# Crew Resource Management Training and Research in a Military Organization

*Hilde van Ginkel*

## Introduction

Military operations, whether in the field, in the air or at sea, are characterized by their complexity, the high risks that are involved and the specialized teams who have to reach their goals under these circumstances. The improvement of high-tech equipment and the increasing complexity and uncertainty of the environment necessitates flexibility of the military involved. Cooperation with international teams in a specific environment (e.g. Afghanistan) complicates the operations even more. The big challenge is to train both individuals and teams to operate in such an environment.

Crew Resource Management (CRM) training is one of many different trainings to develop skills necessary to face the variety of situations described above. In this specific training, students become aware of the importance of team-work and the skills involved in working as a team under high-risk conditions. CRM skills are supportive skills, they are not a goal in themselves. Improvement of these skills helps to improve the effectiveness, efficiency and safety of a team operating in a high-risk environment.

This article consists of two parts. In the first part we will show the importance of CRM in military operations and the necessity to lay a scientific foundation for CRM training and coaching. In the second part of this paper the research done within the Netherlands Defence Academy (NLDA) will be explained. One of the specific models in this research will be highlighted and some preliminary results will be shown. How these results can help improve CRM training and therefore help to prepare military service men and women for their missions will be explained in the discussion.

## CRM in a military environment

### 2005, Afghanistan

The Netherlands Air Force Chinook-D104 helicopter was on transit from Mazar-e-Sharif to Kandahar Air Field with personnel and supplies on board. During the flight, the pilot in command decided to take a shortcut through the mountains to save time and fuel. The shortcut led them through a mountainous area into a cull valley with a high mountain ridge at the end. Due to lack of preparation and miscommunication during the flight a faulty indication of the height of the ridge was presumed. Although the pilot often asked and received feedback, the helicopter (technically perfect) had to make a sharp avoidance manoeuvre (it could not climb to the height of the ridge) and crashed into the mountains. The crash caused the loss of the helicopter and injured one of the people transported on board (see Figure 1).

Figure 1: Crashed Chinook helicopter in Afganistan.

### 2006, Curaçao

During a demonstration frigate NLHMS Van Speijk with visitors on board collided with support ship NLHMS Pelikaan on open water near Curaçao (see Figure 2). During the collision a Lynx helicopter with 3 persons on a rope was forced to fly away from the ship to avoid danger to the visitors, thereby endangering the personnel on the rope. Luckily, there were no casualties and the ships were both able to sail back to the harbour. Investigation showed the cause of this accident was due to human errors within the team sailing the Van Speijk and due to miscommunication during the preparation of the demonstration. The overall conclusion from the board of investigation was that the accident happened due to a lack of CRM.

Figure 2: Left: HNLMS Pelikaan; middle: HNLMS van Speijk; right: Fastrope under a Westland Lynx Helicopter.

Both examples show the danger of human error in military situations. All equipment was working perfectly, the crew was experienced, the weather conditions were reasonable. Still, when looking at both preparation and execution, these were accidents waiting to happen.

The collision between HNLMS Van Speijk and HNLMS Pelikaan prompted the Commander in Chief of the Royal Netherlands Navy to demand improvement of CRM within the naval fleet. This was the start signal for the NLDA to consider its current Bridge Resource Management (BRM) training and propose a plan for both an update of BRM and development of a new (CRM) program from a different perspective.

Both BRM training of the Naval Academy and the Aircrew Coordination Training (ACT; predecessor of CRM) of the Netherlands Naval Fleet Air Arm were developed in 1993 with at its core the improvement of teamwork in the real world. The trainings given were an answer to the questions from practice based on experience, often with very limited scientific background. Both BRM and ACT offer practical training, focused on the specialized community (i.e. BRM was training for bridge officers, ACT was training for the crew of Westland Maritime Lynx Helicopters and P3C Maritime Patrol Aircraft of the Netherlands Naval Fleet Air Arm). SAS Flight Academy Stockholm developed BRM for seafarers in international collaboration with several pilot services, merchant shipping schools and naval academies. The instructor courses were given at the SAS Flight Academy (which facilitated both Cockpit and Bridge Resource Management); the NLDA was certified to train their own students in BRM. ACT was developed by the US Naval Fleet Air Arm, the courses given in Pensacola, USA. Although both trainings had the same goal, enactment was different. BRM was a course of one week, divided in workshops and ending with a simulator sortie. ACT was a week course as well, but the theory and practice were (and are) afterwards coached throughout the entire education period. It was incorporated in the training assessment sheets as well, forcing both instructors and students to acknowledge the importance of ACT behavior and train the appropriate skills. Therefore, after their education, the entire flight crew ‘breathed’ ACT.

