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Abstract

With a view to new operational and command and control concepts, modelling and analysis must explicitly account for human and organizational issues. Thus, knowledge of how and to what degree human and organizational issues affect joint decision making and collective action in and between teams is indispensable for assessing edge organizations in the context of network-centric operations.

This paper presents a research project aimed at closing some of the current knowledge gaps on these issues. For this purpose, an experimental approach is developed for testing hypotheses on the impact of individual and team characteristics and behaviours (ITCB) on the effectiveness of collaboration in network-centric operations. In particular, the authors discuss determinants and indicators of collaboration effectiveness, and tools to measure them, hypotheses on how ITCB variables affect collaboration effectiveness, and an experimental design for data collection. The proposed research will involve some 1350 students of the German Armed Forces officer schools as test subjects. Data collection is scheduled for late summer and autumn 2006.

In conclusion, aspects and criteria related to an effective composition of networked teams and for the selection of additional determinants to be explored by means of the proposed research design are discussed based on preliminary results.

Introduction

Collaboration has been defined as “working together for a common purpose” (Alberts, Gartska, Hayes & Signori, 2001). It is considered to be one of the key variables underlying the tenets of network-centric or network-enabled operations. When individual team members are spatially distributed and focused on accomplishing their specific tasks depending on their individual role responsibilities, they are hardly able to individually access all information required for developing consistent awareness and understanding of the situation and the task that has to be accomplished collectively. Very likely, mental representations may diverge, thus driving them to draw inappropriate conclusions and reach faulty decisions. Thus, it appears evident that individual team members need to share information that permits them to complement their information basis. However, while sharing information is a necessary prerequisite, it is not sufficient for team members to accomplish their collective task. Shared information needs to be translated into shared awareness of the situation at hand which, in turn, provides the basis for shared situational understanding (e.g. Artman, 2000) and shared mental models, both prerequisites of effective collective action in a given situation (Salas, Burke & Samman, 2001; Mathieu, Goodwin, Heffner, Salas & Cannon-Bowers, 2000).

However, this bottom-up process, of developing shared situational awareness and shared understanding and, finally, shared mental models, is not sufficient to explain the processes of team decision-making. Evolution of awareness, and subsequently understanding of what one has come to be aware of, are highly subjective processes. Thus, they are also informed top-down by the team members’ individual socialization, previous experiences, and mental models that have emerged from previous experiences. In other words, predispositions and the history of the individuals in a team and, therefore, the composition of teams, affect the likelihood of shared awareness, shared understanding, and shared mental models to emerge.

At the core of the research described here is the question as to what team composition supports the quality of collective decision-making and team performance. Individual characteristics that psychological research has found to be relevant for individual performance in non-C2 contexts, such as *locus of control, ambiguity tolerance, MBTI® personality structure* and *field dependence*, were selected to explore their potential effects on the team level in a C2 context. In addition, team-specific characteristics, i.e. *task cohesion* and *social cohesion,* are investigated with respect to their potential effects on team performance in C2, using a simple C2 simulation game. Findings provide the basis for the investigation of the effects of these characteristics on the performance of teams of different degrees of homogeneity.

Theoretical Background and Hypotheses

Team Performance

Conceptions of team performance are quite diverse and often difficult to compare. In a comprehensive meta-analysis summarizing the numerous approaches to measure team performance, Beal, Cohen, Burke & McLendon (2003) distinguish two basic dimensions, one referring to performance behaviour, the other one to performance as an outcome. Performance behaviour refers to actions or behaviours of team members that are relevant to the goal achievement. Performance as an outcome refers to the results of performance behaviours which may be measured in term of effectiveness and efficiency. Whereas effectiveness refers to the quality of outcomes, efficiency accounts for the resources (including time and effort) invested to achieve the outcome as reflected by the ratio of inputs to outputs. This taxonomy provides the framework for the following overview of team performance measures.

Measures of Performance Behaviour

Focused on actions during the collaborative decision making process, measures of performance behaviour are applied to evaluate "actions or behaviours relevant to the goals" of the team (Beal et al., 2003, p. 993). Performance behaviour includes unobservable cognitive behaviours and results thereof, such as statements or solutions produced by team members. A review of the relevant literature indicates that team performance is only rarely measured via behavioural constructs referring, for example, to social loafing, team learning, and information acquisition, to mention just the more promising ones (Boone, Van Olffen & Van Witteloostuijn, 2005; Hedlund, Ilgen & Hollenbeck, 1998).

Teamwork depends to a large extent on the individual team members' willingness to contribute to the team task. Karau & Hart (1998) found that, in contrast to high-cohesiveness teams, members of low-cohesiveness teams tend to engage in social loafing, a phenomenon that ultimately causes negative synergy, i.e. the quality of team results falls below the sum of individual team members' capacities. Similarly, task cohesion has been found to have beneficial effects on team performance behaviour (Zaccaro, Gualtieri & Minionis, 1995). It should be pointed out, however, that most research on the cohesion-performance relationship tends to focus on team performance as an outcome rather than performance behaviour.

Ellis, Hollenbeck, Ilgen, Porter, West & Moon (2003) stress the role of team learning during task accomplishment. Starting from a low level of competence due to lack of familiarity with the meaning of specified stimuli they came across while working on the task, team members could promote team learning by immediately sharing every piece of knowledge they had gained from their individual experience. Team learning during the task could be measured by aggregating the gains in effectiveness and efficiency of the team members' actions.

Information acquisition during the task is another measure indicating team performance behaviour (Boone et al., 2005; Hedlund et al., 1998). In turn, based on insights from the groupthink literature it may be concluded that insufficient information acquisition may lead to defective collective decision making (Leana, 1985), and ultimately to faulty decisions.

Measures of Effectiveness

As pointed out above, team performance outcomes refer to the results of performance behaviours measured in terms of effectiveness and/or efficiency. Team effectiveness refers to the "evaluation of the results of performance with no consideration of the costs of achieving the results" (Beal et al., 2003, p. 995). Numerous effectiveness measures for team performance can be found in the literature some of which appear especially appropriate for the study described here.

In command and control games or similar settings, team effectiveness has been measured by parameters such as the team's offensive and defensive scores during the game (Ellis et al., 2003), speed of operations (Moon, Hollenbeck, Humphrey, Ilgen, West, Ellis & Porter, 2004; Beersma, Hollenbeck, Humphrey, Moon, Conlon & Ilgen, 2003; Ellis et al., 2003), quantity of operations (Ellis et al., 2003), and quality of operations as reflected by variables such as frequency of friendly fire and rules of engagement errors (Beersma et al., 2003; Ellis et al., 2003). Team decision accuracy reflects the degree to which the team's decision fits the best solution that could have been achieved (Beersma et al., 2003; Hedlund et al., 1998; Hollenbeck, Colquitt, Ilgen, LePine & Hedlund, 1998; Mennecke & Valacich, 1998).

