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"**Exploring Joint Usability and Decision Effectiveness using a Networked-Enabled Virtual Collaborative Working and Visualisation Environment for Military Planning**"

Topics: Collaborative Technologies, Network Centric Experimentation, Cognitive and Social Issues

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Abstract

This paper concerns the use of a Collaborative Working and Visualisation Environment (CWVE), i.e. using virtual collaborative desks (VCDs), for the development of shared situational awareness using a common operational picture to support collaborative military planning in joint command and control situations. Joint usability, critical task and situational awareness assessment methods are employed to determine the effectiveness of this CWVE in supporting commanders' joint decision making. With reference to the British Army's seven questions estimate process and intelligence preparation of the battlefield, together with employing a small military judgement panel for the simulation experiment, the research focuses on the how effectively networked VCDs highlight commander's critical information requirements and their purpose including the commander's evolving requests for information during planning; and, how collaborative technologies might improve joint decision effectiveness in the specification and delivery of planning products, such as: the decision support overlay, decision support matrix and the synchronisation matrix within a distributed HQ environment in order to enable distributed working. As a result of this research a joint usability framework has been developed. This research has military significance in terms of enabling synchronised joint decision making in resilient agile distributed HQ groups and thereby reducing security risk of commander and staff.

Keywords: virtual teams, collaborative working environment, collaborative tools, joint usability, collaborative ease-of-use, military planning effectiveness, technology readiness level, combat estimate process

1. Introduction

Many of the challenges of the Command and Control process are related to or will be compounded by the requirements for future army forces to participate in distributed collaborations. According to the US Army (2001), distribution of task forces will have a serious impact on the collaborative planning process and collaborative problem solving. This statement illustrates that there is a need for collaborative tools, like VCDs, to provide mechanisms that retain the integrity of the interactive collaborative planning process, synchronization matrix, operation orders, etc. and support effective distributed planning and decision making. Therefore, exploiting information and communication technologies for collaborative working has attracted attention from many industry sectors including the military. The benefits that may be derived through virtual collaborative working are many, whilst being cognisant of any the limitations which may inhibit adoption.

With the reference to the above statement the research objectives of this study are to:

1. Investigate the usability and effectiveness of VCDs for Military Planning in a virtual collaborative working environment;
2. Inform the development of VCD design as an enabling tool for collaborative military planning in a distributed environment;
3. Develop a theoretical framework to inform the product development of a VCD as a tool for military planning in a virtual collaborative working environment.

In accordance with the research objectives, the main purpose of the literature review section is to (*i*) frame the research; and (*ii*) identify the relevant concepts, methods, facts and variables necessary to underpin a qualitative survey framework and research instrument, which will be used to assess system usability, interface quality and design of the VCD for collaborative military planning effectiveness. Following the literature review section the remaining sections will: (*i*) present the research methodology which includes a hypothesised framework and research instrument; (*ii*) give the basic set of VCD's features; (*iii*) describe the experimental procedure; (*iv*) provide a detailed data analysis; and (*v*) present the theoretical model developed as a result of the analysis, and research findings drawn from the experimental results. Finally, the concluding statement will highlight what has been achieved from the experiment.

2. Literature Review

The Driving force behind Virtual Team Collaboration

The emerging knowledge economy and the development of global organizations; global competition and the networked digital technologies made available has enabled organisations to create virtual teams to become involved in more complex and dynamic projects (Oakley, 1998; Townsend et al., 1998) in order to improve and create efficient and effective collaboration for organisational benefit and success. Although some organisations are realising the benefits of virtual teams, there are some that still use conventional face to face teams (Martins et al., 2004). However, many organisations are endeavouring to increase their productivity by utilising a mix of collaboration technologies to enable an effective and efficient virtual collaborative working environment.

Virtual teams, unlike co-located teams, replace the need for regular face-to-face interactions with regular, electronically supported virtual interactions. Lipnack and Stamps (1997) in their book, "Virtual Teams: People Working Across Boundaries with Technology", provide a tangible definition of virtual organization. "a virtual team is a group of people who work interdependently with a shared purpose across space, time and organization boundaries using technology to accomplish a defined task" with members of virtual teams seldom, if ever meeting face-to-face (Johnson et al, 2001, Bell & Kozlowski, 2002). Johnson, Heimann & O'Neil, (2001) takes a slightly different view, as they suggest that individuals participating in virtual collaboration activities generally communicate synchronously and they also may be located together and are not separated by space, time or organisational barriers or remotely. Kirkman and Mathieu, (2005) define virtual teams as *(a) the extent to which team members use virtual tools to coordinate and execute team processes (including communication media such as email and videoconferencing and work tools such as group decision support systems, (b) the amount of informational value provided by such tools, and (c) the synchronicity of team member virtual interaction"*

There are numerous other definitions on virtual teams that have been composed by researchers in this area, with the majority of the definitions encompassing the use of technology whilst working across different geographical, time, cultural and organisational boundaries (Jennings, 1993; Chase, 1999; Kristof et al., 1995; Langevin, 2004, Tucker & Panteli, 2003, Dutton, 1992; Duklis, 2006, Cohen and Mankin, 1999; Igbaria, 1999; Yager, 2000). For the purpose of this paper virtual teams are defined as: "*a distributed organisation that can meet mission requirements without a static spatial frame of reference across time and organisational boundaries using technology enhancements and innovative techniques that allow an organisation to: function, provide transparent and responsive support in order to enhance situational awareness and accomplish its mission*" (Duklis, 2006).

It has been acknowledged by Arnison & Miller, (2002) and Page (1997) that technology is the fundamental driving force behind the existence of pure virtual teams to engage in collaborative work and is therefore critical to its existence. Similarly a study conducted by Rico and Cohen (2005) on how technology impacts virtual collaboration, identified that communication technologies serve as the bond linking the members of virtual teams together in order to communicate, share data and information despite the differences in location and time. The technology provides task support primarily for the individual team member or for the group's activities. These communication technologies are utilised to overcome space and time constraints that burden face-to-face meetings, to increase the range and depth of information access, and to improve group task performance effectiveness, especially by overcoming "process losses" (McGrath & Hollingshead, 1993, 1994). They can also "reduce or eliminate the expense and inconvenience associated with distributed work" (Galegher & Kraut, 1994, p. 11 1). One objective of using these technologies is to create equal levels of communication speed and effectiveness as those achieved at traditional meetings. Without the technology we are left with little more than the idea of individuals working independently from dispersed locations (Handy, 1995). This indicates that it is the technology concept that makes the idea of "virtuality" unique, since technology is the main channel for interaction in virtual teams (Bell and Kozlowski, 2002).

However, according to Fisher & Fisher (1997) and Haywood (1998), it is not about *serving* the technology but rather about the technology serving the team as there should be no over optimistic expectation on what the technology can deliver. Lurey & Raisinghani (2001) have candidly suggested that teams could be more effective if provided with the opportunity to meet virtually, if the most advanced technology was made available. However it has been noted by Warkentin et al., (1997) that the technology is only a partial factor for the success of virtual team effectiveness as it has been suggested that these mediums must be supplemented with traditional team practices (i.e. face-to-face meetings). This is because relational links among team members were found to be a significant contributor to the effectiveness of information exchange, and total dependency on technologies to provide the necessary mediums to build a team can potentially hinder the development of a sense of unity and satisfaction with the group's interaction process.

