Transactive Memory System in Heterogeneous Teams: handling unique knowledge in military cockpit teams

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ABSTRACT

The increasing complex environment in which military service teams operate during missions necessitates knowledge specialization of individual team members in order to execute the mission objectives. This specialization and differentiation of team members (heterogeneity of the team) brings a new challenge into the decision making process of the team: besides knowledge of the mission field and situation, knowledge about the specialization of the team members (Transactive Memory System, TMS) and what kind of team composition to use during different missions is vital. Recent research indicates the effect of TMS on team effectiveness, decision making and situation awareness. Empirical evidence of dangers of 'illusory' TM on team performance in ambiguous situations (Tschan et al., 2009) shows the importance of TMS in service teams working in unknown, complex conditions.

In this research, military cockpit crews that vary on team composition, operating the same helicopter, are compared on TMS Specialization, TMS Credibility and TMS Coordination. The heterogeneity will be varied on four aspects: team task specialization; cultural background; ranks; experience. Then, the overall effect of TMS on objective and subjective performance will be measured.
Both literature and empirical results of this research show the importance of TMS in heterogeneous teams. The results of this research can help to enhance the training of our service men and women, to improve their skills necessary to operate in an unknown, highly complex environment and ensure their safe return.

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INTRODUCTION

Curacao, Dutch Antilles, 2006: A combined international military exercise takes place in the Caribbean. Several nations joined the exercise with units of the Navy, Air force and Army. International HQ and staff are stationed at Curacao. During the exercise a small group of Dutch Forces tries to join a French Frigate. In the Dutch team, one of the operators acts as injured and has to be hospitalized on board of the French ship. Due to misunderstandings, the French suspect a trap, which results in throwing over board all equipment the Dutch team took with them (this was mostly personal stuff like clothing). Also, it took valuable time to explain the injuries of the operator due to language problems.

This example shows that misunderstandings can arise between units and operators. During the exercise it became apparent that information exchange and cooperation suffered due to misunderstandings and intelligence differences. One of the issues is language: though everybody speaks English, interpretation is not uniform. Also, information exchange between different Defense organizations is a challenge due to lack of understanding of each other's abbreviations, procedures and protocols. Therefore, different units do not know what information another unit carries. Also within units, formed by operators with different backgrounds and sometimes even from different nations, challenges arise due to misunderstanding about each other's knowledge.

Worldwide armed forces of different nations cooperate in environments far more hostile than the exercise described above. These operations are characterized by the high threats and risks that are involved. In the last decades, the risks and threats involved in military operations have changed. Due to hi-tech equipment, weapons and intelligence, the complexity of operations has increased, forcing the military to adapt to the situation. Specialized units of different services, ranks and nations operate together in teams to face these situations. This specialization results in a team with members who have a different background, each member having unique knowledge.

This team heterogeneity puts an extra challenge into the team and mission management. Besides knowledge about the situation, knowledge about the specialization in the team is vital for reaching the objectives and perform safely. The knowledge of who-knows-what is called Transactive Memory System (TMS).

The goal of this research is to explore the effects of team composition (team heterogeneity) on Transactive Memory System in a small team operating in a high-risk, military setting. Then, the effect of TMS on both objective and subjective performance will be measured.

The results of this study can be used to enhance training of armed forces to improve their skills necessary to operate in unknown, complex, high-risk situations. This improves the safety and effectiveness of the operations, enlarging the chance of a safe return from their missions.

Transactive Memory System (TMS)

A TMS is the cooperative division of labor for learning, remembering, and communicating relevant team knowledge (Hollingshead, 2001; in Lewis, 2003). 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 (Mohammed & Dumville, 2001). Recent research indicates the effect of TMS on team effectiveness, decision making and situation awareness (Prichard & Ashleigh, 2007; Smith-Jentsch, Kraiger, Cannon-Bowers & Salas, 2009). Empirical evidence of dangers of 'illusory' TM on team performance in ambiguous situations shows the

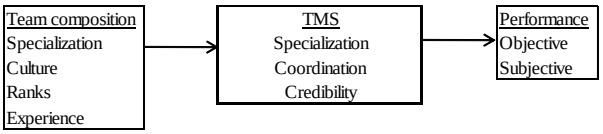

Figure 1. The influence of Team Composition and Team Interaction on TMS and Team Performance

importance of TMS in military teams working in unknown, complex conditions (Tschan, Semmer, Gurtner, Bizzari, Spychiger, Breuer & Marsch, 2009). TMS is a combination of three constructs: TMS Specialization shows team members' awareness of unique knowledge within a team, TMS Credibility shows whether team members perceive this knowledge (and person) to be reliable and TMS Coordination shows if the unique knowledge could be put into use effectively (Liang et al., 1995, Moreland & Myaskovsky, 2000; in Lewis, 2003 p 589). Therefore, to examine the impact of team composition on TMS and of TMS on performance, one needs to examine the impact of team composition on each of these constructs, and the impact of each of these constructs on performance (Figure 1).