The number of information items acquired and shared in order to accomplish the task, such as task information on the impact of specified actions or competitive information on the adversary, may serve as a mediating variable of the relationship of team composition and team performance (Boone et al., 2005).

Measures of Efficiency

Team efficiency combines measures of effectiveness with measures of investments that have been made in order to accomplish a task. Beal et al. (2003, p. 995) suggest to define efficiency as "effectiveness of a group with some consideration of the cost of achieving that level of effectiveness". Efficiency measures tend to add value to the application of effectiveness measures since in practice tasks usually have to be accomplished on the basis of a limited pool of resources. Beal et al. (2003, p. 991) suggest to measure team performance via an efficiency measure rather than via effectiveness, assuming that "cohesive groups should be able to use their groups' resources more efficiently because they know the members of the group better and are motivated to complete the task successfully". However, in most studies effectiveness measures appear to be preferred over efficiency measures for the assessment of team performance (Stewart & Gosain, 2006; Beersma et al., 2003).

In command and control studies, measures of efficiency are important because of limitations of resources, especially of time, that characterize operational C2 processes. For locally distributed teams the efficiency of communication and the integration of information retrieved from different sources adds another dimension that tends to increase complexity. Thus, the efficiency with which information integration is managed in distributed teams is considered a crucial measure of team performance (Colquitt, LePine, Hollenbeck, Ilgen and Sheppard, 2002).

Measures of Team Performance in this Study

The measures to be applied depend on the nature of the team tasks that have to be accomplished and the research questions posed in a study. To investigate effects of team composition on group processes, measurement of the team members' performance behaviours may be most appropriate. For other studies, performance behaviour may rather be considered as mediating the effects of the team members' characteristics on the ultimate performance outcomes.

This study uses a computer supported networked operations simulation which requires the team members to detect and combat, within a given time and with limited material resources, targets hidden in a specified area. Thus, it appears appropriate to apply both measures of effectiveness and efficiency to represent team performance.

Parameters Affecting Team Performance

Empirical research suggests that team performance depends on a variety of individual-level phenomena such as characteristics, attitudes and behaviours of team members as well as on shared team-level constructs that emerge from individual-level phenomena through social interaction (Katz-Navon & Erez, 2005).

Individual Characteristics

Numerous studies suggest that individual characteristics are quite well explored with respect to their effects on team performance. However, whereas most of the research on team performance appears to be focused on demographic characteristics of team members (Boon et al., 2005), this study will address the question as to what degree personality traits of team members affect team performance.

An obvious determinant of team performance is *cognitive ability*, i.e., the capacity to understand complex ideas, to learn from experience, to reason and to adapt to the environment (Sternberg, 1997). The overall level of team members' cognitive abilities has been found to be positively related to both team learning (Ellis et al., 2003) and team performance (Barrick, Stewart, Neubert & Mount, 1998). However, a meta-analysis by Devine and Philips (2001) revealed stronger relationships between cognitive ability and team performance for laboratory than for field settings.

On the individual level, consistently positive relationships between *self-efficacy*, i.e., an individual's beliefs in their own capabilities to pursue a course of action to meet situational demands (Bandura, 1997), and performance were found (Judge & Bono, 2001). Whereas individual-level self-efficacy also turned out as predictive of individual performance in the team context under conditions of low task interdependence, the less frequently investigated construct of collective-efficacy was found to influence team performance only when a highly interdependent task required team members to closely interact and coordinate their efforts (Katz-Navon & Erez, 2005).

Several studies have investigated the role of the Big Five personality factors in team processes. The significance of emotional stability has been demonstrated through its positive effects on interpersonal performance (Barrick, Parks & Mount, 2005), collaboration quality (Porter, Hollenbeck, Ilgen, Ellis & West, 2003; Spector, Vance, Schneider & Hezlett, 2000), social cohesion (Van Vianen & De Dreu, 2001; Barrick et al., 1998) and – consistent with findings on the individual level that emotional stability is clearly positively related to job performance (Judge & Bono, 2001; Salgado, 1998) – this relationship appears to apply to the aggregate level as well (Barrick et al., 1998). Similar results were obtained for conscientiousness which appears to predict task cohesion (Van Vianen & De Dreu, 2001), collaboration quality (Porter et al., 2003), as well as team performance (English, Griffith & Steelman, 2004; Van Vianen & De Dreu, 2001; Barrick et al., 1998). Also, openness to experience was found to be positively related to interpersonal performance (Barrick et al., 2005; Spector et al., 2000), and team members who are more open to experience should find it easier in a computer-assisted team task to efficiently integrate verbal and computerized communication (Colquitt et al., 2002). Furthermore, high levels of team members' agreeableness are consistently found to positively contribute to team cohesion (Beersma et al., 2003) and team viability, i.e., the ability of team members to continue working together (Barrick et al., 1998), and cooperation (Porter et al., 2003; Ross, Rausch & Canada, 2003). Finally, extraversion was found to be positively related to task performance (Barrick et al., 2005), interpersonal performance (Barrick et al., 2005; Spector et al., 2000) and cooperation (Ross et al., 2003). Furthermore, the team's mean score in extraversion was found to be positively related to team cohesion and team viability (Beersma et al., 2003; Barrick et al., 1998; Van Vianen & De Dreu, 2001).

Apart from the team performance antecedents previously described, some influential human factors have been almost exclusively investigated on the individual level whereas little is known yet about their effects on the aggregate level. For this study, a number of apparently influential antecedents were selected to explore their relationships with team performance. These are locus of control, the personality dimensions underlying the MBTI® typology, ambiguity tolerance, and field dependence.

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 fates. 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.

A large body of research strongly suggests that there is a significantly positive relationship between the extent to which individuals describe themselves as having an internal locus of control and work attitudes such as motivation and satisfaction, performance behaviour such as absenteeism and displayed effort, and job performance (Judge & Bono, 2001; O'Brian, 1984; Spector, 1982). Furthermore, 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 (Boon et al., 2005; Lefcourt, 1982; Phares, 1976). The amount of information available in a team and the quality with which the team evaluates the information has in turn been shown to affect the quality of decisions made in the team (Boone et al., 2005), suggesting that an internal locus of control should be positively associated with team decision quality.

