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## **Team Modelling: Literature Review**

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PWGSC Contract No.: W7711-047911/001/TOR; Call-up 7911-04

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## **Defence Research and Development Canada - Toronto**

Defence R&D Canada – Toronto Contract Report DRDC CR 2006-091

August 2006



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# Abstract

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Increasingly, Canadian Forces operations require the use of highly complex teams that function in joint, interagency, and often distributed environments. This report is a literature review of scientific and military research pertaining to team performance.

This review consists of three sections. First, the factors influencing team performance are explored, and three major sets of factors are considered in relation to team performance: team factors, task factors, and team processes. Although very large, the team performance research has generally not built progressively upon previous work and illustrates equivocal results. Nonetheless, it is clear that characteristics of the team, the task, and team processes are all important influences on team performance. However, exactly how each of these factors influences team performance is often dependent on other factors. Moreover, the majority of the existing team research is limited in that it has not generally been conducted in realistic settings. The second section addresses measures of team performance, considers the conceptual challenges of measuring team performance, and explores specific measures of team processes and outcomes. The final section reviews some conceptual and computational models of team performance. Although models have generally not been subject to extensive validation efforts, they provide confirmation of the factors that are prominent throughout the team literature. The review ends with a short overview of the literature, and recommendations for a program of team research. Specifically, the existing team literature is inadequate with respect to understanding distributed teams consisting of people from diverse backgrounds and experience. Moreover, as teams of the future are also likely to be increasingly complex, more understanding of how heterogeneous teams as well as an entire team of teams will function in distributed, joint, and interagency environments will be critical.

## Résumé

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De plus en plus, les opérations des Forces canadiennes nécessitent le recours à des équipes très complexes qui fonctionnent dans des contextes interarmées, interagences et souvent décentralisés. Le présent rapport passe en revue les résultats d'études scientifiques et militaires consacrées au rendement des équipes.

Le rapport comprend trois sections. Premièrement, il explore les facteurs qui influent sur le rendement des équipes et il détaille trois grands ensembles de facteurs : facteurs liés à l'équipe, facteurs liés à la tâche et facteurs liés aux processus d'équipe. Malgré son ampleur, la recherche sur le rendement des équipes n'exploite généralement pas les travaux antérieurs et donne des résultats équivoques. Quoi qu'il en soit, il est clair que les caractéristiques de l'équipe, de la tâche et des processus d'équipe influent sur le rendement des équipes. L'effet précis de chacun de ces facteurs sur le rendement de l'équipe est souvent tributaire d'autres facteurs. Par ailleurs, la majorité des études actuelles sur les équipes sont limitées en ce sens qu'elles ne sont généralement pas menées dans des contextes réalistes. Deuxièmement, le rapport traite de la mesure du rendement des équipes, examine les défis conceptuels liés à la détermination de ces mesures et explore des mesures précises applicables aux processus et aux résultats. La troisième section du rapport est consacrée à certains modèles conceptuels et informatiques de rendement des équipes. Même si les modèles n'ont généralement pas fait l'objet de vastes travaux de validation, ils confirment l'importance des principaux facteurs mentionnés dans la documentation. Le rapport se termine par un bref aperçu de la documentation et la formulation de recommandations concernant un programme de recherche sur les équipes. Plus précisément, il conclut que la documentation actuelle sur les équipes est inadéquate pour ce qui est de comprendre le fonctionnement des équipes décentralisées formées de personnes d'horizons variés. En outre, comme les équipes de l'avenir seront sans doute de plus en plus complexes, il sera essentiel de mieux comprendre comment des équipes hétérogènes ou des équipes formées de plusieurs équipes fonctionneront dans des contextes décentralisés, interarmées et interagences.

## Executive Summary

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This report reviews the literature on team performance obtained via a systematic keyword search for the relevant scientific and military research. The purposes of this review were to explore the factors that influence team performance, review existing measures of team performance and effectiveness, and evaluate models of team performance.

The search of the relevant behavioural sciences, military, and business databases generated approximately 200 titles and abstracts. Of these, 80 articles were determined to be of primary importance and were reviewed in detail.

The literature review suggested that a team can be defined as two or more people who must interact in order to accomplish a goal or complete a task (Salas, Dickinson, Converse, & Tannenbaum, 1992). The literature review indicated three sets of factors that influence team performance. These include team factors such as size and history, task factors such as complexity and workload, and team processes such as mental models, communication, and coordination. Unfortunately, very few studies accessed for this review directly addressed joint military teams that worked in distributed environments. Nonetheless, considerable research has accumulated about diverse teams, and some research has focused on distributed rather than co-located teams. Moreover, a wide body of other research has addressed relevant team characteristics and processes. Although there was some disparity among researchers and findings, the literature showed implicit agreement that team processes make the most important contribution to team performance.

With regard to measures of team performance, the literature showed that the current state of team performance and effectiveness measures is relatively disjointed and researchers have not built on previous work. This has resulted in a large volume of inconsistent measures, each addressing specific factors, but generally lacking validation efforts.

Finally, the literature yielded many models of team performance, but no established model although there is often little substantive difference from one model to the next. Moreover, existing models may contain a variety of weaknesses. Conceptual models are becoming more elaborate and complex, but efforts toward validating them are sparse. In contrast, mathematical and computational models tend to be rather narrow in that they focus on relatively specific aspects of team performance. However, a recently developed groupware model may be most applicable to the complex distributed teams that are of interest to the Canadian Forces.

Overall, the literature review indicated that the existing team performance research is still in a relatively early stage of development, and that considerable work is still required toward elucidating this complex topic. The report concludes that four areas of future team research are particularly germane to the needs of the Canadian Forces.

- Diversity within teams: The rising number of joint, interagency, or multinational operations suggests a need to explore the impact of different organizational cultures, ethnicities, and ethos on team performance.



- Distributed teams: Future research needs to focus on the differences in team performance between co-located and geographically distributed teams. In particular, research needs to explore how leaders perform in distributed contexts.
- True teams and military participants: The bulk of current research employs university undergraduate participants arbitrarily grouped into *ad hoc* teams. In order to extrapolate directly to a military population, military participants should be studied.
- Teams of teams: Interdependence within multi-team systems is an important subject for the Canadian Forces. In particular, conflicting demands between a sub-team's goals and overall team objectives have implications for network-enabled military operations.

# Sommaire

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Le présent rapport porte sur la documentation consacrée au rendement des équipes, réunie grâce à une recherche systématique par mots clés pour repérer les travaux scientifiques et militaires pertinents. Cet examen visait à explorer les facteurs influant sur le rendement des équipes, à examiner les mesures actuelles du rendement et de l'efficacité des équipes et à évaluer des modèles de rendement applicables aux équipes.

La recherche menée dans les bases de données pertinentes des sciences du comportement, du domaine militaire et du monde des affaires a produit quelque 200 titres et résumés. De ce nombre, 80 articles ont été jugés d'importance primordiale et examinés en détail.

L'analyse documentaire indique qu'une équipe peut être définie comme étant formée d'au moins deux personnes qui doivent collaborer afin d'atteindre un but ou d'effectuer une tâche (Salas, Dickinson, Converse et Tannenbaum, 1992). Elle dégage trois ensembles de facteurs qui influent sur le rendement d'une équipe, soit les facteurs liés à l'équipe, dont la taille et l'historique, les facteurs liés à la tâche, dont la complexité et la charge de travail, et les processus utilisés par l'équipe, notamment les modèles mentaux, la communication et la coordination. Malheureusement, parmi les études consultées pour la présente analyse, très peu s'intéressent directement aux équipes militaires interarmées qui œuvrent dans des contextes décentralisés. Quoiqu'il en soit, un nombre considérable d'études a été consacré à des équipes diversifiées, dont certaines mettent l'accent sur des équipes décentralisées plutôt que coimplantées. Par ailleurs, un vaste corpus de recherches examine des caractéristiques et des processus d'équipe pertinents. Malgré quelques disparités entre les chercheurs et les constatations, la documentation témoigne d'un accord implicite sur le fait que les processus d'équipe sont le principal facteur influant sur le rendement des équipes.

Pour ce qui est des mesures du rendement des équipes, la documentation montre qu'actuellement, les mesures du rendement et de l'efficacité des équipes sont relativement disparates et que les chercheurs n'ont pas exploité les travaux antérieurs. En conséquence, il existe une grande diversité de mesures incohérentes, chacune portant sur des facteurs spécifiques, mais on constate l'absence généralisée d'efforts de validation.

Finalement, la documentation propose de nombreux modèles applicables au rendement des équipes, mais aucun modèle unifié ou normalisé, même s'il existe souvent peu de différences notables entre les modèles. De plus, les modèles existants présentent diverses faiblesses. Les modèles conceptuels sont de plus en plus complexes, mais les efforts pour les valider demeurent rares. Par contre, les modèles mathématiques et informatiques sont en général plutôt étroits et portent sur des aspects relativement spécifiques du rendement des équipes. Un modèle de logiciel de groupe récemment mis au point pourrait toutefois s'appliquer en particulier aux équipes décentralisées complexes qui intéressent les Forces canadiennes.

Dans l'ensemble, l'analyse documentaire indique que les travaux de recherche qui s'intéressent aux équipes en sont encore aux premières étapes du développement et qu'il faudra y consacrer des efforts considérables pour mieux comprendre ce sujet complexe. Le rapport indique que quatre secteurs de recherche sur les équipes semblent particulièrement prometteurs, compte tenu des besoins des Forces canadiennes.

- Diversité des équipes : le nombre croissant d'opérations interarmées, interagences ou multinationales semble indiquer la nécessité d'examiner l'incidence de diverses cultures organisationnelles, ethnies et éthiques sur le rendement des équipes.
- Équipes décentralisées : la recherche doit mettre l'accent sur la différence de rendement des équipes selon qu'elles sont coimplantées ou géographiquement décentralisées. Les études doivent examiner En particulier le rendement des chefs d'équipe dans des contextes décentralisés.
- Validité des équipes et participants militaires : l'essentiel de la recherche actuelle fait appel à des étudiants de niveau universitaire arbitrairement réunis pour former des équipes spéciales. Afin d'extrapoler directement pour une population militaire, il faudrait recourir à des participants ayant une expérience militaire.
- Équipes d'équipes : l'interdépendance au sein de systèmes multiéquipes est un thème important pour les Forces canadiennes. Les exigences contradictoires découlant des buts d'une équipe secondaire et des objectifs de l'équipe globale ont des conséquences sur les opérations militaires basées sur des réseaux.

# Table of Contents

---

|                                                       |            |
|-------------------------------------------------------|------------|
| <b>ABSTRACT .....</b>                                 | <b>I</b>   |
| <b>RÉSUMÉ.....</b>                                    | <b>II</b>  |
| <b>EXECUTIVE SUMMARY .....</b>                        | <b>III</b> |
| <b>SOMMAIRE .....</b>                                 | <b>V</b>   |
| <b>TABLE OF CONTENTS.....</b>                         | <b>VII</b> |
| <b>LIST OF FIGURES .....</b>                          | <b>IX</b>  |
| <b>LIST OF TABLES .....</b>                           | <b>X</b>   |
| <b>1. INTRODUCTION .....</b>                          | <b>1</b>   |
| 1.1 BACKGROUND .....                                  | 1          |
| 1.2 PURPOSE.....                                      | 1          |
| 1.3 SCOPE.....                                        | 1          |
| <b>2. METHOD FOR SCIENTIFIC/ACADEMIC SEARCH .....</b> | <b>3</b>   |
| 2.1 KEYWORDS.....                                     | 3          |
| 2.2 DATABASES .....                                   | 4          |
| 2.3 CREATION OF MINDMAP .....                         | 5          |
| 2.4 SELECTION OF ARTICLES .....                       | 6          |
| 2.5 REVIEW OF ARTICLES .....                          | 6          |
| 2.6 STRUCTURE OF THE REPORT .....                     | 6          |
| 2.7 LIMITATIONS .....                                 | 7          |
| <b>3. TEAMS AND TEAM FACTORS .....</b>                | <b>9</b>   |
| 3.1 DEFINING TEAMS.....                               | 9          |
| 3.2 HISTORICAL OVERVIEW OF TEAM RESEARCH .....        | 11         |
| 3.3 TEAM FACTORS .....                                | 13         |
| 3.3.1 <i>Team Structure</i> .....                     | 13         |
| 3.3.2 <i>Team Size</i> .....                          | 16         |
| 3.3.3 <i>Team History</i> .....                       | 18         |
| 3.3.4 <i>Physical Distribution</i> .....              | 21         |
| 3.3.5 <i>Individual Characteristics</i> .....         | 24         |
| 3.3.6 <i>Team Diversity</i> .....                     | 28         |
| 3.3.7 <i>Leadership</i> .....                         | 33         |
| 3.4 OVERVIEW OF TEAM FACTORS .....                    | 36         |
| <b>4. TASK FACTORS .....</b>                          | <b>39</b>  |
| 4.1 TASK COMPLEXITY.....                              | 39         |
| 4.2 WORKLOAD .....                                    | 40         |
| 4.3 TASK INTERDEPENDENCE .....                        | 41         |

|           |                                                                 |            |
|-----------|-----------------------------------------------------------------|------------|
| 4.4       | OVERVIEW OF TASK FACTORS AND GAPS IDENTIFIED .....              | 43         |
| <b>5.</b> | <b>TEAM PROCESSES .....</b>                                     | <b>45</b>  |
| 5.1       | SHARED KNOWLEDGE .....                                          | 45         |
| 5.2       | COMMUNICATION .....                                             | 53         |
| 5.3       | TEAM COORDINATION .....                                         | 61         |
| 5.4       | TEAM ADAPTABILITY .....                                         | 65         |
| 5.5       | PLANNING.....                                                   | 69         |
| 5.6       | TEAM CLIMATE .....                                              | 72         |
| 5.7       | OVERVIEW OF TEAM PROCESSES .....                                | 75         |
| <b>6.</b> | <b>TEAM MEASURES .....</b>                                      | <b>79</b>  |
| 6.1       | CONCEPTUAL ISSUES AND CHALLENGES .....                          | 79         |
| 6.1.1     | <i>Team Process vs. Team Outcomes</i> .....                     | 79         |
| 6.1.2     | <i>Levels of Analysis</i> .....                                 | 81         |
| 6.1.3     | <i>Multiplicity of Team Constructs</i> .....                    | 82         |
| 6.2       | MEASURES OF TEAM OUTCOME .....                                  | 82         |
| 6.3       | MEASURES OF TEAM PROCESS .....                                  | 84         |
| 6.3.1     | <i>Measures of Shared Knowledge</i> .....                       | 84         |
| 6.3.2     | <i>Measures of Communication</i> .....                          | 87         |
| 6.3.3     | <i>Measures of Coordination</i> .....                           | 89         |
| 6.3.4     | <i>Measures of Team Adaptability</i> .....                      | 90         |
| 6.3.5     | <i>Measures of Planning/Resource Allocation</i> .....           | 91         |
| 6.3.6     | <i>Measures of Team Climate</i> .....                           | 92         |
| 6.3.7     | <i>Example of Team Measures used in Military Research</i> ..... | 92         |
| 6.4       | OVERVIEW OF TEAM MEASURES .....                                 | 94         |
| <b>7.</b> | <b>MODELS OF TEAM PERFORMANCE .....</b>                         | <b>99</b>  |
| 7.1       | CONCEPTUAL MODELS .....                                         | 99         |
| 7.2       | MATHEMATICAL MODELS .....                                       | 107        |
| 7.3       | COMPUTATIONAL MODELS.....                                       | 110        |
| 7.4       | OVERVIEW OF TEAM MODELS .....                                   | 115        |
| <b>8.</b> | <b>FINDINGS AND RECOMMENDATIONS .....</b>                       | <b>119</b> |
| 8.1       | CHALLENGES OF TEAM RESEARCH.....                                | 119        |
| 8.2       | RECOMMENDATIONS .....                                           | 120        |
| 8.2.1     | <i>Research exploring diversity within teams</i> .....          | 121        |
| 8.2.2     | <i>Research exploring distributed teams</i> .....               | 121        |
| 8.2.3     | <i>Research with true teams and military participants</i> ..... | 122        |
| 8.2.4     | <i>Research on teams of teams</i> .....                         | 122        |
| <b>9.</b> | <b>REFERENCES .....</b>                                         | <b>125</b> |
|           | <b>ANNEX A: TEAM PERFORMANCE .....</b>                          | <b>A-1</b> |

# List of Figures

---

|                                                                                      |     |
|--------------------------------------------------------------------------------------|-----|
| FIGURE 1. TRANSFORMATIONAL LEADERSHIP & TEAM PERFORMANCE MODEL (DIONNE ET AL., 2004) | 34  |
| FIGURE 2: DECENTRALIZED COMMUNICATION NETWORKS (BECK & PIERCE, 1996, p. 13)          | 54  |
| FIGURE 3: CENTRALIZED COMMUNICATION NETWORKS (BECK & PIERCE, 1996, p. 13)            | 54  |
| FIGURE 4: HIERARCHICAL COMMUNICATION NETWORK (BECK & PIERCE, 1996, p. 13)            | 55  |
| FIGURE 5. TEAM VS. INDIVIDUAL MEASURES (CANNON-BOWERS AND SALAS, 1997)               | 79  |
| FIGURE 6. TEAMWORK ASSESSMENT SCALES (KYNE, THORDSEN ET AL. 2002, PP. 6)             | 93  |
| FIGURE 7: PRINCIPLES FOR MEASURING TEAMWORK SKILLS (BAKER AND SALAS, 1997)           | 95  |
| FIGURE 8. TEAM EFFECTIVENESS MODEL (CANNON-BOWERS ET AL., 1995)                      | 100 |
| FIGURE 9. INPUT-PROCESS-OUTPUT MODEL OF TEAM PERFORMANCE (ESPINOSA ET AL., 2004)     | 101 |
| FIGURE 10. COMMAND TEAM EFFECTIVENESS MODEL (ESSENS ET AL., 2005)                    | 102 |
| FIGURE 11. CONTEXTUAL MODEL OF GROUPWARE DEVELOPMENT (DRISKELL & SALAS, 2006, p. 19) | 104 |

## List of Tables

---

|                                                                 |     |
|-----------------------------------------------------------------|-----|
| TABLE 1: PROPOSED KEYWORDS .....                                | 3   |
| TABLE 2: PRIMARY DATABASES FOR SCIENTIFIC/ACADEMIC SEARCH ..... | 5   |
| TABLE 3: TYPES OF SHARED MENTAL MODELS WITHIN TEAMS .....       | 46  |
| TABLE 4: PRODUCT MEASURES .....                                 | 83  |
| TABLE 5: SHARED KNOWLEDGE MEASURES .....                        | 85  |
| TABLE 6: COMMUNICATION MEASURES .....                           | 88  |
| TABLE 7: COORDINATION MEASURES .....                            | 90  |
| TABLE 8: ADAPTABILITY MEASURES .....                            | 91  |
| TABLE 9: PLANNING AND RESOURCE ALLOCATION MEASURES .....        | 91  |
| TABLE 10: TEAM CLIMATE MEASURES .....                           | 92  |
| TABLE 11. TEAMWORK DIMENSIONS (DRISKELL & SALAS, 2006) .....    | 105 |
| TABLE 12. CONTEXTUAL FACTORS (DRISKELL & SALAS, 2006) .....     | 106 |

# 1. Introduction

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## 1.1 Background

As the Canadian Forces (CF) look toward the future, there is an increased emphasis on operations that are highly integrated. Military operations will also increasingly interact with domains outside of the armed forces. As such, interoperability with allies, with other government departments (OGDs) and with non-government organizations (NGOs) will be critical. This will require people with different backgrounds, skills, and levels of authority to work effectively within teams in order to achieve common objectives. These teams will be required to perform diverse tasks, and to use technology to assist communication and to enable coordination of their activities. Thus, it will be critical for the CF to understand the factors that contribute to successful teamwork.

The following literature review originates from a larger 4-year Applied Research Project (ARP) related to teams, and is one of three tasks being undertaken in the Project Definition phase. Other ongoing work focuses on reviewing existing experimental platforms for the study of teams, and developing scenarios and evaluating possible tools for scenario implementation.

## 1.2 Purpose

The purpose of the literature review is threefold. The first part investigates the extent to which a wide range of factors are likely to influence team performance. The second part of the literature review focuses on measures of team performance and effectiveness, and explores a select subset of these measures. Finally, the third component of the literature review includes a review of the existing models of team performance, which includes available normative, descriptive, and predictive models used to understand how teams work.

## 1.3 Scope

This contract involved the systematic searching of published literature exploring teams and team performance. This literature review focused on teams that engage in cognitive work in dynamic and complex environments, such as information sharing, planning, problem solving, decision-making, etc. However, this review excludes teams engaged in work of a predominantly physical nature, teams that work in entirely self-paced environments, and teams that engage in social or recreational activities.

Further, to the extent possible, the literature review has focused on teams engaged in command and control, and in similar or related activities, such as mission/incident/emergency planning and/or response, and intelligence analysis. Consistent with current thinking in the CF, teams that are interdisciplinary, interagency, and/or network-enabled (e.g. Babcock, 2004) were of primary interest, though not exclusively. Due to the sheer scope of this review, some specific areas of research (which although relevant to team performance) needed to be excluded. These include the sizable literature related to team training.

The following literature review investigates factors that are likely to influence team performance, including characteristics of the team, task factors, and team processes. It also provides definitions of these factors, and explores the theoretical and empirical research that has addressed each factor's relationship with team performance.

With respect to team measures of performance, to the extent possible, the literature review targeted measures that have been applied to teams engaged in command and control, planning, analysis, and/or the coordination/management of real-time response to incidents, emergencies, or mission changes. Specific efforts were directly at finding measures related to interdisciplinary and/or interagency teams. For a subset of the measures that are deemed particularly relevant to teams that will be found in the future CF, the review discusses how these measures can be operationalized and discusses relevant methodologies for data collection.

Finally, the following literature review identifies conceptual, mathematical, and computational models of team performance that have already been developed. It also identifies the various factors that have been included in the models, explores the primary components and structure of these models, and considers whether the models are normative (specifying how teams should behave), descriptive (specifying how teams actually behave), and/or predictive (specifying how teams would behave). In addition, the relative strengths and weaknesses of existing models of team performance, and available efforts to validate them are considered. Lastly, their normative, descriptive, and predictive power, their maturity, and their potential for further development and validation are considered.

## 2. Method for Scientific/Academic Search

### 2.1 Keywords

We developed a set of keywords (see Table 1) for the literature search based on our experience with the pertinent scientific/psychological, human factor, and military domains during a brainstorming session with all members of the literature review team. These keywords were chosen because they focused the search on topics directly related to team activity and were intended to be able to identify any other related theoretical approaches or conceptualizations that might be relevant.

**Table 1: Proposed keywords**

| Core Concept     | Primary Keywords                                                                                                                                                                                                                                                                  | Related Keywords                                                                                                                                                                            |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Team             | teamwork, group, work group, crew, organization                                                                                                                                                                                                                                   | relationship, connection, alliance, coalition, working (group), association, dyad, unit, section, platoon, company, squad, contingent, corps,                                               |
| Team concepts    | shared mental model, shared situation awareness, shared knowledge, team knowledge, shared cognition, team cognition, common intent, common understanding, shared understanding, common goals/purpose/objectives, shared goals/purpose/objectives, mutual agreement, common ground | goals, purpose, objectives, norms, rules, procedures, beliefs, values, expectations                                                                                                         |
| Team structure   | Ad-hoc, interagency, multiagency, multinational, multicultural, joint, joint operations, joint services, task force, special forces, interdisciplinary, hierarchical, rank                                                                                                        | distributed, dispersed, virtual, co-located, commander-staff, commander-sub-commander, horizontal team, vertical team, lateral                                                              |
| Team composition | Team members, teammates, leadership, individual KSA, management                                                                                                                                                                                                                   | proximity, roles, responsibility, authority, personality, leadership styles, culture, diversity, gender, sex, homogeneous, heterogeneous, hierarchy, size                                   |
| Team activities  | command and control, mission planning, emergency planning, emergency response, information analysis, response, planning, analysis                                                                                                                                                 | strategic, operational, tactical, mission, decision making, judgement, problem solving, information sharing, team cognition, management, managing, crisis planning, deliberation, enactment |
| Team process     | communication, coordination, collaboration, cooperation, interdependence, integrative, interaction, connectivity                                                                                                                                                                  |                                                                                                                                                                                             |
| Team             | Team performance, team effectiveness,                                                                                                                                                                                                                                             | collective efficacy, cohesion, morale, mutual trust,                                                                                                                                        |

|                           |                                                                                                                  |                                                                                                                                                                                                                                                               |
|---------------------------|------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Outcomes                  | task performance, task effectiveness, team process                                                               | confidence, success, successful, unsuccessful, goals, intentions, expectations, social loafing, error rates, commitment, motivation, identification, competence, predictability, group think, consensus, social facilitation, group think, group polarization |
| Situational factors       | stress, workload, time pressure, complex, risky, high risk, hostile, conflict, task complexity, uncertainty      |                                                                                                                                                                                                                                                               |
| Modelling                 | descriptive, normative, prescriptive, mathematical, computational                                                | validation                                                                                                                                                                                                                                                    |
| Organization              | Team interventions, reward systems, information systems, support systems                                         | team training, team building, organizational climate, organizational culture, ethos, ethics                                                                                                                                                                   |
| Human-Machine Interaction | automation, interface, human-system integration, technology, human computer interaction, mechanization, networks | decision support systems, menu-driven interface                                                                                                                                                                                                               |
| Military                  | Army, Navy, Air Force, Armed Forces                                                                              | hierarchical, rank, specialty, arms (e.g., infantry), force, crew, detachment, squad, troop, unit, battalion, armament, mission type, ROE                                                                                                                     |

The primary keywords were the most important words used in the search, as they represented the broad relevant constructs likely to be of importance in research concerning teams. The primary keywords were used in order to ensure sampling of literature from several different areas within the core construct, and their use was guided by what emerged from the core concepts. For example, when thinking about the concept of a “team”, primary keywords such as “teamwork”, “shared mental model”, “shared situation awareness”, “shared knowledge”, “shared cognition”, “common intent”, “common understanding” and “common goals” emerged. In many cases, primary keywords were used in tandem with the word “team”. For example, searching team processes, the research team would use an advanced search, such as “team” and “coordination” or “team coordination” to yield hits for this team process. The purpose of the primary keywords, then, was to ensure that those aspects particular to teams were tapped. Related keywords provided a further layer of detail to the core concept, and were used in conjunction with the core concept and primary keywords.

## 2.2 Databases

The following primary databases were the most relevant for searching the scientific/academic literature.

**Table 2: Primary databases for scientific/academic search**

| Database      | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PsycINFO      | The PsycINFO database is a collection of electronically stored bibliographic references, often with abstracts or summaries, to psychological literature from the 1800s to the present. The available literature includes material published in 50 countries, but is all presented in English. Books and chapters published worldwide are also covered in the database, as well as technical reports and dissertations from the last several decades.                                                                   |
| NTIS          | National Technical Information Service is an agency of the U.S. Department of Commerce's Technology Administration. It is the official source for government sponsored U.S. and worldwide scientific, technical, engineering, and business related information. The database contains almost three million titles, including 370,000 technical reports from U.S. government research. The information in the database is gathered from U.S. government agencies and government agencies of countries around the world. |
| CISTI         | Canada Institute for Scientific and Technical Information houses a comprehensive collection of publications in science, technology, and medicine. It contains over 50,000 serial titles and 600,000 books, reports, and conference proceedings from around the world.                                                                                                                                                                                                                                                  |
| Public STINET | Public STINET is available to the public, free of charge. It provides access to citations of unclassified unlimited documents that have been entered into DTIC's Technical Reports Collection, as well as the electronic full-text of many of these documents. Public STINET also provides access to the Air University Library Index to Military Periodicals, Staff College Automated Military Periodical Index, DoD Index to Specifications and Standards, and Research and Development Descriptive Summaries.       |
| WWW           | World Wide Web                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |

## 2.3 Creation of Mindmap

In order to be able to focus the search process to some extent, it was important to understand the scope of the team literature. As such, the research team worked as a group during the early stages of the search procedure to map out the team domain, and to identify the many different factors likely to influence team performance. To do this, we reviewed several hallmark articles in the literature (e.g. Salas, Bowers, & Cannon-Bowers, 1995) and scanned articles retrieved for the factors that they addressed. From this process emerged a mindmap that posited team factors, task factors, and team process factors as critical impacts on team performance. This mindmap was then used to guide the rest of the search process. With the broad scope indicated in the statement of work, it was critical to retrieve the best possible articles that addressed each of the factors (at an empirical level whenever possible) while ensuring the procurement of theoretical articles that could help to provide the best possible “overview” of the research and literature relevant to each factor. This was important due to the limited number of articles that could be reviewed.

## 2.4 Selection of Articles

The search of the databases generated approximately 200 titles and abstracts. We reviewed these and categorized each by its priority (high, medium, or low) to the purpose and scope of the literature review. Priority was given to articles that seemed relevant to the core concepts developed earlier (Table 1). Higher priority was given to articles that discussed multiple core concepts than to articles that addressed only a single core concept (e.g., team structure and team composition versus team structure only). Once titles and abstracts were prioritized, we identified the approximately 120 sources that were rated as highest priority and obtained as many of these as possible. We were able to obtain approximately 100 for review, which covered a range of research areas on teams. Specific attention was given achieving coverage of each factor likely to influence team performance with more influential factors (e.g. shared knowledge, communication and coordination) receiving more attention. Overall, the references comprised books, journal articles and technical reports from the behavioural sciences, military, and business domains.

## 2.5 Review of Articles

Once final articles were obtained, researchers began to review and write pieces on the articles that pertained to various sections of the report. After reviewing approximately 20 articles and chapters, we developed a broad outline of the major issues. We used this outline to categorize the applicability of the other articles and to further focus our review of the remaining obtained articles.

## 2.6 Structure of the Report

Chapter 1 of this report describes the background and goals of this review. This chapter (Chapter 2) describes the search strategies used for this review, and the preparatory processes before starting the review. Chapter 3 explores the definition of “team” and provides a brief historical overview of team research, and then considers team characteristics with potential to influence team performance. Chapter 4 considers characteristics of tasks likely to influence team performance. Chapter 5 addresses team process factors likely to impact on team performance. Chapter 6 explores approaches to team measurement. Chapter 7 explores several models related to teams and team performance. Chapter 8 presents findings and recommendations for the way ahead.

In terms of the organization of this report, it is also important to note that although this review separates discrete factors that influence team performance, many of the existing articles addressed several distinct factors, so they needed to be discussed in more than one section throughout the document. This approach, hopefully, allows focus on the specific factor in relation to other research focusing on the same factor.

## 2.7 Limitations

It is critical to acknowledge some of the most obvious limitations of our review. First, due to the sheer size of the existing team literature, and because we were only able to review 80 articles in detail, we worked to find articles that represented both the “state of the art” in the team research, as well as research stemming from the more applied domain. However, it is important to note our conclusions with respect to specific factors are often necessarily based on a small sample of articles. Moreover, in order to meet the scope of the work, it was necessary to rely on existing team theorists and research for more context and overview of the literature, as it would have been impossible to describe patterns without this context.

The primary limitation of this review, however, is that research directly addressing the target domain was relatively limited. As the goal of this review was to target teams that functioned within joint contexts, required interagency cooperation and were often distributed, the current state of the literature did not enable complete fulfilment of this goal, as very few articles directly addressed this kind of team. As such, although our efforts were clearly directed toward finding and reviewing articles that addressed this specific type of team, it was also deemed critical to provide the strongest possible base on which to found a long term program of team research. This kind of base would only be possible if the current state of the team research was presented in full while highlighting current gaps and areas that need to be explored in more detail. As such, even though the team literature is clearly incomplete (in relation to the exact scope of this review), the key principles and concepts that are critical in understanding the performance of teams are reflected in the research and theory reviewed in this report.



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## 3. Teams and Team Factors

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### 3.1 Defining Teams

Before attempting to understand the factors that influence team performance, it is critical to understand exactly how teams are defined in the available research and literature. Although there are many different definitions evident in the literature, most definitions have several common features. A prominent definition argues that a team is “a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/object/mission, who have each been assigned specific roles or functions to perform, and have a limited life span of membership” (Salas, Dickinson, Converse, & Tannenbaum, 1992, p. 4). The exact form of interdependence within a team can be variable, but there is clearly a requirement for interdependence.

The definition of a “team” also distinguishes it from similar constructs. Teams are distinct from workgroups, understood simply as two or more people who interact frequently and maintain some interdependence within some unspecified time frame (McGrath, 1984; cited in Webber and Klimoski, 2004). Moreover, teams are recognized by members and non-members as “a social entity”, rooted within an organizational context (Devine, 2002). Groups, on the other hand, are not always recognized in this way, nor are they necessarily embedded within the context of an organization. Members of teams have clearly demarcated and assigned roles, unlike group roles, which are often undefined. Team members also “share responsibility for specific outcomes for their organizations” (Sundstrom, De Meuse, and Futrell, 1990, p. 120). Thus, a team differs from a group in that it is recognized as a social entity; each member adopts a specific role and shares responsibility for the outcomes of the team’s activity. Moreover, within typical teams, interdependence is absolutely necessary, interactions are dynamic and adaptive, and the team is most often rooted within an organizational context.

According to Webber and Klimoski (2004), teams had previously been defined merely by the tasks that they performed, but today this distinction is far too narrow. Webber and Klimoski (2004) identify a number of thinkers who provide classifications for different types of teams. For example, in proposing “an analytic framework for team effectiveness”, Sundstrom, DeMeuse, and Futrell (1990) classified teams according to their levels of integration (i.e., the relation of the team to the greater organization) and degree of specialization (i.e., how specialized their activity is in comparison to other work teams). As such, this classification system included four teams, advice/involvement, production/services, project/development, and action/negotiation with varying high and low degrees of integration and specialization. For example, the most relevant classification for a military command

team, action/negotiation, is understood as highly integrated and are highly specialized.