This emphasises the importance of effective technology being made available to virtual team members for project communication and coordination. Although not definitive in terms of specific effects, the research in this area suggests that virtual teams exchange information and communicate differently, less effectively and efficiently than face-to-face groups (Chidambaram, 1996; Straus, 1996; Hightower & Hagmann, 1996, 1995; Hightower & Sayeed, 1995; Hiltz, Johnson, & Turoff, 1986; Kiesler & Sproull, 1992; McGrath & Hollingshead, 1994; Siegal, Dubrovsky, Kiesler, & McGuire, 1986; Wiseband, Schneider, & Connolly, 1995). However, it has to be noted that many of these studies are limited in two important aspects. First, they used ad hoc groups or did not give their groups sufficient time to adapt to one another or the communication medium which explains the less effective communication process. Durate and Snyder (1999), further expand the previous point by saying that the lack of physical contact in virtual teams may 'erode meaning and understanding'. Consequently, in Chidambaram's (1996) research, evidence suggests that when virtual teams are given sufficient time to develop strong intra-group relationships and to adapt to the communication medium, they may communicate as effectively as face-to-face groups. Moreover, Maznewski and Chudoba (2000) state that whilst some studies support the hypothesis that face to face teams communicate more effectively, others reflect better performance in virtual than in face to face

teams although this may dependent on the size of the team. Clearly defined goals and objectives are the most important factors that contribute to successful virtual team working (Lipnack & Stamps, 1997, Henry & Hartzler, 1997, Fisher & Fisher, 1997, Haywood, 1989). Durate and Snyder (1999) apply similar views in that a clearly understood statement of direction at the beginning of any team serves as a starting point for more detailed plans. Loss of identity as a team member in virtual teams can occur, therefore there is the need to be provided with clear goals in order to make a cohesive contribution and a need to know what other individuals roles are as poor interaction among members due to lack of understanding about their roles can reduce the opportunity for cohesiveness. For most people being part of virtual team is not only an organisational change but a cultural one too. Culture is viewed as one of the most significant boundaries of virtual teams (Durate & Snyder, 1999) that may involve new interpersonal relationships; a new way of communication, and possibly a different work ethic and climate which can affect values, norms, expectations, vision and work practices (Hartzler, 1998). One of the major cultural shifts in a virtual organisation is the absence of face to face contact with team members, which can undeniably cause a cultural shift in communication skills, leadership, and trust.

Research has indicated that often, rank, position, service and perceived expectations created barriers preventing the development of trust and subsequently, the sharing of information. This is critical, as information sharing enhances quality of information and shared situational understanding. In the case of the military trust is not necessarily an issue due to their doctrinal training. Fisher & Fisher, (1997) maintain it is important that there is a Virtual team leader in order to link the distributed minds (knowledge workers) together without superimposing their own mind on top of team members. Effective and strong leadership is essential for the successful functioning of the virtual environment to ensure deadlines are met within a set time frame and to ensure progress is continuous and positive (predominantly relevant in military planning process), particularly if the skills and knowledge acquired by team members are diversified. The diversity, mixed with distance could create conflicts because of the increase in communication barriers. However, according to (Lipnack & Stamps; 1997; Parker, 1991; Durate & Snyder, 1999) in order to ensure successful leadership in teams, leadership needs to be shared when dealing with complex issues and problems with leadership changing to a team member who has certain expertise in dealing with specific problems. Though is not the case of military planning where the commander remains in charge.

Keeping synergy and creativity flowing without face-to-face interaction is the greatest challenge to a virtual team (Henry & Hartzler, 1997). Haywood, 1989, has suggested that if virtual teams are not managed properly communication can be less effective than in traditional teams. This is supported by Carletta et al, (1997) who points out that even the best communication via video links etc does not allow as clear communication as face-to-face. Plus there tends to be a psychological distance between the users, which results in more formal interaction. However it is also maintained that a less social presence can sometimes be better as it reduces interpersonal distractions which may interface with logical and analytical abilities Durate and Snyder (1999). When creating effective virtual teams another factor to consider is the personality characteristics of the specific team members and their psychological profiles (allowing individuals to experience each other as being psychologically close or present (Fulk & Boyd, 1991). In order to be successful in a virtual environment, team members need to possess patience, persistence, and perseverance along with a certain degree of tolerance, flexibility, and understanding.

Physical Interaction and Collaborative Ease of Use

The VCD presents a platform for knowledge sharing, team collaboration and decision making. Performance measurement facilitates individual decision making and gives guidelines for improving team environment and leveraging the support of technology. It is essential to measure the negative outcomes brought about by requirements and limitations of the VCD, such as errors of the system. Likewise it is important to measure the positive outcomes brought about by efficiency and quality. Measures of satisfaction and affect need to be considered too along with identifying users needs of the VCD (Landauer, 1995).

Virtual collaboration may also impose constraints on communication that is likely to affect a group's performance. People rely on multiple modes of communication in face-to-face conversation, such as preverbal (tone of voice, inflection, voice volume) and nonverbal (eye movement, facial expression, hand gestures, and other body language) cues. These cues help regulate the flow of conversation, facilitate turn taking, provide feedback, and convey subtle meanings. As a result, face-to-face conversation is a remarkably orderly process. In normal face-to-face conversation, there are fewer interruptions or long pauses and the distribution of participation is consistent, though skewed toward higher status members (McGrath, 1990).

In studies conducted by McGrath & Hollingshead, (1994); Hightower & Sayeed, (1995,1996) substantial evidence has been provided that virtual teams communicate less efficiently that face-to-face groups. Likewise, Anderson et al (1999) also reported successful outcomes in virtual team collaboration but more difficulties were encountered in handling smooth transitions between speakers. This is because exchanging information is more difficult due to factors such as opportunity & motivation (willingness of group members to contribute information that may contradict their own opinions or those of others). However, evidence provided by Majchrzak et al, (2004) and Malhotra et al, (2001) suggests that individuals can successfully collaborate with little or no face to face interaction, by leveraging collaborative technologies to share their knowledge including integrating and using others shared knowledge productively.

A distinct disadvantage working in a virtual environment is the opportunity to access the usual cues and clues that are acquired via daily interaction on a traditional basis. A small misunderstanding in a virtual team can quickly escalate into an intractable resentment (Way, 2000). Individuals may also see the perceived modes of interaction enabled by the virtual workplace as unreliable leading to unpredictable continuity of their routine interactions and meetings. Virtual members may find it hard to develop positive attitudes towards others and feel uneasy about the activities of the rest of the team.

Some members may also report feelings of social isolation due to lack of f2f contact and work performance may be impeded by co-ordination difficulties between members and teams may be less cohesive due to lack of f2f contact and the decreased proximity in teams (Kiesler & Cummings, 2002) which can lead to high levels of anxiety (Nandhakumar & Baskerville, 2006). This can be particularly prevalent in remote locations, where technology is exclusively relied upon for interaction with other members (Goffman, 1990). Communication problems can be associated with technical difficulties (file sharing problems, server connection failures, power failures and any other telecommunications failures that prevent efficient networking and can also contribute to the feeling of isolation and abandonment. The creation of a shared space may solve this, however according to Cohen and Mankin (1999), this is seen to be quite difficult to apply in virtual communities, thus compounding the problem even more so.

Using technology as a primary means of communication has been found to significantly delay a project where team members are reliant on the technology as their primary means of communication (Cramton, 2001, Kayworth and Leidner, 2002, Suchan & Hayzak, 2001, Van Ryssen and Hayes Godar, 2000). Team effectiveness can also be reduced because of increased communication problems associated with lags and delay of communication medium. The inability to assess understanding of fellow team members, and team members' differing frames of reference, language, culture, and motivation to participate can also reduce team effectiveness. These difficulties are magnified for short-term virtual teams that work under significant time pressure (Cramton, 2001; Galegher and Kraut, 1994; Jarvenpaa et al., 1998; Jarvenpaa and Leidner, 1999; Robey et al., 2000; Walther and Burgoon, 1992; Warkentin and Beranek, 1999; Warkentin et al., 1997). Though, virtual collaboration may be the only option for geographically distributed teams to work together.

Good competency with technology is required in order to work confidently in a virtual team environment; otherwise the capacity to meet the objectives may be limited. It is also essential that access to information is provided to all members of the team will determine the success of the teams ability to perform well. Yet, a main advantage of virtual teams is their flexibility and it enables them to draw upon the most appropriate set of expert individuals required to complete a specific task regardless of their location (Qui et al, 2007; Jarvenpaa and Leidner, 1999; Carincross, 1997 and Townsend et al., 1996). For this reason, virtual teams are frequently employed for atypical and highly specialized projects involving unique information and changing requirements (Jarvenpaa and Ives, 1994; Robey et al., 2000).

