10th International Command and Control Research and Technology Symposium

Coping with Social and Cultural Variables in C2 modelling for Networked Enabled Forces

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ABSTRACT

This paper seeks to address the question "How much is enough?" when it comes to modelling socio-technical problems. Of particular concern is the impact of social and cultural variability on the ability of forces to implement and exploit Network Enabled Capability and the Effects Based Approach to operations. UK modellers have a long tradition of good quality modelling in support of Defence investment and Military operations. However, the opportunities and expectations raised by the Information Age have challenged modellers to broaden their horizons and to re-appraise the requisite scope of their models. The paper reports developments in a research project designed to improve the state-of-the-art in operational analysis modelling to allow for support to balancing investments across all lines of development, including the differential effects of people, training, doctrine, and organisation as well as equipment and process. The paper will expose the modelling work and the theoretical and empirical evidence which support the needs for such modelling, including lessons learned form recent conflicts and civilian experiences in the Information Age.

1. Introduction

In a previous paper [Mathieson & Dodd, 2004] we argued that exploiting the potential of Information Age technology to support effective Defence will require agile[1] headquarters (HQ) organisations, as part of a wider development of Information Age Command and Control (C2) concepts [Alberts, et al, 2001]. Further, we challenged as naïve the widespread belief that the dramatic improvement in military capability promised by investment in IT is best realised by emphasising the role of information in supporting human decision-making. Instead, a pluralist approach should be taken, recognising that a typical HQ is a complex, socio-technical system in which behaviour emerges from the interaction of factors and processes from across physical, informational, cognitive, organisational and social (PICOS) domains. Consequently, requisite modelling to support understanding the response of an HQ to interventions, such as the introduction of IT or other measures to improve agility, requires a comprehension of the multiple "dimensions" of human variability. Mathieson & Hynd (2004) take this reasoning further, resulting in a recommendation that requisite modelling for operational analysis (OA) involving socio-technical systems should be based on a balanced representation across the PICOS domains (at least as an initial working assumption until there is positive evidence for a bias in the representation).

[1] Agility in the context of this paper includes adaptability, flexibility, responsiveness, robustness, innovativeness, and resilience as defined by Alberts and Hayes (2003)

In a continuation of the work reported at Mathieson & Dodd (2004), this paper presents practical developments towards a requisite HQ model and considers the question "How much is enough?" to make the model fit for purpose. The paper exposes the modelling work and the theoretical and empirical evidence supporting the need for such modelling, including lessons learned from recent conflicts and civilian experiences in the Information Age.

UK Defence Policy is now focused on "delivering flexible forces able to configure to generate the right capability in a less predictable and more complex operational environment. This will require us to move away from simplistic platform-centric planning, to a fully "networked enabled capability" able to exploit effects-based planning and operations, using forces which are truly adaptable, capable of even greater levels of precision and rapidly deployable. This implies significant changes in the way we plan, prepare and execute operations, placing different pressures and demands on our people, equipment, supporting infrastructure and processes" [Defence White Paper, 2003]. All of these developments will require forces to deliver agile C2, capable of adapting to the demands of rapidly evolving situations and force structures.

If OA is to support Defence planning and acquisition effectively in the future, then it will need to allow for both a more integrated assessment of interventions across the Defence Lines of Development (DLoDs) and an ability to handle the implications of higher force (and C2) agility.

This paper seeks to address the problem of modelling a military HQ sufficiently well to support OA across the DLoDs, including the differential effects of people, training, doctrine, and organisation as well as equipment and process. It focuses particularly on capturing the impact of social and cultural variability on the ability of forces to implement and exploit Network Enabled Capability (NEC) and the Effects Based Approach (EBA) to operations.

The EBA is a development in UK military thinking in response to the complex security issues of the dynamic global environment. It seeks to improve the application of military (and other) capabilities by a focus on outcomes and on a wider collaboration across all actors in security issues. Adopting the EBA requires developments in both *ways of thinking* and *enabling processes, activities and structures*. Effects Based Operations (EBO), i.e. Military operations under the EBA, will require a more integrated C2 capability, such as that envisaged under NEC initiatives, and this will critically involve investment across the DLoDs. If OA is to rise to this challenge, then the art of C2 modelling will need to advance considerably to encompass the wide range of investments and effects involved.

There is an important distinction to be made between medium level OA (MLOA), i.e. that which supports Capability Management and Acquisition, and High Level OA, where most UK C2 modelling research has historically been focussed. The significance of MLOA is that the requisite model needs to represent the internal processes and structures of C2 rather than just their external effects. This is because the variables which the model is being used to explore include changes inside the C2 systems of interest rather than just in their environment. The 'system of interest' here is a socio-technical system, in which humans are integral, rather than peripheral users.

2. **Overall conceptual model of an HQ**

It would be presumptuous to believe that all of the individual, organisational and social factors relevant to an agile HQ can be captured, even abstractly, in a practical simulation model. However, we believe we have defined a requisite conceptual model, capable of explaining the range of variables and relationships involved in the PICOS domains and of representing their effects with a fidelity suitable to facilitate system level OA.

The key to an effective explanatory model is that its core architecture captures the essential concepts of that which is modelled. Most OA modelling of teams begin by defining the task that the team is undertaking and explain performance in terms of a task-oriented information-decision-action loop. Human factors then become moderating influences on the task, usually degrading task performance. This conventional view, however, does not help in building a requisite model when social and organisational variables are significant. While the task undertaken by the HQ is important to consider, it does not fully define what the HQ is, nor does it fully explain variability in its behaviour and performance.

We begin, therefore, by describing the essence of a military HQ not as a task organisation, nor as a decision-making entity, but as a human enterprise. Like any other human enterprise, the HQ is a complex, socio-technical system with many dimensions and facets. At the core of any human enterprise are the natural collective behaviours of humans, evolved to survive the problems of co-operation in the context of a tribal culture. Groth (1999) provides a useful analysis of the evolution of organisational forms in human society based on the progressive relaxation of constraints through the exploitation of intervening technologies, such as writing, communications, information networks and databases. These technologies allowed humans to co-operate and effectively synchronise their actions within larger and more dispersed groups, and across longer time-spans. This allowed different types of task to be undertaken, including task on a scale previously inconceivable, such as landing a man on the moon, or managing a country-sized battle-space.

At the core of even the most sophisticated enterprise, however, there still lie the basic organisational and social processes that evolved in ancient times to cope with quite different tasks. These influence task performance, but cannot be understood from a task-oriented viewpoint alone. Therefore, we have developed a conceptual model architecture which reflects the multiple viewpoints required for explaining team behaviour and performance.

The conceptual model architecture is summarised in figure 1. As well as dealing with the HQ task, it contains structures to represent variability arising from human agency and individuality, teamworking, organising, and socialising.