Between 1993 and 2010, the ACT developed into CRM training. Until 2004, the Royal Netherlands Naval Fleet Air Arm followed this development and updated their assessment (the update from error avoidance to error management was made). BRM was also updated in 2004, introducing the module ’threat and error management’.

Even with these trainings, accidents due to human error occurred (these trainings were in use when the accidents described above happened). Therefore, a new approach to CRM was made. In order to structure the present training and coaching within the Naval Fleet Air Arm and start coaching in a similar way at the NLDA, education at the NLDA was reformed (based on the same approach as within the Netherlands Naval Fleet Air Arm, applied to the sailing community) and scientific research was started to combine practical expertise with scientific knowledge of topics related to CRM.

## Research

Originally, this research was defined by the practical question of improvement of CRM training within the Royal Netherlands Naval Fleet. At the NLDA, this question was translated in a two-way program: the BRM course had to be remodeled and updated, and the course had to have a scientific base, founded in scientific research.

The method for training BRM was by using workshops and case studies. These didactic tools proved to be effective and were readopted in the new course. The content was based on a different training: the most up-to-date version of the CRM course as offered by the US Naval Fleet Air Arm in Pensacola. This training is on a high abstract level and thus applicable for a wide range of students. Therefore the name of the course changed from BRM to CRM. “CRM can be defined as a management system which makes optimum use of all available resources - equipment, procedures and people - to promote safety and enhance efficiency of [flightdeck] operations” [1]. The basic content of the course is based on the ‘skills’ described in the team competence model of Cannon-Bowers, Tannenbaum, Salas and Volpe [2] and includes the following issues:

- **D**ecision Making
- **A**ssertiveness
- **M**ission Management
- **C**ommunication
- **L**eadership
- **A**daptability/ Flexibility
- **S**ituation Awareness
- **F**atigue
- **E**rror management
- **S**tress

The topics Fatigue and Stress are not skills. However, they are causes for human limitations, and therefore related to CRM.

Research is done into different aspects of CRM (i.e. [3-6]). All the different aspects of CRM are not yet measured together in a field team working in a complex high-risk environment.

The goal of this research is to determine the influence of individual and team characteristics on CRM behavior and team performance in a team working in a high-risk environment. The influence of the situation and interventions on CRM behavior and team performance will also be determined.

Practically, this information is very useful as support of CRM training and coaching. The scientific relevance lies in joining individual and team characteristics of teams working in a high risk environment in a military (non-academic) setting, combining models from different types of research in one new model (see Figure 3). This research builds a bridge between scientific knowledge and practical application in the military field.

