CRC Construction Innovation
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Final Report
Generic Skills in Design Teams

Research Project No: 2002-024-B-04

The research described in this report was carried out by:

Project Leader	Mary Lou Maher	
Researchers	Robin Drogemuller	Zafer Bilda
	Kirsty Beilharz	Linda Candy
	Andy Dong	Mijeong Kim
	John Gero	Tony Shi
	Mike Rosenman	Ji Soo Yoon
	Thomas Bellamy	Figen Gul
	Rod Gameson	Yinghsiu Huang
	Willy Sher	Sue Sherratt
	Tony Williams	Adel Ahmed
	Stephen Egan	Owen Macindoe
	Kathryn Merrick	Robert Shen
Project Affiliates	David Marchant	
	Carolyn Mitchell	
	Kanyarat Nemprempree	
	John Crawford	
	Lan Ding	
	Melissa James	
	Richard Hough	
	Steve Pennell	

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Distribution List

Cooperative Research Centre for Construction Innovation
Authors

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Please direct all enquiries to:

Chief Executive Officer
Cooperative Research Centre for Construction Innovation
9th Floor, L Block, QUT, 2 George St
Brisbane Qld 4000
AUSTRALIA
T: 61 7 3138 9291
F: 61 7 3138 9151
E: enquiries@construction-innovation.info
W: www.construction-innovation.info

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1 PREFACE

The Cooperative Research Centre for Construction Innovation (CRC-CI) research project 2002-024-B: ‘Team Collaboration in High Bandwidth Environments’ is supported by a number of Australian Industry, government and university based project partners: University of Sydney; University of Newcastle; CSIRO; and Woods Bagot Pty.

This final report has been produced by The University of Newcastle in collaboration with all of the other project partners.

2 EXECUTIVE SUMMARY

Recent developments in networked three dimensional (3D) virtual worlds and the proliferation of high bandwidth communications technology have the potential to dramatically improve collaboration in the construction industry.

This research project focuses on the early stages of a design/construction project in which models for a project are developed and revised. We have investigated three aspects of collaboration in virtual environments:

1. The **processes** that enable effective collaboration using high bandwidth information communication technology (ICT);
2. The **models** that allow for multiple disciplines to share their views in a synchronous virtual environment;
3. The **generic skills** used by individuals and teams when engaging with high bandwidth information communication technology.

The third aspect, led by the University of Newcastle, explores the domain of **People** and the extent to which they contribute to the effectiveness of virtual teams. This report relates, primarily, to this aspect.

This final report reviews and presents literature on the issues of teamwork, virtual teaming, generic skills involved with teamwork, and virtual teams. These are examined in the environment of early design from the perspective of a range of industries. The literature is then evaluated in relation to the overall research project's aims and objectives, concentrating on the areas of: teamwork, virtual teams, generic skills and early design. Using this literature an analysis framework, which facilitates the examination of 'people' issues within design teams, has been constructed. Video data collected by the University of Sydney was then examined based on the analysis framework.

This report has found that there are differences between the generic skills used in a face-to-face and virtual environment. This is also true of a number of other domains such as interactions and linguistic functions. Recommendations have been created based on these significant differences.

3 BACKGROUND

The design/construction industry is widely perceived to be a ‘people industry’. As such it relies heavily on collaboration between individuals to achieve results. With increasing globalisation and the availability of competitively priced information and communication a technology (ICT) emphasis needs to be placed on enhancing the efficacy of virtual interactions. Team members working in virtual environments need to appreciate and develop relevant skills. There have been numerous studies of collaboration in Europe and the USA that have resulted in systems which support data transfer and information sharing. This project focuses on how these systems and associated commercial tools can be used in high bandwidth environments. It focuses on the early stages of a construction project in which the concepts for the project are being developed and revised. The project looks at three aspects of virtual collaboration:

1. The **processes** that enable effective collaboration using high bandwidth ICT.
2. The **models** that allow multiple disciplines to share their views in a synchronous virtual environment.
3. The **generic skills** used by individuals and teams when engaging with high bandwidth ICT.

The third aspect, led by the University of Newcastle, explores the **People** domain, and the extent to which they contribute to the effectiveness of virtual teams within the construction industry. The scope of the **generic skills** aspect is limited to the early design phase experiments developed and implemented by the University of Sydney for 1 and 2 (above). Briefly, the research methods adopted included a review of relevant literature, followed by the collection and analysis of data collected by the University of Sydney. This enabled the factors which influence effectiveness across the domains identified above to be mapped. Conclusions are then drawn and recommendations made on how to facilitate the development of skills for virtual team members. It is envisaged that the development of skills profiles, both at the individual and team levels, will provide the basis for work-based training, feeding into educational and continuing professional development (CPD) programs.

