduce the oxygen level. At different stages during the task, the mixed gas would contain different levels of oxygen, to simulate different heights, varying between 2000 meters and 6000 meters above sea level.

After this, the physician instructed the participants about the possible side effects of the reduced oxygen levels. Participants were told that they could experience tingling feelings in their fingers and toes, respiratory problems, headaches, heart palpitations and in about 5% of the cases fainting. The physician also told them that all the effects would quickly disappear once the door of the climatic chamber was opened, as the oxygen level would stabilize rapidly. The participants were asked to continue with the task as long as possible. In case they wanted to stop, they were instructed to give a signal to the experimenter (which never occurred during the actual experiment), who would then open the door. After these instructions, the door of the climatic chamber was closed and locked from the outside. Participants then performed a 45-minute experimental task (see below). After the task, the experimenter opened the door of the climatic chamber. No comments were made about the oxygen manipulation at this moment. Participants were asked to fill out a final questionnaire.

After this, teams were told that no reduction of oxygen level had taken place during their participation. In case they had experienced any of the symptoms described by the physician, the experimenter explained that this was a perfectly normal reaction in this situation, due to suggestion, tension, and effort. All participants were fully debriefed after the experiment about the true nature of the experiment, and offered the possibility to withdraw their data from the study. None of the participants withdrew their data.

No-threat condition

In the no-threat condition the procedure was the same as in the threat condition, with the exception of some critical points. Upon their arrival, teams in the no-threat condition were told that they had been assigned to the control condition and that they would perform the tasks under normal conditions. Participants did not have to fill out an anamnesis form. After having been taken to the climatic chamber, participants were told that they had to perform the task in the same environment as teams in the experimental condition, so as to maximize experimental control and be able to attribute any differences in performance between the conditions to the oxygen manipulation only. The physician did not instruct these participants about possible side effects. Moreover, participants in the no-threat condition were assured that nothing would happen while inside the climatic chamber. Just as in the threat condition, the door of the climatic chamber was closed and teams worked for 45 minutes on the experimental task, after which they were debriefed and thanked for their participation.

Task

All teams engaged in a complex planning and problem-solving scenario in the Planning Task for Teams (PLATT, see for a detailed description: Kamphuis & Houttuin, 2007). PLATT is a platform for experimental research on team behavior. It consists of two components: a software architecture and research-specific scenarios. In the present study, teams engaged in a scenario in which they had to develop a plan to evacuate a group of people from a hostile area to a safer place. They had to develop this plan on the basis of complex and constantly changing information.

PLATT was chosen as a research platform because it makes controlled experimental research on complex team processes possible. In addition, PLATT is capable of generating automated behavioral measures, which contributes to a deeper understanding of the team processes. All actions participants perform are logged by the server. Afterwards, the log-file delivers detailed information about the processes during the task. The specific PLATT-scenario used in this study, was designed to create a high level of task complexity. According to Brown and Miller (2000) the following attributes determine the complexity of a task: information load; number of subtasks; unfamiliarity with the task (referring to the absence of well-learned procedures or repetitive actions for performing the task), task uncertainty (pertaining to the ambiguity of information in the task and the lack of knowledge concerning the outcome of potential solution alternatives); and the number of goals or pathways to goals. The scenario used in this study scored high on each of these characteristics, and was highly dynamic as well. Below, we describe the scenario in more detail.

Teams in this evacuation scenario consisted of three roles, each of which had unique responsibilities, expertise, and prior knowledge. One team member ('Operations') was assigned the leadership role. This team member was responsible for directing the activities of the other team members and had the final responsibility for the team's outcome. Another team member ('Intelligence') was responsible for determining the credibility of information and checking the safety of the roads. The last team member ('Logistics') was responsible for personnel and material, and information concerning the condition of the roads. Each team member was trained with role-specific knowledge and instructions, so that during task performance information within a certain role's area of expertise could only be dealt with appropriately by the team member who occupied that role. This created interdependency between team members. Only when all team members combined their knowledge and information, they were able to deliver an optimal evacuation plan. To evacuate the group of people teams could make use of three different types of units: transportation units, infantry units, and engineer units. Many different routes were possible, but teams had to determine which route was the fastest. After 45 minutes, teams had to deliver an evacuation plan on a standardized form. In this plan, they had to describe via which route they planned to evacuate the group of people and in what way they planned to make use of their units.

In this scenario, in real-time, a large number of scenario-driven messages differing in relevance and coming from an abundance of sources differing in reliability were sent to the three participants. Team members, for example, could receive highly relevant messages from their units in the field, which are reliable sources of information. But they could also receive messages from a local radio station which is less reliable, or irrelevant messages from their home front. Some information contradicted other information, causing ambiguity. In addition, information was selectively made available to Intelligence and Logistics on distinct websites. On these websites, they could search for missing information, concerning, for example, the safety of roads, or the capacity of transportation vehicles. Information on these sites also changed as a result of changes in the scenario. Participants communicated with each other by e-mail. Additionally, they all had access to a shared digital map of the area in which the evacuation had to take place. This shared map could be edited by the leader of the team to assimilate new information in it, which in turn could be viewed and checked by the other team members.

Measures

Most of the team processes of interest in this study were measured behaviorally (on the basis of the log files). In addition, we used some self-report measures. All questions in these self-report measures were scored on 7-point Likert scales; a score of 1 indicated *complete absence* of the construct and a score of 7 *complete presence*. All process measures were collected at the individual level and then aggregated to the mean team score and analyzed at the team level. The reason for aggregation to the team level was that the individual data were not independent from each other since team members worked interdependently on the same task. Therefore, the individual measures within a team could not be analyzed as distinct cases. Aggregation was not done on the basis of within-group agreement or reliability.

Information management

One variable at the behavioral level and one questionnaire scale measured to what extent teams restricted their information processing. The behavioral indicator was *attention to peripheral information.* During the scenario, team members received messages differing in relevance. Some sources usually provided irrelevant information. Now and then, however, these sources sent useful messages. We calculated the average number of times the three team members read these messages as a behavioral indicator of how much attention they gave to relevant peripheral information. The questionnaire concerning information management consisted of a scale of three items (Cronbach's alpha = .59) measuring the participant's *lack of overview* (e.g., "I found it hard to inspect all available information").

Leadership

We used two scales (based on Syroit, 1997) to assess how threat affected the way leadership was exercised. The scales measured the degree of *leadership control* and *participative leadership*. The first scale measured the degree of control exerted by the leader as judged by the other two team members (two items, Cronbach's alpha = .67, e.g., "The leader determined to a large extent how I had to do my job"). A high score on leadership control indicates a high degree of control within the team. The second scale of four items (Cronbach's alpha = .76) measured the degree of participation in decision making allowed by the leader as judged by the other two team members (e.g., "In case of important decisions, the leader took my opinion into consideration"). A high score on participation in decision making indicates a low degree of control.

Communication

We measured the *amount of deliberation* that took place in the team as a behavioral indicator of the degree of control. Two judges coded all communication that took place on the basis of the e-mail messages in the log files. They grouped every e-mail message team members sent to each other into one of four categories of a collectively exhaustive and mutually exclusive categorization. The judges coded 5 (18.5%) of the 27 teams together. The interrater reliability for these five teams was .76 (Cohen's Kappa). Because this indicates a good level of agreement, the remaining 22 teams were coded by just one of the judges. The categories were labeled 'request information', 'reply to information request', 'allocate information', and 'deliberation'. In this study, we focused on deliberation. Deliberation consisted of all messages participants sent to each other to deliberate (communicate on a higher level) about the task, the planning or their team roles. Whereas messages in the other categories could be sent more or less automatically, deliberation messages required more cognitive effort, as they aimed to integrate information and make sense of it. Typical messages in this category contained information about the strategy, potential routes, and decisions to be made. The total number of e-mail messages in this category constituted the variable amount of deliberation.

Coordination

To determine the extent to which team members collaborated in a coordinated manner, we combined communication content and communication flow on the basis of the log files. We measured coordination by investigating the manner in which team members distributed information within the team. Specifically, we determined to what extent they allocated role-specific information based on team members' specific areas of expertise. The resulting variable, *coordinated information allocation*, consisted of the percentage of e-mails in which team members allocated role-specific information (information that could only be adequately dealt with by one specific team member; e.g., information concerning the status of one of the transportation vehicles) to the team member with the relevant area of expertise (in this case Logistics), instead of allocating it to the other team member, or to both team members at the same time (which would be inefficient and could lead to errors, as the other team member would not have the expertise to deal with this information correctly).

Supporting behavior

Supporting behavior consisted of the percentage of times participants forwarded 'wrongly delivered' e-mail messages to the right role. Normally, e-mail messages team members received were meant for them. But sometimes, information meant for one role, was programmed to be delivered to a team member with another role, to investigate how this team member would handle this information. Sending this information to the teammate possessing the relevant area of expertise is an act of supporting behavior, and would require a focus on the team. In the log file we counted the number of times participants sent these 'wrongly delivered' messages to the right teammate, and divided this by the total number of 'wrongly delivered' emails, to get the percentage of times participants engaged in this kind of supporting behavior.

Team performance

At the end of the task, the leader had to fill out a form to describe via which route the team had planned to evacuate the group of people, how much time the evacuation would take with this route, and in what way they had planned to make use of their infantry, engineer, and transportation units. As a measure of team performance we took the total number of objective *errors* the team had made in their evacuation plan. Errors could be made in the selection of the roads they planned to make use of in the evacuation (some roads were one-way roads for example), the planned deployment of their engineer and infantry squads, the planned use of vehicles for transportation of the group, and the calculated travel times. A team could make maximally 10 errors.

Results

Manipulation Checks

To check whether the threat manipulation succeeded, participants filled out a psychosomatic symptom experience checklist based on Wientjes and Grossman (1994) just before they started with the experimental task, and just after the 'threat condition' had received the information of the physician about the possible side-effects of the oxygen manipulation. This questionnaire consisted of three scales. The first scale of three items (Cronbach's alpha = .89) measured on a scale ranging from 1 (*not at all*) to 7 (*very strongly*) to what extent participants expected to experience anxiety symptoms, (e.g., "feeling anxious"). The second scale measured to what extent participants expected to experience respiratory symptoms (three items, Cronbach's alpha = .95, e.g., "unable to breath deeply enough"). The third scale measured to what extent participants expected to experience cardiac symptoms (three items, Cronbach's alpha = .90, e.g., "rapid heart rate"). Results indicated that participants in the threat condition expected to experience more anxiety symptoms (M = 3.81, SD = 1.17) than participants in the no-threat condition (M = 2.09, SD = 0.99; $t(76) = 7.03$, $p < .001$), more respiratory symptoms (M = 4.21, SD = 1.10) than participants in the no-threat condition (M = 1.21, SD = 0.31; $t(76) = 16.74$, $p < .001$), and also more cardiac symptoms (M = 4.12, SD = 1.16) than participants in the no-threat condition (M = 2.17, SD = 1.29; $t(76) = 7.00$, $p < .001$).

After the task, participants completed a threat questionnaire (four items, Cronbach's alpha = .85, ranging from 1 [*strongly disagree*] to 7 [*strongly agree*], e.g., "During the task, I felt threatened by the circumstances"). Participants in the threat condition reported feeling more threatened (M = 3.48, SD = 1.33) than those in the no-threat condition, M = 1.90, SD = 1.15; $t(76) = 5.59$, $p < .001$.

Tests of Hypotheses

Table 3.1 presents means, standard deviations and intercorrelations at the team level for all variables. To assess the effects of the physical threat manipulation, we conducted three one-way multivariate analyses of variance (MANOVAs) on the three groups of process measures (relating to information processing, exercise of control, and team perspective) and a *t* test on the performance measure. Below we present the results of each overall MANOVA followed by *t* tests for each process measure and the team performance measure (see Table 3.2).

Table 3.1
Descriptive Statistics and Intercorrelations at the Team Level of Analysis (N = 26)

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Peripheral attention	2.52	1.45	–						
2. Lack of overview	3.88	0.61	.07	–					
3. Leadership control	2.47	0.79	-.10	$.38^{\dagger}$	–				
4. Participative leadership	5.62	0.73	.11	$-.53^{**}$	$-.53^{**}$	–			
5. Amount of deliberation	26.42	11.54	-.14	$-.38^{\dagger}$	$-.42^{*}$	$.45^{*}$	–		
6. Coordinated allocation	65.10	21.91	.29	-.09	.06	-.04	.31	–	
7. Supporting behavior	50.00	29.15	.04	-.19	-.24	$.37^{\dagger}$	-.05	-.22	–
8. Errors	3.08	1.26	-.20	.18	.10	-.08	$-.34^{\dagger}$	$-.43^{*}$	-.19

$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$.

Information management

Hypothesis 1 proposed that physical threat would lead to a restriction in information processing such that teams under threat would show less attention for peripheral information (H1a), and experience more problems in maintaining an overview of the situation (H1b) than teams under normal conditions. We conducted a MANOVA with threat as the between-groups variable and the behavioral and self-report measures concerning information management as dependent variables. Results showed a significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .65$, $F(2, 23) = 6.12$, $p < .01$, partial $\eta^2 = .35$. Follow-up *t* tests revealed that threat negatively affected both measures. Teams in the threat condition paid less attention to peripheral information than teams in the no-threat condition, $t(24) = 1.77$, $p = .04$. They also suffered more from a lack of overview than teams in the no-threat condition, $t(24) = -2.52$, $p = .01$. Both results are indicative of a restriction in information processing in teams under threat and provide support for Hypothesis 1.

Leadership and communication

Hypotheses 2 and 3 proposed that physical threat would lead to a constriction in control such that in teams under threat, team leaders would exert more control (H2a) and act in a less participative way (H2b), and team members would deliberate less with each other (H3) than under normal conditions. We conducted a MANOVA with threat as the between-groups variable and the leadership and deliberation measures as dependent variables. Results showed a significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .67$, $F(3, 22) = 3.69$, $p = .03$, partial $\eta^2 = .33$.

Table 3.2
Mean Scores, Standard Deviations, and t test Results

	No threat (n = 13)		Threat (n = 13)			
Variable	*M*	*SD*	*M*	*SD*	*t*(24)	Cohen's *d*
1. Peripheral attention	3.00	1.82	2.03	0.74	1.77*	0.72
2. Lack of overview	3.61	0.57	4.15	0.54	-2.52**	1.03
3. Leadership control	2.08	0.52	2.87	0.84	-2.87**	1.17
4. Participative leadership	5.93	0.51	5.48	0.71	1.87*	0.76
5. Amount of deliberation	31.69	11.03	21.15	9.78	2.58**	1.05
6. Coordinated allocation	73.90	22.56	56.29	17.98	2.20*	0.90
7. Supporting behavior	59.62	31.52	40.38	24.02	1.75*	0.71
8. Errors	2.76	1.73	5.85	1.38	-5.04*	2.06

Note. t-values, except for the test on differences in errors, were tested one-sided because of directional hypotheses.
*$p < .05$. **$p < .01$.

Follow-up *t* tests revealed that threat produced differences on all three univariate measures. Team leaders in the threat condition exerted more control than leaders in the no-threat condition, $t(24) = -2.87$, $p < .01$, and they allowed less participation of their teammates in decision making, $t(24) = 1.87$, $p = .04$. In addition, team members in the threat condition deliberated less with each other than team members in the no-threat condition, $t(24) = 2.58$, $p < .01$. Note that the total amount of communication did not differ between conditions ($M = 73.54$, $SD = 19.57$ in the threat condition and $M = 78.77$, $SD = 14.74$ in the no-threat condition; $t(24) = 0.77$, $p = .45$). These results are indicative of a constriction in control and provide support for Hypotheses 2 and 3.

Coordination and supporting behavior

Hypotheses 4 and 5 proposed that physical threat would lead to a narrowed team perspective such that team members would coordinate their actions less well (H4), and engage less in supporting behavior (H5) than under normal conditions. We conducted a MANOVA with threat as the between-groups variable and the behavioral measures of coordinated information allocation and supporting behavior as dependent variables. Results showed a significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .64$, $F(2, 23) = 6.43$, $p < .01$, partial $\eta^2 = .36$. Follow-up *t* tests revealed that threat negatively affected both measures. Team members in the threat condition allocated a smaller percentage of their e-mail messages with role-specific information to the team member with the relevant area of expertise, $t(24) = 2.20$, $p = .02$, indicating worse coordination in teams under threat. In addition, team members in the threat condition forwarded only 40% of the ‘wrongly delivered’ e-mails to their teammates, while team members in the no-threat condition did so in almost 60% of the cases, $t(24) = 1.75$, $p = .05$, indicating a decrease in supporting behavior in teams under threat. These results are indicative of a narrowed team perspective and provide support for Hypotheses 4 and 5.

Team performance

Finally, we also investigated whether there was a difference in the performance of the teams in the two conditions. An independent samples *t* test comparing the amount of errors in the threat and no-threat conditions yielded a significant result. Teams in the threat condition made more than twice as many errors as team in the no-threat condition $t(24) = -5.04$, $p < .01$. This result indicates that teams in the threat condition performed worse than teams in the no-threat condition.

Discussion

This study experimentally investigated the effects of physical threat on team processes during a complex planning and problem-solving task. Three-person teams had to develop an evacuation plan on the basis of a multitude of complex information either under threat of experiencing a reduction of oxygen level, or under normal conditions. We measured five critical team processes using automated behavioral logging and self-report scales. We expected that threat would cause problems in the team’s information management, result in more controlling leadership and less group discussions, and lead to a reduction in coordination and supporting behavior. Our results provide support for these hypotheses. We will discuss the results and theoretical implications for each of the processes separately.

As expected, teams in the threat condition showed a restriction in information processing compared to teams working in the no-threat condition. Specifically, teams under physical threat paid less attention to information provided by sources that appeared to provide merely irrelevant information. As a result they also overlooked or ignored the relevant and useful information provided by these sources. In addition, they reported to have had more problems keeping an overview of all the information during the task. These effects found for information management under physical threat bear resemblance to the so-called need for closure effects (Kruglanski & Webster, 1996). Need for closure has been defined as a desire for definite knowledge on some issue, and can be evoked by conditions that make information processing difficult, such as time pressure (e.g., Kruglanski & Webster, 1991). Need for closure, however, has a motivational nature, while the effects proposed by the threat-rigidity thesis do not necessarily presuppose motivational aspects. It would be interesting to investigate whether the effects of threat also have motivational aspects or that they occur more or less automatically, without conscious control of the persons being threatened.

Furthermore, as hypothesized, the results indicated a constriction in control in teams under threat. Team members under threat described their leaders as more controlling than did team members in the no-threat condition. In addition, team members' ratings of the degree of participation in decision making allowed by their leader were lower for teams under threat, indicating that team leaders under threat were less receptive to the opinions of their team members. These results contribute to the debate concerning the effects of threat and stress on the degree of control in teams. Past research found evidence for both a constriction in control and a loosening of control under threat. We proposed that these mixed findings could be explained by the presence (or absence) of formal leadership in a team. In this study, teams had an assigned, formal leader. Although we did not manipulate emergent versus assigned leadership, the results provide support for the notion that in teams with existing leadership, authority will become more centralized under threat. Two processes may cause this. Firstly, threat may make team members feel uncertain and insecure (e.g., Lanzetta, 1955) and pass full responsibility to the team leader, who, after all, has the final responsibility (e.g., Foushee & Helmreich, 1988). Secondly, under threat, the leader may feel even more responsible and tighten the reins as a result. In contrast, in teams without formal leadership, threat may cause the same feelings of uncertainty and insecurity among team members, but in this case there is no one they can depend on. The resulting situation may be characterized by group-oriented behaviors as described by Lanzetta (e.g., cooperativeness, group discussion), since these behaviors are indicative of the group members' needs to find security in the group in the absence of the possibility to put themselves in the hands of a leader. Eventually, leadership may emerge as a result of which the same processes may surface as in teams with an assigned leader (e.g., Argote et al., 1989; Harrington et al., 2002).

Another result supporting the idea of a constriction in control under threat concerned the content of the communication in the e-mails team members sent to each other. As we expected, teams in the physical threat condition deliberated less with each other than teams in the no-threat condition. Fewer messages contained communication about strategies, potential routes, decisions to be made, or meta-communication about information they received and the roles they occupied. There was no difference, however, in the total amount of communication between the teams in the two conditions. Only the nature of the communication differed. In the no-threat condition, team members exchanged information and at the same time collectively tried to make sense of it. On the contrary, in the threat condition, team members mainly exchanged information, and made fewer efforts to integrate it, or make sense of it. This was apparently for the larger part solitarily done by the leader of team. Again, this may have been caused by team members feeling insecure and passing responsibility to the one who should ‘know best’. It may also have been caused by team leaders feeling a greater need to exert control under threat, by discouraging team members to make sense of the information they received or think collectively about the implications of it, and instead requiring them to send all information to the leader (e.g., Borkowski, 2005).

Results also indicated that physical threat led to a reduction in coordination, as hypothesized. Specifically, team members under physical threat allocated a smaller percentage of their e-mail messages with role-specific information (information that could only be adequately dealt with by one specific team member) to the team member with the relevant area of expertise. Instead, they sent role-specific information to the wrong team member or to both other team members at the same time. Hence, the coordinated allocation of information suffered under physical threat. As with the results for information processing, it is unclear to what extent this result reflects a lack of awareness of the roles and responsibilities of other team members (i.e., a less effective transactive memory system), or a lack of motivation to act upon this knowledge, or a combination of both. Research by Ellis (2006) indicates that under acute stress the former might be the case. He measured team interaction mental models after task performance, and found these models to be less similar and less accurate in team members that had performed under acute stress. It is unclear, however, whether these less accurate models developed as a result of automatic processes, or as a result of a motivated individualistic focus. In other words, it is the question whether team members under threat are less able or less willing to focus on the team. Future research is necessary to address this question.

As expected, the effects for supporting behavior also indicated a narrowing of team perspective. Team members under threat showed less supporting behavior than team members in the no-threat condition. They forwarded information that was meant for one of their teammates, only in 40% of the cases to that particular teammate as opposed to 60% by team members in the no-threat condition. To our knowledge, no previous research has experimentally investigated the effects of threat or stress on supporting behavior in teams. Especially in complex task environments, however, team members supporting each other can make the difference between success and failure. Previous research (Driskell et al., 1999; Ellis, 2006) showed that stress causes team members to be less focused on the team, and negatively affects their team mental models and transactive memory systems. The present study extends these results, by showing that this narrowed team perspective also reveals itself in degraded supporting behavior. Again, it is not clear whether this result indicates a lack of willingness or a lack of ability in team members to support their teammates.

Finally, results also pointed out that threat negatively affected team performance on the planning and problem-solving task. Teams under threat delivered evacuation plans containing more than twice as many errors as teams in the no-threat condition. As can be seen in Table 3.1, the amount of deliberation and the extent to which information was allocated in a coordinated manner displayed moderate correlations with the amount of errors. The other process measures had smaller correlations with performance on this task. Distraction may have been an extra factor that influenced the amount of errors teams made. Threat not only initiates the processes described by the threat-rigidity thesis (Staw et al., 1981), and measured in the present study, but may also affect concentration. Threat captures and holds attention (Gaillard, 2008; Turner & Horvitz, 2001). Since the threat in this study was not task-related, it did not draw team members' attention to specific aspects of the task, but instead it distracted them from the task. This distraction may have had a unique effect on the amount of errors teams made in their evacuation plan.