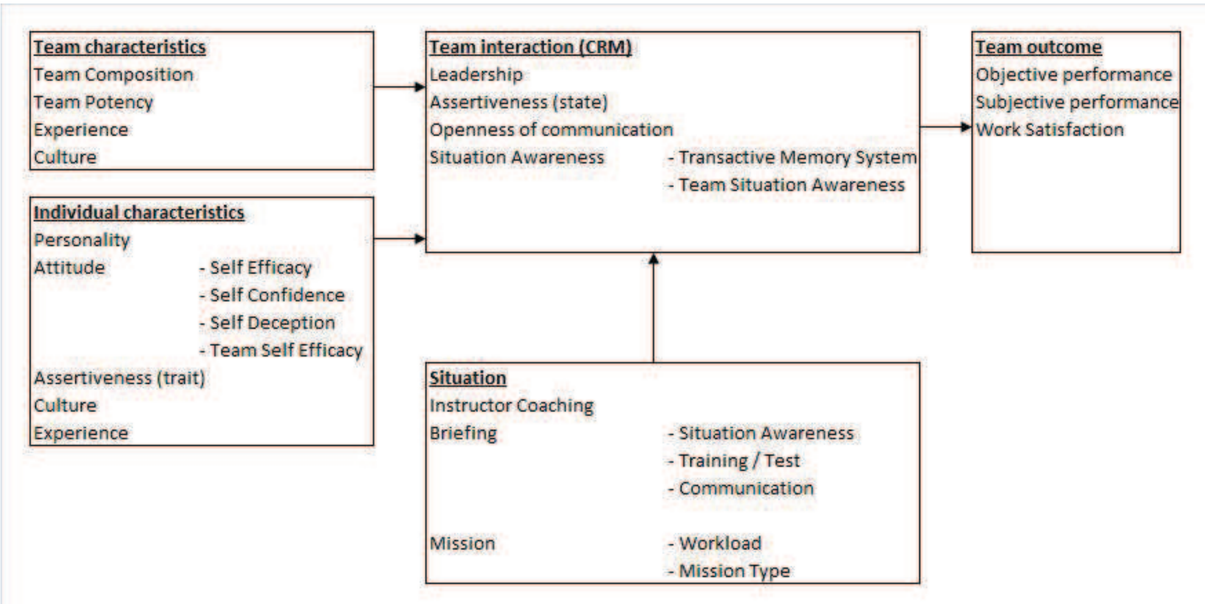


Figure 3: CRM Construct model (CC-model).

The CC-model of Figure 3 shows all the topics related to CRM that are discussed in this research. As can be seen there are 3 major questions in this research:

1. What is the influence of team characteristics on team interaction and team outcome?

2. What is the influence of individual characteristics on team interaction and team outcome?

3. What is the influence of the situation on team interaction and team outcome?

Each of the research questions consists of several models containing the aspects described in the CC-model. One of the aspects specifically important in military settings is the use of specialized teams (heterogeneous team composition). In a team with specialized individuals team knowledge is important for team performance. One construct especially relevant for understanding team knowledge processes is Transactive Memory System (TMS). Therefore, this is a very important construct of CRM.

### The Influence of Team composition on Transactive Memory System and Performance

The increasing complex environment, in which service teams operate during missions, necessitates specialization of individual team members in order to execute the mission objectives. This specialization and differentiation of team members (team composition - team specialization) adds a new challenge into the decision making process of the team: besides knowledge of the mission field and situation, knowledge about both the specialization of the team members (TMS) and what kind of team composition to use during different mission types is vital. A TMS is the cooperative division of labor for learning, remembering, and communicating relevant team knowledge [7]. It is a cognitively interdependent system for encoding, storing and retrieving information that combines the knowledge possessed by individual members with a shared awareness of who knows what [8]. Recent research indicates the effect of TMS on team effectiveness, decision making and situation awareness [9,10]. Empirical evidence of dangers of 'illusory' TM on team performance in ambiguous situations shows the importance of TMS in military teams working in unknown, complex conditions [11].

Figure 4 shows a part of the CC-model, indicating the influence of several Team characteristics on one of the CRM skills (TMS) and Performance.

"TMSs [can] be discerned from the differentiated structure of member's knowledge (specialization), member's beliefs about the reliability of other member's knowledge (credibility), and effective, orchestrated knowledge processing (coordination)" [7]. Therefore, to examine the impact of team composition on TMS and of TMS on performance, we need to examine the

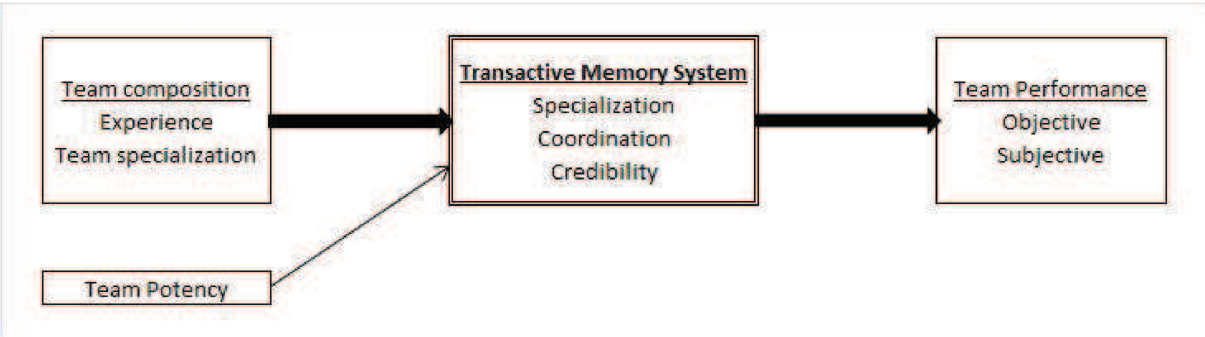


Figure 4: Influence of team compostion and team potency on TMS and team performance.

impact of team composition on each of these constructs, and the impact of each of these constructs on performance.