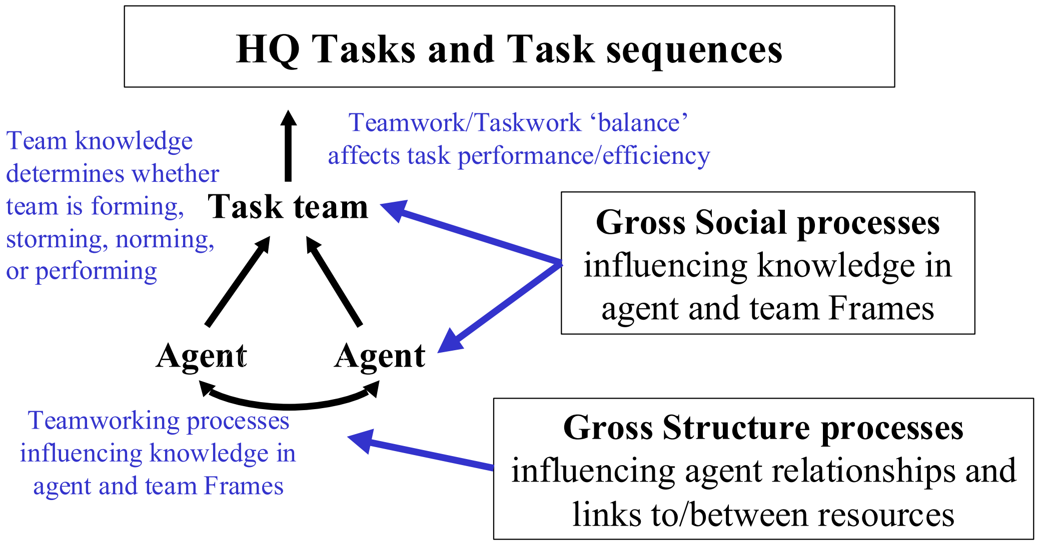

Figure 1: Illustration of the overall conceptual model architecture.

In developing this conceptual model we have chosen to make the HQ task a key feature. However, from a social domain perspective, the formal task of an enterprise is just one of many social processes in which people are engaged. It can be misleading to treat the 'formal' task as different in kind from the many 'informal' activities undertaken (such as teamworking, socialising, private tasks, etc). Strictly, the only difference is that the 'formal' task is declared or asserted by the enterprise owner. The behaviours of the enterprise, and its performance in satisfying the owner's goals, depend crucially on the interaction between all activities and, in many cases, the declared 'formal' process is not what people actually do to achieve the outputs they perceive as required. This issue re-surfaces in the treatment of motivation and goals within the more detailed model design.

As illustrated in figure 1, the overall conceptual model comprises four key elements:

- A representation of task work based on a state transition logic (similar to the mission-oriented modelling in Moffat (2004)) rather than a process model, thus allowing process to be varied by setting task transition criteria, as well as leaving space for additional processes to be 'imported' by individual agents and teams;
- An agent/team representation, which carries out tasks using knowledge held in individual and team 'frames' (as described by Klein (1997)) and provides for variability in behaviour and performance;
- A representation of gross structure processes, which generates behaviour at the organisational level, including forming teams, giving them resources and assigning tasks;
- A representation of broad social processes, which encompasses the influence of cultural factors and non-task activities on individual and team knowledge (and, hence, team behaviour and performance).

The conceptual foundations of our modelling approach across all of these elements are described further in Mathieson & Dodd (2004). The present paper focuses on developments in the representation of how teams acquire the knowledge they need to perform taskwork effectively, and the impact of variations in that knowledge arising from, for example, the presence of different cultural influences, organisational forms, individual experiences or training histories.

3. **Teams, knowledge and task work efficiency**

Team Maturity

A defining feature of the agile HQ will be the forming and transforming of teams in response to context and task demands. Thus, the conceptual model must represent the processes of team forming and re-forming and their impact on task work. A well-established conceptualisation of team dynamics is the forming, storming, norming, performing and adjourning process described by Tuckman and Jensen (1977). We interpret this process to describe the maturity of a team and use it to explain the relationship between teamworking and the performance of task work, in terms of effort sharing and consequent task work efficiency.

The stages in Tuckman's team maturity process are described in Table 1. In order to allow for agile team forming we suggest an additional stage, "transforming", which represents the effect of a team changing in a way that causes it to be 'knocked back' down the maturity 'ladder' without losing its team identity. We define "transforming' to be a transitional to a lower maturity stage without losing team identity (as would occur in adjourning). For example a change in membership may requires more norming activity, while a change of goal may require some re-forming of the team.

Team maturity stage	**Description**
Forming	Individuals have not yet come to recognise themselves as a team. They are busy finding out who the other people are. They seek to know one another's backgrounds and attitudes, and to establish ground rules. Members are also keen to establish their personal identities in the group and make a personal impression on the others. Group issues are cohesion and involvement.
Storming	This is a conflict stage in the team's life and can be a very uncomfortable period. Members bargain with each other as they try to sort out what each of them individually, and as a group, want out of the group. Individuals reveal their personal goals and it is likely that interpersonal hostility is generated when differences in these goals are revealed. Members may resist the control of other group members and may show hostility. The early relationships established in the forming stage may be disrupted. The key issues in this stage are group direction and the management of conflict.
Norming	The members of the team develop ways of working to develop closer relationships and camaraderie. The questions of who will do what and how it will be done are addressed. Working rules are established in terms of norms of behaviours and role allocation. A framework is therefore created in which each group member can relate to the others and the questions of agreeing expectations and dealing with failure to meet them are addressed.
Performing	This stage is concerned with actually getting on with the job in hand and accomplishing objectives. The fully mature team has now been created which can get on with the work. Not all teams develop to this stage but may become bogged down in an earlier, and less productive stage. The issues are individual performance and co-ordination.
Adjourning	The literature ("Stages of Small Group Development Revisited", Tuckman and Jensen, 1977) considers Adjourning as the final stage, involving the group disbanding either because the task has been completed or the members have left.
Transforming	In the present construct we define Transforming as a transition to a lower maturity stage without losing team identity, typically as a consequence of some change in the team goal, resources or context. Transforming is important in representing Agile Mission Grouping concepts, under which team members group and re-group in a dynamic way to satisfy different task and organisational goals.

Table 1: Tuckman's team maturity process (adapted)

Knowledge Enablers

Progression through Tuckman's team maturity process can be described in terms of the acquisition and sharing of various kinds of knowledge. Here we draw heavily on the research work of Noble (2004a/b), who has successfully used an analysis of the knowledge held by team members to diagnose the causes of team behaviour and performance.