Team composition and TMS

A team is 'two or more people with different tasks who work together adaptively to achieve specified and shared goals' (Brannick, Salas & Prince, 1997; p4). The environment in which a team has to achieve its goal determines 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 and unique knowledge in order to meet this goal. This Team composition-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 the another team member knows, but members will be more aware of the differences in knowledge. This means that TMS specialization will increase with increased differentiation of Team composition-specialization (TCS) (Wegner, 1987).

When a team is more specialized, members have to rely on each others' specific knowledge. Because individual members cannot judge other members' specific knowledge, they have to rely on their credibility. Whether someone is credible depends on several factors. Expertise is important for credibility (Wegner, 1987), but it can also be a self-fulfilling prophesy: when someone believes he is credible, he will act that way (i.e. share information), inviting team members to think he is credible (Nandkeolyar, 2010). 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 positively 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.

Cultural differences can have an impact on unique knowledge, coordination and credibility in a team when team members come from various nations. Communication can be complicated when team members do not share the same tongue.

Even when working in the same community (i.e. pilots), the culture defined by the nation and organization can have their effect on operator behavior (Helmreich, 2000). Therefore, Team composition-culture (a team with members from different nations) will be positively related to TMS specialization. As members are aware of their different background, they will put more effort in coordination in order to ensure mutual understanding and goal orientation. This will improve TMS coordination. When teams consist of members from different nations it is difficult to estimate the quality of knowledge from other members. It depends on the nation whether members perceive their foreign member as credible (Hofstede, 2004).

Hypothesis 2a: Team composition-culture will be positively related to TMS specialization.
Hypothesis 2b: Team composition-culture will be positively related to TMS coordination.
Hypothesis 2c: Team composition-culture will be related to TMS credibility.

When team members have worked in a certain context more often, they are more aware of the complexity of

the situations they can encounter. Therefore, they are more aware of the unique knowledge necessary for task and goal achievement in different scenario's that can occur. As experienced team members know what can happen in different situations, they will act accordingly. As they are more flexible in handling these situations they will act credible. Also, they will be able to determine whether their team members are credible. When experience is limited, the complexity of TM can create confusion; especially when expertise is in dispute and important information falls through the cracks (Wegner, 1987). 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 (Glaser & Chi, 1988).

Hypothesis 3a: Team composition-experience will be positively related to TMS specialization.
Hypothesis 3b: Team composition-experience will be positively related to TMS coordination.
Hypothesis 3c: Team composition-experience will be positively related to TMS credibility.

In a military organization hierarchy is strictly defined by ranks. Hierarchy has its influence on information processing in both organizations and teams (Lambert, Kunz & Levitt, 2001) and thus has its impact on TMS. 'The hierarchy is the way in which an organization or team is employed to handle exceptions. In routine, stable task environments the information processing capacity of the hierarchy is sufficient for handling the moderate information processing demands associated with the relatively few exceptions that do arise. This changes in a more complex dynamic task environment with high uncertainty and more exceptions. In such cases the information processing of the hierarchy can quickly overload, resulting in degradation of team performance' (Lambert et al., 2002; p1). In a complex uncertain military setting formal hierarchy rules and regulations can hamper the TMS coordination. Also, the risk exists that members will respond to each other according to rank instead of knowledge. This will have a negative influence on TMS specialization. TMS credibility will also be connected with rank, but this relationship will be two-folded: lower (officer or NCO) ranks are related to trainees, who have accurate knowledge but lack experience and skills. Average ranks (officer or NCO) are operational and therefore have both knowledge and skills. High ranks (officers or NCO) are often management, having a lot of experience but lacking routine. Team composition-rank is defined by the deviation of rank of the team members.

Hypothesis 4a: Team composition-ranks will be negatively related to TMS specialization.
Hypothesis 4b: Team composition-ranks will be negatively related to TMS coordination.
Hypothesis 4c: Team composition-ranks will be positively related to TMS credibility.

TMS and 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 (Nandkeolyar, 2010).

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 (Nandkeolyar, 2010). 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 (Thomas-Hunt, Ogden & Neal, 2003; in Nandkeolyar, 2010). Therefore, a positive relation between TMS credibility and team performance is expected.