Cognitive Interaction in a collaborative Virtual Environment

Due to intense information exchange based on a wide range of views of individual team members, collaboration in virtual environments promotes high levels of cognitive complexity. This difficulty can be overcome through knowledge integration and mental model building in order to successfully collaborate and accomplish complex, unclear and interdependent tasks with conflicting dialogue (Vandenbosch & Higgins, 1996). Mental model building in this context is a function of participating in a dialogue of sharing one's own unique knowledge, but not to the extent to which they internalise and reflect on others perspectives. Individuals who share knowledge and understand perspectives of others are better equipped to apply that knowledge towards complex problems with which they are tasked (Boland et al, 1994).

Transactive memory refers to a system where one uses others as memory aids to supplement limited memory and allows the 'pooling' of unshared information (Mohammed & Dumville, 2001), to enlarge group memory which is made available and accessible to the group. Individual members of the group however, will require a system of encoding, storing, retrieving and communicating their own and others representations (Wegner, 1987) which includes the cognitive abilities of the individuals as well as meta-memory (Beliefs that the members have about their memories). The benefit of transactive memory is that specialising knowledge in a group and having a shared awareness of who knows what information, leads to a reduction in cognitive load, therefore increasing the groups cognitive processing capacity in which greater expertise can be achieved as there is less redundancy of effort (Wegner, Erber & Raymond, 1991). Moreland (1999) also maintains that the idea that familiarity and training people together may help the development of transactive memory for the development of such a system and improves performance. However, it has to be noted that most research conducted on transactive memory has been in tasks which are unlike those faced by workers.

Virtual Collaboration in the Military Domain

Researchers focusing on organisations working in high-risk areas, such as in the military domain, recognise the importance of having good social, organisational and technological conditions to support communication and information exchange between the involved teams (Johansson, 2005). When there is a heavy workload and time pressure, communication is difficult and thus, team mental models may serve a greater function than when communication is easy (Mathieu, Goodwin, Salas, & Cannon-Bowers, 2000). The military overcome this communication problem through the use of a thinking framework, the Seven Questions (AFM, 2005), which imposes precision, order and discipline. This facilitates an understanding of the common purpose and planning intent. Also, this form of cognitive consensus enables planning teams to interpret and communicate in a similar way (Mohammed & Dumville, 2001).

Shared Situation Awareness

Situation Awareness (SA) has been defined by (Endsley, 1995) as 'the perception of all the elements in the environment within a volume of space and time, the comprehension of their meaning and the projection of their status in the near future'. SA is integrated into the Orientation Task in the OODA Loop (Boyd 1987) which focuses on the tactical side which is reactive and determined by dynamic information needs. This is why SA is critical in the planning process as it is a dynamic process that is continuously modified and updated over time (Salas, Prince, Baker & Shrestha, 1995).

In team decision making the process of achieving situation awareness consists of team members testing out their mental models of the situation by collecting and sharing information and then negotiating to endorse one theory of the situation to use a common frame of reference for the task. The amount and quality of communication is key to this process. Communication leads to similar expectations. This allows for similar perceptions of environmental information. It is important for team members to have an up to date view of the situation and the state of the task as a foundation is created when there is a development of mutual understanding regarding knowledge, beliefs, goals or attitudes (Kraut, Fussell and Siegel (in press).

If schema similarity is achieved amongst team members, they are more likely to attend to, interpret and communicate about the environment in a similar way (Rentsch & Hall, 1994). An essential element of collaborative Command and Control (C2) work is communication and information seeking. Shared information needs to be translated into shared awareness of the situation at hand which, in turn, provides the basis for shared situational understanding (Artman, 2000) and shared mental models, both prerequisites of effective collective action in a given situation (Salas, Burke & Samman, 2001; Mathieu, Goodwin, Heffner, Salas & Cannon-Bowers, 2000). The accuracy of group SA depends not only on the shared information, but also on the shared "mental model". In the planning process there is the need to perceive, interpret, and exchange large amounts of frequently ambiguous information in order to develop and keep the SA required for successful decision making performance (Rasker, 2000).

Accurate situation assessment in virtual collaboration is the ready access to shared workspaces comprising the C2 system (Ackerman, 2005) as SA requirements focuses on not only on what the information the planner needs, but also on how the data is presented through various systems and devices and integrated or combined to make operational decisions. Ungvarsky et al's (2001) study of evaluating commanders using a collaborative software package indicated that soldiers maintained that nothing could ever replace the value of standing around a paper map and discussing the mission. Likewise, the U.S Army doctrine, still maintains that the commander's intent must be expressed in face to face communication whenever possible

(Majchrzak et al., 2004). Although the wide spread use of VCD and full acceptance in military development has not yet been achieved, which may be due to high purchase price and operating costs of some of these systems or simply because organisational, operational, behavioural, and research issues remain to be identified, studied and understood.

It does have to be recognised that the move to 'virtuality' within the military domain could be very useful in many ways. Traditionally paper maps and acetate overlays have been used predominately in the military to visualise situations. Using a collaborative virtual workspace will reduce the effort required to make changes as well as having the opportunity to reduce or eliminate risk involved of having a centralised Headquarters. Planning products must be disseminated to the appropriate units in a timely manner. The faster plans are distributed the more time there is available for outlining details required to be successful during combat and this can potentially achieved via a virtual collaborative environment. Thus it is important that the following questions are addressed in the experiment (a) Does the virtual workspace lessen ambiguity or increase it in the planning process; (b) Compared to the co-located planning sessions, did the shared virtual workspace provide the necessary features, functions and interaction mechanisms to support effective co-ordination? (c) Compared to the co-located planning sessions, did the shared virtual workspace provide the necessary features and functions and interaction mechanisms to allow for the necessary dialogues between commanders and his staff to occur?

Virtual Technologies and HCI

Since all CVEs have to consider interaction via technology, the first consideration is the impact of the user interface. Interaction in HCI is related to how the user can interact/communicate with the system. Interaction techniques have a strong influence on the collaboration in multi user VEs by affecting how individuals act to obtain their goals and disturb the flow of social interaction (Steed et al, 2003). The requirements for social interaction can also make certain demands on the infrastructure of the application.

There are factors of functionality and usability that have to be taken into account in designing a virtual workspace. Research has concentrated mainly on the technical challenges of representing complex spaces, movement and communication (Carlsson & Hagsand, 1993) plus work focusing on the usability of the virtual environment for individuals or collaborating groups (Kalawsky, 1999, Stanney et al, 1998 and Kaur et al, 1999).

There is a broad array of technologies to choose from when developing virtual workspaces. They are all different in media richness and synchronicity and range from very simple to quite complex ones to choose from. To suggest what technological features might be best suited to different work environments in cognitive situations is a great challenge for researchers (Malhotra and Majchrzak, 2005; Anderson et al., 2007). Very often it is the perceptions of communication richness rather than objective assessments that are critical to understanding how individuals chose and experience different technologies (Carlson and Zmud, 1999).

CVEs provide a potentially powerful medium for exploring and communicating in the military domain. Research on the usability of CVEs is still at an early stage, however there has been some studies of collaborative virtual environments (Tromp et al, 2003 and Heldal, 2003). There are several reasons why there has been so little research on the usability of collaborative virtual environments (CVEs). According to Schroder et al, (2006) the technology for CVEs is not at a mature stage which has meant that there have been few CVEs available where users could be observed regularly using the CVEs. This in turn has led to severe usability problems

of CVEs as these systems have not been regularly used and lack of familiarity (which in the military could affect the planning process greatly). Many issues like presence, performance, intuitiveness or leadership have been identified as being important in CVEs, and studies have demonstrated that each of these issues might depend on the technology (Draper et al, 1998, Steed et al, 1999).