Noble identifies 4 basic premises as a starting point for describing the role of knowledge in effective teams. These outline the most important premises in his knowledge-centred theory:

- Knowledge is central to collaboration and teamwork. Teams whose members know what they need to know can work together effectively. Those that do not are prone to various kinds of predictable errors, with the type of error dependent on the type of knowledge deficiency. (Liang, 1995)

- Knowledge must be distributed among members of a team. Everybody does not need to know everything for a team to be effective. But every team member does need to know how to get the knowledge he or she needs. (Wegner, 1987)

- Individuals need to know about both "taskwork" and teamwork. Teamwork knowledge is what team members need to know to work together effectively. Taskwork knowledge is what team members need to know in order to accomplish their part of the team's tasks. (Canon-Bowers, 1993)

- The collaborative dialogue helps generate the needed teamwork and taskwork knowledge. Team members exchange ideas to put in place the knowledge and understandings that team members must have for the team to achieve its mission. (Argote, 2000)

Noble identifies 12 knowledge enablers (categories of knowledge a team needs to have to operate well), which are shown in Table 2. Each category is related to different behavioural phenomena or pathologies, which arise when there are knowledge deficits. Noble also identifies mitigation for knowledge deficits, which we intend to exploit to understand the impact of various intervention strategies.

Knowledge Enabler	**Definition**
Goal understanding	Knowing what the customer wants
Understanding of roles, tasks, and schedule	Knowing who's supposed to do what and when, and with what information and resources.
Understanding of relationships and dependencies	Knowing how entities, events, and tasks impact the plan.
Understanding others	Knowing what other team members' backgrounds, capabilities, and preferences are.
Understanding of team "business rules	Having and knowing effective and agreed upon rules for team members interacting with each other.
Task skills	Knowing how to do one's assigned work.
Activity awareness	Knowing what others are doing now and current need for doing it.
Understanding of the external situation	Knowing status of people (including client), things, and events of the world outside of the team and projecting future changes.
Current task assessment	Keeping tasks on track, knowing how well own and other's tasks are progressing, and when to offer help.
Mutual understanding	Knowing what other team members understand now and knowing if they agree or disagree.
Plan assessment	Predicting whether the plan will still enable the team to achieve its goals.
Understanding of decision drivers	Judging and applying the criteria for selecting an action.

Table 2: Noble's Knowledge Enablers, representing categories of knowledge needed by a team to operate effectively. Deficits in knowledge can be associated with performance and behaviour problems

By combining Tuckman and Noble we can create a bridge between the social and cultural aspects of the team, from which variations in knowledge are derived, and team performance, based on maturity in relation to the team task. Making this connection has revealed a need to extend Noble's work to include an affective component, an enabler we have called "Emotional Knowledge". This category encompasses critical enablers to team performance, such as 'Trust' and 'Will', which are implied by Tuckman's maturity process and are widely recognised to be important in the operational of military C2.

Figure 2 shows the top-level dependencies between Noble's knowledge enablers (plus emotional knowledge) and Tuckman's stages. Since the modelling presented here is still a 'work in progress' we are keen to obtain review and critique.

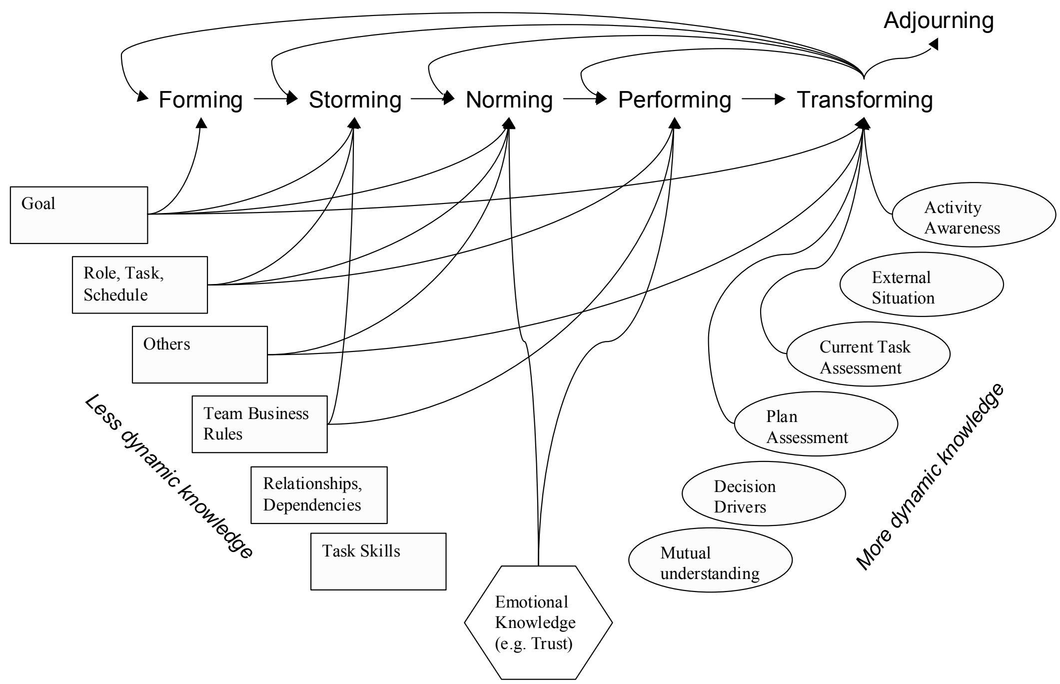

Figure 2: Illustration of knowledge dependencies of the team maturity process. Where a knowledge enabler is linked to more than one maturity stage it means either different levels or sub-types of knowledge are required. Lack of a link may mean that the knowledge enabler is only indirectly related to team maturity or is knowledge required for task work only.

Some knowledge categories are derived from or influenced by others, as indicated in figure 3. These connections represent the transformation of knowledge within the team frame, and the way that some knowledge types enable acquisition of others.

In the full version of the conceptual model each knowledge enabler category is broken down into individual knowledge variables, which can be operationalised in a practical simulation. These details are contained in Mistry, et al (2005).

The set of knowledge variables can be considered to form a knowledge 'vector', which exists within the cognitive network (or team frame) formed by the team members and their individual cognitive frames. In order to operationalise the knowledge vector in a way which has psychological plausibility, we intend to implement a team forming and interaction process using separate individual and team frames. Individual vectors will contain a representation of the knowledge brought to the team by its individual members, such as prior knowledge of each other, knowledge of business rules and task skills.

When a team forms, the individual knowledge vectors form the initial pool from which the team knowledge vector is derived. However, teams do not coalesce into a single cognitive entity, similar to an individual. This would be to infer too close an integration within the team, leaving no room for the variability arising from cultural diversity and subsequent social interaction. In the conceptual model, therefore, the team knowledge vector describes the distribution and synchronisation of individual knowledge across the team's cognitive network. In this way the model can faithfully represent the way that teams mature and acquire the knowledge enablers described by Noble.