Hypothesis 5a: TMS specialization will be positively related to team performance.
Hypothesis 5b: TMS coordination will be positively related to team performance.
Hypothesis 5c: TMS credibility will be positively related to team performance.

METHODS

The data for this research are collected at the Full Mission Flight Trainer at Naval Air Base De Kooy in Den Helder, the Netherlands (Figure 2). This trainer is a high-end simulator for the Westland Lynx Helicopter. The instructor manages the scenario and the aircraft from the instructor station.
103 participants (100 male, 3 female; average age 37.6, SD 8.1) from 5 different countries (Netherlands: 60;

Figure 2: FMFT; the instructor station; flying in the simulator

Denmark: 20; Germany: 19; Portugal: 3; United Kingdom: 1) flew 100 flights in the simulator. All flights consisted of a briefing prior to the flight, a simulator sortie, and a debriefing directly after the sortie. The Netherlands, Germany and Denmark operate in a single pilot concept: the pilot is sole responsible for flying and handling the helicopter. The other team member can assist the pilot when necessary but has other responsibilities as well (i.e. tactical operation, navigation or operating the sensors on board). The cockpit teams were formed by a Pilot (Right Seat; RS) and either a Co-Pilot, Tactical Coordinator (Tacco), Sensor Operator (sensop) or Technician (Left Seat; LS). All measures were done during regular training and testing hours.

Measures

For this research, a questionnaire was developed. It was given to the participants directly after the sortie prior to the debriefing. This questionnaire consisted of items concerning TMS Specialization, TMS Credibility, TMS Coordination and subjective team performance.

Transactive Memory was measured using the scale developed by Lewis (2003) for measuring this process in field studies. This scale contains 15 items designed to assess the 3 constructs of TMS (specialization, coordination, credibility). Example of items:

Specialization: Each team member had specialized knowledge of some aspect of the flight.

Coordination: Our team worked together in a well-coordinated fashion.

Credibility: I trusted that my colleagues' knowledge about the flight was credible.

Team composition-specialization was defined as a 2 point scale: 1- pilot-copilot, 2- pilot-other.

Team composition-culture was defined as a 2 point scale: 1- the same cultural background, 2- different cultural background.

Team composition-ranks was defined both individual and as a delta between the crew members. Ranks ranged from Corporal (1) to Commander (9).

Experience for individuals is defined by the number of flight hours in a Westland Lynx Helicopter cockpit. Flight hours in the FMFT count as flight hours in a Lynx helicopter. The difference in experience (delta experience) is the absolute difference between the crew member flight hours.

Subjective team performance was measured using an adaptation of the scale developed to assess perceived team performance of Civil Aviation Crews. The scale contains 3 items designed to assess perceived team performance.

All items were measured on a 5-point Likert-type scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Objective performance was measured using the instructor evaluation. The instructor assessed team performance on 3 issues: navigation, procedures and teamwork. The responses were given on a 4-point Likert-type scale ranging from 1 (poor) to 4 (above standard).

RESULTS

Table 1: Cronbach's Alpha for Independent and Dependent Variables

TMS Specialization	RS	,56
	LS	,63
TMS Credibility	RS	,64
	LS	,59
TMS Coordination	RS	,65
	LS	,74
Subjective performance	RS	,64
	LS	,64

Table 1 shows Cronbach's Alpha for all variables. All variables have $\alpha > .55$, so for all variables scales were computed.

Table 2: Correlation matrix Team Composition and TMS

	TMS Specialization		TMS Credibility		TMS Coordination	
	RS	LS	RS	LS	RS	LS
Specialization in team	,40**	,10	-,04	,32**	,07	,11
Cultural Background	,09	,04	-,09	-,05	-,16	-,04
Experience	,29**	,16	,02	,16	,15	-,04
Rank	,24*	,17	-,04	-,06	-,07	-,08

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

Table 2 shows the correlations between the different aspects of team composition and TMS Specialization, TMS Credibility and TMS Coordination as perceived by the RS and the LS. Hypothesis 1a, Team composition-specialization is positively related to TMS specialization is confirmed for the RS ($r = .40$, $p < .01$) but not for the LS. This can be explained by looking at the roles of the RS and LS. The RS flies with different LS's according to the task at hand. He is aware that the LS has knowledge that differs from his own. The LS is always flying with a pilot in the RS and has to provide backup for the RS when he needs it. Therefore, the RS will have less unique knowledge, so the LS is not as aware of the knowledge differences as the RS.