Implications, Strengths, Limitations, and Future Research

The results of this study support the propositions of the threat-rigidity thesis concerning information processing and the exercise of control, and they extend previous research by demonstrating effects on coordination and supporting behavior as well. Moreover, to our knowledge for the first time, we were able to demonstrate the effects of a physical threat on teams executing a complex planning and problem-solving task.

Organizations that employ teams to carry out dangerous and complex operations can benefit from the results of this study, because it demonstrates in a clear manner how team processes are affected by physical threat. Although at this time no definite answer exists as to how to mitigate these effects, organizations could attempt to use each of these processes as a starting point to prevent the detrimental effects of threat from occurring. The effects we found for information management could, for example, be countered with interfaces that support operators to divide their attention in a better way or software agents that dynamically take over those tasks that the operator neglects (Bosse, Van Doesburg, Van Maanen, & Treur, 2007). The effects on leadership and the amount of deliberation could be responded to by specific participative leadership trainings or by flattening team structures. The effects on coordination and supporting behavior could be averted by specific trainings, for example cross-training, wherein team members are not only trained for their own tasks, but also for the tasks of their teammates (e.g., Marks, Sabella, Burke, & Zaccaro, 2002). Other recent research has shown positive effects of a generic team-skills training program on transactive memory in teams performing a complex task (Prichard & Ashleigh, 2007). When such training programs are not possible, teams could probably benefit from assigning one team member a specific role aimed at facilitating cooperation between team members and integrating the knowledge and expertise possessed by his or her team mates.

Methodologically, the strength of this experiment lies in the fact that we used a complex planning and problem-solving team task, characterized by a high information load, high task-ambiguity, absence of well-learned procedures or repetitive actions, multiple subtasks, and numerous pathways to goals. As a result of this, we were able to investigate a level of complexity that can not be attained with the more executive, tactical team tasks often used in this kind of research (e.g., TANDEM, Weaver et al., 1995; DDD, Kleinman, Serfaty, & Luh, 1984; TIDE^2, Hollenbeck, Sego, Ilgen, & Major, 1991). This complexity is an integral part of the reality in which, for example, teams in high hazard industries, military teams and crisis management teams have to operate. In addition, the three team members occupied different roles, knowledge, and expertise. As a result of this, real interdependency existed between team members. In team research, this crucial characteristic is frequently highly artificial or even absent due to the simplicity of the task used.

In addition, we managed to successfully manipulate a realistic, physical threat, something that is hard to realize in an experimental setting. For teams that have to operate in dangerous environments, like crisis management and military teams, physical threats are part of their daily reality. Since Klein (1976) found that physical threats lead to different processes than material threats do, it is necessary for researchers to adequately address the threats these teams face, in order to be able to generalize research findings to the reality of these teams. We are convinced that the present manipulation constitutes a threat that causes effects that can be generalized to these situations, albeit to a less severe extent. In addition, as opposed to many stress manipulations, the manipulation in the present study was not task-related. As a result of this, the threat had an uncontrollable nature, had no implications for the manner in which teams had to perform their tasks, and was similar for all teams no matter how well they performed.

Finally, the use of PLATT as research platform enabled us to collect objective, behavioral data to measure the relevant team processes. We did not have to fully rely on subjective questionnaire measures, but supplemented these with behavioral data from the log files. In this way, we were able to objectively measure processes that up till now, in this research domain, had mainly been measured using subjective self-report scales (i.e., peripheral attention, amount of deliberation, supporting behavior). Obtaining the data in this way supports the validity of our results.

We should also note some limitations. Although the task environment ensured a high degree of realism, the findings were obtained in an experimental setting, with short-lived teams and an artificial task. Future research should also be directed toward investigating whether these results hold in a more natural setting. Furthermore, two of the employed questionnaire scales (lack of overview and leadership control) had rather low reliabilities (Cronbach's alphas respectively .59 and .67). This was due to the fact that they consisted of only a small number of items (respectively three and two). Finally, only a relatively small number of teams could participate in this study. More studies should be conducted to establish the reliability of the results.

It is further recommended that future research investigate methods to protect the team processes found to be vulnerable to the effects of threat. Some research has been done in this domain (e.g., Serfaty, Entin, & Johnston, 1998), but more research is necessary to develop methods to mitigate the negative effects of threat, especially on coordination and supporting behavior in teams. Future research might also examine more closely the role of leadership in teams under threat, consistent with our earlier discussion relating to the presence or absence of formal leadership. We proposed that in teams with existing leadership, threat would lead to a constriction in control. Although our results support this proposition, we did not manipulate the existence of leadership. Future studies manipulating this could test our proposition that threat interacts with the existence of leadership in such a way that it leads to a constriction in control in teams with existing leadership, while this effect would not occur, or might even be reversed (i.e., a loosening of control), in teams without existing leadership.

Much research remains to be done in the domain of team performance in threatening environments. A picture starts to emerge of the detrimental effects of threat on crucial team processes, but it is still unclear in what way the negative effects of threat can be mitigated. The present study enhances our understanding of how teams react to physical threat, and we hope that mere awareness of these effects may already improve the performance of teams in threatening situations.

Chapter 4

Team Performance under Threat: The Mediating Role of Threat-Rigidity Processes[1]

This study examined how team reactions to threat mediate the relationship between threat and team performance during complex tasks. Fifty-eight three-person teams engaged in a complex planning and problem-solving task, either under high or low manipulated social threat. It was expected that threat would cause rigidity in team processes, which in turn would lead to a deterioration of team performance. Team processes were measured by automated behavior recordings and questionnaires. Findings confirmed that threat caused a restriction in information processing, a constriction in control, and a narrowing of team perspective, and negatively affected team performance. Results of a multiple mediation analysis showed that the set of processes as a whole mediated the negative effect of threat on team performance. These results provide support for the threat-rigidity thesis, and extend previous research by capturing the full array of mediating processes in a single design.

Suppose you are walking through the woods, listening to the beautiful songs of birds. Suddenly, you are face to face with a huge bear. In a moment, your body prepares itself to fight or flight. Adrenaline is released into your bloodstream, your heart starts pumping like a madman, your breathing becomes deeper and faster,

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[1] This chapter is based on Kamphuis, Gaillard, & Vogelaar (2009b).

your pupils dilate, and you don't notice the bird songs anymore. All these automatic reactions contribute to your chances of survival in this situation (cf. Cannon, 1915).

But now suppose you are in a different situation. You are the pilot of a large commercial airliner approaching for landing. Suddenly, all kinds of warning signals indicate serious problems. It is not clear what is causing the problems, but if you and your crew don't solve them, the plane will go down with all its passengers. This threat will also cause a fight or flight response, but there is nothing to fight or to flee from. Rather than physical activation, you will need all your cognitive abilities to solve this complex problem. In addition, you will need your social abilities to collaborate with your crew. What reactions would you and your team show in this situation, and would these reactions contribute to your chances of survival?

Many tragedies in aviation, the military, emergency medicine, and other safety-critical industries suggest that the responses of teams in these situations may not contribute to their chances of survival (e.g., Cannon-Bowers & Salas, 1998b; Flin, Slaven, & Stewart, 1996; Helmreich & Schaefer, 1994; Kanki, 1996). Teams in less safety-critical organizations may suffer performance decrements caused by threats too (e.g., potential financial loss, negative publicity, hostile take-over, etc.). Results from experimental research have confirmed that threat and stress negatively affect team performance (e.g., Cannon-Bowers & Salas, 1998b; Driskell, Salas, & Johnson, 1999; Ellis, 2006). But a clear understanding of how threat affects team performance is only beginning to develop (e.g., Burke et al., 2004; Turner & Horvitz, 2001). Precise knowledge of the pathways through which threat affects team performance is of great concern, because organizations can use such knowledge to determine what processes should be targeted in interventions aimed at mitigating the effects of threat. The present study aimed to contribute to this knowledge by investigating team reactions to threat and examining how these reactions mediated the effects of threat on team performance during a complex task.

Theory and Hypotheses

The Effects of Threat on Teams

Threat can be defined as a possible impending event perceived by a person or group of persons as potentially causing material or immaterial loss to, or the obstruction of goals of that person or group of persons (cf. Argote, Tuner, & Fichman, 1989; Lazarus, 1966; Staw, Sandelands, & Dutton, 1981; Turner &

Horvitz, 2001). Staw et al. (1981) suggested that there is a general tendency for individuals, teams, and organizations to behave rigidly in threatening situations. This threat-rigidity thesis describes two types of rigidity. First, threat may cause a *restriction in information processing*. This may be demonstrated by a narrowed field of attention, a reduction in the amount of information used for decisions, and reliance upon prior expectations. Second, threat may cause a *constriction in control*. This may be demonstrated by authority becoming more centralized and fewer people making the decisions. Together, these effects cause a system's behavior to become less diverse and flexible. In stable and predictable environments, this rigidity may be adaptive. In dynamic, ambiguous, and unpredictable environments, however, this rigidity is likely to be maladaptive, leading to performance decrements (Staw et al., 1981; Weick, 1979).

The limited research investigating team performance under threat, has generally confirmed the occurrence of a restriction in information processing and a constriction in control. For example, Gladstein and Reilly (1985) found that teams facing a potential financial loss in a management simulation had less group discussions and used less information to make decisions. In addition, Argote et al. (1989) found that higher levels of threat were associated with more centralized communication structures in a laboratory team experiment. Similarly, Harrington, Lemak, and Kendall (2002) found that teams participating in a student team project reported to have used a more rigid approach to their decision making process when under high threat. Moreover, Driskell et al. (1999) and Ellis (2006) showed that restricted information processing under threat extended to team perspective as well, leading team members to shift from a broader, team orientation, to a more narrow, individualistic focus. Finally, Kamphuis, Gaillard, and Vogelaar (2009d) showed that teams performing a complex planning and problem-solving task reacted to physical threat with restriction in information processing, more controlling leadership, less group discussion, and a reduction in coordination and supporting behavior. Together, these studies provide support at the team level for the proposed rigidity-processes by the threat-rigidity thesis.

Mediational Role of Threat-Rigidity Processes

However, hardly any research investigated how the processes caused by threat relate to the performance of teams. The only two studies examining the mediational role of the rigidity-processes, focused on team members' shift in attention from the team to the self (Driskell et al., 1999; Ellis, 2006). These studies showed that a narrowing of team perspective (Driskell et al., 1999) and a deterioration of team mental models and transactive memory (Ellis, 2006) under threat, mediated the negative relationship between threat and team performance in a command-and-control simulation task. The mediational role of other team reactions to threat, such as task information processing becoming more restricted, leadership becoming more controlling, and group discussions becoming less frequent, has not received any research attention yet. Knowledge concerning the mediational properties of these processes is relevant, however, since some of these processes might be far more important in causing deterioration of team performance than other processes. Interventions aimed at mitigating the effects of threat on team performance should target those processes that are responsible for the performance deterioration. Therefore, in this study, we investigated how threat affected these processes, and whether changes in these processes were adaptive or maladaptive for team performance on a complex task.

Present Study

We modeled our study after the Kamphuis et al. (2009d) study and investigated how threat affected information processing, exercise of control, and team perspective in teams during a complex planning and problem-solving task. In line with the threat-rigidity thesis (Staw et al., 1981) and the earlier study (Kamphuis et al., 2009d), we expected that threat would cause: a *restriction in information processing*, such that teams under threat would show less attention for peripheral information and would experience more problems in maintaining an overview of the situation than teams under normal conditions; a *constriction in control*, such that team leaders would become less participative and more controlling, and team members would engage in less deliberation than under normal conditions; a *narrowed team perspective*, such that teams under threat would coordinate their actions less well and engage in less supporting behavior than under normal conditions.

Extending previous research, we simultaneously investigated the mediational role of all these expected threat reactions in the relationship between threat and team performance. As described above, the threat-rigidity thesis states that rigidity in reactions may be adaptive in stable and predictable environments, whereas in dynamic, unpredictable, and novel environments, flexibility rather than rigidity may be necessary to perform well (Staw et al., 1981). Because teams performed a complex problem-solving task, which was novel for them, we expected that rigidity in reactions caused by threat, would negatively affect team performance. In other words, we expected that restricted information processing, constricted control, and a narrowed team perspective would mediate the relationship between threat and team performance.

In sum, this chapter addresses the following hypotheses: teams performing a complex task under threat will show a restriction in information processing (*Hypothesis 1*); a constriction in control (*Hypothesis 2*); a narrowing of team perspective (*Hypothesis 3*); and a deterioration of team performance (*Hypothesis 4*). The effects of threat on team performance will be mediated by information processing, exercise of control, and team perspective (*Hypothesis 5*).

Method

Participants and Design

Participants were 174 officer cadets of the Netherlands Defence Academy (31 women and 143 men; mean age = 21.2 years) who were arrayed into 58 three-person teams. In exchange for their participation, teams could win cash prizes depending upon the team's performance (150 Euro for the best performing team within each cohort). Teams were randomly assigned to either the high threat (n = 29) or the low threat condition (n = 29).[2]

Task

PLATT

Participants engaged in a complex planning and problem-solving scenario in the Planning Task for Teams (PLATT; see Kamphuis, Essens, Houttuin, & Gaillard, 2009; Kamphuis & Houttuin, 2007). PLATT is a software platform for controlled experimental research on team performance in complex environments. It has been used in other studies investigating different aspects of team performance (e.g., Kamphuis, Gaillard, & Vogelaar, 2008, 2009c; Van Bezooijen, Vogelaar, & Essens, 2009a, 2009b; Langelaan & Keeris, 2008). It consists of a generic software architecture and research-specific scenarios. Participants playing a scenario are seated behind computers connected via a network. They receive scenario-messages via e-mail and can search for additional information on web sites. Participants communicate with each other via e-mail and have access to a digital

[2] This study actually used a 2 (threat: high vs. low) × 2 (training vs. no training) factorial design. In this chapter we only address the effects of the threat manipulation. The other factor did not interact with any of the measures reported in this chapter. In Chapter 5 we report results for the full design on a different set of measures.

shared workspace in which they can work jointly on certain team tasks. All participants' actions are automatically recorded in a log file. Based on this log file, different behavioral measures can be constructed.

Scenario

In the present study, teams engaged in a highly complex military evacuation scenario. In this scenario, teams have to develop a plan to extract a group of people from a hostile area to a safer place. They have to determine the fastest route and plan how they will employ their transportation, engineer, and infantry units, to realize the extraction. There are eighteen possible routes to use for the evacuation, ranging from very slow to very fast. Whether a route is fast not only depends on the length of the roads, but also on the condition of these roads, and whether there are enemy activities on these roads.

During the scenario, in real-time, a large number of scenario-driven messages are sent to the three participants. These messages pertain to road conditions, enemy activities, delays due to different causes, the position of the units, personnel and materiel problems, weather conditions, unrelated events, et cetera. This information varies in relevance and is sent by many sources differing in reliability (e.g., headquarters, local civilians, the enemy). The scenario also controls changes in information on the websites participants can access. The events in the scenario are constructed in such a way that at different moments in time, different routes are optimal. Teams accordingly have to adjust plans and adapt to circumstances. The shared workspace in this scenario consists of a digital map of the evacuation area. This map can be used to integrate the most recent information, using symbols indicating, for example, enemy activities, locations of units, road conditions.

After 45 minutes, the scenario ends and teams have to deliver an evacuation plan using a standardized form. In this plan, they have to describe via which route they plan to extract the group of people and how they will employ their units.

Roles

Team members were randomly assigned to one of three roles: *Operations*, *Logistics*, or *Intelligence*. Each role had unique responsibilities, expertise, and tasks. In addition, each role received unique information (via e-mail or websites) during the scenario. Operations was the leader of the team and responsible for directing the activities of the other team members. Operations was the only team member who could edit the shared map of the area in which the evacuation had to take place. Intelligence was responsible for all information concerning the safety of the roads, and had unique expertise concerning determining the reliability of the information sources in the scenario. Logistics was responsible for personnel and materiel, and for information concerning the condition of the roads. Logistics had unique expertise concerning calculating the duration of the various routes. The distribution of expertise and information created interdependence between team members. Only when all three team members combined their knowledge and information, they were able to deliver an optimal evacuation plan.

Procedure

Participants arrived at the location of the experiment in groups of three. The experimenter seated the participants according to the roles they had randomly been assigned to and explained that the purpose of the experiment was to gain a better understanding of team problem-solving and team decision-making processes. He further explained that they would perform a team task, in which an evacuation had to be planned. Following this, participants watched a video instruction containing information about the team task. After having watched this video, participants had the opportunity to ask the experimenter questions about these instructions. The experimenter answered these questions and then handed out three different packets containing information about the roles participants would occupy during the scenario. After participants had studied this information, the experimenter announced the next phase of the experiment.

Threat manipulation

The experimenter informed all participants that, prior to engaging in the team task, they had to perform a brief individual task, the Synwork task (Elsmore, 1994). Synwork requires participants to execute four different subtasks at the same time. Participants were told that performance on this individual task was a good predictor of performance on complex planning tasks like the one they were about to engage in. The experimenter further told them that their mean team score would be compared to the mean score of a civilian population that had been tested before, to estimate how well they could perform on the team task. After this, all participants received instructions for the Synwork task, and subsequently performed this task for 2 minutes.

At the end of the individual task, participants in the low threat condition received false positive feedback. The experimenter told them that they had performed well and had scored above the average of the civilian population. He further told them that he expected them to perform well on the team task as well, and reminded them of the prize of 150 Euro for the best performing team within each cohort.

Participants in the high threat condition, on the other hand, received false negative feedback at the end of the individual task. The experimenter told them that they had performed rather poorly and that their score was below the average of the civilian population. He further told them that he expected them to have difficulty with the team task as well, and explained that both the researchers and their own commanders were particularly interested in teams that had difficulties with these kinds of task. Therefore, to gain better insight into what happens in ill-performing teams, their performance would be recorded using a video camera, which was set up prominently in front of the team, and webcams, which were fixed on top of the participants' monitors. Moreover, the experimenter told them that they ran the risk of having to come back for an evaluation with their commanders and the researchers if their team would be one of the five lowest performing teams. Finally he told them that the videotape could be used as course material.

Consistent with previous research, this manipulation aimed to create an evaluative situation with potentially negative consequences in case of poor performance (e.g., Blanchette, Richards, & Cross, 2007; Ellis, 2006; Turner, Pratkanis, Probasco, & Leve, 1992). When persons expect to perform poorly, such a situation is likely to be perceived as threatening (e.g., Thompson, 1981; Blascovich & Tomaka, 1996). We manipulated the expectation of poor performance by giving negative feedback on an unrelated task said to be predictive of performance on the task of interest (cf. Mogg, Mathews, Bird, & Macgregor-Morris, 1990). We deliberately chose not to provide false negative feedback on the task of interest because teams might have used this feedback as an indication that they had to alter their strategies. This would have been an unwanted effect, as it might have obscured the effects of threat.

Task execution and conclusion

Following the feedback on the individual task, the experimenter asked the participants to fill out a short electronic questionnaire (which constituted the manipulation check for the threat manipulation), after which the scenario for the team task was started. Teams then performed the 45-minute military evacuation scenario. After this, participants were asked to respond to a final questionnaire (with dependent measures described below). After the experiment, all participants were fully debriefed about the true nature of the experiment, and offered the possibility to withdraw their data from the study. None of the participants withdrew their data.

Measures

The central processes, information processing, exercise of control, and team perspective were measured behaviorally (on the basis of the log files) and by means of questionnaires. All questions were scored on 7-point Likert scales; a score of 1 indicated *complete absence* of the construct and a score of 7 *complete presence*. All measures, except the team performance measure, were collected at the individual level. Because the unit of analysis was the team level, and variance in team members' behavior or reports was of no concern, individual scores were aggregated to the mean team score.

Information processing

One variable at the behavioral level and one questionnaire scale measured to what extent teams restricted their information processing. The behavioral indicator was *attention to peripheral information*. During the scenario, team members received messages differing in relevance. Some sources usually provided irrelevant information. Now and then, however, these sources sent useful messages. We calculated the percentage of these relevant messages that was read by team members as a behavioral indicator of how much attention teams gave to peripheral information. The questionnaire concerning information processing (adapted from Kamphuis, et al., 2009d) consisted of a scale of three items (Cronbach's alpha = .76) measuring the participant's *lack of overview* (e.g., "I found it hard to inspect all available information").

Exercise of control

To investigate to what extent a constriction in control took place, we investigated how the leaders behaved and what kind of communication took place. The leadership scales (adapted from Kamphuis, et al., 2009d) measured the degree of *leadership control* and *participative leadership*. The first scale measured the degree of control exerted by the leader as judged by the other two team members (three items, Cronbach's alpha = .68, e.g., "The leader determined to a large extent how I had to do my job"). A high score on leadership control indicated a high degree of control exercise within the team. The second scale of four items (Cronbach's alpha = .78) measured the degree of participation in decision making allowed by the leader as judged by the other two team members (e.g., "In case of important decisions, the leader took my opinion into consideration"). A high score on participation in decision making indicated a low degree of control exercise.

We measured the *amount of deliberation* that took place in the team as a behavioral indicator of the degree of control, with a low amount of deliberation being indicative of a high degree of control (e.g., Borkowski, 2005). To construct this measure, two judges coded all e-mail messages in the log files. They grouped every e-mail message into one of seven categories of a collectively exhaustive and mutually exclusive categorization (Kamphuis et al., 2009c). The judges coded 10 (17.2%) of the 58 teams together. The interrater reliability for these 10 teams was .95 (Cohen's Kappa). Because this indicates almost perfect agreement, the remaining 48 teams were coded by just one of the judges. One of the categories, deliberation, consisted of all messages participants sent to each other to deliberate (communicate on a higher level) about the task, the planning or their team roles. Typical messages in this category contained information about the strategy, potential routes, and decisions to be made. The total number of e-mail messages in this category constituted the variable amount of deliberation.

Team perspective

Team perspective was measured by investigating to what extent team members engaged in coordination and supporting behavior. Both kinds of activities indicate that team members maintain a broad team perspective, rather than having a narrow focus on their own tasks. To determine the extent to which team members collaborated in a coordinated manner, we investigated the manner in which team members handled role-specific information (i.e., information that could only be adequately dealt with by one specific team member). One of the categories of the above described categorization of e-mail messages pertained to the allocation of role-specific information. We determined who received the e-mails in this category. The resulting variable, *coordinated information allocation*, consisted of the percentage of e-mails in this category that was sent to the team member with the relevant area of expertise, instead of to the other team member, or to both team members at the same time (which would be inefficient and could lead to errors, as the other team member would not have the expertise to deal with this information correctly). An example of an e-mail message in the category 'allocation of role-specific information' would be: "I received a report from local civilians of sniper shootings between Iskra and Golesh". When a team member would send this information to Intelligence, the team member with the relevant area of expertise (safety), that would be an example of coordinated information allocation.