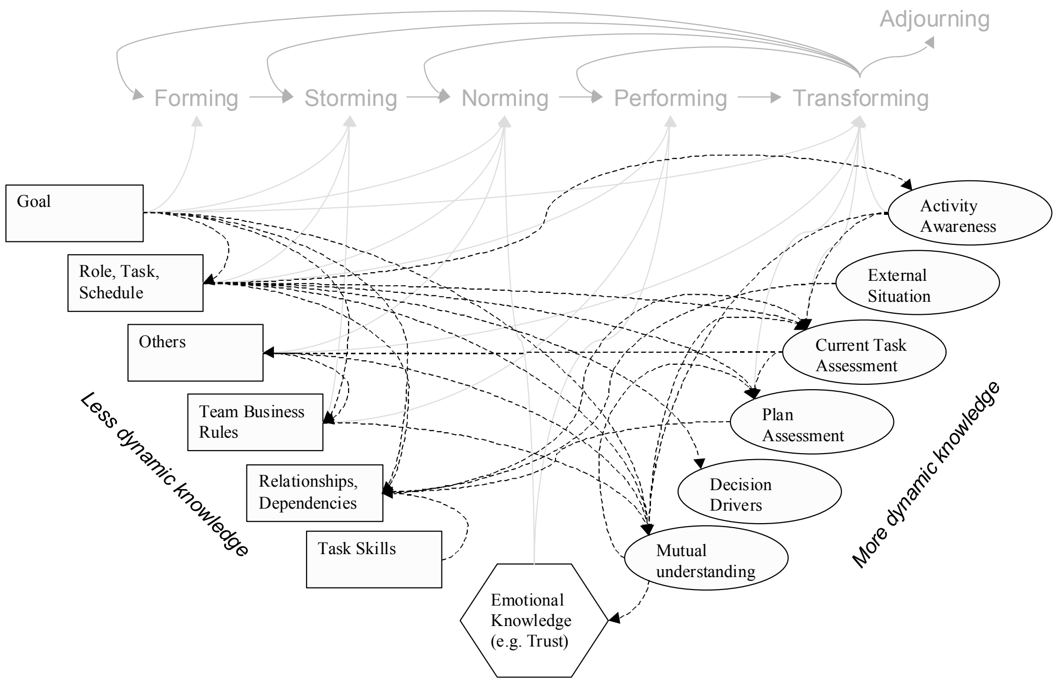

Figure 3: Illustration of knowledge enabler inter-dependencies. Lack of an output from one knowledge enabler to another may mean that the knowledge enabler this knowledge is required for task work only.

Knowledge Acquisition

Knowledge in different categories can be acquired through different processes. Figure 4 illustrates some of the major sources of team knowledge, as captured by the conceptual model.

When a team is first formed by an organisation its members are identified and given knowledge of goals as part of the team initialisation process. Mutual understanding within the team and knowledge of appropriate team business rules and task skills are initially based on the a-priori socialisation of team members, including culturally-based knowledge acquired from social groups, and previous training, education and experience. With these basics, the team is able to begin task working, an act which rapidly builds many of the other knowledge enablers.

Planning tasks develop understanding of team goals, roles, tasks, schedules, interactions and dependencies. Working together enhances knowledge of other team members and of task relationships and dependencies. The rate at which some knowledge is acquired will depend upon a variety of knowledge acquisition moderators, particularly the degree of co-location of team members. Working in the same physical environment provides opportunities for off-task interaction and socialisation not readily available to those working across technologically-mediated communication networks, as envisaged under NEC. Being co-located out of work time also provides opportunities for socialisation, which enhances the acquisition of key knowledge enablers, particularly those linked to emotional knowledge.

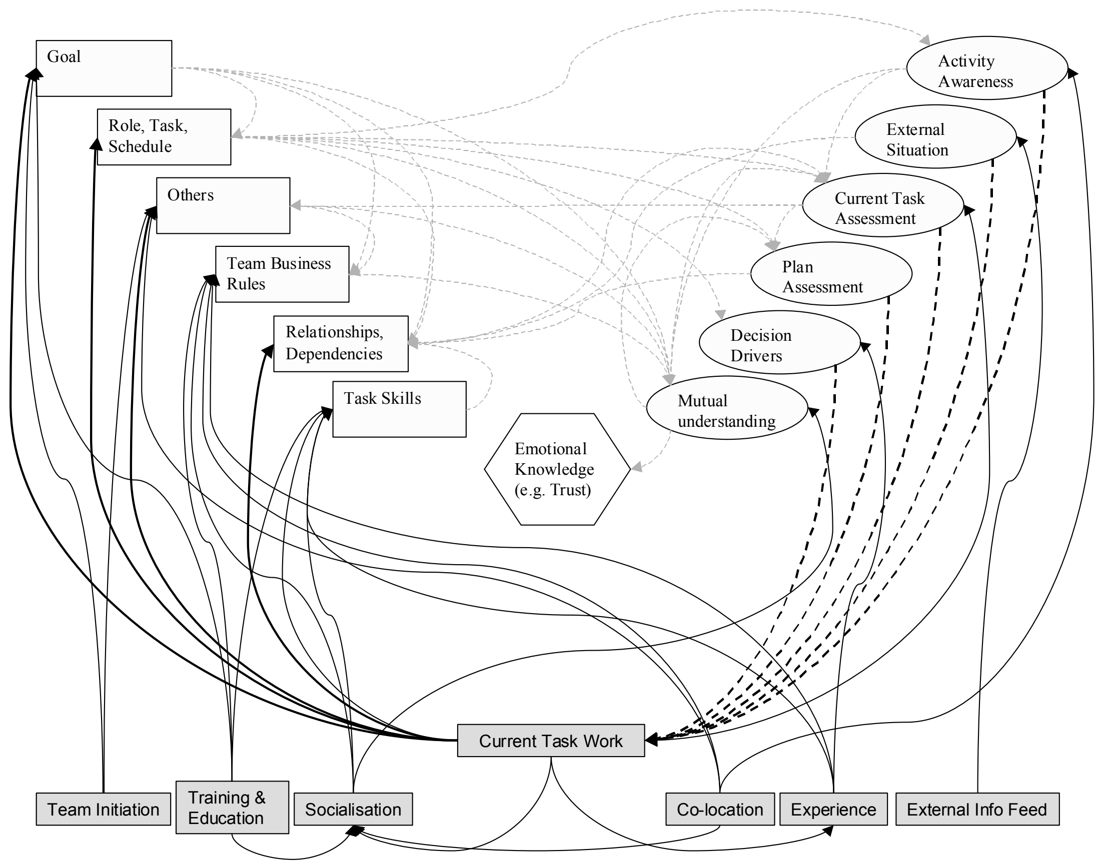

Figure 4: Illustration of how knowledge enablers are acquired by teams, initially from prior factors such as training and experience, and subsequently through current task work and the physical and social context in which it is undertaken.

Team members will also use categorical associations derived from cultural understanding (derived from past socialisation) to fill gaps in knowledge. Remote teams may use such associations to substitute for interpersonal knowledge as a basis for building trust. It may also be reasoned that a team lacking interpersonal knowledge will find it more difficult to establish team roles (as required by the 'storming' phase of team building) and the normal rules of business (as required by the 'norming' stage). Understanding the range of knowledge generation mechanisms will help us to discriminate co-located and remotely networked teams.