## Relationship between Team composition and TMS

A team is "two or more people with different tasks who work together adaptively to achieve specified and shared goals" [12]. The environment in which a team has to achieve its goal is of importance for the team composition. Military operations often take place in a high-risk environment. A high-risk environment is defined as an operating area with a high level of uncertainty. As the situation becomes increasingly complex, a team has to have a wide range of knowledge and skills to reach the mission objectives. Therefore, team members will have their own specialization in order to meet this goal. This specialization reduces the redundancy within the team, while increasing the flexibility of the team to face uncertain and unpredictable situations.

As specialized team members each have unique knowledge necessary for goal achievement, coordination of the resources in the team is required in order to create team knowledge. Team composition-Specialization will therefore be positively related to TMS coordination. With highly specialized team members it is more difficult to know exactly what another team member knows. This means that TMS specialization will decline with increased differentiation of team composition-Specialization (TCS) [13].

When a team is more specialized, members have to rely on eachother's specific knowledge. Because individual members cannot judge other member's specific knowledge, they have to rely on their credibility. Whether someone is credible depends on several factors. Expertise is important for credibility [13], but it can also be a self-fulfilling prophecy: when someone believes he is credible, he will act that way (i.e. share information), inviting team members to think he is credible [14]. In teams with more differentiated specialization, individual members are forced to act credible, as there is no redundancy. Therefore, team composition will be positively related to TMS credibility.

Hypothesis 1a: Team composition-specialization will be negatively related to TMS specialization.

Hypothesis 1b: Team composition-specialization will be positively related to TMS coordination.

Hypothesis 1c: Team composition-specialization will be positively related to TMS credibility.

When team members have worked with each other more often, they know eachother's specific knowledge better than when they work together as a team for the first time. Members of an experienced team also know the reliability of eachother's specific knowledge and therefore have better credibility of eachother. When experience is limited, the complexity of TM can create confusion; especially when expertise is in dispute and important information falls through the cracks [13]. Experts (team members with specific knowledge) relate to the structure that is at the core of the situation instead of the problem itself. Therefore, they will tend to direct and coordinate when it is appropriate [15].

Hypothesis 2a: Experience will be positively related to TMS specialization.

Hypothesis 2b: Experience will be positively related to TMS coordination.

Hypothesis 2c: Experience will be positively related to TMS credibility.

Team potency is the mutual confidence in the effectiveness of the team [16]. Transactive Memory is an antecedent of team potency [17]. Practice also indicates the reverse: confidence in team effectiveness can be the effect of team composition and team experience, which will result in positive TMS credibility and positive TMS specialization. As confidence in the effectiveness can result in incorrect assumptions about the coordination, the relation between team potency and TMS coordination will be two fold [13].

Hypothesis 3a: Team Potency will be positively related to TMS specialization.

Hypothesis 3b: Team Potency will be related to TMS coordination.

Hypothesis 3c: Team Potency will be positively related to TMS credibility.

### Relationship between TMS and Team Performance

When team members with distinct roles have an overlapping knowledge amongst themselves, this causes redundancy in information. In a specialized team, team members are more efficient in cognitive processing on their specific knowledge, as only the individual assigned to a particular expertise attends to the relevant information. This frees up other team members to concentrate on their specific tasks and improves information processing in the entire team, resulting in better team performance [14].

Coordination is critical for team performance, and effective TMS will only come from effective coordination of team members. TMS coordination helps in increasing the storage capacity of the group and makes retrieval more efficient [14]. This will improve team performance.

It is not exactly understood how credibility improves performance. It has been found that individuals perceived as experts engage in more information seeking than perceived non-experts. They actively share their expertise as well as engage in seeking out unique information held by minority members [14]. Therefore, a positive relation between TMS credibility and team performance is expected.

Hypothesis 4a: TMS specialization will be positively related to team performance.

Hypothesis 4b: TMS coordination will be positively related to team performance.

Hypothesis 4c: TMS credibility will be positively related to team performance.