Supporting behavior consisted of the percentage of times participants forwarded 'wrongly delivered' e-mail messages to the team member with the relevant area of expertise. Normally, team members only received scenario e-mail messages that were meant for them, and not for one of their teammates. But sometimes, information meant for one role, was deliberately sent to a team member with another role, to investigate how this team member would handle this information. We considered sending this information to the teammate with the relevant area of expertise to be an act of supporting behavior. On the basis of the log files, we calculated the percentage of the total number of 'wrongly delivered' e-mail messages, in which team members sent these messages to the team member with the relevant area of expertise.

Team performance

The team performance measure consisted of a single score, ranging from 0 (very poor) to 10 (excellent). This score was composed of a score for the quality of the route they had chosen minus the total number of errors the team had made in their evacuation plan. The score for the quality of the route ranged from 5 (slowest routes) to 10 (fastest routes). Errors could be made in the way teams planned to deploy their infantry, engineer, and transportation units (e.g., no deployment of a unit whereas it should have been deployed, deployment on the wrong part of a route, deployment from a wrong starting point, etc.), and in calculating the travel times for the roads they planned to use. The scenario was constructed in such a way that in each of the eighteen routes, teams could make a maximum of five errors, resulting in an overall minimum score of 0 and a maximum score of 10.

Results

Prior to data analysis, seven teams had to be removed from the data set. Four teams had to be removed, because one of their members had indicated to have dyslexia. Because all information and communication during task performance was textual, dyslexia would have large effects on team processes and team performance. In addition, two teams had to be removed because of technical problems. Finally, one team in the high threat condition had to be removed, because members of this team had been informed about the threat manipulation by other participants.

Manipulation Checks

Threat appraisal

To examine the effects of the threat manipulation, participants first completed two items that measured participants' appraisal of the situation, immediately after the feedback on the individual task and just before engaging in the team task. These items did not explicitly ask participants how threatened they felt, because that would have hinted them about the true nature of the experiment, but instead indirectly measured how participants appraised the situation. The first item ("How important is it for you to perform well on this task?") measured on a scale ranging from 1 (*not important at all*) to 7 (*very important*) the extent to which participants judged that something was at stake, because having a stake in the outcome is a necessary condition for threat (cf. primary appraisal, e.g., Folkman & Lazarus, 1985; Lazarus & Folkman, 1984). The second item ("How well, do you think, are you going to perform as a team on this task?") measured on a scale ranging from 1 (*very poorly*) to 7 (*very well*) to what extent participants anticipated to be able to deal with this situation, because believing to have power to control the outcome of an encounter involving potential harm or loss, diminishes the degree of threat (cf. secondary appraisal, e.g., Folkman & Lazarus, 1985; Lazarus & Folkman, 1984). Both appraisal-items were combined to yield a single index of threat appraisal. This index was computed as a ratio of the first to the second item and reflected the extent to which a situation is appraised as potentially causing the obstruction of goals (i.e., as threatening). This method of measuring appraisal was adapted from research on challenge and threat (e.g., Blascovich & Tomaka, 1996; Tomaka, Blascovich, Kibler, & Ernst, 1997) and is consistent with the transactional theory of stress (Lazarus & Folkman, 1984).

An independent samples *t* test was performed comparing the mean threat appraisal ratios in high and low threat conditions. Results indicated that the mean threat appraisal ratio was larger in the high threat condition (M = 1.11, SD = 0.26) – indicating higher stakes than coping ability – than in the low threat condition, M = 0.99, SD = 0.20; $t(151)$ = 3.26, p < .01, Cohen's d = 0.53. This indicates that instructions in the high threat condition caused participants to appraise the situation as more threatening than in the low threat condition.

Threat emotions and state anxiety

After task performance, participants completed the Folkman and Lazarus (1985) threat emotions scale (three items, Cronbach's alpha = .72). They indicated on a scale ranging from 1 (*not at all*) to 7 (*a great deal*) to what extent they felt worried,

Table 4.1
Descriptive Statistics and Intercorrelations at the Team Level of Analysis (N = 51)

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Peripheral attention	50.98	25.26	–						
2. Lack of overview	3.18	0.73	-.26†	–					
3. Leadership control	2.77	0.77	-.14	.10	–				
4. Participative leadership	5.22	0.84	.23†	-.27†	-.31*	–			
5. Amount of deliberation	29.90	9.85	.13	.05	-.36*	.12	–		
6. Coordinated allocation	62.40	33.19	.03	-.07	.07	.39**	.05	–	
7. Supporting behavior	31.37	25.42	-.16	.14	-.23†	-.02	.23	.49**	–
8. Team performance	4.66	1.81	.07	-.20	-.08	.29*	.34*	.29*	.47**

†$p < .10$. *$p < .05$. **$p < .01$.

fearful, and anxious. Results from an independent samples *t* test comparing the mean threat score for the high and low threat condition indicated that participants in the high threat condition reported having felt stronger threat emotions (*M* = 2.44, *SD* = 0.92) than participants in the low threat condition (*M* = 2.01, *SD* = 0.83), $t(151) = 3.04$, $p < .01$, Cohen's $d = 0.49$. In addition, participants completed the six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (Marteau & Bekker, 1992). They indicated on a scale ranging from 1 (*not at all*) to 7 (*a great deal*) to what extent they had felt anxiety emotions during task performance. Cronbach's alpha reached .79 in this study. Results from an independent samples *t* test comparing the mean anxiety score for the high and low threat condition indicated that participants in the high threat condition reported having felt stronger anxiety emotions (*M* = 3.37, *SD* = 0.87) than participants in the low threat condition (*M* = 2.79, *SD* = 0.85), $t(151) = 4.12$, $p < .01$, Cohen's $d = 0.67$. These manipulation checks indicate that the threat manipulation was successful.

Test of Hypotheses

Table 4.1 presents means, standard deviations, and intercorrelations at the team level for all variables. Our hypotheses predicted that threat would affect information processing, exercise of control, team perspective, and team performance. In addition, we expected that the effects of threat on team performance would be mediated by the seven process variables. To evaluate the effects of threat, we conducted three one-way multivariate analyses of variance (MANOVAs) on the three groups of process measures, and a *t* test on the performance measure.

Table 4.2

Mean Scores, Standard Deviations, and t *test Results*

Variable	No threat (n = 25)		Threat (n = 26)			
	M	*SD*	*M*	*SD*	*t*(49)	Cohen's *d*
1. Peripheral attention	57.33	24.57	44.87	24.84	1.80*	0.51
2. Lack of overview	2.95	0.74	3.41	0.67	-2.38*	0.68
3. Leadership control	2.42	0.61	3.11	0.76	-3.57**	1.02
4. Participative leadership	5.49	0.88	4.97	0.74	2.26*	0.65
5. Amount of deliberation	33.32	7.97	26.62	10.49	2.56**	0.73
6. Coordinated allocation	60.93	33.61	63.81	33.37	-0.31	0.09
7. Supporting behavior	37.67	27.76	25.32	21.79	1.77*	0.51
8. Team performance	5.26	1.60	4.08	1.85	2.45**	0.70

Note. All *t*-values were tested one-sided because of directional hypotheses.
*$p < .05$. **$p < .01$.

Second, to test our multiple-mediation model, we conducted bootstrapping analyses to simultaneously estimate the indirect effects of our proposed mediators (Preacher & Hayes, 2008). Below, we present the results of each overall MANOVA followed by *t* tests for each process measure and the team performance measure (see Table 4.2). Then, we describe the analyses we used to test our multiple-mediation model and present the results from these analyses.

Information processing

Hypothesis 1 proposed that threat would negatively affect information processing. We conducted a MANOVA with threat as the between-groups variable and peripheral attention and lack of overview as dependent variables. Results showed a significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .87$, $F(2, 48) = 3.67$, $p = .03$, partial $\eta^2 = .13$. Follow-up *t* tests revealed that threat negatively affected both measures. Teams in the high threat condition paid significantly less attention to peripheral information than teams in the low threat condition, $t(49) = 1.80$, $p = .04$. They also suffered more from a lack of overview than teams in the low threat condition, $t(49) = -2.38$, $p = .01$. These results provide support for Hypothesis 1.

Exercise of control

Hypothesis 2 stated that threat would cause a constriction in control. We conducted a MANOVA with threat as the between-groups variable and the leadership and deliberation measures as dependent variables. Results showed a significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .73$, $F(3, 47) = 5.91$, $p < .01$, partial $\eta^2 = .27$. Follow-up *t* tests revealed that threat produced differences on all three univariate measures. Team leaders in the high threat condition exerted more control than their counterparts in the low threat condition, $t(49) = -3.57$, $p < .01$, and they allowed less participation of their teammates in decision making, $t(49) = 2.26$, $p = .01$. In addition, teams in the high threat condition deliberated less with each other than teams in the low threat condition, $t(49) = 2.56$, $p < .01$. These results provide support for Hypothesis 2.

Team perspective

Hypothesis 3 posited that teams under threat would exhibit a narrowing of team perspective. We conducted a MANOVA with threat as the between-groups variable and coordinated information allocation and supporting behavior as dependent variables. Results showed a marginally significant multivariate effect for the threat manipulation, Wilks' $\Lambda = .91$, $F(2, 48) = 2.52$, $p = .09$, partial $\eta^2 = .10$. Follow-up *t* tests revealed that threat did affect supporting behavior but not coordinated information allocation. Team members in the high threat condition engaged less in supporting behavior than team members in the low threat condition, $t(49) = 1.77$, $p = .04$. However, teams in both conditions did not differ in the way they allocated role-specific information, $t(49) = -0.31$, $p = .38$. These results provide partial support for Hypothesis 3.

Team performance

Hypothesis 4 proposed that threat would negatively affect team performance. An independent samples *t* test was performed comparing the mean performance score in high and low threat conditions. Results indicated that teams in the high threat condition performed worse than teams in the low threat condition, $t(49) = 2.45$, $p < .01$. This result provides support for Hypothesis 4.

Multiple-mediation model

Finally, one of the purposes of this study was to determine how threat affects team performance. Hypothesis 5 proposed that information processing, exercise of control, and team perspective would mediate the link between threat and team performance. We tested this multiple-mediation model by conducting bootstrapping analyses using the approach described by Preacher and Hayes (2008) for estimating indirect effects with multiple simultaneous mediators (also see Preacher & Hayes, 2004; Shrout & Bolger, 2002). The use of this approach has two important advantages over the most widely used causal steps approach advocated by Baron and Kenny (1986). First, using the bootstrapping approach allowed us to formally test the null hypothesis of no difference between the total effect and the direct effect, rather than having to infer mediation from a series of regression analyses (Preacher & Hayes, 2004, 2008). Second, bootstrapping has higher power than the causal steps approach while maintaining reasonable control over the Type 1 error rate (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002). In addition, in comparison with a commonly used formal test of mediation, the Sobel (1982) test, bootstrapping has the advantage that it does not rely on the assumption of a normal sampling distribution of the indirect effect, making it more suitable for small to moderate sample sizes (e.g., Preacher & Hayes, 2008, Shrout & Bolger, 2002). Furthermore, the bootstrapping method described by Preacher and Hayes (2008) allowed us to enter all seven proposed mediators into the model simultaneously and to test the indirect effect of each mediator while controlling for all other variables in the model.

We used the SPSS macro created by Preacher and Hayes and entered threat as the independent variable, team performance as the dependent variable, and the seven process measures as proposed mediators. The results presented here are based on 10,000 bootstrap resamples and bias corrected and accelerated (BCa) intervals, following the recommendations by Preacher and Hayes (2008). See Figure 4.1 for the model.

The total effect of threat on team performance was -1.18, $p < .01$. This effect became non-significant when the proposed mediators were included in the model (direct effect = -0.09, $p = 0.43$). Bootstrap results revealed that the difference between the total and the direct effect (the total indirect effect) was significant, with a point estimate of -1.09 and a 95% BCa bootstrap confidence interval (CI) of -2.37 to -0.22. Therefore, we can claim that the difference between the total and the direct effect of threat on team performance is different from zero, and conclude that the seven proposed mediators, taken as a set, did indeed mediate the effect of threat on team performance. This result provides support for Hypothesis 5.

The specific indirect effects for each mediator were calculated by multiplying the path from the independent variable to the mediator by the path from the mediator to the dependent variable. The directions of these specific indirect effects were consistent with our hypotheses that threat leads to a restriction in information processing, a constriction in control, and a narrowed team perspective, which in turn leads to a deterioration of team performance. The only specific indirect effect deviating from this pattern was leadership control, which showed a positive indirect

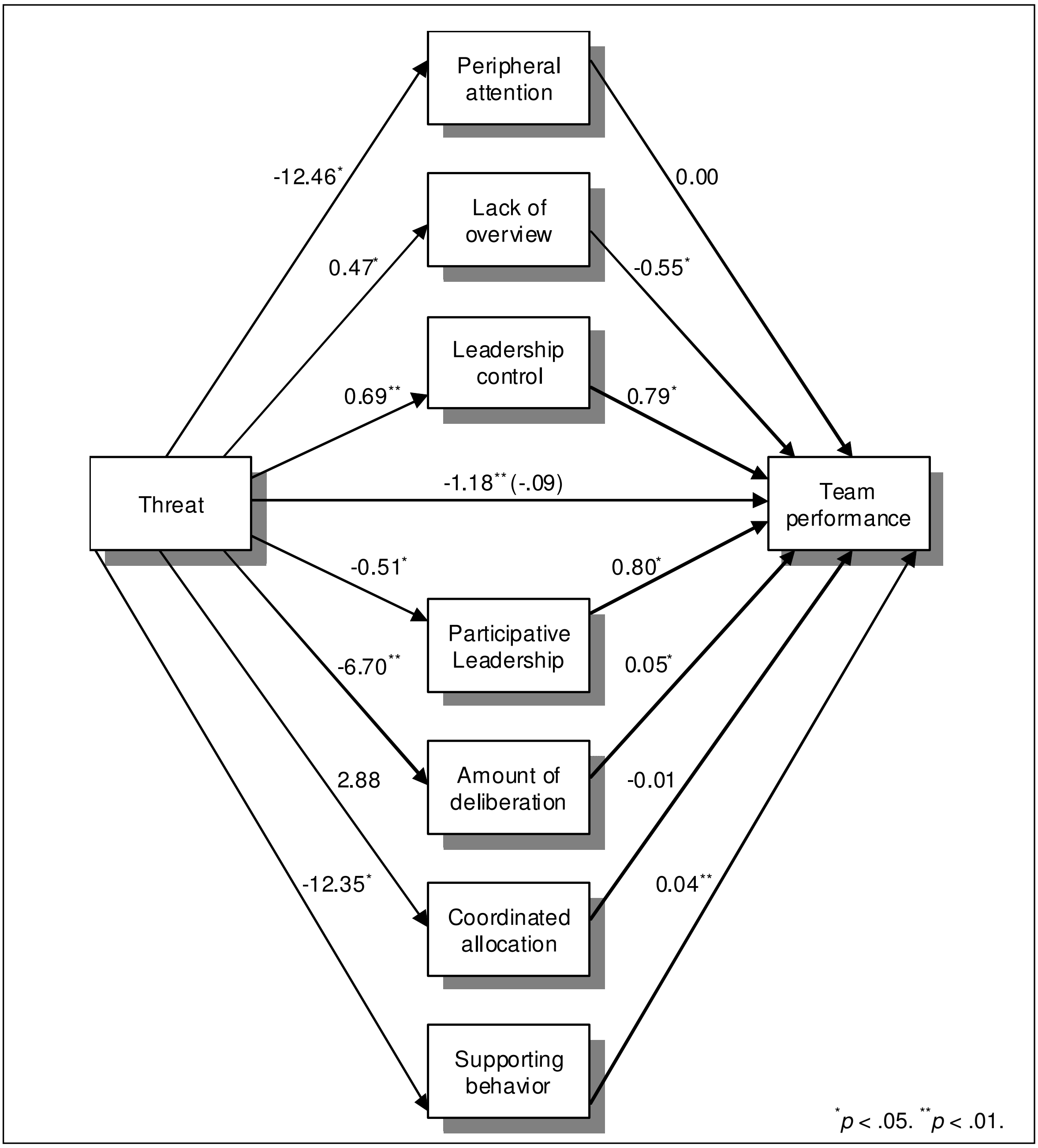

Figure 4.1
Multiple-Mediation Model for the Effects of Threat on Team Performance

effect, indicating that threat had a positive effect on team performance through leadership control.

An examination of the size of the specific indirect effects revealed that lack of overview (point estimate of -0.26 and 95% BCa CI of -0.77 to -0.02), leadership control (point estimate of 0.55 and 95% BCa CI of 0.13 to 1.26), participative leadership (point estimate of -0.41 and 95% BCa CI of -1.10 to -0.07), amount of deliberation (point estimate of -0.35 and 95 % BCa CI of -0.90 to -0.07), and supporting behavior (point estimate of -0.55 and 95% BCa CI of -1.34 to -0.02) were all unique mediators. Peripheral attention (point estimate of -0.03 and 95% BCa CI of -0.36 to 0.19), and coordinated allocation (point estimate of -0.03 and 95% BCa CI of -0.53 to 0.16) did not contribute significantly to the overall model.

Discussion

The goal of this study was to investigate team reactions to threat and to determine how these reactions affected team performance on a complex task. We expected that threat reactions would be characterized by rigidity. In addition, we expected that this rigidity would be maladaptive for team performance because complex tasks require flexibility rather than rigidity. The results of this study largely support these assumptions. We will discuss the findings for the processes and the outcomes below.

Threat-Rigidity Processes

The results of this study clearly showed that teams reacted rigidly to threat. They exhibited a restriction in information processing, a constriction in control, and a narrowed team perspective. These results support the threat-rigidity thesis (Staw et al., 1981), and replicate the findings of Kamphuis et al. (2009d). The only team behavior not affected by threat was coordinated information allocation. Team members under threat allocated role-specific information in the same way team members under normal conditions did. It is not clear why threat did not affect this behavior, particularly because previous studies employing similar measures (Ellis, 2006; Kamphuis et al., 2009d) did report effects of threat.

The results found for the effects of threat on control are particularly interesting. Previous research investigating control in teams under adverse circumstances did not always find evidence for a constriction in control (e.g., Brown & Miller, 2000; Gladstein & Reilly, 1985; Lanzetta, 1955), whereas other studies did (e.g., Argote et al., 1989; Foushee & Helmreich, 1988; Janis, 1954; Kamphuis et al., 2009d; Klein, 1976). It has been proposed that these mixed findings could be explained by the presence (or absence) of formal leadership in a team (Kamphuis et al., 2009d). Kamphuis et al. (2009d) suggested that when a team has a formal leader, who has been assigned the final responsibility for the team's performance, a constriction in control will be far more likely to emerge under threat than when no formal leader is present from the start. Because in the present study, teams had a formal leader, the results of this study provide support for this proposition. However, we could not formally test it. Future research should examine this subject more closely by systematically varying presence and absence of formal leadership in teams under threat (cf. Kamphuis et al., 2009d).

Team Performance

A major purpose of this study was to examine how rigidity in team processes affects team performance during a complex task. The results of the present study showed that threat negatively affected team performance. To be able to trace the pathways by which threat exerted its harmful effects, we employed a multiple-mediation model. The results of our multiple mediation analysis showed that the total set of processes measured, mediated the effect of threat on team performance, as expected. Examination of the specific indirect effects showed that threat negatively affected team performance through increasing lack of overview, and reducing participative leadership, deliberation, and supporting behavior in teams. Thus, the rigidity caused by threat proved to be maladaptive for team performance on the task used in this study. This task was characterized by high complexity due to its dynamic nature, the information load, the number of subtasks, the unfamiliarity with the task, the task uncertainty, and the number of possible solutions (cf. Brown & Miller, 2000). Therefore, these findings provide empirical support for the notion that rigidity in reactions is maladaptive in dynamic and complex environments (Staw et al., 1981; Weick, 1979).

However, not all rigidity-effects had a negative impact on team performance. An unexpected, but interesting result was that threat had a positive effect on team performance through leadership control. The direct effects show that threat caused team leaders to become more controlling, as expected, but that this in turn unexpectedly improved team performance. Hence, it seems that amongst all negative effects, threat also exerted positive effects on team performance, by causing team leaders to exert more control over the way their team members performed their tasks. As can be seen in Figure 4.1, the positive direct effect of leadership control on team performance is nearly as large as the positive direct effect of participative leadership on team performance. So given this set of processes, the effects of both, participative and controlling leadership contribute positively to the performance of teams.

The finding that threat may have positive effects on team performance as well, through leadership control, is not entirely implausible. After all, in certain situations, there can be merit in a leader who tells you clearly what to do, and how to do it. Under threat, when team members may have lost overview themselves, and rely on their leader for directions and decisions (e.g., Foushee & Helmreich, 1988; Hamblin, 1958; Janis, 1954), a strong, directive leader could be very effective.

However, this result should be interpreted with caution. As can be seen in Table 4.1, the zero-order correlation of leadership control and team performance is non-significant. Only when all other process variables are held constant, the relationship between leadership control and team performance becomes positive. Therefore, it is questionable whether in practice this relationship is meaningful. It is very well imaginable that parts of the relationship between leadership control and the other process variables are causal in nature. In other words, when leaders become more controlling, they might, for example, cause a reduction in the amount of deliberation within the team, which in turn has a negative effect on team performance. Similar effects might surface for the other variables. Thus, although the unique effect of leadership control may be positive, employing this kind of leadership might cause changes in other processes that negatively affect team performance, undoing the positive effects of leadership control and rendering its total effect insignificant.

Based on the present study, we cannot draw definite conclusions about the role of a directive leadership style in the relationship between threat and team performance. Future research should examine this issue more closely by manipulating different leadership styles, and investigating their interactive effects with threat on team performance.

Two of the processes measured, peripheral attention and coordinated allocation, did not contribute uniquely to the overall mediation model. As was discussed above, coordinated allocation was not affected by threat in the present study and as a result could not transmit the effect of threat to team performance. Peripheral attention, in turn, had no relationship with team performance, as a result of which the effects of threat on peripheral attention were not passed on to team performance.

Apart from that, the difference between the total effect and the direct effect of threat shows that the set of mediators we chose almost fully mediated the negative effect of threat on team performance. The processes proposed by the threat-rigidity thesis supplemented with team perspective processes thus seem to capture the full array of negative threat effects. This finding has practical relevance, because it shows which processes should be targeted to effectively prevent threat from exerting any negative effect on team performance.

Implications

The results of this study have implications for all organizations that make use of teams to perform complex tasks. At some point, most of these teams will be confronted with threat, whether it be physical (e.g., plane-crash), material (e.g., financial loss), or social (e.g., negative evaluation) in nature. Although at this time no definite answer exists as to how to mitigate the effects of threat on teams, organizations could use the results of this study in different ways to prepare their teams. Firstly, merely creating awareness of the specific effects of threat on teams may contribute to their performance in threatening situations. If team members maintain awareness of their reactions during exposure to threat, they may be able to adjust their behavior and prevent threat from influencing team performance through the rigidity reactions. Creating knowledge of typical reactions to stressors is an important component of many effective individual stress training programs (e.g., Stress Exposure Training, Johnston & Cannon-Bowers, 1996) and might be beneficial in a team context as well.