One may argue that what was found on the individual level should to some degree apply to the team level as well. The simplest and most often used approach to a team level measure is to take the average of the scores of the individual team members. In fact, in a management simulation study, Boon 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 a financial value in terms of return on equity. The study by Boon et al. (2005) 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. In particular, we propose to test two hypotheses referring to the team members' locus of control, the first of which deals with the team's mean score:

> *Hypothesis 1a: A team's internality, measured as the average of the individual team members' score of internal locus of control, is positively related with team performance.*

Even though the team's mean score is extensively used in most studies of team performance, this measure requires applicability of the additive aggregation model. In this study, this would imply that the team level locus of control is nothing more than a summation of the individual level locus of control scores, at the same time neglecting potential effects of the variance among the team members' locus of control scores. Therefore, it is intended to investigate in this study the general validity of the additive aggregation model for the internal locus of control scores in a command and control context. Chan (1998) suggests that team mean scores should predict team level outcomes only in case of low variance of the predicting variable. In fact, Boon et al. (2005) found support for this assumption in their management simulation

study in that homogeneous teams with high mean internality scores gathered more information and achieved better financial performance than teams with higher diversity of the team members' internality scores. Thus, one might assume that increasing the standard deviation of internality in a team with a high internality mean score by adding individuals with low internality scores would reduce the team's performance level. Conversely, increasing the standard deviation of internality in a team with a low internality mean score by adding individuals with high internality scores would increase the team's performance level. To put it differently, the effect of a team's internality mean score on team performance can be expected to depend on, or be moderated by, the team's diversity in internality.

Furthermore, a large body of evidence exists for the notion that high diversity in teams with respect to, among other variables, personality traits promotes destructive conflict within teams, which in turn tends to impair cohesiveness and, ultimately, team performance (e.g. De Dreu & Weingart, 2003; Jehn, Northcraft & Neale, 1999).

> *Hypothesis 1b: The standard deviation of a team's internal locus of control will moderate the positive effects of the team's internal locus of control mean score on team performance, i.e., the higher a team's standard deviation in the team members' internal locus of control scores, the lower will be the correlation between the team's internal locus of control mean score and team performance.*

MBTI® Personality Structure

Personality psychology knows quite a few theories that have become widely applied in human resource management practice. Among those most frequently used in research is the Big Five personality concept (Barrick & Mount, 1991) introduced earlier in this paper when the effects personality traits of team members – agreeableness, conscientiousness, emotional stability, openness to experience and extraversion – on team performance were discussed (see Barrick et al., 1998, 2005; Beersma et al., 2003; Colquitt et al., 2002; English et al., 2004; Porter et al., 2003; Ross et al., 2003; Van Vianen & De Dreu, 2001).

Another personality concept that is highly influential in human resource management and on which a widely used personality assessment instrument, the Myers-Briggs-Type indicator (MBTI®), is based, has however received less attention in research, especially with respect to team processes. Carl Gustav Jung (1921, 1971) developed the underlying typology which is based on the four dimensions *introversion–extraversion*, *sensing–intuition*, *thinking–feeling*, and *judging–perceiving*. Depending on the combination of an individual's dichotomized scores on each of these four dimensions, one of sixteen (2^4) personality types may be assigned to an individual. Thus, personality assessment based on this concept reveals categorical rather than continuous data. For purposes of research such as discussed in this paper, however, 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 (Thatcher & De La Cour, 2003; Myers, 1993).

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 acquire experiences through their senses, and focus on immediate experiences, facts and details from which awareness is being 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 (sensing versus intuition) preferences and team performance, one may argue that individuals oriented toward sensing should be able to react quite 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 possible 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. As previously mentioned, the team task used in this study deals with the detection of and appropriate reaction to targets located in a defined area and thus may be considered as quite well-defined and structured. Therefore, individuals who prefer the sensing perception mode should perform better on this kind of task.

> *Hypothesis 2a: A team's sensing tendency, measured as the average of the individual team members' scores in preference for the perception mode of sensing, will be positively related to team performance.*

Similar to the argumentation in regard to the effects of team mean score of locus of control on team performance, it appears reasonable to assume that the positive effect of the team's sensing tendency on team performance may decrease as the diversity of the team members' sensing tendencies increases.

> *Hypothesis 2b: A team's sensing standard deviation will moderate the positive effects of the team's sensing mean score on team performance, i.e., the higher the standard deviation in team members' sensing scores, the lower will be the correlation between the team's sensing mean score and team performance.*

Thinking (T) and *feeling (F)* are opposite styles of *judgment*. Thinking 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.

> *Hypothesis 3a: A team's thinking tendency, measured as the average of the individual team members' scores in preference for the judgment mode of thinking, will be positively related with team performance.*

Moderating effects of the team's diversity in thinking on this effect should also apply to the thinking mode of judgment.

> *Hypothesis 3b: A team's thinking standard deviation will moderate the positive effects of the team's thinking mean score on team performance, i.e. the higher the standard deviation in team members' thinking scores, the lower will be the correlation between the team's thinking mean score and team performance.*

The dimensions *perception* and *judgment* also represent opposites of another dimension, *orientation to the outer world*. Individuals who prefer the perceptive attitude (P) 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 (J) 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 appears reasonable to assume that individuals who prefer the judgment attitude will accomplish the task more effectively.

> *Hypothesis 4a: A team's tendency toward the judgment attitude, measured as the average of the individual team members' scores in preference for the judgment attitude, will be positively related with team performance.*

With regard to moderator effects of the team's diversity in the judgment attitude, we hypothesize the following:

> *Hypothesis 4b: A team's judgment standard deviation will moderate the positive effects of the team's judgment mean score on team performance, i.e. the higher the standard deviation in team members' judgment scores, the lower will be the correlation between the team's judgment mean score and team performance.*

The dimension of *introversion (I) versus extraversion (E)* plays a particularly central role in personality research. For example, it also represents one of the Big Five personality factors, and one of the two dimensions of the Eysenck personality concept (Eysenck & Eysenck, 1975). Introverted individuals tend to draw energy from the environment 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; Straus, 1996).

Since 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, extraverted team members should find it easier to accomplish this task because of their outside orientation and their preference for communication with others.

> *Hypothesis 5a: A team's mean score in extraversion will be positively related with team performance.*

Finally, a team's diversity in the dimension introversion – extraversion may moderate the relationship between the team's mean score in extraversion and team performance.