Similarly, Devine (2002) has argued that six types of teams are associated with intellectual work: Executive, command, negotiation, commission, design, and advisory. Executive teams refer to high level organization teams who are engaged in ill-structured tasks. Such teams must detect opportunities and challenges, identify and evaluate alternatives and make decisions and plans that will be carried out by others in the organization. Command teams make critical organizational decisions by collecting and integrating information from a variety of sources and are highly reliant on sophisticated technology as they often operate as geographically distributed teams. The tasks are usually well structured and their activities can impact the health and safety of many individuals. Negotiation teams engage in competitive tasks whereby members represent the interests of larger entities and exist for the duration of the negotiation. The tasks are well structured and procedures or regulations are often in place to standardize the negotiations. Commission teams engage in special projects that require judgement and planning and only exist for the duration of a particular mission. The teams are often cross-functional and are composed of diverse members in terms of individual characteristics. These teams rarely operate under tight time constraints and the procedures associated with the task may be mandated by the organization or outside authority. Design teams perform hands on work requiring creativity or technical innovation. Membership in design teams tends to be diverse and the teams usually disband after the task completion. Finally, advisory teams are involved with tasks that require the investigation of problems associated with sociotechnical systems or they search for ways to improve organizational effectiveness. These teams tend to be cross-functional and they operate outside of the formal organizational structure. This work suggests that each kind of team has unique characteristics, and these characteristics impact on important processes like team effectiveness, member selection, leader preparation, and training (Webber & Klimoski, 2004). According to this classification scheme, the most obvious classification for a military command team would be the command classification.

Another kind of team particularly relevant to the current review, however, is a team of teams. In the literature, these teams have been described as multiteam systems (e.g. Marks, DeChurch, Mathieu, Panzer, & Alonso, 2005). The formal definition is:

*“...two or more teams that interface directly and interdependently in response to environmental contingencies toward the accomplishment of collective goals. MTS boundaries are defined by virtue of the fact that all teams within the system, while pursuing different proximal goals, share at least one common distal goal; and in so doing exhibit input, process and outcome interdependence with at least one other team in the system.”*  
(Mathieu, Marks and Zaccaro, 2001; cited in Marks et al., 2005, p. 964).

Theorists studying multiteam systems (MTS) argue that they are more than simply large teams, but that the key issue in MTSS relates to how team members allocate

their efforts to the subteam in addition to the larger team as a whole. Clearly, from the perspective of the CF (i.e. moving to increasing joint, interagency and multinational operations), how a team of teams will be able to work together under competing goals is a critical issue to understand in more detail.

## 3.2 Historical Overview of Team Research

An important purpose of this review is to provide an overview of the “state of the art” in team theory and research. In order to do this, it may be helpful to begin with a broad depiction of the state of the team literature in the last several decades and to the current day. This depiction of the current state of the team research derives from both our literature review, and from recent articles by Fiore and Salas (2004) and Bowers, Salas, and Jentsch (2006) that provide overviews of the current status of team research.

Team research has clearly been prominent for several decades, but seemed to have emerged most prominently during the 1970s. Clearly, the very requirement for a field of team research has been prompted by (and continues to be influenced by) the increasing complexity of the tasks that need to be undertaken within an increasingly technological environment. For example, Cooke, Kiekel, Salas, Stout, Bowers, and Cannon-Bowers (2003, p. 179) argued that:

*“...the growing complexity of tasks frequently surpasses the cognitive capacities of individuals and thus necessitates a team approach, which simultaneously introduces an additional layer of cognitive requirements that are associated with the demands of the working together effectively with others. Team members need to coordinate their activities with others who are working toward the same goal.”*

This suggests that as the requirements of workplace tasks have become increasingly complex, more than one person has often been necessary to address these tasks. This has brought teams into increasing prominence, and has prompted the need to better understand team processes and performance.

As the field of psychology matured throughout the 70's, team research became increasingly prominent. In 1984, a thorough review of the team literature by Dyer (1984; cited in Salas et al., 1995) concluded that even a clear definition of teams had not emerged to that point. Moreover, Dyer also noted that the team research to that point had been primarily observational in nature, and had focused a good deal of attention on understanding team processes (e.g. coordination and communication). In terms of measurement, researchers in the 80s relied on subjective assessment or behavioural checklists made by trained or expert observers (Salas et al., 1995). These assessments therefore had to rely on observable behaviours and were rather static, focusing on more surface-level process phenomena. It is important to recognize,

however, that this measurement fit with the popularity of behavioural approaches of the time. At the time of her review, however, Dyer argued that the team research was in need of more elaborate measures and more rigorous scientific approaches to understanding teams and team performance. At a theoretical level, Dyer (1984; cited in Salas et al., 1995) also lamented the relative lack of comprehensive models of team performance, and argued that existing models focused only on the factors that directly influenced performance, ignoring other important factors.

A decade later, Salas et al. (1995) explored the status of military team research in a review spanning 1985 to 1995. In this review, they noted that a reasonable definition of “team” had emerged in the time since the Dyer (1984; cited in Salas et al., 1995) review. Specifically, early military team research focused on team-related behaviours “that lead to effective team performance” and focused on describing “the behavioural correlates of effective teamwork” (Salas et al., 1995, p. 57). As such, most studies into military teams were descriptive in nature involving observation in the field (Salas et al., 1995). Progress was also made with regard to understanding team processes. For example, communication and coordination were shown to be highly important for effective team performance, and critical distinctions between explicit and implicit communication and coordination were made. That is, explicit communication involves having team members offer information in response to specific requests, whereas implicit communication involves voluntarily offering such information without an explicit request (Swain & Mills, 2003). Similarly, explicit coordination occurs when teams explicitly manage dependencies by requesting communication and applying direct communication, whereas implicit coordination occurs when members manage dependencies by anticipating the information needs of others through the knowledge they share about the task (Espinosa, Lerch, & Kraut, 2004). Moreover, research undertaken in the 80s led naturally into more consideration of the cognitive underpinnings of team performance, and gave rise to increasing attention to the concept of mental models (Salas et al., 1995). Indeed, within the 90’s, and no doubt influenced by “cognitive revolution” within psychology as a whole, team research became increasingly focused on shared knowledge and shared mental models. This trend has continued strongly to the current day, with prominent researchers such as Cooke and Salas continuing to exert considerable efforts within this area. And, as innovations within the team research accrued, researchers also began to consider a broader set of factors, and team performance models increasingly began to include not only team processes, but also task, individual, and team characteristics. There have also been increasingly elaborated measures of team processes and team performance.

In general, then, it is possible to characterize the first stage of team research as focusing on basic concepts, and working toward understanding the simple “main effects” of key constructs. As research grew, however, Salas et al. (1995, p. 68) commented that research had become more about “studying the subtle interactions among input, process, and outcome variables”. At the same time, however, there is also much work left to do within this area. Our review will attempt to characterize both the nature of the existing work (both theoretical and empirical), to provide

examples of how these factors have been measured by previous researchers, and to indicate gaps remaining to be addressed by future theorists and researchers.

### 3.3 Team Factors

#### 3.3.1 Team Structure

##### Theoretical Research

From the literature, team structure has been conceptualized as comprising lines of authority within the team as well as the allocation of tasks and resources (e.g., MacMillan, Entin & Serfaty, 2004). Team structure has been argued to be optimal when adaptive to changing situations. For example, command and control teams are often forced to adapt to various situations and may need to alter their architectures in order to deal with unexpected changes (Entin, 1999). However, a team's organizational structure is most often depicted as impacting indirectly rather than directly on team performance, by influencing team processes such as the ability to communicate or to properly coordinate team members' actions. As will be reviewed later, issues of team structure have also been explored in relation to configuration of communication networks (Beck & Pierce, 1996). In general, there is good theoretical agreement that the structure of a team will influence team performance. However, as the following section will attest, despite this agreement, there is relatively little work that directly addresses the relationship between team structure and team performance.

##### Empirical Research

Just one publication accessed for this review directly explored the relationship between team structure and team performance. This work described two studies. The first experiment involved ten 6-person teams of military officers participating in a Joint Task Force (JTF) Command Team simulation (Macmillan et al., 2004). A Joint Task Force command team, of course, includes members from all elements, air, land, and sea. The experimental task required participants to work together in a simulation-based experiment that involved "regain[ing] control of an allied country" through "performance of a sequence of operational tasks in the face of opposition" (MacMillan et al., 2004, p. 66). This task included several subtasks such as "take the beach, advance on the airport", etc.

The traditional JTF structure<sup>1</sup> requires interdependence among nodes because each node (air, land, or sea) is solely responsible for resources pertaining to their node alone. Thus, in order for a task to be accomplished, nodes must

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<sup>1</sup> It is not indicated in Macmillan et al. (2004) precisely how the participants were allocated to each node (e.g., two individuals per node) or exactly what the responsibilities were within each node.

work hard to coordinate their activities. Task accomplishment in this structure is made more difficult because often within the traditional joint task force structure, many of the tasks needed to be done sequentially; that is, one has to be done before the other can be started, and some require the use of many resources simultaneously. MacMillan et al. (2004) argued that this traditional structure imposed high coordination, and hence, communication demands.

Team performance within this traditional structure was then compared with performance in an optimised team structure in which each node/team member (air, land, and sea) worked independently. This kind of structure, presumably, would reduce the need to coordinate and balance workloads across team members. Relevant measures included both simulator based measures and observer measures, and included indicators of both team process (e.g. coordination rates) and team performance.

Results found that teams using the optimized structure required fewer coordination actions than those in the traditional structure and achieved superior performance in terms of mission outcomes. Further, although the optimized team communicated less overall, their limited communication was more efficient than the traditional team. The positive results evidenced for the optimized team structure were argued to be due to the reduction in interdependence, thereby reducing the need for coordination and increasing communication efficiency. In support of this, results also showed that workload was also marginally lower in the optimized team structure than in the traditional structure.

A second study conducted by MacMillan et al. (2004) determined whether coordination and team performance were affected by divisional versus functional team structures. The experiment used twelve 3-person teams of university students completing an all-air simulated humanitarian assistance mission involving planning and delivering food to several refugee sites. Unfortunately, specific tasks other than general planning, coordination, and communication were not defined in Macmillan et al. (2004).

In the divisional structure, each team member was responsible for a portion of each type of resource (i.e., some of the food supply planes, medical supply planes, and Combat Air Patrol planes). As such, each person was able to work relatively autonomously, and indeed, some of the refugee sites were configured such that a single team member could have accomplished the delivery. In the functional structure, however, one team member was responsible for one type of plane only (e.g., all food supply planes). Thus, multiple people were needed to complete all deliveries and this functional team structure therefore required significant coordination.

Macmillan et al. (2004) note that these two team structures are similar to those in the first experiment. Specifically, the divisional structure is comparable to the optimized JTF structure, whereas the functional structure is comparable to the traditional JTF structure. The authors noted, however, that

while these concepts are comparable in some ways, the rationale behind them is somewhat different. That is, the JTF structures in the first experiment were explicitly driven by team process requirements (e.g., workload balance), whereas the divisional/functional structures in the second experiment were driven simply by resource balance.

Moreover, adequacy of resources was predicted to interact with the team structures. When team members had adequate resources, divisional structure was expected to be effective; when they did not, teams with divisional structure were expected to be less effective than when they had adequate resources because team members would be less experienced in coordinating their efforts. Functional structure was hypothesized to be less effective either way, as it imposed more demands for coordination.

Measures of team performance included task accuracy (percentage of time team delivered all necessary supplies to the site). This indicator showed that task accuracy was higher in the functional than in the divisional team. Another outcome indicator was coordination success. This measured the percentage of team members required to perform each task relative to the number that actually participated in performing each task. As such, if a given task was rated to require 2 people, teams that actually had two people working on this task would be given a higher coordination success rating than teams where only 1 member performed the task. Results showed that this “coordination success” indicator was higher for teams in the functional structure than for teams in the divisional structure. Although the divisional structure, then, imposed fewer coordination demands, when divisional teams did need to coordinate, they were less successful in doing so. The success of the functional teams was explained by the existence of more shared mental models developed during pre-mission planning (see Planning section for more discussion of this aspect of the study).

Taken together, differing results for these two studies suggest that the role of team organizational structure is dependent on the nature of the task, and on the kinds of interdependencies created by the task. Nonetheless, this work shows the interrelatedness of team structure, team communication, and team coordination, and provides a compelling argument that simple changes to team structure can influence both team process and performance.

### **Gaps in Research**

The research examining the relationship between team structure and team performance is relatively sparse. Certainly, the MacMillan et al. (2004) work is very relevant, as it was conducted with military officers within a Joint Task Force (JTF) Command Team simulation. Despite its relevance, however, it is important to point out that this research tests some aspects of team process and performance within varying team structures, but does not explore the extent to which teams adapt to varying structure at a very pragmatic level.

And, from the perspective of the CF, questions related to how team structure will influence team process and team effectiveness will need to be answered. For example, moving to a NEOps paradigm would promote increased decentralization of authority, in favour of providing people closest to the action with more opportunity to contribute the decision making process (Babcock, 2004). The implications of a change from more centralized to more decentralized command and control structure would be an important area of future research.

### **3.3.2 Team Size**

#### **Theoretical Research**

The number of individuals in a team is an important aspect of team composition. At a theoretical level, team size is argued to have the potential to both improve and reduce team performance. Although larger teams can generate more outputs because they consist of more resources and skills, they can also increase team processing demands. For example, it has been theorized that larger teams can cause coordination problems (Bass, 1982; cited in Morgan & Lassiter, 1992) and communication errors (Morgan & Lassiter, 1992) due to increases in the number of team member interactions. Therefore, the more resources that are directed towards interacting and coordinating with teams members, the less time is directed toward the actual task at hand. Even having additional resources because of increased team size can actually be detrimental to team performance due to potential problems of communication, coordination, and integration. Moreover, large team sizes have also been related to social loafing and the diffusion of responsibility as the size of the team may provide a shield for team members that are not performing at high levels (Bowers, Pharmer and Salas, 2000),.

Some researchers have suggested that three to five members is an ideal size for a team (Horwitz, 2005) but this clearly depends on the nature of the task. For intellectual tasks, such as decision making or problem solving, the numbers should be no more than five or six (Horwitz, 2005). Regardless of the actual number, the overall consensus is that smaller teams tend to be more productive as this size better facilitates communication, cohesion, and coordination (Horwitz, 2005). On the other hand, teams that are too small to accomplish their assigned tasks are also unlikely to perform optimally. As such, theorists have argued that optimal team size should be determined by the type of task and by the needs for interdependence in accomplishing the task but that there may be value in staffing teams with the smallest number of people needed to do the task (Essens et al., 2005). This is consistent with the assumption in the literature that smaller teams tend to be more cohesive and have improved communication and coordination (Horwitz, 2005).

## **Empirical Research**

Cited empirical research has shown that as team size increases beyond the optimum size, there seem to be increases in process losses and decreases in team integration (Dennis & Valacich, 1994; cited in Horwitz, 2005). Having larger teams has been shown to heighten coordination needs (Bass, 1982; cited in Morgan & Bowers, 1995) and more conformity among group members (Gerard, Wilhelmly, & Conolley, 1968; cited in Morgan & Lassiter, 1992). For instance, Morgan, Coates, and Rebbin (1970; cited in Morgan & Bowers, 1995) found that team performance actually improved when one team member was missing from a team.

A meta-analysis of more than 567 teams in 13 studies by Bowers, Pharmer and Salas (2000) exploring the impact of team composition (homogeneity or heterogeneity of composition) on team performance also included team size as a factor in this analysis. Results showed that larger teams performed significantly better, but as the focus of this research was on team composition, no further discussion of this finding was provided. However, a serious limitation of this work is that only a small number of the teams included in this meta-analysis had more than 2 members. As such, this work does not allow strong conclusions to be drawn.

## **Gaps in Research**

Clearly, there is more theoretical than empirical exploration of the relationship between team size and team performance. The available literature suggests that team size has received little discrete attention on its own, but was often studied in combination with other research questions.

A potential limitation of the existing work is that the impact of team size on team performance appears to have been understood relatively simplistically, as a relatively linear relationship of more size increasing a team's need for coordination. This implicit assumption denies the potential power of social processes, and that fact that the addition of a new team member into a 3 person team is psychologically very different from the addition of a new team member into a 10 person team. As such, the potential changes that occur within a team in relation to varying team size will be a critical issue to address.

As a whole, theoretical research suggests that optimal team size is dependent on the type of task because processes such as communication and coordination could become overly complicated with larger teams. The research has generally focused on teams that work face-to-face and there does not appear to be any research investigating team size in relation to distributed or virtual teams. This is unfortunate, and given that more and more organizations (including the military) are using distributed teams of varying sizes and compositions, it is critical that research explores more complex accounts of how team size influences team performance.

### 3.3.3 Team History

#### Theoretical Research

Team history is an important dimension that has the potential to impact on team performance. Experience working as a team makes it easier for members to be aware of each other's strengths and weaknesses, as well as to anticipate other's motivation and ability to share information and express disagreement (Levine, Moreland, Argote, & Carley, 2005). Team history has also been argued to promote shared knowledge and expectations, attitudes, and shared commitment to team goals (Bowers, Braun, & Morgan, 1997). In general, then, team theorists agree that the more team members work together, the better their communication, coordination, and overall performance are likely to be (Adelman, Bresnick, Christian, & Gualtieri, 1997).

One of the most prevalent assumptions within the literature is that prolonged history with other teammates will promote shared mental models (i.e., shared knowledge, expectations, etc.).<sup>2</sup> For example, Espinosa, Lerch, and Kraut (2004, p. 121) argued that:

*"Teams that have worked together for a long time may have well-developed team cognition mechanisms and work practices that help them to minimize dependencies. Not only can team variables affect team cognition development, but they also influence which explicit coordination mechanisms its members use."*

This suggests that team history will be an important construct to consider in modelling team performance.

Just as team history has been argued to be a positive contributor to team performance, turnover within teams has also been argued to have the potential to harm both team process and team performance. Turnover represents changes in team composition that can have positive and negative consequences as it alters distribution of knowledge and relations among members (Levine et al., 2005). A shared mental model has the potential to be seriously effected by turnover within a team, because it "alters both the distribution of knowledge within the team...and the relations among team members" (Levine et al., 2005, p. 2). Thus, the integrity of the team's mental models may be shaken with the loss of team members (key or otherwise), and with the introduction of newcomers. New team members may also bring alternative mental models, which could help the team generate alternative points of view, which can increase creativity but also may rattle the team's cohesion (Levine et al., 2005). As such, there is a strong link noted in the literature between team turnover and shared mental models.

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<sup>2</sup> Shared mental models (clearly closely related to team history) will be discussed in detail later.

Further, when teammates know more about each other, planning and coordination is enhanced and problems can be solved more quickly and easily because they can anticipate each other's behaviour and know where their skills and challenges lie. Teams that operate in dangerous environments, such as combat infantry squads, typically experience higher rates of turnover than teams in safer environments and therefore they have to develop techniques for handling the change. It has been theorized that teams with a history of repeated and predictable change more readily develop procedures for handling disruptive turnover (Levine et al., 2005). Given that knowledge of each other can contribute positively to a team, turnover and replacement of members can prove disruptive to a team's functioning. Because turnover is often unavoidable, understanding how to best handle such a challenge is likely to be beneficial to a team's performance (Levine et al., 2005). As such, team history is an important factor to study empirically.

### **Empirical Research**

Research assessing the impact of turnover on team performance has found both positive and negative effects, often in conjunction with other factors. For instance, it has been shown that groups with changing membership are more creative than groups with stable membership (Ziller, Behringer, & Goodchilds, 1962; cited in Levine et al., 2005) and that the gradual addition of members to a team produces higher quality decisions than do conventional groups that work together from the beginning (Rogelberg, Barnes-Farrell, & Lowe, 1992; cited in Levine et al., 2005).<sup>3</sup> Turnover, however, can be problematic, especially when group members work interactively rather than independently (Naylor & Briggs, 1965; cited in Levine et al., 2005), when the group has low structure (e.g., Carley, 1992; cited in Levine et al., 2005) and when the task is routine (Argote, Insko, Yovetich, & Romero, 1995; cited in Levine et al., 2005). In fact, turnover has been argued to have curvilinear relationship with performance both at the group level (Glaser & Klaus, 1966; cited in Levine et al., 2005) and at the organizational level (Argote, Epple, Rao, & Murphy, 1997; cited in Levine et al., 2005). Specifically, when turnover is extremely low or high, performance is low, but when turnover is mid level, performance is high.

Other research has explored the relationship between team turnover and the accumulation of knowledge within teams. Transactive memory is defined as common knowledge residing within the team (Levine et al., 2005). Research has shown that a team's mental models (or transactive memory) are more negatively affected by turnover when the team has trained together than when

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<sup>3</sup> Unfortunately, not enough information is provided about these groups to understand their relative levels of interdependence and common goals, and whether they fit the definition of teams (as opposed to groups) in 3.1. However, this work does seem an important base in order to understand the broad patterns in collaborative work groups.

team members have been trained individually to perform a task (Levine et al., 2005). Further, transactive memory may be better sustained in teams who are informed about possible turnover than in teams who do not have this information (Levine et al., 2005).

Some directly relevant empirical research has sought to explore the relationship between team history and team performance. In the U.S. Army, having set teams such that personnel routinely work together has been referred to as “battle rostering” (Adelman et al., 1997). In a study of Patriot air defence teams, Adelman and colleagues investigated the effects of team history and team composition on decision making. The hypothesis was that the more team members worked together (in terms of the number of hours), the better their communication and coordination and, in turn, their performance. Using a Patriot training simulator, teams performed two decision making tasks. In the “many track/no conflict” task there were multiple waves of enemy aircrafts flying as well as friendly aircrafts moving to engage the enemy aircrafts. As such, there were seldom fewer than ten aircrafts on the screen at any given time. The aircraft, however, exhibited no conflicting information and “behaved” as a defence operator would expect them to. In the “few track/cue conflict” task there were one to three aircrafts on the screen at a time, and information about aircraft in this condition was sometimes conflicting, in that some information about an aircraft indicated it to be friendly whereas other information suggested that it was hostile. The operators, therefore, had to work as a team in order to make a decision as to whether incoming aircrafts were friendly or hostile.

Results showed that teams who had worked together longer had higher quality communication<sup>4</sup> and better performance but only for tasks on which Patriot teams routinely trained. Team history did not help on the more cognitively stressful tasks when teams received conflicting information about unknown aircraft. Patriot teams, it was argued are not highly trained for these situations and rarely encounter them (Adelman et al., 1997). This suggests that team history will be most helpful when supplemented with training on a range of tasks.

### **Gaps in Research**

Although it would appear that team history is important to team performance, little empirical evidence has been conducted to directly support this notion. Indeed, prominent researchers have argued that “little research has focused on

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<sup>4</sup> Communication quality was measured with sufficiency scores. Sufficiency scores measured the quality of a team's interaction on the following processes: (1) give information, (2) ask for information, (3) give opinion, (4) ask for opinion, (5) give an order, (6) take an order, and (7) express disagreement. For each process, a team received a sufficiency score equal to 1.0 if they scored one standard deviation above the mean on that process. Otherwise they received a score of zero on that process. A cumulative sufficiency score was developed for each team across the various tasks by summing the sufficiency scores over all processes.

team development and its impact on team performance” (Baker & Salas, 1997, p. 337). Rather than receiving discrete attention on its own, the “team history” factor appears to have been incorporated into other work, particularly work exploring shared mental models.

As such it is necessary to look at how teams with different levels of experience perform with regard to various team processes. For example, examining whether teams that have more experience working together communicate less frequently because of certain shared mental models would create an important link between team history and team performance. As such, further research is required to examine when turnover within teams is beneficial and what factors might offset its negative impact.

### 3.3.4 Physical Distribution

#### Theoretical Research

Although the majority of team research has examined teams that are located in the same physical space (Lenné, 2003), team performance is likely to be very influenced by the physical location of team members, and whether teams are distributed or co-located. Geographically distributed teams consist of individuals in different locations who share accountability and therefore are required to work together to accomplish the team’s goals (Mohrman, 1999).

Certainly, the team members of today are more likely than ever to participate in distributed rather than face-to-face teams (Colquitt, Hollenbeck, Ilgen, LePine, & Sheppard, 2002). However, by their very nature, distributed teams also present several other challenges. Physical distribution of team members may result in communication difficulties because it eliminates useful implicit and explicit cues such as tone of voice, facial expressions, posture, and gestures (Driskell, Radtke, & Salas, 2003), often resulting in what has been termed ‘team opacity’ (Lenné, 2003). Distributed teams are generally argued to be less aware of the actions of other team members. Distributed teams also often vary in terms of membership constituency, are more likely to be ad-hoc teams than stable and fixed teams, and must often undertake complex tasks (Driskell and Salas, 2006).

Of course, technology (e.g. computer-mediated communication) can be used in order to offset some of the negative effects of team distribution. The exact form of mediation used (e.g. face-to-face, computer chat, or videoconference settings), however, also influences many different dimensions that are likely to influence team performance. These dimensions include co-presence, visibility, audibility, cotemporality, simultaneity, and sequentiality (Driskell et al., 2003). For example, the extent to which technology facilitates co-presence, the psychological perception of working as a team, has been argued to influence team performance (e.g. Driskell and Salas, 2006).

*“A reasonable and cautious interpretation of the evidence at this point is that, indeed, distance matters – that working remotely in a mediated team environment is different from working face-to-face – but that the matter in which mediation affected team interaction warrants closer examination.” (Driskell et al., 2003, p. 298).*

A critical issue within distributed teams, of course, involves learning how to use technology in order to communicate and to coordinate the team's actions. This suggests that how team performance and process are influenced by physical distribution will be an important area of research for the future. It is important to note that a substantial body of research in the area of computer-mediated communication does seem to exist. Unfortunately, this area of research and true team research both seem to have developed in relative isolation of each other. In concluding a review of the literature related to the effects of technological mediation on team performance, Driskell et al. (2003, p. 318) reach a pessimistic conclusion:

*“....the reality is that this body of literature on computer-mediated teams virtually ignores the operation of key team and task variables. Accordingly, in many cases, our analyses are speculative rather than conclusive, and more research is needed to further elucidate the specific conditions under which technological mediation impacts team interaction.”*

The computer-mediated literature has been focused primarily on the more technological aspects of the problems while giving secondary focus to cognitive issues. The mainstream team literature, on the other hand, appears to have given little consideration to the impact of differing technologies, and has focused more on “what” has been communicated rather than “how” this has occurred. This suggests that bringing together these two areas of research will aid the understanding of team performance in both camps.

### **Empirical Research**

Limited empirical work has addressed the relationship between team distribution and team performance. Work by Cooke, Shope, and Kiekel (2001), for example, explored shared knowledge in distributed and co-located teams. The task was a three person task based on USAF Predator Uninhibited Air Vehicle operations, and required participants to work as a team to “control and navigate the UAV to take photographs of designated targets” (Cooke et al., 2001, p. 20). Participants were 11 teams of 3 Air Force cadets. Teams communicated using headsets and an intercom system, and team members were in separate rooms. Results showed that distributed and co-located teams were no different in terms of their taskwork knowledge, although knowledge in both kinds of teams did grow with experience. There were also no differences in teamwork knowledge.

Cooke (2004) conducted another UAV study examining the effects of distributed versus co-located environments on team performance. The objective of the study was to examine the effects of Distributed Mission Environments (DMEs) on team performance, team process, and cognition. Twenty 3-person teams of university students volunteered to participate in two six-hour sessions. Teams were randomly assigned to either a co-located condition (in which they communicated over headsets and discussed the task face-to-face), or a distributed condition (whereby team members were located in separate rooms and could only communicate via headsets). Missions also varied in terms of workload requirements (either high or low). Teams participated in 7 missions over the two sessions. During the missions, experimenters coded team process behaviours. In addition, shared knowledge measures were also taken.

Results indicated no performance differences between the distributed versus co-located teams, although there were trends for distributed teams to do better under high workloads, and for co-located teams to do better under low workloads. Despite the failure to find significant differences for co-located vs. distributed teams, however, Cooke still argued that there were indications of a “distributed disadvantage”, as co-located teams performed better on a number of tasks. For example, although distributed vs. co-located teams did not differ in the degree to which they shared team and task mental models, co-located teams were able to develop taskwork models slightly more quickly than were distributed teams. This suggests that teams might have been able to get “on track” a bit faster because of co-location. Co-located teams also had better team process behaviour, in terms of proportion of appropriate behaviours, and had more accurate holistic teamwork knowledge than distributed teams. There was no measure that showed distributed teams to have an advantage over co-located teams. However, due to relatively small sample sizes, the lack of significant differences was argued to be a product of poor power.

As a whole, then, the research addressing team performance and physical distribution is relatively sparse, and somewhat contradictory. Early work by Cooke et al. (2001), for example, suggests no difference in shared knowledge in co-located and distributed teams, but later work suggested a “distributed disadvantage”. Additional research will be necessary to fully understand the relationship between team performance and physical distribution.

### **Gaps in Research**

Although teams are becoming increasingly distributed, within the mainstream team literature there is still relatively little research examining team performance in distributed versus co-located environments. As Priest, Stagl, Klein and Salas (2006, p. 187) argue,

*“Although teamwork has been studied extensively, it remains to be established what differences, if any, exist between co-located coordinated action and distributed teamwork.”*

Similarly, Espinosa et al. (2004, p. 123) has lamented:

*“...there is almost no empirical research in different-place contexts (i.e., geographically dispersed).”*

These criticisms are certainly supported by our review of the literature, and there is very little empirical research within the mainstream team literature that is directly relevant to distributed teams.

Given that the frequency of these types of teams will only increase, determining whether there are performance differences between dispersed and co-located teams would help with efforts to improve their functioning. In addition, if performance differences are found, determining how team processes lead to performance differences is critical. For instance, examining such things as communication and shared mental models as they relate to distributed versus co-located teams would aid in understanding performance differences.

It is also important to note that the potential positive effects of geographical dispersion have also not been adequately considered in the existing research. The majority of research within this area has focused on potential disadvantages of team members working in separate locations (Driskell et al., 2003). However, some of the more positive aspects of physical distribution (e.g. pressure for conformity and biases in decision making) have been underemphasized in existing research (Driskell et al., 2003). This suggests that it will be important to consider both positive and negative relationships between physical team distribution and team performance.

Dispersed teams are becoming more frequent due to organizations locating operations throughout the world along with the need to leverage knowledge, products and activities worldwide (Mohrman, 1999). Because team performance is dependent on such team processes as communication and cohesion, understanding the impact of physical distribution on such processes is vital to team performance. And, given the research reviewed herein, it will also be important to use more realistic tasks and military participants in order to understand the impact of physical distribution on team performance.

### **3.3.5 Individual Characteristics**

Differences in individual team member characteristics have also been suggested to influence team performance (e.g. Doane, Bradshaw, & Giesen, 2004). As such, understanding how variations in individual characteristics might relate to team performance (as well as other aspects of team functioning) is critically important to understanding teamwork. The most

prominent individual differences represented in the available literature relate to cognitive ability and to personality dimensions. Cognitive ability is usually defined as general cognitive and/or reasoning ability (*g*), spatial orientation, and verbal comprehension.

In terms of personality, Jordan (2001) has argued that research on personality has generally been defined using the Big Five personality dimensions developed by McCrae and Costa (1996). These personality dimensions include: (a) extroversion - being sociable, gregarious, assertive, talkative, and active (b) emotional stability - being secure, stable, relaxed, self-sufficient and tolerant of stress (c) agreeableness - being courteous, flexible, cooperative, and tolerant (d) conscientiousness - being careful, thorough, organized, achievement oriented and hardworking and (e) openness to experience - being imaginative, cultured, intelligent and broadminded (Jordan, 2001). Most of the team research pertaining to the Big Five factors has focused on the conscientiousness and agreeableness factors.

### **Empirical Research**

Empirical findings within this area appear to be inconsistent. A study with peer ratings of office skills by Neuman and Wright (1999) found that team members' conscientious and agreeableness scores correlated with supervisor and peer rated performance, however, only conscientiousness was predictive of actual work accuracy.

In a study of decision making in hierarchical teams, LePine, Hollenbeck, Ilgen, and Hedlund (1997) explored the impact of individual differences on team performance. Participants were undergraduates assembled into 51 four-person teams. Participant teams completed a simulation task called Team Interactive Decision Exercise for Teams Incorporating Distributed Expertise (TIDE2). This task involved a naval command and control scenario, and required participants to monitor the airspace surrounding their naval carrier, to gather information about aircraft and to share this information with other teammates in order to respond appropriately to an aircraft that was either friendly or enemy. One of the team members had been designated as the team leader. Measures included an indicator of team performance (i.e. accuracy of the teams' decision about the aircraft), general cognitive ability (as measured by scholastic records), and conscientiousness.

Results showed that teams whose members were more conscientious also performed better, but only when both leaders and team members exhibited the trait (LePine et al., 1997). This suggests that personality traits such as conscientiousness as well as the uniformity of these traits in team members and leaders are both important predictors of team performance.

Similarly, Halfhill, Sundstrom, Nielsen, and Weilbaeher (2005) examined group personality composition variables as predictors of effectiveness in 53 intact military service teams. During two monthly drill sessions, participants completed surveys assessing individual agreeableness and conscientiousness

and supervisors completed rating forms of team performance. Results showed that military teams' average conscientiousness and agreeableness correlated with supervisor-rated and team-level performance. Moreover, teams with the most uniformity in agreeableness also had the highest performance ratings, whereas those teams with more diverse traits performed the worse.

Further, team minimum scores on conscientiousness and agreeableness predicted performance almost as well as team averages, therefore indicating that the weakest link in the team could be very influential to team performance (Halfhill et al., 2005). This study illustrates that personality composition correlates with team performance and the high level of convergence on these personality dimensions within teams suggests that teams may develop norms around their collective personality traits (Halfhill et al., 2005). Based on this data, the authors argue that group norms may have reinforced individual inclinations through conformity and suppression of deviance in groups. This finding is potentially a very important one, as it indicates that the "weakest link" within a team may be the best predictor of observer-rated team performance.

Apart from conscientiousness, emotional stability and extroversion have also been found to relate to team performance. For instance, Doane et al. (2004) simulated a military operational environment using a dynamic and interactive computer game called "Half-Life". Team members had a variety of tasks, including escorting a VIP to a target destination (Doane et al., 2004). Team performance was measured as time to complete the task and injuries to team members and/or VIPs. Results showed that teams with higher emotional stability and less extroverted team leaders took less time to complete the task and caused less harm to themselves and to the VIP. Further, teams with higher scores on other factors related to conscientiousness (achievement motivation, social orientation, and stress tolerance) took fewer shots per kill and required less time to eliminate hostiles (Doane et al., 2004). These results are argued by the researchers to show that teams whose members are more emotionally stable and whose leaders are less extroverted have higher "coordinative ability". Unfortunately, however, although more emotionally stable and conscientious teams did achieve better results, the extent to which coordination was the reason for better performance remains to be seen.