Secondly, each of the affected processes could be used as leverage points to prevent the effects of threat from occurring. Pertaining to information processing, teams could, for example, be trained to keep a broad focus under all circumstances, or they could be provided with information systems that support operators to divide their attention in an optimal way. It might even be feasible to use software agents that dynamically take over those tasks team members neglect (Bosse, Van Doesburg, Van Maanen, & Treur, 2007). Such interventions could prevent threat from affecting team performance through restricting the team's information processing. Similarly, teams could be trained to maintain a broad team perspective under all circumstances, to prevent threat from causing team members to develop an individualistic focus, resulting in worse team performance. Cross-training, a strategy in which team members are trained in the tasks and duties of their fellow team members (Volpe, Cannon-Bowers, Salas, & Spector, 1996), has been suggested as a potentially promising way of realizing this (e.g., Ellis, 2006; Marks, Sabella, Burke, & Zaccaro, 2002). Methods aimed at facilitating the development of transactive memory (i.e., knowledge of who knows what) may also contribute to the maintenance of team perspective under threat (e.g., Ellis, 2006). Finally, the results concerning the mediating role of leadership under threat warrant caution. Clearly, threat negatively affected team performance through causing a reduction in participative leadership and the amount of group deliberation. This would suggest that leaders should be trained to maintain a leadership style that actively encourages team members to participate in decision making processes. However, at the same time, the results of the present study indicate that leadership control (i.e., instructing team members what to do, and how to do it) positively affected team performance under threat. Although it might be possible for leaders to be both, participative and controlling, during the same task, more research is needed to examine how leaders can contribute to effectiveness in a threat situation.

Limitations and Directions for Future Research

The findings of the present study were obtained in an experimental setting, with an artificial task environment. Given the nature of our research question, we believe that the choice for such a context was appropriate (cf. Driskell & Salas, 1992). Moreover, the task environment used ensured a high degree of realism. However, future research should investigate whether the findings of this study can be replicated in more natural settings. Furthermore, this study used ad hoc teams which were assembled for the sole purpose of participating in the experiment. As such, these teams bore close resemblance to action teams, whose members occupy distinct areas of expertise and have been brought together for a short period of time, often to respond to emergency situations. Generalizing the findings of this study directly to teams with a more permanent nature and less within-team specialization, might prove problematic. One could, for example, imagine that team members in more permanent teams are at smaller risk of loosing their team perspective than team members in ad hoc teams. The extent to which threat affects more permanent teams in similar ways should be the subject of future investigation. Finally, it is recommended that future research investigate methods to strengthen the processes found to be vulnerable to transmit the negative effects of threat on team performance. Researchers have begun to investigate training methods to enhance team performance in stressful environments (e.g., Serfaty, Entin, & Johnston, 1998; Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998). The results of the present study can help refine these training methods to exactly target the relevant processes.

Conclusion

The results of this study provide a comprehensive model of the effects of threat on team performance. By simultaneously investigating the effects of threat on information processing, exercise of control, and team perspective we were able to capture the central mediating processes in the relationship between threat and team performance. As such, this study enhances our understanding of the effects of threat on teams.

Returning to our example in the introduction, where you were the pilot of a large commercial airliner about to go down, we may now predict your reactions. At the moment the warning signals start flashing and sounding, your attention is likely to be drawn to these signals and away from other indicators and meters. With all these signals going off, you will feel like you can not maintain an overview of the situation. You will start giving your co-pilot orders to check out some potential causes, without asking his or her opinion about the problem. Both of you will become completely absorbed by your own ideas about what causes the problems, and you will fail to discuss your views with each other. As a result, when the cause of these problems can only be found by combining alarm signal information with less central information, or by comparing your information with that of your co-pilot, you will be highly unlikely to solve the problems. Thus it seems safe to say that your reactions, rigid as they would be, would not contribute to your chances of survival in a complex team situation. It is our hope, however, that the results of the present study eventually will.

Chapter 5

Armoring Teams:

The Mitigating Effects of Transactive

Memory Training on Teams under Threat[1]

Teams are dangerously vulnerable to the effects of threat. Little is known about how to protect them. In this study, a transactive memory training intervention (TM-training), which aimed to mitigate the effects of threat on teams, was designed and tested in an experiment with 58 three-person teams performing a complex task. TM-training combined principles of cross-training with ideas of transactive memory theory. The study employed a 2 (threat: high vs. low) × 2 (TM-training: training vs. no training) factorial design. Team processes were measured by automated behavior recordings and questionnaires. Results showed that TM-training enhanced transactive memory, teamwork processes, and team performance. Moreover, significant interactive effects showed that TM-training had the ability to protect the performance of teams under threat by reducing the negative effects of threat.

Despite their widespread use in dangerous and complex circumstances, teams frequently appear to be vulnerable to the effects of threat. Many tragedies in

[1] This chapter is based on Kamphuis, Gaillard, & Vogelaar (2009a). The data were collected during the same study as reported in Chapter 4. In this chapter, however, we focus on a different set of measures and describe the full 2 (threat: high vs. low) × 2 (training vs. no training) factorial design.

aviation, the military, emergency medicine, and other safety critical industries have been attributed to teams giving way under pressure (e.g., Cannon-Bowers & Salas, 1998b; Flin, Slaven, & Stewart, 1996; Helmreich & Schaefer, 1994; Kanki, 1996). Indeed, a number of studies have confirmed that threat and stress negatively affect team performance (e.g., Cannon-Bowers & Salas, 1998b; Driskell, Salas, & Johnston, 1999; Ellis, 2006).

Threat not only affects individual task work in teams, but also undermines team processes and team cognition. Under threat, team members are in danger of losing their sense of being part of a team (Driskell, et al., 1999). This may negatively affect a team's transactive memory system (TMS), which combines the knowledge possessed by individual team members with a shared awareness of who knows what (Wegner, 1995). This negative effect of threat on TMSs may result in inferior team performance (Ellis, 2006).

Although our understanding of the processes through which threat negatively affects team performance has developed over the last years, our knowledge of how to mitigate these effects is still in its infancy. Organizations could greatly benefit from interventions that would help reduce the negative effects of threat on teams. Therefore, the purpose of the present study was to develop and test an intervention aimed at reducing these negative effects. We thereby built on the knowledge that has been developed regarding the effects of threat on team processes and investigated the effects of an intervention designed to reinforce the processes that are negatively affected by threat. Specifically, we designed a brief training method, which combined principles of cross-training (Volpe, Cannon-Bowers, Salas, & Spector, 1996) with ideas of transactive memory theory (Wegner, 1987, 1995), and aimed to enhance transactive memory in teams. We investigated this 'transactive memory training' (TM-training) as a potential moderator of the relationship between threat and team performance. We conducted an experiment to examine the effects of TM-training on team performance under threat and expected the training to have a positive effect on team performance through its effects on transactive memory, performance monitoring, and supporting behavior. We expected this effect to be largest in teams under threat, since TM-training targets the same processes threat affects.

Theory and Hypotheses

The Effects of Threat on Teams

Threat can be defined as a possible impending event perceived by a person or group of persons as potentially causing material or immaterial loss to, or the obstruction of goals of that person or group of persons (cf. Argote, Turner, & Fichman, 1989; Lazarus, 1966; Staw, Sandelands, & Dutton, 1981; Turner & Horvitz, 2001). According to the transactional theory of stress (e.g., Lazarus, 1966; Lazarus & Folkman, 1984), threat is one of the major determinants of stress. The most comprehensive theory addressing the effects of threat on performance is the threat-rigidity thesis (Staw et al., 1981). The threat-rigidity thesis states that there is a general tendency for individuals, groups, and organizations to behave rigidly in threatening situations. Staw et al. (1981) distinguish two categories of effects. First, threat may cause a *restriction in information processing*. This may manifest itself in a narrowed field of attention, a reduction in the number of alternatives considered, and reliance upon internal hypotheses and prior expectations. Second, under threat, there may be a *constriction in control*, demonstrated by power and influence becoming concentrated in higher levels of a hierarchy. Together these effects in information and control processes cause a system's behavior to become less diverse and flexible. In changing, ambiguous, and unpredictable environments, this reaction is likely to be maladaptive, because in these environments flexibility, rather than rigidity, is necessary to survive (Staw et al., 1981; Weick, 1979).

The limited research that has investigated team performance under threat has generally supported the propositions of the threat-rigidity thesis (e.g., Argote et al., 1989; Gladstein & Reilly, 1985). More recent research has highlighted that a narrowing of attention under threat does not merely affect individual task performance in teams, but also leads team members to shift from a broader, team perspective to a more narrow, individualistic focus (Driskell et al., 1999; Ellis 2006). This attentional shift may lead to impaired team performance because of the interdependent nature of team tasks. Team tasks after all do not only require taskwork processes, defined as a team's interactions with tasks, tools, machines, and systems (Bowers, Braun, & Morgan, 1997), but also teamwork processes (McIntyre & Salas, 1995). Teamwork refers to those behaviors, cognitions, and emotions that are needed to function as a team (e.g., Goodwin, Burke, Wildman, & Salas, 2009; Marks, Mathieu, & Zaccaro, 2001), and includes processes such as coordination, communication, performance monitoring, and supporting behavior (e.g., McIntyre & Salas, 1995).

Driskell et al. (1999) examined to what extent a narrowing of attention under stress affected teamwork processes. They found that stress indeed resulted in a narrowing of team perspective as measured by the extent to which members felt like a team and were oriented at team versus individual activities during the task. This shift of attention from the team to the self led to impaired team performance. Ellis (2006) reasoned that this shift in attention might negatively affect TMSs and team mental models. A TMS is a set of distributed, individual memory systems for encoding, storing, and retrieving information that combines the knowledge possessed by particular members with a shared awareness of who knows what (Wegner, 1995). Team mental models are defined as emergent cognitive states, containing a shared understanding and mental representation of knowledge concerning key elements of the task, the task environment, and the other team members (Cannon-Bowers, Salas, & Converse, 1993; Klimoski & Mohammed, 1994). Ellis did indeed find that the narrowing of the team member's attention under threat negatively affected TMSs and team mental models, which mediated the relationship between threat and team performance.

In sum, in line with the propositions of the threat-rigidity thesis, past research has shown that threat affects information processing and exercise of control in teams. Threat not only affects individual task work processes, but also causes team members to shift their attention away from the team, to the self. This shift in attention leads to a deterioration of teamwork processes, eventually resulting in poorer team performance. The central question is how to prevent these threat effects from occurring. Several researchers have suggested that one potentially promising way of realizing this is through team training, particularly cross-training (Ellis, 2006; McCann, Baranski, Thompson, & Pigeau, 2000; Volpe et al., 1996).

Cross-Training

Cross-training has been defined as "a strategy in which each team member is trained on the tasks, duties, and responsibilities of his or her fellow team members" (Volpe et al., 1996, p. 87). The goal of cross-training is to enhance team members' interpositional knowledge: information that each team member holds regarding the roles, responsibilities, and appropriate task behaviors of their teammates (e.g., Marks, Sabella, Burke, & Zaccaro, 2002; Volpe et al., 1996). This knowledge helps team members to understand the activities of their fellow team members and thus contributes to anticipation of their needs, improved communication, and increased coordination (Blickensderfer, Cannon-Bowers, & Salas, 1998). Especially in highly interdependent teams, these effects of cross-training are expected to contribute significantly to team performance (e.g., Marks et al., 2002).

Blickensderfer et al. (1998) specified three types of cross-training which differ with respect to the depth of the information provided and the method in which the information is taught. *Positional clarification* is the least in-depth form of cross-training and is aimed at providing team members with general knowledge of each member's roles and responsibilities through lecture or discussion methods. *Positional modeling* provides details beyond what is learned in positional clarification, because team members' roles are not only discussed, but also observed. Finally, *positional rotation* provides team members with a working knowledge of each member's specific tasks through active participation and first-hand experience in each member's role.

Research has found positive effects of cross-training on various aspects of team functioning, including interpositional knowledge, communication, coordination, and team effectiveness (Cannon-Bowers, Salas, Blickensderfer, & Bowers, 1998; Volpe et al., 1996). Cannon-Bowers et al. (1998) found that cross-training interacted with workload, such that under high-workload conditions, teams having received cross-training exhibited significantly better team performance than teams that were not cross-trained, whereas under low-workload conditions, there was no difference between trained and untrained teams. In addition, McCann et al. (2000) showed that cross-trained teams withstood the negative effects of team member reconfiguration. Furthermore, Marks et al. (2002) showed in two studies that the three types of cross-training all enhanced the development of team-interaction mental model similarity among team members participating in a military computer simulation. These shared mental models in turn were positively associated with backup and coordination processes, which mediated the relationship between shared mental models and team performance.

These results all support the use of cross-training as a strategy to enhance team performance in interdependent settings. Cross-training helps to develop interpositional knowledge and enhances team mental model similarity in that way. As such, cross-training might reduce the negative effects of threat: while threat leads team members to shift their attention away from the team and negatively affects team mental models, cross-training is likely to have the exact opposite effect. Thus, it seems sensible to cross-train teams that have to operate under threatening circumstances.

However, in some settings, it might not be feasible to cross-train team members to develop interchangeable expertise. Consider, for example, surgical teams. It is not very practical to try to train nurses in the tasks, duties and responsibilities of the surgeons. Moreover, in many settings, training each member in the roles of all other members may not be time-efficient (Marks et al., 2002). In fact, McCann et al. (2000) showed that although cross-training may lead to better team mental models, this may come at the expense of poorer individual task mental models, resulting in worse performance. Therefore, instead of entirely focusing on the development of shared mental models through cross-training, it might be more effective to accentuate the distribution of knowledge within the team and learn team members how they can access the knowledge of their team mates (cf. Gorman et al., 2007).

Transactive Memory Theory

In essence, the above argument pertains to the distinction between shared mental models and transactive memory. Both refer to cognitive structures that enable team members to adequately process information in a team context, but whereas shared mental models refer to knowledge structures held in common, transactive memory refers to knowledge of information distribution within a team and to how this distributed knowledge is combined (e.g., Ellis, 2006; Kozlowski & Ilgen, 2006). According to transactive memory theory (Wegner, 1987, 1995), team members divide the cognitive labor for their tasks, and rely on one another to be responsible for specific expertise. In this way, an individual member can develop highly specific expertise while still being able to use other team members' knowledge. The whole team can only benefit from the specific expertise distributed across members of the collective, when each team member knows in general what others know in detail. This transactive memory can be used to distribute and retrieve information based on team members' specific areas of expertise (Hinsz, Tindale, & Vollrath, 1997). Because of the distribution of specialized knowledge across team members, TMSs should be cognitively efficient. TMSs should reduce the cognitive load of team members, expand their pool of expertise, and reduce redundancy (Hollingshead, 1998). In addition, TMSs should allow teams to plan their work more sensibly, assigning tasks to team members with the relevant area of expertise, and improve coordination, since team members are better able to anticipate each other's behavior (e.g., Moreland, 1999). Findings of both field and laboratory research show that TMSs indeed enhance team performance (e.g., Ellis, 2006; Lewis 2003, 2004;

Liang, Moreland, & Argote, 1995; Moreland & Myaskovsky, 2000; Prichard & Ashleigh, 2007; Zhang, Hempel, Han, & Tjosvold, 2007).

To sum up, transactive memory theory draws attention to the distribution of unique knowledge and expertise in teams, and to the mechanisms that are necessary to make use of that distributed knowledge. As such, it complements the focus on shared knowledge in team mental model research. Given that cross-training team members to develop interchangeable expertise may not be very time-efficient, may not always be feasible (e.g., Marks et al., 2002), and may come at the expense of individual task performance (McCann et al., 2000), a similar broadening of cross-training may be useful. Such training would not merely be aimed at enhancing shared knowledge in teams, but also at increasing knowledge of who knows what and developing strategies to utilize this distribution of knowledge in the best possible way. Particularly when considering ways of mitigating the detrimental effects of threat on teams, the focus on transactive memory could be effective, given that Ellis (2006) showed that threat not only affects team mental models, but also transactive memory and coordination processes in teams (cf. Liang et al., 1995; Rulke & Rau, 2000). Mitigation strategies therefore should not mainly focus on creating similarity, overlapping knowledge, and interchangeable expertise, but rather aim to create awareness of who knows what and learn how to draw on this distributed expertise. Although at this moment knowledge concerning techniques to develop TMSs in teams is scarce, previous research does provide some suggestions.

Early research on the development of TMSs in teams showed that training together as a team provides opportunities to learn about other members' expertise and facilitates the development of TMSs (e.g., Liang et al., 1995). More recent research showed that training together as a team is not a necessary precondition for the development of a TMS. Merely providing individually trained team members with information about other team members' skills also facilitated development of TMSs (Moreland & Myaskovsky, 2000). Other research supports the idea that early development of knowledge concerning who knows what is critical for subsequent TMS maturation (Lewis, 2004; Rulke & Rau, 2000). Furthermore, it has been suggested that accompanying this knowledge with strategic considerations about how to take advantage of the expertise of others could probably lead to even better TMSs (cf. Moreland & Myaskovsky, 2000).

Previous research thus provides some useful initial notions that could be used in training interventions aimed at developing TMSs in teams. Creating knowledge of who knows what in an early stage may be essential, and combining this knowledge with techniques that facilitate the employment of the distributed knowledge may be beneficial as well. These insights coincide with two of the three key processes of a TMS, namely *directory updating* and *retrieval coordination* (Wegner, 1995). Through directory updating, team members learn about each other's areas of expertise and through retrieval coordination, team members plan how to retrieve information known to be within other team members' areas of expertise. The third key process, *information allocation*, pertains to the allocation of new information to team members with the relevant area of expertise. A training intervention for the purpose of TMS development in teams thus should aim to facilitate the two processes of directory updating and retrieval coordination. The directory updating component of such a training intervention would correspond to low-intensity cross-training, whereas the coordinated retrieval component would augment the focus on sharedness with a focus on distribution and coordination. When these two components have been used to help a TMS emerge in an early phase of a project, it is expected that this TMS will improve teamwork processes, as it helps team members to better anticipate how other members will behave (Lewis, 2004).

Present Study

In the present study we investigated the effects of an intervention designed to mitigate the negative effects of threat on team performance. Previous research suggested that cross-training might be a promising method to overcome these negative effects. Based on studies showing some potential shortcomings of cross-training, and guided by research showing that threat not only negatively affects team mental models, but also transactive memory and coordination processes in teams (Driskell et al., 1999; Ellis 2006) we developed a training intervention aimed at developing TMSs in teams in order to resist the negative effects of threat. This *transactive memory training* (TM-training) was founded on the principles of cross-training, but rather than entirely laying the emphasis on developing interpositional knowledge, this intervention highlighted the distribution of expertise within the team and addressed strategies to combine this expertise effectively. It combined the least in-depth form of cross-training, positional clarification (Blickensderfer et al., 1998), with a brief guided group discussion (cf. Moreland & Myaskovsky, 2000), which aimed to facilitate the distribution and communication of knowledge within the team.

We expected that this TM-training intervention would enhance transactive memory and teamwork processes (performance monitoring and supporting behavior), which in turn would positively influence team effectiveness. Because threat negatively affects the same cognitions and processes this intervention aimed to enhance, we expected an interaction with threat, such that the negative effects of threat would be smaller for teams receiving TM-training, than for teams not receiving TM-training. Specifically, this study addressed the following hypotheses:

> Hypothesis 1. *Threat will negatively affect transactive memory, teamwork processes, and team performance.*
> Hypothesis 2. *Transactive memory training will positively affect transactive memory, teamwork processes, and team performance.*
> Hypothesis 3. *The negative effects of threat on transactive memory, teamwork processes, and team performance will be smaller for teams that received transactive memory training, than for teams that did not receive transactive memory training.*

Method

Participants and Design

Participants were 174 officer cadets of the Netherlands Defence Academy (31 women and 143 men; mean age = 21.2 years) who were arrayed into 58 three-person teams. In exchange for their participation, teams could win cash prizes depending upon the team's performance (150 Euro for the best performing team within each cohort). We used a 2 (threat: high vs. low) × 2 (TM-training: training vs. no training) factorial design. Teams were randomly assigned to one of the four conditions.

Task

PLATT

Participants engaged in a complex planning and problem-solving scenario in the Planning Task for Teams (PLATT; Kamphuis, Essens, Houttuin, & Gaillard, 2009; Kamphuis & Houttuin, 2007). PLATT is a software platform for controlled experimental research on team performance in complex environments. It has been used in other studies investigating different aspects of team performance (e.g., Kamphuis, Gaillard, & Vogelaar, 2008; Van Bezooijen, Vogelaar, & Essens, 2009a, 2009b; Langelaan & Keeris, 2008). It consists of a generic software architecture and research-specific scenarios. Participants playing a scenario are seated behind computers connected via a network. They receive scenario-messages via e-mail and can search for additional information on web sites. Participants communicate with each other via e-mail and have access to a digital shared workspace in which they can work jointly on certain team tasks. All participants' actions are automatically recorded in a log file. Based on this log file, different behavioral measures can be constructed.

Scenario

In the present study, teams engaged in a highly complex military evacuation scenario. In this scenario, teams have to develop a plan to extract a group of people from a hostile area to a safer place. They have to determine the fastest route and plan how they will employ their transportation, engineer, and infantry units, to realize the extraction. There are eighteen possible routes to use for the evacuation, ranging from very slow to very fast. Whether a route is fast not only depends on the length of the roads, but also on the condition of these roads, and whether there are enemy activities on these roads.

During the scenario, in real-time, a large number of scenario-driven messages are sent to the three participants. These messages pertain to road conditions, enemy activities, delays due to different causes, the position of the units, personnel and materiel problems, weather conditions, unrelated events, et cetera. This information varies in relevance and is sent by many sources differing in reliability (e.g., headquarters, local civilians, the enemy). The scenario also controls changes in information on the websites participants can access. The events in the scenario are constructed in such a way that at different moments in time, different routes are optimal. Teams accordingly have to adjust plans and adapt to circumstances. The shared workspace in this scenario consists of a digital map of the evacuation area. This map can be used to integrate the most recent information, using symbols indicating, for example, enemy activities, locations of units, and road conditions.

After 45 minutes, the scenario ends and teams have to deliver an evacuation plan using a standardized form. In this plan, they have to describe via which route they plan to extract the group of people and how they will employ their units.

Roles

Team members were randomly assigned to one of three roles: *Operations*, *Logistics*, or *Intelligence*. Each role had unique responsibilities, expertise, and tasks. In addition, each role received unique information (via e-mail or websites) during the scenario. Operations was the leader of the team and responsible for directing the activities of the other team members. Operations was the only team member who could edit the shared map of the area in which the evacuation had to take place. Intelligence was responsible for all information concerning the safety of the roads, and had unique expertise concerning determining the reliability of the information sources in the scenario. Logistics was responsible for personnel and materiel, and the information concerning the condition of the roads. Logistics had unique expertise concerning calculating the duration of the various routes. The distribution of expertise and information created interdependence between team members. Only when all three team members combined their knowledge and information, they were able to deliver an optimal evacuation plan.