The extent to which different knowledge enablers are needed by a team will depend, to some extent, on the style of their mechanisms of co-ordination. Mintzberg (1979) and Groth (1999) identify a range of such mechanisms including direct supervision, mutual adjustment, and standardisation. They associate these with different forms of organisations (conditioned by other factors such as size, complexity of task and complexity of environment). The HQ model will need to treat this variability in organisational norms, if it is to represent successfully the differences between different ways of organising.

In our initial implementation we propose to deal with this issue by setting the organisational norm for the team as an input and using this to moderate the knowledge criteria for transitioning between team maturity states. For example, a team using direct supervision will require less knowledge of others to achieve the performing state than a team relying on mutual adjustment. The mutual adjustment team, on the other hand, will be less bound by knowledge of roles and schedules, but will be critically dependent on good activity awareness.

A balanced representation of knowledge acquisition moderators is, therefore, critical to understanding the impact of factors such as cultural diversity (moderating socialisation) and co-location. These types of factor lie at the heart of the problem of implementing NEC and the EBA.

Task Efficiency

The final step in our conceptual modelling is the connection between team maturity and performance. Ideally, our modelling would be able to encompass both team behaviour and performance. However, the empirical knowledge upon which this work has been based (see Mathieson & Dodd (2004)) does not support a complete enough treatment of task work behaviours (e.g. content of plans or courses of action). Behaviours related to teamwork interactions are incorporated into the knowledge enabler relationships described above in terms of their effect on team maturity.

We propose to link team maturity to team performance by making the assumption that a less mature team will be less efficient in its task work for 2 reasons. Firstly, it will require to spend a proportion of its energy and effort in the teamwork processes aimed at acquiring the knowledge needed to mature and, secondly, its lack of maturity will result in an increased friction in taskwork, further reducing efficiency. The interpretation of 'task efficiency' is still being developed, though it will depend upon the representation of task work itself. Initially, a simple representation of task performance in terms of time delay is planned, and this will require efficiency to be interpreted in the same way. If subsequent developments of task model include representations of quality of output, then it may be possible to attribute reduced output quality to team maturity as well.

It might be expected that the ability of the immature team to operate efficiently will depend upon the type and difficulty of particular tasks and task contexts. For example, a straightforward deliberate planning task can probably be carried out reasonably well by a fairly immature team, while managing a crisis situation will require more maturity. For this reason we intend to characterise tasks (in terms of team maturity requirements) and apply different transfer functions between team maturity and task efficiency.

Figure 5 summarises the knowledge processes contained within our conceptual model, along with an indication of the objects implied by the design. The initial implementation of the model focuses on the team initiation to task work part of the process, allowing aspects of the team knowledge vector to be set directly, rather than derived from a manipulation of individual vectors. In object terms, the initial implementation will, therefore, focus on the team object. Further elements from the conceptual design will be progressively introduced in an iterative model implementation and calibration process.

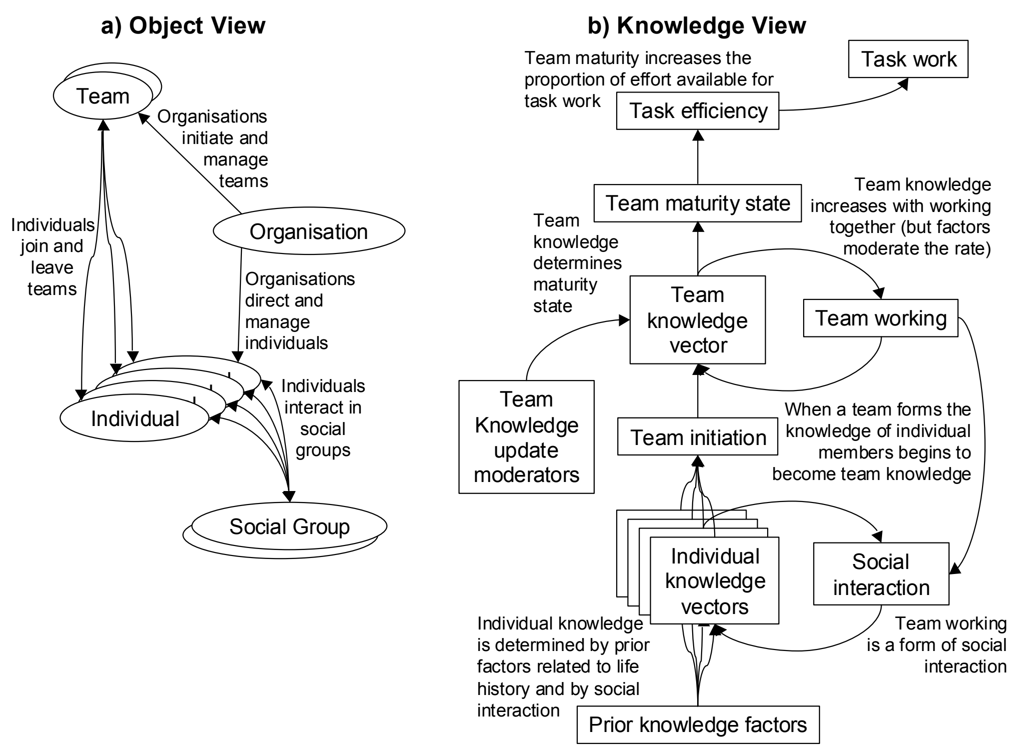

Figure 5: a) Summary of the objects and their relationships implied by the conceptual model design. b) Summary of the knowledge processes contained in the conceptual model design.

4. **Empirical Evidence for Modelling Needs**

The conceptualisation described above is rich and complicated. It might be thought to be over-complicated, but even a cursory consideration of the empirical evidence from real HQ contexts suggests that all the dimensions currently included are necessary to construct a requisite model of even apparently simple issues, such as co-location. Broader problems associated with NEC and EBO are likely to be at least as rich.

This section provides a high level overview of an exercise to examine a range of empirical evidence from the military domain to test the need for including the proposed breadth of representation in a requisite HQ model. The term 'requisite' is used here to describe a model with sufficient content to provide a secure basis for reliable analysis. The evidence is, therefore, intended to inform a case for inclusion based on necessity (to create a model fit for purpose) rather than seeking an 'ideal' model. This is an important distinction because it implies that extant models of C2 that are non-requisite are, potentially, unfit for use.

The section is divided into 3 main parts. The first part describes the results of two thought experiments conducted by the research team to test the content and completeness of the theoretical synthesis reported at Mathieson & Dodd (2004). Although not (strictly) empirical evidence, these 'thought experiments' were a valid way to test whether the theoretical synthesis, developed largely from civil organisational experience, was likely to be relevant to the military HQ context.

The second part contains anecdotal material derived from discussions with a variety of military officers, exploring how, in their experience, social and organisational factors affect the operation of HQ.