Within the context of CRC-CI, research into virtual teams and skills originated in previous research (Project Team Integration: Communication, Coordination and Decision Support [2001-008-C-04] conducted at the University of Newcastle (Kajewski 2003). One component of this scoping study investigated issues relevant to project teams working in virtual environments. A case study was conducted where project team supply chain participants (from client representative to subcontractors) in a recently completed construction project were interviewed. The project used a web portal for communication between team members. Although there was consensus that the case study project team possessed the skills required to execute their responsibilities, most interviewees acknowledged that they had learnt and / or developed skills on the project, but found it difficult to identify the particular aspects / areas that had been learned / developed. With respect to the impact of ICT and its impact on construction professionals engaging electronically in teams, we argue that identifying the mix of skills required to operate in such environments facilitates targeted (rather than ad-hoc) skills development programs. Goulding and Alshawi (2002; p501) note that managers are, *"….continually striving to match market opportunities with core competence, and increased importance is being placed on understanding how skills (and competence) contribute to organizational* *performance*." An audit of the skills of participants in the construction supply chain will provide this strategic advantage as well as a focus for the identification of appropriate skills development opportunities.

A recommendation from this research was to identify and audit construction project virtual teams. The investigations documented in this report are a direct result of this recommendation.

4 AIMS AND OBJECTIVES

Technology is continually changing and this is particularly true of the design process. One of the principal manifestations in the construction industry is a move from team working in shared workspaces to team working in virtual spaces, using increasingly sophisticated electronic media. There are significant differences when working in shared and virtual spaces (refer to Section 5.2.4) and it is imperative that those working in new e-environments adapt and 're-tool' their skills to meet the challenges these new environments present. Our investigations have focussed on the **generic skills** used by individuals and teams when engaging with high bandwidth ICT.

4.1 Research Aims

The aims of this aspect of the research project are to:

1. Map and develop personal and team-working generic skills of virtual team members working in the design stage of construction projects, and,
2. Specify requirements to enable Construction Industry individuals and teams to operate effectively in CRC-CI ICT assisted environments during the design stage of construction projects.

4.2 Research Objectives

The objectives of this aspect of the research project are to:

a) Develop guidelines for the analysis of design teams and their participants whilst designing in virtual environments;
b) Develop a questionnaire for the analysis of ICT and generic skill usage within the Australian design/construction industry;
c) Analyse and document experience of collaboration amongst design teams and their members whilst working in virtual environments;
d) Analyse and document skills profiles required for different forms of collaboration in virtual environments, and
e) Report on the knowledge, skills, and attitudes required to effectively participate in design teams in virtual environments.

4.3 Literature Review: Research Context

This review presents literature on the issues of teamwork, virtual teaming, generic skills involved with teamwork and virtual teams. These themes are examined in the context of early design from the perspective of a range of industries. The literature is then evaluated in relation to the research aims and objectives, and informs the creation of the analysis framework described in Section 7.

5 LITERATURE REVIEW

This review was compiled to inform the creation of a generic skills coding scheme for collaborative design teams and also to highlight the potential areas of virtual teaming which may affect the generic skills of design participants. Grasping the concept of virtual design collaboration begins with the basic construct of teamwork. The review then examines the differences between traditional co-located (face-to-face) and virtual teams. These differences are explored and advantages and disadvantages of the virtual domain identified. Material regarding generic (non-technical/core) skills is then presented. A framework of common generic skills is presented as a basis for the creation of a generic skills coding scheme for design teams. Possible impact of the virtual environment on these generic skills is analysed and used as a platform for drawing conclusions from the results of this study.

5.1 Teamwork

As time and technology progress and design projects become more complex, relationships, roles, and responsibilities have become more varied. It is through the sharing of ideas that superior products are created and delays and miscommunication are avoided (Maher, Simoff and Cicognani 2000). Teams are a cluster of two or more people usually of differing roles and skill levels who interact '*…adaptively, interdependently, and dynamically towards a common and valued goal*' (Salas, Burke and Cannon-Bowers 2000). They are the vehicle for the process of collaboration (Beyerlein *et al.* 2003). A wide variety of challenges and issues around teamwork exist in most organizations and these are discussed below.