This research also included a series of analyses that explored how team composition related to team performance, based on several possible competing models predicting performance on the basis of team personality characteristics. For example, a "compensatory" model would predict that team performance would be best predicted by team members with the highest abilities. A "synergy" model would predict team performance in relation to aggregated team member abilities, whereas an "average" model would predict team performance on the basis of mean ability scores of all members. The "weakest link" model predicts performance on the basis of the skills of the lowest ranking member of the team. Results showed that the "weakest link"

model best explained team performance. This pattern of results is consistent with previously reviewed work by Halfhill et al. (2005), and this kind of research represents a critical area of investigation for future team researchers.

Other research has explored the relationship between openness to experience and team using computer-assisted communication in a simulated air traffic decision making task (Colquitt et al., 2002). Unlike computer-mediated communication in which no person-to-person communication is enabled, computer-assisted communication allows network members to communicate via a mix of verbal and non-verbal (e.g., buttons or text messages) means. Moreover, these researchers argued that teams in which individuals show high openness to experience may be better able to adapt to changing technology, as they have been shown to have higher learning proficiency and more creativity. Undergraduates participating were randomly assigned to one of two communication conditions. In the face-to-face condition, “participants communicated by talking to each other” via headsets (Colquitt et al., 2002, p. 405). In the computer-assisted condition “participants could communicate through a mixture of verbal and computer-mediated communication” (Colquitt et al., 2002, p. 405). This involved talking to each other via headsets and also using text messages, which were sent through the computer. Participants had to choose the communication they would use during the simulation. Measures included an openness to experience measure, team decision making performance, and efficiency of verbal and computerized communication.

Results indicated that computer-assisted teams characterized by higher levels of openness performed better (correctly classified more aircraft) than those characterized by lower levels of openness. These results suggest that personality variables such as openness to experience may interact with the technologies available to teams to influence team decision making performance.

Overall, then, there is some evidence that individual personality factors are likely to influence team performance.

### **Gaps in Research**

This area is one specifically cited in the team research to be in particular need of further empirical exploration. Researchers have concluded that are still critical gaps in the team literature in relation to team composition. As Bowers et al. (2006, p. 4) have argued:

*“There is a significant need for understanding the role of individual differences and other team composition effects.”*

The research that does pertain to individual differences and team performance has typically shown that cognitive ability and the personality dimensions of conscientiousness and agreeableness are positively related to team

performance. The studies investigating personality attributes have generally ignored other personality characteristics.

Another potential moderator between individual differences and team performance is task type. A small amount of research has already investigated task type as a potential moderator (e.g., English, Griffith, & Steelman, 2004); however, further research is necessary to fully understand how task type can affect the relationship between personality dimensions and performance. For the future, it will be important to understand how the various personality dimensions might be related to different types of teams or missions. For example, one type of team may require team members who are high on extroversion whereas this type of personality dimension could be detrimental to another type of team. Similarly, teams conducting peacekeeping missions may benefit from team members with different personality dimensions (e.g. diplomacy and tact) than would teams in warfighting situations (e.g. such teams might require aggressiveness and assertiveness).

Similarly, there is also little evidence that existing research has investigated different personality characteristics or levels of cognitive ability as they relate to distributed teams. Given that such teams are becoming more prevalent, it would be helpful to establish what types of personality characteristics would contribute to team success in distributed contexts.

### **3.3.6 Team Diversity**

#### **Theoretical Research**

Diversity has been conceptualized in a variety of ways in the literature. An earlier taxonomy introduced by Jackson (1995; cited in Horwitz, 2005), distinguishes between detectable attributes and underlying attributes. Detectable attributes are readily apparent and include such demographic markers as ethnicity, gender, and age. Underlying attributes, on the other hand, are less apparent upon brief exposure. These attributes include ability and personality characteristics (Bower et al., 2000). Similarly, Harrison, Price, and Bell (1998) characterized diversity as consisting of surface-level (demographic) diversity or deep-level (attitudinal) diversity. Surface level diversity is defined as differences in observable biological characteristics, whereas deep level diversity is not readily apparent and is defined as differences in attitudes, beliefs, and values (Horwitz, 2005).

Having established that there are two broad categories of diversity, it is also important to understand how diversity may affect team performance. Overall, diversity within teams is purported to have both positive and negative effects. For example, diverse teams have been argued to show less cohesiveness because of differing backgrounds, and have less interpersonal similarity and common experiences to rely on to promote mutual attraction and motivation to work together (Knouse, Smith, & Knouse, 1996). Diverse groups can also take longer to solve problems, may communicate less effectively (Knouse et

al., 1996), and be less conducive to the creation of shared mental models (Knouse, Smith & Knouse, 2001). Two competing theories, namely the similarity-attraction theory and cognitive resource diversity theory (Horwitz, 2005) have been advanced in order to explain the probable effects of team diversity.

The similarity-attraction theory argues that members of homogenous group are likely to be more productive than heterogeneous groups because of the mutual interpersonal attraction of team members with similar characteristics (Bowers et al., 2000). Conversely, heterogeneous groups are believed to be less productive due to tensions and conflict arising from team member differences. Although the similarity-attraction theory is plausible, however, some have questioned key assumptions of this theory. For instance, Bowers et al. (2000) suggest that although members of similar backgrounds may be attracted to each other, whether this attraction translates into higher levels of performance is questionable.

Contrary to similarity-attraction theory, cognitive resource diversity theory proposes that diversity has a positive impact on team performance due to the unique resource each member brings to the team (Horwitz, 2005). This theory argues that heterogeneous teams are likely to benefit from a variety of diverse perspectives within the team and to promote creativity, innovation, and problem solving. As such, they are also argued to be likely to perform better (Horwitz, 2005). Similarly, Knouse et al. (1996) argue that diversity may facilitate more creative approaches to solving problems and allow a higher level of synergistic efforts to be directed toward group goals. Diverse teams that are functioning well also seem to use the strengths of their members to enhance group performance, focusing on both commonalities and individual differences when necessary.

Several different factors have been argued to influence the relationship between team diversity and team performance. For example, task difficulty and/or complexity can affect the relationship between diversity and team performance (Horwitz, 2005). Complex tasks require team members to pool their resources and formulate strategies. As such, having diverse background would significantly aid in this endeavour. According to Horwitz (2005) diversity can be unnecessary and counterproductive in dealing with simple, routine tasks. Because diversity brings a variety of perspectives, this may complicate simple tasks and therefore impede performance by creating conflict or causing delays. Task interdependence refers to the degree to which task completion requires the interaction of team members (Stewart & Barrick, 2000; cited in Horwitz, 2005). It has been suggested that task interdependence moderates the relationship between team diversity and team performance (Horwitz, 2005). High task interdependence requires that team members depend on each other for expertise, resources, and knowledge, however, in tasks with low interdependence, members work as individuals

with little need for coordination, thereby reducing the potential for conflict in heterogeneous groups (Stewart & Barrick, 2000; cited in Horwitz, 2005).

### **Empirical Research**

The lack of theoretical agreement about the role of team diversity is also evident within the empirical literature. Varying types of diversity seem to have different implications for team performance. Some past research has indicated that similarity in team member age enhances performance, whereas diversity in age has negative consequences. Project teams with more similar ages showed more frequent communications (Zenger & Lawrence, 1989; cited in Horwitz, 2005), whereas differences in age were related to higher turnover rates within teams (Wiersema & Bird, 1993; cited in Milliken & Martins, 1996). Although the findings relating to age diversity has tended to favour homogenous teams, theoretical research has focused on the potential benefits of age diversity, such as having a wider range of perspectives and experience (Horwitz, 2005). The research on age diversity and performance is still relatively limited and it is necessary for research to further study the consequences of having members of different age groups within the same team.

Other research has explored the impact of gender diversity within teams. As with many previously male-dominated work domains, the military has seen an increase in the number of women entering into the profession, which has ultimately led to a proliferation of gender diverse work teams. Research on gender diversity has shown mixed results, however, some researchers have argued that there are benefits for gender diverse teams (Horwitz, 2005). For example Pelled (1996; cited in Horwitz, 2005) found that gender diversity in work teams was related to intragroup conflict and lower performance ratings, whereas, other researchers have found that mixed-gender teams outperformed same gender teams on problem solving tasks (Bowers et al., 2000).

Research by Elliott, Hollenbeck, Tower, and Bradford (1997) explored the gender composition of tactical decision making teams in terms of both team process and team performance. This work used the TIDE2 decision making platform to explore team process and performance in teams with varying numbers of men and women. Participants were 120 people from a hiring agency who were assembled into 3 person teams with 1 of 6 gender configurations, which ranged from 0, 1, 2, to 3 women, and included the designation of a male or female leader. These teams undertook a command and control task trying to protect a military base from hostile aircraft. This task required the team to work interdependently. Relevant measures included team decision accuracy and communication adequacy.

Results showed that “all male” teams performed more accurately, and that teams with a male leader and two female subordinates performed least accurately. Moreover, communication analyses showed that these

performance differences were related to the efficiency/effectiveness of information exchange. In short, poor performing teams simply did not receive the information that they needed. The negative effects of mixed gender teams are explained in terms of varying interaction and communication styles between men and women. More specifically, men are argued to be task oriented in their communication behaviours (e.g., providing suggestions), whereas women display more social behaviours in their communications (e.g., facilitating discussion) (Wood, 1987; cited in Elliot et al., 1997). Men's propensity for task related communication may be due to their perceptions of higher status and women's lower status (Elliott et al., 1997). Therefore, gender-related differences in communication patterns and subsequent team performance could arise out of perceived status differences. Nonetheless, this work clearly contradicts the assertion that gender diverse teams are likely to show performance benefits.

Unfortunately, our search did not find any studies exploring racially diverse teams, and hence, our analysis must rely on a review article exploring team diversity. Research on racial and ethnic diversity within teams is also reported to be inconsistent (Horwitz, 2005). Because of differences in backgrounds and experience, ethnically diverse teams are generally assumed to be more likely to have diverse perspectives within them. In theory, when innovation or creativity is required, racially diverse teams should perform better (Horwitz, 2005). However, there is also some reported evidence that this diversity can hinder other team processes. For example, research has shown that teams in a hospital setting with diverse racial composition demonstrated more conflict than racially homogenous groups (Sessa, 1993; cited in Horwitz, 2005).

Apart from demographic diversity, job-related attributes can also vary within a team. Heterogeneity in functional expertise and educational background have been found to positively relate to team effectiveness as this form of diversity provides teams with access to a variety of expertise, information bases, and resources that may not be available if all members were from the same functional area (Horwitz, 2005). Although diversity in functional expertise has shown to be beneficial, it may also be responsible for increased conflict, complicate internal communication, and hamper coordination within teams (Jenh & Bezrukova; cited in Horwitz, 2005). Similarly, differences in educational backgrounds have been associated with increased conflict and discomfort among team members (Horwitz, 2005).

A longitudinal study of diverse teams found that heterogeneous teams were less effective than homogenous teams for the first 17 weeks of working together. However, after the first 17 weeks, heterogeneous teams outperformed homogenous teams on some aspects of task performance, such as problem perspectives, and the range of possible solutions (Watson, Kumar, Michaelsen, 1993; cited in Knouse et al., 1996). The increase in performance of diverse teams can be explained as a function of the weakening of surface-level effects and the strengthening of deep-level effects. For instance,

Harrison, Prince and Bell (1998) showed that initial negative effects of gender diversity dissipated as team members engaged in more meaningful interactions and deep-level attributes were increasingly taken into account.

Studies examining team composition characteristics in relation to team performance appear to be somewhat lacking in the literature. Overall, a meta-analysis of more than 567 teams by Bowers et al. (2000) concluded that there was little evidence that teams homogeneous in terms of ability, personality and gender performed any better, and in fact, the general trend was that heterogeneous teams showed slightly higher performance. However, this review did show a significant relationship between task difficulty and team performance. When the tasks are low in difficulty (i.e., low stimulus uncertainty, processing demands, and response complexity) homogenous teams perform better than heterogeneous teams. However, when tasks are high in difficulty, highly diverse teams often perform better, but this effect is not consistently evidenced (Bowers et al., 2000).

To summarize, although the literature is very mixed, it would appear that any form of team diversity could have either positive or negative effects on team performance. Potentially beneficial effects of diversity include a broader range of perspectives, abilities, and knowledge, which can aid in efforts relating to innovation and creativity. Heterogeneous teams, however, are also associated with increased conflict and diminished communication. These effects, however, seem to be somewhat dependent on a range of other factors, including team size, the type of task, task complexity/difficulty, task interdependence and frequency/duration of team member interactions. To this point, then, researchers have tended to conceptualize the relationship between team diversity and team performance in relation to other potential moderators.

### **Gaps in Research**

Although research on team diversity has been conducted for decades, significant gaps in the team literature still exist.

As Bowers et al. (2000, p. 310) have argued,

*“There is surprisingly little research on the effects of homogeneity of personality composition on team performance.”*

One specific area in need of further research concerns the link between team diversity and team process. For instance, research has demonstrated that gender diversity is associated with difficulties in communication because males and females may exhibit different communication behaviours. Research needs to determine how diversity affects the various team processes and which processes in particular are most susceptible to the effects of diversity. The literature has touched on various moderators that could alter the relationship between diverse team and team performance, but more factors also need to be considered. For instance, the organizational context

within which the team operates could ameliorate or hinder the performance of diverse teams.

It would also be worthwhile to investigate the differential impact of diversity on majority and minority group members. Because majority members are accustomed to being dominant, they may have more difficulty adjusting to increased diversity. Similarly, it would be important to explore how minority group members are negatively impacted by negative stereotypes and expectations associated with disadvantaged groups, and to consider how this might affect team performance. For instance, if they experience less job satisfaction due to their feelings of being different from other group members, this could affect their performance in the team. Finally, expanding on the work of Harrison et al. (1998), more longitudinal research is needed in order to better understand the changing interactions of diverse teams.

It is also clear that the changes in the future composition of teams will challenge team researchers of the future. In military contexts, for example, increased emphasis on distributed and multinational teams with people from diverse backgrounds has the potential to impose increased urgency on understanding how teams can best be supported in their efforts to work as coherent systems despite many different forms of diversity. This suggests that issues of culture will need to receive considerable attention from future team researchers.

### **3.3.7 Leadership**

#### **Theoretical Research**

Leaders of a team have a variety of functions and can ultimately make or break a team. Leaders can be either assigned or emergent. Assigned leaders are formally given the role of leader whereas emergent leaders have informal influence over the team due to their knowledge or skills (Essens et al., 2005). Whether a team leader is assigned or emergent, however, a leader's role is to shape team members' understanding of the task (McCann & Pigeau, 2000; cited in Essens et al., 2005), direct and influence member behaviour (Marks, Zaccaro, & Mathieu, 2000; cited in Essens et al., 2005), and mediate information flow with the larger organization (Essens et al., 2005).

As noted in a recent review of the literature exploring the "state of the art" in leadership and team research (Day, Gronn & Salas, 2004), researchers are argued to have typically construed leadership as an input to a team's performance. Emerging perspectives, however, emphasize leadership as more of an outcome at the team level. According to this perspective, the leader of a team should not be seen as a single influence as the team does its job, but as a dynamic part of the team that both helps to shape team performance while simultaneously being shaped at the same time (Day et al., 2004).

Many different types of leaders have been proposed in the literature; however, recently research has tended to focus on transformational and transactional leadership. Transactional leadership has been depicted as contingent-reinforcement, such that leader-subordinate relationships are based on exchanges. Transformational leaders, on the other hand, go beyond the exchange relationship and have been suggested to exhibit charisma, inspirational motivation, intellectual stimulation, and individualized consideration. These leaders accomplish this by providing meaning and challenge to their subordinates' work, expanding followers' use of their potential skills and abilities and being attentive to their subordinates' needs for achievement and growth (Lim & Ployhart, 2004). Whereas transactional leaders focus on the short term goals, transformational leaders look at the long term goals and emphasize their vision (Lim & Ployhart, 2004). Although much research has been conducted on transformational leadership and individual level outcomes, little attention has been paid to the influence of transformational leadership on team level performance or process (Lim & Ployhart, 2004). This is ironic considering leadership has been found to have much more of an effect on group performance than individual performance (DeGroot, Kiker, & Cross; cited in Dionne, Yammarino, Atwater, & Spangler, 2004).

One paper accessed in this review did address the relationship between transformational leadership and team performance. According to Dionne et al. (2004), transformational leadership influences team performance through its effect on various team processes, as shown in Figure 1.

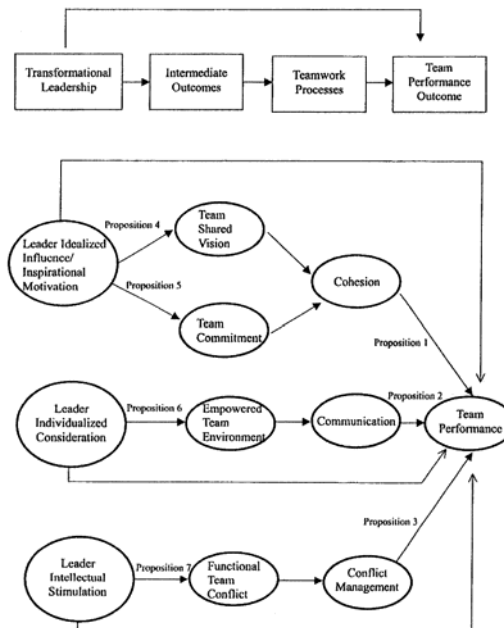


**Figure 1. Transformational Leadership & Team Performance Model (Dionne et al., 2004)**

The proposed model argues that specific dimensions, such as motivation, consideration, and stimulation, produce intermediate outcomes that could positively influence team processes and ultimately team performance. Specifically, they proposed that leader's inspirational motivation would positively influence team cohesion; leader's individualized consideration would positively impact team communication; and leader's intellectual stimulation would positively impact team conflict management. Examining how the various dimensions of transformational leadership effects team processes would aid in understanding how transformational leadership is associated with team performance. However, there is no evidence available that this model has been tested.

### **Empirical Research**

Of the few available studies accessed that have investigated the effects of transformational leadership on team performance, the findings have generally been positive. Dvir, Eden, Avolio, & Shamir (2002; cited in Lim & Ployhart, 2004), for example, demonstrated that transformational leadership training resulted in better unit performance.

In a study of U.S. light infantry rifle platoon leaders, Bass and colleagues (Bass, Avolio, Jung, & Berson, 2003) examined the extent to which transactional and transformational leadership predicted performance. Leadership ratings were collected during normal operational assignments and they were used to predict performance in a 2-week simulation designed to test the unit's effectiveness under high levels of stress and uncertainty. In addition, the researchers also evaluated how transformational and transactional leadership were mediated by unit cohesion (degree to which members of the platoon pull together to get the job done) and potency (degree to which platoon members were confident in themselves) in their prediction of performance. Ratings of the platoon leaders and sergeants were made 4 to 6 weeks prior to the training simulation. Expert observers also judged the platoon mission performance during the training exercise.

Results indicated that both transformational and transactional leadership had positive and direct effects on platoon performance (Bass et al., 2003). The finding that both transactional and transformational leadership predicted unit performance is in contrast with previous research, which has tended to favour transformational leaders (Bass et al., 2003). The authors speculate that the instability of the environment and complexity of procedures impose requirements for clear standards and expectations of performance which are representative of transactional-type leadership and that this might explain the inconsistent results (Bass et al., 2003). Mediation analyses showed that transformational leadership was related to team performance through its effect on team cohesion; however, transactional leadership was not similarly related to team cohesion (Bass et al., 2003). As a whole, then, this research points to the potential for leadership style to influence team performance.

Lim and Ployhart (2004) investigated transformational leadership in both a maximum and typical performance context. A maximum performance context includes conditions of short time span, awareness of being evaluated, and acceptance of instructions to exert maximum effort (e.g., small unit combat teams), whereas a typical performance context includes conditions of overall performance over a longer time span (Lim & Ployhart, 2004). Although transformational leadership was found to be predictive of team performance in both performance contexts, it was more predictive in the maximum performance context. It was speculated that certain team processes such as cohesion, trust and commitment matter most in maximum performance conditions (Lim & Ployhart, 2004). As a whole, then, there is some evidence of the importance of leadership in promoting team performance, but inconsistent results about the actual type of leadership that is likely to be most effective.

### **Gaps in Research**

Several important gaps were noted in theory and research. A theoretical article by Day et al. (2004) has argued that a critical need in the area of understanding leadership and team performance is in the area of distributed leadership. Understanding how leaders can be effective in both co-located and distributed contexts is certainly likely to be a critical area of research for the future. The few studies that have examined leadership have found that transformational leadership is positively associated with team performance, however, there is little if any research investigating why or how transformational leadership and/or transactional leadership is related to performance. And, although there is a vast amount of literature examining the relationship between leadership and individual performance, the research pertaining to the effect of leadership on team performance within the target domain (e.g. multinational and interagency teams) appears to be especially limited. Given that leadership can have such a large impact on team performance, especially in the military, full understanding of how to develop successful leaders in a way that maximizes team performance is of utmost importance.

## **3.4 Overview of Team Factors**

A multitude of team factors have been identified in the literature review. These factors include several characteristics of a team, including its organizational structure, team size, team history, physical distribution, individual characteristics, diversity, and leadership. Although there are other possible factors that contribute to team performance, these aforementioned variables are the most prevalent in the literature. The following section will summarize the findings in relation to different team factors.

Team structure has been shown to be a determinant of team performance through its effect on certain team processes. For instance, Macmillan et al., (2004) demonstrated that some optimized teams who are less interdependent (such that team members more independently control the team's resources) have fewer coordination problems thus leading to better performance.

Team size is another important consideration. Although larger teams can generate more inputs, studies have shown that coordination needs may increase (Bass, 1982; cited in Morgan & Bowers, 1995) and communication is more difficult with increased team size (Morgan & Lassiter, 1992). With regard to actual numbers, research has generally suggested that the optimal team size is anywhere from three to twelve people depending on how well the team is trained. Other variables, such as the type of task, must also be taken into consideration when determining the optimal size of the team.

Whether or not a team has a history of working together has been suggested to affect communication, coordination, and overall performance (Adelman et al., 1997). Team history has also been shown to promote shared knowledge, such that the longer teams have worked together the more experience they have with each other and thus the greater amount of shared task and team knowledge (Bower et al., 1997; cited in Essens et al., 2005), which are both critical to team performance.

The physical distribution of a team can have a large impact on performance; however, relatively little mainstream team research has investigated this area. Research examining physical distribution has found that co-located teams sometimes perform better than distributed teams on a number of tasks, showing indication of a "distributed disadvantage" (Cooke, 2004). Co-located teams had better team process behaviour, in terms of proportion of appropriate behaviours, and had more accurate holistic teamwork knowledge than distributed teams (Cooke, 2004).

Turning to team composition, the literature suggests that the two most frequently studied traits are conscientiousness and agreeableness, which have both been found to positively relate to team effectiveness.

Diversity has been conceptualized in a number of ways in the literature, however, most taxonomies agree that diversity can either be surface level (demographic) or deep level (attitudinal). Overall, diversity has been shown to have both positive and negative effects on performance. For instance, age diversity results in higher turnover rates, gender diversity leads to communication issues and racial diversity can lead to conflict. Apart from negative influences, diversity also brings about different perspectives and experiences which can be beneficial depending on the type of task (e.g., problem solving task). There are also a number of potential moderators that can alter the relationship between diversity and performance, including task difficulty, task interdependence, frequency, and duration of interactions and team size. As such, these variables need to be taken into account when studying the effects of diversity.

Leadership in teams has been shown to influence team performance. Recent research has focused on transformational and transactional type leaders. Although much attention has been given to leadership and individual level outcomes, relatively little research has focused on team outcomes. Of the research that has been conducted, it has generally found that transformational leadership has positive outcomes on team performance and team cohesion (Bass et al., 2003; Lim & Ployhart, 2004). In addition, transactional leadership has also predicted team performance in certain environmental settings (e.g., environments requiring the execution of complex procedures) (Bass et al., 2003).

In general, there can be little argument that all of these team characteristics have the potential to impact on team performance. The relative theoretical/empirical split seems to indicate that although these factors are important in their own right, they are more likely to be addressed simultaneously with other factors, perhaps as moderators of the relationship between tasks, team processes, and team performance. Although the research to date has provided us with a good framework, more empirical exploration of team factors will be necessary.

## 4. Task Factors

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A number of task characteristics have the potential to influence team performance. These include task complexity, workload required to complete the task, and the type of interdependence required to complete the task. Each of these task characteristics is reviewed in the following sections.

### 4.1 Task Complexity

Task complexity is an important task characteristic. At a theoretical level, more complex tasks have the potential to influence team performance negatively, as they are likely to impose more processing and coordination demands on teams. For example, in exploring communication networks within teams, Beck and Pierce (1996) have argued that the optimal communication network may depend on whether the task to be performed is simple or complex (Beck & Pierce, 1996). Centralized networks may be better for simple or repetitive tasks and decentralized networks may be best suited for more complex or novel tasks.

Apparently dissatisfied with the existing lack of clarity in terms of exactly how task complexity should be defined objectively, Rothrock, Harvey & Burns (2005) present a theoretical framework in order to quantify “task complexity” with more scientific rigour. They argue that within the available literature, there are many different researchers purporting to employ “highly complex” tasks in their research, but that there are no clear definitions or standards for what makes a task complex. The end result, then, is that findings fail to build on each other.

*“...we submit that the reason that researchers find different outcomes for similar tasks is largely based on their definition of the task. One researcher may call his task complex. Similarly, another researcher may call her task complex. Thus, the field of team performance assessment is inhibited by the ability to compare scientific studies.” (Rothrock, Harvey & Burns, 2005, p. 159).*

This framework offers several defining characteristics that can be used to further refine the actual complexity of a team task. Task complexity has been defined along three primary task characteristics: scope, structurability, and uncertainty (Harvey, 2001; cited in Rothrock, Harvey, & Burns, 2005). The scope of the task refers to the breadth, extent, range, reach, or general size of the task. The second task characteristic, structurability, refers to how well the sequences and relationships among the sub-tasks are defined. And finally, task uncertainty measures the degree of predictability or confidence associated with a given task (Rothrock et al., 2005). With this approach, then, these researchers hope that task complexity will be more objectively defined, and that this will promote the ability to compare across studies in

order to accumulate knowledge about how task complexity might correlate with team performance.

### **Empirical Research**

There is some evidence that task complexity impacts on team performance. For instance, a meta-analysis by Bowers et al. (2000) found a significant moderating effect of task complexity on the relationship between team diversity and performance. It was suggested that for tasks low in complexity, performance increases for homogenous teams, however for highly complex tasks, heterogeneous groups perform better. Unfortunately, this research is the only available study accessed for this review that discretely addressed task complexity and team performance.

## **4.2 Workload**

### **Theoretical Research**

Although correlated with task complexity, the workload imposed by a given task has also been argued to impact on team performance. Workload is often conceptualized in terms of the external demands of the situation as experienced by the individual (Essens et al., 2005). These demands can derive from task requirements or situational factors (e.g. time pressure). There are a number of different types of workload that can be experienced, including physical workload, cognitive workload, emotional workload, and time pressure. These factors, however, have typically been considered as indicators of global workload.

### **Empirical Research**

Workload has been argued by Salas, Bowers, and Cannon-Bowers (1995) to be one of the most studied issues in team performance. In general, workload has most frequently been conceptualized as a moderator of team performance rather than as a direct influence.

Physical workload and its effect on performance have been studied empirically. For instance, in a study of command and control operators, fatigue among operators resulted in decreased communications regarding their assets and coordinating strategies, as well as fewer expressions of encouragement (Harville, Lopez, Elliott, & Barnes, 2005). The findings from the study further illustrated that the number of hostiles killed by friendlies decreased and the number of friendlies killed by hostiles increased with higher levels of fatigue (and presumably workload).

Morgan, Braun, and Kline (1992; cited in Bowers et al., 1997) studied workload in terms of decision complexity (i.e. cognitive workload) and found that although there were no performance differences among teams under high or low workload conditions, teams in the high workload condition communicated more frequently.

Moreover, teams under low workload demonstrated more task-related statements, while high workload teams demonstrated more non-task related statements (Bowers et al., 1997).

Other research suggests that the relationship between workload and team communication is not necessarily a linear one. For instance, Kleinman & Serfaty (1989; cited in Bowers et al., 1997) had teams perform a resource allocation task in a given timeframe. The results of the study indicate that as workload (conceptualized as time pressure) increased from low to medium, participants increased the frequency of explicit task-related communication. However, when workload increased from medium to high, communication decreased drastically, although team performance was maintained (Kleinman & Serfaty, 1989; cited in Bowers et al., 1997). It seems likely, however, that other team processes (e.g. shared knowledge) might have helped to buffer the impact of increased workload. However, the fact that changes in workload influenced team communication but not team performance is an interesting one worth further investigation.

More recent empirical studies have shown that workload impacts on both team performance and process. Research by Cooke (2004) showed that both co-located and distributed teams were more likely to learn the task during lower workload missions, (conceptualized as the number of targets and mission constraints), and were less adept once workload increased. Moreover, there was also evidence that higher levels of workload impaired team processes, as observed process scores were significantly lower in high workload missions than in low workload missions. As such, there is good empirical evidence from research in relevant domains that workload can influence both team performance and process. It will be important for future researchers to develop a common operationalization of workload in order to move this area of research forward.

## 4.3 Task Interdependence

### Theoretical Research

Task interdependence refers to the extent that team members interact and depend on each other in order to attain a goal (Campion, Medsker, & Higgs, 1993; cited in Rico & Cohen, 2005). The interdependence required to perform a task within a team setting is a very important task characteristic. For instance, Steiner (1972; cited in English et al., 2004) suggested that there are four types of tasks to be performed by teams. The first type is the additive task, which requires that individual resources are summed or averaged in order to perform the task (e.g., brainstorming task). The level of performance is based on the extent to which each member adds to the collective pool of the overall team. The second task type is the conjunctive task, whereby performance is based on the team's lowest performer (e.g., assembly line task). Conversely, the third task type, the disjunctive task, is based on the team's highest performer (e.g., problem solving task). In a disjunctive task such as problem solving,

only one good answer is required to represent the team's performance. Finally, the discretionary task is only performed by self-managed work groups as they have the authority to autonomously decide how to divide their resources (e.g., management team initiating organizational initiatives).

Similarly, Thompson (1967; cited in Wageman, 1999) specified three types of task interdependence based on the degree of coordination that is required among team members. Pooled interdependence does not require any coordination as sub-tasks are performed separately and in no specified order. Sequential interdependence requires linear coordination, such that subtasks are completed in a specified sequence (with no return to earlier steps). Finally, tasks requiring reciprocal interdependence impose the most complex coordination requirements as the completed subtask of one team member becomes the input for the second, and the second's completed subtask becomes the input for the third and so on (Wageman, 1999). Certain structures of the task affect the degree of required task interdependence (Wageman, 1999). For instance, the physical technology of the task may demand simultaneous action by team members or it can prevent it. As such, tasks that require different forms of interdependence clearly put different coordination demands on teams.

In this sense, it is critical to point out the interrelatedness of the task interdependence construct and several other relevant team constructs. For example, research by MacMillan et al. (2004; reviewed in Team Structure and Coordination sections) shows the critical relationship between task interdependence and team structure. Indeed, in a real way, these dimensions can perhaps be considered different sides of the same coin. The task interdependencies determine the nature of coordination required, as do the "pathways" created by changes in team structure.

### **Empirical Research**

Task interdependence has been generally researched as a moderating variable with regard to team performance. A number of studies have investigated how task interdependence can alter the relationship between factors such as team composition or team process and team performance.

As most research on task interdependence has focused at the individual level, there is little available research addressing the team level. The research that does exist has generally considered task interdependence as a moderating variable and not as a predictor of team performance. For instance, English et al. (2004) found a significant relationship between conscientiousness and crew performance only for tasks that were additive and disjunctive but not when the task was conjunctive. This suggests that the form of task interdependence influences the relationship between team members' personalities and their performance.

A more relevant study of multiteam systems manipulated the degree of interdependence required for success amongst teams (Marks et al., 2005). The multiteam systems consisted of four human participants who flew two simulated aircraft as two-person

teams, “as part of a larger system that included six other allied aircraft controlled by artificial intelligence” (Marks et al., 2005, p. 966). The air-to-air team was responsible for destroying enemy aircraft, and air-to-ground team was responsible for destroying enemy ground threats. There were also three task interdependence conditions. In the pooled goal hierarchy condition, interdependent action amongst teams was not required for success. In the sequential goal hierarchy condition, teams were interdependent, but the task was sequential rather than simultaneous such that one team needed to complete its part before the next could begin theirs. Finally, in the intensive goal hierarchy condition, “concurrent, coordinated efforts” were required of both teams (Marks et al., 2005, p. 967). Thus, greater coordination across teams (rather than within teams) was required in the latter two conditions. Team processes were measured in terms of transition phase processes (e.g. planning, mission analysis) at the multiteam level, as well as action phase processes (e.g. monitoring, backup behaviour) at the multiteam level and at the within-team level. These measures allowed a comparison of whether efforts were directed more toward cross-team processes or within-team processes. Multiteam performance was measured in four ways: 1) primary and secondary target destruction, 2) health/survival of the two human-controlled aircraft, 3) health/survival of the six artificial intelligence-controlled aircraft, and 4) penalty for friendly fire.

Results indicated that performance was significantly predicted by within-team action phase processes. This suggests that the efforts of individuals within their teams did contribute to multiteam performance. However, cross-team processes also explained additional variance in team performance, with higher levels of cross-team processes predicting performance above and beyond what could be predicted by within-team processes. This was particularly true in the high interdependence condition. This suggests that when task interdependence is high, the performance of multisystem teams is likely to be better predicted by processes that occur between than within teams. Moreover, contrary to researcher expectations, multiteam transition phase processes were most highly related to performance when teams worked in less interdependent goal hierarchies. From our perspective, this is an interesting finding, as it suggests that planning and mission analysis is most highly related to multi-team performance when team members are less rather than more interdependent. Given the future importance of this area of research, it will be critical to better understand the relationship between task interdependency and team performance.