It has been identified that interaction in CVEs can cause problems because collaboration is frequently interrupted by lack of awareness of what the other person is doing as little information is available about other participants and their physical location, or about any changes that occur in their physical space that may affect the behaviour of that user in the virtual space (Linebarger et al, 2005 and Hindmarsh, Fraser, Heath & Benford, 2002). As people have different kinds of problems navigating and orientating themselves in different settings, CVEs should be designed in such a way that there are some ways of organising workspaces that facilitate better knowledge sharing and awareness (Malhotra & Majchrzak, 2005). Other problems associated with CVEs include 'field of view limited' with object interaction and navigation clumsy (Wilson, 2003). Although the number of CVE applications are on the increase there are still many problems regarding the user interfaces (West & Hubbold, 2001; Hindmarsh et al, 1998), the flow of interaction (Tromp et al, 2003); how the user communicates and their social interaction as this can heavily influence how collaboration takes place using CVEs (Schroeder, 2002).

The factors which lead to the realization of user expectations and hence satisfaction are often difficult to isolate due to their complex inter-relationships. Ditsa and MacGregor (1996) examined a wide range of user satisfaction models and identified the following 4 key factors that can inhibit user satisfaction: (a) The quality of the information from the IS; (b) The user interface features of the IS, (c) The support provided and (d) The user attitudes toward the IS. Other factors influence interaction on shared virtual workspaces such as the individual's ability and willingness to collaborate and to use the VCD. Therefore by investigating more about individual factors, the context of the collaborative applications and available technologies, will make it easier to identify critical issues that influence virtual collaborative interaction.

As a result of this literature review, the main variables relevant to this research have been identified and made explicit and may be categorised under the following headings: (a) Physical Interaction; (b) Collaborative Ease of Use; (c) Cognitive Interaction (d) Joint Usability (e) Military Planning Effectiveness (f) Intention to Use.

3. Research Methodology

In accordance with the research objectives and the review of methods in the literature review, the research design adopted in this study is a multi-method approach that is principally qualitative explanatory approach combined with a simulation experiment associated with the tasks undertaken in the Estimate Process (AFM, 2005). The Research Instrument developed contained both structured and unstructured questions in order to assess system usability, interface quality and design of the VCD for collaborative military planning effectiveness. Ultimately the research instrument and framework developed herein informs the product development trajectory of the VCD for potential exploitation and usage as a military planning tool within a distributed HQ environment. Furthermore, as the nature of the experiment was collaborative, a Military Judgement Panel (MJP) was necessary. Given the same doctrinal

background and training of Subject Matter Experts (SMEs), the MJP[1] has a central tendency of expertise which is a pragmatic and accepted representation of the SME population (DERA, 2000).

Research Instrument

The **QARS** (Qualitatively Anchored Rating Scales) technique was developed for this qualitative research. This is a combination of assessing qualitative responses with a 5 point likert scale, a guiding scale to enable respondents in the MJP to gauge their response within a consensus discussion and to provide a justified decision outcome. This is appropriate for analysing results collected from a relatively small but representative population, such as a MJP. Furthermore, this is an effective technique for eliciting and making explicit experts tacit knowledge.

The research instrument used in this study draws upon the methods and variables drawn primarily from the literature review. The variables were grouped into principle categories illustrated in the high level theoretical framework depicted in Figure1.

Physical interaction
Cognitive interaction
Joint usability
Military Planning Effectiveness
Intention to Use

Figure 1. *High-level theoretical framework for assessing technology usability for Planning in a Virtual Collaborative Environment*

Each of the above categories was assessed using am as set of variables, which are discussed individually in the rest of this section. The entire qualitative research instrument employed in this study, together with its main components and variables, is depicted in Appendix section.

Validation of the Questionnaire

Following content, face, scale and construct validity checks with the SMEs the research instrument was designed accordingly. Questionnaires 1-4 (see Appendix section) comprises the aspect of Human Computer Interaction (HCI), specifically, its physical and cognitive side. **Physical interaction** was assessed using QARS technique (*Questionnaire 1*) and open-ended questions (
Questionnaire 2) for the 'look and feel' assessment of the VCD (i.e. VCD functions and features). **Collaborative Ease of Use** refers to the VCD features that SMEs can collaboratively use and were assessed in terms of complexity, learnability, and intuition (*Questionnaire 3*).
Cognitive interaction
Questionnaire 4 captures qualitative data which helped to understand the cognitive thinking of SMEs and how this cognitive information was made explicit and shared amongst the team to create shared data products to execute the planning process. In particular, questions aimed to evaluate the team situation awareness and collaborative decision making. The purpose of these questions was to provide an insight into the SME's operational decision making.

[1] "The power of the MJP lies in bringing the expertise of military and technical specialists to bear on issues that cannot be resolved readily by other more quantitative means. When designed and conducted properly, an MJP can approach the objectivity and rigour of more traditional scientific procedures." (DERA, 2000)

Designing for maximum usability is the goal of interactive systems design (Dix et al, 2004). **Joint usability is about** achieving specific goals in a virtual collaborative environment (i.e. physically distributed environment), namely through physical and cognitive interaction. Joint usability is assessed against two variables: efficacy and efficiency (*Questionnaire 5*). This approach is to some extent different from one defined in (Dix et al, 2004) and ISO 9241 standard (BS EN ISO, 1998) where the system usability is measured in the context of three measures: effectiveness, efficiency and user satisfaction. In this study, efficacy is defined as the systems ability to produce a desired or intended result. Clearly, by assessing the efficacy of the system and how well it works will in turn influence any possible design issues/changes.

Effectiveness, which is a standard measure of usability (BS EN ISO, 1998) was assessed within **Military Planning Effectiveness**. This together with Joint Usability, which was defined in terms of efficacy and efficiency, forms an overall system usability of military planning process. *Questionnaire 6* was developed to measure against the following dimensions of planning process effectiveness: accuracy, process quality, product quality, productivity and workload. With the reference to the literature review, effectiveness is defined as the accuracy and completeness with which specified users achieve specified goals in particular environments. Efficiency is defined as the resources expended in relation to the accuracy and completeness of goals achieved, while user satisfaction is defined as the comfort and acceptability of the work system to its users and other people affected by its use (ISO 9241). In this assessment we used user satisfaction to gauge the user's **Intention to Use** the system (*Questionnaire 7*).

Finally, the open-ended questions in *Questionnaire 8* were designed to collect qualitative data regarding the key benefits the VCD environment provided during the planning process.

Virtual Collaboration Desks: Basic Set of Features

The Virtual Collaboration Desks consisted of two workspaces: a vertical workspace for video projection and a horizontal one for visualisation of the documents. The horizontal workspace projected bitmap images of the actual documents, which the user had the capability of making public and/or private annotations, move documents, share them with other participants, save the documents together with the annotations, save the workspace, reopen the workspace with the attached documents etc. The desks had a high and a low resolution area with a working area always being the high resolution one. The desks could only project electronic documents, therefore making it impossible to share hardcopies.

Apart from the public workspace, there a private workspace was also provided. This enabled the participants to work in their private area whilst participating in the collaborative session at the same time. It was not possible for documents in the private workspace to be seen by remote participants. However, the owner of the private workspace could share their documents with others simply by moving them to the public area.

Every time a large document was uploaded, the video stream projected onto the vertical workspace was paused to enable faster transfer of the document. Mouse pointers with different initials and colours are visible on the desk which indicated different participants in the session.

Experimental Design

A number of methods have been proposed in the literature to evaluate interactive systems. Experimental evaluation is among the most powerful method for system evaluation (Dix et al,

2004). This simulation experimental study included: a pre-experiment phase, detailed plan for conducting the actual experiment, data collection and analysis for interpreting the research findings of the experiment within the context of the existing research literature. Each of these phases is discussed in more detail in the remaining sections.

