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Reiner K. Huber[1], Petra M. Eggenhofer[1],
Jens Römer[1], Sebastian Schäfer[1], Klaus Titze[1]

[1]Institute of Technology of Intelligent Systems (ITIS)
Universität der Bundeswehr München
Werner-Heisenberg-Weg 39 * 85577 Neubiberg * Germany
Tel. +49 89 6004 2697 / Fax: +49 89 6004 3036
e-mail: petra.eggenhofer@unibw.de

Point of Contact: Petra Eggenhofer

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Abstract

Command and Control in the 21st century is characterized by transformation from traditional industrial age C2 to networked information age C2 concepts. While a requisite information infrastructure is widely recognized as enabler of networked C2, the contribution of humans to C2 performance is still underestimated. The authors argue that knowledge of how and to what degree characteristics of individuals and teams affect networked C2 and collective action, both in teams and between coalition forces, is indispensable for an efficient implementation of information age C2 concepts.
This paper presents results of an empirical study aimed at uncovering the effects of selected individual and team characteristics – measured by means of standard psychological tests – on team collaboration and effectiveness by means of simulation experiments. The study involved 130 teams, of four cadets and junior military officers of the German *Bundeswehr* each, tasked to locate and fire at targets distributed over a simplified terrain grid in a simulated operation. The results show whether and to what degree personality structures, both on the individual and team level, affect team collaboration measured in terms of shared situational awareness and task performance.

Introduction

Command and Control of network-centric or network-enabled operations is characterized by extensive sharing of information in networked teams and to develop shared situational awareness and understanding for responsive collective decision making and effective action in complex mission environments (Alberts, Gartska, Hayes & Signori, 2001). A robust information network notwithstanding, physically separated individuals focused on role-specific tasks are hardly able to individually select and retrieve all information required for developing consistent individual awareness and understanding especially since their mental models may make them to draw incompatible conclusions from information. Thus, team members need to complement their information base through information sharing and collaboration to translate shared information into shared awareness of the situation at hand which, in turn, provides the basis for shared situational understanding (e.g. Artman, 2000) as a prerequisite of effective collective action in a given situation (Mathieu, Goodwin, Heffner, Salas & Cannon-Bowers, 2000; Salas, Burke & Samman, 2001). Thus, evolution of awareness and understanding involve cognitive and social processes that are shaped by the team members' individual socialization, previous experience, and the mental models that have emerged from previous experience. In addition, personality traits of the team members and the composition of teams affect team performance (Barrick, Stewart, Neubert & Mount, 1998; Halfhill, Sundstrom, Lahner, Calderone & Nielsen, 2005; Morgeson, Reider & Campion, 2005). Thus, at the core of the research described in this paper are the questions as to how individual and team characteristics affect collaboration in networked C2 teams and what team composition supports the quality of collective decision-making and team performance measured in terms of effectiveness and/or efficiency.[1]

Theoretical Background and Hypotheses

In order to provide some empirical evidence to answer these questions, a research approach was chosen that involves the development of hypotheses on potential effects of individual and team characteristics and testing them in a team collaboration experiment. The selection of individual characteristics for hypotheses development was focussed on characteristics that psychological research has found to be relevant for individual performance in social processes and business contexts. Moreover, it was assumed that what applies at the individual level should also apply at the team level, albeit to a different degree. The team task to be solved in the collaboration experiments involves a computer simulation fairly typical for problems facing tactical level C2 of network-enabled operations. It requires members of a spatially distributed team to search for a number of hidden targets and to jointly decide, based on the collected reconnaissance results, where the targets are located. A great deal of – not always unambiguous – information has to be processed concisely, and actions have to be coordinated by the team members communicating by means of online chat and a shared situational picture. In addition, team-specific characteristics are investigated with respect to their potential effects on team performance.

[1] Team effectiveness refers to the evaluation of the results of performance with no consideration of the costs of achieving the results. Team efficiency combines measures of effectiveness with measures of investments that have been made in order to accomplish a task (Beal, Cohen, Burke & McLendon, 2003).

Individual Characteristics and Team Performance

The selected individual characteristics are Locus of Control, Ambiguity Tolerance, and the four personality dimensions underlying the MBTI® typology, i.e., Extraversion versus Introversion, Sensing versus Intuition, Thinking versus Feeling, and Judging versus Perceiving. The Myers-Briggs-Type indicator (MBTI®) is a widely used personality assessment instrument based on a theory of psychological types by Carl Gustav Jung (1921). Research suggests that the distribution of preferences in the team affects team performance (Bradley & Hebert, 1997). Depending on the combination of an individual's preferences on each of these four dimensions, one of sixteen personality types may be assigned to an individual. Thus, personality assessment based on this concept reveals categorical rather than continuous data. However, for research purposes, the scores in each of the four dimensions can be treated as continuous variables, in particular in correlative research when personality structure is to be related to other (e.g. behavioural) variables (Myers, 1993; Thatcher & De La Cour, 2003).

Extraversion versus Introversion

The dimension *Extraversion (E) versus Introversion (I)* plays a central role in personality research and assessment. Introverted individuals tend to draw energy from inside themselves and are mainly interested in the inner world of concepts and ideas. They may develop interest in the clarity of concepts and ideas, often show thoughtful, contemplative detachment, and enjoy solitude and privacy. In team situations they tend to keep information to themselves rather than to communicate openly (Kroeger & Thuesen, 1992). Conversely, extraverted individuals tend to direct their attention toward objects in the environment and other individuals, and they are energized by interaction with others. Also, they rely on the environment for stimulation and guidance, are action-oriented and sometimes impulsive, frank and sociable, and find it easy to communicate (Myers & McCaulley, 1992). Accordingly, extraversion was shown to be positively related to levels of participation in the team and the number of verbal exchanges between team members (Barry & Stewart, 1997).
The team task used in this study requires individuals to process information on stimuli in the outside world, and to cooperate by exchange of information and coordination of their actions. Thus, it may be hypothesized that team members with an extraverted attitude may, because of their outside orientation and their preference for communication with others, find it easier than introverted individuals to accomplish the task. Consequently, a strong tendency toward Extraversion on the team level may facilitate communication and coordination in the team. This may furthermore have positive effects on the overall team performance in a team task that strongly relies on communication and coordination such as the task used in this study.

> *Hypothesis 1a: A team's preference for Extraversion is positively related with team performance.*

Sensing versus Intuition

Sensing (S) and Intuition (N) are two kinds of *Perception*. Sensing refers to perceptions that are observable by way of the senses. Individuals who prefer this perception mode tend to focus on immediate experiences, facts and details from which awareness is developed. Sensing-focused individuals often show characteristics such as realism, memory for details, and practicality. In contrast, individuals preferring the intuitive perception mode focus on possibilities, meanings, and relationships by way of insight. Unconscious intuitions may pop up in consciousness quite suddenly, thereby facilitating creative combination of seemingly unrelated issues. Intuitive individuals also tend to be more imaginative, theoretical, abstract, and future oriented (Myers, 1993).
With respect to the relationship between individual team members' perception preferences (Sensing versus Intuition) and team performance, one may argue that individuals oriented toward sensing should be able to react quickly to stimuli from the physical environment and to process these stimuli to sensations, and further to information, in a detail-focused and differentiated way. Hence, this perception mode may be assumed to be more effective in reacting to situations and problems that are well structured and clear, and when consequences of decisions are rather predictable. Under similar circumstances intuitive individuals may run the risk to be strongly distracted by ideas emerging from earlier, possibly unconscious, experiences. However, intuitive individuals may be more effective in solving unstructured, ill-defined problems which require consideration of future events and developments that may be hard to predict.
Thus, it may be hypothesized that individuals who prefer the sensing perception mode should perform better in a more simply structured task such as the one used in this study.

> *Hypothesis 2a: A team's preference for Sensing is positively related to team performance.*

Thinking versus Feeling

Thinking (T) and *Feeling (F)* are opposite styles of *Judgment*. The thinking judgment mode links ideas and concepts by way of logic. Individuals who prefer the thinking mode tend to rely on principles of cause and effect and to be impersonal and detached. They may develop characteristics associated with principles of justice, criticality, and a time orientation that is distinguished by connecting past, present, and the future. Individuals preferring the mode of feeling are more subjectively than objectively oriented and tend to reach decisions by weighing relative values and merits of an issue. They try to understand personal and group values and are thus more likely to be attuned to the values of others and their own values. They make decisions by attending to other individuals' needs, they are more concerned with human as opposed to technical aspects of problems, and display a strong need for affiliation, a desire for harmony, and a time orientation that includes preservation of the values of the past (Myers, 1993).
The team task used in this study requires team members to logically conclude from observations and information on actions that have to be taken. Team members primarily exchange objective information on their observations and communicate in order to coordinate their actions based on these observations. Team members' values and needs play a subordinate role in this kind of task so that one may hypothesize that teams consisting of individuals preferring the thinking mode should be more effective in accomplishing the task while the presence of individuals preferring the feeling mode reduces effectiveness.