#### **4.4 Overview of Task Factors and Gaps Identified**

The literature review showed task complexity, workload, and task interdependence to be the most common task characteristics noted in research. However, although there is agreement that task factors are important variables in team effectiveness, the research on task type and task characteristics is often noted to be relatively scarce (e.g. Espinosa et al., 2004). The majority of task characteristics have been studied as moderating variables.

Task complexity refers to the scope, structurability, and uncertainty of the task. Research examining task complexity has found that it moderates the relationship between team diversity and performance, such that for tasks low in complexity, performance increases for homogenous groups, however, for tasks high in complexity, heterogeneous groups perform better (Bowers et al., 2000).

A second task characteristic, workload, refers to the demands of the situation and can include physical workload, cognitive workload, emotional workload, and time pressure. Physical workload, in terms of fatigue, has been found to result in decreased communications, coordination strategies and expressions of encouragement in command and control operators (Harville et al., 2005). Cognitive workload, in terms of decision complexity, and time pressure do not necessarily lead to performance differences but they do result in different communication patterns, such that those in low workload conditions demonstrate more efficient communication.

Finally task interdependence refers to the degree to which team members interact and depend on each other in order to attain a goal (Campion et al.; cited in Rico & Cohen, 2005). The literature has identified a number of different types of task interdependence, including pooled interdependence, sequential interdependence, and reciprocal interdependence. Similar to other task characteristics, task interdependence has been mainly researched as a moderating variable with regard to team performance. For instance, studies have found a strong relationship between autonomy and team performance when task interdependence is high and a negative relationship when task interdependence is low (Langfred, 2005).

As Bowers et al. (2006, p. 4) have argued, there is considerable work left to do in understanding the relationships between task characteristics and teams:

*“We know some factors that seem to be associated with effective teams, but we really do not know how well they generalize across tasks.”*

Understanding the nature of a team’s task, however, has been argued to be critical, in part because different tasks create different kinds of interdependencies that impact on other team processes, such as coordination (Espinosa et al., 2004). Therefore, although task characteristics are typically unlikely to impact directly on team performance, they are likely to interact with both team processes and team characteristics.

Task complexity, although deemed an important variable influencing team performance, has not been extensively researched. The problem regarding task complexity is how it is defined. Given the lack of consistency in conceptualizations of task complexity, strong conclusions regarding its effect on performance cannot be drawn. As such, research needs to further investigate how to accurately define and measure task complexity. Defining task complexity in terms of scope, structurability, and uncertainty (e.g. Rothrock et al., 2005) may help to ensure more consistency.

## 5. Team Processes

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Team processes play an important role in team performance. Team processes refer to “factors that members do not bring to the group, but which emerge out of group interactions” (Essens et al., 2005, p. 4-3). More formally, team processes can be defined as:

*“members’ interdependent acts that convey inputs to outcomes through cognitive, verbal, and behavioural activities directed towards organizing taskwork to achieve collective goals...Team processes are the means by which members work interdependently to utilize various resources, such as expertise, equipment and money, to yield meaningful outcomes. (Marks, Mathieu and Zaccarro, 2001; cited in Marks et al., 2005, p. 965).*

There are a host of team processes that are examined in the team performance literature, with some broad agreement across researchers as to what major team process factors or variables contribute to team performance, but differences in how these factors are labelled and organized..

### 5.1 Shared Knowledge

#### Theoretical Research

The extent to which team members share knowledge is one primary aspect of team processes. At a team level, shared knowledge refers to a team’s collective knowledge about various team- and task-relevant parameters. Shared knowledge may include roles and responsibilities, time constraints, and progress toward goal attainment (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Conceptualizations of shared knowledge consistently suggest that it is reflected in mental models. Shared knowledge has been conceptualized as “...a component of team cognition that includes constructs such as shared mental models and team situation models” (Cooke, Kiekel, et al., 2003, p. 180). The terms shared knowledge and shared mental models appear from the literature to be interchangeable (e.g., Mathieu et al., 2000; Swain & Mills, 2003). Although not always defined at a team level, mental models refer to “organized knowledge structures that allow individuals to interact with their environment” (Mathieu et al., 2000, p. 274). These knowledge structures include “team members’ expectations concerning the time-sequencing of events, the tasks to be performed, and how individual efforts will be coordinated” (Bailey & Thompson, 2000, p. 1). Thus, shared knowledge is reflected in mental models that are common among members of a team participating in the same system.

Mental models serve three primary functions of “help[ing] people to describe, explain, and predict events in [the] environment” (Mathieu et al., 2000, p. 274). In

addition, in the context of teams, optimal mental models require individuals to be aware of “the problem structure, the roles and skills of the team member as they relate to the problem and the shared awareness that each member of the team possesses this knowledge” (Fiore & Schooler, 2004, p. 139). Within a team context, then, several different mental models must be simultaneously in play. The two most important types of models include task-related mental models and team-related mental models (Cannon-Bowers et al., 1993; cited in Mathieu et al., 2000; Klimoski & Mohammed, 1994; cited in Mathieu et al., 2000), as shown in Table 3.

**Table 3: Types of shared mental models within teams  
(Mathieu et al., 2000, p. 275)**

| Type of model        | Knowledge content                                                                                                                             | Comment                                                                                                                                                                                          |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Technology/equipment | Equipment functioning<br>Operating procedures<br>System limitations<br>Likely failures                                                        | Likely to be the most stable model in terms of content. Probably requires less to be shared across team members.                                                                                 |
| Job/task             | Task procedures<br>Likely contingencies<br>Likely scenarios<br>Task strategies<br>Environmental constraints<br>Task component relationships   | In highly proceduralized tasks, members will have shared task models. When tasks are more unpredictable, the value of shared task knowledge becomes more crucial.                                |
| Team interaction     | Roles/responsibilities<br>Information sources<br>Interaction patterns<br>Communication channels<br>Role interdependencies<br>Information flow | Shared knowledge about team interactions drives how team members behave by creating expectations. Adaptable teams are those who understand well and can predict the nature of team interactions. |
| Team                 | Teammates' knowledge<br>Teammates' skills<br>Teammates' attitudes<br>Teammates' preferences<br>Teammates' tendencies                          | Team-specific knowledge of teammates helps members to better tailor their behavior to what they expect from teammates.                                                                           |

Other important mental models concern the technology and equipment a team uses, team interaction such as roles and responsibilities, and the skills, attitudes, and preferences of team members (Cannon-Bowers et al., 1993; cited in Mathieu et al., 2000).

It is also critical to note the strong interrelatedness between shared mental models and other critical team processes. Indeed, team knowledge has been argued to be the mechanism underlying “the seamless execution of coordinated behaviors” (Fiore & Salas, 2004, p. 236). To the extent that team members can understand the probable

actions of other teammates, they are likely to be better able to anticipate their actions, and to gauge their own actions accordingly. This, at its core, is implicit team coordination. Similarly, although differing patterns are noted in the literature, there is also a strong relationship between shared mental models and team communication. On one hand, some researchers have noted that as a team's mental models improve, the need for coordination and/or communication should decrease (e.g., Lindgren, Berggen, & Hirsch, 2004; MacMillan et al., 2004). However, other researchers have noted that mental models become redundant in environments in which communication among team members is freely accessible because hypotheses about other team members' behaviours are not required (Cannon-Bowers et al., 1993; cited in Mathieu et al., 2000). Clearly, other key team processes such as team planning and the ability to adapt to changes are also integral to shared mental models.

The relative importance of shared mental models will likely also depend on the demands of a task. For example, shared mental models are argued to be critical in helping teams to organize their efforts in highly chaotic environments, and in response to changing task demands, but may be less critical when time is unlimited and explicit communication is possible (Stout, Cannon-Bowers, Salas & Milanovich, 1999). This suggests that factors such as workload may influence the need to share mental models.

### **Empirical Research**

Empirical research with undergraduate students has found that shared mental models are positively related to both team processes and team performance. In a study (Mathieu et al., 2000) with undergraduate students assigned to two-person teams operating a simulated fighter aircraft, participants received training for both individual and collective responsibilities. That is, one team member was responsible for flying and positioning the plane; the other was responsible for maintaining speed "calling up different weapons systems, and gathering information" (Mathieu et al., 2000, p. 276). Both players were collectively responsible for firing weapons. Mental models were assessed using individual relatedness rankings of various relevant attributes such as diving and climbing, banking and turning, etc. Individual team member rankings were compared with the rankings of the other team member for "sharedness". Team process was measured by two independent coders providing ratings of strategy formation and coordination (e.g., "To what extent did the team plan together and coordinate its efforts?"), cooperation (e.g., "To what extent did they cooperate well during the missions?"), and communication ("To what extent was information about important events shared within the team?"). Measurement of performance included computer-based measures of survival, reaching waypoints, and shooting down enemy planes. Hypotheses explored whether teams with more experience would display more "sharedness" in their models, whether teamwork and taskwork models could be distinguished, and whether team processes such as communication and cooperation would mediate the relationship between shared mental models and team performance.

Results indicated that participants did have distinct task and team mental models and that the sharedness of these models affected team processes which, in turn, influenced performance. Specifically, team and task model sharedness were both significantly related to team processes, and team processes were significantly related to team performance. However, while team model sharedness was significantly related to team performance regardless of team processes, task mental model sharedness was not. This suggests that team mental models impact significantly on team performance by shaping team processes. In contrast, taskwork mental models may impact team performance indirectly through team process.

Work by Cooke, Shope and Kiekel (2001; reviewed in Physical Distribution section) explored shared mental models in the context of distributed versus co-located teams. Results showed that distributed and co-located teams showed no differences in terms of their shared taskwork mental models, although knowledge in both kinds of teams did grow with experience. There were also no differences in shared teamwork mental models. However, shared taskwork mental models within the teams did predict team performance, as teams with higher levels of knowledge accuracy, intrateam similarity and consensus accuracy earlier in a mission performed better later in the mission.

A series of experiments by Cooke, DeJoode, et al. (2004) examined the development of teamwork and taskwork mental models within distributed teams. The first randomly assigned three-person teams of students to distributed or co-located teams tasked to fly a simulated UAV and to navigate the UAV to target areas in order to take overhead pictures of these areas. In order to complete the mission, team members were required to work together. Teamwork and taskwork knowledge were measured with self-assessment questionnaires at the individual and team level and included ratings as to the communications necessary for goal attainment as well as relatedness ratings for relevant aspects of the mission. Several aspects of team performance were measured including the duration each team member spent in alarm and warning states and the rates at which "...critical waypoints were acquired" and targets were photographed successfully (Cooke, DeJoode et al., 2004, p. 24). Team process behaviour (including communication and coordination) was also scored by independent raters.

Results indicated that the sharedness of the teamwork and taskwork mental models did not differ in distributed vs. co-located teams. The only significant difference was that co-located teams developed taskwork models slightly more quickly than did distributed teams, suggesting that teams might have been able to get "on track" a bit faster because of co-location.

A second experiment with similar participants changed the timing of some key measures slightly while holding the general experimental procedure constant. The results of this experiment contradicted those of the first study. Distributed teams showed poorer shared mental models of both teamwork and taskwork. However, this did not impact on subsequent team performance, as there were no significant differences between distributed and co-located teams. Importantly, however, results

did indicate that team processes such as communication and coordination were better predictors of team performance than was shared knowledge.

Research by Marks, Sabella, Burke, and Zaccaro (2002) offered more insight into the relationship between mental models, coordination and team performance. Although the main part of the study relates to the impact of cross-training on team performance, other elements of this research are highly relevant to the problem at hand.

Participants were 135 undergraduate students divided into 45 teams of 3. An Apache helicopter flight simulator was used with participants assigned to one of 3 roles: a pilot, a gunner and a radar specialist. The goal of the experimental scenario was for the team to work together on this tactical task to take out enemy targets on the ground. There were 3 main challenges, including protecting against enemy helicopters trying to shoot down the team's Apache, the unfamiliar terrain, and intermittent enemy surface-to-air missiles. Measures included shared team interaction models, team coordination (including backup behaviours) and team performance (e.g. number of targets killed).

Relevant results focused on the relationship between shared mental models and team performance, and showed that the relationship was completely mediated by team coordination and backup behaviours. This again suggests that shared mental models are perhaps more directly relevant to team processes than to team performance.

A second study with a similar design used a different task. This task required participants to function as part of a 3-person tank platoon, whose goal was to work as a team to retrieve enemy pillboxes located in enemy territory. Measures again included shared team-interaction models, measures of coordination and team performance.

Results again showed that the relationship between shared mental models and team performance was wholly mediated by coordination. That is, after controlling for coordination, there was no relationship between shared mental models and team performance. This research again supports the view that shared mental models help to enable team performance through their positive effects on the ability of team members to work as a team.

Marks, Zaccaro, and Mathieu (2000) explored whether shared mental models (in terms of both similarity and accuracy) were positively associated with both better communication and better team performance in general, but particularly in novel environments.

Participants were assembled into 79 mixed-gender 3-person teams, and undertook a tactical tank simulation called Team Wargame Interactive Simulation Training

(TWIST).<sup>5</sup> This task required participants to operate as part of a 3-tank platoon and to work together to shoot 10 enemy targets and return them to “friendly” territory. The novelty of the simulation environment was also manipulated to be either high or low. The low novelty environment matched those encountered in practice missions. The high novelty environment presented a wholly different terrain and layout in order to present a familiar task in an unfamiliar context. Relevant measures included shared mental models (accuracy and similarity), team communication processes (quality of assertiveness, decision-making and mission analysis, adaptability and flexibility, situational awareness, leadership, and communication<sup>6</sup>) as rated by observers, and team performance measures (e.g. number of enemies destroyed).

Analyses explored the relationship between shared mental models and communication. Results showed that mental model similarity (assessed as degree of overlap among members by observers) explained a significant proportion of variance in team communication processes but that the sheer accuracy (assessed by raters pertaining to critical mission functions, appropriateness of role assignments, and reasonable sequence of actions) of mental models did not. Looking at the interaction between mental models and communication showed that “...similar mental models enhanced communication processes regardless of accuracy level” (Marks et al., 2000; pp. 979). Lastly, there was also evidence linking shared mental models (both accuracy and similarity) and team performance. The pattern of results suggested that teams with good mental models could perform well even when they were not completely similar in their perceptions. However, simply being “in sync” did not result in good team performance. This suggests that mere similarity in some forms of shared knowledge may predict good communication, but does not necessarily predict good team performance.

Research by Sterling and Burns (2005) examined whether networked battle command provided command teams with a shared mental model that enabled cooperation. Sterling and Burns (2005) examined this question at the three different levels in a hierarchical chain of command. From high to low, these levels included the unit of employment, unit of action, and combined arms battalion.<sup>7</sup> This study was part of a 19-day battle command simulation that employed future organization, doctrine, and explored manoeuvre command and control (MC2) procedures. Twenty military participants were organized as commanders into three command teams: UE command team, UA-level commanders, and CAB-level commanders.

Relevant measures included shared mental model assessments, which consisted of commander congruence and team congruence. This research used a daily survey

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<sup>5</sup> Manipulations of leader briefing and team interaction training are not relevant here and are not discussed.

<sup>7</sup> The Unit of Employment and Unit of Action are new nomenclature used in the United State’s Objective Force military transformation plan (Objective Force Echelonment, 2005; Unit of Employment, 2005; Unit of Action, 2005).

asking participants to pick the two most significant threats to operational success from a list. Agreement between any two participants was assessed as 0 (no congruence) or 1 (complete congruence). Commander congruence was calculated by averaging subordinate commanders' congruence with the superior commander's mental model. Sterling and Burns (2005, p. 6) indicated that an example would be the average of "the first, second, and third UA commanders, fires UA commander, and aviation UA commander with the UE commander's mental model". Team congruence was the average congruence among subordinate commanders only. Unfortunately, no additional information detailing calculations was provided except that the authors stated that due to small sample size, inferential statistics were not conducted. In addition, measures of workload and situation awareness were also taken.

Overall, descriptive analyses suggested that the teams were able to maintain moderate perceived workload and good situation awareness. In comparison, the objective measures of team and commander mental model congruence remained low throughout the experiment, suggesting a low shared understanding of mission threats amongst commanders, and a lack of team learning despite networked battle technology. The authors advocate that smaller scale, structured experiments may enable better understanding of the inability for teams to develop shared mental models within this type of setting.

Other empirical work provides additional evidence of importance of workload in promoting mental model development. A study by Bailey and Thompson (2000; reviewed in Team Adaptability section) with participants in air traffic control simulations of varying difficulty based on air traffic density (low, medium, or high) showed that air traffic density was differentially predictive of performance, with better performance in low density conditions but the formation of better team mental models in higher density. This may be because mental models are integral in stressful or risky conditions in order to achieve successful performance.

Team mental model research presents little clear and unequivocal evidence that shared knowledge is predictably related to team performance, but fairly consistent findings suggesting that team processes are very important in shared knowledge. Indeed, there is some evidence that teamwork mental models have a stronger relationship with team performance than do taskwork mental models (e.g. Mathieu et al., 2000). In addition, team processes seem to be better predictors of team performance than mental models (Cooke, DeJoode et al., 2004). This might suggest either that current measures of shared knowledge do not adequately capture the complexity of team knowledge or that simply addressing the facts and information that team members hold might be only one small part of the "story" of how teams perform. Clearly, as prominent researchers and theorists have noted, more attention needs to be given to the truly social aspects of team knowledge in order to better predict actual team performance.

## Gaps in Research

Six years ago, Mathieu et al. (2000) suggested that mental models had not received a great deal of empirical study because of the host of other team performance predictor variables competing for attention. There appears to have been much research concerning mental models since that time which has sometimes shown that better mental models lead to better team performance.

However, some researchers have argued that more attention needs to be paid to the exact mechanism by which shared team knowledge is actually converted into the coordination of a unitary entity (Fiore & Salas, 2004, p. 236). The implicit assumption that shared team knowledge will necessarily result in team coordination needs to be tested more explicitly. They argue that "...based on the consistent appearance of the coordination goal, one could reasonably argue that team coordination is almost the de facto goal of team cognition." What is critical to remember, they argue, is that the process by which shared cognition actually does enable team coordination is still the critical issue that is, as yet, unresolved. This, they argue, will only be achieved with a broader view of how teams actually function from both cognitive and social perspectives.

As has been noted by shared team knowledge researchers, the role of knowledge about other teammates appears to have been underemphasized in existing shared knowledge research. Moreover, the measures that do exist have perhaps little true hope to capture the dynamism and complexity of social knowledge. Simply understanding one's teammates' role is likely to have little impact unless one truly believes that one's teammate is competent and motivated to successfully execute the role. As such, conventional measures of team knowledge may well neglect critical aspects of team knowledge such as the level of trust within a team. As such, in light of the fact that team processes seem to mediate the shared knowledge/team performance relationship, the actual power of team processes may actually be underrepresented in the existing literature. Clearly, more attention needs to be paid to a richer set of team processes than is reflected in current approaches to understanding team knowledge.

Another specific area of interest purported to be underrepresented in the current shared team knowledge literature relates to the development of shared team knowledge over time. Cooke and colleagues (Cooke, DeJooode et al., 2004) suggest that scholars should begin to look beyond whether or not team mental models are developing, but to how their content evolves as teams work together over time. That is, although research clearly suggests that mental models do develop, and although there is some expectation that they aid team performance, we do not know how they emerge or evolve. This suggests a greater need to consider team history and shared knowledge simultaneously.

There is also some mention in the literature that shared team knowledge research has been lacking in quantity of empirical studies. For example, Espinosa et al. (2004, p. 113) have argued that:

*“Team cognition research has focused primarily on developing theoretical foundations, but there has been a paucity of empirical studies. Fortunately, this is beginning to change.”*

Indeed, it is encouraging that this is beginning to change. However, to this point, shared knowledge research has, in general, focused primarily on co-located and real-time teams (Espinosa et al., 2004). This is certainly a major criticism that has been addressed by the research programs of Nancy Cooke, but the issue of how distributed teams work to develop shared knowledge is currently inadequately addressed. Although there has been good progress within this area of research, there is still considerable work needed in order to draw strong and unequivocal conclusions about the relationship between shared knowledge and team performance. From the perspective of the CF, more attention needs to be paid to shared knowledge within more diverse contexts, in which people from different elements and even different agencies need to share their knowledge in order to work as team members.

## 5.2 Communication

### Theoretical Research

There is considerable work addressing team communication. Some researchers conceptualize communication from an information processing approach, whereas others use a broader social interaction perspective. Researchers with an information processing approach define it as “the active exchange of information among team members using proper technology, to clarify or acknowledge the receipt of information” (McIntyre, Strobel, Hanner, Cunningham, & Tedrow, 2003, p. 4). Social interactionists define communication as “aspects of openness, style, and expressing feelings and thoughts” (Essens et al., 2005, p. 5-14).

The literature suggested an important theoretical distinction relevant to communication, namely, implicit versus explicit communication. Implicit communication involves the voluntary or spontaneous delivery or provision of information without an explicit request for it, and explicit communication involves “offering information in response to a specific request” (Swain & Mills, 2003, p. 2). As will be discussed in the upcoming measurement section, this relationship between transfers of information and requests for information has been captured by anticipation ratios.

Team communication has frequently been explored in relation to the technologies that enable communication. Recent advances in technology including faxing, computer networking, e-mail, and the internet have revolutionized communication in our working and social lives (Colquitt et al., 2002; Driskell et al., 2003; Lindgren et al.,

2004). Such computer-mediated technology typically allows the ability to configure different types of networks depending on which team members need to communicate with whom. These network configurations also have the potential to influence team communication, team process and team performance.

A theoretical paper by Beck and Pierce (1996) explores the impact of differing network configurations within teams. Network configurations can be characterized as decentralized, centralized, or hierarchical (Beck & Pierce, 1996). The two configurations in Figure 2 represent decentralized configurations “because all group members have a potentially equal impact on communication flow” (Beck & Pierce, 1996, p. 13).

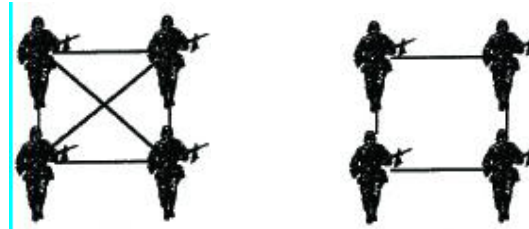


**Figure 2: Decentralized communication networks  
(Beck & Pierce, 1996, p. 13)**

In contrast, the three configurations in Figure 3 represent centralized networks “because messages are routed through a key member” (Beck & Pierce, 1996, p. 13).

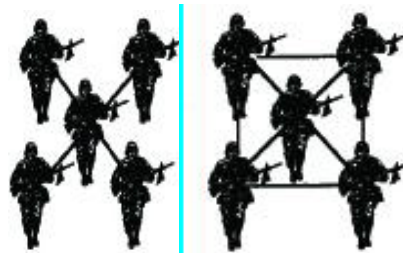


**Figure 3: Centralized communication networks  
(Beck & Pierce, 1996, p. 13)**

Hierarchical networks are similar to centralized networks in that there is a key member, the leader. However, a tier immediately beneath the leader consists of more junior leaders, who communicate the top leader’s messages to the bottom tier (Beck & Pierce, 1996). Figure 4 depicts such a network.

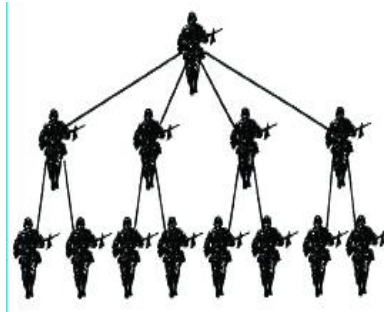


**Figure 4: Hierarchical communication network  
(Beck & Pierce, 1996, p. 13)**

Centralized networks are probably most representative of military networks (Beck & Pierce, 1996). The message filtering function of centralized networks may enhance coordination and reduce extraneous communication leading to more efficiency. However, centralized networks may lead to reduced team performance, reduced individual member satisfaction with working in the team, and reduced communication possibly because non-central members perceive their contributions as insignificant (Beck & Pierce, 1996). In addition, centralized networks may be associated with reductions in interdependent teamwork and information transfer because some team members may not know what others are doing or whether they require help (Beck & Pierce, 1996). Clearly, this could result in reduced performance due to poor resource allocation or a lack of back-up behaviour. Further, bottlenecks in information transfer may occur in centralized networks when the central member becomes overloaded with task work (Beck & Pierce, 1996). Ironically, this is most likely to occur in the leader in high-stress situations in which leadership and communication are crucial. A hierarchical network may “protect the key member from work overload” (Beck & Pierce, 1996), however, it imposes size constraints and requires a strong second tier in order to ensure accuracy of messages.

Beck and Pierce (1996) also argue that the optimal communication network may depend on whether the task to be performed is simple or complex (Beck & Pierce, 1996). Centralized networks may be better for simple or repetitive tasks and decentralized networks may be best suited for more complex or novel tasks. Unfortunately, however, these ideas do not appear to have been tested empirically.

It is important to emphasize that team communication is inextricably linked with team coordination and other team processes. For example, some researchers have argued that communication is necessary for team coordination and may be the foundation for good team performance (MacMillan et al., 2004). In this sense, the need for communication has also been conceptualized as a critical form of “overhead” that may detract from team performance if the team is not able to manage the many interdependencies necessary for the team to perform. As MacMillan et al. (2004, p. 61) have noted:

*“Because communication is essential to team performance, effective team cognition has a communication “overhead” associated with the exchange of information among team members. Communication requires both time and cognitive resources, and, to the extent that communication can be made less necessary or more efficient, team performance can benefit as a result.”*

Similarly, development of mental models may replace communication (Mathieu et al., 2000). Moreover, researchers believe that because “communication requires both time and cognitive resources”, team performance can benefit from a reduction or increased efficiency in communication (MacMillan et al., 2004, p. 61). MacMillan et al. (2004, p. 63) argue that

*“Implicit coordination is associated with effective performance if, and only if, team members have an accurate understanding of each other’s needs, responsibilities, and expected actions; and communication is essential to that understanding.”*

This shows that team coordination and shared knowledge are inextricably linked with team communication.

Theoretically, then, there is agreement that good communication is a positive influence on team performance, and that team communication is integrally linked with other key team processes including team coordination and shared mental models. In addition, there is also good agreement that communication technologies may play an important role in communication processes. The distance and communication configurations afforded by technology have likely affected communication among teams and these changes may influence team performance (Beck & Pierce, 1996; Colquitt et al., 2002). Moreover, theorists have also argued that good communication that is relatively equal among team members and contains crucial information, such as status, may lead to better team performance (Beck & Pierce, 1996; Lindgren et al., 2004).

### **Empirical Research**

As noted earlier in this review, team communication research is one of the most prominent forms of team research, and it continues to thrive. In general, this body of work can be best described as “mixed” and as showing very inconsistent results (Salas et al., 1995). This, of course, may be due to the lack of consistent measures of team communication, and by the fact that tasks with very different characteristics are likely to show different team communication patterns as well as impacts on performance.

Research has found evidence of a positive link between good communication and team performance (i.e., MacMillan et al., 2004). This research argues that the need for communication is generated by coordination requirements, while communication efficiency is related to mental models. In a study already reviewed in this paper (see

the Team Structure section), an experiment with ten 6-person teams of military officers participating in a Joint Task Force (JTF) Command Team simulation of a mission, MacMillan et al. (2004) examined communication within an optimized structure and a traditional structure. Communication measures identified two aspects of communication including communication rates (showing the need for communication, and the efficiency of communication (as measured by anticipation ratios).

Results found that communication was reduced but more efficient in the optimized team. Moreover, the optimized team performed better than the traditionally structured team. The researchers argued that this was because the reduction in interdependence that went along with the optimized team structure reduced the need for coordination. In turn, the reduced need for coordination apparently reduced communication “overhead” increasing communication efficiency. These results therefore suggest that communication efficiency was positively related to team performance, but communication need was negatively related to team performance.

According to these results (MacMillan et al., 2004) communication likely influences team performance through its relationship with coordination. MacMillan et al. (2004, p. 76) suggest that “the workload associated with communication... was a critical factor in the performance of teams under the different organizational structures” and that this workload was successfully mitigated in the optimized teams through resource allocation strategies. It seems that when communication workload can be reduced, communication efficiency and outcome performance within teams can improve.

The failure to find similar results in a second study (MacMillan et al., 2004; reviewed in Team Structure section) suggests that reductions in communication overhead do not necessarily result in improved team performance. In this study, teams with high communication needs were able to perform more efficiently than teams with less need. This suggests that the relationship between communication needs and team performance may depend somewhat on the nature of the task.

Research by Stout, Cannon-Bowers, Salas, & Milanovich (1999; reviewed in Planning section) also shows that teams that use more efficient communication strategies (by providing higher rates of information in advance) perform significantly better under high pressure conditions than teams that use less anticipatory communication. Importantly, this work also showed that the existence of anticipatory communication was also related to team planning capabilities, as teams with better planning abilities also communicated more efficiently. This suggests that communication and good team planning go hand in hand.

The three UAV simulator studies described in the Shared Knowledge section also suggest that good communication behaviours are related to team performance (Cooke, DeJoode et al., 2004). Recall that three experiments involved novices and experts flying simulated UAVs in distributed or co-located three-person teams. Communication measures were combined with other team process indicators (e.g.

coordination). Several aspects of team performance were measured including time spent in alarm and warning states, attainment of critical waypoints and photographs of targets.

Overall, team processes including communication were slightly better in co-located teams than in distributed teams with distributed teams communicating less. These effects were strongest in conditions of high workload. Moreover, team processes such as communication and coordination were better predictors of team performance than was shared knowledge. This work provides good evidence that communication is an important factor in team performance.

However, this research seems somewhat contradictory to the findings of the MacMillan et al. (2004) study, which suggests that lower need for communications (and higher communication efficiency) are associated with better performance in optimized teams. Clearly, it is difficult to find clear and consistent convergence in the team communication literature.

Other research has focused on the technological constraints of computer-mediated communication. Although the kind of technology available to assist communication has the potential to seriously impact team performance, empirical research has been equivocal. Research suggesting that computer-mediated communication is not as desirable as face-to-face communication include findings that indicate that computer-mediated communication reduces information exchange (e.g., Hedlund, Ilgen, & Hollenbeck, 1998; cited in Colquitt et al., 2002), increases decision making time thereby slowing progress toward a goal (e.g., Siegel, Dubrovsky, Kiesler, & McGuire, 1986; cited in Colquitt et al., 2002; McLeod, 1992; cited in Driskell et al., 2003), and reduces the likelihood of developing mental models (e.g., Thompson & Coover, 2003; cited in Driskell et al., 2003). Other research, however, indicates that teams with computer-mediated communication show comparatively more equal participation among members than face-to-face communication in teams (e.g., Weisband, 1992; cited in Colquitt et al., 2002; Weisband, Schneider, & Connolly, 1995; cited in Driskell et al., 2003). As such, although results in research exploring communication technologies and team performance are fairly inconsistent, this area of research has clearly burgeoned in recent years, and stands as an important future area of research.

An example of new communication technology is shared workspace programs such as Microsoft NetMeeting®. As reviewed in detail in the Physical Distribution section, Fletcher and Major (2006) examined how three different modes of communication (face-to-face, audio, and shared workspace) influence objective and self-perceived team performance and team processes in distributed dyadic teams. As noted earlier, teams in the shared workspace (objective error rate = .03) performed better than did distributed participants in the audio-only condition (objective error rate = .08), but there were no performance differences between teams in the face-to-face (objective error rate = .05) and audio-only conditions. This suggests that richer forms of team

communication that facilitate collaborative planning may help to enable team performance.

Research has also shown that the efficiency of team communication is influenced by the relationship between personality factors and the technology assisting with communication (Colquitt et al., 2002; reviewed in Team Composition section). Undergraduate students completed a simulated air traffic decision-making task in one of two communication conditions. In the face-to-face condition, “participants communicated by talking to each other” via headsets. In the computer-assisted condition “participants could communicate through a mixture of verbal and computer-mediated communication” (Colquitt et al., 2002, p. 405). This involved talking to each other via headsets and also using text messages that were sent through the computer. Measures of decision-making performance and efficiency of communication were taken. The efficiency of team communication was conceptualized as the match between the nature of the task and the communication mode chosen to send information. As such, numerical information sent by text would be rated as more efficient than asking opinions of other teammates via text.

Results showed that computer-assisted communication improved team performance only for teams with high openness to experience. However, it is important to note that this effect was mediated by the efficiency with which teams were able to manage the verbal and computerized forms of communication. More specifically, teams that were better able to manage this communication showed a stronger relationship between openness to experience and team performance. In this study, then, the processing of communication affected the strength of the relationship between team personality factors and team performance.

A qualitative study within a highly relevant domain explored the relationship between the content of team communication and team performance (Lindgren et al., 2004). In a study conducted in Stockholm, two pairs of firefighters were required to safely and effectively find injured ‘persons’ in the context of a live firefighting training simulation. The first pair of firefighters (Team 1) had worked together for 11 years, but Team 2 had never worked together. There was also a breathing apparatus leader (BA leader) who can be considered a third team member consistent across both teams. Team 1 entered the building first and Team 2 was sent in when the BA leader saw fit. Communications, teamwork, and performance were observed by the BA leader. The BA leader was videotaped, but his communications were not analyzed. The communication between the firefighters in each team was recorded with microphones and recording equipment. In addition, questionnaires assessing the quality of the teams’ communication and impressions of the overall performance of the teams were completed by all four team members and the BA leader.

Due to the small sample size, statistical analyses were not possible. However, interpreting the frequencies, the content of communication appeared to be more important to team performance differences than the frequency of the communication (Lindgren et al., 2004). Team 1 was seen to perform better than Team 2 according to

their pencil and paper opinions. Overall, both teams communicated with the same frequency, suggesting that frequency alone could not explain variations in their performance. However, content analyses showed that the better performing team's communication focused more on their present and intended status (e.g., safety, location, movement) more than communication about tactics, whereas the content of the communication of the poorer performing team was less focused on status and more focused on tactics. In addition, the better performing pair uttered a greater number of confirmations of messages than the poorer performing pair. This suggests that the content of team communication may be far more important than the sheer frequency of communication in understanding team performance.