Procedure

Participants arrived at the location of the experiment in groups of three. The experimenter seated the participants according to the roles they had randomly been assigned to and explained that the purpose of the experiment was to gain a better understanding of team problem-solving and team decision-making processes. He further explained that they would perform a team task, in which an evacuation had to be planned. The experimenter then informed the participants which role they would occupy during the task, without going into any details. Due to their education as officer cadets, participants knew in general what kind of responsibilities and duties would be associated with these roles. They did not know, however, what specific responsibilities and duties in this task were associated with these roles.

Instruction

Following this, participants watched a 20-minute video instruction containing information about the team task. The information in this video was relevant for all roles in the task. After having watched this video, participants had the opportunity to ask the experimenter questions about these generic instructions. The experimenter answered these questions and then handed out three different packets containing role specific information to the participants, one packet for Operations, one for Intelligence, and one for Logistics. Participants studied the information concerning their own roles individually for 10 minutes, after which the experimenter announced the next phase of the experiment. After this instruction phase, each team member had general knowledge about the task and the task environment and specific knowledge of his or her own area of expertise and not of the areas of expertise of one of the other team members.

TM-training

Participants in the TM-training condition watched an extended version of the same video instruction, which was about 4 minutes longer. In these four additional minutes, detailed information was given about the areas of expertise of the different roles in the team task. In addition, in the packets the experimenter handed out after the video instruction, besides role specific information concerning their own roles, a short description of the areas of expertise of the other team members was included as well. Participants in this condition were given 5 minutes to study this information. After this, the experimenter instructed team members in this condition to use an additional 5 minutes to discuss each other's responsibilities, expertise, and tasks, and to determine who could process which information, and how information should be allocated and retrieved within the team. The experimenter guided this discussion, to make sure that all relevant aspects were addressed, and that no other topics were discussed. All in all, team members in the training condition had 10 minutes of preparation time after having watched the video instruction, just as team members in the no-training condition.

This training intervention aimed to create awareness of the distribution of unique knowledge and expertise within the team. It combined the least in-depth form of cross-training, positional clarification (Blickensderfer et al., 1998), with a brief guided group discussion that aimed to facilitate the use of the distributed knowledge. These two components (the positional clarification and the group discussion) targeted the TMS-processes of directory updating and retrieval coordination (Wegner, 1995). Directory updating was jump-started through the positional clarification (and continued in the guided group discussion). Retrieval coordination could take place in the guided group discussion. The third TMS-process, information allocation, was measured as a dependent behavioral variable during task execution, together with information retrieval.

Threat manipulation

After these instructions, the experimenter informed all participants that, prior to engaging in the team task, they had to perform a brief individual task, the Synwork task (Elsmore, 1994). Synwork requires participants to execute four different subtasks at the same time. Participants were told that performance on this individual task was a good predictor of performance on complex planning tasks like the one they were about to engage in. The experimenter further told them that their mean team score would be compared to the mean score of a civilian population that had been tested before, to estimate how well they could perform on the team task. After this, all participants received instructions for the Synwork task, and subsequently performed this task for 2 minutes.

At the end of the individual task, participants in the low threat condition received false positive feedback. The experimenter told them that they had performed well and had scored above the average of the civilian population. He further told them that he expected them to perform well on the team task as well, and reminded them of the prize of 150 Euro for the best performing team within each cohort.

Participants in the high threat condition, on the other hand, received false negative feedback at the end of the individual task. The experimenter told them that they had performed rather poorly and that their score was below the average of the civilian population. He further told them that he expected them to have difficulty with the team task as well, and explained that both the researchers and their own commanders were particularly interested in teams that had difficulties with these kinds of tasks. Therefore, to gain better insight into what happens in ill-performing teams, their performance would be recorded using a video camera, which was set up prominently in front of the team, and webcams, which were fixed on top of the participants' monitors. Moreover, the experimenter told them that they ran the risk of having to come back for an evaluation with their commanders and the researchers if their team would be one of the five lowest performing teams. Finally he told them that the videotape could be used as course material.

Consistent with previous research, this manipulation aimed to create an evaluative situation with potentially negative consequences in case of poor performance (e.g., Blanchette, Richards, & Cross, 2007; Ellis, 2006; Turner, Pratkanis, Probasco, & Leve, 1992). When persons expect to perform poorly, such a situation is likely to be perceived as threatening (e.g., Thompson, 1981; Blascovich & Tomaka, 1996). Therefore, we manipulated the expectation of poor performance by giving negative feedback on an unrelated task said to be predictive of performance on the task of interest (cf. Mogg, Mathews, Bird, & Macgregor-Morris, 1990). We deliberately chose not to provide false negative feedback on the task of interest because teams might have used this feedback as an indication that they had to alter their strategies. This would have been an unwanted effect, as it might have obscured the effects of threat.

Task execution and conclusion

Following the feedback on the individual task, the experimenter asked the participants to fill out a short electronic questionnaire (which constituted the manipulation check for the threat manipulation), after which the scenario for the team task was started. Teams then performed the 45-minute military evacuation scenario. After this, participants were asked to respond to a final questionnaire (with dependent measures described below). After the experiment, all participants were fully debriefed about the true nature of the experiment, and offered the possibility to withdraw their data from the study. None of the participants withdrew their data.

Measures

Most of the variables of interest in this study were measured behaviorally (on the basis of the log files). In addition, two self-report measures were used. All measures, except the team performance measure, were collected at the individual level. Because the unit of analysis was the team level, and variance in team members' behavior or reports was of no concern, individual scores were aggregated to the mean team score.

Transactive memory

In this study, we used both self-report and behavioral measures to assess transactive memory and transactive memory systems in teams. At the self-report level, we measured team members' evaluation of their own and others' knowledge concerning other members' expertise with a *transactive memory* scale adapted from previous research (Kamphuis et al., 2008). Cronbach's alpha for this scale reached .75. The formulation of the items of this scale was as follows: "During task performance, I was well informed about the possibilities of my team members", "During task performance, my team members were well informed about my possibilities", "I knew exactly which team member had what kind of information", "The other team members knew exactly what kind of information I had". Team members scored each item on a 7-point Likert-type scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*).

In addition, we measured the *transactive memory system* by using a Dutch translation of Lewis's (2003) 15-item scale measuring the three dimensions (specialization, credibility, and coordination) of TMSs. The original scale was modified according to the recommendation made by Lewis to make the 4 reverse-worded items consistent with the other scale items (i.e., not reversed). Team members scored each item on a 7-point Likert-type scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). The Cronbach's alpha reliabilities for the specialization, credibility, and coordination subscales were .74, .62, and .86 respectively. The data across the three subscales were aggregated to form a single

TMS measure (see Lewis, 2003; 2004). The Cronbach's alpha for the entire scale reached .84.

At the behavioral level, a TMS is indicated by directory updating, retrieval coordination, and information allocation (Wegner, 1995). As described above, we let teams in the TM-training condition engage in the processes of directory updating and retrieval coordination before task execution to stimulate the development of a TMS. During task execution, we measured information allocation and information retrieval as behavioral indicators of a TMS (cf. Ellis, 2006). *Differentiated information allocation* and *differentiated information retrieval* occurred when team members respectively sent role-specific information (i.e., information that could only be adequately dealt with by one specific team member) to, or asked role-specific information from, the teammate with the relevant area of expertise. To construct this measure, two judges coded all e-mail messages in the log files. They grouped every e-mail message into one of seven categories of a collectively exhaustive and mutually exclusive categorization (Kamphuis et al., 2009c). The judges coded 10 (17.2%) of the 58 teams together. The interrater reliability for these 10 teams was .95 (Cohen's Kappa). Because this indicates almost perfect agreement, the remaining 48 teams were coded by just one of the judges. One of the categories pertained to the allocation of role-specific information, another to the retrieval of this information. The measures reported here consist of the percentage of e-mails in these categories that were sent to the team member with the relevant area of expertise, instead of to the other team member or to both team members at the same time (which would be inefficient and could lead to errors, as the other team member would not have the expertise to deal with this information correctly, or answer the question). An example of an e-mail message in the category 'allocation of role-specific information' would be: "I received a report from local civilians of sniper shootings between Iskra and Golesh". When a team member would send this information to Intelligence, in this case the team member with the relevant area of expertise (safety), that would be an example of differentiated information allocation. An example of an e-mail message in the category 'retrieval of role-specific information' would be: "How long does it take to travel from Iskra to Golesh?". When this question would be posed to Logistics, in this case the team member with the relevant area of expertise (calculating the duration of the various routes), that would be an example of differentiated information retrieval.

Teamwork processes

We measured two important teamwork processes, relevant in the present task: *performance monitoring* and *supporting behavior*. To measure the degree to which teams engaged in performance monitoring, we investigated their communication. As described above, all e-mail messages were coded. One of the categories pertained to performance monitoring, which consisted of team members keeping track of each other's work to ensure that everything is done the way it should be (e.g., McIntyre & Salas, 1995). The measure for performance monitoring consisted of the percentage of e-mail messages in this category out of the total number of e-mails team members sent to each other. An example of an e-mail message in this category would be: "Operations, I just sent you information about rebels between Iskra and Golesh, but I do not see them yet on the map. Could you put them on the map, please?".

Supporting behavior consisted of the percentage of times participants forwarded 'wrongly delivered' e-mail messages to the team member with the relevant area of expertise. Normally, team members only received scenario e-mail messages that were meant for them, and not for one of their teammates. But sometimes, information meant for one role, was deliberately sent to a team member with another role, to investigate how this team member would handle this information. We considered sending this information to the teammate with the relevant area of expertise to be an act of supporting behavior. On the basis of the log files, we calculated the percentage of these messages that was sent to the teammate with the relevant area of expertise, out of the total number of 'wrongly delivered' e-mail messages.

Team performance

Teams received a single performance score, ranging from 0 (very poor) to 10 (excellent), for their performance. This score consisted of a score for the quality of the route they had chosen minus the total number of errors the team had made in their evacuation plan. The score for the quality of the route ranged from 5 (slowest routes) to 10 (fastest routes). Errors could be made in the way teams planned to deploy their infantry, engineer, and transportation units (e.g., no deployment of a unit whereas it should have been deployed, deployment on the wrong part of a route, deployment from a wrong starting point, etc.), and in calculating the travel times for the roads they planned to use. The scenario was constructed in such a way that in each of the eighteen routes, teams could make a maximum of five errors, resulting in an overall minimum score of 0 and a maximum score of 10.

Results

Prior to data analysis, seven teams had to be removed from the data set. Four teams had to be removed, because one of their members had indicated to have dyslexia. Because all information and communication during task performance was textual, dyslexia would have large effects on team processes and team performance. In addition, two teams had to be removed because of technical problems. Finally, one team in the high threat condition had to be removed, because members of this team had been informed about the threat manipulation by other participants.

Manipulation Checks

Threat appraisal

To examine the effects of the threat manipulation, participants first completed two items that measured participants' appraisal of the situation, immediately after the feedback on the individual task and just before engaging in the team task. These items did not explicitly ask participants how threatened they felt, because that would have hinted them about the true nature of the experiment, but instead indirectly measured how participants appraised the situation. The first item ("How important is it for you to perform well on this task?") measured on a scale ranging from 1 (*not important at all*) to 7 (*very important*) the extent to which participants judged that something was at stake, because having a stake in the outcome is a necessary condition for threat (cf. primary appraisal, e.g., Folkman & Lazarus, 1985; Lazarus & Folkman, 1984). The second item ("How well, do you think, are you going to perform as a team on this task?") measured on a scale ranging from 1 (*very poorly*) to 7 (*very well*) to what extent participants anticipated to be able to deal with this situation, because believing to have power to control the outcome of an encounter involving potential harm or loss, diminishes the degree of threat (cf. secondary appraisal, e.g., Folkman & Lazarus, 1985; Lazarus & Folkman, 1984). Both appraisal-items were combined to yield a single index of threat appraisal. This index was computed as a ratio of the first to the second item and reflected the extent to which a situation is appraised as potentially causing the obstruction of goals (i.e., as threatening). This method of measuring appraisal was adapted from research on challenge and threat (Blascovich & Tomaka, 1996; Tomaka, Blascovich, Kibler, & Ernst, 1997) and is consistent with the transactional theory of stress (Lazarus & Folkman, 1984).

An independent samples *t* test was performed comparing the mean threat appraisal ratios in high and low threat conditions. Results indicated that the mean threat appraisal ratio was larger in the high threat condition (*M* = 1.11, *SD* = 0.26) – indicating higher stakes than coping ability – than in the low threat condition, *M* = 0.99, *SD* = 0.20; $t(151) = 3.26$, $p < .01$, Cohen's *d* = 0.53. This indicates that instructions in the high threat condition caused participants to appraise the situation as more threatening than in the low threat condition.

Threat emotions and state anxiety

After task performance, participants completed the Folkman and Lazarus (1985) threat emotions scale (three items, Cronbach's alpha = .72). They indicated on a scale ranging from 1 (*not at all*) to 7 (*a great deal*) to what extent they felt worried, fearful, and anxious. Results from an independent samples *t* test comparing the mean threat score for the high and low threat condition indicated that participants in the high threat condition reported having felt stronger threat emotions (*M* = 2.44, *SD* = 0.92) than participants in the low threat condition (*M* = 2.01, *SD* = 0.83), $t(151) = 3.04$, $p < .01$, Cohen's *d* = 0.49. In addition, participants completed the six-item short-form of the state scale of the Spielberger State-Trait Anxiety Inventory (Marteau & Bekker, 1992). They indicated on a scale ranging from 1 (*not at all*) to 7 (*a great deal*) to what extent they had felt anxiety emotions during task performance. Cronbach's alpha reached .79 in this study. Results from an independent samples *t* test comparing the mean anxiety score for the high and low threat condition indicated that participants in the high threat condition reported having felt stronger anxiety emotions (*M* = 3.37, *SD* = 0.87) than participants in the low threat condition (*M* = 2.79, *SD* = 0.85), $t(151) = 4.12$, $p < .01$, Cohen's *d* = 0.67. These manipulation checks indicate that the threat manipulation was successful.

Test of Hypotheses

Our hypotheses predicted that threat would negatively (H1) and transactive memory would positively (H2) affect transactive memory, teamwork processes, and team performance. In addition, we expected that the negative effects of threat would be smaller for teams that received TM-training (H3). A two-way between-groups multivariate analysis of variance (MANOVA) was conducted to evaluate the effects of threat and TM-training. The between-groups factors were threat, with two levels (high vs. low) and TM-training (training vs. no training). Table 5.1 presents means, standard deviations and intercorrelations at the team level for all variables of interest.

Table 5.1

Descriptive Statistics and Intercorrelations at the Team Level of Analysis (N = 51)

Variable	*M*	*SD*	1	2	3	4	5	6	7
1. Transactive memory	4.71	0.78	–						
2. TMS	5.57	0.45	.59**	–					
3. Differentiated allocation	62.40	33.19	.53**	.25	–				
4. Differentiated retrieval	73.53	31.28	.42**	.16	.45**	–			
5. Performance monitoring	4.41	3.12	.27	.02	.15	.42**	–		
6. Supporting behavior	31.37	25.42	.48**	.10	.49**	.46**	.39**	–	
7. Team performance	4.66	1.81	.44**	.32*	.29*	.35*	.58**	.47**	–

*$p < .05$. **$p < .01$.

Significant multivariate effects emerged for the threat manipulation (Wilks' Λ = .52, $F(7, 41) = 5.41$, $p < .01$, partial $\eta^2 = .48$), the TM-training intervention (Wilks' Λ = .23, $F(7, 41) = 19.85$, $p < .01$, partial $\eta^2 = .77$), and their interaction (Wilks' Λ = .62, $F(7, 41) = 3.55$, $p < .01$, partial $\eta^2 = .38$). The analysis shows that, overall, threat and TM-training had effects on the dependent measures, and that the effects of threat differed depending on whether teams received TM-training or not. Univariate follow-up two-way analyses of variance (ANOVAs) with threat and training as the independent variables were used to investigate the effects for the separate dependent measures (see Table 5.2 for cell means and significant relations for each dependent measure).

Transactive memory

Results of the follow-up ANOVA on transactive memory revealed a significant main effect of threat ($F(1, 47) = 12.81$, $p < .01$, $\eta^2 = .14$), indicating that teams under high threat reported having worse transactive memory than teams under low threat. The main effect of TM-training was also significant ($F(1, 47) = 27.60$, $p < .01$, $\eta^2 = .30$), indicating that teams that received TM-training reported having better transactive memory than teams that received no training. The effects were qualified by a significant threat × TM-training interaction ($F(1, 47) = 4.44$, $p = .04$, $\eta^2 = .05$; see Figure 5.1). Simple slopes analyses revealed that only when teams did not receive TM-training, threat negatively affected transactive memory ($F(1, 23) = 12.23$, $p < .01$, $\eta^2 = .35$). In contrast, when teams did receive TM-training, threat had no effect on transactive memory ($F(1, 24) = 1.54$, $p = .22$). These results provide support for all three hypotheses.

Table 5.2

Mean Scores, Standard Deviations, and Significant Effects

Variable		No training (n = 25)		Training (n = 26)		Effects
		No threat (n = 12)	Threat (n = 13)	No threat (n = 13)	Threat (n = 13)	
1. Transactive memory	*M*	4.74	3.83	5.25	5.01	a^{**}, b^{**}, c^{*}
	SD	0.76	0.53	0.50	0.47	
2. TMS	*M*	5.68	5.25	5.76	5.26	a^{**}
	SD	0.50	0.41	0.29	0.40	
3. Differentiated allocation	*M*	35.40	44.11	84.50	83.51	b^{**}
	SD	26.97	30.40	18.42	23.55	
4. Differentiated retrieval	*M*	69.64	40.29	92.47	91.41	a^{*}, b^{**}, c^{*}
	SD	31.55	26.39	12.00	19.39	
5. Performance monitoring	*M*	4.31	2.05	4.89	6.40	b^{**}, c^{*}
	SD	2.95	1.99	2.52	3.42	
6. Supporting behavior	*M*	16.67	10.90	57.05	39.74	a^{*}, b^{**}
	SD	15.89	10.96	21.48	20.46	
7. Team performance	*M*	4.95	3.40	5.55	4.76	a^{*}, b^{*}
	SD	1.55	1.49	1.64	1.97	

Note. a = main effect of Threat; b = main effect of TM-training; c = Threat × TM-training interaction.
$^{*}p < .05$. $^{**}p < .01$.

Results of the follow-up ANOVA on teams' transactive memory systems revealed a significant main effect of threat ($F(1, 47) = 16.74$, $p < .01$, $\eta^2 = .26$), indicating that teams under high threat reported having less well developed TMSs than teams under low threat. There was no main effect of TM-training ($F(1, 47) = 0.12$, $p = .73$), and no interaction effect ($F(1, 47) = 0.10$, $p = .75$).[2] These results provide support for Hypothesis 1, but not for Hypotheses 2 and 3.

[2] A series of additional two-way ANOVAs with threat and training as the independent variables was conducted to explore the results for the three separate subscales: specialization, credibility, and coordination. Results of the ANOVA on the specialization subscale revealed a significant main effect of threat ($F(1, 47) = 15.16$, $p < .01$, $\eta^2 = .24$), indicating that teams under high threat reported less specialization ($M = 5.65$, $SD = 0.42$) than teams under low threat ($M = 6.10$, $SD = 0.42$). The main effect of TM-training was also significant ($F(1, 47) = 4.99$, $p = .03$, $\eta^2 = .10$), indicating that teams that received TM-training reported more specialization ($M = 6.00$, $SD = 0.44$) than teams that received no training ($M = 5.74$, $SD = 0.47$). There was no interaction effect ($F(1, 47) = 0.14$, $p = .71$). Results of the ANOVA on the credibility subscale revealed no significant effects (main effect of threat: $F(1, 47) = 0.95$, $p = .34$; main effect of TM-training: $F(1, 47) = 1.81$, $p = .19$; interaction effect: $F(1, 47) = 2.91$, $p = .10$). Results of the ANOVA on coordination revealed a significant main effect of threat ($F(1, 47) = 17.15$, $p < .01$, $\eta^2 = .27$), indicating that teams under high threat reported less coordination ($M = 4.39$, $SD = 0.78$) than teams under

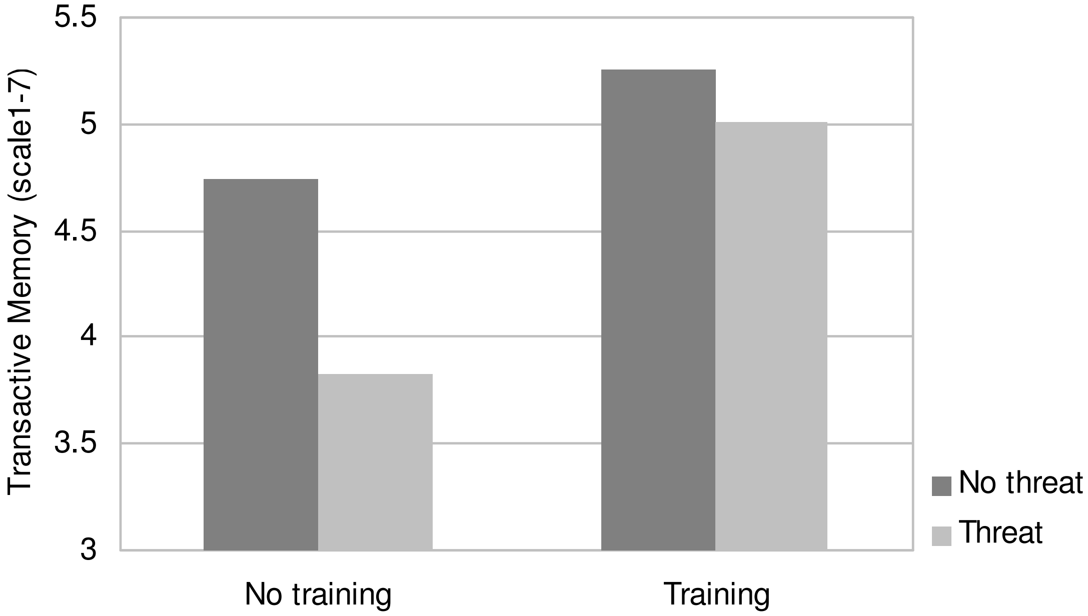

Figure 5.1
The Interactive Effects of Threat and Training on Transactive Memory

Results of the follow-up ANOVA on differentiated information allocation revealed no main effect of threat (F(1, 47) = 0.30, p = .59). The main effect of TM-training did reach significance (F(1, 47) = 39.30, p < .01, η^2 = .45) indicating that team members that received TM-training allocated a higher percentage of role-specific information to teammates with the relevant area of expertise than team members that received no training. There was no interaction effect (F(1, 47) = 0.47, p = .50). These results provide support for Hypothesis 2, but not for Hypotheses 1 and 3.

Results of the follow-up ANOVA on differentiated information retrieval revealed a significant main effect of threat (F(1, 47) = 5.42, p = .02, η^2 = .06), indicating that team members under high threat retrieved a higher percentage of role-specific information from teammates with the relevant area of expertise than team members under low threat. The main effect of TM-training was also significant (F(1, 47) = 32.03, p < .01, η^2 = .36), indicating that team members that received TM-training retrieved a higher percentage of role-specific information from teammates with the relevant area of expertise than team members that received no training.

low threat (M = 5.24, SD = 0.63). There was no main effect of TM-training (F(1, 47) = 0.00, p = .95), and no interaction effect (F(1, 47) = 0.04, p = .85).