## Methods

The hypotheses are tested during real time training and practice session. These sessions take place on the Maritime Westland Lynx Full Mission Flight Trainer (FMFT) at Maritime Air Base De Kooy in Den Helder. This high-end simulator contains a Maritime Westland Lynx Helicopter Cockpit and can be set in motion. The instructor manages the scenario and the aircraft from the 'instructor station' (see Figure 5).

Figure 5: Left: Maritime Westland Lynx Full Mission Flight Trainer (FMFT); middle: FMFT instrcutor station; right: FMFT cockpit view.

The participants were 61 pilots (operational (N=13), students (N=4) and instructors (N=15)), TACtical COordinators (operational (N=9), students (N=1) and instructors (N=6)), SENSor OPerators (operational (N=3), students (N=1) and instructors (N=6)), technicians (operational (N=2)) and Test Flight Engineers (operational (N=1)), average age m = 32, 60 male, one female, from the Maritime Lynx community of five countries (Netherlands, Germany, Denmark, Portugal, Norway). The team size varied, with an average member total of 2.2, flying a total of 29 flights in the simulator. The teams differed in composition and experience. All the flights contained a briefing directly before the flight and a debriefing directly after the flight. The questionnaire was administered after the flight before the debriefing. No explicit reference was made about TMS or Team Potency. When participants completed the questionnaire, they referred to the crew (Oxford Compact Dictionary defines crew as "a group of people who work on and operate a ship, boat, aircraft, or train") they flew with during the simulator flight. The questionnaire was designed to be completed anonymously. Participants were ensured of confidentiality.

**Measures**

*Transactive Memory* was measured using the scale developed by Lewis [7] for measuring this process in field studies. This scale contains 15 items designed to assess the three constructs of TMS (specialization, coordination, credibility). Each item was scored on a five-point Likert-type scale ranging from one (strongly disagree) to five (strongly agree).

*Team Potency* was measured using an adaptation of the scale developed to assess Team Potency of Civil Aviation Crews [18]. The scale contains three items designed to assess team confidence and team spirit. The responses were given on a five-point Likert-type scale ranging from one (strongly disagree) to five (strongly agree).

*Experience* for individuals is defined by the amount of flight hours in a Westland Lynx Helicopter cockpit. Flight hours in the FMFT count as flight hours in a Lynx helicopter. As all individual flight hours are in crew composition, experience in this research is defined as the mean of total individual Flight Hours of the crew members.

*Objective Performance* was measured using the instructor evaluation. The instructor assessed team performance on three issues: navigation (Pnav), procedures(Pproc) and teamwork (Pteam). The responses were given on a four-point scale (O = poor, S- = below standard, S = standard, S+ = above standard).

*Subjective Performance* was measured using an adaptation of the scale developed to assess perceived team performance of Civil Aviation Crews. The scale contains three items designed to assess perceived team performance. The responses were given on a five-point Likert-type scale ranging from one (strongly disagree) to five (strongly agree).

## Preliminary Results

The data shown are for a small sample as the assessment and data collection are currently in progress: all data are preliminary results, which can only give indications for answers on the hypotheses. Therefore, significant results and trends should be used cautiously. As there were 6 sorties with 3 persons on board, results for the third person were too limited to include in this analysis.

For all data analysis, the Statistical Package for Social Sciences (SPSS 16.0) was used. Before analysis, all scales were checked on internal consistency (see Table 1). The table shows an average alpha for Specialization. As there was a different outlier for the Right Seat (RS) and the Left Seat (LS), no items were removed from the lists.

Table 1: Reliability analysis for all scales.

| | | | Cronbachs alpha |
|---|---|---|---|
| TMS | Specialization | RS | 0.55 |
| TMS | Specialization | LS | 0.62 |
| TMS | Coordination | RS | 0.86 |
| TMS | Coordination | LS | 0.77 |
| TMS | Credibility | RS | 0.60 |
| TMS | Credibility | LS | 0.78 |
| Team Potency | | RS | 0.80 |
| Team Potency | | LS | 0.80 |

Combined RS/LS TMS scales of specialization, coordination and credibility were created: TMS specialization: $\alpha = .61$; TMS credibility: $\alpha = .68$; TMS coordination: $\alpha = .87$. Also, a total RS/LS Team Potency scale was made: $\alpha = .82$. A total RS/LS scale of experience was not created: $\alpha = -.34$.