There is also some evidence suggesting a significant link between shared mental models and good team communication, as well as showing that the quality of communication within a team will impact on the performance of the team (Marks et al., 2000; reviewed in Shared Knowledge). Results showed that shared mental models were positively associated with both better communication and better team performance in general, but particularly in novel environments.

Research by Swain and Mills (2003) explored implicit vs. explicit communication within either novice or expert teams. This work is based on the common assumption that team experience promotes the emergence of shared mental models, and allows communication to occur at a more implicit (rather than explicit) level. Moreover, it is also commonly assumed that implicit communication is likely to be most helpful in novel and/or high stress situations because it enables coordinated action without imposing "communication overhead" (MacMillan et al., 2004). These ideas were tested in empirical research.

Participants were 36 volunteers, civilian novices, civilian experts and military experts. Expert teams were defined as teams whose members had recently worked together quite extensively. Novice teams had no previous experience together. The experimental task required building a paper bridge as a team with 20 minutes for planning and 10 minutes for construction. Communication was recorded and coded in terms of requests for information about the bridge, questions of a more general nature, information that was responses to questions, voluntary information not related to questions, commands and acknowledgements. Anticipation ratios were calculated as the ratio of explicit (information transfers divided by requests for information) and implicit communication (voluntary information given divided by general requests). In addition, a self-report measure of implicit communication was also administered.

Results showed that expert teams rated themselves as using more implicit communication than did novice teams, and are also reported as showing higher rates of implicit communication behaviours. Unfortunately, however, no information is provided about the relative rates of implicit versus explicit communication. As such, it is perhaps impossible to understand whether expert teams simply used more communication overall, or whether the key difference is only in use of implicit communication. Moreover, the lack of performance data is also unfortunate, as it is

impossible to know whether expert teams with higher levels of implicit communication actually built their bridges more successfully or not. Nonetheless, this work does highlight the importance of the distinction between implicit and explicit communication.

### **Gaps in Research**

Empirical research exploring the actual relationship between communication and performance is relatively mixed. There is some empirical evidence that communication and coordination may be highly interdependent and that reducing the need for coordination reduces the need for communication (MacMillan et al., 2004). When this happens, communication becomes more efficient and performance may improve (MacMillan et al., 2004). In general, however, in this area (as in many others), there is little equivocal research that can speak definitively to the relationship between team communication and team performance. Unfortunately, however, most of this team communication research has been done in relative isolation of the mainstream team literature, although there is some hopeful evidence that these two areas of research are converging more (e.g. Driskell, 2006).

For the future, more focus on distributed rather than co-located teams will be critical for communication research, as will more emphasis on how team communication will be influenced by team diversity in terms of background and expertise (e.g. within joint contexts) as well as broader cultural differences. Clearly, although this area of research has generally aimed to be applied to settings targeted by the current review, there is little communication research that uses high-fidelity approaches with actual military personnel. As such, it is unclear how much undergraduate communication within ad hoc teams is likely to generalize to communication within real military teams. This is an important gap in the existing literature that will need to be addressed.

In military contexts, the CF is moving increasingly toward distributed teams who communicate via various technologies while on a mission. This suggests that understanding the factors that influence team communication as well as its relationship with other team processes and team performance will need to be a critical goal of future research.

## **5.3 Team Coordination**

### **Theoretical Research**

Coordination can be understood as “the need for team members to combine the resources under their control to successfully accomplish each task” (MacMillan et al., 2004., p. 66) and “occur[s] when team activities are executed in response to the behaviours of other members” (McIntyre et al., 2003, p. 5). Similarly, Espinosa et al. (2004; cited from Malone and Crowston, 1990) define coordination as “...the

effective management of dependencies among subtasks, resources (e.g., equipment, tools) and people.” There is some agreement at the theoretical level that coordination is one of the most important (if not the most important) team process factor(s) (e.g., Janicik & Bartel, 2003; MacMillan et al., 2004).

Coordination can be conceptualized as both a predictor and an outcome of team performance (Espinosa et al., 2004; McIntyre et al., 2003). As a process predictive of team performance, coordination refers to “the activities carried out by team members when managing dependencies” (Espinosa et al., 2004, p. 110). For example, a tank driver’s performance depends on the information the navigator provides. As an outcome, coordination refers to “the extent to which dependencies have been effectively managed” (Espinosa et al., 2004, p. 110), for example, the efficiency with which information is provided by the navigator. This section explores coordination primarily (but not exclusively) as a predictor of team performance.

Within this area of research, a key distinction relates to explicit versus implicit coordination. Explicit coordination “requires that team members communicate to articulate their plans and responsibilities” (MacMillan et al., 2004, p. 63). Explicit forms of coordination include planning of roles, responsibilities, tasks, and procedures, and communicating (Espinosa et al., 2004). In contrast, implicit coordination “describes the ability of team members to act in concert without the need for overt communication” (MacMillan et al., 2004, p. 63). Implicit coordination might involve team members providing information to each other before being asked (Espinosa et al., 2004). Implicit coordination obviously reflects several other cognitive processes including shared team knowledge (Espinosa et al., 2004). Furthermore, coordination and communication are sometimes inextricable in the team literature, for example, MacMillan et al. (2004) argue that coordination requirements create the very need for team communication. In fact, many researchers use measures of communication as indicators of coordination.

### **Empirical Research**

Research suggests a positive relationship between coordination and team performance. A study of US Navy teams showed team coordination to be a significant predictor of team performance in team training tasks (Morgan et al., 1986; cited in Ilgen, 1999). There is also qualitative evidence that teams that perform better also consider themselves more coordinated, as better-performing firefighters engaged in a simulated live rescue mission indicated that they felt more coordinated than poorer performing firefighters as measured with a questionnaire (Lindgren et al., 2004, described in Communication section).

Previously cited work by MacMillan et al. (2004) also argues that the ability to coordinate more effectively improves team performance. Recall that this work involved two different team structures, hypothesized to impose either low or high coordination requirements, by virtue of the need for team members to work interdependently in order to accomplish their goal (functional structure) or not

(divisional structure). As reported earlier, teams with lower coordination requirements performed better than other teams.

Recall that a second study was conducted by MacMillan et al. (2004) in order to determine whether coordination and team performance were affected by divisional versus functional team structures. It was hypothesized that a functional structure would require more coordination than a divisional structure, as functional structures required more than one person to complete a given task. Coordination was “measured by the percentage of team members required to complete a coordinated task who actually participated in that task” (MacMillan et al., 2004, p. 74). Task performance was measured by the percentage of times teams delivered 100% of supplies to refugees.

Contrary to expectations, results indicated that actual coordination was better in the functional teams than in the more autonomous divisional teams. Even though the percentage of team members needed to participate in a task was higher for the functional teams, they still performed more efficiently than did divisional teams because more participants actually worked together relative to the requirements for coordination. This suggests that coordination requirements alone do not necessarily hinder team performance – if the team is well equipped to handle these requirements, they do not impede performance. As such, this suggests that factors such as the nature of the task may interact with coordination demands to influence team performance.

Several different research papers already reviewed in this document suggest that coordination impacts positively on team performance. For example, research by Marks and Panzer (2004; to be reviewed in Team Adaptability section) has shown that coordination (as rated on scales by observers) is significantly related to team performance. Research by Marks et al. (2002; reviewed in Shared Knowledge section) showed that not only was more team coordination associated with better performance, but that the relationship between shared mental models and team performance was fully mediated by team coordination and backup behaviours. This suggests that coordination is a product of shared mental models, and that it impacts directly on team performance.

A second study showed a similar pattern of better team coordination predicting better team performance, and of team coordination completely mediating the relationship between shared mental models and team performance. It is important to note, however, that this study measured team coordination as the distance between tanks in a 3-tank platoon. It might be important to work for a more direct indicator of coordination, as there may be factors other than coordination that could influence the distance of tanks in the simulation (e.g. physical obstructions). Nonetheless, this research does show the positive relationship between team coordination and performance.

Research by Marks et al. (2005; reviewed in Task Interdependence section) exploring teams of teams also provided evidence of the critical link between coordination and team performance. Recall that this study of multiteam systems manipulated the

coordination requirements by varying the degree of interdependence required for success amongst various subteams within the team (Marks et al., 2005).

Results indicated that although aspects of the team's performance were significantly predicted by within-team processes, cross-team processes also explained additional variance in team performance, with higher levels of cross-team processes predicting performance above and beyond what could be predicted by within-team processes. This was particularly true in the high interdependence condition. This suggests that when task interdependence is high, the performance of multisystem teams is likely to be better predicted by the levels of coordination between teams than by coordination within the team. This suggests that in very complex teams, multiteam coordination as well as coordination within teams are both likely to be critical. Clearly, this kind of research represents the future of research studying multinational and interagency teams.

There is also good evidence of coordination positively influencing the relationship between shared knowledge and team performance. Recall research by Mathieu et al. (2000; reviewed in Shared Knowledge section) that also showed team processes (e.g. coordination, cooperation and communication) to totally mediate the relationship between shared mental models and team performance. It is clear from the articles reviewed that coordination has a potentially important role in predicting team performance. However, the role of coordination is also influenced by both other team processes, such as shared mental models, as well as by the active goal hierarchies at play within a team.

### **Gaps in Research**

Several critical gaps exist in this literature. It is troublesome that there does not appear to be a validated way to measure coordination as a distinct construct. Rather, researchers tend to assume it is evidenced by communication behaviours (i.e., MacMillan et al., 2004) or imply that it is generated by interdependence (i.e., MacMillan et al., 2004; Marks et al., 2005). Can coordination be examined as a construct unto itself or is it embedded so deeply in other team process variables that it cannot be extricated?

Moreover, given the stated importance of coordination in team performance, there is still relatively little exploration of coordination within real-world teams. With the exception of the MacMillan et al. (2004) work, all of the studies exploring coordination deal with undergraduates performing simulated tasks. Considering the criticality of coordination within military teams, this is a very disappointing fact. Hopefully, future research can be conducted with actual teams working on actual tasks, and the nature of coordination can be better understood. Similarly, the coordination research reviewed for this paper did not explicitly examine distributed teams (with the exception of Marks et al., 2005). Assuming that the coordination issues are similar in co-located and distributed teams seems an unwise assumption. Although the MacMillan et al. (2004) work makes an important start in looking at the

relationships between team structure, coordination, and performance, it will be critical to understand further the extent to which varying team structures imposes different demands for both coordination and communication and changes how teams are likely to perform their duties.

It is also important to note the lack of attention in the available research to issues of team diversity. Although using members of joint teams, even the MacMillan et al. (2004) study did not in any way consider the potential impact of different experiential factors related to team members coming from very different backgrounds. For future research, working to understand team coordination within diverse teams will be an important achievement.

## 5.4 Team Adaptability

### Theoretical Research

Team adaptability refers to the process wherein “team members exchange their behaviour and relationship with other team members according to the changes in the environment of the team” (Essens et al., 2005, p. 5-15). Team adaptability is critical because success in a dynamic situation necessitates flexibility in pre-ordained plans, roles, or skills (Essens et al., 2005).

Theorists seem to agree that the major constituents of adaptability are monitoring, correction or feedback, and backing-up behaviours (e.g., Essens et al., 2005; Porter, Hollenbeck, Ilgen, Ellis, West, & Moon, 2003). As these were also used to define coordination somewhat, it should be evident yet again that it is very difficult to separate many team processes in the team performance literature. There also appears to be some disagreement in the literature as to whether or not the above processes are distinct. Some treat them as separable processes (e.g., Essens et al., 2005), but others appear to believe correcting to be a type of backing-up and monitoring to be a correlate of backing-up (e.g., Porter et al., 2003).

Monitoring refers to the process whereby “team members observe and assess their own and each other’s performance for the purpose of remediating deficient taskwork and teamwork behaviours” (Essens et al., 2005, p. 5-15). Thus, monitoring requires good awareness of the workloads or tasks that other team members must accomplish (interpositional knowledge). It seems intuitive that monitoring would be necessary for correcting that “occurs when team members offer feedback or guidance to improve their team members’ performance” (Essens et al., 2005, p. 5-15). Correcting might involve suggestions and offers of advice (Essens et al., 2005). Monitoring would obviously have to be involved because otherwise team members would not notice that cohorts require correcting. Researchers distinguish between explicit corrections, which occur at the request of someone in need, and implicit corrections that occur without an explicit request but when it is apparent that correcting would be helpful (Essens et al., 2005). Monitoring and correction may occur in tandem when one team

member notices (monitoring) that another team member is performing a task in an inefficient manner and provides either implicit or explicit correction to suggest a more efficient method of working.

Backing-up behaviours are argued to be one of the most critical team process factors in team performance (McIntyre & Salas, 1995, cited in Porter et al., 2003). Generally, definitions of backing-up behaviours focus on teammates' monitoring or situational awareness of the needs of other teammates and responding in a timely manner to their needs (e.g., Essens et al., 2005; McIntyre et al., 2003, p. 5). Backing-up might involve "assuming duties, offering coaching, feedback, or assistance" to teammates who need it (Essens et al., 2005, p. 5-16). Backing-up behaviour clearly requires responding with flexibility in changing circumstances.

### **Empirical Research**

Some research has explored the relationship among monitoring of other teammates, team processes, and team performance. While positive effects of backing-up on team performance have been obtained, for example, in team training in US Navy teams (Morgan, Glickman, Woodward, Blaiwes, & Salas, 1986; cited in Ilgen, 1999), research is generally lacking.

Marks and Panzer (2004) expected that monitoring other teammates while performing a common task would improve team performance because it would improve team coordination and would allow more opportunity for feedback. Undergraduate participants were arranged into 32 3-person teams. The experimental task was an Apache helicopter simulation in which the team members had to work together to "fly into enemy territory, destroy enemy targets, and return safely to friendly territory" (Marks & Panzer, 2004, p. 31). Measures included observer ratings of each team's monitoring behaviour. As monitoring is a primarily cognitive task, it was defined by more indirect indicators such as behaviours and verbal indications of monitoring having occurred. Coordination was measured using observer ratings of coordination quality. Feedback behaviours included verbal coaching or backup behaviours and these were also rated by SMEs. Performance measures included the amount of time taken to complete the mission and number of targets destroyed.

Results showed that monitoring was significantly positively correlated with both team coordination and levels of feedback given. More complex mediational analyses showed that although coordination, feedback and monitoring as a set all predicted team performance, monitoring had no unique impact on team performance after accounting for coordination and feedback. This suggests, these researchers argue, that monitoring impacts on coordination (and to a lesser extent, feedback) which, in turn, influence team performance. In this work, then, monitoring other teammates impacted positively on team performance, but did so indirectly rather than directly.

Other empirical research has explored the influence of team adaptability on team performance. Recall the three studies conducted with three-person teams of experts

and novices tasked to fly a simulated UAV (i.e., Cooke, DeJoode et al., 2004; reviewed in Shared Knowledge section). Adaptability was one of the team process variables measured by the scores provided by independent raters. This research showed that better adaptability was one of the major distinguishing features of co-located teams, but that these adaptability behaviours were not “*absolutely* necessary to complete the mission” (Cooke, DeJoode et al., 2004, p. 75, italics included). Thus, although adaptability did account for some of the variance in superior co-located team performance, it was not one of the major factors.

Other research explored the relationship between backing-up behaviours and team member personality characteristics. Porter et al. (2003) hypothesized that backing-up behaviours would be more likely to occur in teams whose members were more extroverted and conscientiousness (Porter et al., 2003). Extroversion, of course, may make people more likely to want to interact with others (and/or to accept help from them), and conscientiousness would make team members more likely to want to either give or to accept help from their teammates when they were not performing well. Research with undergraduate students completing a simulated military C2 radar task examined the frequency of helping behaviours occurring in teams whose members were characterized as either extroverted or not and conscientious or not. The task involved a simulation of a team radar tracking task requiring participants to work together to protect airspace. Teams were organized such that all members were either all high or all low in extroversion and conscientious. Moreover, teams were randomly assigned to conditions in which they were either evenly split in terms of workload (low need for backing-up behaviours) or to one in which one individual was overloaded with work (high need for backing-up behaviours). Backing-up behaviour was measured by “the total number of times that team members other than [the overloaded person] attacked and cleared an enemy wave track from the [overloaded person’s] quadrant” (Porter et al., 2003, p. 397).

Results indicated that more backing-up behaviours occurred in teams characterized by extroversion and conscientiousness, but this was contingent upon the legitimacy of back-up need. That is, backing-up behaviour was more likely to happen in the high-need than the low-need condition, but was dependent on the members providing back-up behaviours to be extroverted and conscientiousness. This research supports the existence of a ‘backing-up behaviours’ construct, however, it did not assess the relationship between backing-up behaviour and ultimate team performance.

Other research looked at the impact of performance feedback on subsequent coordination and performance of teams (Bailey & Thompson, 2000). Participants were untrained adults who undertook a simulated air traffic control (ATC) task. It was expected that video performance playbacks would help crews to identify realistic and factual examples from their own behaviours that may affect their coordination (Bailey & Thompson, 2000). It was also expected that team level training would result in better performance and mental model development than individual level training because participants’ would benefit from a holistic understanding of their team’s needs.

Two hundred and forty participants from the general population comprised sixty four-person teams. Each team participated in three air traffic control simulations of varying difficulty based on air traffic density (low, medium, or high). In addition, teams were randomly assigned to one of two training types (individual or team), resulting in a 2x3 experimental design. The individual training condition focused on individual team members' management of the sector of the 'air' that they were directly responsible for, whereas the team training condition focused on training the team as a whole. In the latter training type, participants should gain an appreciation of the needs of their other team members. Playback videos of their performance were either focused at the individual level or team level according to their level of training; that is, those who were trained individually received individual feedback and vice versa. Thus, teams were trained, shown videos from their 'training', and then given the chance to discuss ways to improve their performance.

Three measures of team performance and three measures of individual performance were administered after each scenario was completed. Team performance was measured by a shared mental model index (Kendall's W) based on intra-team agreement on the importance of safety, efficiency and effectiveness, and coordination. Team performance was also measured by the percentage of aircraft that successfully reached their destination and a questionnaire assessing team cohesion. Individual performance was measured by aircraft activation and destination delay time, safety errors, and subjective workload.

Results indicated that feedback at the team level was associated with better team performance, but only in the low density air traffic condition. This was indicated by the fact that a higher percentage of aircraft reached their destinations when the participant had been trained at the team level than at the individual level. This suggests that feedback at the team level may be more important than feedback at the individual level, but that the effect of team training may be compromised under conditions of higher workload. Although this study examined the relationship between feedback and performance, the feedback was not provided by one team member to another team member during task performance. Rather, feedback was provided by a third party (i.e., the experimenters) to the teams after task performance (i.e., via video playback).

As a whole, then, the available empirical research seems to argue that team adaptability behaviours do not impact directly on team performance, but most often exert their influence through other team processes. This is likely the case because monitoring, backup-behaviours and correction are strongly linked with key team processes such as coordination.

### **Gaps in Research**

As such, although theorists seem to agree that team adaptability is positively related to team performance (e.g., Essens et al., 2005; Morgan, Glickman, Woodward, Blaiwes, & Salas, 1986; cited in Ilgen, 1999), the empirical evidence in support of

this is generally lacking (e.g., Porter et al., 2003). In addition, researchers have noted several shortcomings in the scant body of research that does exist. These include a general lack of attention to the effects of workload (e.g., legitimacy of need), a focus on the frequency of requests rather than backing up provision, and a focus on dyadic rather than team-level configurations (Porter et al., 2003). Preliminary research (i.e., Porter et al., 2003) suggests that these factors are important to consider in future research on adaptability.

Further, research appears somewhat skewed in that it is conceivable that backing-up may not always be a desirable behaviour, but it is consistently examined from such an assumption (Porter et al., 2003). Indeed, the literature search conducted for this project did not uncover any work that considered possible negative effects of backing-up. It is conceivable, however, that backing-up when it is not needed could lead to reduced performance via a doubling-up of taskwork (Porter et al., 2003). Such an action would likely lead to redundancy and therefore a reduction in efficient resource allocation.

## 5.5 Planning

### Theoretical Research

Planning appears to be another important team process that is related to team performance. Planning refers to “the process of formulating the actions that are necessary for attaining a team goal, determining the time needed for each of these actions, and comparing the latter to time available” (Essens et al., 2005, p. 5-13). Thus, planning occurs in the preparatory phase before a mission or assignment commences (Fleishman & Zaccaro, 1992) and incorporates anticipation of future events and resource allocation, the latter of which involves specifying and scheduling resources including time, personnel, and materials, and defining strategies to accomplish goals (Essens et al., 2005). Planning affords a team the ability to set goals, create an open environment, share information, clarify roles and responsibilities, discuss relevant environmental characteristics and constraints, prioritize tasks, and discuss expectations (Stout et al., 1999, p. 62). At the team process level, positive benefits of planning include increased motivation (Smith, Locke, & Barry, 1990; cited in Mumford, Schultz, & Van Doorn, 2001) and teamwork (Weldon, Jehn, & Pradhan, 1991; cited in Mumford et al., 2001). Cited research is also argued to support a positive relationship between planning and both team process and team performance (Mumford, Schultz, & Van Doorn, 2001)

An important part of planning is resource allocation (e.g., Essens et al., 2005; Fleischman & Zaccaro, 1992; Kleinman, Luh, Pattipati, & Serfaty, 1992; Mohrman, Cohen, & Mohrman, 1995). Resource allocation, or resource distribution, refers to the division of all the things that a team requires to complete a job that are limited in availability, including personnel, time, materials, energy, etc. (Essens et al., 2005; Fleischman & Zaccaro, 1992; Kleinman et al., 1992). It can be defined as “decisions

regarding the assignment of members and their resources to particular responsibilities linked to task accomplishment” (Fleischman & Zaccaro, 1992, p. 44). It is believed that “failure to spend time on resource allocation needs... is a central cause of performance failure in team settings” (Mohrman et al., 1995, p. 220). With regard to the allocation of personnel, it is necessary to match member resources to task requirements and balance workload across team members (Fleischman & Zaccaro, 1992). Within a military context, resource allocation may consist of providing a finite amount of time to different aspects or stages of a mission. It is clear that either too-conservative or too-liberal time allotment could affect the outcome in that poor usage of time at earlier stages will likely have detrimental effects at later stages if there is too little time left for important or more time-consuming tasks. As described, resource allocation could potentially have ramifications for subsequent team performance.

### **Empirical Research**

Although only a few studies specifically examined issues of team planning, there is some evidence that better planning is associated with better team processes and team performance. MacMillan et al.’s (2004) research involving humanitarian airlift missions suggested that the type of planning available to teams may be important (MacMillan et al., 2004; see Team Structure section). Students participating in a simulated humanitarian mission were randomly assigned to electronic/collaborative planning or pencil and paper/non-collaborative planning. Results found that collaborative planning was associated with better team performance. This was especially true in functional teams who were required to be interdependent as opposed to divisional teams who functioned relatively autonomously (MacMillan et al., 2004). Collaborative rather than non-collaborative planning procedures are also argued to be likely to affect the development of shared mental models, thereby enhancing team performance (MacMillan et al., 2004).

A study by Stout et al. (1999) explored the relationship between planning, shared mental models and coordinated team performance. This research argued that teams that planned better would be more likely to develop better shared mental models, to show a higher rate of anticipatory communication, and to perform better. Moreover, planning was expected to be particularly important in high workload conditions.

Two participants assigned to a team with two confederates undertook a helicopter surveillance and defence mission. Each took the role of either mission commander or second in command, and the task required working as a team to fly the helicopter toward different landmarks in order to do surveillance, as well as defending the helicopter from enemy targets that appeared on the surveillance screen. Teams completed missions in either low or high workload conditions (conceptualized as performing both dimensions of the task serially or simultaneously). Measures included observer ratings of each team’s planning quality within the mission, which included dimensions related to creating an open environment, clarifying roles and information to be shared, self-correction etc. Dependent measures included shared

mental model measures, provision of information in advance, and the frequency of errors made by the team, as provided by observer ratings.

Relevant results showed that better planning teams did show better shared mental models. Subsequent analyses focused only on comparisons within the high-workload conditions. These showed that better planning teams were significantly better at providing information in advance than were teams with poorer planning, as well as showing fewer errors in mission performance during high workload periods. This work suggests that planning both aids in the development of shared mental models, and is positively associated with team performance. Importantly, analyses also showed that better performing dyadic teams were also more likely to undertake planning during lag-times (Stout et al., 1999) than during peak times.

There is some empirical evidence of differential planning processes in co-located and distributed teams. Three studies of simulated UAV flights in three-person teams (Cooke, DeJoode et al., 2004) showed that mission planning was better in co-located than distributed teams.

In research by Marks et al. (2005), however, pre-mission planning (i.e., a transition phase activity) was somewhat related to team performance, especially when the multiteam systems had less rather than more interdependent goal hierarchies. In fact, although teams were expected to use transition-phase activities to work toward multiteam goals, they appeared to put more effort into goals specific to their teams. Moreover, there was some evidence that teams may have created plans for cross-team coordination that were not very adaptive. This would seem to be particularly problematic for teams with highly interdependent goal hierarchies. In addition, Marks et al. (2005) also argue that pre-planning might not have strongly influenced team performance because the nature of the task allowed concurrent planning to occur during the mission execution. As such, planning before the mission may not have been critical for the defined task, and this might explain why planning was not a strong predictor of team performance.

These results, then, seem to suggest that distributed teams are likely to have more problems in planning, and that these problems may influence team performance. On the other hand, even having team members assembled and active in team planning will not necessarily ensure good team performance.

### **Gaps in Research**

There is relatively little research that has explored planning within teams. As Mumford et al. (2001) have suggested, this might be because planning is not typically considered a “sexy” or exciting topic of research. However, there is some ambiguity in the literature around exactly how planning should be defined. For example, some researchers appeared to confine planning to the time prior to the commencement of a project (Marks et al., 2005) while others appeared to believe it can occur throughout the course of a mission or project as needed (e.g., Stout et al., 1999). It also seems

possible that the lack of planning research may be due to the lack of a reliable measure of planning or agreement on exactly what is meant by the term.

Clearly, further research is needed in order to identify the underlying mechanisms of planning, but it appears that planning can lead to better performance through better team mental models and better communication (Stout et al., 1999) at least within co-located teams. However, there is an unfortunate scarcity of research addressing the impact of planning within distributed teams. Moreover, there is no apparent consideration of the relationship between team diversity and planning strategies, even though this would be a very logical extension of existing theory and research. To the extent that team members derive from diverse backgrounds, such teams may experience considerable difficulty in planning their missions as a team.

## 5.6 Team Climate

### Theoretical Research

The literature also suggested several other factors that might affect team performance, all related to the climate within a team. Team climate refers to a team's subjective attitudes, beliefs, and feelings about their team's policies, practices, procedures, or processes. (Bower, Campbell, Bojke, & Sibbald, 2003, p.274) These beliefs, attitudes and feelings that comprise a general team climate can be understood to contain several related but distinct constructs. These constructs include cohesion, morale, motivation, trust, and collective efficacy and/or team identity.

Cohesion has been one of the most studied team process variables. Indeed, cohesion "is considered to be one of the most fundamental aspects of groups" (Golembiewski, 1962, p. 149; cited in Driskell et al., 2003, p. 302) and is generally accepted as relating "strongly to team performance" (Essens et al., 2005, p. 5-18). Researchers distinguish between social cohesion, "interpersonal attraction to the team or group", and task cohesion, "group-related affiliation for the purposes of achieving task-related outcomes" (McIntyre et al., 2003, p. 3).

Morale refers to "the enthusiasm and persistence with which a member of a group engages in the prescribed activities of that group" (Manning, 1991, p. 457; cited in Essens et al., 2005, p. 5-15). Morale may be an affective factor that refers to the feeling one has when one participates in certain activities. High morale is typically seen by scholars as positively associated with team performance (Essens et al., 2005). Indeed, it seems intuitive that if team members lack morale, they will not do their jobs well. However, a high amount of enthusiasm may help teams through rough spots and ensure persistence during difficult times.

Motivation is a widely used term that refers to "the maximization of intended affect" (Naylor, Pritchard, & Ilgen, 1980; cited in Judge & Ilies, 2002) or a desire to perform (Locke, 1997; cited in Judge & Ilies, 2002; Colquitt, LePine, & Noe, 2000; cited in

LePine, LePine, & Jackson, 2004). Motivation is generally accepted among scholars as positively associated with team performance (e.g., Essens et al., 2005). For example, research has found that motivation was positively associated with undergraduates' performance in their courses (LePine et al., 2004). Motivation can be extrinsically stimulated by (e.g., by military team leaders through rewards), or intrinsically stimulated through individual genuine interest in a task (Essens et al., 2005).

Trust reflects "a psychological state that manifests itself in [people's] behaviours toward others" and is based on expectations we have about other people's behaviours, and "on the perceived motives and intentions in situations entailing risk" (Costa, Taillieu, & Roe, 2001, p. 225). Within a team context, trust is predicated on interpretations about the motives and intentions of other people and issues of trust arise in situations with risk, uncertainty and vulnerability (Adams, Bryant, & Webb, 2001). Moreover, trust develops over time (Rempel, Holmes, & Zanna, 1985) and as the product of personal experience and history. In addition, trust may enable efficiency and coordination in small teams (McEvily, Perrone & Zaheer, 2003), and may thus influence other team process factors.

Finally, collective or team efficacy has been demonstrated to affect team performance. Team efficacy refers to "perceptions of task-specific team capability" (Gibson, 1996; cited in Gully, Incalcaterra, Joshi, & Beaubien, 2002, p. 819) and "a sense of collective competence shared among individuals when allocating, coordinating, and integrating their resources in a successful, concerted response to specific situational demands" (Zaccaro et al., 1996, p. 309; cited in Karrasch, 2003, p. 2). The construct of collective efficacy thus invokes a team-level application of Bandura's (1986; cited in Karrasch, 2003) self-efficacy, consisting of beliefs about personal competency and the likelihood of success.

### **Empirical Research**

As noted earlier, a range of researchers seem to agree that team cohesion improves team performance (e.g., (Driskell et al., 2003; Essens et al., 2005; McIntyre et al., 2003). Both social cohesion and task cohesion are argued to affect team performance positively (McIntyre et al., 2003). The relationship between cohesion and team performance has been empirically well-established (Driskell et al., 2003; Essens et al., 2005; McIntyre et al., 2003). Research has demonstrated that cohesion has the potential to effect many positive outcomes including greater re-enlistment in the U.S. military, higher team morale, greater satisfaction with working in the military, and a perception of combat readiness (Griffith, 1988; cited in Beck & Pierce, 1996). However, there is also conflicting evidence. For example, longitudinal research has suggested that over time, team performance and cohesion become less related or possibly negatively related (McIntyre et al., 2003). A nine-month longitudinal study of cohesion in undergraduate student project teams indicated considerable variation in cohesion both within and between teams over time. For example, analyses showed that more cohesive teams sometimes obtained lower grades than the less cohesive

teams and that team cohesion sometimes declined with time (McIntyre et al., 2003). These findings are clearly somewhat counterintuitive, and suggest that more empirical research will be necessary to understand the relationship between team cohesion and performance.

There is some evidence that the effects of cohesion on team performance may be mediated by the type of task (Driskell et al., 2003). That is, additive tasks in which team members work independently toward a goal may be less dependent on cohesion, and disjunctive tasks in which team members work interdependently may be more dependent on team cohesion (Driskell et al., 2003). This position seems logical because independent tasks would not be expected to require a great deal of cohesion because parties would be essentially working alone, but dependent tasks would. Another reason for caution concerning the connection between cohesion and performance is because the literature in this area has been largely correlational and therefore lacks robustness (McIntyre et al., 2003).

Trust within teams has also received some empirical attention. Overall, this work suggests that trust is positively associated with team performance. For example, a previous literature review found that trust was necessary for good teamwork and performance among various types of teams including *ad hoc* laboratory teams (e.g., Dirks, 1999), work groups (Simons and Peterson, 2000) and Israeli military teams (e.g., Shamir, Brainin, Zakay, & Popper, 2000; cited in Adams, Bruyn, & Chung-Yan, 2004). However, research has also increasingly suggested that trust within teams impacts indirectly rather than directly on team performance (Simons and Peterson, 2000; Dirks, 1999).

In general, research provides inconsistent evidence that collective efficacy is positively related to team performance. For example, in a study with platoons engaging in basic training exercises and other duties (e.g., vehicle maintenance, etc.), subjective team efficacy was found to be related to other team process variables such as cohesion, but not to performance as rated by SME observers (Bass et al., 2003). However, research has also shown that team efficacy is positively related to team performance in a laboratory study with undergraduates tasked to assign merit points to a fictitious employee (Katz-Navon & Erez, 2005). In this study, teams with higher efficacy correctly completed greater numbers of recommendations than those with lower team efficacy, but only in conditions requiring high levels of interdependence (Katz-Navon & Erez, 2005). Thus, it appears that collective efficacy may be positively related to team performance.

Research conducted for the Army Research Institute explored issues of collective efficacy in multi-national teams of 68 military officers serving as NATO and non-NATO staff members of the Stabilization Force Headquarters (SFOR HQ) in Bosnia (Karrasch, 2003). This research used questionnaires to explore participants' perceptions of the ability of the personnel within this headquarters to work as a team. As participants belonged to both their primary team (e.g. intelligence team) as well as

their larger organizational team (SFOR HQ), results were analyzed at both levels of analysis.

Results showed that perceptions of collective efficacy were stronger within smaller primary teams than within the larger SFOR HQ group, with more heterogeneity of responses for the latter team. Unfortunately, however, no measures of team performance were collected in order to explore how these perceptions of team efficacy might have related to actual team performance.

Meta-analysis suggests that collective efficacy predicts team performance, but that the relationship may be mediated by task interdependence (Gully et al., 2002). A meta-analysis conducted by Gully et al. (2002) explored the relationship between team efficacy and team performance. More than 60 articles, primarily from the psychological literature were retrieved, and coded according to level of analysis (individual vs. team level), and the type of interdependence required for task, goal and outcome.

Results of this meta-analyses showed that teams with higher levels of efficacy did show higher levels of team performance ( $r = .41$ ), but that interdependence did moderate the efficacy/performance relationship. More specifically, results showed that efficacy was more strongly related to performance when interdependence was high rather than low. This suggests that teams may be more likely to show a strong relationship between efficacy and their performance when the task being performed requires more coordination amongst team members. However, in this area of research, the results are inconsistent and largely task dependent.