> *Hypothesis 5b: A team's extraversion standard deviation will moderate the positive effects of the team's extraversion mean score on team performance, i.e. the higher the standard deviation in team members' extraversion scores, the lower will be the correlation between the team's extraversion mean score and team performance.*

Ambiguity Tolerance

Uncertainty and ambiguity are increasingly becoming organizational reality as global defence and security conditions change and require adaptation of command and control concepts and organizational structures and processes such as edge organizations or networked operations. Although more flexible, these new structures and processes tend to be distinguished by increased complexity, and thus ambiguity, which agents will have to learn to adapt to (Huber & Eggenhofer, 2005). Individual differences in tolerance of ambiguous situations can be expected to affect reactions of individuals to such situations: Inspired by the pioneering work of Frenkel-Brunswik (1948), the concept of ambiguity tolerance (AT) has since then been investigated in various branches of psychology such as clinical, cognitive, educational, occupational, personality, and social psychology (Curley, Yates & Abrams, 1986). It "refers to the way an individual perceives and processes information about ambiguous situations or stimuli when confronted by unfamiliar, complex, or incongruent clues" (Furnham & Ribchester, 1995, p. 179). Individuals high in ambiguity tolerance tend to perceive ambiguous situations and stimuli as desirable, challenging, and interesting rather than to deny their complexity or incongruity whereas individuals low in ambiguity tolerance are considered to easily experience stress and to avoid ambiguous stimuli, including a tendency toward early selection and maintenance of one single solution in ambiguous situations. 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).

In the course of its research history, the concept has been found to be related to a large variety of cognitive, perceptual, and attitudinal human factors: Frenkel-Brunswick (1951) attributed ambiguity tolerance substantial influence on an individual's emotional and cognitive functioning, cognitive style, belief and attitude systems, interpersonal and social functioning, and problem solving behaviour. In regard to decision making styles, Rowe and Boulgarides (1992) report ambiguity tolerance to be positively related to analytical decision-making characterized by logical, abstract thinking and to the conceptual decision-making style described as broad, creative thinking. Contrarily, ambiguity tolerance appears to be negatively related to behavioural decision-making preference (supporting behaviour and empathy) and to the directive decision style, i.e. focused thinking and production of rapid results.

Although avoidance of ambiguity also appears to have relieving effects for individuals 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; Johanson, 2000; Furnham & Ribchester, 1995).

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 who are highly tolerant of ambiguity would be tempted to take high risks which may ultimately impair decision quality and performance. In a team context that requires team members to achieve joint decisions and coordinate their actions, this implies that the team members' mean score in ambiguity tolerance may be related to team performance in an inverted-U-shaped way.

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

As discussed for the previously described potential antecedents of team performance, i.e. locus of control, sensing–intuition, thinking–feeling, judging–perceiving and introversion–extraversion, a team's diversity in ambiguity tolerance may as well play an important moderating role in the relationship between ambiguity tolerance and team performance.

> *Hypothesis 6b: A team's standard deviation in ambiguity tolerance scores will moderate the effects of the team's ambiguity tolerance mean score on team performance, i.e. the higher the standard deviation in team members' ambiguity tolerance scores, the lower will be the curvilinear relationship between the team's ambiguity tolerance mean score and team performance.*

Field Dependence – Field Independence

Field dependence is a cognitive style characterized by the perceptual context, i.e. the field, strongly influencing an individual's perception of an object. In contrast, field-independent individuals have the propensity to differentiate perceptual and other experiences from their contexts (Colman, 2003) and thus more strongly focus their attention on a specified object appearing in the context. Although the perceptual style becomes particularly evident in visual perception, it applies to other perceptual aspects such as auditory perception, and to social perception as well. Field dependent individuals appear to be more interested in other individuals, more sensitive to social cues, more emotionally open and show a stronger tendency to reach consensus in conflicts, or even to resolve conflict in that they follow other people's opinions (Witkin & Goodenough, 1977).

Several interesting empirical findings show the discriminative effects of field dependence and suggest advantages of field-independent over field-dependent individuals. For example, field-independent individuals were found to perform better than field-dependent individuals in complex dynamics problems in that they more easily formed a clear map of motion (Wang, Wang & Ren, 2003). In a simulated shooting condition, field independent individuals performed better in describing a witnessed event (Vrij, Van der Steen & Koppelaar, 1995) which may be due to their lower tendency to become distracted by surrounding details. And a comparison of bomb-disposal experts and anti-terror operatives suggested that the former scored significantly higher on field independence than the latter (Glicksohn & Bozna, 2000), indicating selective effects of task-specific requirements.

The networked operations simulation game that will be used in this study requires team members to detect and combat hidden targets which may favour field-independent individuals. However, one may argue that integration of each individual's information into a shared picture requires the ability to consider individual details in their overall context and, thus, field-dependent individuals may be better able to perform this task so that in the end both field-independent and field-dependent styles may be effective in some respect. Thus, it may be hypothesized that

> *Hypothesis 7a: A team's mean score in field dependence will be related to team performance in an inverted-U-shaped way, i.e. teams with a medium mean level of field dependence will perform better than teams with a low or high mean level of field dependence.*

If both field-dependent and field-independent tendencies may be required for team effectiveness, diversity within a team may be functional because field-dependent and field-independent individuals may complement one another. Thus, a team's diversity with respect to field dependence is hypothesized to moderate the relationship described in hypothesis 7a in that positive effects of the team's mean score on team performance will be the higher the lower the team's diversity. For highly heterogeneous teams however, effects of the team's mean score may be less identifiable.

Hypothesis 7b: A team's standard deviation in field independence scores will moderate the effects of the team's field independence mean score on team performance, i.e. the higher the standard deviation in team members' field independence scores, the lower will be the correlation between the team's field independence mean score and team performance.

Team-specific Characteristics

Apart from individual team members' characteristics that may be aggregated to reflect some team-level measure which may in turn be investigated in regard to effects on team performance, a range of influential team-specific characteristics exist. These are primarily distinguished from the variables previously discussed in that they cannot be attributed to individuals. Instead, they only make sense when applied to the team level. Among the team-specific characteristics most frequently investigated in the team performance research stream 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 et al., 2003, 2005; Artman, 2000), reward structure (Beersma et al., 2003), role ambiguity (Eys & Carron, 2001), and tenure (Mennecke & Valacich, 1998).

Furthermore, the notion of diversity within a team has received particular attention. Research has identified distinct forms of diversity that appear to have distinguishable effects on team processes and performance. Generally, the relevant criteria are technical knowledge and skills, social category, and personality and values held by individuals, yielding three types of diversity, i.e. informational diversity, social category diversity, and value diversity (Jehn et al., 1999). In their comprehensive research, the authors found that diversity tends to cause conflict which in turn affects the team members' attitudes and behaviours as well as team performance. Specifically, informational diversity appears to stimulate task conflict which is generally considered as constructive and hence to be positively related to team performance. Social category diversity was reported to positively influence team member morale whereas value diversity increased relationship conflicts that is generally viewed as destructive, and thereby decreased the team members' satisfaction and commitment to the team (Jehn et al., 1999).