Pre-experiment Phase

The pre-experiment phase is key to a successful experiment and its objectives are to develop a plan for carrying out the experiment (Alberts and Hayes, 2002). This study included a number of activities performed during this phase. First, the SMEs took part in a VCD demonstration session. The aim of that session was namely to: get SMEs familiar with the VCD environment and to provide feed back to help the research team formulate a detailed experiment plan. Secondly, the SMEs were asked to select and validate a proper scenario to be used in the planning process during the experiment. The training sessions were organised for SMEs to ensure that all the participants had adequate user knowledge of the VCD equipment before the experiment started. Additionally, the de-risking exercise was required to make appropriate adjustments to the experimental design.

Scenario selection and baseline approach

The aim of the research was to determine whether VCDs can be used for military planning when the Commander and his staff are not co-located. The research domain of this study in the context of virtual collaboration was conducted for a planning process in the military domain using the 7 Questions (7Qs) estimate process (AFM, 2005). This was based on a real scenario in order to evaluate the virtual environment. The 7Qs Estimate Process is a part of the British Army Doctrine, which reflects better the commander's decision making during the planning and execution of a plan. The 7Qs (also known as the Combat Estimate) guides the commander and his staff through a logical sequence of steps to determine what effect needs to be achieved and the best way to do this. According to Lurey and Raisinghani (2001) a structured approach is more beneficial in virtual collaborative sessions than unstructured one. Therefore, the 7Qs estimate process, as a highly structured process, was most appropriate for assessing virtual team effectiveness.

During the experiment the SMEs used VCDs instead of theconventional bird-table (map board) and acetates. The conventional approach in conducting the 7Qs estimate process was adopted as the baseline approach and provided a basis for comparison between distributed and co-located military planning.

Training of the SMEs

It was essential for this research that the SMEs were provided with adequate training on the VCDs in order to avoid experiment's results being dominated by the learning curve of the subjects, which historically is something that has often been overlooked. Therefore, a performance-based testing of SMEs was required to ensure that all the participants had adequate user knowledge before the experiment started (Alberts and Hayes, 2002). Additionally, researchers found that groups that trained together developed shared mental models or collective minds and were shown to have higher performance levels than those that were not trained together (Liang et al., 1995). Therefore, in addition to training the SMEs a technical support team was employed during the experiment to cover any potential blindspots or pitfalls encountered using the VCD. This enabled the service quality to be kept at the highest possible level and at the same time reduced the effect of the learning curve of the SMEs.

De-risking exercise and informing the main experiment

The aim of the de-risking exercise was twofold. Firstly, to make adjustments to the design of the experiment where necessary and to ensure respondents would participate and complete the exercise set. Secondly, to go use Questions 1-3 of the 7Qs process (see below) for de-risking and specifying the warning orders, intent schematic and RFIs in preparation for developing the actual plan, which is the main experiment using a Computer Generated Forces (GCF) application in the VCD environment using Qs4-Q7. Four SMEs conducted the experiment (two SMEs per VCD) were using the CGF application within the VCD system to generate the products from the Estimate Process: Decision Support Matrix (DSM), Decision Support Overlay (DSO), Intent Schematic, Request for Information (RFI) and Synchronisation Matrix.

7 Questions Process

- Q1-What are the enemy doing and why?
- Q2 – What have I been told to do and why?
- Q3 – What effects do I want to have on the enemy and what direction must I give to develop a plan
- Q4 - Where can I accomplish each action/effect?
- Q5 - What resources do I need to accomplish each action/effect?
- Q6- When and where does each action take place in relation to each other?
- Q7 – What control measures do I need to impose?

4. Data Analysis and Research Findings

This section presents the analysis and findings of the VCD evaluation experiment. This was done in accordance with the research methodology and using the qualitative research instrument developed for this investigation (See Appendix 1)

Data Analysis

Physical interaction

The data collected and analysed regarding the actual physical interaction with VCDs, illustrates that further development is required to facilitate users' intention to use the tool in planning process in the future. The SMEs experienced various conflicts whilst moving/navigating the documents, i.e. conflict over ownership of the shared documents as they were moved off the workspace whilst another person was still using them:

As a consequence, individual navigation of the documents, including 'drag and drop', zoom in and out, and annotation facilities, were very difficult. Sharing the documents and/or applications is an essential feature for planning process and this was reported by the MJP as a significant limitation to working on the VCD. Another major constraint was the size of the shared high resolution workspace. As the SMEs worked on the various documents at the same time, they needed all documents placed in the shared workspace which in turn hampered visibility of the shared planning environment.

The SMEs used all of the VCDs communication channels (shared workspace, video, and voice) during the planning exercise. All three channels were considered to be functional and equally important. Despite the low bandwidth limitation, the video screen was a very useful feature for facilitating non-verbal communication and observing body language. Additionally, the pen device was one of the most useful elements of VCD but, as previously mentioned, needs redesigning to provide better functionality for military planning purposes.

Collaborative ease-of-use

The participants' perception of ease of use of the VCD is correlated with confidence and the level of training. They stated that once confident and better trained the tool should be easy to use. Additionally, knowing the dynamics of working in a distributed way could improve participants' perception of ease of use of the VCD.

It has been identified that the VCD is intuitive to use and the learnability factor was high for using the VCD on a basic level and this was demonstrated in the experiment. With fairly minimal training the SMEs managed to successfully conduct the experiment and produce quality estimate products. However, trying to use the VCD's advanced functions and features was recognised as being more difficult, therefore, more training and technical support would be required in order to exploit the full capability of the VCD and in order to deal with unexpected events (e.g. document disappearing) and unfamiliar applications. Although the tool is perceived to be easy to learn, the complexity of using the VCD in the planning process was relatively high. The main barriers that led to this complexity were: navigation issues, difficulties including 'drag and drop' facilities, sharing of documents and using the pen as an input device.

Compared to the conventional co-located planning process, the SMEs were reluctant to agree that the VCD provided the necessary features, functions and interaction mechanisms to support effective coordination, which indicates there are areas for improvement. It was emphasized many times during this data collection exercise that VCD-enabled planning is never as good as co-located planning. However, they said it is "a good second best" solution in a physically distributed environment; especially, in static HQ operations (i.e. Peace support operations, Peace keeping, Peace enforcement, etc.). This enables the commander to direct the planning process and concentrate on his primary functions of command whilst in a distributed environment. This analysis confirms that, as a virtual collaborative tool, the VCD enables good team coordination and does enhance team-working.

Cognitive interaction

Having the ability to successfully elaborate knowledge with others and apply that knowledge, individuals are better able to integrate that knowledge and apply it to decision making in complex situations (Vandebosch & Higgins, 1996). As a result of the integration of the shared data products created in the Estimate Process and cognitive interaction between commanders using the transactive memory process, Situation Awareness was synergistically raised. This enabled good decisions to be made and the most appropriate Course of Action to be developed through joint usability of the VCD to facilitate effective military planning. This can be compared to Boyd's OODA Loop (observe, orient, decide, act) (Boyd 1987) as Situation Awareness (SA) is directly related to the orientation task which defines the process of placing observations into context. It also helps the SMEs to observe possible actions of their opponent's and gives them the ability to orient themselves to the unfolding situation.

The Shared data products of the estimate process (DSO, DSM) were assessed in terms of information quality and quantity. Information quality was assessed on the variables of accuracy, timeliness, trust, relevancy and usefulness. Due to limitations of the system Timeliness was unsatisfactory. This is qualified by the following SMEs' statement: "We couldn't see products in real time because of limitations in number of shared application active at the same time". The MJP strongly agreed that the four aforementioned variables scored highly in quality. They also agreed that the VCD facilitated the exchange of sufficient amount of information. For measuring shared information quality the participants were asked questions

regarding information accuracy, timeliness, trust, relevancy and usefulness. The SMEs thought that the VCD's workspace facilitated good knowledge sharing but also agreed it would have been even better with multiple shared applications. They strongly agreed that the trust, a prerequisite of knowledge sharing, is key to successful virtual collaboration.

As a consequence of the high quality of the shared data products and shared knowledge, shared Situation Awareness was achieved. The SMEs confirmed that a common operational picture could be maintained throughout the planning process. Additionally, the SMEs agreed that the VCD enables good collaborative decision making, which is further enhanced by a reduction in cognitive load through team work.