The final part contains evidence derived from the human factors part of the Operation TELIC lessons learned exercise, carried out using interviews conducted by experienced human scientists.[2]

Thought experiments

Two thought experiments were carried out as case studies to test whether the scope of the theoretical synthesis, which underlies the present modelling work, was requisite in relation to typical OA study questions that might be faced in the future. The first case study considered a reachback scenario that arose from considerations of the exploitation of information networking to allow for distributed HQ working. The second considered a more radical change in the way of command, involving the provision of some combat support capabilities via service agreements. This second case study workshop was run with the help of a leading military adviser to the NEC research programme.

The thought experiments comprised an initial creativity session to identify key issues, followed by a systematic exploitation of the theoretical synthesis to identify which variables and areas of the Synthesis[3] were likely to be involved in a requisite model of the case study problem.

Thought experiments – Reachback case study

Fielded HQs typically suffer limitations in their ability to access and synthesise knowledge derived from out of theatre. This is particularly important in expeditionary operations with a strong diplomatic as well as military content. There are also perceived issues about the speed of deployment, mobility and protection of HQ's numbering hundreds of personnel. This thought experiment considered the possibility of exploiting Information Age ICS to allow it to place the bulk of HQ personnel in the rear or, even better, in the UK, where they could be provided with more secure and effective broadband communication networks and easier access to wider knowledge

[2] Operation TELIC refers to the UK involvement in the recent Gulf War.
[3] The term "the Synthesis", when used in this paper, refers to the theoretical synthesis of variables and relationships, captured as a causal network, that was derived from the organisational and social science literature during the previous work reported in Mathieson & Dodd (2004).

networks. This would leave only a small core command cell forward deployed to provide local situation awareness, command and leadership.

The rear element, conceptually termed the Operations Support Cell (OSC), would probably comprise the bulk of HQ staff functions and would operate from a fixed base with well-established communication networks. The forward element would comprise all of the necessary C2 functions but would probably be represented by only one or two officers who would use the OSC to provide residual and co-ordinating control functions.

The benefits of such an arrangement would be a smaller, hence more agile forward element and an improved level of access for the staffing functions to knowledge and expertise available on wider Defence networks without consuming as much limited satellite communications bandwidth. If the OSC were retained in the UK then a further benefit may be a significant reduction in the deployment and sustainment effort for the HQ as well as the operational footprint and the risk to its personnel.

Potential negative effects of the creation of the OSC could be a loss of coherence between the deployed and rear element of the HQ, affecting awareness and performance, and possibly impacting motivation and participation.

The initial creativity session identified 5 categories of factors critical to the study (team performance, motivation, process change, interaction mechanism, and structure change) with several sub-categories, including some not already captured in the theoretical synthesis. Using these as a starting point, the systematic exploitation process highlighted virtually all of the variables in the theoretical synthesis.

The conclusion that virtually all of the variables in synthesis are required for a study of reachback is both encouraging and problematic. It is encouraging that the research leading to synthesis proves to have been appropriate and well matched to the military problem. It is problematic because the resultant conceptual model is considerably more complicated than that conventionally used by and expected within the OA and study customer community. The implication is that current conceptualizations in HQ modeling are non-requisite, and OA people will need strong evidence to accept this.

Thought experiments – Combat Services case study

The exploitation of NEC and agile mission grouping implies the possibility of alternative organisational structures to deliver military effect. In particular, the issues of resource ownership and command relationships may need to be examined critically. For example, how will a low-level unit be prevented from using the whole formation's 155mm ammo supply? NEC implies an approach in which capabilities to carry out missions may be arranged as a network of services rather than as a hierarchy of units under the command of a task group.

The advantages of such an arrangement would be the ability to organise scarce specialist resources more efficiently and to reduce the management burden on task group C2. Already areas such as Logistics and, increasingly, ISTAR are provided on a service basis. Taking the idea further, one can envisage combat capability elements such as force protection also being provided on a service basis. This raises problematic issues around availability and level of service guarantees.

As before, the initial creativity session identified categories of critical factor (command structure, ownership, cohesion of task group/force, unity of effort, unity of C2/intent, trust, reliability of service provision, perceptions of reliability, morale, formal (vs. informal) relationships, authority to command vs. peer collaboration), which were used as roots for a systematic review of the Synthesis. Despite appearing to be a more complex problem this case did not cover quite as much of the Synthesis. However, it still touched significantly upon most of the theoretical factors, supporting the idea that a requisite HQ model would require a broad dimensionality.

Anecdotal Evidence

To back up the thought experiments, a set of anecdotal evidence was elicited from experienced military officers and other field personnel. Where views expressed by interviewees related to specific experiences (rather than their general experience) the incident in question is described as an example. However, the need to protect the privacy of those involved means that this paper only contains abstracted summaries drawing out the key conclusions of each story.

It should be noted that anecdotal evidence may be prone to subjective bias on the part of both interviewee and interviewer. The conclusions drawn below are the considered opinions of the authors, taking into account (declared and implied) interviewee bias. We gratefully acknowledge the assistance of the officers from whose anecdotes we abstracted this evidence, and affirm that any error in the interpretation is solely ours.

From the evidence collected it was possible to identify a range of factors likely to be important in explaining HQ performance. These are briefly discussed below under a series of subject area headings:

- **HQ layout:** It is observed that the most effective HQ staff tended to re-arrange their local environment, although there is a limit to how much you can do this in an operationally deployed field HQ. In the days of the Cold War, when HQ survival was paramount, staff typically worked from their vehicles or in small 2-3 man tents, connected by tented corridors. Since then, the survivability constraint has relaxed somewhat, leading to more use of open plan layouts with much more physical movement and informal interaction. This has many advantages in terms of better sharing and activity monitoring, but limits staff control over their workspace, reduces their ability to evolve efficient local short-cuts in communications and sharing protocols, and creates more general 'bustle'.
- **Interpersonal variability:** Training gives HQ staff most of the skills they currently need to provide a 60% solution to desired collective performance, which is then refined and improved through experience and team-building. For example, in the Falklands, in the period after the war, patterns of land patrol activity were one of the key elements of the staff briefing. On one occasion a change of Commander gave rise to variations in Staff performance of the briefing task. The outgoing Commander had been interested in the location, footprint and objective of his patrols while his successor was interested in patrol compositions, call signs, etc. The result was that Staff had to spend much time in Q&A sessions, until they

learned to anticipate the new Commander's particular information requirements. This interpersonal variability between Commanders is important when considering the provision of electronic information services, as a substitute for staff briefings. It also highlights the importance of team learning in the face of changes in personnel.