While certain levels of various types of diversity tend to yield various types of conflict, extremely low levels of diversity may promote cohesion among team members. Just as in the case of conflict, distinct types of cohesion may be distinguished. In their comprehensive meta-analysis, Beal et al. (2003) report three components of cohesion (see also Mullen & Copper, 1994): interpersonal attraction, group pride, and task commitment.

Interpersonal attraction (Mullen & Anthony, 1994) refers to the shared attachment to the other team members; group pride is the extent to which the team members like the ideologies represented by the team, or the shared importance of being a member of that team; task commitment represents the extent to which the team members experience a shared commitment to the team task. However, most studies on cohesion distinguish, if at all, two components: task cohesion and social cohesion (Chang & Bordia, 2001; Van Vianen & De Dreu, 2001; Widmeyer, Brawley & Carron, 1985). Adopting this distinction for this study, several findings in regard to the relationship between cohesion and team performance are briefly reviewed to provide the theoretical background for subsequent hypothesizing.

Research on the expected positive effects of team cohesion on team performance is ample and strongly supports the notion of this relationship to be mediated by shared situational awareness. This concept may be defined as "the sharing of a common perspective between two or more individuals regarding current environmental events, their meaning and projected future" (Wellens, 1993, p. 272). Artman adds that the involved agents actively construct a model of the situation which is however only "partly shared and partly distributed" and which enables them to "anticipate important future states in the near future" (2000, p. 1113). Furthermore, shared situational awareness is closely linked to shared understanding (Salas,

Prince, Baker & Shrestha, 1995) and serves as a prerequisite of the quality of a team's decision (Artman, 2000). Also, it should be mentioned that shared situational awareness is related to shared mental models (Cannon-Bowers, Salas & Converse, 1993). These "include the team members' models of the coordinating routines and knowledge within the team, while SA [situation awareness] is the conception of the situation 'out there', here the battle field" (Artman, 2000, p. 1113). According to the literature on the distinct components of cohesion, task cohesion and social cohesion may also exert somewhat different influences on teams.

Social Cohesion

Social cohesion has been shown to particularly promote system viability which means that members of socially cohesive teams reported that they enjoyed working with other team members and were positive about coming back to work with their original team on a different task in the future (Chang & Bordia, 2001). However, an extremely high level of social cohesion in a team bears the risk of groupthink to emerge (Janis, 1982). This phenomenon is characterized by exceptionally strong group norms to avoid conflict and preserve consensus and harmony 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) and perhaps even disastrous effects (e.g. Choi & Kim, 1999; Moorehead, Ference & Neck, 1991; Leana, 1985). Accordingly, one may hypothesize that a medium level of social cohesion should yield the most favourable effects on team performance.

> *Hypothesis 8: The level of social cohesion in a team will be related to team performance in an inverted-U-shaped way, i.e. a medium level of social cohesion will yield higher team performance than will a low or a high level.*

Task Cohesion

Task cohesion was found to be an even better predictor of team performance than social cohesion (Chang & Bordia, 2001; Mullen & Copper, 1994). In regard to distinct concepts of team performance, Beal et al. (2003) indicate that cohesion is more closely linked to performance behaviours that to performance outcomes. As far as their suggested distinction between performance measures of effectiveness and measures of efficiency is concerned, they indicate that cohesion may be more closely related to efficiency measures since cohesion motivates team members to complete the team task successfully and thus enables them to use their resources more efficiently. These findings on effects of task cohesion on team performance lead to the following hypotheses.

> *Hypothesis 9a: A team's level of task cohesion is positively related to team performance, measured as efficiency.*

> *Hypothesis 9b: The effect described in hypothesis 9a will be stronger for measures of efficiency than for measures of effectiveness.*

The Research Design and Program of Work

The research design for testing the collaboration hypotheses is outlined in Figure 1. It is basically an iterative process comprising four principal activities:

- Proposal and modification of collaboration hypotheses specifying the relationship between determinants and results of team performance;
- Data collection involving
  - a survey to measure, by means of appropriate scores, the independent variables describing the collaboration-relevant individual characteristics as a basis for establishing the corresponding characteristics of the teams in terms of the means and variances of the individual scores of team members;
  - collaboration experiments involving teams of five test subjects tasked to cooperatively plan and implement task-oriented action plans in a simulation experiment measuring the output of team collaboration in terms of task performance parameters as a basis for assessing the degree of collaboration in each of the test teams;
- Data analysis comprising explorative analyses of the collected input and output data to determine team characteristics and the degrees of collaboration that the test teams were able to accomplish, and testing, in an iterative manner, the hypotheses in the light of the results of data analysis;
- The findings will provide information on whether or not the data support the proposed hypotheses, what the significance of the independent variables is for team performance, and whether the research design is adequate or requires modification and refinement.

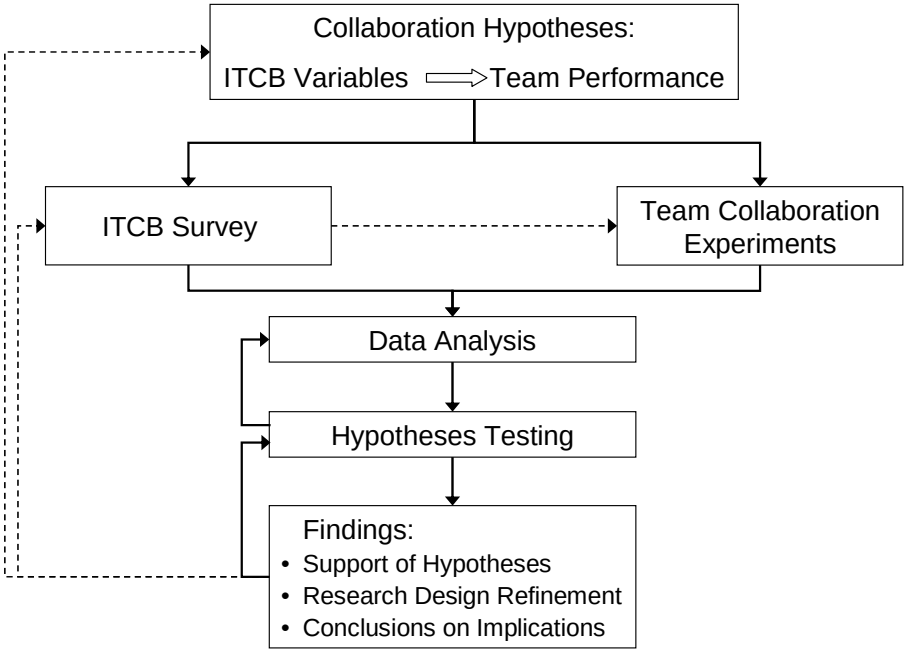

Figure 1: Research Design

It should be noted, however, that iterations symbolized by dashed arrows will not be exercised in this first investigation of team cooperation hypotheses as discussed in the previous chapter. Due to the limited availability of test subjects an essentially consecutive approach has to be

followed that also precludes the composition of teams based on the evaluation of the individual characteristics of team members.[1]