The three objective performance measures each assess a different part of Team performance ($\alpha = .31$). Therefore, the 3 objective performance measures are analyzed separately. A total scale of subjective performance (RS: $\alpha = .77$; LS: $\alpha = .50$) was created: $\alpha = .80$.

*Hypothesis 1*
There is a significant relationship between TCS and TMS Specialization, r = .32, p(one tailed) < .05.

There is no significant relationship between TCS and TMS Coordination, r = .10, p(one tailed) > .05.

There is a significant relationship between TCS and TMS Credibility, r = .34, p(one tailed) < .05.

*Hypothesis 2*
There is no significant relationship between experience and TMS Specialization, RS: r = .27, p(one tailed) < .10; LS: r = -.22, p(one tailed) > .05.

There is no significant relationship between experience and TMS Coordination, RS: $r = .08$, $p(\text{one tailed}) < .35$; LS: $r = -.08$ $p(\text{one tailed}) > .05$.

There is no significant relationship between TCS and TMS Credibility, RS: $r = .10$, $p(\text{one tailed}) < .30$; LS: $r = -.08$ $p(\text{one tailed}) > .05$.

*Hypothesis 3*
There is no significant relationship between Team Potency and TMS Specialization, $r = .23$ $p(\text{one tailed}) > .05$.

There is a significant relationship between Team Potency and TMS Coordination, $r = .79$, $p(\text{two tailed}) < .01$.

There is a significant relationship between Team Potency and TMS Credibility $r = .65$, $p(\text{one tailed}) < .01$.

*Hypothesis 4*
There is no significant relationship between TMS Specialization and Objective Performance: Pnav, $r = .17$, $p(\text{one tailed}) > .05$; Pproc, $r = .11$, $p(\text{one tailed}) > .05$; Pteam, $r = -.14$, $p(\text{one tailed}) > .05$.

There is no significant relationship between TMS Coordination and Objective Performance: Pnav, $r = .10$, $p(\text{one tailed}) > .05$; Pproc, $r = .09$, $p(\text{one tailed}) > .05$; Pteam, $r = -.07$, $p(\text{one tailed}) > .05$.

There is no significant relationship between TMS Credibility and Objective Performance: Pnav, $r = -.05$, $p(\text{one tailed}) > .05$; Pproc, $r = .18$, $p(\text{one tailed}) > .05$; Pteam, $r = -.09$, $p(\text{one tailed}) > .05$.

There is no significant relationship between TMS Specialization and Subjective Performance, $r = -.09$, $p(\text{one tailed}) > .05$.

There is a significant relationship between TMS Coordination and Subjective Performance, $r = .42$, $p(\text{one tailed}) < .05$.

There is a significant relationship between TMS Credibility and Subjective Performance, $r = .30$, $p(\text{one tailed}) < .05$.

## Conclusions

Since the data collected represent a small amount of simulator flights, the results can give implications for answers on the hypotheses, but no final conclusions can be made.

The hypothesis that Team Composition Specialization is negatively related to TMS Specialization is not confirmed. Instead, the data indicate a positive relationship between TCS and TMS Specialization. Although the result is significant (p (one tailed) $< .05$), the correlation is .32, indicating there are more factors of influence on TMS Specialization than TCS. The result can be explained by looking at the items of TMS Specialization. Of these 5 items, 4 items are about specialized knowledge, and 1 item is about the knowledge content of the other crew member. Therefore, the results indicate that the crewmembers were aware of their colleagues' expertise in a different area than their own and confirmed the necessity of that expertise in the flight. Whether the crew knew the contents of each other's expertise is neither confirmed nor rejected by these results.

The expected positive relationship between TCS and TMS coordination is not confirmed. This indicates that team coordination does not vary according to the composition of the team. This can be due to the setting in which the measurement took place. There are strict procedures about communication and task handling in the cockpit crew of a Lynx Helicopter. Therefore, coordination is fixed in procedures. This hypothesis might be confirmed when looking at a specific flight type in which the tasks between the pilot and pilot-non-flying, tacco or sensop differ widely. There is not enough data available to examine this explanation.

The hypothesis of a positive relationship between TCS and TMS Credibility is confirmed with these results. However, the correlation $r = .34$ is indicating there are more factors of influence on TMS Credibility. This cannot be due to experience of the team, as the hypothesis of a positive relationship between experience and TMS is not confirmed.