The problems reported by the SMEs during the physical interaction with the VCD influenced the commander's cognitive process. The pen device was a good example of this. Because of the poor ergonomic design of the pen, the SME acting the role of the commander stated: "I was more concentrated on writing rather than thinking.". This is concerned with use processes, joint usability may only be determined in terms of efficacy and efficiency of usefulness of the cognitive and physical interaction. This can be achieved once the planning products have been produced. As a result of joint usability they can be assessed against the military planning effectiveness criteria.

Joint usability assessment

Efficiency, efficacy and user satisfaction, were used as criteria for assessing joint usability of the VCD and the user's intention to use the VCD. Compared to a co-located planning process, the efficiency of the distributed VCD in the planning process is poor. However, in a physically distributed environment the VCD efficiency was considered good and does not increase ambiguity of the planning process. The VCD allowed users to achieve a high level of productivity during planning in a distributed environment; especially in a less dense battle-space, such as: peace support operations, peace keeping, peace enforcement etc. The efficacy of the VCD in the planning process, measured as potential for errors and potential criticality of the errors in overall Plan was very high in a distributed environment since it requires a scribe at both ends and is less prone to transliteration errors as all participants can check and verify accuracy and completeness of estimate products.

User satisfaction is subject to improvements in the VCD tools, in particular, the pen device, multiple shared applications, better resolution, and bigger shared workspace. Providing these system features/functions are in place, the overall SMEs' satisfaction level in usage was high. The SMEs believe that the VCD is suitable for decision making and joint usability in the planning process in a distributed environment. This indicates they would be comfortable in using this for planning purposes in the future, subject to certain feature improvements as mentioned above.

Further, the following statements are the SMEs' recorded comments regarding VCD usability in the planning process:

SME 3: "*It is a good bit of development work.*"
SME 1, 2 & 3: "*Never as good as co-located planning.*"
SME 1, 2 & 3: "*A good second best.*"
SME 1: "*With more structured training the effectiveness of collaboration would be better.*"
SME 1: "*VCD has a substantial potential.*"
SME 1: "*I started to enjoy the environment.*"

SME 3: "*This is quite good fun!*"

From the above SMEs' statements it is obvious that the SMEs were positive regarding the potential usage of the VCD in the planning process. They clearly stated herein and during the data collection process that design changes would be necessary to make the system appropriate for the planning process in a distributed environment.

Military Planning Effectiveness

Military Planning Effectiveness (MPE) is best measured in the context of utility, which takes into account positive and negative aspects and measures the degree of success as a trade-off. The independent variables of the MPE associated with utility have been identified: product quality, process quality, accuracy, productivity and workload.

The results of the experiment illustrated that the overall products that were created during the planning process i.e. Intent Schematic, RFIs, DSO, Synchronisation Matrix and the control measures confirmed that productivity, accuracy of the planning process and the developed products was very good. The participants generally followed the planning process and being in a disturbed virtual environment they managed to achieve a sufficient level of debate regarding the planning process and were able to create an effective plan.

5. Theoretical Framework and Salient Findings

As a result of the data analysis, it has been possible to determine linkages and a logical sequence of the principal categories outlined for the Research Instrument that forms the basis for an effective planning process in a military environment using a VCD. A theoretical model for assessing technology usability, functionality and acceptability of an interactive virtual collaborative system in military planning process has been formulated (Figure 2). Its purpose is twofold: first, to demonstrate the process of product development through the evaluation of the system usability and its transferability into customers' benefits that ultimately inform their intention to use the system. Secondly, to raise the TRL (Technology Readiness Level) as a result of feedback obtained regarding modifications of the VCD.

The theoretical model was based on the initial framework (Figure 1) and consists of all five framework's components with additional subcomponents added as integral parts of Physical and Cognitive interaction elements. Additionally, the TRL component was included as an essential component for determining the level of the technology readiness.

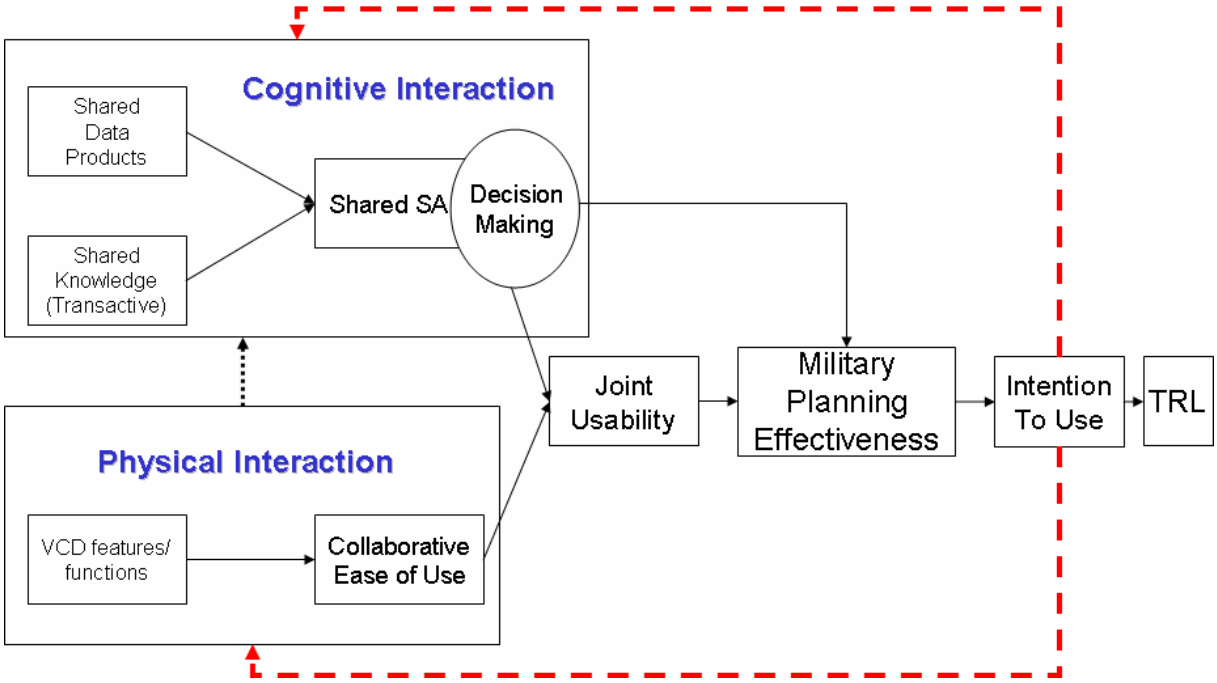

Figure 2. *Technology Usability and Acceptance Model for Military Planning in a Collaborative Virtual Environment*

A finding from the evaluation experiment shows that the VCD for military planning purposes is still at the lower end of the Technology Readiness Scale and requires further development to facilitate: (*i*) users' intention to use the tool for planning purposes in a distributed environment and (*ii*) system validation in a military environment. From the results and findings of this experiment, it is evident that the main areas for system improvements are: moving and navigation of documents, pen redesign, sharing of multiple applications, size and resolution of the shared workspace, and implementation of overlays. Hence, there is a link between users' Intention to Use the tool and TRL. This stipulates a series of validating contexts and qualification criteria that must be carried out for technology maturation and successful mission operation.

Only the VCD functions required for military planning were tested in this experiment. However, it was evident from the experiment that there are design and usability issues of the CVE that do not make it robust enough for operational use in theatre. In order to exploit the full capability of the VCD it is essential to provide a good integration of the VCD features and their associated functions for the planning process. Critical to the success of the experiment was the training and technical support. This would need to be enhanced for any formal rollout.

VCD-enabled military planning process in a physically distributed environment in its current status would never be as good as conventional co-located planning, which coincides with the literature (McGrath and Hollingshead, 1994; Hightower and Sayeed, 1995, 1996). Nevertheless, the SMEs agreed that the VCD is a good second best to conventional planning and would be very useful in static HQ operations rather than in an operational environment.