The program of work features four steps (for more details see Annex 1):

- Step 1 (Preparation): Literature research; identification of measures for independent variables (individual and team-specific characteristics) and dependent variables (measures of effectiveness and efficiency of team performance); development of the research design (largely completed);
- Step 2 (Pre-investigation): Test runs with a small sample of test subjects; collection of feedback from the test subjects; if necessary, refinement of the measures and/or research design (under preparation at the time this paper is submitted, completed by the time it will be presented);
- Step 3 (Data collection): Data collection, involving approximately 1350 test subjects recruited from the officer candidate schools of the German Federal Armed Forces (ongoing by the time the paper is presented);
- Step 4 (Evaluation): Hypothesis testing and documentation of research results, including preparation of the final report and of research papers.

The test sample in step 2 will involve approximately 50 officer candidates and junior officers of all three services currently in their third year of academic training at the Universität der Bundeswehr München.

Data collection will take place between July and November 2006 depending on the availability of test subjects at the officer schools. In each case, data collection involves an initial introduction of the test subjects to the purpose and organization of the data collection, followed by a survey to measure the independent variables and team simulation experiments to measure the dependent variables.

After the teams have been composed, participants will be introduced to the networked operations simulation game as the tool for measuring team performance. Immediately thereafter, the five spatially separated members of each team will be interconnected by local networks to play the simulation game during which team performance measures are taken and documented. This step will be followed by manipulation checks for the experimentally set conditions of social and task cohesion, using appropriate surveys.

ITCB Survey: Measuring the Independent Variables

The independent variables affecting team cooperation include both individual-level variables (individual characteristics as well as specific attitudes on a controversial topic which are expected to reflect their private beliefs and values) and team-specific variables referring to characteristics and attitudes of teams. While most of the team-specific variables may be measured in terms of aggregations of the values of individual-level variables of the team members, variables describing team characteristics such as *social cohesion* and *task cohesion* that develop gradually as team members get to know each other and each other's needs and preferences (e.g. Beal et al., 2003; Artman, 2000) may not be measured directly as the teams in this study are created ad hoc for the collaboration experiments. Thus, it was decided to manipulate them by setting the respective experimental conditions through a combination of three levels of social cohesion and two levels of task cohesion as shown in this table.

[1] Since each of the five classes at the German officer schools will only be available for three consecutive days, data collection will start with the survey involving all members of a class for about 3 hours to fill in a series of questionnaires, immediately followed by the 2-3 hour collaboration experiments involving five members each, distributed over 2.5 days.

	High task cohesion	Low task cohesion
High social cohesion	High social cohesion and high task cohesion	High social cohesion and low task cohesion
Medium level social cohesion	Medium level social cohesion and high task cohesion	Medium level social cohesion and low task cohesion
Low social cohesion	Low social cohesion and high task cohesion	Low social cohesion and low task cohesion

Table 1: Experimental conditions of task and social cohesion

The manipulations involve instructions given to the teams composed for the simulation experiments depending on which of the six experimental conditions is assigned to them. To set the experimental conditions, the following instructions are given to teams:

- *High social cohesion:* Test subjects know the names of their fellow team members and are told that the scores, on the individual characteristics and the attitudes surveys, of all members of their team were very similar, i.e., all team members share very similar personality traits, attitudes and preferences.
- *Medium level of social cohesion*: Test subjects are not told the names of their fellow team members, and they are not allowed to request this information from them during the simulation. They are given no information on the results of the individual characteristics and the attitudes surveys.
- *Low social cohesion:* Test subjects are not told the names of their fellow team members, and they are not allowed to request this information from them during the simulation. They are informed that the scores, on the individual characteristics and the attitudes surveys, of all members of their team, were very dissimilar, i.e. all team members have very dissimilar personality traits, attitudes and preferences.
- *High task cohesion*: Test subjects are told that comparable teams having played the game were able to accomplish the task within a certain (extremely short) time and scored a certain (very high) number of hits. Thus, a very challenging goal will be set for the teams.
- *Low task cohesion:* Test subjects are not given any information on the performance of referent teams, or on expected performance levels. Test instructors give them the impression to not have much personal interest in the experiments.

This manipulation is validated by comparison with specific cohesion indices determined, as described below, based on a modification the model of Karau & Hart (1998) who created three items asking participants about their perceptions of their fellow team members.

Locus of Control

Locus of control will be 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 of .69 - .76 (Furnham & Steele, 1993). Respondents choose between an internal and an external control alternative for each item. The total score is built by summing the number of external control alternatives chosen by the respondent. Two team-level measures will be used: the team members' mean score (average external 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).

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 seems to show good validity of the predicted four factor structure and construct validity supported by factor analysis (Hammer, 1996).

Tolerance of Ambiguity

Tolerance of ambiguity will be measured with a German translation of an instrument developed out of a selection of 27 items from the MAT-50 (Norton, 1975) which is reported to have an internal consistency (average item inter-correlation) of .89 (Furnham & Ribchester, 1995) and 6 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 will be required to be rated on a 6-point Likert scale (1=not at all agree; 6 =strongly agree).

Field Dependence – Independence

Field dependence will be measured with a German version (Schmidtke & Schaller, 2006) of the Group Embedded Figures Test (Witkin, Oltman, Raskin & Karp, 1971). In 18 test figures, simple figures, each embedded within complex figures, have to be located by the test subjects. After a practice stage involving seven figures, two sections of nine figures each have to be completed within a given time. The total number of correct answers on these two sections is the performance measure ranging from zero to 18. The German version is reported to have internal consistency scores between .82 and .87 (Schmidtke & Schaller, 2006).

Social Cohesion

Social cohesion will be measured with four items three of which were reproduced from Karau & 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 asks how much they felt integrated into the team. Answers will be rated on a 6-point Likert-type rating scale (1=not at all agree; 6 =strongly agree).

Task Cohesion

Task cohesion will be measured with four items adopted from Carless & 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 will again be rated on a 6-point Likert-type rating scale (1=not at all agree; 6 =strongly agree).