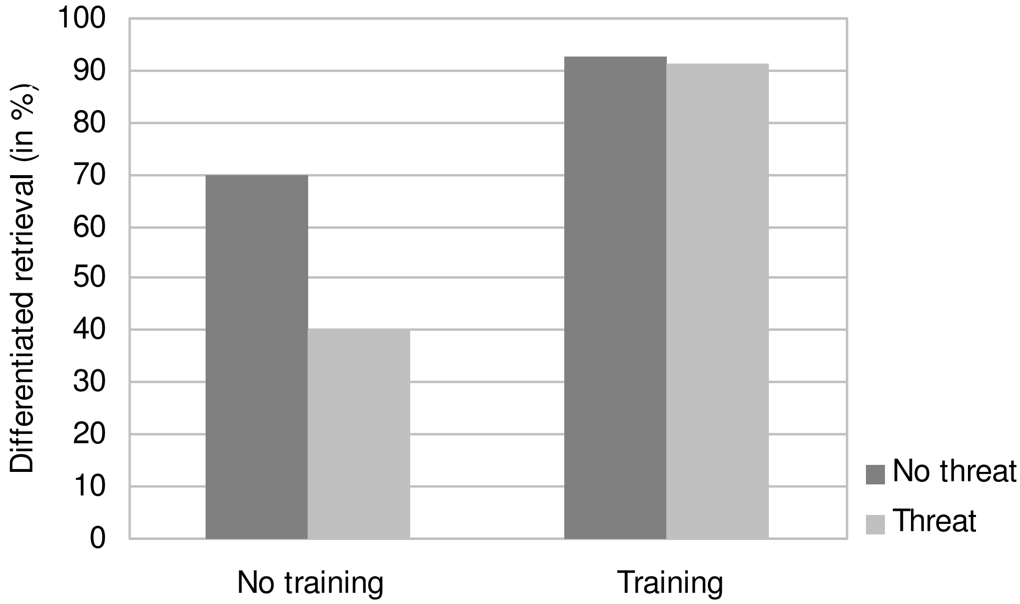

Figure 5.2
The Interactive Effects of Threat and Training on Differentiated Information Retrieval

The effects were qualified by a significant threat × TM-training interaction ($F(1, 47) = 4.69$, $p = .04$, $\eta^2 = .05$; see Figure 5.2). Simple slopes analyses revealed that only when teams did not receive TM-training, threat negatively affected differentiated information retrieval ($F(1, 23) = 6.41$, $p = .02$, $\eta^2 = .22$). In contrast, when teams did receive TM-training, threat had no effect on differentiated information retrieval ($F(1, 24) = 0.03$, $p = .87$). These results provide support for all three hypotheses.

Teamwork processes

Results of the follow-up ANOVA on performance monitoring revealed no main effect of threat ($F(1, 47) = 0.23$, $p = .63$). The main effect of TM-training did reach significance ($F(1, 47) = 10.14$, $p < .01$, $\eta^2 = .16$), indicating that teams that received TM-training monitored each other's performance more than teams that received no training. This effect was qualified by a significant threat × TM-training interaction ($F(1, 47) = 5.94$, $p = .02$, $\eta^2 = .09$; see Figure 5.3). Simple slopes analyses revealed that only when teams did not receive TM-training, threat negatively affected performance monitoring ($F(1, 23) = 5.14$, $p = .03$, $\eta^2 = .18$). In contrast, when teams did receive TM-training, threat had no effect on performance monitoring ($F(1, 24) = 1.65$, $p = .21$). These results provide support for Hypotheses 2 and 3. Hypothesis 1 was only supported in the no-training condition. In the TM-training condition teams

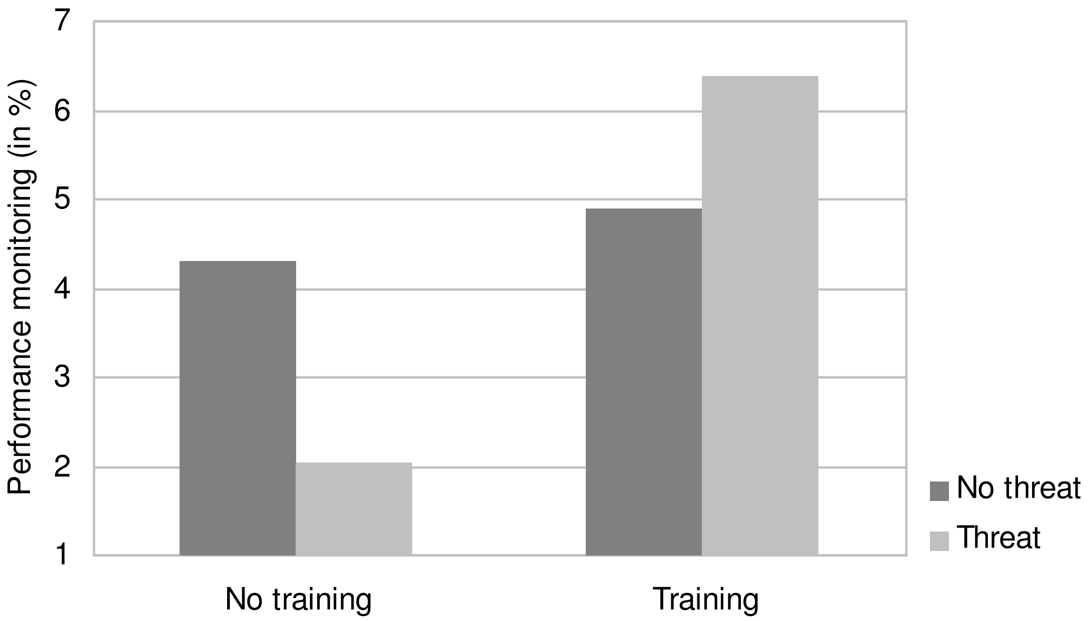

Figure 5.3

The Interactive Effects of Threat and Training on Performance Monitoring

engaged in *more* performance monitoring under high threat (although this effect did not reach significance), as a result of which there was no main effect of threat.

Results of the follow-up ANOVA on supporting behavior revealed a significant main effect of threat ($F(1, 47) = 5.39$, $p = .03$, $\eta^2 = .05$), indicating that teams under high threat showed less supporting behavior than teams under low threat. The main effect of TM-training was also significant ($F(1, 47) = 48.54$, $p < .01$, $\eta^2 = .47$), indicating that teams that received TM-training showed more supporting behavior than teams that received no training. There was no interaction effect ($F(1, 47) = 1.35$, $p = .25$). These results provide support for Hypotheses 1 and 2, but not for Hypothesis 3.

Team performance

Results of the follow-up ANOVA on supporting behavior revealed a significant main effect of threat ($F(1, 47) = 6.22$, $p = .02$, $\eta^2 = .11$), indicating that teams under high threat performed worse than teams under low threat. The main effect of TM-training was also significant ($F(1, 47) = 4.38$, $p = .04$, $\eta^2 = .08$), indicating that teams that received TM-training performed better that teams that received no training. There was no interaction effect ($F(1, 47) = 0.64$, $p = .43$). These results provide support for Hypotheses 1 and 2, but not for Hypothesis 3.

Discussion

The purpose of this study was to investigate *transactive memory training* as an intervention to reduce the negative effects of threat on teams. TM-training sought to enhance team members' transactive memory by combining aspects of cross-training with key processes of transactive memory systems. Prior to performing a complex planning and problem-solving task, team members either received TM-training or standard instructions. Threat was manipulated by creating an evaluative situation with potentially negative consequences, and expected to negatively affect transactive memory, teamwork processes and team performance. We expected that TM-training would positively affect these variables, especially in teams under threat. Overall, our results supported these hypotheses, although the expected interaction was found only for some of the measures. We will discuss the findings for each of the hypotheses below.

Threat and Team Performance

The results of this study showed that threat negatively affected transactive memory, teamwork processes, and team performance. Teams under threat reported having worse transactive memories and less well developed TMSs, showed less performance monitoring and supporting behavior, and performed worse than teams under normal conditions.

These results are in line with the proposition of the threat-rigidity thesis that groups restrict their information processing under threat (Staw et al., 1981). These findings also support more recent research showing that this restriction in information processing may cause team members to adopt an individualistic instead of a team focus (Driskell et al., 1999), and may result in less effective TMSs (Ellis 2006). In addition, the results of the present study extend our knowledge by showing that threat affects two key teamwork processes as well: performance monitoring and supporting behavior. The only team behavior not affected by threat was information allocation. It is not clear why threat did not affect this behavior, particularly because it did affect information retrieval, a quite comparable measure.

TM-training and Team Performance

Our TM-training intervention had large positive effects on transactive memory, teamwork processes, and team performance. Trained teams reported having better transactive memories, exhibited more differentiation in their information allocation and retrieval behavior, showed more performance monitoring and supporting behavior, and outperformed teams that had not been trained. By itself, the TM-training intervention explained on average 26% of the variance in the dependent measures.

This finding has relevance in light of the question how intensive cross-training should be, in order to enhance team performance (e.g., Marks et al., 2002). Although more intensive forms of cross-training (i.e., positional modeling and positional rotation) have been argued to have larger effects, previous research has shown that these forms do not necessarily lead to better team results than simply providing members with information about their teammates' roles and responsibilities (i.e., positional clarification; e.g., Marks et al., 2002; McCann et al., 2000). In addition, in many settings, training members of a team intensively in the tasks and duties of other team members may not be very practical and time-efficient (cf. Marks et al., 2002). The TM-training intervention used in the present study provided team members with detailed information about the distribution of expertise within the team, and subsequently gave team members the possibility to discuss each other's expertise and to determine how information should be allocated and retrieved within the team. As such it combined the least in-depth form of cross-training, positional clarification (Blickensderfer et al., 1998), with a method, based on transactive memory theory (e.g., Wegner, 1995), to enhance the teams' strategies to combine their distributed expertise effectively. The dual focus on both interpositional knowledge and coordination appears to have been very effective. Results of the present study therefore suggest that combining low-intensity cross-training with a method to enhance coordination, rather than simply intensifying the development of interpositional knowledge, significantly improves team performance. This finding is in line with recent research that suggests that the development of interpositional knowledge alone may not be the optimal strategy for teams to improve their performance, and that attention to coordination needs may be a critical component of a successful team training intervention (Gorman et al., 2007; Salas, Nichols, & Driskell, 2007).

Furthermore, the effects of our TM-training support theory and research concerning the role of directory updating and retrieval coordination in the development of TMSs. Wegner (1995) argued that team members must have knowledge of the distribution of expertise to be able to effectively allocate information, and also need a retrieval strategy to be able to get information back from the team. Previous research has supported this notion, by showing that uncovering one another's expertise (cf. directory updating) prior to the task or in an early phase of a project facilitates the development of effective TMSs later on (Lewis, 2004; Moreland & Myaskovsky, 2000; Rulke & Rau, 2000). Moreover, research by Prichard & Ashleigh (2007) showed that additionally paying explicit attention to team skills such as coordination and role allocation (cf. retrieval coordination) has added benefits in the development of TMSs. The results of the present study support and extend this research by showing that a fairly brief training intervention attempting to jump-start directory updating and retrieval coordination is potent enough to exert large positive effects on transactive memory and transactive memory processes in later phases of task performance. In addition, findings of this study show that the effects of such a training intervention are not localized to transactive memory processes alone, but also extend to performance monitoring and supporting behavior, two key teamwork processes (e.g., McIntyre & Salas, 1995).

The only measure not affected by TM-training, was the team's TMS, as measured by the Lewis (2003) TMS-scale. Additional analyses on the separate subscales (see Footnote 1) showed that TM-training did have positive effects on specialization, but not on credibility and coordination. Inspection of the items of these subscales helps to explain why TM-training did not affect these scales in the present study. The credibility subscale was supposed to measure the extent to which team members trusted and relied on other's expertise (Lewis, 2003). Items of this subscale referred, among other things, to the reliability of information team members received from each other (e.g., "I was confident relying on the information that other team members brought to the discussion"). However, in the present task, there was a large amount of unreliable information, coming from sources that could not be trusted. Team members would sent this unreliable information to each other, for example, to let it be checked. As a consequence, it is likely that participants related some of the items of this subscale to the unreliability of scenario-information, instead of relating it to the credibility of their teammates' expertise. Other items of the subscale may have been linked to team members' expertise. The low reliability of this subscale (a Cronbach's alpha of .62) supports this idea. Therefore, in the present study, the credibility subscale did not measure what it was supposed to measure. This may explain the absence of effects of the TM-training intervention.

A related argument pertains to the coordination subscale. This subscale was supposed to measure the extent to which team members used coordinated processes to combine their knowledge (Lewis, 2003). Items of this subscale, for example, inquire about misunderstandings, need to backtrack, and accomplishing the task efficiently. As we described in the method section, the task participants had to perform was a very complex task. The scenario was constructed in such a way that at different moments in time, different routes were optimal. Accordingly, when teams processed the scenario events accurately and executed the task as it was meant to be executed, they had to change routes, and backtrack and start over a lot, making the process seem not very efficient. When they reported their seemingly inefficient task processes on the coordination subscale of the TMS-scale, this would have resulted in a low coordination score. However, due to the nature of their task, their reports of inefficiency, quite paradoxically, might have been the result from well-coordinated teamwork. Therefore, the coordination subscale seems not to have been very suited to measure TMS coordination processes in the present study. This may explain the absence of effects of the TM-training intervention.

Overall, these results suggest that the use of the TMS-scale was not appropriate given the task used in the present study. The scale has been explicitly developed as a field measure to study TMSs in organizational teams (Lewis, 2003). Results of the present study suggest that caution is warranted when researchers plan to apply this measure in more controlled settings.

The Combined Effect of Threat and TM-Training

Overall the negative effects of threat were smaller for teams that received TM-training than for teams that did not receive this training, as hypothesized. Accordingly, TM-training had the capacity to mitigate the negative effects of threat. While team members' self-reported transactive memory, information retrieval behavior, and performance monitoring were negatively affected by threat when teams did not receive TM-training, threat no longer exerted these negative effects when teams did receive TM-training. TM-training thus protected team processes from deteriorating under threat, by focusing team members on the interdependent nature of their task, and by facilitating their utilization of distributed knowledge and expertise.

These results advance our understanding of the effects of threat on teams. They support and extend previous research that found that threat causes team members to shift their attention away from the team (Driskell et al., 1999; Ellis 2006) by showing that an intervention designed to enhance team members' transactive memory, has the ability to moderate these threat effects. In addition, these results show that detailed knowledge of the effects of adverse circumstances on team processes can be used to design training interventions to overcome these effects. Targeting these effects with specific interventions might prove more efficient and effective than training teams to cope with stress in general.

A number of variables did not show an interaction effect of TM-training and threat. The lack of an interaction effect for TMSs can be explained by the problems of the use of this scale in the present study, as specified above. No interaction was found for differentiated information allocation either, because threat had no effect on the way team members allocated information. The effects of threat on supporting behavior did not interact with TM-training. This can probably be explained by the finding that teams that had not received TM-training, hardly showed any supporting behavior (i.e., a 'floor effect'). Consequently, threat could only have a small negative effect. TM-training instead could greatly improve supporting behavior under both high and low threat conditions, resulting in main effects only. Finally, the negative effect of threat on team performance was not mitigated by TM-training. The pattern of results, however, corresponded to our expectations. The absence of a significant interaction can probably be explained by the fact that there are other factors influencing team performance besides the processes affected by TM-training, for example individual taskwork processes, leadership, and even luck (cf. Salas et al., 2008; Smith-Jentsch, Johnston, & Payne, 1998). These factors all may explain variance in the team performance measure, with the result that the interactive effects of TM-training and threat may have been obscured.

Practical Implications

The results of this study show that organizations can successfully prepare teams for operating in threatening circumstances through TM-training. TM-training has the ability to prevent teams from falling apart under threat due to team members loosing their attention for their teammates. In addition, the results of this study show that under normal conditions too, teams may benefit from a TM-training intervention. Below, we elaborate on what the findings of this study imply for the design of team training interventions and the types of teams that could potentially benefit from these interventions.

Organizations that aim to prepare teams for operating in potentially threatening circumstances could use the findings of the present study in the design of their training interventions. First, results of this study suggest that it could be valuable for organizations to consider training interventions that consist of a combination of traditional cross-training and methods to enhance the teams' abilities to combine their distributed expertise effectively, rather than placing the entire emphasis on the development of interpositional knowledge. The cross-training component of such an intervention could simply consist of highlighting the distribution of expertise within a team and does not have to be very intensive (i.e., positional clarification rather than positional modeling or rotation). The other component, aimed at facilitating the development of strategies to allocate and retrieve information in an efficient manner, could consist of a guided group discussion (like in the present study) in which a trainer lets team members discuss each other's roles and responsibilities and assists them in developing strategies to accurately process information within the team. Apart from being more feasible in many settings (consider, for example, surgical teams), such a combination has proven to be very effective in the present study. Moreover, designing training interventions in this way prevents team members from learning large amounts of information that is not functional for their own task performance.

Second, results of this study show that even a brief team training intervention that aims to protect the processes affected by threat, can have substantial effects. This can be of considerable value in situations where training time or resources are limited. In those situations, it may not be possible to use extensive and costly stress inoculation programs (e.g., Stress Exposure Training, Johnston & Cannon-Bowers, 1996). Instead, the present research suggests that organizations could provide brief training interventions specifically targeting transactive memory and transactive memory processes. Such interventions ensure that team members maintain their team focus and help protect teamwork processes from deteriorating under threat.

Regarding the types of teams that should be considered for TM-training interventions, it is expected that particularly ad hoc teams, consisting of members with specialized backgrounds, that have to operate under potentially stressful conditions, will benefit from TM-training. Team members in these teams assemble for a short period of time to perform a task that requires expertise from different fields. These teams are especially vulnerable to the negative effects of threat, because members are not familiar with each other and each other's expertise, and consequently have an increased risk of narrowing their team perspective under threat. TM-training has the potential to accelerate the process of learning who knows what within the team, and as such might protect these teams against threat's negative effects. In addition, it is expected that more permanent teams might benefit from TM-training too. Although in these teams, TMSs will have been developed (e.g., Lewis, 2004), threat still has the potential to exert negative effects on transactive memory and team processes. TM-training in these situations might serve literally as a way to update team members' memories about each other's expertise and remind them of their interdependence and the necessity to collaborate in order to accomplish their goals.

The results of this study point out that the TM-training intervention was not only effective under threat, but also under normal conditions, although to a lesser extent. Hence, TM-training might prove useful in any situation where team members that do not know each other assemble for the first time. Organizations should stimulate that in these situations teams shortly discuss each other's professional backgrounds and consider how each member's expertise can be used in the team's project, rather than engaging in a standard introduction round. In this way, teams will be able to develop functional TMSs more rapidly and as a result will be productive faster.

Limitations and Directions for Future Research

The findings of the present study were obtained in an experimental setting, with an artificial task environment. Given the nature of the research question, we believe that the choice for this context was appropriate (cf. Driskell & Salas, 1992). It allowed us to test our theoretical predictions and isolate causal phenomena, to manipulate threat without running the risk of causing actual damage, and to collect valuable, fine-grained behavioral measures next to self-report measures. However, future research should also be directed toward investigating the impact of TM-training in applied settings.

In addition, this research used ad hoc teams, which were randomly assembled to take part in the experiment. Extending these findings directly to permanent teams might prove problematic. It is expected that TM-training will be most useful in newly formed teams. The extent to which such an intervention has the ability to positively influence teams that have a history together should be the subject of future investigation.

Furthermore, results of the present study indicated that the use of the Lewis (2003) TMS-scale was not appropriate given the nature of the task. Although results for this scale largely did not support our hypotheses, behavioral measures indicative of TMSs did. Other researchers (e.g., Ellis, 2006) have employed similar behavioral measures in experimental research of TMSs, and a bifurcation seems to be developing between field and laboratory investigations of transactive memory, whereby field studies employing the Lewis TMS-scale focus on the dimensions specialization, credibility, and coordination, whereas laboratory studies focus on the processes of directory updating, information allocation, and retrieval coordination as behavioral indicators of TMSs. This divergence is questionable, because although both may represent valid operationalizations of TMSs (cf. Ellis, 2006) they clearly target different aspects of TMSs, as a result of which it may become difficult to compare the findings of laboratory and field research. We suggest that researchers include both operationalizations of TMSs in their studies, so as to be able to examine the way these operationalizations relate to each other.

Finally, findings of the present study indicate that augmenting the principles of cross-training, with those derived from transactive memory theory has favorable effects on team processes and team performance. Future research should compare TM-training to cross-training to empirically test whether TM-training indeed has added benefits.

Conclusion

Overall, the contributions of the present study are threefold. First, the results of the present study are useful for organizations, because we developed and tested a training intervention that has the potential to successfully mitigate the negative effects of threat on the performance of teams. Given the vulnerability of teams to the effects of threat, and our current lack of knowledge to avert these effects, the developed TM-training intervention is a valuable tool that can be used by organizations to protect their teams in dangerous circumstances. It provides organizations with a theory-driven method and precise directions for developing interventions tailored to the teams in their specific organizations.

Second, we contribute to the domain of team training by integrating in a single intervention the focus on sharedness dominant in cross-training research, with a focus on distribution and compatibility characteristic of transactive memory theory. Results of the present study indicate that combining a superficial form of cross-training (i.e., positional clarification) with a method that highlights the distribution of expertise within the team can be highly beneficial for the teams' performance, without having to be intensive. Consequently, the problems of feasibility and efficiency surrounding cross-training are overcome, as is the question of how much cross-training would be necessary in a given context (e.g., Marks et al., 2002). Moreover, we extend the currently limited knowledge concerning how to enhance transactive memory in teams (cf. Kozlowski & Ilgen, 2006; Moreland & Myaskovsky, 2000). The present research shows that a training intervention that combines two key processes of TMSs, directory updating and retrieval coordination, has the potential to jump-start the development of a TMS.

Third, the present study extends previous research on the effects of threat on teams by showing that in addition to team perspective and transactive memory, the key teamwork processes of performance monitoring and supporting behavior also deteriorate under threat. In addition, to our knowledge, this study is the first controlled investigation of the combined effects of threat and a training intervention to counter the effects of threat. By showing that the expected effects of threat can be mitigated by an intervention that aims to protect those processes threat is expected to impair, this study provides additional support for the notion that threat-rigidity in teams takes the shape of a narrowed team perspective.

In conclusion, this study presents a training intervention that has the capacity to mitigate the detrimental effects of threat on the performance of teams. Our results signify the importance of paying explicit attention to the distributed nature of expertise in such an intervention. The TM-training intervention we developed shows promising results that call for further investigation. Organizations preparing teams for effective performance in high-risk situations could greatly benefit from applying the principles of TM-training. Understanding who knows what, these teams will be better 'armored' against threat's dangerous effects.

Chapter 6

Summary and Discussion

Many organizations rely on teams to accomplish increasingly complex tasks. These teams often operate in the face of threat, whether it be threat of financial loss, loss of face, or loss of lives. The goal of the present dissertation was to investigate how these threats affect the performance of teams, and how teams can be protected against the negative effects of threat.