- **Familiarity:** Changes to the membership of staff teams require some adjustment and accommodation. This requires frequent practice, a factor which may be important when considering agile mission grouping. On one occasion, when forced to deploy (due to world events), the HQ Chief of Staff, mindful of the need for an ability to conduct regular re-adjustment, arranged local, low-level practice sessions at the home base (involving 6-20 staff). The differences this training made included lower general noise levels in the HQ and more efficient routine briefing (counted both in preparation time and delivery time – and resulting in time away from desk reducing from 1hr to 15min). This evidence is particularly relevant to the need for HQ modelling to represent potentially very significant performance variations arising from initial team familiarity and subsequent variations in team constitution.
- **Time pressure and social norms:** HQ staff respond to time pressure by adapting their process and practices to take short-cuts. One key response is an imposition of discipline on input, including a reduction in the social elements of information exchange as typified by the order "all stations, this is zero, minimise". Subordinate HQs have been observed reacting badly to this brusqueness. However, after a time, people "get to know how to handle this". The time-pressured behaviour could be described as "the disciplined variant of social norms".
- **Time pressure and process variation:** Tasking of some specialist Engineering teams in Op TELIC[4] needed to be quick, so processes developed for Northern Ireland were imported. Under these, the unit raising the need for a support mission raised the request up to their Brigade, who then tasked the teams directly (bypassing the normal Joint Force tasking procedures). This arrangement was formalised through orders so that it could be considered a 'formal ad hoc' process rather than an 'informal' one. Requisite modelling would allow for such process variability.
- **Social attitudes and co-operation:** Another aspect of time pressure was observed in some technical support units in Op TELIC. A difference in general attitude was observed between early operations, where there was an expectation of quick results and early withdrawal, compared with later episodes when it became clear that this would be an extended operation with only intermittent 'wins'. In one case, the situation of intense, but not life-threatening, activity and an expectation of short timescales were associated with the emergence of competition between units who were seeking to be the first to achieve a mission success. This was allied to a lack of interaction between those units, which might have contributed to a lowering in overall efficiency and a possible waste of precious resources.
- **Differences in social behaviour between operations and non-op contexts:** Based on operational experience in Northern Ireland, and responding to the question "were there any differences compared with non-operational contexts", the following insights emerged. There were different 'dynamics' in relationships within and between staff on a 6-month roulement and permanent formations. 'Office politics' were never entirely lost, even in an operational context. For

[4] Op TELIC refers to the UK involvement in the recent Gulf War.

example, when a particular incident occurred, the HQ was able to switch into a concentrated task-orientation for periods of 2 to 3 hours, but for the rest of the time the social 'stuff' re-surfaced (as if it were too much of a strain to sustain task focus for longer). Behaviour during 'relaxed' periods did not differ between operational and non-operational (barracks) contexts. These effects may be important when studying long duration operations, especially where combat is not a dominant feature.

- **Cultural markers:** During MoD postings, staff behaviour is similar to that ‘in barracks’, especially peer-to-peer interactions, however the lack of uniform means rank is less obvious and this leads to an initial caution until 'proper' rank relationship is established.
- **Impact of using reservists:** In one (non HQ) context in Op TELIC a noticeable difference was observed when US reservists were rouled into the theatre. The reservists seemed to be more in tune to “organisational politics” and to the international political context, and this resulted in the (local) organisational goals being re-addressed. As a general point, the cultural background of people is likely to affect how missions are perceived, a fact which could become increasingly important as agile force behaviour comes to depend more on individual choices and imperatives.
- **Value of precision and accuracy in C2:** Operational orders can all too often be ‘crafted’ and developed into large, detailed documents in a vain attempt at greater precision. There is some evidence that the less one puts into orders the better may be the robustness of the C2 process. C2 works with a network of people and a network is able to accommodate error (which can be the result of imprecision) and uncertainty. Indeed, humans are expert at working with uncertain data and don't work so well with very precise or excessively large amounts of data. For example, in one case, near nightfall, a patrol of cold, tired soldiers was ordered to make their way to a local barn for the night. However, the instruction issued contained the grid reference of the barn with a one digit transcription error (e.g. 123556 instead of 123456) placing the ordered location some 10km away from the patrol. There was no barn at the ordered location, but one close by. The patrol proceeded to the wrong barn, incurring extra burden and potential loss of operational capability. Whilst the officer ordering the move was at fault for giving an incorrect order, the patrol leader was also reprimanded for following the order without question. Less precision might have avoided this error. These insights are important when modelling the effect of information flows on staff understanding and command appreciation. Most current models assume that information is transmitted accurately and interpreted rationally using all cues available. The above anecdote emphasises the need to take account of both error in transmission and variability in interpretation.
- **Multi-nationality:** In Op TELIC, after the main fighting phase, there was an initiative to make the Divisional Main HQ in the Basra area more international in its staffing. In one branch the result was not always entirely satisfactory. Problems with English language competence had an impact on the efficiency of work and on the ability to allocate staff to particular roles. There were also problems due to unfamiliarity with the UK procedures that were, by then, firmly established. The effect was a need for additional checking of products. In a different, non-HQ context during the same operation multi-nationality was seen to inhibit agile team forming. The factors involved included: national prejudices based on past experiences; cultural heritage as a noticeable factor in team cohesion; language

problems; incompatible standard operating procedures (SOPs) and priorities (arising from different philosophies of Ops, such as whether causing collateral damage was deemed to matter); legal issues arising from lack of clear procedures; and training requirements which inhibited agile teaming. Similar issues could impact on HQ operation under the agile mission grouping conditions envisaged within NEC. The issue of multi-national staff performance has implications for the representation, in HQ modelling for OA, of communications efficiency and effectiveness as well as in-theatre training requirements.

- **Social contact:** Multiple incidents have been reported from Op TELIC (and other theatres of operations) in which social contact (through sharing off-duty activities) resulted in significant impacts on operational performance. In one case an informal social contact between a specialist Engineering unit and a unit with Uninhabited Air Vehicle (UAV) capability provided the knowledge needed to identify a possible capability combination that could significantly improve the former unit's performance. This knowledge was formally published in the information network, but was unknown to the unit command (due to the large volume of 'available' information).
- **Shared accommodation:** A similar effect is reported, in an entirely different type of unit in theatre, where a move into shared accommodation resulted in a noticeable increase in mixing between the teams.
- **Informal organisation:** In another case a civilian technical team found itself 'orphaned' when its parent military unit was rouled out of theatre. As a result of 'sharing hospitality' with an equivalent US team (e.g. inviting staff to dinner and sharing leisure resources) the team managed to become 'adopted' by an allied military structure and was able to continue effective operation, and create an enhanced capability due to complementary skill sets and a positive social dynamic.
- **Lack of social contact:** On the reverse side, there are also incidents of competition between teams doing the same job but under different command chains. A contributory factor seems to be a physical separation of the teams, preventing them from establishing social contact. Representing the effects of social contact on trust and interoperability is likely to be important to agile mission grouping and coalition operations. In the HQ context, the issues discussed under multi-nationality above could be significantly mitigated if mutual understanding of the sort which arises from social contact were to be established in advance of seeking to interoperate. In modelling terms, this implies that issues such as co-location and resource sharing may be important factors in performance.

These anecdotes from multiple conflict theatres present a consistent pattern of human organisational behaviour variability and emphasise the significance of social and organisational dynamics in shaping the behaviour and performance of military teams in the field. It also suggests that understanding gained from the civilian organisational context will be applicable to the military context, even under deployed operational conditions.