Control Variables

The variables considered as potential moderators of the relationships between the independent variables and team performance are the availability of different communication means, the gender composition of the teams and the cognitive abilities of team members.

The amount of communication between team members is considered to be indicative of cooperation. However, it may be assumed that the amount of communication depends on whether or not a shared situational picture is available.

The teams' gender composition is considered a potentially influential variable moderating the relationships between individual characteristics and performance. Gender composition in a team is indicated by number code.

Furthermore, cognitive ability of team members is 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, three 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), number aptitude (“facility with numerical and quantitative operations”, Reber & Reber, 2001, p. 474) and reasoning (”cognitive processing directed at finding solutions to problems by applying formal rules of logic or some other rational procedure”; Colman, 2003, p. 620). Internal consistency scores are reported to vary between .87 and .96 (Cronbach Alpha).

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**a**me **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) have to solve a common task, whereas 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 results picture (CRP). In each simulation experiment, the objective of the task is to locate and subsequently strike at a number of targets randomly distributed over a rectangular area divided into cells of equal size (Figure 2). Each player owns a specific sensor portfolio that he 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 the results raise the need for communication and cooperation within the team to obtain the best possible reconnaissance (recce) picture and shared situational awareness of the target locations.

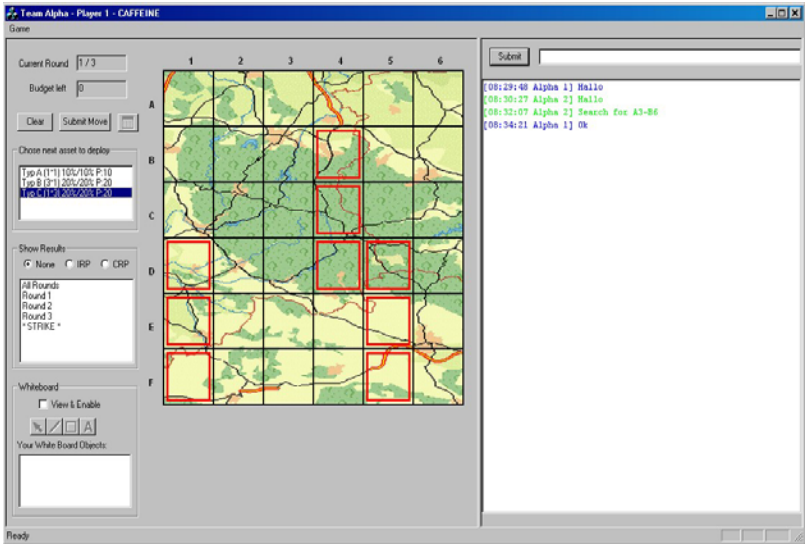

Figure 2. *CAFFEINE* Screenshot

At the end of the game, team performance is assessed based on the data generated by the game. This may be done as the basis of a score calculated as the weighted sum of relevant game outputs. The current version of the software provides a variety of parameters and options for defining the test scenario that will be further evaluated during the study with a view to its use and impact on team behaviour. The logged team actions and the final results offer various ways to define performance measures and evaluate the manner in which the teams

reached the given objectives such as, e.g., shared situational awareness. For example, Stahl and Loughran (2002) measured the degree of shared situational awareness in terms of the ratio of the number of cells commonly designated by all players as containing targets to the total number of recommended target cells. In other words, full shared situational awareness requires that all players recommend the same cells as target cells. However, whether this ratio or combinations of other variables imply appropriate measures for the degree of shared awareness will be one of the questions that the proposed research will attempt to answer.

In measuring collaboration, both team effectiveness and team efficiency need to be measured. To this end, the following data are available from each game:

- number of targets killed (*hit*)
- number of missing shots(*miss*)
- number of chat messages sent (*ChatMsg*)
- number of whiteboard messages sent (*WBMsg*)
- total time consumed to complete the task (*time*)
- total budget invested (*budget*)
- total numbers of shots fired.

Effectiveness may be measured in terms of hits and failures as well as by a combined measure representing the degree of shared situational awareness. Efficiency will be measured in terms of a function combining effectiveness measures with parameters measuring the consumption of resources such as time, recce budget, number of shots, and extent of communication required to achieve the goal. Designed to illustrate the value of sharing information as part of an introduction to the principles of network-based operations, the current version of *CAFFEINE* measures team performance in terms of a Weighted Total Score (WTS) with factors $f_i > 0$, i = 1,…,6.

$$WTS = f_1 * hit - f_2 * miss - f_3 * time - f_6 * budget - f_4 * ChatMsg - f_5 * WBMsg + bonus$$ [2]

In order to provide a background against which to compare different measures of team collaboration, each team member will be asked at the end of the collaboration experiment for a personal assessment of the quality of collaboration in his team.

Test Sample

The test sample will include approximately 1350 subjects available in 2006 from the students at the officer schools of the German Army (700), Air Force (350), and Navy (300). Because of the rather different training schedules and curricula of the three service branches, the military background of the test subjects varies considerably. The Army officer candidates are in their third year of service, having been trained as squad and platoon leaders for two years and subsequently serving in leadership positions. Air Force and Navy candidates are in their first year of service (Air Force: 3-4 months; Navy: 1 month) and thus have had little military training and hardly any leadership experience. Further details on this issue are given in the subsequent section *Research Setting, Procedures, and Data Collection.*

Exact data on the composition of the sample will only be available at the time of data collection. Typically, however, the majority of Air Force and Navy test subjects entered service directly after graduation from secondary schools[3]. The remainder has seen prior military service either as conscripts or NCO candidates qualifying for officer training. Due to the differences in the training systems mentioned above, the Army test subjects have a more

[2] A bonus is given if each target was engaged at least once.

[3] Secondary school education at a German “Gymnasium” lasts 8-9 years at the end of which students have to pass a comprehensive final exam (Abitur) for graduation. The level of education associated with the “Abitur” corresponds approximately to a second year (sophomore) college level in the U.S. system.

extensive military service background including about three to nine months of leadership experience.

Data Analysis and some Implications of Expected Results

The detailed procedures for data analysis will be selected depending on the quality and quantity of the data collected. Data analysis will include the generation of the descriptive data (distribution, means and variances), exploration of interdependencies between variables (inter-correlations), and multiple regression analyses.

The independent variables locus of control, ambiguity tolerance, MBTI® personality structure, and field dependence, and the control variable cognitive ability, are primarily represented by team mean scores. Standard deviation scores, indicating team heterogeneity, are expected to serve as moderators of the relationships between team mean scores and measures of team effectiveness and efficiency. The artificially created experimental conditions of social cohesion and task cohesion, as well as the control variable gender composition are included into the regression analyses as well. However, as they only exist on the group level, they do not yield any within-group variance measures.