### **Gaps in Research**

Again, there is a wealth of research associated with team climate factors, and only a very small subset could be considered in this review. In general, there is some evidence that climate factors can impact on team performance, but these factors are perhaps most often seen to have an indirect rather than direct influence. This is unsurprising considering the many different factors that have the potential to influence team performance. In this area as in most other areas of team research, however, inadequate attention has been paid to the impact of physical distribution, team diversity and differences in work background and experience. For the future, these also stand as important issues to address in considering the impact of team climate on ultimate team performance.

## **5.7 Overview of Team Processes**

There were a host of team processes identified in the literature review, including shared knowledge/mental models, communication, adaptability, planning and resource allocation, and coordination. However, the team process research has been focused in three primary areas, including shared mental models, communication, and

coordination, as these 3 factors are likely to have the most influential effect on team performance.

Shared knowledge or shared mental models are a primary aspect of team process. Mental models are theorized as being positively related to team performance, but the evidence reviewed here is somewhat equivocal in terms of whether the relationship is direct or indirect. There is consistent evidence that shared knowledge does improve team performance, but does so through other team processes such as coordination or communication. As such, it appears that the underlying mechanism by which team mental models influence performance is that they help team members understand each other at a very deep level allowing team members to anticipate each other's needs and actions. Moreover, mental models may not explain as much variance in team performance as other variables such as communication and coordination (e.g., Cooke, DeJoode et al., 2004).

Communication is also an important team process factor related to good team performance. More frequent communication is not necessarily better communication; researchers have found that less communication facilitates greater coordination and performance (e.g., MacMillan et al., 2004). However, more communication may be necessary for the development of mental models in new teams (e.g., Lindgren et al., 2004; MacMillan et al., 2004). Moreover, the content of communication is likely to be more important to performance than the frequency of communication (e.g., Lindgren et al., 2004). Empirical research has shown the power of communication. For example, teams that use more efficient communication strategies (by providing higher rates of information in advance) perform significantly better under high pressure conditions than teams that use less anticipatory communication (Stout et al., 1999).

Coordination is critical to team performance. Coordination is also closely linked to communication. High quality communication is related to better team coordination and therefore better performance, but a lack of need for explicit communication was even better (MacMillan et al., 2004). That is, a reduced need for coordination reduced communication rates but increased communication efficiency, and was associated with better team performance (MacMillan et al., 2004). Coordination was also seen as closely linked to mental models, task interdependence, resource allocation, workload (i.e., MacMillan et al., 2004) making it a major influence on all team process factors that influence team performance.

Teams require adaptability and flexibility in order to achieve success in a dynamic situation (Essens et al., 2005). Team adaptability involves the processes of monitoring, correcting, and backing-up teammates, with backing-up being the most clearly delineated factor. Research indicated that backing-up an overloaded colleague was more likely when both the recipient and the provider were extroverted and conscientious, but the impact on team performance was not assessed (Porter et al., 2003). However, adaptability appeared to relatively under-researched as a whole.

Further, research has failed to consider possible negative effects of backing-up such as excessive backing-up or backing-up when it is not needed.

Finally, planning refers to the process of formulating actions to be undertaken toward attaining a goal (Essens et al., 2005). This may involve allocation of various resources, specification of roles, and prioritization of tasks (Stout et al., 1999). Overall the research appears to support the position that planning is positively related to team performance in terms of motivation and teamwork (Mumford et al., 2001), and better mental models (e.g., Cooke, DeJoode et al., 2004), but this kind of research is generally lacking.

More globally, our review of the literature also showed a potentially important trend calling for increased attention to more social team processes. Rentsch & Woehr (2004, p. 16), for example, in talking about the shared team knowledge literature, argued that “*..largely unexamined in this research are team member schemas about other members of the team.*” As such, even though researchers have given a good deal of attention to how team members come to have shared knowledge with respect to a concrete task, they have given little serious attention to how team members see each other. These social perceptions, of course, are likely to have a serious impact on how team members relate to each other, as well as on how teams actually perform. This shift from purely cognitive accounts to a more complex view of how team actually perform is indicative of the progressive maturation of the team research, and suggests that more complex models incorporating team processes in conjunction with task characteristics and team characteristics will be required.

As a whole, then, there is considerable research within the area of team processes, but much more research is necessary. From the perspective of this review, many areas of critical importance to the CF are currently under-represented in the existing literature. For example, most of the existing research deals solely with co-located rather than distributed teams, and fails to consider how differences in training and culture might be likely to influence team process and performance. These issues are discussed in more detail in the recommendations chapter.



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## 6. Team Measures

This section considers conceptual issues and challenges faced by team researchers working to measure team performance and effectiveness, focuses on existing measures of team processes and products, and describes gaps in current approaches to team measurement.

### 6.1 Conceptual Issues and Challenges

The measurement of team functioning and performance appears to have provided significant challenges to researchers. Prominent team researchers have argued that efforts to measure team constructs has “lagged behind” the conceptual literature related to teams (Rentsch & Woehr, 2004), and knowing how to operationalize key variables within the team literature has been very problematic (Kraiger and Wenzel, 1997).

#### 6.1.1 Team Process vs. Team Outcomes

As noted earlier in this review, theorists and researchers have long noted a distinction between team outcomes and team processes. At a measurement level, this distinction is formalized in Cannon-Bowers and Salas’ table (1997) shown in Figure 5.

|                                 |                                                                                                                                                                                                                                                                                              |                                                                                                                                                                                                                                                                                                                      |                                                                                                                                                                             |                                                                                                                                                                                  |
|---------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P<br>R<br>O<br>C<br>E<br>S<br>S | <b>TEAM</b> <ul style="list-style-type: none"> <li>• Shared Task Models</li> <li>• Cue/Strategy Associations</li> <li>• Task Organization</li> <li>• Compensatory Behavior</li> <li>• Collective Efficacy</li> <li>• Dynamic Reallocation of Function</li> <li>• Task Interaction</li> </ul> | <b>INDIVIDUAL</b> <ul style="list-style-type: none"> <li>• Assertiveness</li> <li>• Information Exchange</li> <li>• Task-Specific Role Responsibilities</li> <li>• Procedures for Task Accomplishment</li> <li>• Cue/Strategy Association</li> <li>• Mutual Performance Monitoring</li> <li>• Flexibility</li> </ul> | <b>TEAM</b> <ul style="list-style-type: none"> <li>• Observational Scales</li> <li>• Expert Ratings</li> <li>• Content Analysis</li> <li>• Protocol Analysis</li> </ul>     | <b>INDIVIDUAL</b> <ul style="list-style-type: none"> <li>• Decision Analysis</li> <li>• Policy Capturing</li> <li>• Protocol Analysis</li> <li>• Observational Scales</li> </ul> |
|                                 | <b>OUTCOME</b> <ul style="list-style-type: none"> <li>• Mission/Goal Accomplishment</li> <li>• Aggregate Latency</li> <li>• Error Propagation</li> <li>• Aggregate Accuracy</li> </ul>                                                                                                       | <ul style="list-style-type: none"> <li>• Accuracy</li> <li>• Latency</li> <li>• Errors</li> <li>• Safety</li> <li>• Timeliness</li> <li>• Decision Biases</li> </ul>                                                                                                                                                 | <ul style="list-style-type: none"> <li>• Observational Scales</li> <li>• Expert Ratings</li> <li>• Critical Incidents</li> <li>• Automated Performance Recording</li> </ul> | <ul style="list-style-type: none"> <li>• Automated Performance Recording</li> <li>• Critical Incident</li> <li>• Expert Ratings</li> <li>• Archival Records</li> </ul>           |

**Figure 5. Team vs. Individual Measures (Cannon-Bowers and Salas, 1997)**

Measures of team process are typically conceptualized as indicators of how teams work to accomplish a task, and measures of outcome are the final result of that effort. Of course, this distinction is not necessarily consistent, as researchers have also explored shared mental models as the outcome of performing a specific task.

Nonetheless, there is also clear agreement that team process and team outcome should be measured together, because they are inextricably linked (Brannick and Prince, 1997). Merely assessing whether or not a team accomplished its goal or what team resources it used in order to accomplish that goal is sometimes less informative than the social processes in play as they performed as a team. According to Brannick and Prince (1997; p. 10), “unlike outcome measures, team process measures may shed light on problems encountered by the team and the means to fix them”. As such, they argue that team measures should contain elements of both team process and outcome. It is also important to note that as a general research strategy, some researchers advocate that team researchers should create measures that sample from all four quadrants shown in Figure 5 (Cannon-Bowers and Salas, 1997). As such, this argues that it is critical to sample at both the individual and team level, and to consider both team processes and team outcome.

While the terms “outcome” and “effectiveness” are often used interchangeably, several researchers have argued that these constructs are not synonymous. Kraiger and Wenzel (1997) distinguish team outcome from team effectiveness by arguing that team outcome refers to process measures (decision making, communication, leadership, coordination, situational awareness, backing up behaviours), whereas team effectiveness refers to product measures such as quantity and quality, time spent, costs, errors and general productivity. Thus, while there is generally consensus that process is distinct from product, the terms “performance”, “effectiveness”, and even “outcome” are sometimes used to refer the same underlying construct.

Other relevant constructs prominent in the literature relate to measures of performance and measures of effectiveness. Measures of performance have been defined as “measures of the lowest level of performance representing subsets of measures of effectiveness (MOEs). Examples are speed, payload, time on station, frequency, or other distinctly quantifiable performance features” (*Competitive*, n.d.). A measure of effectiveness, on the other hand, has been defined as “a measure of operational success that must be closely related to the objective of the mission or operation being evaluated. For example, kills per shot, probability of kill, effective range, etc.” are examples of measures of effectiveness (*Competitive*, n.d.). This definition from the military domain argues that measures of effectiveness relate to achievement of an operation or mission, and that measures of performance relate more to the various substeps required to complete the mission. As such, one might define the successful return of the space shuttle in terms of more global measures of effectiveness (e.g. return safely to the ground at the predefined time) or in terms of smaller measures of performance (e.g. dock successfully at the Russian space station) which are a subset of the tasks that make up a successful mission.

From our perspective, however, regardless of the term used, the general concept is that there should be a distinction between the “how” and the “what” of teamwork.

### 6.1.2 Levels of Analysis

The issue of which level of analysis is appropriate in understanding teams is a pervasive problem in the team measurement (Baker & Salas, 1997; Pritchard, Jones, Roth, Stuebing, & Ekeberg, 1988). Although researchers have generally agreed that teams must be considered at three different levels of analysis (i.e. the individual, team, and organizational level), exactly how these different levels of analysis could be captured with concrete measures has remained unclear.

Measurements made at the team level have traditionally involved the aggregation of individual team scores into a group score either by using the central tendency of individual scores, the total, or some other logical method. In a now-classic article, Pritchard, Jones, Roth, Stuebing, and Ekeberg (1988) argued that a strictly individual approach to team measurement is potentially problematic. Of course, when working within a team, team members will inevitably influence each other. However, aggregating individual scores into a team score ignores the interdependence between team members. This may call the validity of the aggregated score into question (e.g., Cooke, Shope, & Kiekel, 2001; Cooke, Salas, Kiekel, & Bell, 2004).

Tesluk, Mathieu, Zaccaro, & Marks (1997) suggest that for aggregation to be justified, certain conditions must be met. First, there must be theoretically valid reason for doing so. Second, measures must refer to team properties, not individual ones. Third, researchers have noted that “shifting levels of analysis may change the psychometric characteristics of the variable” (Tesluk et al., 1997, p. 212). Simply put, for example, asking individual team members to rate the trustworthiness of their individual teammates and then aggregating their responses is not necessarily the same as asking them to rate the trustworthiness of their team as a whole (Adams et al., 2004). Similarly, in personality research, taking individual personality measures and then using them to indicate “team personality composition” (e.g. English et al., 2004) is also problematic. In order for aggregation to be a valid procedure, adequate levels of within-group agreement or homogeneity must exist. Statistical procedures such as  $r_{wg}$  have been developed to determine the validity of aggregating individual results to the group level (Dunlap, Burke, Smith-Crowe, 2003).

More recently, of course, hierarchical linear modelling has emerged as a methodology that allows the separation of individual and group (e.g. team) levels (e.g. Craig, 2004). As such, it is clear that team researchers continue to face issues of the level at which to measure (and to understand) teamwork.

Resolving this issue, no doubt, has been exacerbated by the complexity of teams and of the need to capture the many tasks that teams perform.

### **6.1.3 Multiplicity of Team Constructs**

As noted throughout this review, it is most difficult to separate all the different factors that impact on team behaviours, and to then measure them discretely. For instance, coordination has often been measured in terms of communication, and several distinct constructs have often been combined into a single indicator of team process (see description of Mathieu et al., 2000 in Shared Knowledge section). This is certainly problematic from both a conceptual and a measurement perspective. This measurement approach begs the question of why distinct constructs are identified, but then disregarded. If coordination is wholly equivalent with communication it is unclear why two different terms are needed. Clearer conceptual definitions about what constructs actually represent should serve as the base for measurement efforts.

Indeed, team researchers have lamented a general lack of coherence in the approach to team measurement, and that researchers often “tend to measure what seems useful to the purpose at hand at the time of the study” (Brannick & Prince, 1997, p. 5). This lack of coherence in approaching measurement has likely had both positive and negative consequences. On one hand, our review suggests that there is a clear abundance of team measurement approaches. On the other hand, after years of research, it is still difficult to find “hallmark” measures of team process and product that researchers have agreed “...should be measured whenever team performance is of interest” (Brannick & Prince, 1997, p.5). Perhaps even more importantly, there is very little evidence that team measures have been subject to extensive validation efforts.

## **6.2 Measures of Team Products**

Team product measures tend to be observable and are often numerically represented such as quantity and quality, time spent, costs, errors and general productivity (Kraiger & Wenzel, 1997). Within the advent of computer technology, research on team products has increasingly used embedded measures. Examples of existing measures of team products seen in the course of this review are provided in Table 4.

**Table 4: Product measures**

| Authors                                                                              | Year | Operational Definition                                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bailey, L.L. & Thompson, R.C.                                                        | 2000 | Percentage of aircraft reaching their destination.                                                                                                                                                                                                                                          |
| Bass, B.M., Avolio, B.J., Jung, D.I., Berson, Y.                                     | 2003 | Observer based. Standardized questionnaire assessing how well a team performed on a scale from 0 (much less than could have been expected) to 4 (much more than could have been expected). Also, a 5-point scale rating individual teams' performance against all other teams' performance. |
| Cooke, N.J., DeJoode, A., Pederson, H.K., Gorman, J.C., Connor, O.O., & Kiekel, P.A. | 2004 | Computer-based. Measures of rate at which pictures of targets were taken, time spent in alarm and warning states, and rate of acquisition of weapons.                                                                                                                                       |
| Cooke, N.J., Shope, S.M., & Kiekel, P.A.                                             | 2001 | Computer-based. Measure of rate at which pictures of targets were taken, time spent in alarm and warning states, and rate of acquisition of weapons.                                                                                                                                        |
| Doane, S., Bradshaw, G., & Gisen, J.M.                                               | 2004 | Computer-based. Measures of amount of damage sustained (i.e., number of hits taken), efficiency (i.e., amount of ammo used and time taken per kill, time to completion), risk (i.e., amount of time VIP was protected and not protected).                                                   |
| Kyne, M.M., Thorsden, M.L., & Kaempf, G.                                             | 2002 | Observer based. SMEs completed standardized rating forms for whether or not expected behaviours were observed throughout missions, including planning, monitoring, and adjusting. Performance reflected the cumulative numbers of times expected behaviours were observed.                  |
| Lindgren, I., Berggren, P., Janger, H., & Hirsch, R.                                 | 2005 | SME ratings of performance on a standardized questionnaire.                                                                                                                                                                                                                                 |
| MacMillan, J., Entin, E.E., & Serfaty, D.                                            | 2004 | The percentage of successful deliveries of supplies.                                                                                                                                                                                                                                        |
| Marks, M.A., DeChurch, L.A., Mathieu, J.E., Panzer, F.J., & Alonso, A.               | 2005 | Computer based. Measures of target destruction and survival of team subtracted by hits on neutrals and allies.                                                                                                                                                                              |
| Marks, M.A., & Panzer, F.J.                                                          | 2004 | Computer based. Amount of time taken to complete the mission and the number of targets destroyed.                                                                                                                                                                                           |
| Marks, M.A., Sabella, M.J., Burke, C.S., & Zaccaro, S.J.                             | 2002 | Computer based. Experiment 1: Measures of number of enemy kills, survival of team, duration of mission during which team remained alive<br><br>Experiment 2: Measures of number of enemy pillboxes destroyed and rebuilt in 40min.                                                          |
| Marks, M.A., Zaccaro, S.J., & Mathieu, J.E.                                          | 2000 | Computer-based. Measures of number of enemy pillboxes destroyed and rebuilt in 40 min.                                                                                                                                                                                                      |
| Mathieu, J.E., Heffner, T.S., Goodwin, G.F., Salas, E., & Cannon-Bowers, J.A.        | 2000 | Computer-based. Measures of survival, reaching waypoints, and destroying enemies.                                                                                                                                                                                                           |

Clearly, the majority of team product measures in the literature reviewed were computer-based measures. Examples included number of enemy kills made in various flight and tank simulations (e.g., Marks et al., 2005; Marks & Panzer, 2004; Marks et al., 2000; Mathieu et al., 2000), team survival (e.g., Marks et al., 2005; Marks & Panzer, 2004; Mathieu et al., 2000), amount of fuel used (e.g., Cooke et al., 2001; McGlynn et al., 1999; Sorkin, 2002), targets they detected and detection accuracy (e.g., Bailey & Thompson, 2000; Cooke et al., 2001), and progress toward established waypoints (e.g., Cooke et al., 2001; Marks & Panzer, 2004; Mathieu et al., 2000). These measures, of course, provide important data with minimum need for observers, and do not rely on impressions or opinions of interested parties and are less likely to be erroneous or biased. Although more rare, however, there was also evidence of observer (SME) ratings of team products (Bass et al., 2003; Kyne, Thorsden, & Kaempf, 2002; Lindgren et al., 2004).

## 6.3 Measures of Team Process

This section explores existing measures of team process accessed during this review.

### 6.3.1 Measures of Shared Knowledge

Measuring shared knowledge has received a good deal of research effort. At the most general level, many different tools have been used, including participant sequencing of events performed (e.g., Marks et al., 2002), questionnaires (e.g., Cooke et al., 2004), and observer ratings (e.g., Marks et al., 2000). In general, these techniques have identified or elicited relevant aspects of the knowledge domain, and have required team member to rate the importance of these elements to their own understanding of the problem space. There is considerable evidence of increasing elaboration and complexity in the measurement of shared knowledge over the past decade.

As noted earlier, two types of shared mental models are most often measured: taskwork knowledge which relates to the known information about the task, and teamwork knowledge which relates to knowledge about other team members (e.g. their working style, their role).

There are many different methods of measuring shared knowledge or shared mental models. Specifically, measures of shared knowledge usually involve completion of questionnaires by individual team members. Typically these questionnaires involve a list of terms, phrases, or concepts that are relevant to the task a team must accomplish. Individual team members typically receive a list and are asked to indicate how related they see two concepts as being. Table 5 shows examples of shared knowledge measures evidenced in the literature.

**Table 5: Shared knowledge measures**

| Authors                                                                              | Year | Operational Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Bailey, L.L. & Thompson, R.C.                                                        | 2000 | Self-report. Standardized questionnaire for relatedness of pairs of relevant terms.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Cooke, N.J., DeJoode, A., Pederson, H.K., Gorman, J.C., Connor, O.O., & Kiekel, P.A. | 2004 | Self report.<br><u>Teamwork knowledge</u> : 2 measures.<br>Accuracy measure: Standardized checklist of necessary teamwork behaviours completed by each team member compared against a standardized scoring key of the correct answers.<br>Cohesion measures: Two types: Comparison of the individual responses on the checklist above by assigning points depending on how many team members agreed. More points indicated more cohesion. Also, a holistic measure of the same questionnaire. The team as a whole discussed the response options and indicated their team answer upon agreement among the entire team.<br><u>Taskwork knowledge</u> : Standardized questionnaire for relatedness of pairs of relevant terms (e.g., altitude, focus, zoom). Accuracy and cohesion assessed as above. |
| MacMillan, J., Entin, E.E., & Serfaty, D.                                            | 2004 | Self-report. Standardized questionnaire given after a mission. Team members indicated which of 12 predefined categories of behaviours they were performing at a given time, such as just completing takeover of a target location, and the tasks that other team members were performing. Average agreement among team members was then assessed.                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Marks, M.A., Sabella, M.J., Burke, C.S., & Zaccaro, S.J.                             | 2002 | Self-report.<br>Experiment 1: Questionnaire of relatedness of critical task concepts including 'escape enemy attacks' and 'position helicopter for targeting' rated on a scale from 1 (not related) to 9 (very related).<br>Experiment 2: Team members were tasked to develop a hierarchical structure illustrating the sequence in which 12 items from a standardized list of 50 events should occur during the mission (e.g., travel in V formation).                                                                                                                                                                                                                                                                                                                                             |
| Marks, M.A., Zaccaro, S.J., & Mathieu, J.E.                                          | 2000 | Self-report. Participants specified the sequence of actions of all team members that were necessary to complete the mission based on a standardized list.<br>Observer based. SMEs rated the self reports of event sequences described above on a standardized scale from 1 (inaccurate) to 7 (highly accurate).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Mathieu, J.E., Heffner, T.S., Goodwin, G.F., Salas, E., & Cannon-Bowers, J.A.        | 2000 | <u>Task mental model</u> : Standardized rating scales assessing relatedness of task concepts (e.g., diving versus climbing, banking versus turning).<br><u>Team mental model</u> : As above, but in relation to team concepts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Sterling and Burns                                                                   | 2005 | Measure involved choosing the most significant and 2 <sup>nd</sup> most significant from a list of 22 possible threats to current operations. Eight battlefield functions with respect to friendly and enemy (command and control, sustainment, information, communication, manoeuvre, fire support, air defense, aviation) and 6 current threats in environment (sensors, terrestrial weather, space weather, terrain, time, civilian population). Binary measure of congruence with other members of team.                                                                                                                                                                                                                                                                                        |
| Stout, Cannon-Bowers, Salas and Milanovich                                           | 1999 | Self-report. Participants presented with a pair of concepts related to mission, and rated level of informational relation between the 2 concepts (e.g. type of target vs. what kind of weapon to use against target).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

In making assessments about the sharedness of team knowledge, a critical decision is how the “sharedness” assessment is made, and researchers have used many different procedures for doing this. In the earliest studies of mental models, the focus was primarily on levels of agreement amongst team members. This would require simply comparing the extent to which each team members’ answers matched those of the other team members. If they matched each other closely, the team was said to have common mental models or to have a shared knowledge structure. More recently, however, researchers have started to emphasize other indicators, such as the accuracy of individual team members’ mental models. In fact, some team researchers have argued that there should be less focus on similarity and more on accuracy (Langan-Fox, Code, & Langfield-Smith, 2000; cited in Cooke et al., 2003; Rentsch & Woehr, 2004).

Traditional measures of team knowledge can be called collective or holistic (Cooke et al., 2004). Collective team knowledge refers to “long-term and situation-specific knowledge, possessed by the aggregate of all individual team members” (Cooke et al., 2001, p. 7). However, the problem with this aggregation is that important differences have the potential to be obscured in the aggregation process. An alternative to the aggregation of collective team knowledge is a more holistic approach. Cooke and colleagues (Cooke, Salas et al., 2004) have proposed a method for obtaining more holistic mental models that represent the team *a priori* rather than by aggregating data from individuals. Holistic team knowledge refers to knowledge that is “both long-term and situation-specific that is reflected in team actions and the ultimate outcome of those actions and that derives from the interaction between collective team knowledge and team process behaviours” (Cooke et al., 2001, p. 7). Within this holistic approach, team members discuss the relatedness of various concepts, and then provide the agreed-upon answer together. Cooke et al. (2001, p. 7) suggest that although both methods are probably predictive of team performance, collective knowledge has the potential to ignore important team process behaviours that “transform the collective knowledge into effective knowledge”. As such, there is increasing emphasis from the Cooke program of research to use more holistic data gathering methods rather than relying on the aggregation of individual responses (Cooke et al., 2001; Cooke et al., 2004).

It is worth noting that some empirical research has shown that how team data is aggregated may influence the results of mental model research. Preliminary data from Cooke and colleagues (Cooke, DeJoode et al., 2004) found that distributed teams performed as well as co-located teams when mental models were measured holistically, but worse when they were measured individually and then aggregated. This suggests that the results of experiments on mental models may be affected by the method of data gathering (Cooke, Salas et al., 2004).

Shared knowledge measures have been subject to some validation efforts. Research by Cooke et al. (2003)<sup>8</sup> explored the relationship between shared knowledge and team performance. As the taskwork and teamwork measures of shared knowledge were administered twice, this provided the opportunity to explore not only the predictive validity of the measures in relation to team performance, but also their ability to reflect meaningful changes in shared knowledge over time.

Results showed that the shared knowledge measures did successfully predict team performance. This finding is critical, as measures of shared team knowledge are predicated on the notion that the degree of common understanding within a team will facilitate team performance (Rentsch & Woehr, 2004). In the later mission (after teams had the opportunity to build shared knowledge), teams with higher levels of taskwork knowledge accuracy, positional (and interpositional) accuracy and intrateam similarity in their knowledge structures also performed better on the search and rescue task. However, teamwork knowledge was not significantly related to performance. The best predictors of team performance were positional knowledge and intrateam similarity. Just as importantly, these measures were also sensitive enough to capture the knowledge acquisition that had apparently happened within the teams. This provides good evidence of the measures being valid.

In general, however, the range of approaches indicated in Table 5 presents good evidence that there is actually very little agreement amongst researchers as to how shared knowledge should actually be measured (e.g. Espinosa et al., 2004), even though there is considerable interest in doing so. This suggests that more consistent (and agreed upon) measurement approaches will need to be used in order to move this area of research forward.

### **6.3.2 Measures of Communication**

Empirical research also evidences many different efforts to measure communication within a team context. Examples are provided in Table 6.

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<sup>8</sup> This specific paper is an earlier version of the Cooke et al. (2004) research reviewed earlier. However, one specific section speaks to validation efforts, and this research is not presented elsewhere.

**Table 6: Communication measures**

| Authors                                                                               | Year | Operational Definition                                                                                                                                                                                                                                    |
|---------------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cooke, N.J., DeJooode, A., Pederson, H.K., Gorman, J.C., Connor, O.O., & Kiekel, P.A. | 2004 | Observer based. Standardized questionnaire completed by SME raters on a 5-point scale from 1 (terrible) to 5 (excellent).                                                                                                                                 |
| Cooke, N.J., Shope, S.M., & Kiekel, P.A.                                              | 2001 | Observer based. Checklist completed by 2 independent SME raters. Represented by proportion of behaviours indicated as present.                                                                                                                            |
| Elliott, L.R., Hollenbeck, J.R., Tower, S.L., & Bradford, K.                          | 1997 | Inefficiency measured by proportion of requests for information to receiving requested information. Also implicit coordination measured by anticipation ratios.                                                                                           |
| Lindgren, I., Berggren, P., Janger, H., & Hirsch, R.                                  | 2005 | Observer based. Researchers recorded all communications and coded each transmission for different content categories (e.g., tactics, status). Researchers assessed content, frequency, and length of communication (total and per transmission) per team. |
| Marks, M.A., DeChurch, L.A., Mathieu, J.E., Panzer, F.J., & Alonso, A.                | 2005 | Observer based ratings of quality of transition processes (planning, mission analysis, goal specification) and action phase processes (monitoring, backup, coordination) on 1 (low) to 5 (high) scale.                                                    |
| Marks, M.A., Zaccaro, S.J., & Mathieu, J.E.                                           | 2000 | Observer based ratings of quality of team communication processes such as assertiveness, adaptability and flexibility on a 1 (extremely poor) to 7 (extremely good) scale..                                                                               |
| Mathieu, J.E., Heffner, T.S., Goodwin, G.F., Salas, E., & Cannon-Bowers, J.A.         | 2000 | Observer based ratings of frequency of team processes such as communication (e.g., "To what extent was information about important events and situations shared within the team?") from 1 (not at all) to 5 (to a very great extent).                     |
| Swain, K., & Mills, V.                                                                | 2003 | Observer based. Standardized questionnaire completed by SMEs. Anticipation ratios computed from SME responses.                                                                                                                                            |
| Colquitt, J.A., Hollenbeck, J.R., Ilgen, D.R., LePine, J.A., & Sheppard, L.           | 2002 | Index of efficiency at integrating verbal and computerized communication. Involved comparing numbers of proper and improper uses of voice and computerized communications and total communication frequency.                                              |
| Fletcher, T.D., & Major, D.A.                                                         | 2006 | Self reports of frequency of communication behaviours following completion of a task rated on a 1 (almost never) to 5 (almost always) scale.                                                                                                              |

Early measurement of communication was typically undertaken using either trained observers or SMEs, and through completion of "live" rating of communication as it occurred within scenarios. For example, in one case, measures of communication were embedded within a computer-based scenario (Elliot et al., 1997). In this methodology, observers made ratings of ongoing communication, and the computer recorded the number of times certain communication function keys are depressed. More recently, however, improved technology has enabled audio capture of team

communication and subsequent content analysis. Such analysis typically comprises assessment of a team's communication frequency and quality according to established definitions (e.g. Entin, 1999).

Clearly, the most common forms of team communication measures are observer based rating scales, and actual content analysis coding of communications. Obviously, one of the serious research challenges of undertaking content analysis of team communication data is the sheer amount of information, and developing intricate coding schemes are very labour intensive. Unfortunately, this is also an area in which researchers wanting to understand communication have typically created their own coding schemes rather than working with existing "hallmark" schemes. Perhaps the most common coding scheme was developed by Entin, Entin, MacMillan & Serfaty (1993), and has been either used or adapted for use in a range of communication research. This coding strategy requires ratings of each unit of communication and classification into "transfers" (sending information), "requests" (pulling or requesting information), and "acknowledgements" (e.g. of receipts of information). This form of classification then enables the creation of anticipation ratios (proportion of requests divided by total communications).

Several important trends were also noted in the team communication measurement literature. First is the increasing emphasis on "feedback loops". This is also called "pattern analysis" (rather than simple frequency analysis) by Salas et al. (1995). This trend suggests increasing complexity in how communication is analyzed, with more attention being paid to the pattern of requests and acknowledgements made within a team than simply the frequency with which communication is used.

Again, the primary challenge with respect to team measures of communication is that there has apparently been little effort given to validating existing measures, and knowledge has again failed to accumulate.

### **6.3.3 Measures of Coordination**

The approach to measuring coordination has been somewhat unidimensional to this point, and coordination has either been indicated by communication patterns, or observer based (see Table 7).

**Table 7: Coordination measures**

| Authors                                                                       | Year | Operational Definition                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------|------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| MacMillan                                                                     | 2004 | Used communications to measure coordination action and rate, but little detail provided.                                                                                                                                                                                                                                                 |
| Marks, M.A., DeChurch, L.A., Mathieu, J.E., Panzer, F.J., & Alonso, A.        | 2005 | Observer based ratings of transition phase and action phase processes. Goal setting, mission analysis and strategy formation rated for transition phase. Monitoring, backup behaviour and coordination for action phase. All indices combined.                                                                                           |
| Marks, M., & Panzer, F.J.                                                     | 2004 | Observer based. Standardized questionnaire for presence or absence of coordination and how well coordination was executed on a scale from 1 (very poor coordination) to 7 (very strong coordination).                                                                                                                                    |
| Marks, M.A., Sabella, M.J., Burke, C.S., & Zaccaro, S.J.                      | 2002 | Experiment 1: Observer based. SMEs rated frequency and overall quality of coordination on a standardized questionnaire.<br><br>Experiment 2: Computer-based. Measure of distance of the players' tanks from each other every minute over the course of the 40min mission. Tanks that were closer together were seen as more coordinated. |
| Mathieu, J.E., Heffner, T.S., Goodwin, G.F., Salas, E., & Cannon-Bowers, J.A. | 2000 | Observer based measure of strategy formation and coordination with 6 items (e.g. "To what extent did the team plan together and coordinate its actions?") on 5-point scale from 1 (not at all) to 5 (to a very great extent).                                                                                                            |

Typically an observer indicates on a standardized questionnaire the frequency and quality of coordination in general and of predefined coordination behaviours (Marks et al., 2005; Marks & Panzer, 2004). However, computer based measures have also been used (Marks et al., 2002) assessing the relative distance of the players from each other at intervals throughout the course of a simulation. Using this methodology, coordination was operationally defined as the distance between participants, with shorter distance indicating better coordination. As noted earlier in this review, however, this conceptualization is potentially problematic, as factors other than coordination might have affected the distance of the tank players from each other.

#### **6.3.4 Measures of Team Adaptability**

Adaptability measures can be observer based or computer based (see Table 8). Both monitoring and backing-up have been measured with both computer and observer based measures. Observer based measures tend to involve completion of subjective measures by trained observers, whereas computer based measures tend to record the number of times particular events occur such as clearing a team member's area (Porter et al., 2003).

**Table 8: Adaptability measures**

| Authors                                                                          | Year | Operational Definition                                                                                                                                                                                                                                                                                    |
|----------------------------------------------------------------------------------|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Porter, C.O.L.H., Hollenbeck, Ilgen, D.R., Ellis, A.P.J., West, B.J., & Moon, H. | 2003 | Need for backing-up manipulated by overloading one team member more than the others.<br><br>Backing-up behaviours measured by the number of times another team member attacked and cleared enemy targets in the overloaded team member's area of responsibility. Additional information was not provided. |
| Marks and Panzer                                                                 | 2004 | SME ratings of quality of feedback provided to and by team members.                                                                                                                                                                                                                                       |

In terms of scenario development, it also interesting to note that the novelty of the simulated battlefield was believed to induce adaptability (Marks et al., 2000), and the need for backing-up has been manipulated by uneven allocation of resources (e.g., MacMillan et al., 2004; Porter et al., 2003).

### 6.3.5 Measures of Planning/Resource Allocation

Planning measures tend to be subjective, either self-reported or observed by trained raters and assessed for frequency and quality on a standardized questionnaire (see Table 9).