Hypothesis 1b, a positive relationship between Team composition-specialization and TMS Coordination is not confirmed. This can be due to the environment in which the data were collected. In a cockpit, coordination of tasks is fitted in procedures. Which tasks will be performed differs with different Team composition-specialization, but all task execution will be performed according to Standard Operating Procedures (SOPs).

Hypothesis 1c, Team composition-specialization is positively related to TMS Credibility is not confirmed for the RS but it is confirmed for the LS ($r = .32$, $p < .01$). The LS is dependent on the RS for his flight safety and his task execution as the RS flies the aircraft. This dependency can result in experiencing the RS as credible. The RS is flying in single pilot concept and is not dependent on the LS for his/her task execution. This independency might be the cause of lack of result of RS experiencing credibility of the LS.

The hypotheses 2a, 2b and 2c, that Team composition-culture would be related to TMS are not confirmed for RS or LS. This can be explained by looking at the amount of teams with members from different nations. Most of the teams trained with nationals. The few exceptions included international instructors who live in the Netherlands and train both their own nations and the Netherlands. They know the procedures and training of both nations and therefore are not representative for the cultural differences that can occur in a team.

Hypothesis 3a that Team composition-experience is positively related to TMS Specialization is confirmed for the RS ($r = .29$, $p < .01$) but not for the LS. This means that the more flight hours the RS has made, the more he/she regards the team as specialized. This can be explained by the function of the LS. The LS is aware of the RSs unique skills and knowledge regardless of how experienced the RS is because the tasks of the RS do not change in training or in operational flying. For the RS, during his education and training prior to flying operations on board of ships, the LS will act as his back-up, and the RS will not see the LSs unique knowledge. The RS will become more aware of unique knowledge from the LS when he has experience on real time missions where the unique knowledge from the LS is used and vital for mission goal achievement.

Hypothesis 3b that Team composition-experience is positively related to TMS Credibility is not confirmed for the RS and the LS. This can be due to the high training standards: there is a steep learning curve expected from all students (both RS and LS) from the start of the training until the finish and there are qualification tests for operational personnel to ensure the maintenance of that high standard. Therefore, all team members are experienced as credible, regardless of their experience.

Hypothesis 3c, a positive relationship between Team composition-experience and TMS Coordination is not confirmed for the RS nor for the LS. This can be due to the SOPs that are used in the cockpit, ensuring optimal coordination regardless of experience.

Hypothesis 4a, Team composition-rank will be negatively related to TMS Specialization is not confirmed for the LS and is contradicted for the RS. The results show a positive relationship between Team composition-rank and RS TMS Specialization ($r = .24$, $p < .05$). As rank is related to experience this could explain why difference in rank results in a positive TMS Specialization for the RS instead of a negative one. This can also explain why there is no confirmation for the LS.

There is no confirmation of hypotheses 4b (negative relationship between Team composition-rank and TMS Credibility) and 4c (positive relationship between Team composition-rank and TMS Coordination) for the RS nor the LS. This can be explained in the same way as the results on hypothesis 3b and 3c.

Table 3: Correlation matrix TMS and Performance

		Subj. team perf. RS	Subj. team perf. LS	Obj. team Perf. Nav.	Obj. team Perf. Proc.	Obj. team Perf. Coop.
TMS Specialization	RS	,09	-,12	-,02	,07	,09
	LS	-,55**	-,23*	-,07	-,10	-,09
TMS Credibility	RS	,30	-,09	-,06	-,03	-,04
	LS	-,03	,14	-,07	,08	,05
TMS Coordination	RS	,45*	,15	,01	,02	,16
	LS	-,20	,12	,04	,05	,06

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

Table 3 shows the correlation between `TMS and Subjective Performance. It shows that there is a negative relationship between LS TMS Specialization and RS and LS subjective team performance (RS: $r = -.55$, $p < .01$; LS: $r = -.23$, $p < .05$). This means that there is a negative relationship between the LS awareness of unique knowledge in the team, and perceived team performance of both RS and LS. This is directly opposed to hypothesis 5a (there is a positive relationship between TMS Specialization and Team performance). One explanation can be that differentiated unique knowledge in a team makes it more difficult for the team members to assess their own team performance because of lack of in-depth knowledge. This is confirmed by the objective team performance results: there is no significant relationship between TMS Specialization and objective team performance. These results do not implicate that a heterogeneous team with unique knowledge performs bad (no relationship between Team composition and Subjective Team Performance is measured). There are more subjects responsible for the assessment of team performance than TMS Specialization.