The results also show no trends that indicate any correlation between experience and TMS specialization, TMS coordination or TMS credibility. This can be due to the way experience is measured in this research. In the simulator, team members vary with each flight: no experienced flight crews train in the simulator after flying operationally. Therefore, experience is measured as the mean of total individual flight hours of all crew members, reasoning that all flight hours are in crew connection which indicates experience in teamwork. It might be that measurement in real flights will show different results on this hypothesis. Therefore, this hypothesis cannot be rejected.

The results show no indication of a relationship between TMS and objective performance. However, the results indicate a significant relationship between TMS Coordination and subjective performance ($r = .42$, $p$ (one tailed) $< .05$) and between TMS Credibility and subjective performance ($r = .30$, $p$ (one tailed) $< .05$). The measures of objective and subjective team performance assessed different aspects of performance, which explains the difference in results: the objective performance measure assesses navigation, procedural and teamwork performance, while the subjective performance measure assesses whether everything went according to plan. The results show no relationship between TMS and objective performance indicating no relationship between TMS and the flight criterion. However, as TMS Coordination and TMS Credibility are significantly related to subjective performance, there is indication of a relationship between TMS coordination and perceived performance and TMS credibility and perceived performance. This indicates that when a team perceives good coordination and credible colleagues, they perceive good performance. As the results show no clear relationship between TMS and performance, further research is needed to explain this issue.

Although these preliminary data show some promising results, there is an issue that should be considered: team size is very limited in this research. As the cockpit of a Westland Lynx Helicopter is small, the operational team usually consists of 2 persons, with a third person (sensop) in the cabin when necessary. This simplifies team interaction as there are relatively few resources to manage. In testing complicated models like the CC-model this is an advantage. However, it should be taken into account when applying the results to larger teams.

## Discussion

The results of this research, together with field experience can provide a solid base for the design of CRM training and coaching. The model highlighted in this article as part of the CC-model explains and clarifies

TMS. It indicates that team composition and team potency are related to TMS and that TMS is related to (subjective) performance. This means that these topics should be part of CRM training for specialized teams that have to operate in a complex, high-risk environment.

Within CRM training, the results can support the Situation Awareness and Mission Analysis sections. Situation Awareness can be defined loosely as knowing what is going on around you (CRM training reader: the degree of accuracy by which one's perception of the current environment mirrors reality). One's perception starts with information gathering and selection. In a team with differentiated knowledge, this includes knowing what information can be provided by other team members. This is where TMS is of importance.

Mission Analysis is defined as the ability to make short-term, long-term and contingency plans and to coordinate, allocate and monitor crew resources (CRM training NLDA). This occurs during three phases: briefing (pre-mission planning), Mission monitoring and updating and debriefing (post-mission review). In specialized teams, the planning of tasks within the crew prior to the mission, the allocation, adaptation and accomplishment of the mission and the review afterwards are all influenced by the correct allocation of specializations within the team at the appropriate moments. Therefore, within CRM training, TMS can be incorporated in the Mission Analysis section.

The results can also be used in practice. For example, when the preliminary results are confirmed in the final analysis, lessons can be learned from the way communication in a flight crew is handled. As TCS is not related to TMS coordination in flight crews, the flight crew coordination set-up is robust to specialization within the team. This means that their way of using procedures, short, relevant checklists, two-way communication and verification of information when the reliability of information or clear communication is in doubt, ensures TMS coordination. Extended research of implementation of this type of communication and procedures in other differentiated teams (i.e. commando teams in Naval ships or medical teams in hospital OR) is needed prior to adjustment of CRM training. In this extended research, team size has to be considered as well.

The results from this research support and improve practical CRM training for specialized teams operating in a complex environment. As the data are obtained in a military, complex environment with military operators, the results have face validity. This improves the acceptance of the results and the implications that the results might have on CRM training, coaching and practice in the field.

**Acknowledgements**

My special thanks to the flight crews who participated in this research and the instructors who allowed me use their expertise. I would also like to thank the international partners (German Navy, Danish Navy, Portuguese Navy and Norwegian Air force) for allowing me to assess their flight crews. I owe the civil staff of CAE my gratitude for their technical support. My thanks to the head of the FMFT Lt. Rogier van Kralingen for giving me access to the FMFT and his personnel and students.