> *Hypothesis 3a: A team's preference for Thinking is positively related with team performance.*

Judgment versus Perception

The dimensions *Judgment (J) and Perception (P)* represent opposites of the dimension *Orientation to the outer world*. Individuals who prefer the perceptive attitude are attuned to incoming information. They are open for new experiences and change, curious and interested in a wide range of issues, they strive to miss nothing, find it easy to adapt and tend to behave in a spontaneous manner. In contrast, individuals who prefer the judging attitude are primarily concerned with making decisions. They tend to end information intake as soon as they are convinced to have observed enough to be able to make a reasonable decision. Most often, they appear to act in an organized, purposeful, and decisive manner.
With a view to the characteristics and requirements of the team task used in this study, it is to be expected that individuals who prefer the judgment attitude will perform better

> *Hypothesis 4a: A team's preference for Judgment is positively related with team performance.*

Locus of Control

The personality trait *Locus of Control* (LOC) refers to an individual's generalized belief in their capability to control achievable reinforcement (Rotter, 1966). Individuals with an internal Locus of Control consider themselves as masters of their fate. They believe in their capability to influence their environment and the consequences of their behaviour. Individuals with an external Locus of Control, however, perceive themselves as more passive agents. They are convinced that favourable or unfavourable events in their lives originate in uncontrollable external forces such as fate or powerful others.
Results of both experimental and field research indicate that individuals with an internal Locus of Control concerned with decision-making tasks gather more information and can process information more effectively than individuals with an external Locus of Control. As regards the team level, in a management simulation study Boone et al. (2005) found the mean score of the team members' internality (internal Locus of Control) to be positively related to information acquisition, i.e. the amount of information gathered by team members, and a team's information acquisition to positively predict team performance measured in terms of return on equity.[2]
The team simulation used in this study requires acquisition and processing of a considerable amount of information that may be easier accomplished by teams comprising members with a distinct internal Locus of Control (high internality).

> *Hypothesis 5a: A team's internality is positively related with team performance.*

[2] This study appears to be the only one having dealt with effects of the team members' Locus of Control on team performance. No such research could be identified in the C2 arena. Thus, in dealing with effects of team members' Locus of Control on team decision-making in a command and control simulation, the study presented here promises to break new ground and expand the current knowledge about the role of human factors in command and control.

Ambiguity Tolerance

With a view to the complexity and dynamics of the global security environment, uncertainty and ambiguity are increasingly becoming organizational reality which decision makers need to adapt to (Huber & Eggenhofer, 2005). Individual differences in tolerance of ambiguous situations can be expected to affect reactions of individuals to such situations. The concept of *Ambiguity Tolerance* refers to the way in which an individual perceives and processes information about ambiguous situations or stimuli when confronted by unfamiliar, complex, or incongruent clues (Furnham & Ribchester, 1995). Individuals high in Ambiguity Tolerance tend to perceive ambiguous situations and stimuli as desirable, challenging, and interesting whereas individuals low in Ambiguity Tolerance easily experience stress, avoid ambiguous stimuli and tend to early select one single solution and stay the course. Accordingly, individuals tolerant of ambiguity appear to perform better than individuals intolerant of ambiguity on ambiguous as well as on less ambiguous tasks, and to perceive both kinds of tasks as equally easy (Ebeling & Spear, 1980).

Although avoidance of ambiguity appears to have relieving effects for individuals who are low in tolerance of ambiguity since it seems to be functional for avoiding anxiety (Hamilton, 1957), this tendency may in turn restrict the individual's field of awareness and spectrum of behavioural alternatives (Furnham & Ribchester, 1995). This notion plays a key role in the networked operations context of this study. The task to detect and combat targets the location of which is completely unknown at the beginning – with only limited material and time resources available – implies significant ambiguity and the risk of failure. For a team concerned with the task it would hence be ineffective to avoid facing the involved ambiguous situation and the risks associated with the ambiguity. In fact, ambiguity tolerance has been consistently found to be negatively related to risk aversion, i.e. individuals who find it easy to tolerate ambiguity are generally less risk averse than individuals low in ambiguity tolerance (e.g. Lauriola & Levin, 2001).

However, taking into account that individuals who show only low risk aversion generally have high self-esteem (e.g. Johanson, 2000), one may argue that individuals highly tolerant of ambiguity tend to take high risks which may in turn impair decision quality and performance. A team context that requires team members to arrive at joint decisions and coordinate their actions implies that the relationship between team performance and the team members' ambiguity tolerance is of an inverted-U-shaped nature.

> *Hypothesis 6a: A team's Ambiguity Tolerance will be related to team performance in an inverted-U-shaped way, i.e. teams with a medium level of Ambiguity Tolerance will perform better than teams with a low or high level of Ambiguity Tolerance.*

Moderator effects

In one of the few studies so far that explicitly dealt with the problem of how to measure individual characteristics at the team level (Boone et al., 2005), the authors could show that homogeneous teams with high mean internality scores gathered more information and achieved better performance than teams with a higher diversity of the team members' internality scores. Thus, one may assume that increasing the heterogeneity of a team with a high internality score by adding individuals with low internality scores would reduce the team's performance level. Conversely, increasing the heterogeneity in a team with a low internality score by adding individuals with high internality scores would increase the team's performance level. Therefore, the effect of a team's characteristic on team performance can be expected to depend on, or be moderated by, the team's diversity in this characteristic.[3] The set of hypotheses proposed above for the effects of the independent variables at the team level on team performance thus may be enriched by an analogous set of hypotheses on moderator effects.

> *Hypothesis 1b: A team's heterogeneity in Extraversion moderates the effects of the team's preference for Extraversion on team performance, i.e. the higher a team's heterogeneity in Extraversion is, the lower will be the correlation between the team's Extraversion and team performance.*
>
> *Hypothesis 2b: A team's heterogeneity in Sensing moderates the effects of the team's preference for Sensing on team performance, i.e., the higher a team's heterogeneity in*

[3] This is supported by Chan (1988) who suggests that team mean scores predict team level outcomes only in case of low variance of the predicting variable. Furthermore, a large body of evidence exists for the notion that high diversity in teams with respect to personality traits promotes destructive conflict within teams, which in turn tends to impair cohesiveness and, ultimately, team performance (e.g., De Dreu & Weingart, 2003).

Sensing is, the lower will be the correlation between the team's preference for Sensing and team performance.

Hypothesis 3b: A team's heterogeneity in Thinking moderates the effects of the team's preference for Thinking on team performance, i.e. the higher a team's heterogeneity in Thinking is, the lower will be the correlation between the team's preference for Thinking and team performance.

Hypothesis 4b: A team's heterogeneity in Judgment moderates the effects of the team's preference for Judgment on team performance, i.e. the higher a team's heterogeneity in Judgment is, the lower will be the correlation between the team's preference for Judgment and team performance.

Hypothesis 5b: A team's heterogeneity in internality moderates the effects of the team's internality on team performance, i.e., the higher a team's heterogeneity in internality is, the lower will be the correlation between the team's internality and team performance.

Hypothesis 6b: A team's heterogeneity in Ambiguity Tolerance moderates the effects of the team's Ambiguity Tolerance on team performance, i.e. the higher a team's heterogeneity in Ambiguity Tolerance is, the lower will be the curvilinear relationship between the team's Ambiguity Tolerance and team performance.

Team-specific characteristics and team performance

In contrast to individual team members' characteristics that may be aggregated to reflect some team-level measure related team performance, a range of influential team-specific characteristics exist that cannot be attributed to individuals. Among the team-specific characteristics most frequently investigated in team performance research are team size (Mullen & Anthony, 1994), availability of a leader versus self-organized teams (Boone et al., 2005), workload distribution and workflow and communication structure (Ellis, Hollenbeck, Ilgen, Porter, West, & Moon, 2003), reward structure (Beersma, Hollenbeck, Humphrey, Moon, Conion & Ilgen, 2003), role ambiguity (Eys & Carron, 2001), tenure (Mennecke & Valacich, 1998), various types of diversity that tend to cause conflicts affecting performance, and team cohesion. As the population was not available for repeated experiments over extended time periods that testing hypotheses on the relationships between team performance and team-specific parameters requires, this research is limited to investigating the impact of team cohesion which is generated by manipulating team behaviour through setting experimental conditions. The respective literature distinguishes between task cohesion and social cohesion may exert somewhat different influences on teams (Wellens, 1993).