5.1.1 Definition of Operational and Project Teams

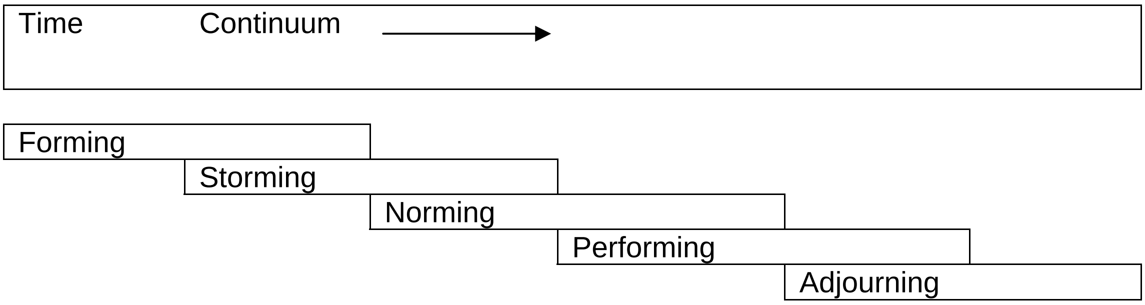
Literature tends to classify teams into two facets: 'operational' and 'project'. Operational teams are stable teams existing in the same business environment (Jaafari and Tooher 2002). 'Stable' refers to the fact that those members are fixed and the same team operates together for an extended period of time over many projects. Teams which assemble for a specific project are defined as project teams (Jaafari and Tooher 2002). These teams are primarily formed quickly and disbanded in the same manner. They often comprise members from different backgrounds (i.e. professions) who bring specialised skills to a project. Project teams often have multiple points of authority and share '*…decisions, results, and rewards…'* (Cleland and Ireland 2002). Project teams form the basis of the review of virtual team literature as this research encompasses the early design process.

Invariably each time a construction project team is formed its composition (both at an individual and organisational level) changes, resulting in little or no consistency of membership (Emmitt and Gorse 2003). However, more recent trends, promoted in particular by large private and, more recently, public sector clients have led to the use of more 'collaborative' procurement systems such as 'strategic alliancing' and 'partnering' (Love *et al.* 2002). Such alliances have, to some extent, encouraged and promoted the developments and utilisation of newer technologies as they promote longer term relationships between participants and thus encourage investment and utilisation of such technologies. For example, strategic partnering is used by companies to obtain advantages from long term cooperative work on more than one particular project (Love *et al.* 2002). Therefore changes to the structure of the construction industry, in particular longer term 'alliances', to work together on multiple projects, between different organisations, are seen as a driver of technological change and uptake.

5.1.2 Project Team Lifecycle and Processes

There is significant consensus between authors on the life cycle of a project team based upon Tuckman's (1965) model (Blair 1991, Jaafari and Tooher 2002, Lipnack and Stamps 2000). Figure 5.1, developed from Lipnack and Stamp's (2000) work, illustrates stages in the project team lifecycle.

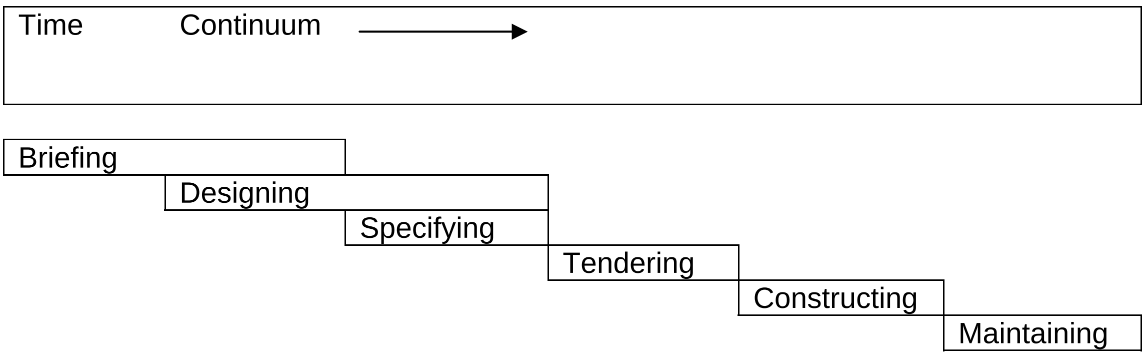
Figure 5.1 Model of stages in the project team lifecycle (based on Lipnack and Stamps, 2000).