Hypothesis 5b (a positive relationship between TMS Credibility and Team performance) is not confirmed: There is no significant relationship between TMS Credibility and objective and subjective performance. One explanation is that team members in this specific situation cannot assess the quality of unique knowledge and performance of the other team member and they cannot assess whether the information provided by the other team member is valid and reliable. Therefore they tend to be cautious in assessing the team performance resulting in no observed correlation.

Hypothesis 5c is confirmed for the RS: There is a positive relationship between RS TMS Coordination and RS Subjective performance ($r = .45$, $p < .05$). There is no significant relationship between LS TMS Coordination and LS Subjective team performance nor between TMS Coordination and objective performance.

CONCLUSION

The overall conclusion about the first part of this research is that Team composition (specialization, experience, rank) of a Lynx cockpit team of one of the partners of the FMFT, is positively correlated with TMS Specialization and TMS Credibility. In the observed teams, team coordination of tasks and knowledge is regulated by the use of Standard Operating Procedures (SOPs). This can explain the lack of confirmation of a correlation between Team composition and TMS Coordination.

There is no evidence in this research that Team composition-culture is correlated to TMS. It is important to notice that the crews operating in this research were from different countries, but operated in the cockpit with fellow compatriots. In teams with members from different nations, one of the members is or has been an international instructor for the FMFT community. These international instructors have been living in the Netherlands for more than 3 years, integrated in Dutch Lynx teams, and therefore are necessarily familiar with both national and Dutch SOPs. These results cannot be transferred to other communities without caution. More research is needed to explore the relation between Team composition-culture and TMS.

One conclusion that can be made from the results of this research is that the correlation between Team composition-rank and TMS Specialization is a positive one and that there is no confirmation of the hypothesis that there is a negative relationship between Team composition-rank and TMS credibility or TMS coordination. This can be attributed to the culture and attitude inside the Lynx community. This result is in line with results from Helmreich (2000) who observed the existence of an international commercial pilot culture. Operations in a Lynx helicopter are like all other military ones: a cockpit team has to be able to operate in a complex, unreliable environment, challenging the boundaries of humans and machine in order to reach their mission objective. In training their teams, instructors specifically stress the danger of not speaking up because of hierarchy differences. During training students are forced to criticize both their own performance and the other members' performance, regardless of their rank. This way of operating allows information sharing in the team, encouraging the team to operate flexible and search for creative solutions in difficult circumstances. The result of this way of training is that hierarchy differences are seen as experience differences. More research is needed to get more insight in the correlation between Team composition – rank and TMS as the Lynx community may not be representative for other military communities.

The results regarding TMS and performance are not as explicit as expected. These results show no correlation between TMS and objective performance for this community and team composition. There are some limitations in this research that deny the possibility of transferring the results to other communities. One of them is that objective performance is defined as team performance assessed by the instructor facilitating the simulator flight. It might be that using other 'objective' measures will result in a relationship between TMS and objective performance. Therefore, more research is needed in order to clarify the relation between TMS and objective performance.

DISCUSSION

The results of this research can be used for training in military communities, especially the results concerning team composition and TMS. One of the lessons that can be learned is that TMS coordination in a heterogeneous team can be regulated by the use of SOPs. In that way the risks of not using existing unique valuable knowledge in the team, will be minimized. SOPs are used widely in the flying community, but this is not widespread within other military communities.

This research also shows that difference in rank within a team does not have to hamper coordination of knowledge, if the members focus on knowledge and experience instead of hierarchy. It is important in such a situation that responsibilities within the team are clearly defined and agreed to. The team member responsible will make the final decisions, but the decision making process in complex situations will be enhanced by using all knowledge available in a team.

The results show no correlation between TMS and objective performance in this community. Therefore more research is needed to get insight in the relationship between TMS and performance.

Although the relation between TMS and performance is not proven in this research, the results show some valuable information that can be used in training armed forces high-risk teams. Armed forces are characterized by strong hierarchical relations. Sometimes these hierarchical relations block the decision making process of using and coordinating all available knowledge in a team. When focusing on experience and knowledge instead of rank (as in the community examined in this research) coordination of knowledge does not decrease due to differences in rank. This focus might increase the chance of both mission accomplishment and the safe return of our military service men and women.

ACKNOWLEDGEMENTS

I would like to thank the flight crews who participated in this research and the instructors who allowed me to use their expertise. I would also like to thank the international FMFT partners (Netherlands Royal Navy, German Navy, Danish Royal Navy, Portuguese Navy and Norwegian Royal Air force) for allowing me to assess their flight crews. I owe the civil staff of CAE my gratitude for their technical support.

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