**Table 9: Planning and resource allocation measures**

| Authors                                                                              | Year | Operational Definition                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cooke, N.J., DeJoode, A., Pederson, H.K., Gorman, J.C., Connor, O.O., & Kiekel, P.A. | 2004 | Observer based. Single-item for planning quality within a standardized questionnaire of rated on a 4-point scale.                                                                                                                                                                                                   |
| MacMillan, J., Entin, E.E., & Serfaty, D.                                            | 2004 | Planning was manipulated using pencil and paper vs. electronic collaboration.                                                                                                                                                                                                                                       |
| Stout, R.J., Cannon-Bowers, J.A., Salas, E., & Milanovich, D.M.                      | 1999 | Observer based. Standardized questionnaire assessing planning quality on nine dimensions with a 7-point scale, including exchanging preferences and expectations, and clarifying roles and information to be traded. The two raters then met to form a consensus about the overall quality of each team's planning. |
| Marks, M.A., DeChurch, L.A., Mathieu, J.E., Panzer, F.J., & Alonso, A.               | 2005 | Transition phase was planning phase; action phase was execution. Goal setting, mission analysis and strategy formation rated for transition phase. Monitoring, backup behaviour and coordination for action phase. All indices combined.                                                                            |

Planning and resource allocation have also been manipulated in order to examine their influence on the effects of other factors on performance (e.g., Elliott et al., 1997; LePine et al., 1997; MacMillan et al., 2004).

### 6.3.6 Measures of Team Climate

Team climate measures tend to rely on self-reports involving degrees of agreement with statements concerning various attributes of these factors. This is not surprising given that team climate factors are generally more affective or attitudinal in nature. Several different examples of typical team climate measures are indicated in Table 10.

**Table 10: Team Climate measures**

| Team Climate Factor | Authors                                                                                                                                                                                                                                                                                                  | Measurement Tools                                                                                       |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| <b>Cohesion</b>     | Bailey, L.L. & Thompson, R.C. (2000); Bass, B.M., Avolio, B.J., Jung, D.I., Berson, Y. (2003); Harrison, D.A., Price, K.H., Bell, M.P. (1998); McIntyre, R.M., Strobels, K., Hanner, H., Cunningham, A., & Tedrow, L. (2003).                                                                            | Self-reports on questionnaires. Often assessed as teamwork, attraction to the team/liking team members. |
| <b>Motivation</b>   | Bass, B.M., Avolio, B.J., Jung, D.I., Berson, Y. (2003); also LePine et al. (2004).                                                                                                                                                                                                                      | Self-reports on questionnaires. Often assessed in relation to leadership style.                         |
| <b>Trust</b>        | Cooke, N.J., Kiekel, Salas, E., P.A., Stout, R., Bowers, C., & Cannon-Bowers, J. (2001); Dirks (1999);<br>Also Currall & Judge(1995); McAllister, (1995); Meyerson, Weick, & Kramer, (1996)                                                                                                              | Self-reports on questionnaires.                                                                         |
| <b>Efficacy</b>     | Bass, B.M., Avolio, B.J., Jung, D.I., Berson, Y. (2003); De Shon, R.P., Kozlowski, S.W.J., Schmidt, A.M., Milner, K.R., and Wiechmann, D. (2004); Harville, D.L., Lopez, N., Elliott, L.R., Barnes, C. (2005); Karrasch, A.I., (2003); Katz-Navon, T.Y., Erez, M. (2005); Swain, K., & Mills, V. (2003). | Self-reports on questionnaires. Often assessed as confidence, potency.                                  |

Clearly, these team climate measures have received a good deal of attention in the literature. Unfortunately, however, there is little evidence of established and validated scales for any of these measures that would be directly applicable to military teams.

### 6.3.7 Example of Team Measures used in Military Research

We now turn to a specific example of an effort to measure team products and processes in applied military research.

Kyne, Thordsen et al. (2002) reported their development of a draft instrument for the U. S. Army Research Institute to assess team decision-making and performance. Because the authors could not secure access to military test sites, firefighters were used to design the draft instrument based on the Advanced Team Decision-Making 2.0 model. The draft instrument requires observers to provide subjective ratings of ATDM 2.0 behavioural dimensions (Figure 6).

Date: \_\_\_\_\_ Time: \_\_\_\_\_ Coder: \_\_\_\_\_ Incident #: \_\_\_\_\_  
Incident Type: \_\_\_\_\_

| Behavioral Dimensions | P                        | A                        | n/o                      | n/a                      | L | > | > | > | H |
|-----------------------|--------------------------|--------------------------|--------------------------|--------------------------|---|---|---|---|---|
| Member Resources      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Leader Resources      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Other Resources       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Procedures            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Roles & Functions     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Engagement            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Compensation          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Envision Goals        | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Range of Factors      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Time Horizon          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Manage Uncertainty    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Diverge               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Converge              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Course of Action      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Expectancies          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Monitor & Adjust      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |
| Time Management       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | 1 | 2 | 3 | 4 | 5 |

**Figure 6. Teamwork Assessment Scales (Kyne, Thordsen et al. 2002, pp. 6)**

Researchers accompany the fire department on incident calls, observe the firefighters in action and interview the firefighters before and after the incidents. The observer records two aspects for each of the ATDM 2.0 behavioral dimensions: whether the behaviour was “observed” (expected behaviours occurred), “absent” (expected behaviours did not occur), “not observed” (expected behaviour might have occurred, but observer missed it) or “not applicable” (behaviour was not applicable for the incident) and the quality of the observed behaviours on a scale from 1 (Very Ineffective) to 5 (Highly Effective).

Results showed that the behavioural dimensions of ATDM 2.0 were generalizable to firefighting. The instrument also helped firefighters identify dimensions for improvement. The draft instrument showed a high degree of inter-rater reliability between research observers, and also with assessments from the firefighting battalion chief. However, mean behavioural ratings were high overall; for example, “absent” or “not applicable” was not indicated for any of the behavioural dimensions. The authors explain that this might have occurred because the firefighters were all very well trained. In any case, it was not possible to tell whether the instrument is sensitive to differences in team performance.

## **6.4 Overview of Team Measures**

Despite the lack of agreement within the literature, some researchers have provided several general principles to guide the measurement of teamwork, as shown in Figure 7.

TABLE 15.1  
Principles for Measuring Teamwork Skills

| <i>Original Principles</i>                                                                               | <i>Emerging Principles</i>                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. For understanding teamwork, there is nothing more practical than a good theory (Baker & Salas, 1992). | 1a: Full understanding of team performance requires behavioral, cognitive, and attitudinal-based measures.<br>1b: The development of team performance measures must be guided, in part, by theory and, in part, by empirical research.                                                                                                                                                                                                 |
| 2. What you see may not be what you get (Baker & Salas, 1992).                                           | 2a: Measures must capture the dynamic nature of teamwork.<br>2b: Measures and measurement tools must reflect the maturation process of a team.<br>2c: Measures must account for team member experience with a team.                                                                                                                                                                                                                    |
| 3. There is no escaping observation (Baker & Salas, 1992).                                               | 3a. Team performance is not simply represented by what team members do.<br>3b. Observation is critical for measuring and providing feedback regarding team behavioral skills.<br>3c. Measures that assess team member shared mental models and interpositional knowledge must be developed and validated.                                                                                                                              |
| 4. Applications, applications, applications (Baker & Salas, 1992).                                       | 4a. Team performance measures must be developed, implemented, and evaluated for a wide variety of teams in a wide variety of settings.<br>4b. Psychometric data must be collected on all new measures of team performance.<br>4c. Measures that assess team knowledge, attitude, and skill competencies must be developed, applied, and evaluated.                                                                                     |
| 5. Judges and measures must be reliable (Baker & Salas, 1992).                                           | 5a. Reliability studies must reflect characteristics of the measurement tool.<br>5b. Team performance expert observers must demonstrate high levels of agreement (around 90%).<br>5c. Team performance measures must demonstrate internal consistency.<br>5d. Measures must establish the reliability of team performance.                                                                                                             |
| 6. Validation for practice and theory (Baker & Salas, 1992).                                             | 6a. The content and construct validity of team performance measures must be determined.<br>6b. Valid team performance measure must contribute to the development of valid team performance theories.<br>6c. The criterion-related validity of team performance measures must be determined.<br>6d. Team performance measures must predict team outcomes.<br>6e. Team performance measures must look like they assess team performance. |

Figure 7: Principles for Measuring Teamwork Skills (Baker and Salas, 1997)

As a whole, then, this critical advice argues that team measures should be driven by theory, that they should capture the dynamic nature of teamwork. The primacy of

observation is another critical principle. Simply observing what teams do is not adequate, but must be supplemented with measures of their cognitions as well as their behaviours. Other principles argue that measures must be tailored to capture teams with diverse settings, and must be shown to be both reliable and valid in order to be used.

Baker and Salas (1997) also note that it is critical to understand when to and how to measure team performance. The former depends on how old the team is, how quickly it matures, and whether multiple assessments are necessary to understand the question at hand. The latter concerns the type of measure and whether or not team performance can be measured objectively.

There are several gaps evident in current approaches to team measurement. At the broadest level, measures of teamwork appear to be relatively disjointed. At least in part, this is likely because they have been developed by specific researchers in efforts to research specific team issues. The lack of attention to previously developed measures has resulted in a non-systemic set of measures. Indeed, Baker and Salas (1997, p. 336) have argued that

*“unified theories of teamwork have been proposed, but unified measures of teamwork have not.”*

The inconsistency in methodologies is not necessarily problematic if it is controlled and is intended to be used as a validation tool, for example establishing similar results using various methodologies and contexts.

As noted earlier, despite the considerable progress that has been made in the area of team research, much more attention has been directed at understanding the more pragmatic aspects of team functioning than the relational or social aspects. In keeping with this, Cooke et al (2004) has argued that much more is known about how to measure taskwork knowledge than about teamwork knowledge. This suggests that increasing attention needs to be paid to the social processes implicated in teamwork.

The most prominent criticism of existing measures of teamwork relates to the relative lack of measurement validation. Prominent researchers have argued that measures must demonstrate validity (i.e., construct, content, and face) and reliability (i.e., criterion and inter-rater) (Baker and Salas, 1997), and these issues have not often been addressed in many existing team measures. For this to occur, of course, researchers have to give more attention not just to developing measures for their specific research questions, but to systematically showing that these measures are valid. Unfortunately, at least to this point, researchers have focused more on research questions around teams rather than on the measures that they use. For example, as Baker and Salas (1997, p. 345), “evidence for the internal consistency of team performance measurement tools has been less than encouraging”. This suggests that researchers need to pay more attention to this issue. Not only do measurement tools need to prove

reliable and valid, but procedures need to be undertaken to ensure good inter-rater reliability.

In keeping with the research gap related to team development, it is also clear that existing measures have generally been constrained to a single point in time, but pay little attention to team experience and team development (Baker and Salas, 1997). For example, Cooke, Salas et al. (2004, p. 85) argue that “.... *team cognition is more than the sum of the cognition of the individual team members. Instead, team cognition emerges from the interplay of the individual cognition of each team member and team process behaviours*”. This suggests that team measures need to be more dynamic, and more capable at reflecting “the maturation process of a team” (Baker and Salas, 1997).

Similarly, other researchers have also questioned whether “team cognition is an epiphenomenon, in that is it merely an *additive* process/product associated with multiple members, or it is truly a *synergistic* process/product?” (Fiore & Salas, 2004, p. 243). Clearly, there is some agreement that seeing teams holistically, and as a team being more than the mere sum of its constituent parts is the way of the future. The challenge, of course, is in designing team measures that are able to capture this dynamism and complexity. What seems to be somewhat lacking in existing team measures is a clear ability to capture both individual and team level attitudes, as well as being able to capture both dynamic and static team processes and properties.



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## 7. Models of Team Performance

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For more than 2 decades, researchers, scientists, and individuals from a variety of disciplines have attempted to model team behaviour. Yet even today, although there are a variety of team effectiveness models, there is no commonly accepted model of team effectiveness (Henderson & Walkinshaw, 2000; cited in Essens et al., 2005). Our review focused on the most prominent ones, and on the ones likely to be most relevant to the applied research program at hand. This section describes the various components of each model, and considers their potential strengths and weaknesses, as well as their promise for further development.

Although conceptual models have been at the forefront in terms of explaining teamwork, there has also been some attention directed to the creation of mathematical models. More recently computational models have begun to surface. Mathematical models provide a means by which to model complex phenomena using known relationships or universal laws. Such models, however, are geared to depict the relationship amongst constructs with no true temporal or dynamic quality. Computational models, on the other hand, allow a higher level of fidelity, as they depict dynamic relationships amongst variables. These types of models are still early in their conception; however, a select few have focused on teamwork. Examples of these computational models will be described and critically assessed.

### 7.1 Conceptual Models

Teamwork is often conceptualized as occurring within an input-process-outcome framework (e.g. Mathieu, Heffner, Goodner, Salas & Cannon-Bower, 2000). Within this framework, inputs are comprised of conditions that exist prior to performance, such as member, team, or organizational characteristics. Processes “describe how team inputs are transformed into outputs” (Mathieu et al., 2000, p. 273) and outputs refer to products of team activities.

It is, however, important to note that this I-P-O framework may be somewhat outdated, and has been increasingly criticized because it treats outcomes as the “end-point” of a team cycle. This way of construing the process does not give adequate representation to the importance of “feedback loops on team processes or the dynamic nature of team performance” (Day et al., 2004, p. 861). This suggests that a more holistic model that incorporates team performance might be important to consider. Within the leadership literature, a model that extends to consider inputs, mediational influences, and outcomes as well as feedback loops at the end have been noted to be in development (Ilgen, Hollenbeck, Johnson & Jundt, 2005; cited in Day et al., 2004).

The majority of conceptual models accessed for this review are normative models of team performance. An influential normative model was proposed by Cannon-Bowers, Tannenbaum, Salas and Volpe (1995).

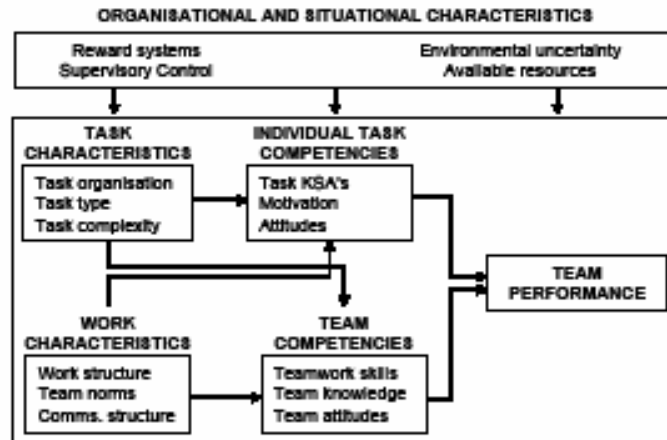


**Figure 8. Model of Team Effectiveness (Cannon-Bowers et al., 1995)**

This model consists of a number of factors that influence team performance. Aside from team and task characteristics, Cannon-Bowers et al. (1995) also suggest that organizational and situational characteristics (e.g., reward systems, environmental uncertainty) can play a substantial role in defining team performance. In addition, their model indicates that task and work characteristics influence team performance because these factors determine which task and team competencies are necessary for successful performance. Therefore, although task and work characteristics do not directly impact on team performance, they do indirectly impact through their influence on team and task competencies.

The major advantage of this model is that it emphasizes the importance of environmental factors. Most of the past models of team performance did not consider environmental factors as contributing to team performance. This past omission was problematic, as most teams do not operate within a vacuum. On the other hand, this model also seems to under-emphasize the potential power of team processes. Teamwork skills, such as communication and coordination are highly researched areas in the team literature, and are clearly very influential factors to the overall functioning and ultimate success of a team. As such, these factors should be represented more prominently in any model of team performance.

Espinosa et al. (2004) proposed an input-process-output model (Figure 9) of team performance suggesting that interdependencies among team members (and how these interdependencies are handled) are critical to team performance.

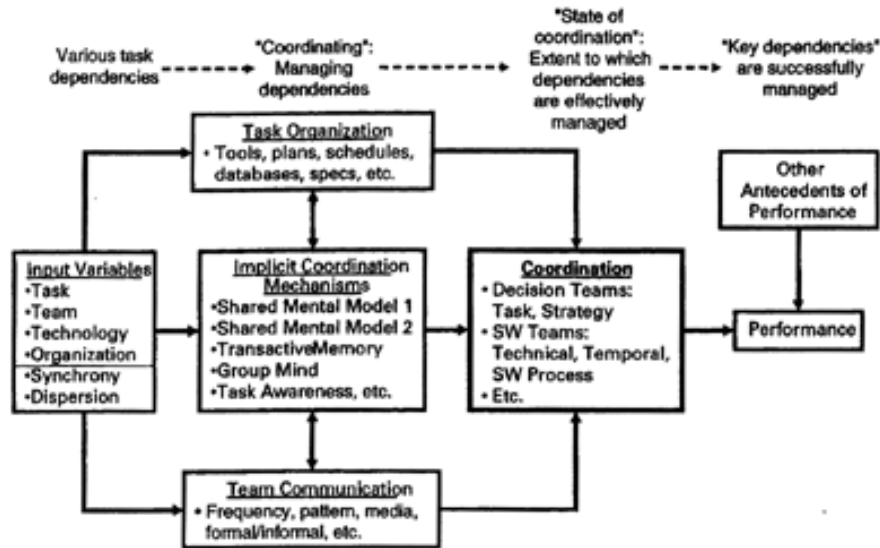


**Figure 9. Input-Process-Output Model of Team Performance (Espinosa et al., 2004)**

The three major factors in the Espinosa et al. (2004) model are task dependencies, managing dependencies, and the effectiveness of coordination. According to Espinosa et al. (2004) a team copes with task dependencies through processes such as organization, implicit coordination (i.e., shared knowledge such as shared mental models), and communication. How well the team executes these processes predicts the team's coordination levels, which in turn directly predict team performance. Through this model, Espinosa et al. (2004) posit that the degree to which a team must depend on each other and how well they manage these dependencies are crucial to team performance.

To support their model, Espinosa et al. (2004) referred to two of their previous studies. The studies used different types of teams: asynchronous *ad hoc* student decision teams managing virtual companies (Espinosa, Carley, Kraut, Lerch, & Fusell, 2002; cited in Espinosa et al., 2004) and geographically distributed *a priori* software teams from a large telecommunications company (Espinosa, 2002; cited in Espinosa et al., 2004).

Research with the student team found that while they lacked coordination at the beginning of the study, they gradually developed it as they worked together more, suggesting that shared team knowledge needs time to develop (Espinosa et al., 2003; cited in Espinosa et al., 2004). This research also showed the importance of coordination, as poor coordination led to decreased performance (Espinosa et al., 2003; cited in Espinosa et al., 2004). However, the results also showed that good coordination on its own does not necessarily lead to increased performance

suggesting that other variables may be more important (Espinosa et al., 2003; cited in Espinosa et al., 2004). Similar results were obtained with the software team wherein shared team knowledge and coordination resulted in faster project completion (Espinosa, 2002; cited in Espinosa et al., 2004).

In summary, the model proposed by Espinosa et al. (2004) highlights the importance of team coordination with regard to team performance and in particular managing task dependencies in a team environment. The major strength of this model is its detailed description of how coordination affects performance and is affected by various coordination mechanisms and input variables. The primary disadvantage is that the model is limited in terms of its coverage of the processes that affect performance; it describes coordination to the exclusion of other factors such as other team process and climate variables that can have a significant effect on performance. Finally, the two studies cited in Espinosa et al. (2004) to support their model do not test the full model, only specific parts of it. Thus, the validity of the Espinosa et al. (2004) model remains to be tested.

A third model of team performance, the Command Team Effectiveness Model (CTEM) was proposed by Essens et al. (2005) in order to identify critical factors in command team effectiveness (see Figure 10).

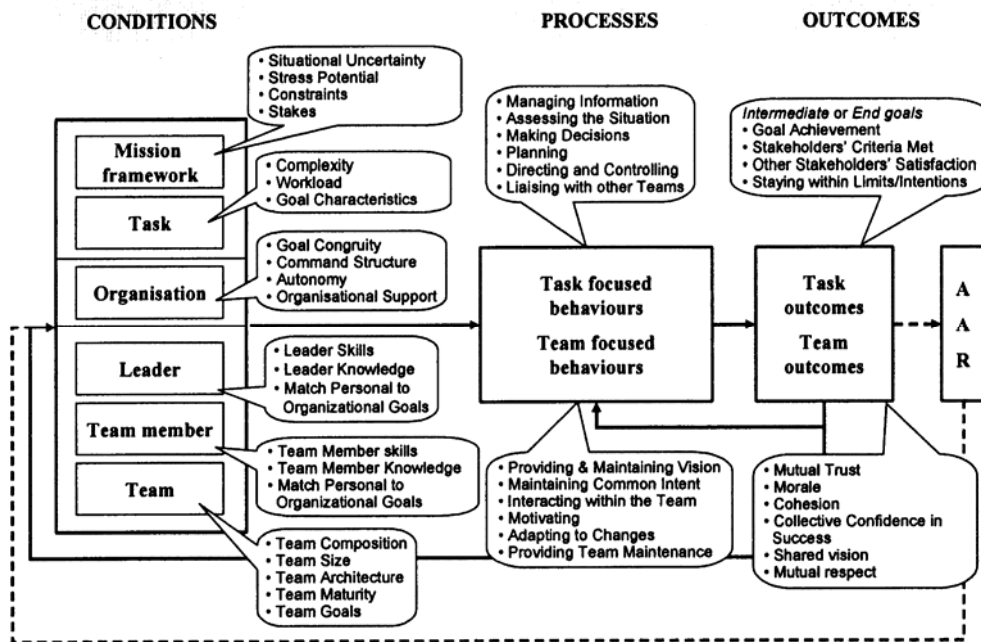


**Figure 10. Command Team Effectiveness Model (Essens et al., 2005)**

This model once again uses the input-process-output framework in modelling team effectiveness, however, unlike previous models, this one included feedback loops at

each level of the model (i.e., process adjustment loop, conditions adjustment loop, organizational learning loop).

The three major building blocks of the model (Conditions, Processes, Outcomes) are further broken down into distinct components. These factors determine how effective the team will be in specific circumstances. In the Conditions section, Essens et al. (2005) specify contextual factors (i.e., mission framework, task, and organization), and people factors (i.e., leader, team member, and team). The Processes are the second block in the model and include Task- Focused Behaviours (e.g., managing information) and Team-Focused Behaviours (e.g., motivating). These behaviours either capitalize on existing team strengths or compensate for limitations in the team. Finally the Outcomes are defined as the result of the processes and focus on the extent to which the team has reached its assigned goal (e.g., met the criteria set by the stakeholder) or the extent to which the team has developed as a team (e.g., development of trust). The command team effectiveness model (CTEF) does not end at the team and task outcomes but also includes an after action review (AAR). The AAR is a process in which the commander, along with the team reviews performance in terms of team and task outcomes, and therefore overall how effective the team was. This review session allows the team member and commander to identify lessons learned and improve upon these if necessary. This is all part of the feedback loop.

This model, it is important to point out, was designed to be used as a pragmatic information tool for commanders at the operational and tactical level. When linked with the related assessment instrument, the model is intended to provide commanders with the tools they need to better understand the effectiveness of the teams that they command.

This model makes a number of important contributions to understanding military teams. First, unlike many other models, it explicitly posits that team outcomes are part of a feedback loop that helps to further refine team performance. Secondly, it presents a much broader and much more specific account of the many factors likely to impact on team performance. For example, the conceptualization of outcomes as including both task and team-centred outcomes is an important addition to the thinking about teams. Although team performance is of critical importance in relation to a specific task, if one takes a more longitudinal approach to understanding team functioning, a critical aspect of “performance” is how the team has managed the social issues within the teams during the task. At least in part, one would expect that this milieu is likely to make a strong contribution to how the team is likely to perform in subsequent tasks. As a whole, then, from our review, this model has emerged as the one that best specifies the factors that are likely to influence team performance. The weakness of the model in our view is in the Processes section, as it fails to articulate the exact processes of coordination, communication, shared mental models that are likely to be the primary drivers of team performance. Nonetheless, with the addition of the factors identified in this review into the Processes section, this model shows good potential for further development and validation.

Lastly, an important new model exploring team performance within distributed environments also depicts teamwork as a product of both the technology that teams use in order to interact, the processes that are invoked, and the various moderating or contextual factors (Driskell & Salas, 2006). Incorporating research on teamwork dimensions by Cannon-Bowers, Tannebaum, Salas, and Volpe (1995), Driskell and Salas (2006, p. 19) created the ‘Contextual Model of Groupware Development.’ (Figure 11). This model depicts groupware development in terms of specific team factors that influence overall team performance), as shown in Figure 11.

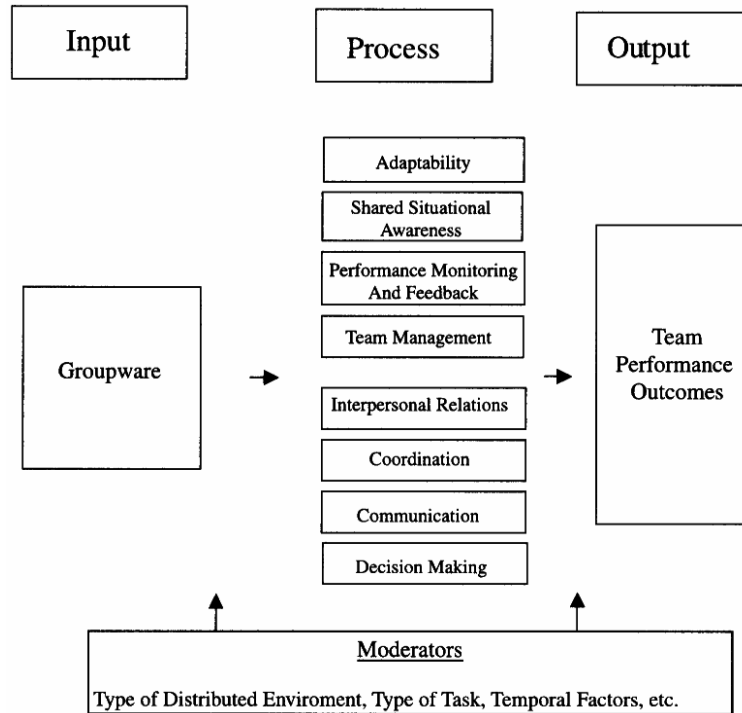


**Figure 11. Contextual model of groupware development  
(Driskell & Salas, 2006, p. 19)**

This model also posits several team processes that are influenced by the presence of groupware and which combine to influence team performance. These factors are indicated in Table 11.

**Table 11. Teamwork Dimensions (Driskell & Salas, 2006)**

| Teamwork Dimensions                 | Description                                                                                                                   |
|-------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|
| Adaptability                        | Mutual adjustment, compensatory behaviour, reallocation of resources for team goals.                                          |
| Shared situational awareness        | Contextual task and team information must be communicated to and understood by the team.                                      |
| Performance monitoring and feedback | Team members have to keep track of individual contributions, team progress, identify errors, and provide feedback and advice. |
| Team management                     | Direction of members and planning to achieve team goals.                                                                      |
| Interpersonal relations             | Conflict resolution, fostering cooperation and building morale.                                                               |
| Coordination                        | 'Knowing who is going to do what, when, and with whom' (Driskell & Salas, 2006, p. 18)                                        |
| Communication                       | The effective and timely exchange of information.                                                                             |
| Decision making                     | Identifying and assessing problems, generating and implementing solutions, and evaluating consequences.                       |

This research also argues for the importance of various contextual factors in the performance of distributed teams, as shown in Table 12.

**Table 12. Contextual factors (Driskell & Salas, 2006)**

| Moderator                       | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type of distributed environment | Based on theories of social presence (Short, Williams, & Christie, 1976) and media richness (Daft & Lengel, 1984), the communication of contextual information is reduced as teams move from face-to-face, to audio-only, to textual modes of communication.                                                                                                                                                                                                                                      |
| Type of Task                    | Cognitive versus physical requirements (McGrath, 1984; Shaw, 1973; Steiner, 1972); mechanical/technical, intellectual/analytic, imaginative/aesthetic, social, manipulative/persuasive, or logical/precision tasks (Driskell, Hogan, & Salas, 1987); generating, choosing, negotiating, or executing tasks (McGrath, 1984); task difficulty (Gallupe, DeSanctis, & Dickson, 1988); task uncertainty (Samburthy, Poole, & Kelly, 1993); interdependence (Shaw, 1973; Steiner, 1972; Herold, 1978). |
| Temporal Context                | Newly formed groups may be able to perform tasks that pool together individual efforts, but not tasks that require much collaboration. There are five basic stages through which groups develop a productive relationship: orientation, conflict, cohesion, performance and dissolution.                                                                                                                                                                                                          |
| Group Size                      | Influences performance in terms of team diversity, coordination requirements, conformity pressures (Steiner, 1972), opportunities for participation, individual performance and satisfaction.                                                                                                                                                                                                                                                                                                     |
| Status Structure                | Influences member interaction requirements, group resource command, and group decision-making. Presence of status structures can benefit or impair performance depending on type of task, and groupware can impose different team structural changes with unknown effects. For example, text-based systems lead to equal participation and flattens status hierarchies (Driskell, Radtke, & Salas, 2003; Dubrovsky, Kiesler, & Sethna, 1991; Brennan & Rubenstein, 1995).                         |
| High Stress or High Demand      | High stress or demanding environments can reduce team members' willingness to assist each other and cooperation, increase interpersonal aggression and lead to neglect of social cues (Mathews & Canon; Sherrod & Downs, 1974); narrow attention focus (Driskell, Salas, & Johnston, 1999); and require the use of less time-consuming decision-making strategies.                                                                                                                                |

This model is very encouraging because it suggests increasing understanding of the complex domains in which distributed teams must perform. More specifically, this model argues that the type of distributed environment (e.g. the form that communication must take), the type of task, temporal demands, group size, status structure and workload demands within a given situation will all influence team processes and performance. Although the focus of the model is the groupware context, this model is perhaps the most promising in terms of its description of the constructs that are likely to be critical within a typical CF context of the future. Clearly, physical distribution, and the need to have computer-mediated

communication, working under high time pressure, and in uncertain environments are important components of this model.

Moreover, it is also heartening that such a recent model matches very closely with the constructs emphasized throughout this review, perhaps showing gradual convergence within the team literature of the most critical aspects of team performance. As noted earlier as well, this kind of work also suggests increasing convergence of the mainstream team literature with the more technological/collaborative work literature. Clearly, this model shows good promise for helping to understand distributed team performance.

## 7.2 Mathematical Models

Mathematical models of team performance emerged in the 1980s (described by Salas et al., 1995). Mathematical (and other forms of) models could be normative or descriptive. Modelling tends to be an iterative process. In the model development phase, the modeller starts by forming a model of optimal team performance (for normative models) or expected team performance (for descriptive models) on a given task. In the model validation phase, the model predictions are compared to actual team performance. If the primary objective were to develop a normative model, then observed discrepancies between model predictions and actual performance would be attributed to factors such as cognitive biases or information-processing limitations. In other words, the normative model then serves as a basis for characterizing why or how performance is suboptimal and for exploring how it may be optimized. If the primary objective were to develop a descriptive model, then observed discrepancies would serve as the basis for adapting or extending the original model to yield predictions that more closely approximate actual behaviours. A model is also considered to have predictive power when it can produce testable predictions of how a team would perform in conditions for which no data yet exists (e.g., performance by a distributed team on a task that is traditionally performed by a co-located team). The model's predictions could be validated by collecting data on actual task performance under the new conditions. Mathematical modelling has been applied to the weighing of information from distributed sources, hypothesis testing in uncertain environments, and to resource allocation.

Several mathematical models were developed for multi-human decision making under the Office of Naval Research's Distributed Tactical Decision Making (DTDM) Program (Kleinman et al., 1992). For example, the Distributed Information-Processing (DIP) model is a mathematical model that predicts how team members weigh and combine sequential information from distributed sources, including their prior knowledge, initial measurement data, probe data, and communicated data. At the beginning of this program of research, a normative model was developed to "predict the optimal fusion of information in a two-person team" (Kleinman, 1992, p. 186). To test this mathematical model, an experiment was conducted using the distributed decision making paradigm (DDD) to simulate a naval C2 environment

(Kleinman et al., 1992). Participants were two-person teams using a workstation with a graphics display (showing position of a static target on a simulated radar screen) and an alphanumeric display (showing target information, information transferred between members, and input command line). Participants were required to estimate the targets' attributes as accurately as possible. Comparisons of the model predictions and experimental data revealed four cognitive biases: recency effects, anchoring to prior knowledge, not discounting common prior knowledge, and undervaluing the information received from other team members. This descriptive information portraying the cognitive biases was then incorporated into the normative model and the final model was again used to predict the actual experimental data. This model (labelled by Kleinman as normative/descriptive) performed better at predicting the experimental data than the initial normative model.

A second model, the Hierarchical Information-Processing (HIP) Model, investigated how a leader combines the opinions of his or her subordinates to solve a hypothesis testing problem (i.e., correctly decide whether a target is a neutral or a threat) (Kleinman et al., 1992). Again, a normative model was first created depicting two subordinates and a leader. This model posited that subordinates and a leader make an initial decision about an ambiguous object, but that the subordinates then 'feed' their information to the leader. The leader then decides how/whether to use this new information to change the final team decision. To test the model, experiments were conducted on three computer workstations. These experiments required 6 teams (matching the structure of the normative model) to identify 60 static targets each appearing on screen as either "threats or neutrals" under varying levels of ambiguity, and evolved in two stages. In the first stage, subordinates made their decisions (and did confidence ratings) using their own data and global data available. The leader then made a decision using only the global data. Then, subordinates sent their data to the leader, and the leader made the final team decision (and confidence ratings), now based on both the global data and information provided by subordinates. Comparisons between the model predictions and experimental results showed that the model and participants had roughly the same amount of error, but that the model failed to predict the participant's decisions in 20-25% of the cases. A critical difference noted between the normative model and the experimental data was that subordinates and the leader (in stage 2) are more conservative in their confidence estimates than was the normative model. This information was then used to create a new version of the initial model, again arriving at a model that Kleinman called a "normative/descriptive model".