Social Cohesion

Social cohesion has been shown to particularly lead to team members' enjoying to work with each other and being positive about coming back to work with their original team on a different task in the future (Chang & Bordia, 2001). In general, an extremely high level of social cohesion in a team bears the risk of groupthink (Janis, 1982), a phenomenon characterized by exceptionally strong group norms to avoid conflict and preserve consensus among team members. Shared mental models play an essential role in the emergence of groupthink (Jones & Roelofsma, 2000) in that information and opinions deviating from the shared mental model are neglected or denied so that fresh perspectives are prevented from adding value to the current shared understanding, which may finally result in deficient decision-making (Postmes, Spears & Cihangir, 2001). However, in the simulation setting of this study, team members interacted only for a short period (approx. 30 minutes) so that it is unlikely that groupthink could emerge in this context. Accordingly, one may propose the following hypothesis.

Hypothesis 7: A team's level of social cohesion is positively related to team performance.

Task Cohesion

Task cohesion was found to be an even better predictor of team performance than social cohesion (Chang & Bordia, 2001). Beal et al. (2003) indicate that cohesion may be more closely related to efficiency than effectiveness measures since cohesion motivates team members to complete the team task successfully and thus enables them to use their resources more efficiently. This justifies the approach taken in this paper to measure team performance in terms of efficiency. The following hypothesis is proposed:

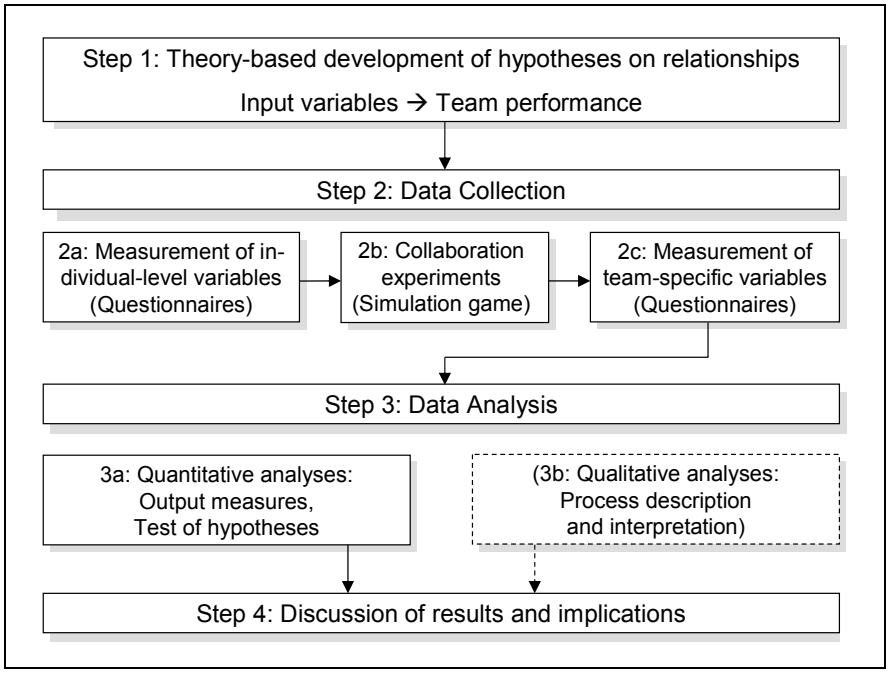
Hypothesis 8: A team's level of task cohesion is positively related to team performance.

Research Design

The research design is outlined in Figure 1. It comprised four principal activities:

1. Theory-based development of hypotheses specifying the relationships between potential determinants and team performance measures;
2. Data collection involving
   a. a set of questionnaires to measure the independent variables describing the relevant individual characteristics (hypotheses 1-6) and control variables;
   b. collaboration experiments involving teams of four participants tasked to cooperatively plan and implement task-oriented actions in a simulation experiment;
   c. a set of questionnaires to measure team-specific variables (hypotheses 7-8).
3. Data analysis comprises the description of the collected input and output variables and tests of the proposed hypotheses on relationships between potential determinants and performance measures (step 3a). The qualitative data collected during the simulation games will be analysed in step 3b in order to gain additional insights in processes such as the emergence of team structure that turned out to be effective or non-effective in terms of the ultimate team performance. Step 3b is subject to further research not covered in this paper.

Figure 1: Research Design



The limited availability of participants only allowed a consecutive approach that precluded team composition based on the individual characteristics of team members. The main body of the sample consisted of some 500 students of the German Air Force officer school where the constraints imposed by the course curriculum and the availability of the requisite IT infrastructure left only about half a day for the collection of data per test group. A focussed team composition based on the participants' individual characteristics was not possible. Thus, teams were composed randomly. The unambiguous linkage between questionnaires (step 2a), game performance (step 2b) and measurement of team characteristics (step 2c) was ensured by a unique identifier per participant.
The functionality of the research design was tested in a pre-investigation involving 60 junior officers during academic training at the *Universität der Bundeswehr München*. Their data are incorporated in the results presented in this paper.

Measurement of the Independent Variables

MBTI® Personality Structure

The Myers-Briggs Type Indicator, a 95-item forced choice questionnaire, is widely used in many organizations for recruiting and personnel development purposes. Retest reliability was found to be

over .80 on average, which may be regarded as good for a personality measure (Bayne, 1995). The instrument shows good validity of the predicted four factor structure and construct validity supported by factor analysis (Hammer, 1996).

Locus of Control

Locus of Control was measured using a German translation of Rotter's (1966) well-known and widely used *Locus of Control* scale, a 23-item forced-choice scale with reported reliability scores between .69 and .76 (Furnham & Steele, 1993). Respondents chose between an internal and an external control alternative for each item. The total score was built by summing the number of internal control alternatives chosen by the individual respondents. Two team-level measures were used, the team members' mean score (average internal Locus of Control) and the standard deviation (Locus of Control heterogeneity). A sample item from the scale is: "What happens to me is my own doing" (indicating internal Locus of Control) versus "Sometimes I feel that I don't have enough control over the direction my life is taking" (indicative of an external Locus of Control). The scale reliability (Cronbach Alpha) in this study was .74 which can be considered as satisfactory.

Ambiguity Tolerance

Tolerance of ambiguity was measured with a scale developed from a selection of 27 items from the MAT-50 (Norton, 1975) which is reported to have an internal consistency of .89 (Furnham & Ribchester, 1995) and six items from MacDonald's (1970) revised AT scale that revealed an internal consistency of .78 (Furnham & Ribchester, 1995). A sample item is "A problem has little attraction for me if I don't think it has a solution". Statements were rated by the respondents on a 6-point Likert scale (1=not at all agree; 6 =strongly agree). The internal consistency of the scale (Cronbach Alpha) was .76 which is satisfactory and allows for collapsing the item scores into an average score.

Social Cohesion

Social cohesion was measured with four items three of which were reproduced from Karau and Hart (1998, p. 188), asking team members how much they liked their fellow team members, how willing they would be to work with their fellow team members again in the future, and how similar they thought they were to their fellow team members. One additional item asked how much the team members felt they had been integrated into the team. The statements were rated on a 6-point Likert-type rating scale (1=not at all agree; 6 =strongly agree). The scale's reliability was .86 which is rated as good.

Task Cohesion

Task cohesion was measured with four items adopted from Carless and De Paola (2000) who report an internal consistency value of .74 (Cronbach Alpha). The items were slightly modified, in particular to reflect the past collaboration situation rather than the present as in the original. One sample item is: "Our team was united in trying to reach its goal for performance." Answers were rated on a 6-point Likert-type rating scale (1=not at all agree; 6 =strongly agree). The scale revealed a reliability of .81 which is considered as good.