'Forming' refers to early development where all communication is directed by emergent leaders (Blair 1991, Lipnack and Stamps 2000, Tuckman 1965). 'Storming' is the next stage, associated with little communication and an increase in conflict between team members. The 'Norming' stage involves an opening of communication channels and a free flow of information with all members expressing their individual ideas. In 'Performing' a team system is established and project results are revealed (Blair 1991, Lipnack and Stamps 2000, Tuckman 1965). According to Jafaari (2002) and Lipnack and Stamps (2000) there is one final stage, 'Adjourning', which encompasses the annulment of a team. This stage involves the slowing of work processes as the final product is delivered and feedback is sought. Feedback at this stage could result in a team-ending interaction or moving to a new stage. However, this is dependent upon the particular task (Lipnack and Stamps 2000).

It is interesting and relevant to juxtapose the project team lifecycle shown in Figure 5.1 with Cornick and Mather's (1999) model describing a generic model of the stages in a construction project team lifecycle, Figure 5.2.

Figure 5.2 Generic construction model of the stages of a project team lifecycle (based on Cornick and Mather, 1999).



‘Briefing’ refers to the phase of construction where the requirements of a project are identified (Cornick and Mather 1999). ‘Designing’ encompasses the proposal and agreement stages of the design solutions. ‘Specifying’ is the defining of those production necessities for the construction process. ‘Tendering’ is the process through which prices are determined. ‘Construction’ and ‘Maintaining’ are respectively the physical production and the post construction care and management of the project (Cornick and Mather 1999).

Each of the construction stages, as defined by(Cornick and Mather 1999) can be compared with Lipnack and Stamps’s (2000) stages of the project lifecycle, as shown in Table 5.1.

Table 5.1 Comparison of Lipnack and Stamp (2000), and Cornick and Mather (1999) models.

Lipnack and Stamp Stage	**Cornick and Mather Stage**	**Comparison**
Forming	Briefing	Project team comes together to identify and define project requirements
Storming	Designing	Presentation of solutions to design problems with potential for conflict as designs presented
Norming	Specifying	Design finalised and translated into information to enable construction / building services to be procured
	Tendering	No equivalent stage in the Lipnack and Stamps model, due to construction domain process specificity
Performing	Constructing	Translation of a design into a physical artifact
Adjourning	Maintaining	Construction of facility completed and team generally disbanded (unless some form of BOOT project). Feedback on project and team performance i.e. debriefing)

5.2 Composition and Nature of Teams

Before examining the skills involved with teamwork and how they may be affected by virtual technologies, the composition and nature of teams requires definition. A succinct summary is provided by McDonough, Bahn and Barczak (2001; p 111) who categorise various types of teams, as follows:

- **Co-located teams** are comprised of individuals who work together in the same physical location and are culturally similar.
- **Virtual teams** are comprised of individuals who have a moderate level of physical proximity and are culturally similar. One example of a virtual team is where team members are in the same building but work on different floors.
- **Global teams** are comprised of individuals who work and live in different countries and are culturally diverse.

Each of the above categories is discussed below.

5.2.1 Definition of Co-located Teams

Historically co-location was the principal way that teams operated synchronously before technology provided methods to communicate with others in different physical locations. Co-located teams are those whose members operate in the same physical and cultural space (Mcdonough Iii, Bahn and Barczak 2001). Co-located teams' interactions are synchronous, occur in a similar place, and their members may be culturally different in terms of different organisations. It is thought that team strength is a result of this social face-to-face (co-located) interaction with team members at work and outside of work (Lurey and Raisinghani 2001). However, with the increasing globalisation of projects it is becoming harder to co-locate national and global team members (Mcdonough Iii, Bahn and Barczak 2001). Lipnack and Stamps (2000) suggest that in the North American culture, team members need to be physically close to operate effectively, reporting that if members are more than 50 feet apart the number of team interactions begins to drop dramatically. They argue that systems need to be put into place to increase the amount of interaction between spatially remote team members.

5.2.2 Definition of Virtual Teams

Virtual teams exist when members of a team are culturally similar but operate, for the majority of their existence, in different physical spaces such as different cities within the same country (Lurey and Raisinghani 2001, Mcdonough Iii, Bahn and Barczak 2001). Kimble et al (2000) classify virtual team-working by defining three dimensions, each with two variables, as shown in Table 5.2.