A third mathematical model was developed to study resource allocation in teams. This work on the Distributed Resource Allocation and Management (DREAM) model is reported to be the first study of dynamic resource allocation in a team (Kleinman et al., 1992). The DREAM model depicted a two-person team required to complete a number of tasks with shared resources. Tasks were programmed to arrive at random intervals, and to have different reward structures, processing and time requirements etc. Moreover, tasks were predefined to give team members "different but overlapping processing responsibilities" (Kleinman et al., 1992, p.

200), and to require team coordination. The team goal was to maximize the reward gained from task completion. To test this descriptive model, a distributed decision making experiment was conducted using a workstation display and implementing the key attributes of the model. Comparisons of the model-generated data and the experimental data<sup>9</sup> indicated that the model predicted well on certain dependent variables (e.g., final team strength) but inaccurately predicted other variables. For instance, the model processed all tasks but with lower accuracy whereas humans naturally processed fewer tasks but at a greater level of accuracy. This suggests that certain factors may bias the timeliness/accuracy trade-off and identifying and including these into the model would help its predictive power.

Finally, the goal of the Team Distributed Scheduling (TDS) Model was to examine how team decision making and coordination strategies adapt to increased workload and resource scarcity under different responsibility structures (Kleinman et al., 1992). Specifically, this model explores a team of 3 decision makers who must respond to new tasks that must be completed by one of the team members. However, the team has fixed resources and each team member can only address one task at a time. As such, to be maximally effective, the team must share the load. First, a normative model was created. For the experiment, three decision makers sat at workstations and were presented with randomly arriving tasks that required processing by one of the team members. Several variables were manipulated, including functional overlap, resource scarcity, and arrival rate of tasks. The normative model matched the performance of human teams relatively well, in terms of final strength and slack time performance; however, their strategies showed differences. Several biases were identified as being responsible for the discrepancies (e.g., a reluctance to project the effects of a decision into the future). Based on the experimental data, the model was then revised.

Millhiser and Solow (2005) developed a mathematical model to investigate when a growing team benefits from being divided and how interactions among workers and management impact this decision. The first descriptive mathematical model developed depicted the decrease in team performance occurring with team growth due to less time available from the manager, as well as showing multiple teams in a hierarchical organization. For example, this model included elements such as the number of workers on the team, the team leader, the team leader's motivational skill, and the relationship between the leader and the worker. The data derived from running this mathematical model showed there is an optimal size and partition to the reorganization of a growing team. Further, other factors, such as how much managerial attention a team requires, the probability distribution of labour-management relationships, and the distribution of individual worker performance were shown to impact the value of dividing a team. It is important to note, however,

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<sup>9</sup> Unfortunately, the sample size of this experiment is not reported.

that there is no evidence that this mathematical model has been experimentally validated.

Extending the research by Millhiser and Solow (2003), Solow, Burnetas, Piderit, and Leenawong (2005) examined the value of motivational leadership in the study of the team replacement problem. The descriptive mathematical model aimed to study the impact of motivational leadership in teams. The models included parameters whose values reflected the amount of interaction among team members and the amount of skill and variability in the skill of the leader. Comparisons were made between the performance of teams who had motivational leaders and those who did not. Results of running the mathematical model indicated that having a leader with no motivational skill is the same as having no leader, and that the more skilful the leader, the better the performance of the team. Making subtle changes in the parameters of the mathematical models further refined the results. For instance, it was found that having a skilful leader was more important for team performance than controlling the amount of interaction among leaders. Unfortunately, there is no evidence that this mathematical model has been experimentally validated.

These mathematical models, then, evidence a range of different team-related research questions that have been pursued, and show the potential utility of being able to model complex processes, and to study how teams might perform given changes to specific parameters of the model. Beyond this, testing the fit of the model data to actual human performance data can also help to refine the mathematical model. Although many important efforts have been undertaken, however, efforts to develop mathematical models of team processes and performance have been relatively simplistic to this point, and have only typically addressed select team constructs. However, they provide a very important potential tool at the early stages of team research.

## 7.3 Computational Models

Recently, computational models have become more prevalent and increasingly important in the development of theories of complex systems such as groups, teams, organizations, and their command and control architectures (Carley, 1999). Their growth is in large part due to the realization that underlying processes are complex, dynamic, adaptive, and non-linear; group or team behaviour emerges from interactions between and within agents and entities; and that the relationship among the entities both constrain and enable unit level action (Carley, 1999). A second reason for the movement towards computational models is the recognition that people are inherently computational as they need to scan and observe their environment, store facts and programs, communicate among members and with their environment, and transform information by human or automated decision-making (Carley, 1999). Computational models are valuable for a number of reasons. First, they are useful for generating hypotheses that can be tested using human groups. Second, computational models make it possible to extend upon laboratory conditions. Finally, data obtained

in experimental studies can be used to validate, refine and elaborate simulation models (Levine et al., 2005).

Our review accessed some computational efforts to model teams and team performance. An effort by Sun, Council, Fan, Ritter and Yen (In press), for example, worked to compare teams using two different modelling approaches, namely CAST (Collaborative Agents for Simulating Teamwork) (Yen et al., 2001; cited in Sun et al., in press) and SOAR (Laird, Newell, & Rosenbloom, 1987; cited in Sun et al., in press). The implicit assumption of both approaches is that agents are composed of both architecture (i.e., “mechanisms and structures that process content (knowledge) and generate behaviors”) and actual knowledge (Sun et. al, in press, p. 1). Whereas the CAST model was developed specifically for studying teamwork issues (<http://faculty.ist.psu.edu/yen/Center/1-CAST.html>), SOAR is a general cognitive modelling architecture adapted in this research to the teamwork domain.<sup>10</sup>

The purpose of this research was to model teamwork using two different modelling approaches and to compare the resulting agents’ knowledge and behaviour. Both the CAST and SOAR approaches were applied to a dTank simulation, a tank game previously used to model distributed agents working as a team, and both approaches allowed agents to “anticipate potential information needs among teammates and to exchange information proactively” (Sun et al., in press, p. 1) using both procedural and declarative knowledge. As such, both approaches used operators in order to represent both communication and collaboration. Examples of operators incorporated into the models included “hello-team”, “lock-target”, “rotate-turret”, etc. In this study, the CAST and the SOAR teams were exposed to the same enemy agents in each scenario 20 times in a between-teams design.

CAST and SOAR dealt differently with domain-dependent vs. domain-independent knowledge, and that the “behaviour” of the two models was not predicted by knowledge alone. More specifically, results showed that simply understanding the “decision rules” built into the system did not enable accurate predictions about team performance. The authors suggest that this may have been the case because capturing “teamwork behaviours” might be an important part of modelling team performance. Moreover, this comparison of CAST and SOAR also showed that CAST was more amenable to modelling teams, and performed somewhat better in contexts where communication was important. SOAR, on the other hand, showed that it could be adaptable to the team domain, and that it can use “more productions for making choice decisions” (Sun et al., p. 2). However, it is important to note that there was no available experimental validation of this work.

Although only limited information was provided about the implementation or testing of these computational models, the recognition that team performance is more than

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<sup>10</sup> More information about SOAR (adapted to the team domain) can be found at <http://www.soartech.com/research/teams.php>.

the sum of knowledge and that team process is also a necessary variable to be considered is very much in keeping with our review of the literature. Clearly, even teams with similar team composition, leadership etc. will necessarily exhibit wide variation in their performance because of distinct team processes. Yet, these more social factors have apparently been given only rudimentary consideration to this point.

Work by researchers from the Netherlands (TNO) has explored more complex team computational models (van den Dobbelsteen & van den Broek, 2004). Specifically implemented in order to explore whether variations in team structure could reduce manning requirements in the command and control room of a frigate, this research used an Integrated Performance Modelling Environment (IPME). Traditionally, frigates are divided into 3 functions, addressing anti-air, surface and subsurface warfare. This work explored whether integrating these functions could reduce manning requirements by focusing on workload levels in varying team structures.

This modelling approach simulated the tasks assigned to 10 different members of a team comprised of anti-air, surface, and subsurface personnel. This model incorporated both the communication and coordination required to function as a team, and measured levels of workload in both a normal and a high-speed scenario. Unfortunately, no detail about how these processes were incorporated was available.

The first model represented the existing manning structure. The second “evolutionary” model collapsed the 3-level hierarchy into 2 levels. The “revolutionary” model replaced the hierarchical structure with a decentralized and more functionally clustered structure. Running these models showed that manning could be reduced by 20% while maintaining the same levels of workload by simply re-arranging the structure and by reducing the lines of communication to 2 levels rather than 3. The more radical revolutionary model showed possible reductions of 50% in manning requirements with restructuring of the team. Workload was the dimension considered in determining manning requirements, and being able to see the potential impact of changes in team structure on team workload is an important accomplishment of this work. However, there is no available experimental validation of this computational model.

Horii, Jin and Levitt (2004) modelled cultural differences between Japanese and American firms in project teams using the Virtual Design Team (VDT) modelling approach. The VDT is a computational model used to conduct “what-if” analyses and examine team effectiveness. For this research, the VDT model was used to analyse the effects of cultural differences on team performance. The research examined two main cultural differences: practice differences and value differences. Practice differences were characterized by the level of centralization of authority, the level of formalization of communication, and the depth of organizational hierarchy, whereas value differences were characterized by decision making and coordination behaviours. American firms are characterized as having decentralized authority, a medium level of formalization in communication, a flatter hierarchy, individual

decision-making and individually-based communication. Japanese firms, on the other hand, are believed to have centralized authority, a high level of formalization in communication, multi-level hierarchies, consensual decision making, and group-based communication.

Using “what-if” analyses in the VDT model, the effects of organizational and group behavioural changes were analyzed. The research looked at four independent variables: 1) organizational style (cultural practice: Japanese vs. American style), 2) micro-level behaviour (cultural value; Japanese vs. American behaviour patterns 3) task complexity (four levels of task interdependence), and 4) team experience (low, medium, high). A total of 48 scenarios with all possible combinations of the 4 independent variables ( $2 \times 2 \times 4 \times 3$ ) were simulated. Measures of performance included hidden work volume (duration and cost), product quality risks and project quality risks. Results indicated that each culture’s organizational style is built to match its culturally preferred micro-behaviours in terms of efficiency. The impact of mismatches between practices and behaviour depends on the characteristics and requirements of the project (task complexity, level of experience, etc). For instance, increasing task complexity increases the impact of cultural practice-behaviour mismatches. This research only focused on how different micro-level behaviours and organizational structures affect performance and therefore many opportunities exist for future research using computational models. Given the nature of globalization, understanding how organizations can create effective and efficient cross-cultural teams will remain an important area of research. However, there is no available experimental validation of this computational model.

Levine et al. (2005) examined turnover within teams using both laboratory experiments and computational simulations. The computational models they used were OrgAhead (Carley & Lee, 1996; cited in Levine et al., 2005) which emulated a decision making task and Construct (Carley, 1990, 1991; cited in Levine et al., 2005) which emulated a production task. The modelling approaches were used to extend the laboratory work by examining turnover in larger social units, under different technology configurations, and over longer time periods.

With the use of Construct, simulation experiments were conducted to examine transactive memory, turnover and team performance in a production task. Similar to the laboratory experiments, it was found that group training builds transactive memory, facilitates more complex transactive memory as well as faster performance (Levine et al., 2005). Comparisons between real humans in lab experiments and the simulated agents showed that the agents did not guess as much as humans. Further, simulations showed that newcomers lack transactive memory therefore decreasing group performance. Finally, Construct was utilized to model larger brigade-size groups (50 people or more) and findings indicated that transactive memory is more valuable in moderately sized groups (15-21 members) than in smaller section- or squad-sized (3 to 9 members) or larger groups. A second simulation examined the impact of changes in the task environments (the team’s mission) and found that the more often the mission changed, the more important transactive memory was to the

team, and that databases of who knows what cannot substitute for transactive memory, although some form of technology may be needed for groups with more than 50 members.

The simulation research using OrgAhead showed that turnover, team structure, and member training interact, and more hierarchical organizations can absorb poorly trained newcomers (Levine et al., 2005). Further, it was found that if newcomers were not forced into particular positions, there was little impact on performance. As a whole, this work by Levine et al. (2005) demonstrates how computational models can be used to extend laboratory experiments and test hypotheses that would otherwise be difficult to assess with traditional methods.

Developing and testing theories with computational models has become a growing trend, however, there is a need to understand when and how these models should be validated (Carley, 1996). Although there are six types of validation, including conceptual, internal, external, cross-model<sup>11</sup>, data, and security, we will only focus on external validation. External validation refers to the adequacy and accuracy with which the computational model reflects real world data. Although validation is only one aspect of computational modelling, it is important and often requires a team of researchers over several years to accomplish (Carley, 1996).

There are a number of validation techniques that can be applied to computational models (Carley, 1996). They fall into four main categories: grounding, calibrating, verifying, and harmonizing. Grounding refers to establishing the reasonableness of the model and the goal is to determine whether the simplifications inherent in the model do not detract from its credibility. Calibrating is an iterative process of tuning the model to fit the real data and is often used to determine the feasibility of the model. Verification refers to the validity of the models predictions with regard to a set of real data. This technique is used to move a model from the theoretical to the applied realm. Finally, harmonization establishes the theoretical adequacy of a model in relation to a linear model and a set of non-computational data. The goal is to show that the assumptions of the model are in line with the real world.

Another critical aspect of validation is selecting among competing computational models. Although there are a number of criteria that can be used when choosing among various theoretical explanations, the three primary criteria include its descriptive adequacy (i.e., does the model provide a good description of the observed data?), generalizability (i.e., does the model predict well the characteristics of data that will be observed in the future?), and complexity (i.e., does the model capture the phenomenon in the least complex manner?) (Pitt, Myung, and Zhang, 2002).

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<sup>11</sup> The goal of cross-model validation (also called “docking”) is to measure to the degree to which two models match (Carley, 1996). Carley references a paper by Axetel, Axelrod, Epstein and Cohen (1996) entitled “Aligning computational models: A case study and results” published in *Computational and Mathematical Organization Theory*, 1(2), 123-142 that might be helpful.

Although a number of prior approaches have been used in validating computational models, these methods have been criticized for being unable to adequately measure complexity or because they focus only on goodness of fit (Pitt et al., 2002). To address this, Pitt et al. (2002) have proposed the Minimum Description Length (MDL) Method of model selection as a possible alternative method. The goal of model selection under MDL “is to choose the model that permits the greatest compression of data in its description” (Pitt et al., 2002, p.480). The MDL method works to compare models on the basis of both their goodness of fit, as well as in terms of relative levels of complexity. The MDL method “chooses” the model that requires the shortest possible length of computer code necessary to describe the data given the model, as well as the model that minimizes the expected error in predicting future data. In summary, MDL is able to select the model that provides sufficient goodness of fit to the data in the most simplistic manner. This, its authors argue, has the potential to increase the generalizability of the models.

In general, then, computational models offer significant potential for future team researchers to be able to model complex team processes. To the extent that key parameters can be identified and implemented within computational models, team research can iterate between computational efforts and validation with human participants. Unfortunately, the computational models reviewed herein are still very constrained to understanding a very specific aspect of team process and performance. As such, increased complexity will be required in order to depict the richness of teams.

## 7.4 Overview of Team Models

To date, then, there are clearly many different models of team performance. In keeping with a general theme uncovered during this review, though, there is both convergence and divergence in descriptions of the factors that influence team performance. One encouraging trend is that the conceptual models have become increasingly elaborated, and have come to include a broader range of factors and influences (e.g. contextual factors). However, although this level of complexity may clearly be required to represent the complexities of actual teams, this does pose difficulties for attempting to validate these models. The complexity inherent in striving to describe the entire landscape of teams creates difficulties in validating models’ abilities to predict actual performance. In fact, there is very little direct evidence of model validation efforts.

Having emerged in the 1980s, mathematical models were created in an attempt to understand military team performance (Salas et al., 1995). As opposed to developing strictly normative models of team performance, predictions of most of the mathematical models have been compared to actual team performance, to understand the factors that influence actual human teams or to help introduce complexities into the mathematical models so that these models could more accurately predict actual human behaviour. Mathematical modelling has been successfully applied in a variety

of areas, including the weighing of information from distributed sources, hypothesis testing in an ambiguous environment, and resource allocation (Salas et al., 1995). Thus it appears that mathematical modelling could be applicable to diverse areas.

The computational models that exist offer researchers the opportunity to explore key aspects of teams, team process or performance. Due to the complexity of teams, it would be extremely difficult and time consuming to develop a computational model that incorporates all of the team performance antecedents and consequences. Further, making the models more complex would cause difficulties in terms of validating such models with real world data. With so many different factors, large-scale efforts that attempt to measure all the possible factors that relate to team performance seem ill advised, and more constrained efforts have clearly been the choice of many team researchers.

For future team researchers, however, the models reviewed herein still give important direction. First, it is clear that team performance is a product of team factors, task factors, team processes as well as the context in which the team must perform, and all of these factors would be necessary to include in a comprehensive model of team performance.

An important part of this chapter, however, is to suggest which models might offer the most promise for future development. In general, our search revealed many different efforts to model team performance (normative, descriptive and predictive). For the mathematical and computational models, it is important to note two reasons why a definitive recommendation of the “best” models for future research would be difficult. First, these models are so specific that identifying the “best” model in each category would be difficult, as this really depends on the nature of the research questions to be answered. Moreover, the quality of these models is in large part a product of how well the key constructs are actually represented in the models. Unfortunately, the exact implementation of these models is not discernable from the descriptions reviewed for this report. That being said, however, some aspects of team performance seem more suited to mathematical and computational models than others. For example, some of the models described examined the impact of varying team structures on team performance, and these kinds of questions seem particularly well suited to mathematical and computational models. Moreover, issues of how varying team structure will impact on team performance is likely to be of critical importance in the CF of the future.

In terms of conceptual models, there is currently no widely accepted conceptual model, and there is little evidence that any model has been subject to extensive validation efforts. Again, this is likely due to the relatively young age of the team modelling literature. However, both the Essens et al. Command Team Effectiveness Model (2005) and the Driskell (2006) frameworks provide critical consensus that understanding the team context will require knowledge about the complex interaction between the team itself, the nature of the task, and characteristics of the context in which the team must perform. Again, in terms of long-term research, we would argue that complex and distributed teams are likely to be of most interest to the CF and that

models may need to focus at this level. In this sense, the Driskell and Salas (2006) groupware model appears to be the most clearly applicable and relevant conceptual model in this context. Although it does not provide substantive “new” information about teamwork in distributed environment, it is the only model that could be accessed during this review that brings together the team literature relevant to distributed environments, and combines them in an integrated way.

That being said, there are several features of team models that seem necessary to emphasize in a developing program of team research. First, the notion of “feedback” loops should be a critical component of a team model. Clearly, teams do not typically perform in a linear fashion, moving from task identification to task completion, but they often perform several successive tasks, and team and task knowledge, as well as team processes are changed by the very experience of having worked as a team. This suggests that having a model that depicts this gradual shaping of teams would be critical.

In the end, the choice of what conceptual model is likely to be of most use for the future must depend on the scope and focus of the team research project. Future team models should also allow the depiction of a broad set of factors, but also allow for “focusing in” on specific factors of interest. Given the complexity of team performance, it would be counterproductive to attempt to design and test a model with every factor depicted. However, our review also suggests that researchers and theorists interested in understanding team performance have sometimes adopted an approach whereby they work to model only limited aspects of team process and performance. Particularly early on in a program of research, this kind of approach seems to have many merits, as it helps to focus on specific constructs (and to understand their effects) without striving to capture every possible aspect of team performance. And, if modelling efforts were successful, using a controlled approach in order to achieve an even higher level of complexity would be possible. Our sense from the reviewed literature is that it has been very difficult for researchers to be able to understand the patterns in their data because there have simply been too many constructs in play, and that this has hindered progress that could be made in understanding the factors that influence team performance. Whatever the case, it is clear that the future in terms of team modelling is relatively open, and that careful and systematic research about important team questions is likely to be influential.



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## 8. Findings and Recommendations

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The goal of the literature review was to support a 4-year Applied Research Project on Modelling Team Performance. The purpose of the literature review was threefold. The first part examined a wide range of the literature on teams in order to identify the factors that influence team performance. The second part of the literature review focused on team measures such as measures of effectiveness and measures of performance. Finally, the third component of the literature review outlined various models of team performance and effectiveness, including conceptual models, mathematical models and computational models.

This section considers the findings of the literature review with respect to the challenges of team research, and provides some recommendations for the “way forward” for the Applied Research Project.

### 8.1 Challenges of Team Research

The literature reviewed in this report suggests that team performance is a complex topic that has shown considerable progress in establishing basic principles, but one in which considerable research is still required. The research has identified a variety of factors that contribute to team performance and although the literature often varies in the focus given to various factors, there is core agreement about the basic components. Many different team factors, such as team structure (i.e., team size, history, physical distribution, leadership) and team composition (i.e., individual traits, diversity) are critical to the success of a team. Several task characteristics (e.g., task complexity, workload) have also been shown to have an impact on performance. Given the relative proportion of attention given to team process factors, however, there is at least some implicit agreement that team process factors are perhaps the most important influences on team performance. These factors include communication, coordination, shared knowledge, adaptability, planning, and team climate.

However, a number of important challenges remain for future team researchers. At a conceptual level, one problem is that constructs are often inextricably linked. For example, communication, coordination, and shared mental models (arguably the three most critical constructs) are very closely related, and are not always defined in a way that they can be clearly distinguished. Moreover, the general lack of convergence on definitions and measures of key constructs appears to have hindered the ability to build systemic and cumulative knowledge. Rather than building progressively, knowledge appears to have accumulated more laterally, with little true hierarchical structure. In addition, much of the research also shows either conflicting or inconsistent results.

As noted throughout this review, as the team research has matured, it has moved steadily from dealing with single constructs and their relation to team performance (that is, main effects models) to more complex and interactive models, in which the nature of the task and the team processes in question combine in unique ways to influence performance. Indeed, there is good evidence that this kind of approach has been fruitful. At this point, however, there is also good recognition within the team literature that each task presents different demands on a team. In order to capture the full complexity of teams, it is misguided to assume that the team processes influential while performing one task will be the same as those in other tasks (even with the same team). This speaks to the potential importance of having more clearly defined constructs, such as task complexity, in order that variables can be standardized and compared across studies. Only then will empirical knowledge accumulate optimally.

## 8.2 Recommendations

Of course, there are many ways to make a decision about where to focus one's efforts with respect to conducting team research. Our perspective is that it will be important to balance two simultaneous needs. On one hand, it is important to identify a branch of team research that requires more attention in order to make a valuable contribution to the area. As a relatively young field of study, there is literally no research area that is saturated, or in which there is agreement that there are clear and unequivocal answers. This provides the opportunity for any prospective team researcher to make a meaningful contribution to the existing literature with creative and targeted research.

On the other hand, this wealth of opportunity for making a contribution within the team research area also presents a challenge as to how to focus a long-term program of team research. From our perspective, there are clear and critical gaps in the literature with respect to the future needs of the CF. More specifically, although some of the research on teams is relevant to the command context, the majority of it is more relevant to the tactical level. Moreover, our review suggests that very little research to date has considered teams functioning in an interagency context, and virtually no research simulates the true complexities of a joint context. Furthermore, the only research that does address the joint issue (MacMillan et al., 2004) only considers task dependencies, ignoring many other critical dimensions (e.g., diversity, norms and values) that are likely to influence team performance in joint or interagency operations. The decision about how to proceed should be guided primarily by the needs of the CF as an organization. Clearly, as the CF moves toward its transformation goals, understanding how teams with high levels of diversity, of varying structure, and with complex interpersonal dynamics will perform is an important issue. Indeed, there are many areas critically under-represented in the team literature likely to be of considerable importance to the future of the CF. Based on this review, the following issues are critically under-represented in the existing literature.

### **8.2.1 Research exploring diversity within teams**

At a very general level, our review suggests that the area of diversity within teams is currently under-represented in the existing literature. As trends in military operations increasingly move toward joint and interagency designs, it will be important to explore how organizational culture, for example, is likely to impact on both team processes and team performance. The CF seems very intent on helping its various elements (i.e. Army, Navy, and Air Force) learn how to work well together despite some obvious differences in backgrounds and ethos. Research that seeks to address these issues should include the most arguably relevant team processes (i.e., shared knowledge, communication and coordination) as well as addressing team performance as a whole.

Similarly, within multinational operations, cultural diversity also has the potential to influence critical team processes. As noted earlier, changes in the future composition of teams will challenge future team research to be able to represent more aspects of diversity. In military contexts, for example, increased emphasis on distributed and multinational teams with people from diverse backgrounds has the potential to increase the urgency in understanding how teams can best be supported in their efforts to work as coherent systems. Indeed, the ability to build “common intent” (e.g., Pigeau & McCann, 1995) within teams may well be compromised if team members cannot adequately communicate their ideas and needs, or find the common ground that links them. This suggests that issues of culture (and other forms of team diversity) will need to receive considerable attention from future team researchers, as finding ways to bridge the potentially negative impact of diversity within teams has the potential to make a very important contribution.

It is also critical to point out that positive effects of diversity in teams have yet to be explored adequately. Although the literature argues that there is considerable benefit in having divergent perspectives and approaches to problems, there was little available evidence in our review that this was the case. This issue stands as an important one for future team researchers to address.

### **8.2.2 Research exploring distributed teams**

As noted earlier, research exploring distributed teams is currently under-represented within the mainstream team literature

As such, as the CF will increasingly perform in distributed teams, it will be critical to explore this issue in the team ARP. Moreover, existing research has also failed to focus on some of the potentially positive aspects of physical distribution, such as lowered pressure for conformity and fewer biases in decision-making (Driskell et al., 2003). This issue will also be important to address in the context of the CF.

Finally, it will be critical to focus on the effect of distributed leadership on team performance. Understanding how leaders can be effective in both co-located and distributed contexts is certainly likely to be an important area of research for the future. Moreover, research pertaining to the effect of leadership on team performance within the target domain (e.g. multinational and interagency teams) will need to be explored, as this area appears to be especially limited.

### **8.2.3 Research with true teams and military participants**

As our review has shown, the majority of team research to date involves university undergraduates. Although this research has clearly made important contributions to understanding the basic processes that influence team performance, research that will be most relevant to the CF should involve the highest possible level of fidelity in empirical research with actual military team members. Of course, this has the potential to be very challenging as military participants can be difficult to access. Furthermore, studying intact teams may be even more difficult due to high levels of turnover and changes in tasking. In this sense, it may be helpful to take an approach that allows for research with undergraduates (and ad hoc teams) at the early stages of research, moving progressively to military participants after more basic principles are established.

### **8.2.4 Research on teams of teams**

From the perspective of the CF, some of the most important future research is likely to relate to multiteam systems (Marks et al., 2005). As reviewed earlier, the form of interdependence required within these systems is likely to have very real implications for how well the team as a whole is likely to perform. For example, if subteam members devote attention to their own team's goals rather than to the multiteam system as a whole, performance is likely to suffer. On the other hand, they must focus enough attention on their task in order to contribute to the overall effort. This area of research shows good potential in terms of broadening scope and increasing effort. This is very important given that military systems are increasingly moving toward network-enabled operations. The challenge of the future from the team perspective, in fact, may well be how small teams (often with diverse goals and priorities) will be able to work together in order to meet the goals of a larger multiteam system. As such, it will be important to explore the small body of existing research within this area (only some of which could be covered in this review) in more detail.

For the future, then, this review suggests many potential areas that could receive focus in a long-term program of research. This review suggests that the mainstream team literature is vast and complex, and that not enough is known about the kinds of teams most relevant to the CF. Clearly, there are



many different factors that influence team performance, but the key issue for the future will be how to understand how combinations of factors work together to influence the real-world performance of teams. In a very real sense, then, there is great opportunity for designing and conducting targeted research that helps to improve the performance of teams working within the CF context.



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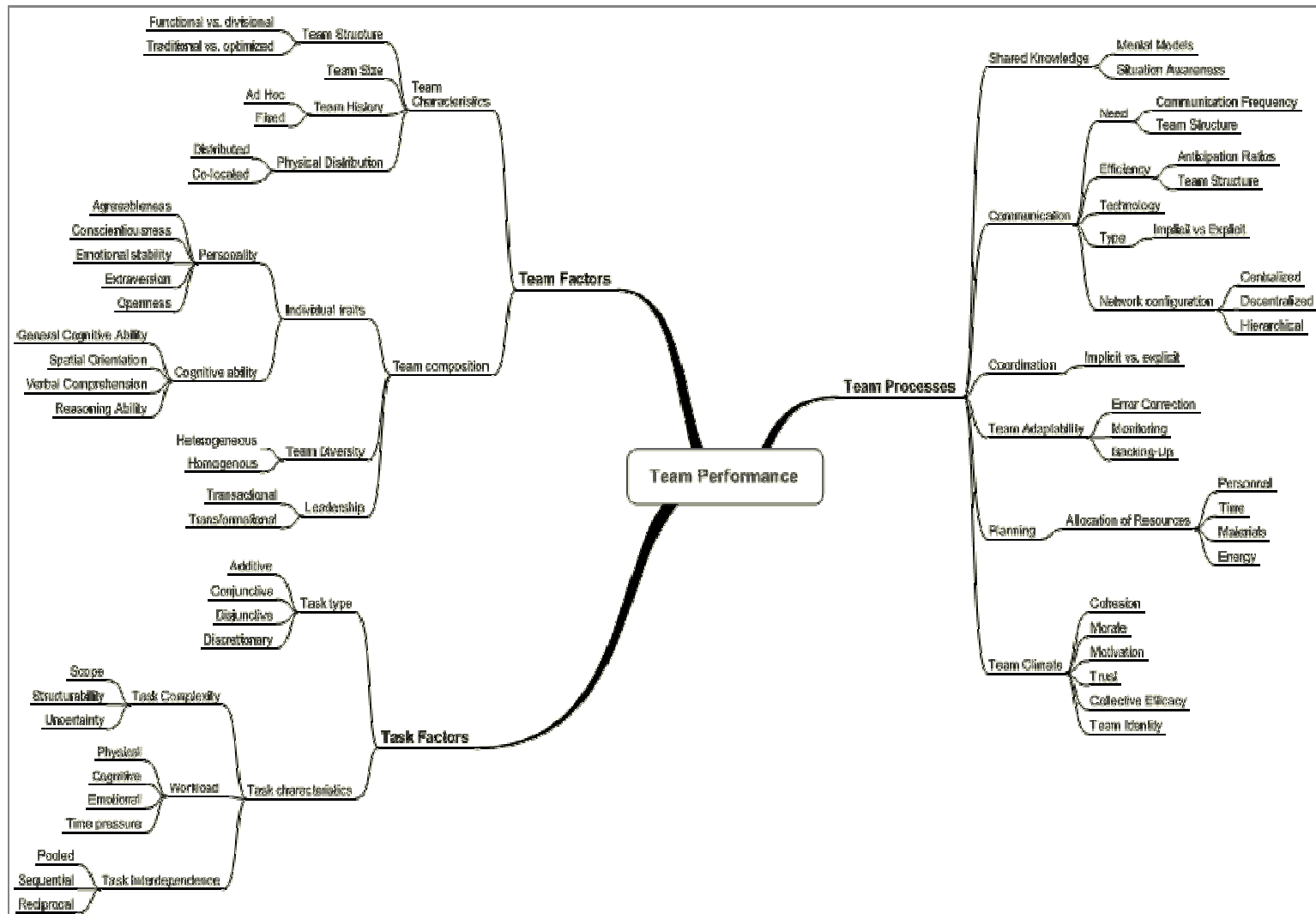
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## Annex A: Team Performance



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|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1. ORIGINATOR</b> (The name and address of the organization preparing the document, Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's document, or tasking agency, are entered in section 8.)<br><br>Publishing: DRDC 1133 Sheppard Ave. W, Toronto,<br>Toronto ON M3M 3B9<br><br>Performing: Humansystems® Incorporated, 111 Farquhar<br>Street, , Guelph, ON N1H 3N4<br><br>Monitoring:<br>Contracting: |                                                                                                                                                       | <b>2. SECURITY CLASSIFICATION</b><br>(Overall security classification of the document including special warning terms if applicable.)<br><br><b>UNCLASSIFIED</b> |
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| <b>5. DATE OF PUBLICATION</b><br>(Month and year of publication of document.)<br><br>August 2006                                                                                                                                                                                                                                                                                                                                                   | <b>6a NO. OF PAGES</b><br>(Total containing information, including Annexes, Appendices, etc.)<br><br>149                                              | <b>6b. NO. OF REFS</b><br>(Total cited in document.)<br><br>108                                                                                                  |
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| <b>9a. PROJECT OR GRANT NO.</b> (If appropriate, the applicable research and development project or grant under which the document was written. Please specify whether project or grant.)<br><br>16ki01                                                                                                                                                                                                                                            | <b>9b. CONTRACT NO.</b> (If appropriate, the applicable number under which the document was written.)<br><br>W7711-047911/001/TOR; Call-up<br>7911-04 |                                                                                                                                                                  |
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(U) Increasingly, Canadian Forces operations require the use of highly complex teams that function in joint, interagency, and often distributed environments. This report is a literature review of scientific and military research pertaining to team performance. This review consists of three sections. First, the factors influencing team performance are explored, and three major sets of factors are considered in relation to team performance: team factors, task factors, and team processes. Although very large, the team performance research has generally not built progressively upon previous work and illustrates equivocal results. Nonetheless, it is clear that characteristics of the team, the task, and team processes are all important influences on team performance. However, exactly how each of these factors influences team performance is often dependent on other factors. Moreover, the majority of the existing team research is limited in that it has not generally been conducted in realistic settings. The second section addresses measures of team performance, considers the conceptual challenges of measuring team performance, and explores specific measures of team processes and outcomes. The final section reviews some conceptual and computational models of team performance. Although models have generally not been subject to extensive validation efforts, they provide confirmation of the factors that are prominent throughout the team literature. The review ends with a short overview of the literature, and recommendations for a program of team research. Specifically, the existing team literature is inadequate with respect to understanding distributed teams consisting of people from diverse backgrounds and experience. Moreover, as teams of the future are also likely to be increasingly complex, more understanding of how heterogeneous teams as well as an entire team of teams will function in distributed, joint, and interagency environments will be critical.

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(U) teams; team performance; team effectiveness; collaboration; team measures; team models

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