The starting point and theoretical framework for this dissertation was the threat-rigidity thesis (Staw, Sandelands, & Dutton, 1981). This thesis proposes a restriction in information processing and a constriction in control under threat, resulting in maladaptive performance in the case of complex and dynamic tasks. Previous team research on this subject has been limited, especially where it concerns complex tasks. To be able to address the complexity present-day teams face, and at the same time objectively capture the relevant team processes, a new task environment for team research was developed for the purpose of the present dissertation. The propositions of the threat-rigidity thesis were experimentally investigated in this environment with teams performing complex planning and problem-solving scenarios.

The studies presented in this dissertation investigated threat-rigidity reactions in information processing, exercise of control, and team perspective due to physical and social threats. A multiple-mediation model was used to investigate the appropriateness of these threat-rigidity reactions in a complex task environment. Finally, a training intervention aimed at protecting teams from the negative effects of threat by enhancing transactive memory was developed and tested.

In the next section, the research of this dissertation will be summarized. In the remainder of this chapter, theoretical, methodological, and practical implications of the present research will be discussed and directions for future research will be suggested. This chapter ends with the identification of some strengths and limitations and an overall conclusion.

Summary

Chapter 2

Chapter 2 describes the development of PLATT, a task environment for controlled research on team performance in complex environments. The development of this environment was guided by a series of requirements that aimed to create the appropriate balance between complexity and control. The application of PLATT in a broad range of experiments in different research programs has shown that PLATT has the ability to meet each of these requirements. Specifically, PLATT has the ability to elicit real team behavior and makes it possible to investigate team planning, problem-solving and decision-making processes in complex environments. It does so, while offering a good degree of experimental control and relatively convenient data collection by means of a broad range of team process measurement possibilities. Finally, the PLATT software guarantees a high degree of flexibility, making it suitable for investigating a wide array of team related research questions. The development of PLATT thus provided a research environment in which the effects of threat on teams performing complex tasks could be investigated in a controlled manner.

Chapter 3

In Chapter 3, it was investigated how physical threat affected team processes during a complex task. Three-person teams engaged in a complex planning and problem-solving scenario in PLATT, either anticipating a potential reduction in oxygen level, or under normal conditions. In line with the threat-rigidity thesis, this physical threat was expected to cause a restriction in information processing, a constriction in control, and a narrowing of team perspective.

The results of this study confirmed these expectations. Specifically, teams under physical threat exhibited reduced peripheral attention, degraded overview, more controlling and less participative leadership, less group discussions, and reduced coordination and supporting behavior. The results of this Chapter thus show that teams react to physical threat with a restriction in information processing, a constriction in control, and a narrowing of team perspective.

Chapter 4

In Chapter 4, the findings of Chapter 3 were extended by examining the appropriateness of the threat-rigidity reactions of teams for their performance in a complex environment, using a multiple-mediation model. Officer cadets of the Netherlands Defence Academy engaged in a similar complex planning and problem-solving scenario as was used in the study described in Chapter 3. Instead of a physical threat, this time a social threat was manipulated. This social threat was expected to cause rigidity, manifested in a restriction in information processing, a constriction in control, and a narrowing of team perspective. In line with the treat-rigidity these reactions were expected to contribute negatively to the teams' performance, because the task teams had to perform was characterized by high complexity, necessitating flexibility rather than rigidity.

The results presented in this chapter largely supported these hypotheses. Replicating the findings of Chapter 3, teams under threat exhibited reduced peripheral attention, degraded overview, more controlling and less participative leadership, less group discussions, and reduced supporting behavior. In addition, threat negatively affected team performance. Results of a multiple mediation analysis showed, as expected, that the total set of processes measured, mediated the negative effect of threat on team performance. Examination of the effects for the separate processes revealed that threat negatively affected team performance through a reduction in overview, participative leadership, group discussions, and supporting behavior. The results presented in Chapter 4 thus demonstrate that, in general, the rigid reactions caused by threat are maladaptive for team performance in a complex work environment.

Chapter 5

Finally, in Chapter 5, the effects of a training intervention designed to protect teams from the negative effects of threat was investigated. This Transactive Memory training intervention (TM-training) combined aspects of cross-training with key processes of transactive memory systems, and aimed to reinforce team perspective by enhancing team members' transactive memory. TM-training was tested in a study with officer cadets of the Netherlands Defence Academy engaging in a complex planning and problem-solving scenario in PLATT. A between-teams design was used, with social threat and TM-training as factors. It was expected that threat would cause a narrowing of team perspective, thereby affecting transactive memory, teamwork processes, and team performance. TM-training, instead, was expected to positively affect transactive memory, teamwork processes, and team performance. An interaction between threat and TM-training was predicted, such that the effects of threat would be smaller for teams that received TM-training.

The results presented in this chapter largely supported these hypotheses, although the expected interaction was found only for some of the measures. Specifically, threat negatively affected transactive memory, teamwork processes, and team performance. In contrast, TM-training positively affected all these measures. Overall, the negative effects of threat were smaller for teams that received TM-training than for teams that did not receive training. Particularly, when teams had received the TM-training intervention, threat no longer exerted negative effects on transactive memory, certain transactive memory system (TMS) behaviors, and performance monitoring. No interaction was found for some measures of TMSs, supporting behavior, and team performance. In short, the results presented in Chapter 5 reveal that TM-training has the capacity to positively affect transactive memory, teamwork processes, and team performance, and counters detrimental effects of threat on teams.

Theoretical Implications and Future Research

The findings of the present dissertation contribute to the knowledge of the effects of threat on team performance. In addition, the results have implications for transactive memory theory and for the debate on how to train teams for performance in demanding environments.

Threat-Rigidity Effects

Despite an apparent vulnerability of teams to the effects of threat, up till now, little was known about the specific processes by which threat affects the performance of teams, especially during complex tasks. The most comprehensive theory addressing the effects of threat, the threat-rigidity thesis (Staw et al., 1981), states that teams react to threat with a restriction in information processing and a constriction in control, resulting in performance decrements in complex and dynamic environments. The limited research on these propositions generally supported the proposition of a restriction in information processing (e.g., Gladstein & Reilly, 1985), whereas the proposition of a constriction in control received mixed support (e.g., Driskell & Salas, 1991; Gladstein & Reilly, 1985; Harrington, Lemak, & Kendall, 2002). The meditational properties of these rigidity reactions in the relationship between threat and team performance received little research attention up till now.

Results of the present research supported the proposition of a restriction in information processing, by showing that team members narrowed their breadth of attention under threat and suffered from a lack of overview. In addition, extending research suggesting that this restriction in information processing may cause a narrowing of team perspective as well (Driskell, Salas, & Johnston, 1999; Ellis, 2006), the results presented in this dissertation showed that team members under threat engaged in less performance monitoring and supporting behavior. Additional support for the notion of a narrowed team perspective under threat was provided by the results for the TM-training intervention, because these results showed that an intervention aimed at enhancing transactive memory and team perspective in teams has the ability to moderate the effects of threat.

The proposition of a constriction in control was also supported by the results of the studies presented in this dissertation. Under threat, team leaders became more controlling and allowed less participation in decision making of their team members. In addition, in teams under threat, team members communicated less about strategies, potential routes, and decisions to be made, but instead mainly exchanged information, without collectively trying to integrate this information, or make sense of it. These results contribute to the debate concerning the effects of threat and stress on the degree of control in teams. Previous research found apparently inconsistent results. Some researchers concluded that teams reacted to threat with a restriction in control (e.g., Argote, Turner, & Fichman, 1989), whereas others instead inferred a loosening of control (Driskell & Salas, 1991).

We propose that these mixed findings can be explained by the presence of formal (vs. emergent) leadership in a team, and suggest that particularly when a team has a formal leader, threat will cause a constriction in control, whereas in the absence of formal leadership, threat might also result in a loosening of control. As opposed to previous research investigating the effects of threat on the exercise of control in teams, in the present research, one of the team members always occupied a formal leadership role. This leader was appointed by the experimenter and bore final responsibility for the team's decisions. The results of these studies provide support for the notion that in teams with formal leadership, a constriction in control emerges under threat.

This finding is in line with other research addressing team performance in adverse circumstances under formal leadership (e.g., Foushee & Helmreich, 1988; Hamblin, 1958; Janis, 1954; Klein, 1976). Therefore, we propose that the inconsistent findings concerning constriction in control can be explained as follows: Threat may make team members feel uncertain and insecure (e.g., Lanzetta, 1955). When a leader is present, team members can evade this insecurity by putting themselves in the hands of the leader and pass full responsibility to him or her (cf. Foushee & Helmreich, 1988). The leader, feeling even more responsible now, will become more controlling as a result. Hence, in this situation, threat causes a constriction in control. In contrast, when no leader is present, team members have no one to depend on. In this situation, they will try to find security in the group, displaying group-oriented behaviors such as cooperation and group discussion (Lanzetta, 1955). Consequently, in this situation, threat causes a loosening of control. Eventually leadership may emerge in this situation as well, as a result of which the same processes may surface as in teams with a formal leader (e.g., Argote et al., 1989), causing a constriction in control again.

In the present dissertation, the presence of formal leadership was not varied in the designs. Therefore, although the presented results support the proposed explanation of previous findings, we could not formally test this explanation. Future research therefore should examine the potentially moderating role of formal leadership in the relationship between threat and the exercise of control more closely, by systematically varying the presence and absence of formal leadership.

Finally, the present research was able to demonstrate the inappropriateness of threat-rigidity reactions for teams performing complex tasks, as proposed by the threat-rigidity thesis. It extended previous research by capturing the mediational properties of all central processes in the relationship between threat and team performance in a single model. Because of this, the findings of previous research that suggested that performance decrements in teams under threat are solely attributable to a narrowing of team perspective (Driskell et al., 1999; Ellis, 2006) could be refined. Whereas the design of these previous studies did not allow for the investigation of other processes, the design of the present research made it possible to address the full complexity of the threat-rigidity thesis. The use of a complex task environment ensured that information processing was an important element of the team's task performance, and the appointment of a formal leader made it possible to address the exercise of control. Using a multiple-mediation model, we were thus able to show that restrictions in the processing of task information and constrictions in control both mediated the relationship between threat and team performance, over and above the mediational role of team perspective. Results showed that the total set of mediators almost fully mediated the negative effect of threat on team performance. The original processes proposed by the threat-rigidity thesis supplemented with team perspective processes thus seem to be able to capture the full array of negative threat effects.

Nature of threat

One of the reasons to manipulate physical threat in the study reported in Chapter 3 was that physical threat was thought to have potentially different effects than other threats (cf. Klein, 1976). The results of our study are the first to show that physical threat causes a restriction in information processing and a constriction in control in teams. Because we manipulated a social threat in Chapter 4, while keeping the design of the study very similar to the study in Chapter 3, it is possible to explore whether physical threat indeed affected teams differently than social threat did. Caution is warranted, however, because the results were obtained in different studies, employing different populations.

When the results of the effects of threat on team processes in both studies are compared, the similarity is striking. Only one out of seven effects was not replicated. Hence, it appears that physical and social threat did not have qualitatively different effects on the team processes measured in the present context. However, the magnitude of the effects differed considerably. Where most effects of social threat ranged in size between medium and large, most effects of physical threat ranged between large and very large (cf. Cohen, 1988). Physical threat thus affected the process measures more severely than social threat did. Only the size of the effects on leadership behavior was comparable across threat manipulations: leaders under physical and social threat both became more controlling and less participative to the same extent. Whether this result indicates that physical and social threat indeed have equally large effects on leadership behavior, remains to be seen, however. An alternative explanation is that officer cadets in a leadership role are more prone to behave in a directive fashion than their civilian counterparts, as a result of which the effects of threat on directive leadership behavior are larger for officer cadets than for civilians.

Whereas physical and social threat did not seem to differ qualitatively in their effects on team processes during complex tasks, they did seem to differ in the way they affected team performance. In both studies performance was affected by threat, but in Chapter 3 the effects of physical threat appeared not to have gone ‘through’ the measured team processes (as indicated by an absence of significant correlations between processes and outcomes), whereas in Chapter 4 the team processes fully mediated the effects of social threat on team performance. In Chapter 3 it was suggested that physical threat, in addition to causing rigidity in team processes, might have also distracted team members from their task, because they could not control this threat by performing effectively on their task. This distraction, in turn, may have been an important additional mediator in the relationship between threat and team performance (cf. Gaillard, 2008; Turner & Horvitz, 2001), which might have obscured the mediational role of threat-rigidity processes. On the contrary, the social threat used in Chapter 4, was contingent upon the team's performance: when teams performed well, they would not suffer any negative consequences. Consequently, this threat drew team member's attention to the task, rather than distracting them from the task, as a result of which the mediational role of distraction may have become less important. Although this social threat may have still distracted them to some extent, the results show that this distraction did not cause decrements in performance, because the negative effect of threat on the performance of these teams was fully mediated by the threat-rigidity processes.

This observation has relevance in light of the question whether performance-contingent and non-performance-contingent (or ambient) threats affect teams differently (e.g., Driskell & Salas, 1991). Results of the present dissertation suggest that they do. Although both types of threats caused rigidity in team processes and a deterioration in team performance, in the case of performance-contingent threats, rigidity in team processes appeared to be fully responsible for deterioration in team performance, whereas in the case of non-performance-contingent threats, distraction or loss of concentration may have been an important additional mediator of the negative effects of threat on team performance.

This potential difference would have consequences for the way in which teams should be prepared for operating in threatening circumstances. When performance-contingent threats are expected, preparation should mainly focus on preventing threat-rigidity processes from occurring. However, when non-performance-contingent threats are expected, team members should also be trained to remain focused on their task in the presence of a distracter. Further research is required, however, to examine the proposed differences between performance-contingent and non-performance-contingent threats.

Transactive memory theory

The findings of the present dissertation also have implications for transactive memory theory (Wegner, 1987) by contributing to the question of how to enhance transactive memory in teams. Several scholars have noted that there is ambiguity regarding antecedents of TMSs, and that research on techniques for enhancing transactive memory is as yet not sufficiently developed to justify specific recommendations for improvement (e.g., Kozlowski & Ilgen, 2006; Peltokorpi, 2008). The research presented in Chapter 5 addressed the call for more research on this subject, by developing and testing a transactive memory training intervention (TM-training). Wegner (1995) argued that team members must have knowledge of the distribution of expertise within the team to be able to effectively allocate information, and a retrieval strategy to be able to get information back from the team. Previous research on TMSs also indicated that uncovering one another's domains of expertise and paying explicit attention to coordination issues prior to, or in an early phase of task performance, facilitates the development of effective TMSs later on (Lewis, 2004; Moreland & Myaskovsky, 2000; Prichard & Ashleigh, 2007; Rulke & Rau, 2000). Hence, our TM-training intervention aimed to facilitate two key processes of TMSs, directory updating (through which team members learn about the distribution of expertise) and retrieval coordination (through which team members plan how to retrieve information). The findings presented in Chapter 5 support the idea that updating of directories and coordination of retrieval in an early phase, positively affect transactive memory and transactive memory processes in later phases of task performance. Moreover, this study was the first study to show that transactive memory can be enhanced through a fairly brief training intervention. Future research should investigate whether training interventions based on the principles of directory updating and retrieval coordination have the capacity to enhance TMSs in applied settings. It is expected that such an intervention will be most useful for newly formed teams, in which no TMS is present yet. It has to be determined to which extent TM-training also has the ability to positively influence teams that have a history together.

Team training

The results of Chapter 5 have implications for theories about team training. Particularly, they contribute to the question of how intensive cross-training should be, in order to enhance team performance (e.g., Marks, Sabella, Burke, & Zaccaro, 2002), and what components team training should consist of (e.g., Salas et al., 2008; Salas, Nichols, & Driskell; 2007). Cross-training, a method for enhancing team members' interpositional knowledge, has been put forward as an important strategy for enhancing the performance of interdependent teams, by contributing to communication, coordination, and anticipation of needs (e.g., Blickensderfer, Cannon-Bowers, & Salas, 1998). Three types of cross-training have been specified (i.e., positional clarification, positional modeling, and positional rotation), differing in intensity. Although more intensive forms of cross-training have been argued to have larger effects, previous research has not been able to substantiate these claims (Marks et al., 2002). Intensive forms of cross-training have even been found to interfere with individual task performance in a team context (McCann, Baranski, Thompson, & Pigeau, 2000). The question of how much cross-training is necessary to improve team performance is not without relevance, however, because in many settings, training members of a team intensively in the tasks and duties of other team members may not be very practical and time-efficient.

The TM-training developed and tested in Chapter 5 provides a possible way out of this impasse. The design of this intervention was inspired by both cross-training, with its focus on shared knowledge, and transactive memory theory, with its focus on distributed and compatible knowledge. The intervention therefore did not capitalize on the development of interpositional knowledge, but instead combined the least in-depth form of cross-training (positional clarification), with a method to enhance the teams' strategies to combine their expertise effectively. This resulted in a training intervention far less intensive than positional rotation or positional modeling, because team members did not have to acquire the knowledge of their fellow team members, but only had to learn who had what expertise, and subsequently discuss how they would use each other's expertise. Results of this study showed that the dual focus on sharedness on the one hand (i.e., positional clarification), and distribution on the other hand (i.e., coordination discussion), was very effective in enhancing team processes and team performance. Considering the question of how intensive cross-training should be to enhance team performance, these findings therefore suggest that simply intensifying cross-training to get better results might not be as efficient as combining low intensity cross-training with a focus on distribution and coordination. Such an approach might also be more feasible in teams with divergent professional backgrounds and different educational levels. Future research is necessary, however, to directly compare TM-training and cross-training.

The presented findings are in line with recent research that suggests that the development of interpositional knowledge alone may not be the optimal strategy for teams to improve their performance, and that attention to coordination needs may be a critical component of a successful team training intervention (Gorman et al., 2007; Salas et al., 2007). The findings extend previous research by combining components from different team training strategies in a single intervention. In addition, the presented research addresses the call for research establishing the mechanisms through which team training interventions determine performance (cf. Salas et al., 2007). The findings show that the effects of TM-training are not localized to transactive memory processes alone, but also extend to performance monitoring and supporting behavior, two key teamwork processes that were highly interrelated with team performance in this study.

Methodological Implications

As the complexity of the workplace continues to grow, teams increasingly will be confronted with complex cognitive tasks. More and more, they will have to perform these tasks as virtual teams in networked structures. Theories of teamwork and methods of measurement must keep pace with these developments (cf. Salas, Cooke, & Rosen, 2008). We believe that, by developing PLATT, we were able to successfully address the complexity present-day teams face. PLATT enabled controlled experimental research into team planning, problem-solving and decision-making behavior in a complex, networked world. It offered a broad range of automated and embedded real-time measurement possibilities, which allowed for the measurement of the dynamic aspects of team processes and team cognition (cf. Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke, Salas, Kiekel, & Bell, 2004). On the basis of these characteristics, PLATT made it possible to extend current knowledge and generate valuable practical implications.

The main methodological implication of the present dissertation therefore is that other team researchers should consider employing similar complex team research platforms in their research. As has been described in Chapter 2, platforms like PLATT could enhance research in numerous domains, including research on team structure, team virtuality, and multiteam systems. Moreover, not only research questions directly related to virtual or networked teams could benefit from such environments. The studies presented in this dissertation show that existing knowledge on 'normal' teams may also be extended by the use of research environments like PLATT, because these environments make it possible to address a level of complexity that could not be attained by existing research environments, while maintaining sufficient control. Team research in many domains therefore could benefit from using more complex team research environments, and we recommend that researchers consider this possibility when setting up experimental team research. We believe that research environments like PLATT have the ability to shape current and future theorizing about teamwork.

Practical Implications

Teams in many different work domains face threat on a regular basis. Typical domains associated with threat are the military, the police, and fire-fighting, because professionals in these domains face physical threats themselves, as part of their job. Teams in other domains have to deal with threat too, because the lives of others depend on the way they perform their tasks. Consider, for example, emergency medical teams, aircrews, and crisis management teams. But even in ‘regular’ office jobs, teams may encounter deadlines with severe consequences, run the risk of financial loss, and face threats of negative criticisms.

Organizations in all these domains can use the results of the present dissertation to better protect their teams against the negative effects of threat. First of all, the studies presented in this dissertation demonstrated in a clear manner how threat affects the performance of teams. The studies showed that the way teams deal with information, the way leadership and control is exercised, and the way team members work as a team rather than as a collection of individuals, are all influenced by threat. Organizations may use this knowledge to create awareness of the specific effects of threat among their teams. Creating awareness of typical reactions to stressors is an important component of many effective individual stress training programs (e.g., Stress Exposure Training, Johnston & Cannon-Bowers, 1996) and might be beneficial in a team context as well. If team members manage to maintain awareness of their reactions during performance in threatening circumstances, they may be able to adjust their behavior and prevent threat from negatively influencing their performance.

Second, besides merely creating awareness of the effects of threat, organizations might use the knowledge of the specific processes affected by threat to provide their teams with means that could counter these effects. For example, organizations could apply the knowledge concerning threat’s effect on information processing, by providing teams with information systems that support operators to divide their attention in a better way, or even with software agents that dynamically take over those tasks team members neglect (Bosse, Van Doesburg, Van Maanen, & Treur, 2007). These measures could prevent threat from affecting team performance through restricting the team's information processing. Similarly, organizations could try to avert the negative effects of a constriction in control, by flattening team structures, creating a climate in which team members are encouraged to speak up, and training team leaders to invite input from their team members, even in threatening circumstances (cf. Edmondson, 1999, 2003). Finally, organizations could train teams to maintain a broad team perspective under all circumstances. Previously, cross-training has been suggested as a potentially promising method to achieve this goal (e.g., Ellis, 2006; Volpe, Cannon-Bowers, Salas, & Spector, 1996). Generic team-skills training programs may also have positive effects (Prichard & Ashleigh, 2007). The results of Chapter 5 provide empirical evidence for the beneficial effects of a new method to enhance team perspective: TM-training.

Therefore, the third way in which organizations can utilize the results of this dissertation is by applying the principles of TM-training: a combination of learning about the expertise of fellow team members ('directory updating') with a method that enhances the teams' strategies to combine their expertise effectively ('retrieval coordination'). The directory updating component of such an intervention could simply consist of providing team members with general information of each member's roles and responsibilities (i.e., positional clarification). For this purpose, lectures, written material, or video instructions could be used. The retrieval coordination component could consist of a guided group discussion, in which a trainer lets team members discuss each other's roles and responsibilities and assists them in developing strategies to accurately process information within the team (cf. Dalenberg, Vogelaar, & Beersma, 2009). Other methods may be used as well, as long as participants are actively involved in the process, and it is somehow secured that useful strategies for coordination emerge.

TM-training does not need to be very intensive. The results of Chapter 5 suggest that even a brief training intervention may have substantial effects. This can be of considerable value when training time or resources are limited. Moreover, the design of TM-training ensures that team members do not have to acquire knowledge or learn skills that are not functional for their own task performance. In addition, it is feasible to apply TM-training in teams with widely divergent professional backgrounds (e.g., ad hoc teams) and different educational levels (e.g., surgical teams). It is expected that ad hoc teams that have to operate under threat will benefit the most from TM-training, but more permanent teams working under threat might benefit from TM-training too. The results of Chapter 5 show that TM-training may even exert beneficial effects in teams that operate in non-threatening circumstances.