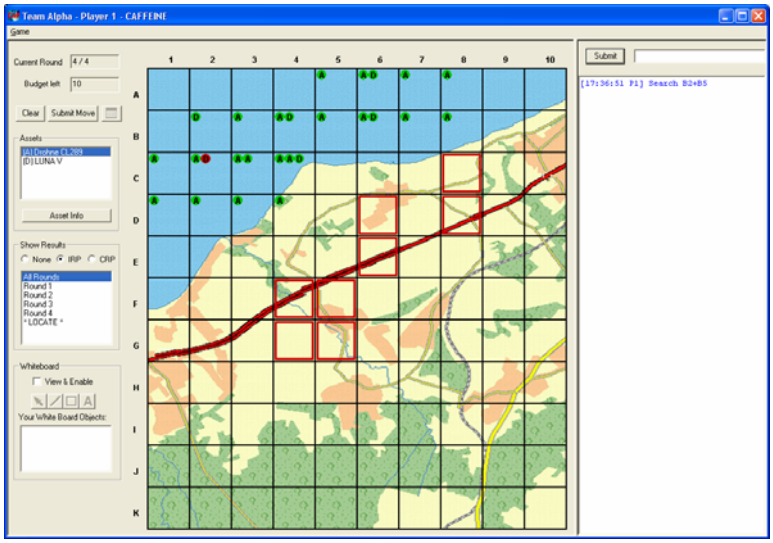
Control Variables

Variables considered as potential moderators of the relationships between the independent variables and the team performance measures were the team members' average age and the teams' gender composition, measured as the number of females in the team.
Furthermore, the team members' cognitive abilities are reported to be positively related to team performance (e.g., Barrick et al., 1998). In particular, the ability to understand the task and its rules and goals as well as task-specific abilities may play a role here. Accordingly, two subtests were selected from the intelligence battery I-S-T 2000-R (Amthauer, Brocke, Liepmann & Beauducel, 2000) to estimate potential moderating effects of spatial ability (the capacity to find "one's way around an unfamiliar environment"; Colman, 2003, p. 695) and number aptitude ("facility with numerical and quantitative operations", Reber & Reber, 2001, p. 474). Internal consistency scores (Cronbach Alpha) of these subscales are reported to vary between .87 and .96 and showed satisfactory scores of .92 (numeral intelligence) and .71 (figural intelligence) in this study.

Collaboration Experiment: Measuring Dependent Variables / Team Performance

Team performance measures will be taken using a simple multi-player computer game called the ***C**ollaborative **G**ame **F**or **F**irst **E**xperiences **I**n A **N**etworked **E**nvironment* (***CAFFEINE***). It was developed by Schäfer (2005) and is currently used in the German Armed Forces to illustrate basic principles and benefits of Network Centric Operations. The basic idea of the game is similar to the concept of StrikeCOM (Twitchell, Wiers, Adkins, Burgoon & Nunamaker, 2005) or ScudHunt (Stahl & Loughran, 2002). Teams of equal size (3 to 8 persons, 4 in this study[4]) have to solve a common task, where the team members are spatially separated but connected through a computer network offering different means of communication like voice and text chat, white board and a Common Result Picture (CRP). In each simulation experiment, the objective of the task is to search for a number of targets randomly distributed over a rectangular area divided into cells of equal size accommodating at most one target each (Figure 2). Each player owns a specific sensor portfolio that he/she may use to perform a number of reconnaissance rounds each limited by a fixed budget. Sensors differ in several attributes like the number and arrangement of cells they can cover, precision (detection and false alarm probability), and cost per deployment. The limited sensor capability and the uncertainty of results raise the need for communication and cooperation within the team to obtain the best possible reconnaissance (recce) picture and shared situational awareness of target locations. In contrast to an Individual Result Picture (IRP) CRP, if available, allows each team players to see immediately the search results of team mates on his/her individual screen. In the final round each player is tasked to select all cells where he/she suspects the targets based on the information available to him/her.

Figure 2: *CAFFEINE* Screenshot



During each game, team activities (mainly chat conversation and moves / actions) and their outcomes are recorded on the basis of which the following variables for assessing team collaboration and performance are compiled at the end of each game:

- *Hit*: Number of cells marked by the team that actually contain targets
- *Fail*: Number of shots at empty cells
- *ChatMsg*: Number of chat messages sent
- *Time*: Total time consumed to complete the task (seconds)
- *Budget*: Unused Reconnaissance Budget (virtual monetary units)

Team performance is assessed on the basis of functional relationships between appropriate measures of effectiveness or efficiency described in terms of the recorded game output variables.
While a linear additive weighted score function was used during the simulation games to provide individual teams with some feedback on their performance[5], a comparative analysis of several functional forms suggested that, given the restrictive circumstances of data collection and the relative simplicity of the task to be performed by the teams, the following functions would be most appropriate

[4] Team size of four was considered as an appropriate compromise between the number of test participants available and the desired interaction levels in the teams.
[5] Total weighted score WTS = 20* hit – 10* fail – time [20sec] – ChatMsg – budget

for the assessment of team cooperation in terms of shared situational awareness (SSA) and team performance in terms of task efficiency (TEF):

$$SSA = \frac{\sum_i x_i}{\sum_{\{i|x_i \geq 1\}} 1} \qquad (1)$$

i = index of cells

x_i = number of players designating cell i to contain a target

Equation (1) for measuring SSA was adopted from Stahl and Loughran (2002). Accordingly, SSA becomes a maximum, represented by the number of players in the team, if all players nominate the same set of cells as target cells. There is no shared awareness if each player nominates a unique set of cells as containing targets, in which case SSA = 1.

$$TEF = \frac{(2 * hit - fail)^2}{time} \qquad (2)$$

Equation (2) assumes that task effectiveness described by the numerator accounts for both targets being hit and, to a lesser degree (expressed by the higher weight), countermanding risks associated with potential collateral damage when non-target areas/cells are being hit. Squaring the net gain accounts for the additional cost per shot, in the sense of time and effort to be spent for successful targeting, as the number of shots increases. Assuming time to be the decisive resource determining task efficiency, rather than the number of shots fired or the reconnaissance budget spent, reflects the importance of time sensitive targeting in a dynamic operational environment.

Data Analysis and Results[6]

The data presented below are based on sample that included a total of 574 officer cadets receiving initial military training at the officer school of the German Air Force and junior officers of all service branches pursuing an academic education at the Universität der Bundeswehr München. The sample consisted of 86.4 percent males and 13.6 percent females. Most of the study participants (75.9 per cent) had entered the Armed Forces in July 2006 directly after graduation from secondary schools[7], hence shortly before data collection and thus possessed no considerable military experience. However, 27.6 per cent had prior experience with military service, either as conscripts or NCO candidates qualifying for officer training. Their average duration of prior military service was 14.94 months (s.d. = 10.7 months). The participants' average age was 20.77 years (s.d. = 2.13 years). In the end, the results of 130 teams[8] were available for analysis. The results reported in the following sections refer to the team level only.

For the simulation experiments, the participants were grouped into teams of four individuals each. For the purpose of statistical analyses and hypothesis tests, the data on the individual characteristics of team members were aggregated to the team level. The team values of the independent variables are calculated as the arithmetic average of the four team members' individual values, whereas a team's heterogeneity in an independent variable is indicated by the team's standard deviation of this variable (e.g., Boone et al., 2005).

Independent Variables at the Team Level

Descriptive statistics of the independent variables at the team level are shown in table 1, including the minimum and maximum values, average scores and standard deviations.

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[6] Data and results presented in this paper are based on quantitative analyses only (step 3a). Even though possibly important for the interpretation of quantitative results, the deadline for submitting this paper did not permit a qualitative evaluation of the content of the some 6,000 chat messages between team members. Aimed at uncovering the structure and dynamics of the team collaboration processes, a qualitative evaluation will take considerable time and will presumably not be completed before summer 2007.

[7] In Germany, secondary school education lasts 8-9 years and ends with a comprehensive final exam. The respective level of education corresponds to a second year (sophomore) college level in the U.S. system.

[8] Theoretically, more than 140 teams could have been built from the total number of participants. However, the number of participants available in the various times slots allocated for data collection was not always an exact multiple of four.

Table 1: Descriptive statistics of independent variables at the team level

Independent and control variables	N	Min.	Max.	Average	s. d.	Z[a]
MBTI® Extraversion vs. Introversion	130	50.50	107.00	75.70	12.42	.59
MBTI® Sensing vs. Intuition	130	62.00	119.00	93.42	10.40	.52
MBTI® Thinking vs. Feeling	130	59.00	124.00	90.33	12.38	.53
MBTI® Judging vs. Perceiving	130	65.00	122.00	90.33	13.24	.71
Locus of Control (internal)	130	9.75	20.75	17.49	2.10	2.20**
Ambiguity Tolerance	130	2.28	3.43	2.83	.23	.50
Intellectual ability (numeral)	130	15.00	35.00	25.74	4.33	.60
Intellectual ability (figural)	130	7.25	15.50	11.11	1.86	.89
Age	130	18.50	24.25	20.46	1.06	1.77**
Gender (number of females)	130	0	3	.51	.77	4.46**
Social Cohesion	130	1.62	5.81	4.18	.76	.91
Task Cohesion	130	1.75	5.94	4.39	.77	.76

s. d. = standard deviation; [a] Kolmogorov-Smirnov-Z statistic for test of normal distribution: Non-significant Z indicates normal distribution; significance levels: + p < 0.10; * p < .05; ** p < .01

Note that for the MBTI® dimensions values below 100 indicate a preference for Extraversion (E), Sensing (S), Thinking (T), and Judging (J), and, conversely, values above 100 indicate a preference for Introversion (I), Intuition (N), Feeling (F), and Perceiving (P). In addition to the calculation of descriptive statistics, the sample distribution for each of the independent variables was tested for normal distribution. As can be seen from table 1, except for *Locus of Control* all independent variables can be considered as normally distributed, whereas the control variables *Age* and *Gender* (number of females in the team) did not show normal distribution.