It has become generally accepted that collaboration, and thus co-operability, is a key factor for successful Network Centric Operations. Co-operability refers to both technical and human prerequisites of collaboration. However, in contrast to the technical aspects captured by the term interoperability, the role of human factors has only recently received closer attention as the nature of military operations has changed from high intensity conflicts involving massive concentration of forces to increasingly asymmetric confrontations in which small team and individual actions count.[4]

While little empirical research has been done on the impact of human characteristics and behaviours on the effectiveness of military operations, research in non-military contexts has generated some significant findings that may be of relevance in military contexts as well. For example, ambiguity tolerance has been found to be related to analytic thinking (Rowe & Boulgarides, 1992) and risk taking (Lauriola & Levin, 2001), a team's average locus of control influences the amount of information shared among the team members (Boone et al., 2005), social cohesion promotes system viability (Chang & Bordia, 2001), and task cohesion is positively related to team performance (Beal et al., 2003). Team heterogeneity should make a difference as well (e.g. Boone et al., 2005; Bradley & Hebert, 1997). One may argue that a reasonable balance among team members with respect to a specific personality structure, e.g. a balance between sensing and intuitive, thinking and feeling, and judging and perceiving individuals, may be key to team tasks, but presumably for more complex tasks rather than for simple tasks (Kroeger & Thuesen, 1992). The lower task complexity is, the more may diversity tend to impair team performance.

Some of the hypotheses to be tested in this study build on these findings and link them to command and control. The results of the ongoing study effort promise to significantly contribute to knowledge about the role of human factors and aspects of personality and team structure with regard to team effectiveness in command and control. In addition, the results of this study are meant to provide the basis for subsequent rounds of experimentation aimed at exploring the influence of training, field experience and cultural background on the relationships between individual and team characteristics and behaviours and team

[4] The importance of human and organizational behaviour has been emphasised in the NATO Code Of Best Practice for C^2 Assessment (revised 2002 to account for non-traditional operations such as in smaller scale conflicts and Operations Other Than War) and in the NATO follow-on study on *New Command and Control Capabilities* (submitted January 2006) showing the significance of human characteristics and behaviours for concepts such as shared situational awareness and shared situational understanding. Nevertheless, empirical research on the impact of human characteristics and behaviours on the effectiveness of military operations is still scarce.

performance. The expected insights will help to improve ongoing transformation processes by enhancing common doctrine development and experimentation, common training, and team composition.

Limitations

While a detailed discussion of limitations of research results has to wait until the results are available, some preliminary observations may be made on potential limitations resulting from the selection of independent variables considered as influential for team cooperation and the research design, especially the relative simplicity of the team cooperation experiment.

The results regarding the relationships between independent and dependent variables, or input and output variables, may be distorted because of interdependencies between input variables. The degree to which such interdependencies can be measured by means of appropriate statistical procedures is limited and depends on the number of variables considered. A relevant interpretation of results may only be possible for a small number of independent variables. Due to the limited timely availability of test subjects, an essentially non-iterative approach has to be followed that also precludes the composition of teams based on the evaluation of the individual characteristics of team members. Thus, there may be too few teams dominated by certain individual characteristics to support, based on comparative data analysis, conclusions regarding the relative importance of individual and team characteristics for collaboration in teams.

Another limitation of results may be due to the fact that the research design does not permit to directly measure task cohesion and social cohesion of teams as the teams are composed by the researchers immediately prior to the cooperation experiment. Conditions of low, medium and high team cohesion are artificially created by means of specified information and instructions given to the teams. Matching these conditions with the ex-post assessment of cohesion, based on the perceptions of team members about the quality of cooperation during the experiment, may provide some, if not conclusive, insights as to whether the strategy of manipulating the test environment was successful or not.

Finally, as the proposed research is conducted in a “laboratory” environment involving, for sake of complexity reduction, a fairly simple task for measuring cooperation, the question as to the external validity of results may be raised, i.e., to what extent the results do apply to a real world environment. It is well known that a laboratory environment tends to suppress effects of a range of influencing factors that would normally interfere with the research objects and thus considerably increase complexity. Therefore, the research results should not be considered as readily applicable to real world environments, but rather as a contribution to the development of a data base for developing team cooperation models that need to be further tested outside the laboratory. Besides, a follow-on series of experiments is recommended to investigate, among others, the question of how task complexity affects team performance.

Future Applications and Research

Even though the research presented here promises important contributions to the current knowledge on the role of human factors for team performance in command and control, its results are merely one more piece in a jigsaw puzzle. In fact, the expected findings may raise a number of new questions and may bring additional determinants of team collaboration to the fore. This may be true for concepts of team performance measurement as well.

Also, it should be remembered that, in addition to providing insights as to which individual characteristics matter for team performance, the project also is meant to test the suitability of the research design for an extended research agenda that addresses 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 the team experiments. To this end, the results of the experiments on the impact of complexity on team collaboration mentioned above should be available.

Conclusions

No definite conclusions can be drawn given the stage of the research project at the time when this paper is submitted. However, it is safe to say that its results will contribute to the evolution of empirical knowledge on how individual and team characteristics affect team performance especially with a view to network-enabled capabilities (NEC). The formal simplicity of the research design notwithstanding, the results will contribute to the development of a data base required for implementing conceptual collaboration models for further testing in exercises conducted in an environment that reflects work conditions and realistic team tasks in the context of network-based operations. After all, the proposed research involves but one, albeit basic, set of experiments in a campaign of experimentation (see Alberts & Hayes, 2005) to test NEC concepts with a view to human and organizational issues and constraints.

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Annex

Project schedule, activities, milestones and deliverables

Step	Activities	Deliverables
Step 1: Preparation (January – March 2006)	- Identification of appropriate measures for independent variables (individual and team-specific characteristics) - Identification of appropriate measures for dependent variables (measures of effectiveness and efficiency of team performance) - Development of the research design	- Measures and methodology to assess the independent variables - Measures and methodology to assess the dependent variables - (Preliminary) research design
Step 2: Pre-Investigation (March – June 2006)	- Pre-test data collection from a small test sample - Collection of feedback from test subjects - Evaluation and, if necessary, refinement of the measures and/or the research design	- Pre-investigation report - Final research design
Step 3: Data Collection (July – Nov. 2006)	- Collection of data on input variables - Collection of data on output variables	- Data base for evaluation
Step 4: Evaluation (Nov. 2006 – Jan. 2007)	- Generation of statistics - Test of hypotheses - Discussion of results - Draft of the final report	- Final report