Strengths and Limitations

The main strength of the research presented in this dissertation is that our research approach enabled us to investigate complex team processes under threat in a controlled manner. The development of the PLATT task environment facilitated the investigation of team processes that had not been studied under threat before. Furthermore, in PLATT, all relevant processes could be studied simultaneously, and team performance could be measured objectively, making it possible to test a comprehensive mediational model of the effects of threat on team performance. Moreover, PLATT allowed the collection of objective, behavioral data, in addition to subjective questionnaire measures, which contributed to the validity of the findings. Taken together, the research approach we developed allowed us to integrate and extend previous knowledge on the effects of threat on teams.

Another strength of the presented research pertains to the chosen approach of manipulating threat. In contrast to previous research, the threat manipulations used in the present research made it possible to determine the unique effects of threat on teams. Because most previous studies combined time pressure or other potential stressors with threat to maximize the stress response, determining the effects unique to threat had not been feasible up till now (cf. Keinan, 1987). The manipulations used in the present research therefore did not combine threat with other potential stressors, nor did they contain cues that might be interpreted by teams as necessitating alterations of the way they performed their task (cf. Turner & Horvitz, 2001). The effects found in the present research therefore can be solely attributed to the occurrence of threat.

At the same time, the research approach used warrants caution in generalizing the results of the present research to applied settings. For although a high degree of realism could be attained using PLATT, the results were still obtained in an experimental setting using an artificial task environment. Given the nature of the research question, the choice for this context was appropriate (cf. Driskell & Salas, 1992). It allowed us to test theoretical predictions and isolate causal phenomena, to manipulate threat without running the risk of causing actual damage, and to collect valuable behavioral measures. The theory that was tested and supported can be applied to the real world.

However, the nature of the research question and the characteristics of the research approach should bring about carefulness in trying to apply concrete results to specific applied questions. Because in aiming to do so, one should bear in mind the specific properties of the task, the participants, and the kind of teams used. For example, the present research used ad hoc teams assembled for the sole purpose of taking part in the experiments. Extending concrete findings of this research directly to more permanent teams in applied settings might therefore prove problematic. Other specific properties would include the low mean age of the participants, the random appointment of team leaders, the military character of the team task, etc. Although these specific properties might limit the generalizability of concrete findings to the real world, they do not hamper our ability to draw conclusions about theoretical predictions, and use the theoretical knowledge that we have gained in our research in applied settings. Future research should determine the exact applicability of concrete results in applied settings.

Concluding Remarks

This dissertation set out to uncover in which ways threat affects the performance of teams and how negative threat effects can be overcome by teams. By developing and using a new, complex team task environment and by employing unorthodox threat manipulations, we feel that we succeeded in providing a comprehensive analysis of team performance under threat. Our research showed that threat causes teams to restrict their information processing, leading to the ignorance of potentially important information and causing problems in maintaining overview. Furthermore, threat affects the exercise of control in teams, such that team leaders become more controlling and allow less participation in decision making from their team members, while at the same time, team members under threat are less likely to get involved in discussions about decisions to be made. In addition, threat causes team members to shift from a broad team perspective to a narrow individualistic focus, leading to underdeveloped team cognitions and reduced efforts at coordinating actions, monitoring the team's performance, and supporting other team members. Our research showed that, all in all, these rigid reactions bring about a deterioration of team performance when teams have to carry out a complex task.

On a more positive note, however, our fine-grained analysis of team reactions to threat makes it possible to develop interventions that accurately target vulnerable aspects of teams to help protect them against threat's destructive effects. The transactive memory training intervention we developed, which focused on the distributed nature of expertise in teams, proves to be a promising method for this purpose. The 'armoring' effect of TM-training found in the present research provides strong incentives for investigating comparable interventions in future (field) research. It is our hope that organizations may benefit from the knowledge gained in the present research by being better able to protect their teams from becoming bound by rigidity under threat.

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Samenvatting

(Summary in Dutch)

Veel organisaties maken gebruik van teams om de steeds complexer wordende werkomgeving het hoofd te bieden. Deze teams kunnen met allerlei soorten dreigingen te maken krijgen. Zo zijn er dreigingen van financieel verlies, verlies van aanzien, of zelfs het verlies van levens. Allerlei catastrofale beslissingen uit het verleden blijken terug te voeren op het onvermogen van teams goed te blijven presteren onder dreiging. Maar ondanks dat we weten *dat* teams kwetsbaar zijn onder dreiging, weten we nog maar heel weinig over *hoe* teams beïnvloed worden door dreiging, laat staan dat we weten wat er tegen te doen valt. De centrale vraag van dit proefschrift luidt dan ook: Op wat voor manier beïnvloedt dreiging het functioneren van teams tijdens complexe taken, en hoe kunnen teams beschermd worden tegen de negatieve effecten van dreiging?

Het onderzoek in dit proefschrift ging uit van de dreiging-rigiditeitshypothese. **Hoofdstuk 1** beschrijft deze hypothese aan de hand van de gebeurtenissen tijdens een hinderlaag in Irak waar Nederlandse militairen bij betrokken waren. De dreiging-rigiditeitshypothese veronderstelt dat ieder systeem (individu, groep, organisatie) onder dreiging geneigd is zich rigide te gedragen. Die rigiditeit bestaat uit een *beperking van informatieverwerking* (bijvoorbeeld een vermindering van het aantal alternatieven dat wordt overwogen) en een *centralisatie van macht* (bijvoorbeeld leiders die minder inspraak in beslissingen toestaan). Samen zorgen deze effecten ervoor dat een systeem minder flexibel wordt, maar juist beter in staat is eerder aangeleerd gedrag automatisch te vertonen (de zogenaamde dominante respons). In een onveranderde en stabiele omgeving kan deze dominante respons adaptief zijn, maar in een complexe en dynamische omgeving is juist flexibiliteit vereist. De dominante respons zal dan waarschijnlijk niet effectief zijn.

Eerder onderzoek in dit domein heeft laten zien dat er in teams onder dreiging inderdaad een beperking van informatieverwerking kan optreden. Dit effect blijkt ook gevolgen te hebben voor de manier waarop teamleden met elkaar omgaan. Teamleden onder dreiging raken namelijk sterk gefocust op hun eigen taak en lijken te 'vergeten' dat ze onderdeel van een team zijn. Er treedt dus een vernauwing van het teamperspectief op. Hierdoor wordt het transactief geheugen systeem (TGS) aangetast. Transactief geheugen in een team zorgt ervoor dat niet iedereen alles hoeft te weten, als iedereen maar weet wie wat weet. Doordat onder dreiging het TGS minder goed werkt, gaan teams minder goed presteren. De resultaten van eerder onderzoek met betrekking tot een centralisatie van macht onder dreiging zijn minder eenduidig. Sommige onderzoeken hebben dit verschijnsel bevestigd, maar andere onderzoeken vonden geen of zelfs tegengestelde effecten.

Het onderzoek in dit proefschrift is erop gericht bestaande kennis te vergroten door aandacht te besteden aan aspecten die in eerder onderzoek niet voldoende aan bod zijn gekomen. Allereerst ligt in dit onderzoek de nadruk op complexe teamtaken en de teamprocessen die daarin een rol spelen. Eerder onderzoek richtte zich namelijk vooral op relatief eenvoudige, uitvoerende taken. Daarnaast hebben we in dit onderzoek expliciet aandacht voor de rol van de leider, aangezien de leider in veel eerder onderzoek afwezig was. Verder hebben we ervoor gekozen op zoek te gaan naar de specifieke effecten van dreiging. Eerder onderzoek combineerde vaak allerlei factoren (bijvoorbeeld tijdsdruk, geluidshinder en dreiging) om op die manier zoveel mogelijk stress te veroorzaken. Hierdoor viel echter niet uit te maken welke aspecten verantwoordelijk waren voor de gevonden effecten. Ten slotte richten we ons op de vraag hoe de negatieve effecten van dreiging kunnen worden tegengegaan. Hoewel organisaties veel baat kunnen hebben bij dat soort kennis, heeft hiernaar nog vrijwel geen onderzoek plaatsgevonden.

In **Hoofdstuk 2** wordt de ontwikkeling van de onderzoeksmethodologie voor dit proefschrift beschreven: de taakomgeving PLATT (PLAnningsTaak voor Teams). Deze omgeving werd ontwikkeld om gecontroleerd experimenteel onderzoek te kunnen doen naar teams die complexe taken verrichten. Eerder onderzoek gebruikte meestal eenvoudige taken, waarin allerlei teamprocessen die tijdens complexere taken een rol spelen, afwezig waren. Of er werden zulke complexe simulaties gebruikt dat de experimentele controle niet meer gewaarborgd was. De ontwikkeling van PLATT werd gestuurd door een serie van vereisten die erop gericht was de juiste balans tussen complexiteit en controle te waarborgen. De resulterende taakomgeving bestaat uit een generieke, modulaire software architectuur waarin onderzoeksspecifieke scenario's kunnen worden gedraaid. De scenario's kunnen zich richten op verschillende typen taken in verschillende soorten operationele omstandigheden. PLATT biedt een breed scala aan geautomatiseerde en geïntegreerde mogelijkheden om teamprocessen te meten. De ontwikkeling van deze taakomgeving maakte het mogelijk om de processen waar we in geïnteresseerd waren (informatieverwerking, centralisatietendensen en teamperspectief) op een gecontroleerde manier integraal te onderzoeken. Op deze manier konden we de huidige kennis op het gebied van het functioneren van teams onder dreiging integreren en uitbreiden.

Hoofdstuk 3 rapporteert over een experiment waarin onderzocht is hoe fysieke dreiging van invloed is op teamprocessen tijdens een complexe taak. Teams worden veelvuldig ingezet in gevaarlijke en complexe omgevingen. Denk bijvoorbeeld aan militaire teams, brandweerteams en politieteams. In eerder onderzoek is er echter nauwelijks aandacht geweest voor de effecten van fysieke dreiging op teams. Bovendien heeft eerder onderzoek weinig aandacht besteed aan complexe teamtaken en de teamprocessen die daarin een rol spelen. In het huidige experiment werden daarom tijdens een complexe teamtaak de effecten van fysieke dreiging op vijf kritieke teamprocessen onderzocht: informatieverwerking, leiderschap, communicatie, coördinatie en ondersteunend gedrag.

Teams van drie personen voerden een plannings- en probleemoplossingstaak in PLATT uit, waarbij ze op basis van een veelheid aan dynamische en ambigue informatie een planning moesten maken voor de evacuatie van een groep personen uit vijandelijk gebied. De teamleden hadden elk hun eigen verantwoordelijkheden, expertises en taken. Eén van hen bekleedde de leiderschapsrol. Fysieke dreiging werd gemanipuleerd door de helft van de teams te laten geloven dat gedurende de taak het zuurstofpercentage in de ruimte waar ze zaten naar beneden gebracht zou kunnen worden, waardoor ze last zouden kunnen krijgen van ademhalingsproblemen, hoofdpijn, hartkloppingen en flauwvallen. In werkelijkheid gebeurde er niets, maar was het de bedoeling dat de deelnemers zich door deze informatie bedreigd zouden gaan voelen. Op basis van de dreiging-rigiditeitshypothese was de verwachting dat teams onder dreiging een beperking van informatieverwerking, een centralisatie van macht en een vernauwing van teamperspectief zouden vertonen.

De resultaten van dit experiment bevestigden deze hypotheses. In vergelijking met teams onder normale omstandigheden hadden teams onder fysieke dreiging minder aandacht voor perifere informatie, een minder goed overzicht, leiders die meer controle uitoefenden en minder inspraak in beslissingen toelieten, minder overleg in het team, en minder coördinerend en elkaar ondersteunend gedrag. Deze resultaten ondersteunen de veronderstellingen van de dreiging-rigiditeitshypothese. Bovendien tonen de resultaten deze effecten voor het eerst aan in het geval van een fysieke dreiging en bouwen ze bestaand onderzoek uit door effecten aan te tonen voor coördinerend en ondersteunend gedrag in teams.

Het onderzoek dat in **Hoofdstuk 4** wordt gerapporteerd, bouwt voort op de resultaten van Hoofdstuk 3 door na te gaan op wat voor manier de reacties van teams op dreiging van invloed zijn op teamprestaties. De dreiging-rigiditeitshypothese veronderstelt dat een rigide respons zowel goed als slecht kan uitpakken, afhankelijk van de omgeving waarin deze respons wordt vertoond. In eerder onderzoek is er weinig aandacht geweest voor de manier waarop de reacties veroorzaakt door dreiging uiteindelijk van invloed waren op de prestaties van teams. Die kennis is echter wel van belang, omdat het bepaalt waarop interventies zich zouden moeten richten. In het huidige experiment werd daarom tijdens een complexe teamtaak onderzocht hoe de reacties van teams op dreiging de relatie tussen dreiging en teamprestaties medieerden.

Cadetten van de Nederlandse Defensie Academie namen in teams van drie personen deel aan een vergelijkbare plannings- en probleemoplossingstaak als in het vorige experiment. In plaats van een fysieke dreiging werd ditmaal een sociale dreiging gemanipuleerd. De helft van de teams kreeg negatieve feedback op een ongerelateerde individuele taak, waardoor de verwachting werd gecreëerd dat ze ook slecht zouden presteren op de teamtaak. Hierna kregen deze teams te horen dat er vervelende sociale consequenties zouden volgen als ze slecht zouden presteren op de teamtaak. De verwachting was dat deze sociale dreiging, net als in het vorige experiment, een beperking van informatieverwerking, een centralisatie van macht en een vernauwing van teamperspectief zou veroorzaken. Op basis van de dreiging-rigiditeitshypothese werd bovendien verwacht dat deze reacties op hun beurt een negatief effect zouden hebben op de prestaties van teams, omdat de taak die ze moesten uitvoeren gekenmerkt werd door complexiteit.

De resultaten gepresenteerd in Hoofdstuk 4 bevestigden deze hypotheses grotendeels. Net als in Hoofdstuk 3 hadden teams onder dreiging minder aandacht voor perifere informatie en een minder goed overzicht, oefenden leiders meer controle uit en lieten ze minder inspraak in beslissingen toe, was er minder overleg in het team en ondersteunden teamleden elkaar minder goed. Bovendien presteerden teams onder dreiging slechter. Zoals verwacht toonden de resultaten van een meervoudige mediatieanalyse aan dat het geheel van de gemeten processen het negatieve effect van dreiging op teamprestatie medieerde. Inspectie van de afzonderlijke processen liet zien dat dreiging teamprestaties negatief beïnvloedde door een vermindering van overzicht, inspraak in beslissingen, groepsoverleg en ondersteunend gedrag. Samengevat tonen de resultaten in Hoofdstuk 4 aan dat de rigide reacties die dreiging veroorzaakt niet adaptief zijn in een complexe werkomgeving. Daarmee vormen deze resultaten een ondersteuning voor de dreiging-rigiditeitshypothese. Bovendien breiden deze bevindingen bestaande kennis uit door in een enkel model de mediërende eigenschappen van alle belangrijke processen in de relatie tussen dreiging en teamprestaties te vatten en zo vrijwel het volledige negatieve effect van dreiging op teams te verklaren.

In **Hoofdstuk 5** is onderzocht of het mogelijk is om de negatieve effecten van dreiging tegen te gaan met behulp van een training die we hebben ontwikkeld, de ‘transactief geheugen training’ (TG-training). Eerder heeft er nog nauwelijks onderzoek plaatsgevonden naar methoden om de negatieve effecten van dreiging op teams tegen te gaan. Dergelijke methoden kunnen echter van groot belang zijn voor organisaties die teams inzetten in gevaarlijke en complexe omgevingen. Voortbouwend op de ontwikkelde kennis met betrekking tot de effecten van dreiging op teams, werd in dit onderzoek een training ontwikkeld en getest die aspecten van een bestaande trainingsmethodiek (cross-training) combineerde met belangrijke processen van een transactief geheugen systeem (TGS). In deze TG-training werd de eenzijdige nadruk op gedeelde kennis, kenmerkend voor cross-training, aangevuld met aandacht voor de verdeling van kennis in het team en de bijbehorende noodzaak tot coördinatie. De TG-training had als doel om het teamperspectief in teams te versterken door het transactief geheugen van teamleden te verbeteren, en op die manier de effecten van dreiging tegen te gaan.

De TG-training werd getest in een onderzoek met cadetten van de Nederlandse Defensie Academie die in teams van drie personen deelnamen aan een complexe plannings- en probleemoplossingstaak in PLATT. Sociale dreiging (gemanipuleerd op de manier zoals beschreven bij Hoofdstuk 4) en TG-training werden gemanipuleerd als tussen-teams factoren. De verwachting was dat dreiging een vernauwing van teamperspectief zou veroorzaken, waardoor het transactief geheugen, teamwerk processen (bijvoorbeeld elkaar ondersteunend gedrag) en teamprestaties zouden verslechteren. Van de TG-training werd juist verwacht dat het een positief effect zou hebben op al deze aspecten. Bovendien voorspelden we een interactie tussen dreiging en TG-training, waarbij we verwachtten dat de effecten van dreiging kleiner zouden zijn voor teams die TG-training zouden krijgen.

De resultaten gepresenteerd in Hoofdstuk 5 bevestigden deze hypotheses grotendeels. Dreiging had een negatief effect op transactief geheugen, teamwerk processen en teamprestaties, terwijl TG-training een positief effect had op al deze aspecten. Over het geheel genomen waren de negatieve effecten van dreiging kleiner bij teams die TG-training hadden gekregen dan bij teams die geen TG-training hadden gekregen, hoewel de voorspelde interactie niet in alle gevallen werd gevonden. Samengevat tonen de bevindingen van Hoofdstuk 5 aan dat TG-training het vermogen heeft om transactief geheugen, teamwerk processen en teamprestaties positief te beïnvloeden en zo de negatieve effecten van dreiging op teams tegen te gaan. Deze veelbelovende resultaten zijn een belangrijke stap in de ontwikkeling van methoden om teams beter voor te bereiden op het functioneren in risicovolle situaties en vragen om vervolgonderzoek.

Hoofdstuk 6, ten slotte, vat de belangrijkste bevindingen van dit proefschrift samen, bespreekt de implicaties ervan en geeft richtingen aan voor vervolgonderzoek. Samengevat laten de resultaten zien dat teams rigide reageren op dreiging: ze vertonen een beperking van informatieverwerking, een centralisatie van macht en een vernauwing van teamperspectief. Samen zorgen deze effecten ervoor dat dreiging de prestatie van teams op complexe taken negatief beïnvloedt. Hiermee vormen de bevindingen van dit proefschrift een solide ondersteuning voor de volledige dreiging-rigiditeitshypothese op teamniveau. De resultaten breiden bestaande kennis uit door effecten aan te tonen op niet eerder onderzochte teamprocessen tijdens complexe taken, door de samenhang tussen de verschillende rigiditeitseffecten te laten zien, door licht te werpen op de rol van leiders in teams onder dreiging en door de effecten van zowel fysieke als sociale dreiging te onderzoeken. Vervolgonderzoek is nodig om te bepalen of het optreden van een centralisatie van macht onder dreiging afhankelijk is van de aanwezigheid van een formele leiderschapsrol, zoals in de het huidige onderzoek het geval was. Verder zou vervolgonderzoek zich kunnen richten op de vraag of het voor de prestatie van een team uitmaakt of een dreiging afhangt van de prestatie op de taak of niet, zoals het huidige onderzoek suggereert.

De resultaten laten ook zien dat het mogelijk is om de effecten van dreiging tegen te gaan door teams een training aan te bieden die gericht is op het verbeteren van het transactief geheugen. Theoretisch zijn deze bevindingen interessant omdat er nog maar weinig bekend is over het verbeteren van het TGS in teams. Dit onderzoek laat zien dat een relatief korte training waarin twee belangrijke processen van een TGS worden gefaciliteerd, positief kan bijdragen aan de effectiviteit van een TGS tijdens de taakuitvoering. Bovendien laat dit onderzoek zien dat het effectief is om in teamtraining niet alleen aandacht te hebben voor het ontwikkelen van gedeelde kennis (zoals in cross-training), maar vooral ook de aandacht te richten op de verdeling van die kennis en mogelijke coördinatiestrategieën. Daarmee biedt TG-training een uitweg uit het rond cross-training spelende vraagstuk hoe intensief teams getraind moeten worden op het ontwikkelen van gedeelde kennis om teamprestaties te verbeteren. Vervolgonderzoek is nodig om TG-training en cross-training direct met elkaar te vergelijken. Daarnaast moet toekomstig onderzoek uitwijzen of TG-training in een toegepaste context en bij teams die al langer met elkaar samenwerken ook kan bijdragen aan het verbeteren van het TGS.

Praktisch zijn de bevindingen van dit onderzoek interessant voor iedere organisatie die met teams werkt, aangezien elk team met dreigingen te maken kan krijgen (fysiek, sociaal, of materieel). Organisaties kunnen de kennis die dit onderzoek heeft opgeleverd op drie niveaus inzetten. Allereerst kunnen ze de resultaten van dit onderzoek gebruiken om bewustwording te creëren van de effecten van dreiging. Als teamleden zich bewust zijn van hun reacties in bedreigende omstandigheden, kunnen ze hun gedrag mogelijkerwijs aanpassen om zo de negatieve effecten van dreiging tegen te gaan. Ten tweede kunnen organisaties de afzonderlijke rigiditeitseffecten aangrijpen om tegenmaatregelen in te zetten. Denk bijvoorbeeld aan het inzetten van informatiesystemen die helpen bij het beter verdelen van de aandacht om beperking in informatieverwerking tegen te gaan, of het platter maken van teamstructuren om centralisatie van macht tegen te gaan. Ten slotte kunnen organisaties de principes van TG-training toepassen om hun teams te beschermen tegen de negatieve effecten van dreiging op teamperspectief. Een dergelijke training zorgt ervoor dat teamleden van elkaar weten wie wat weet, en strategieën tot hun beschikking hebben om op een efficiënte manier gebruik te maken van die verdeeld beschikbare kennis. Op die manier kan TG-training de vernauwing van het teamperspectief die optreedt onder dreiging tegengaan. Al met al hopen we dat de kennis die dit onderzoek heeft opgeleverd eraan kan bijdragen dat teams beter beschermd tegen rigiditeit, dreigingen het hoofd kunnen bieden.

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Wim Kamphuis
Amersfoort, december 2009

Curriculum Vitae

Wim Kamphuis was born in Middelburg, The Netherlands on October 28, 1978. He attended pre-university education at Greijdanus College in Zwolle and subsequently studied Psychology at the University of Groningen. In 2004, he earned his master's degree in Social Psychology (cum laude) with a minor in Methodology. From 2005 until 2009 he conducted the PhD-project reported in this dissertation in a collaborative effort between the Netherlands Organization for Applied Scientific Research (TNO), Tilburg University, and the Netherlands Defence Academy. Currently, Wim Kamphuis is a researcher at TNO Human Factors in Soesterberg. His areas of interest include team performance, stress, and behavioural influence.