Team Performance Results

As the players had no or little experience with CAFFEINE, groups of (approximately 24) participants were provided some time to familiarize themselves with the basic functions of the game. Then participants were randomly allocated teams of four each without getting to know the other members of their team throughout the entire gaming session. The teams played the game twice without interruption, the first game with CRP available and the second with IRP only.

Table 2 shows the descriptive statistics of the results of 130 teams, including minimum and maximum values, means and standard deviations of the team performance measures for both experimental conditions (CRP and IRP). Performance Scores calculated by (2), as well as shared situational awareness (SSA) calculated by (1), were represent the dependent variables in the subsequent analyses.

The results show significant differences (according to the T-Test) between both experimental conditions. For example, with CRP teams scored 24.3 hits on average as compared to 21.1 with IRP only. In contrast, the number of shots at empty cells (Fail) ranged from 0 to 14 for CRP and 0 to 20 for IRP, resulting in a standard deviation of 3.3 and 4.5 respectively.

Table 2: Team performance measures (CRP // IRP)

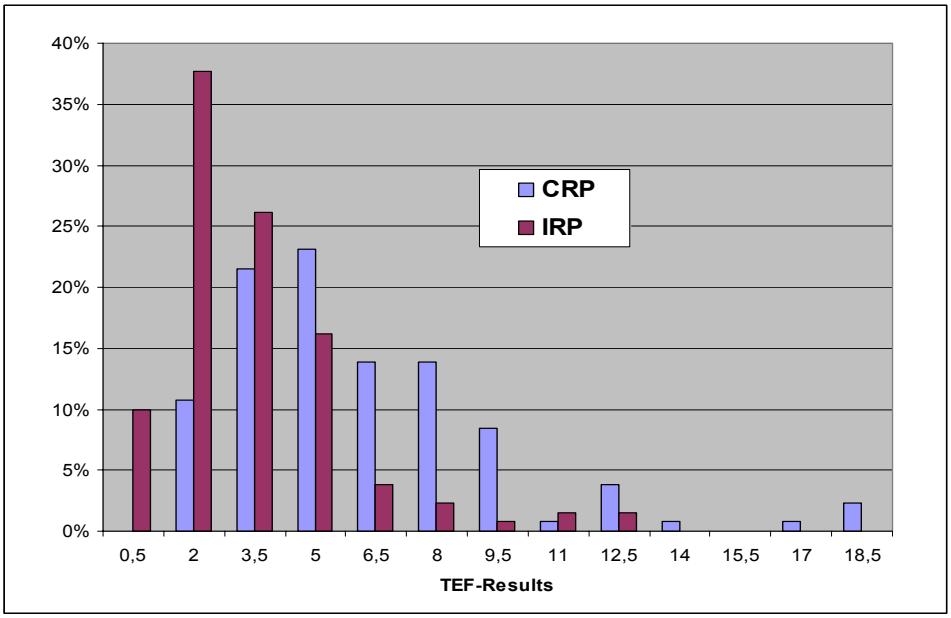
	Min.	Max.	Average	s. d.	T[a]
Hits	12 // 9	28 // 28	24.3 // 21.1	3.4 // 4.2	-8,52**
Fail	0 // 0	14 // 20	4.5 // 7.4	3.3 // 4.5	7,60**
Time (*sec*)	135 // 158	1053 // 1599	452 // 643	177 // 258	9,45**
Chat	0 // 0	65 // 156	17.6 // 28.4	12.8 // 19.0	9,18**
Budget	0 // 0	485 // 385	165 // 125	96 // 86	-5,26**
TEF	0.5 // 0.0	17.8 // 11.7	5.4 // 2.6	3.4 // 2.2	-10,13**
SSA	1.46 // 1.38	4.00 // 4.00	3.2 // 2.7	0.58 // 0.69	-7,44**

[a] Statistics for T-Tests for paired samples on average results; ** p < .01

The relative frequency of the Task efficiency (TEF) over the entire sample is shown in Figure 3. The long tail to the right (due to separating effects of the square in (2) for top teams) notwithstanding, the diagram shows a nearly normal distribution which supports the conclusion that (2) is a plausible

function for assessing team performance. The difference between both graphs underscores the general advantage of CRP as stated above.

Figure 3: Task efficiency results for CRP and IRP



Test of Hypotheses

Table 3 presents the zero-order correlations between all independent, control and dependent variables and their significance levels. The team results for the dependent variables TEF and SSA, each for CRP and IRP, were additionally correlated with two sub-samples, homogeneous and heterogeneous teams with a view to the respective independent variable. Homogeneous/heterogeneous teams were defined as those teams with a standard deviation of the respective variable below/above the standard deviation averaged over all teams. The respective correlation coefficients are shown in lines 13a, 14a, 15a, and 16a for homogeneous teams, and in lines 13b, 14b, 15b, and 16b for heterogeneous teams.

The table shows a number of significant correlations among independent variables in this particular data set. For example, in this sample *Extraversion-Introversion* is significantly positively related to *Sensing-Intuition* and *Thinking-Feeling*, and significantly negatively correlated with *Judging-Perceiving*. This indicates that teams with a higher average preference of Introversion tend to also show a slightly higher average preference for *Intuition* ($r = .28$, $p < .01$) as opposed to *Sensing*, to *Feeling* ($r = .34$, $p < .01$) as opposed to *Thinking*, and to *Judging* ($r = .33$, $p < .01$) as opposed to *Perceiving*. Another striking co-variations seems to exist in particular between the teams' average internality and the average age of the team members ($r = .40$, $p < .01$) in that those teams with lower age averages tend to show higher internality. Furthermore, the degree to which the teams experienced social cohesion significantly co-varies with their task cohesion ($r = .88$, $p< .01$).

In regard to the relationships between independent and dependent variables, only some of the most salient results shown in the table are described in the following. A complete report of the results concerning the hypotheses will only be given in the section after that, based on the regression analyses. The results presented in table 3 indicate that those independent variables that most strongly relate to the teams' Task Efficiency or Shared Situational Awareness seem to be *Extraversion-Introversion*, *Locus of Control* (internality), and *Sensing-Intuition*.

Furthermore, both the teams' social and task cohesion seem to be significantly related to all four outcome measures, indicating that those teams reporting high social or task cohesion were also those with high Task Efficiency and high Shared Situational Awareness.

Finally, among the control variables age seems to be relevant, in particular task efficiency in both experimental settings (CRP: $r = -.19$, $p < .05$; IRP: $r = -.18$, $p < .05$).

Table 3: Correlations among dependent and independent variables

Zero-order variable intercorrelations[a]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. MBTI® Extraversion vs. Introversion	*(.81)*														
2. MBTI® Sensing vs. Intuition	.28**	*(.67)*													
3. MBTI® Thinking vs. Feeling	.34**	.25**	*(.81)*												
4. MBTI® Judging vs. Perceiving	-.33**	-.22*	-.16^{+}	*(.82)*											
5. Locus of Control internal	-.06	.07	-.06	-.12	*(.74)*										
6. Ambiguity Tolerance	.04	.28**	.17^{+}	-.15^{+}	.05	*(.76)*									
7. Intellectual ability numeral	-.01	-.06	.19*	.06	-.08	-.07	*(.92)*								
8. Intellectual ability figural	-.14	-.18*	-.14	.07	-.07	-.05	.28**	*(.71)*							
9. Social Cohesion	.19*	.15^{+}	.10	-.14	.20*	.11	-.06	-.00	*(.86)*						
10. Task Cohesion	.15^{+}	.15^{+}	.09	-.06	.16^{+}	.08	-.10	.03	.88**	*(.81)*					
11. Age	.00	-.09	-.07	.12	-.40**	-.05	.04	.02	-.14	-.09					
12. Number of females in the team	.17*	.14	.03	.05	-.04	.21*	-.19*	-.04	.08	-.02	-.16^{+}				
13. TEF IRP	.20*	.08	.03	.01	.11	-.14 / .10 / .03	-.07	.08	.31**	.39**	-.18*	.03			
13a. TEF IRP (homogeneous teams)	.28*	-.03	.00	.02	-.01	-.19 / .06 / -.13	-.01	.12							
13b. TEF IRP (heterogeneous teams)	.12	.19^{+}	.16	-.01	.23*	-.12 / .21 / .22	-.18^{+}	.05							
14. TEF CRP	.22*	.07	.07	.08	.19*	-.05 / .10 / -.06	.06	-.06	.27**	.24**	-.19*	.04	.44**		
14a. TEF CRP (homogeneous teams)	.33**	-.19^{+}	.12	.14	.21*	.04 / .05 / -.41*	.00	.00							
14b. TEF CRP (heterogeneous teams)	.13	.32**	.03	.02	.16	-.27 / .17 / .13	.04	-.13							
15. SSA IRP	.15^{+}	.17^{+}	-.01	.06	.17^{+}	-.03/ -.11/ -.01	.01	.21*	.46**	.54**	-.16^{+}	-.06	.51**	.28**	
15a.SSA IRP (homogeneous teams)	.16^{+}	.07	.13	-.01	.19^{+}	-.01/ -.05/ -.29	.08	.16^{+}							
15b.SSA IRP (heterogeneous teams)	.09	.34**	-.03	.11	.17^{+}	-.03 / -.14/ .14	-.07	.24*							
16. SSA CRP	-.03	.03	.03	.10	.15^{+}	-.20^{+}/ .08 / .15	.11	.03	.39**	.47**	-.11	-.11	.22*	.50**	.43**
16a.SSA CRP (homogeneous teams)	.00	-.07	.07	.05	.42**	-.14 / .17 / -.03	-.07	.09							
16b. SSA CRP (heterogeneous teams)	-.06	.19^{+}	.14	.12	-.04	-.37* / -.05/ .23	.30**	-.07							