## References

[1 ] United Kingdom. Civil Aviation Authority. *CAP 737, Crew Resource Management (CRM) Training Guidance For Flight Crew, CRM Instructors (CRMIS) and CRM Instructor-Examiners (CRMIES).* 2006. http://www.caa.co.uk/docs/33/cap737.pdf.

[2 ] E. Salas, C.A. Bowers and E. Edens, *Improving teamwork in organizations applications of resource management training.* Mahwah, N.J.: Lawrence Erlbaum, 2001.

[3 ] J.A. Cannon-Bowers and E. Salas, "Making Decisions Under Stress: Implications for individual and team training," *American Psychological Association*, 1998.

[4 ] Helmreich and Merritt, "Safety an error management: the role of crew resource Management," in *Aviation Resource Management*, B.J. Hayward and A.R. Lowe, Eds. Aldershot: Ashgate Publishing Ltd., 2000, pp. 107-119.

[5 ] P. Essens, A. Vogelaar, J. Mylle, C. Blendell, C. Paris, S. Halpin and J. Baranski, "Military Command Team Effectiveness: Model and Instrument for Assessment and Improvement," NATO RTO Technical Report TR-HFM-087, 2005.

[6 ] R. Flin, P. O'Connor and M. Crichton, *Safety at the sharp end: a guide to non-technical skills.* Aldershot: Ashgate Publishing Ltd., 2008.

[7 ] K. Lewis, "Measuring Transactive Memory Systems in the Field: Scale Development and Validation," *Journal of Applied Psychology*, vol. 88 no. 4, pp. 587-604, 2003.

[8 ] S. Mohammed and B.C. Dumville, "Team mental models in a team knowledge framework: expanding theory and measurement across disciplinary boundaries," *Journal of Organizational Behavior*, vol. 22 no. 2, pp. 89-106, 2001.

[9 ] J.S. Prichard and M.J. Ashleigh, "The effect of team-skills training on transactive memory and performance," *Small Group Research*, vol. 38, pp. 696-726, 2009.

[10 ] K.A. Smith-Jentsch, K. Kraiger, J.A. Cannon-Bowers and E. Salas, "Do familiar teammates request and accept more backup? Transactive Memory in air traffic control," *Human Factors*, vol. 51, pp. 181-192, 2009.

[11 ] F. Tschan, N.K. Semmer, A. Gurtner, L. Bizzari, M. Spychiger, M. Breuer and S.U. Marsch, "Explicit Reasoning, Confirmation Bias, and Illusory Transactive Memory: A Simulation Study of Group Medical Decision Making," *Small Group Research*, vol. 40, pp. 271-300, 2009.

[12 ] M.T. Brannick and C. Prince, "An Overview of Team Performance Measurement," in *Team Performance assessment and measurement: Theory, Methods, and Applications*, M.T. Brannick, E. Salas, and C. Prince, Eds. Mahwah, N.J.: Lawrence Erlbaum, 1997, pp. 3-16.

[13 ] D.M. Wegner, "Transactive Memory: a contemporary analysis of the group mind," in *Theories of Group Behavior*, I.B. Mullen and G.R. Goethals, Eds. New York: Springer-Verlag, 1987, pp. 185-208.

[14 ] A.K. Nandkeolyar, "How do teams learn? Shared mental models and transactive memory systems as determinants of team effectiveness," working paper pp. 1-82, 2010.

[15 ] R. Glaser and M.T.H. Chi, "Overview," in *The nature of expertise*, M.T.H. Chi, R. Glaser and M.J. Farr, Eds. Hillsdale, NJ: Lawrence Erlbaum, 1988, pp. xv-xxix.

[16 ] A.E. Akgün, H. Keskin, J. Byrne and S.Z. Imamoglu, "Antecedents and consequences of team potency in software development projects," *Information & Management*, vol. 44, no. 7, pp. 646-656, 2007.

[17 ] E.A. Mannix, T. Griffith and M.A. Neale, "The phenomenology of conflict in distributed work teams," in *Distributed Work*, P. Hinds and S. Kiesler, Eds. Cambridge, MA: Massachusetts Institute of Technology, 2002, pp. 213-234.

[18 ] M.A. Campion, E.M. Papper and G.J. Medsker, "Relations between work team characteristics and effectiveness: a replication and extension," in *Personnel psychology*, vol. 49, 1996, pp.429-451.