All three channels, namely, shared workspace, video and audio, were considered by the SMEs to be functional and equally important, as they provided not only common workspace but also facilitated preverbal (tone of voice, inflection, voice volume) and nonverbal (eye movement, facial expression, hand gestures, and other body language) cues, all of which are modes of face-to-face communications (McGrath, 1990). The existence of three communication channels

eliminates some known barriers for effective communications, primarily building of trust (Hill et al, 1998; Huws et al, 1990; Horwitz et al 2006; Kirkman et al, 2004) and social isolation (Kiesler and Gummings, 2002): workload and cognitive complexity. The SMEs confirmed that within the controlled experimental environment the quality of estimate products, produced during the planning process, was fit for purpose and resulted in good collaborative decision making in a virtual environment.

Hierarchical army structure, strong leadership, military cohesiveness, communication through the established military thinking framework (i.e. the 7Qs estimate process) and group expertise employed in this study eliminated the related problems associated with effective collaboration encountered in the general literature. The VCD-enabled move to 'virtuality' has military significance because the VCDs enable the maintenance of commander's leadership in a distributed planning environment as well as synchronous multi-channel information sharing with his staff.

Overall system usability of the military planning process, assessed through the three measures of performance; namely, efficiency, efficacy and effectiveness of the VCD was found to be satisfactory. However, the findings have illustrated that substantial improvements can be achieved through a redesign of the system, based on the recommended design changes specified herein, to move the VCD to higher levels in the TRL, so that it is fit for military business purpose.

6. Conclusion

The fundamental objectives behind this research study have been to investigate the usability and effectiveness of VCDs for Military Planning in a virtual collaborative working environment and to inform the development of VCD design as an enabling tool for collaborative military planning in a distributed environment. It should be noted that previous studies on virtual collaboration were limited due to ad hoc groups being used, and insufficient time provided to use the virtual communication medium. However, the research conducted herein used a Military Judgement Panel (MJP) of four SMEs to assess the system usability and inform design changes and improvements of VCDs.

From the results and findings it can be concluded that there is an overall positive confirmation of the usefulness of VCDs in the military planning process. Despite scenario limitations, experiment constraints and resource restrictions, the SMEs performed well during the experiment and were able to deliver serviceable planning products. They worked synchronously as a cohesive team and managed to maintain good shared situation awareness and produce qualitative estimate products. This suggests that when these constraints are eliminated, SMEs can communicate as effectively as face-to-face cohorts (Chidambaram, 1996). The MJP agreed that working in CVE reduced the cognitive load of the commanders as VCD also reduces the cognitive load of the SMEs as knowledge applied within the team was through transactive memory system which enabled the 'pooling' of unshared information, hence enhancing shared awareness and increased the teams cognitive processing capacity (Mohammed & Dumville, 2001 and Wegner, Erber & Raymond, 1991). This allows for a greater level of expertise to be achieved in making decisions in situations that involve high stakes, time pressure and uncertainty. It has also been identified that working in a CVE takes collaborative working in the military environment to another level and enables synchronous information sharing with the ability to put plans together at a faster pace than what is done conventionally.

The experiment results have demonstrated that some of the findings from the general literature on virtual teams may not necessarily be applicable to the military domain. Firstly, military cohesiveness and exposure to the same doctrinal principles reduces or even eliminates the lack of meaning and understanding caused by the absence of physical contact in virtual teams (Durate and Snyder, 1999). Secondly, barriers that exist in non-military environments, such as: rank, position, service or force affiliation, and that prevent the development of trust (Cross et al, 2004), are not the issues in military domain due to the highly hierarchical organisational structure, common training and same doctrinal approaches. Thirdly, contrary to the literature findings, military grouping related activities (i.e. G2 – Intelligence, G4 – Logistics, G6 – Communications etc.) increase the benefits of transactive memory (Wegner et al, 1991), which in turn reduces cognitive complexity in a virtual environment and this has been confirmed by the experiment.

A review of the literature on virtual collaboration and the experiment has identified the factors that enable successful virtual collaboration and have had a positive influence in the military domain Specifically, clearly defined goals and objectives and communication through established frameworks (Lurey and Raisinghani, 2001), in this case the 7Qs estimate process, are considered to be one of the most important factors for the successful virtual team working (Lipnack and Stamps, 1997; Henry and Hartzler, 1998; Fisher and Fisher, 1997; Haywood, 1989). Team cohesiveness, defined roles (Durate and Snyder, 1999), strong leadership, and trust are also essential for the successful functioning of virtual teams. Within the military environment, these traits are part and parcel of the SMEs profile.

From a utility perspective, the main benefit of VCDs is the ability to go through the planning process in a distributed environment, which may be more appropriate at times than planning in a co-located environment. VCDs enable HQ team mobility and work to be conducted in a distributed HQ environment, thus reducing security risk of the commanders and staff as a centralised HQ is not required. It has been established that working in a CVE is good for bringing the structure of a plan together and reducing the need to go back to HQ to do the planning process, thus enabling a time efficient distributed HQ. However there are challenges incurred with security and bandwidth. It was observed from the experiment that communication was concentrated on being conducted over the mapping application rather than face-to-face via video application. The video application was considered useful as it gave a feeling of team presence, identity of the other team member's body language awareness and face-to-face contact. This helped to reduce any feelings of isolation which is good as isolation is one of the major factors that has been identified as the literature as a barrier for working in a CVE (Kiesler & Cummings, 2002).

In a virtual environment, the commander is able to work on a VCD over a secure link facilitating a combination of synchronous or asynchronous, passive or active, and single-user or multiple-users communications. Another advantage of using the VCD is that it enables commanders to create plans electronically and to distribute quicker, which would not have been possible to do in the conventional planning process. The VCD also has the capability of recording voice and video, thus enabling an audit trail to be created on the decision making and planning process which can be of potential use for military training purposes in the future.

Another outcome of this study is that the quality of the planning process and products can never be as good as the traditional approach, but using a VCD can help to improve HQ effectiveness in terms of time to deliver the planning process outputs. Nevertheless, the VCD in its current bulky configuration is not feasible to be used in an operational environment.

Although, it would be more useful in static HQ operations, such as: peace support operations, peace keeping, or peace enforcement. However, the SMEs have emphasised that it is a good second-best solution. Hence, a much more mobile and compact form of the VCD is essential if it is to be employed in theatre.

Working in a virtual collaborative environment has been identified as being good, but utilising a virtual desk will not change the thinking process within the military nor does it change the planning process. The MJP view this tool mainly as supporting the output of the planning process and enabling more efficient and effective communication with a plan delivered to an acceptable standard. Working in a CVE essentially gives the commander the flexibility to do other tasks. It also enables the commander to focus on the command functions and to have enough control and influence over the planning process. Hence, confirming the importance of the linkage between physical & cognitive interaction This finding also coincides with earlier studies conducted by McGrath and Hollingshead, (1994); Hightower and Sayeed, (1995, 1996) that VCD-enabled military planning process in a physically distributed environment would never be as good as conventional co-located planning.

Despite the numerous benefits of virtual collaborative working tools, their widespread use and full acceptance in the military domain has not yet been fully embraced. In this paper we have considered virtual collaboration tools in distributed planning from a British Army perspective. However, further investigation is necessary to identify and to understand how virtual collaboration technologies can be successfully implemented in joint operational planning between multi-national forces or other coalitions.

This research has provided specific insights and recommendations to take the VCD through the Technology Readiness Levels (Figure 3). In conclusion, we have determined that the VCD has the potential to fill a capability gap in a distributed military planning environment, providing that the recommendations of this research and its assessment are taken forward and acted upon if the VCD is to be exploited in theatre.

Finally, the theoretical framework derived from this investigation can add value to the body of knowledge as it recommends a systematic sequence of processes necessary to evaluate the effectiveness of the VCDs and the products derived from virtual collaboration in military planning and its Intention to Use this technology in the future.