[a] Pearson correlation coefficients; significance levels (two-sided): $^{+}$ $p < 0.10$; * $p < .05$; ** $p < .01$; scale reliability scores are reported in the principal axis.

Regression Results

To test the proposed hypotheses on main effects of the independent on the dependent variables and the moderator effects of team heterogeneity on these main effects, the independent variables were regressed on the dependent variables This procedure simultaneously assesses the degrees to which each of the proposed predictors individually contributes to the variance of a given dependent variable. Because of space limitations for this paper, regression analysis results are presented only for the dependent variable *Task Efficiency* given CRP and IRP.

Main effects

Table 4 reports the results of the regression analyses for the teams' task efficiency, including the variables entered into the regression equation, the proportion of explained variance (R^2), respectively the changes occurred in the proportion of explained variance (ΔR^2), standardized beta weights, T statistics and related significance levels. The regression models are labeled by the numbers of the according hypotheses. For example, hypothesis 1b refers to the moderator effect of (E – I) heterogeneity and is tested by the respective regression model 1b.

Table 4: Regression Results for Main Effects on Task Efficiency

Regression model (TEF CRP)	Variables	R^2	stand. Beta	T	Tol.[a]
	(Absolute term)			-.00	
	Extraversion – Introversion		.30	3.07**	.73
	Sensing – Intuition		.03	.26	.80
	Thinking – Feeling		-.01	-.12	.78
	Judging – Perceiving		.22	2.38*	.81
Main effects	Locus of Control internal	.16	.17	1.81^{+}	.80
	Ambiguity Tolerance		-.03	-.38	.85
	Intellectual ability numeral		.07	.78	.82
	Intellectual ability figural		-.04	-.44	.86
	Age		-.16	-1.69^{+}	.79
	Gender (number of females)		-.03	-.28	.83
Regression Model (TEF IRP)	**Variables**	**R^2**	**stand. Beta**	**T**	**Tol.**
	(Absolute term)			.01	
	Extraversion – Introversion		.29	2.86**	.73
	Sensing – Intuition		.03	.27	.80
	Thinking – Feeling		-.03	-.33	.78
	Judging – Perceiving		.14	1.51	.81
Main effects	Locus of Control internal	.12	.07	.69	.80
	Ambiguity Tolerance		.09	.91	.85
	Intellectual ability numeral		-.11	-1.16	.82
	Intellectual ability figural		.15	1.62	.86
	Age		-.18	-1.83^{+}	.79
	Gender (number of females)		-.09	-.99	.83

[a] Tolerance: Indicator of collinearity between independent variables entered into the regression: values close to 1 indicate that independent variables are not interrelated; significance levels: $^{+}$ $p < 0.10$; * $p < .05$; ** $p < .01$

Hypothesis 1a suggested that a team's average preference for *Extraversion* is positively related to team performance which is measured in terms of Task Efficiency (TEF) in this study. Since *Extraversion* refers to the low end of the *Extraversion-Introversion* scale, this is the case if the coefficient of the correlation between *Extraversion-Introversion* and TEF is negative. As can be seen in Table 4, *Extraversion-Introversion* reveals positive significant regression weights for both conditions, CRP (β = .30, $p < .01$) and IRP (β = .29, $p < .01$), which indicates that *Extraversion* is related to TEF, but in the opposite than the assumed direction. Thus, hypothesis 1a is not supported.

Hypothesis 2a suggested that *Sensing*, as the low end of the dimension *Sensing-Intuition*, would be positively related to TEF. However, the results for both CRP (β = .03, n. s.) and IRP (β = .03, n. s.) did not reveal a significant contribution of this variable to TEF variance. Hypothesis 2a is hence not supported.

Hypothesis 3a assumed a positive relationship between a team's *Thinking* preference and TEF, but is not supported by the observed data, neither for CRP (β = -.01, n. s.) nor for IRP (β = -.03, n. s.).
Hypothesis 4a, suggesting a positive relationship between a team's *Judging* preference and task efficiency, was not supported since the positive regression weight of *Judging-Perceiving* points in the opposite direction. It is significant for CRP (β = .22, p < .05), but not for IRP (β = .14).
Hypothesis 5a proposed a positive relationship between team internality and task efficiency. The regression weights for the internal Locus of Control is slightly significantly positive for CRP (β = .17, p < .10), but not for IRP (β = .07, n. s.). Thus hypothesis 5a can be considered as partially supported.
Hypothesis 6a suggested an inverted-U-shaped relationship between a team's Ambiguity Tolerance and task efficiency. However, this predictor had to be considered in a somewhat different manner. Even though the observed data for this variable can be considered as normally distributed (see Table 1), the total sample average of 2.83 on a scale of 1-6 indicates that the observed sample of teams is biased to the left of the overall scale. It hence appeared less useful to assume that the observed data would show the inverted-U-shaped relationship with the team performance measures that had been hypothesized for data that would be normally distributed over the entire given scale (1-6). Instead, all observed data fall in the area to the left of the center of the scale (3.5). This suggests that a positive (linear) relationship within the range of the observed data would be compatible with the original hypothesis 6a that postulates the inverted-U-shaped relationship between *Ambiguity Tolerance* and team performance. However, as can be seen from Table 4, Ambiguity Tolerance reveals significant positive regression weights neither for CRP (β = -.03, n. s.), nor for IRP (β = .09, n. s.).
Hypothesis 7 assumed that a team's social cohesion would be positively related to team performance. As can be seen from table 3, social cohesion was positively related to task cohesion to a highly significant degree (r = .88, p < .01). Thus, social and task cohesion seem to interact in producing positive effects on TEF which makes it difficult to identify the isolated effects of either predictor. However, the positive correlations of social cohesion with TEF for CRP (r = .27, p < .01) and IRP (r = .31, p < .01) as well as of task cohesion with TEF for CRP (r = .24, p < .01) and IRP (r = .39, p < .01) support hypotheses 7 and 8. Furthermore, for both CRP and IRP, social and task cohesion produce even stronger positive effects on the teams' SSA (social cohesion: CRP: r = .39, IRP: r = 46; task cohesion: r = .47, IRP: r = .54; p < .01 for all results).

Moderator effects

Hypotheses 1b, 2b, 3b, 4b, 5b and 6b assumed that for each independent variable a team's heterogeneity of that variable would moderate the observed relationship between the respective team average and team performance. That is, these relationships would be the stronger the lower the teams' heterogeneity was in regard to the independent variables. To test that assumption, for each independent variable the interaction term in form of the product of the team average and the standard deviation was entered into the regression equation. Table 5 presents the results for these hypotheses.
Hypothesis 1b suggested that a team's heterogeneity in Extraversion-Introversion would reduce the strength of the effect of the team's Extraversion on task efficiency. As can be seen in table 5, the respective average x heterogeneity interaction term is negative for CRP (β = -.13, n. s.) as well as for IRP (β = -.28, p < .01), and significant in the latter case. This result supports hypothesis 1b although the moderated relationship between *Extraversion-Introversion* is in the opposite than the suggested direction.
Hypothesis 2b assumed a moderator effect of team heterogeneity referring to *Sensing-Intuition* on the relationship between *Sensing* and task efficiency. The average x heterogeneity interaction term is not significant for CRP (β = .13, n. s.) or IRP (β = -.02, n. s.).
Hypothesis 3b suggested an analogous moderator effect for *Thinking-Feeling*. However, results show that the respective average x heterogeneity interaction term is not significantly different from zero for CRP (β = .05, n. s.) or IRP (β = -.08, n. s.). Thus, hypothesis 3b is not supported.
Hypothesis 4b predicted a moderator effect for *Judging-Perceiving*. The average x heterogeneity interaction term is however not significant for CRP (β = .04) or IRP (β = .00) so that hypothesis 4b is not supported.
Hypothesis 5b dealt with the moderator effect for team heterogeneity in internality (internal Locus of Control) on the relationship of team internality and task efficiency. The average x heterogeneity interaction term was not significantly different from zero for CRP (β = -.02) or IRP (β = -.03).
Finally, hypothesis 6b, referring to the moderator effect in the case of Ambiguity Tolerance, was not supported for CRP (β = .04, n. s.) or IRP (β = -.12, n. s.).