Op TELIC human factor lessons identified

A comprehensive 'Lessons Identified' process was carried out under Op TELIC, including Human Factors Lessons Identified. We have exploited this material to identify important variables and relationships relevant to the HQ modelling theoretical synthesis. The aim was to see how the variables contained within the Synthesis compared with the human sciences data collected from the operation.

The analysis identified key variable clusters within the Synthesis that were evident in reports from military personnel deployed on Op TELIC (Culture, Process monitoring, Organisational performance, Reliability, and Effectiveness in communications). There was a large overlap between issues raised from the operation and the variables covered by the Synthesis. For example, under Senior Command Issues in the Op TELIC output, there is agreement on 7 broad categories of variable (Leadership, planning and the orders process, joint and coalition issues, situation awareness, commander's intent and way of command, HQ teamwork, and spectrum of conflict and agility). The language and terminology use to describe variables in the Synthesis could be equated to those found from Op TELIC, but was not the same.

The strong overlap between the Synthesis and the Op TELIC Lessons Identified supports the importance of including the breadth of factors currently in the Synthesis, despite the resulting scale and complexity of the HQ conceptual model that this implies.

Limitations of 'expert' evidence

All of the empirical evidence so far collected supports the argument that a requisite HQ model will require a broad treatment of factors. However, it would be unwise to rely upon expert evidence alone, for reasons that become obvious when one considers the roots of expertise.

Due to the severely limited capacity of cognitive working memory, humans have evolved rich strategies for understanding and managing complex behaviour expertly. These involve a heavy use of sub-conscious cognitive processes operating at all levels up to, and including, higher reasoning. Experts, like people in general, are largely unaware of their cognitive processes and, when asked to explain decisions or behaviours, will construct explanations based on a combination of reconstructive memory, story-telling and educated guesswork. The conceptual model, therefore, cannot be based solely on the self-report of so-called 'subject matter experts', even very experienced and reflective ones.

For this reason, a key part of the next stage of the research programme will be the derivation of a critical empirical research agenda, identifying gaps in the secure knowledge base and proposing research and experimentation to fill them. However, the need to provide OA to ongoing Defence investments means that we cannot delay HQ modelling until the evidence base is complete. Therefore, a creative approach is required to allow practical implementation of requisite modelling.

5. **Model Implementation and Calibration**

The conceptual model described in the previous section is being progressively implemented as an algorithm capable of being integrated into existing C2 models for OA. The intention is to improve the balance of the host model so that it is able to assess a wider range of interventions relevant to NEC and EBO.

Acquiring reliable data for human and organisational modelling is very difficult and it is highly unlikely that the needs of the rich model envisaged here could be fully met at a reasonable cost. However, it would be inappropriate to build a non-requisite model just to avoid gaps in data availability. Therefore, our approach is to build a requisite model in terms of coverage and then treat parameters for which data are not available as uncertain variables, to be subjected to sensitivity analysis.

The main design strategy in the conceptual model is a network of variables with causal connections between them. The initial implementation uses parametric equations, based on a half-wave sinusoid, to produce an ‘S-curve’ representation. These equations are expressed parametrically and the control parameters governing the shape of the ‘S’ are also treated as uncertain variables. Where the variables in question are knowledge update moderators then they will be connected in such a way as to have an effect on the ‘S-curve’ parameters rather than the main knowledge variables. This relationship will, itself, be represented by a parametric equation.

The parametric implementation allows us to construct an executable model, accurately reflecting the qualitative design of the conceptual model, as a vehicle for calibration and sensitivity testing.

The strategy for calibration has 2 key stages. Firstly, the variables and ‘S-curve’ control parameters will be reviewed against the available empirical evidence in order to place reasonable limits on scale value and extent. Once the uncertainty space has been minimised in this way, sensitivity analysis will commence. The goal is to treat uncertainty as a pool of possibilities and to use the data farming techniques developed by Project Albert (2005) to explore the uncertainty space, looking for areas of sensitivity and insensitivity. By this means we hope to be able to further refine the significant range of the variables, especially the control parameters.

The residual uncertainty will be used to define a research and data-collection agenda, which will inform research strategy within MoD and the wider community. The residual uncertainty, combined with sensitivity analysis, will also inform current model development activities in terms of the fidelity of representation that is likely to be practical and significant.

To maximise flexibility in model implementation we are using the Unified Modelling Language (UML) to create formal graphical representations of the conceptual model and described in further detail in Waters, et al (2005). With these representations is has been possible to generate auto-code which can be integrated into extant models via intermediate representational languages such as the Extensible Markup Language (XML) or Visual basic.

The team is currently seeking suitable host models to use as test-beds for the implementation of our model. These will allow the calibration to be done in a more realistic context, giving more power to the sensitivity testing.

6. **Model Application**

We believe that linking knowledge acquisition factors and moderators through Noble's knowledge enablers to the Tuckman team maturity process produces a powerful construct for our HQ modelling task. Our overall purpose is to improve the state of C2 modelling in order to provide an assessment mechanism able to host an understanding of how C2 capability performs under the range of investment options necessary to implement NEC and EBO effectively in future operational contexts.

Key issues, which we intend the model to be capable of addressing, include (in no particular order) assessing the impact on operational effectiveness and capability requirements of:

- New C2 concepts (including Effects Based Planning);
- Agile team forming;
- Rapid deployment (without extended work-up and pre-operational training);
- Joint and coalition collective training;
- Virtual teams (working over computer-mediated networks);
- Multinational teaming;
- Multi-agency teaming (extending wider than the military);
- Collaboration technologies;
- Team structure and process variability.

This is a challenging task, in which we will proceed by a process of iterative development. It may even be an impossible task, but it is critical to attempt since the implications of success (or failure) are far-reaching and significant.

7. **Implications of success (or failure)**

Successful construction of a requisite conceptual model, especially with a practical implementation, will allow us to support analysis for investment in NEC and EBO in a more coherent and integrated way. The model will facilitate a more holistic treatment of critical human, organisational and social variables, which is necessary to support effectively balance of investment across the DLoDs or effective assessment of any socio-technical system.

A failure to implement a requisite model of an agile HQ successfully has significant implications for the way in which future Defence investments can be justified and managed. Current UK policy for military capability acquisition requires the use of cost-effectiveness assessment of investment options [MoD, 2004]. Without requisite modelling, such assessment is likely to be unreliable, and may be very misleading. Making investment decisions without reliable, holistic assessments of effect means that a more risk-taking and experimental approach to acquisition will be required.

Of course, it may be that such an experimental approach will be more effective in generating an evolution of C2 capability capable of achieving competitive advantage in Information Age conflict. However, the research, which underpins our modelling, suggests that the cultural and organisational changes needed for such a radical change in acquisition approach are unlikely to happen quickly. In the meantime, it is worth striving for requisite modelling to avoid the trap of erudite self-delusion.

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