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Appendix

Research Instrument – Questionnaires

1. Ease of use of VCDs in planning process				
1. Very difficult	2. Difficult	3. Neither	4. Easy	5. Very easy
Reason for selecting point on scale.				
2. Learnability of VCDs in planning process				
1. Very difficult	2.DifficultToLearn	3. Neither	4. Easy to learn	5. Very easy
Reason for selecting point on scale.				
3. Complexity of using VCDs in planning process				

Research Instrument – Questionnaires

Questionnaire 1. **Physical Interaction** with VCD – QARS technique (Part 1)

1. Picking up of objects and positioning precisely was difficult.
2. The graphic environment was easy to understand.
3. The graphic environment was easy to navigate.
4. The shared workspace was limited.
5. The video screen was useful.
6. Precise manoeuvring of the virtual embodiment was difficult due to the limited input technology.
7. The field of view for sharing documents was of adequate size
8. I felt I had to speak slower, clearer and louder.
9. Body language helped the interaction between commander and staff.
10. VCDs enabled good team coordination.
11. I experienced conflict whilst moving the documents.
12. I experienced conflict whilst editing the documents.
13. Sharing documents was difficult.
14. The graphical user interface was a true reflection of the shared planning environment.
15. The VCDs enhanced team-working.
16. Compared to the co-located planning sessions, VCD provided the necessary features, functions and interaction mechanism to support effective co-ordination.
17. Verbal communication was good between team members.
18. It was easy to understand and follow the flow of the discussion amongst team members.

Questionnaire 2. **Physical Interaction** with VCD – Open-ended questions (Part 2)

1. Which of the VCD features/functions did you use most frequently?
2. Which of the VCD features/functions did you find most useful?
3. Which of the VCD features/functions did you find less useful?
4. Which additional features/functions would you like the VCD to have?
5. Any further requirements not supplied by the VCD?
6. Do you think VCD would be feasible to use in an operational environment in the future?

7. Do you have any further comments?

Questionnaire 3. **Collaborative Ease of Use** – QARS technique

1. Ease of use of VCDs in planning process
2. Learnability of VCDs in planning process
3. Complexity of using VCDs in planning process
4. VCD was intuitive to use.
5. I need more training with the system.
6. I need technical support personnel available to be able to use the VCD.
7. I understand how the VCD works.

Questionnaire 4. **Cognitive Interaction** with VCD – QARS technique

Shared Data Products – Quality

1. I found the shared information was correct and reliable (accuracy).
2. The shared information was up to date for the task at hand (timeliness).
3. I think the shared information was true and credible (trust).
4. I think that all shared information was relevant.
5. I think that the shared information was useful (usefulness).

Shared Data Products – Quantity

6. VCDs facilitate the exchange of the right amount of information.

Shared knowledge

7. The workspace facilitated good knowledge sharing.
8. Knowing which group members had specialised knowledge reduced cognitive load.
9. Trust between the participants is important for successful virtual collaboration.
10. Knowing the participants in the virtual team is important for successful collaboration.

Shared SA

11. Shared situational awareness was achieved using VCDs.
12. The operational picture was appropriate using VCDs.
13. Virtual collaboration improves Shared Situation Awareness.

Collaborative Decision Making

14. VCDs enable good team decision making.
15. Collaborating as a team reduced cognitive load.

Questionnaire 5. **Joint Usability** of VCD – QARS technique

Efficiency

1. VCDs allow users to achieve high productivity during the planning process.
2. Efficiency of VCDs in planning process
3. VCDs increase ambiguity in the planning process.

Efficacy

4. Suitability of VCDs for planning process
5. Potential for errors in overall planning process when using VCDs
6. Potential criticality of errors in overall Plan when using VCDs

Questionnaire 6. **Military Planning Effectiveness** – QARS technique

Accuracy

1. Accuracy of the overall Plan developed using VCDs

Process Quality

2. Realism of scenario
3. Realism of time available for planning in the experiment
4. Degree to which the team followed the estimate process using VCDs
5. All tasks associated with estimate process were successfully performed.
6. How well has the VCD assisted the estimate process compared to the conventional planning method?[2]

Product Quality

7. Overall quality of Plan using VCDs
8. SME product assessment against standard output

Productivity

9. The other team members performed well during the planning process.

Workload

10. Subjective rating of workload level using VCD
11. Virtual collaboration enables team to achieve a sufficient level of debate.
12. Virtual collaboration provides a sufficient level of detail.

Questionnaire 7. **Intention to Use** – QARS technique

1. Overall user satisfaction with VCDs during the planning process
2. I would be comfortable using VCDs routinely in the planning process in the future.

Questionnaire 8. General Open-ended Questions

1. What are the main benefits of the VCD environment in the planning process?
2. What are the main limitations of the VCD environment in military planning process?
3. Do you trust this way of working in support of your comd's/staff judgement and why?
4. Is this an appropriate tool for military planning in a distributed HQ environment and why?

[2] Answered as an open-ended question

Technology Readiness Level

Technology Readiness Level (TRL) is a measure used to assess the maturity of evolving technologies prior to incorporating that technology into a system or subsystem (DOD, 2005).

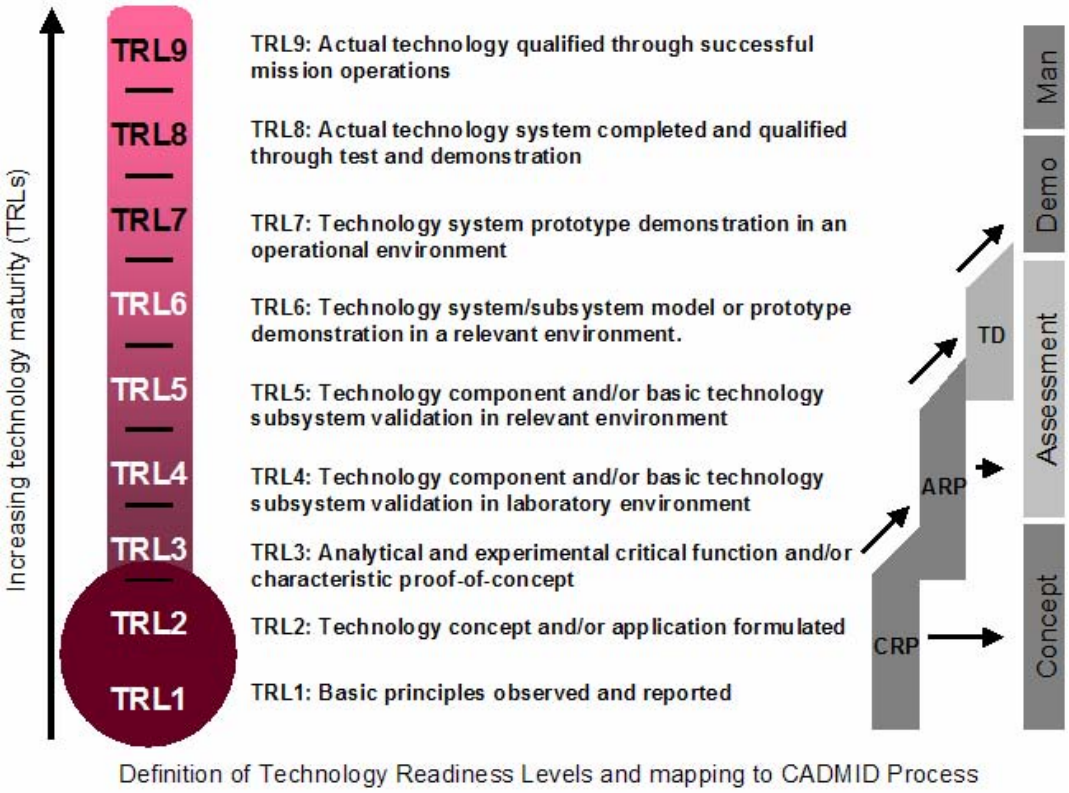

Figure 3. *Technology Readiness Levels*