Table 5: Regression Results for Moderator Effects

Moderator effects (TEF CRP)	Variables	Δ R^2	Standardized Beta	T	Tol.
Model 1a. E – I	E – I team average		.22	2.54**	1.00
Model 1b. E – I heterogeneity moderator effect	E – I team average	.01	.30	2.79**	.64
	E – I interaction term		-.13	-1.25	.64
Model 2a. S–N	S–N team average		.07	.81	1.00
Model 2b. S–N heterogeneity moderator effect	S–N team average	.01	.01	.13	.81
	S–N interaction term		.13	1.38	.81
Model 3a. T – F	T – F team average		.07	.83	1.00
Model 3b. T – F heterogeneity moderator effect	T – F team average	.00	.04	.37	.62
	T – F interaction term		.05	.45	.62
Model 4a. J – P	J – P team average		.08	.94	1.00
Model 4b. J – P heterogeneity moderator effect	J – P team average	.00	.07	.65	.76
	J – P interaction term		.04	.34	.76
Model 5a. LOC (internal)	LOC (internal) team average		.19	2.13*	1.00
Model 5b. LOC (internal) heterogeneity moderator effect	LOC (internal) team average	.01	.19	2.13*	1.00
	LOC (internal) interaction term		-.02	-.26	1.00
Model 6a. Ambiguity tolerance	AT average		-.04	-.48	1.00
Model 6b. Ambiguity tolerance heterogeneity moderator effect	AT average	.00	-.06	-.60	.87
	AT interaction term		.04	.42	.87
Moderator effects (TEF IRP)	**Variables**	**Δ R^2**	**Standardized Beta**	**T**	**Tol.**
Model 1a. E – I	E – I team average		.20	2.28*	1.00
Model 1b. E – I heterogeneity moderator effect	E – I team average	.05	.36	3.42**	.64
	E – I interaction term		-.28	-2.60**	.64
Model 2a. S–N	S–N team average		.08	.85	1.00
Model 2b. S–N heterogeneity moderator effect	S–N team average	.00	.08	.84	.81
	S–N interaction term		-.02	-.18	.81
Model 3a. T – F	T – F team average		.03	.28	1.00
Model 3b. T – F heterogeneity moderator effect	T – F team average	.01	.07	.66	.62
	T – F interaction term		-.08	-.71	.62
Model 4a. J – P	J – P team average		.01	.07	1.00
Model 4b. J – P heterogeneity moderator effect	J – P team average	.00	.01	.06	.76
	J – P interaction term		.00	-.01	.76
Model 5a. LOC (internal)	LOC (internal) team average		.11	1.25	1.00
Model 5b. LOC (internal) heterogeneity moderator effect	LOC (internal) team average	.00	.11	1.25	1.00
	LOC (internal) interaction term		-.03	-.34	1.00
Model 6a. Ambiguity tolerance	AT average		.07	.76	1.00
Model 6b. Ambiguity tolerance heterogeneity moderator effect	AT average	.01	.11	1.18	.87
	AT interaction term		-.12	-1.29	.87

[a] Tolerance: indicator of collinearity between independent variables entered into the regression: values close to 1 indicate that independent variables are not interrelated; significance levels: $^{+}$ $p < 0.10$; * $p < .05$; ** $p < .01$

Split Sample Analyses

To further investigate the effects that the independent variables might have on the teams' performance, teams with distinctively low and high values in the independent variables were separated from the sample and made subject to an additional comparison. Low-valued teams are those teams that show independent variable values of at least one standard deviation below the total sample average whereas the high-valued teams have values of at least one standard deviation above the sample average. Table 6 shows the results of the comparison of averages (t-tests) between these two sub-samples for each of the independent variables.

The comparisons show that differences in the independent variable *Extraversion-Introversion* tend to produce a significant difference in team performance given CRP, but not for IRP. For *Sensing-Intuition*, *Thinking-Feeling* and *Judging-Perceiving,* no significant differences were found for any of the performance measures. In contrast, differences between the teams' average internal *Locus of Control* produced significantly different team performance scores both for CRP and IRP. In addition, *Shared Situational Awareness* was significantly higher in those teams with internal *Locus of Control* scores of at least one standard deviation above the sample average.
Ambiguity Tolerance had to be considered separately. Hypothesis 6a claims ambiguity tolerance to be related to performance in an inverted-U-shaped manner. However, even though the observed data for this variable can be considered as normally distributed (see Table 1), the total sample average of 2.83 on a scale of 1-6 indicates that the observed sample is biased to the left of the overall scale. It hence appeared less useful to assume that the observed data would show the inverted-U-shaped relationship with the team performance measures that had been hypothesized for data that would be normally distributed over the entire given scale (1-6). Instead, all observed data fall in the area to the left of the center of the scale (3.5). This suggests that a positive (linear) relationship within the range of the observed data would not be incompatible with the original hypothesis which postulates the inverted-U-shaped relationship between *Ambiguity Tolerance* and team performance. However, as can be seen from Table 6, there was no significant relationship between *Ambiguity Tolerance* and team performance in either of the two sub-samples.
The control variables *Numeral Intelligence* and *Figural Intelligence* show significant relationships with Shared Situational Awareness: *Numeral Intelligence* appears to be related to Shared Situational Awareness given CRP, while *Figural Intelligence* shows a significant relationship with Shared Situational Awareness given IRP.
Age as another control variable revealed a significant relationship with TEF given CRP in that teams with a lower age average tend to achieve higher TEF than teams with a higher age average. *Gender*, measured as the number of females in a team, appears to have an effect neither on the TEF measures nor on the teams' capabilities to develop shared awareness.
Finally, both team-level independent variables, social and task-related *Cohesion*, show significant positive effects on team' performance. This effect tends to be even stronger for task cohesion.

Discussion

According to type theory, MBTI® variables follow a bimodal (double-peaked) distribution with an average in the middle of the scale (100 points). In the observed sample, however, averages of all four dimensions are strongly biased to the left resulting in an apparently normal distribution of the data that seems to represent the left peak of the normally bimodal distribution. This suggests that the distribution of the sample is not representative of the distribution found in general populations.
Concerning Locus of Control a strong bias is observed towards the right side of the scale (high internality) with a low standard deviation. Ambiguity Tolerance is strongly biased to the lower side of the scale (average of 2,83 on a scale of 1 to 6, s.d.<10%). Therefore, the insights gained from this sample permit only limited conclusions concerning the general impact of team Internality and Ambiguity Tolerance.
According to Table 3 correlation coefficients between independent (Nr. 1-6) and control variables (Nr. 7,8,11,12) do not indicate any significant interference except for Internality (Nr. 5) and Age (Nr. 11). This suggests that younger teams tend to show higher Internality.

Table 6: Comparison of Averages between High- and Low-valued Teams (T–tests)

	N[a]	TEF CRP			TEF IRP			SSA CRP			SSA IRP		
	N[b]	Average	s. d.	T	Average	s. d.	T	Average	s. d.	T	Average	s. d.	T
Extraversion – Intro-version	24	4.81	2.14	**-1.80**$^{+}$	2.11	1.48	-1.59	3.21	.46	.25	2.53	.62	- .65
	18	6.66	3.98		3.20	2.90		3.17	.64		2.66	.61	
Sensing – Intuition	17	5.78	3.90	- .31	2.58	2.64	- .37	3.30	.56	.29	2.59	.77	-1.07
	18	6.23	4.67		2.87	2,05		3.25	.58		2.87	.77	
Thinking – Feeling	22	4.79	2.65	- .99	2.36	1.85	- .72	3.13	.61	- .69	2.65	.79	.07
	20	5.63	2.89		2.83	2.42		3.26	.63		2.63	.60	
Judging – Perceiving	23	5.16	2.68	- .87	2.77	1.94	.76	3.18	.54	-1.05	2.72	.59	- .52
	22	6.06	4.14		2.36	1.61		3.34	.48		2.82	.68	
Locus of Control (internal)	13	3.28	1.92	**-2.82***	1.83	.94	**-2.14***	3.13	.69	- .85	2.51	.41	**-3.20****
	4	8.52	6.14		3.49	2.37		3.44	.39		3.31	.53	
Ambiguity Tolerance	24	6.13	3.92	.86	2.69	2.18	- .17	3.32	.59	- .23	2.70	.71	- .68
	22	5.31	2.33		2.80	2.44		3.36	.50		2.83	.63	
Intellectual ability numeral	20	5.00	3.42	- .74	2.72	2.63	.08	2.84	.73	**-1.82**$^{+}$	2.62	.72	- .73
	24	5.90	4.46		2.66	2.48		3.24	.72		2.79	.79	
Intellectual ability figural	23	5.88	3.80	.54	2.16	1.38	-1.04	3.19	.59	- .01	2.60	.69	**-2.41***
	28	5.31	3.60		2.67	1.97		3.19	.59		3.07	.71	
Age	16	6.50	3.88	**2.05***	3.08	2.95	1.48	3.41	.53	1.58	2.75	.81	1.00
	22	4.21	3.00		1.94	1.80		3.12	.59		2.52	.63	
Gender	84	5.15	3.44	-1.09	2.43	1.97	-1.08	3.23	.56	1.16	2.76	.70	.43
	46	5.84	3.37		2.87	2.61		3.11	.62		2.71	.68	
Social Cohesion	19	4.47	2.61	**-1.92**$^{+}$	1.79	1.53	**-3.5****	2.85	.61	**-4.9****	2.29	.59	**-5.9****
	18	6.89	4.78		3.64	1.68		3.64	.32		3.44	.60	
Task Cohesion	19	4.41	2.95	**-2.17***	1.37	1.18	**-4.9****	2.76	.68	**-5.4****	2.11	.51	**-8.8****
	25	6.97	4.45		4.09	2.19		3.61	.35		3.46	.51	

[a] Size of sub-sample with values of at least 1 standard deviation below average; [b] Size of sub-sample with values of at least 1 standard deviation above average; s. d. = standard deviation;
$^{+}$ $p < 0.10$; * $p < .05$; ** $p < .01$

Note: The resulting sub-sample sizes for each of the independent variables vary depending on the nature of the respective sample distributions. Note that sub-sample sizes of about 22 each indicate high proximity to normal distribution. The inequality between the two sub-samples for a specified independent variable indicates a rather skewed distribution.

According to Table 2, the results of the simulation games illustrate the benefits of the availability of a CRP for all output variables. To avoid that learning effects influenced the anticipated general benefits from CRP, the team experiments with CRP available to teams were played first. On average, all teams hit more targets, incur fewer failures, need less time and invest less in direct communication (send fewer chat messages) for coordination in that case. The generally higher standard deviation in the IRP-results supports the assumption that unavailability of CRP makes the team task more difficult and leads to higher diversification between the teams. The statistically valid differences with and without CRP available empirically support the NCO tenets and reinforce the importance of a Common Operational Picture for mission effectiveness.

Although the experiments did not support the proposed hypotheses, except for locus of control, social and task cohesion, the study offers a number of interesting insights regarding the social implications for teams in a networked environment.

The most striking finding refers to the unexpected result that in contrast to hypothesis 1a teams showing a tendency towards introversion achieved better results in most of the performance measures considered. Hypothesis 1a assumed that a tendency toward Extraversion in the team level would facilitate communication and coordination and, thus, task performance.
The reason why this was not observed could be due to the nature of the primary communication medium. Theory suggests that introverted individuals experience social inhibition in group settings with face to face communication, especially when interacting with extraverts who tend to dominate the process. Online text-chat, however, reduces social pressure and offers equal opportunities to all team members to contribute to collaboration. It appears plausible that voice-chat as a different mode of communication with higher degree of media richness might have generated different results, since extraverts tend to gain energy from rich interaction. However, experience from current operations suggests that responsiveness in a complex mission environment requires a high degree of parallel information processing which is much easier performed by text chat than voice chat.
Another reason for the observed superiority of teams with a tendency to introversion may be that introverts tend to analyse presented problems more precisely and concentrate on efficient communication as time was considered as a precious resource in a tactical situation.
These conclusions are reinforced by the observation that the described effects are even stronger for teams with a high degree of introversion homogeneity.

Regarding the dimension *Judgment / Perception* hypothesis 4a suggests that teams with a preference for Judgment achieve higher performance levels because they tend to act in an organized, purposeful, and determined manner. However, the observed results in the regression analyses point in the opposite direction favouring a preference of Perception over Judgment. Preference for Judgement involves the urge for early closure, i.e. the tendency to end information intake as soon as one is convinced to have observed enough to be able to make a reasonable decision. Thus, one may have difficulties in reassessing the situation when faced with new information in later rounds of the game.

In line with the empirical findings on the individual level hypothesis 5a suggested that teams with a tendency to believe that they are generally in control of the outcomes of their actions will achieve higher performance levels. The results support the assumption that this also applies at the team level.

Results also support hypotheses 7 and 8 in that they show significant positive effects of both social and task cohesion on team performance, for IRP even more than CRP. This may be explained by the fact that the lack of CRP requires teams to cooperate more closely and in a more task-oriented manner.

Beyond evidence on the tested hypotheses the team experiments revealed performance superiority of teams with a lower age average. At a first glance this finding is surprising as the team average age range of the sample varied only between 18.5 and 24.5 years. It suggests that due to the short innovation cycles in information technology even a small difference in age could make a significant difference in efficiently navigating in a networked environment.

Conclusions and Practical Implications

Even though it must be recognized that the sample available for this study is rather homogeneous, thus limiting the general validity of the findings, a number of key conclusions can be drawn from the quantitative analysis regarding the impact of individual and team characteristics on team performance in a networked environment.

- New types of communication media require that criteria for personnel selection be reviewed. Contrary to expectations, teams with a tendency toward extraversion (which represented the majority in the sample) do not communicate as efficiently as teams with a tendency toward introversion, given that online text chat will be the preferred communication medium for collaboration of networked teams. Current operational experience suggests that responsiveness in a complex mission environment requires a high degree of parallel of information processing which is much easier performed by text chat than voice chat preferred by extraverted teams.
- Complex and dynamic environments require cognitive flexibility. Teams with a preference for Perceiving performed better than teams with a preference for Judging. The implication for future C2 in networked environments is that cognitive flexibility in terms of staying open for new information and willingness to spontaneously adapt to changes in a complex and dynamic environment (i.e., preference for Perceiving) appears to be superior to the tendency to act in an organized and decisive manner and to reach conclusions early in the decision process (i.e., preference for Judging) which has been prioritized in traditional C2. Thus, in addition to a change in staffing policies, a major cultural change will be required to adapt to scenarios of the 21st century.
- Agile organizations imply flat hierarchies where decision competencies are delegated to self-organizing networked teams. This requires team members to display substantial degrees of action orientation which is fostered by a team's belief to be in control of the outcomes of their actions (high degree of internality). Although this belief is a generalized expectancy, it can to some extent be enhanced through the experience of one's own competence. A corresponding implication referring to training and leadership is to provide teams with an appropriate performance feedback and thus to support emergence of a sense of team efficacy.
- Social cohesion is a strong promoter of team performance. In our experiments this has been shown to be true even for randomly compiled "ad hoc" teams that were given hardly any preparation time. This implies that, from the very beginning of a team process, emergence of social cohesion is an invaluable asset for future performance and thus that bonding should be promoted by team leaders in a sensible way.
- Finally, the results stressed the significance of task cohesion for the team's performance. This points to the importance of shared commitment to the team goal and, more generally, to the super-ordinate mission purpose. The more future C2 relies on delegating decision competencies to "the edge" the more future staffing and training efforts need to focus on preparing team members not only for their tactical or operational task, but also on helping them to develop a sense of understanding of the strategic significance of the mission.

Future Research and Applications

It is recognized that the findings presented in this paper are merely one more piece in a jigsaw puzzle on the implications of human factors for command and control of networked operations. For one thing, they need further qualification on the basis of a qualitative evaluation of the collaboration behaviour captured by the numerous chat messages sent in the collaboration experiments. In addition, the research results raise a number of new questions important for multinational operations such as, for example, the impact of intercultural differences on collaboration in multinational teams and between teams of different nations. In addition, the question of whether and to which degree team collaboration is affected by mission-specific training and/or field experience of team members merits empirical research that requires, however, more or less seasoned test subjects and possibly a somewhat richer, and thus more complex task to be solved in future team experiments.

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