Table 5.2 A classification of virtual team working (Kimble et al, 2000)

	Place	
Time	Same	Different
Same	*Co-located (synchronous)*	*Synchronous Virtual*
Different		*Asynchronous Virtual*

As construction industry clients demand more efficient and higher quality services the need to innovate increases. Consequently instead of an architect preparing a conceptual design for a structure and then seeking approval from a structural engineer, an engineer may be involved from the beginning and advise on pertinent issues (Kayworth and Leidner 2000). This need for group interaction has led to an increase in partnering between different construction disciplines (Love *et al.* 2002). To facilitate these interactions, more complex and sophisticated electronic media are being used to communicate ideas and designs (Jaafari and Tooher 2002).

5.2.3 Definition of Global Teams

A global virtual team exists when team members are also culturally displaced, such as in international collaborative ventures (Kayworth and Leidner 2000). The majority of definitions of global virtual teams suggest that they are temporary in nature with a lifespan related to a specific project (Jarvenpaa and Liedner 1998). According to

Cantu (1997) organising and planning global virtual teams is most important. Without these, teams will never have a solid foundation from which to run their everyday operations. The reasons why planning is so important is primarily concerned with the challenges facing virtual teams, and this is considered further in Section 5.2.6.

5.2.4 Comparison between Co-located and Virtual Teams

According to Lurey and Raisinghani (2001) there is little difference in the issues that face a co-located team when compared with a virtual team; they are both '*...first and foremost teams.*' (Lurey and Raisinghani 2001).

However, co-located teams are always synchronous, while virtual teams can be both synchronous and asynchronous. At times teams will discuss a project in real time (i.e. via video conferencing and web chat programs) but in the main, the majority of communications currently involve email or electronic bulletin boards with a temporal distortion of received material (Maher, Simoff and Cicognani 2000). Table 5.3, adapted from (Maher, Simoff and Cicognani 2000), shows each of the most common forms of team interaction. It will be seen that not all virtual methods offer the same array of information or synchronicity. However, synchronicity is sometimes not important, particularly to global virtual teams located in different time zones (Kayworth and Leidner 2000).

Table 5.3 Communication options for teams including temporal aspects (adapted from Maher et al 2000a).

Type of communication	Temporal aspect	Media
Email	Asynchronous	Text, Data files
List serves	Asynchronous	Text, Data files
Bulletin boards	Asynchronous	Text, Data files
Talk, chat	Synchronous	Text
Broadcast	Synchronous	Video, Audio
Video conferencing	Synchronous	Video, Audio, Images, Text
Co-located	*Synchronous*	*All*

5.2.5 Advantages of Working in a Virtual Team

With the spread of organisations across the globe, and the increase in industrial alliances, virtual teams have become necessary to achieve efficiency, performance, knowledge, stable relationships, and client satisfaction (Gameson and Sher 2002a). Organisations are able to increase access to knowledge and expertise on a project without having face-to-face meetings, and thereby reduce travel time and expenditure. Advantages often accrue to virtual team members who do not have a shared understanding of the concepts of a project. Without a shared understanding, individuals need to form their own understanding and questioning fellow team members assists in this respect. It frequently occurs that this method of establishing a shared mental model highlights areas of weakness or error (Stempfle and Badke-Schaub 2002). For this reason teams with different cultures often out perform those with homogeneous cultures (Stempfle and Badke-Schaub 2002). Furthermore, virtual teams are also often able to shorten production life-cycle times because the work can be done in parallel instead of in a stereotypical production line or serial mode (Lipnack and Stamps 2000).

5.2.6 Challenges Faced by those in Virtual Teams

With the rapid development of and changes in ICT it is not inconceivable that virtual teams may soon exhibit the same generic attributes as co-located teams, such as body language and other non-verbal cues. Referring to the skills involved with both co-located and virtual teams it is seductive to argue that 'technology has all of the answers', and that the same skills seen in a co-located team will be utilised in a virtual team. However, there are other issues to consider, such as: whether team members are operating synchronously or asynchronously; time differences; and whether the technology is available to all members of the team (Williams and Cowdroy 2002).

In a face-to-face meeting all contextual cues can be utilised; these include body language, eye contact, and changes in speech. These give information about the person speaking, how the message is conveyed, and the success of the communication (Driskell, Radtke and Salas 2003). With virtual teams these verbal and visual cues may not be present. Without the use of gestures, body language and voice intonation in mediums such as e-mail, there can be significant misunderstandings due only to contextual constraints, that can lead to inter-group conflicts (Riedlinger *et al.* 2004). Jaafari and Tooher (2002) outlined a number of constraints of virtual team including:

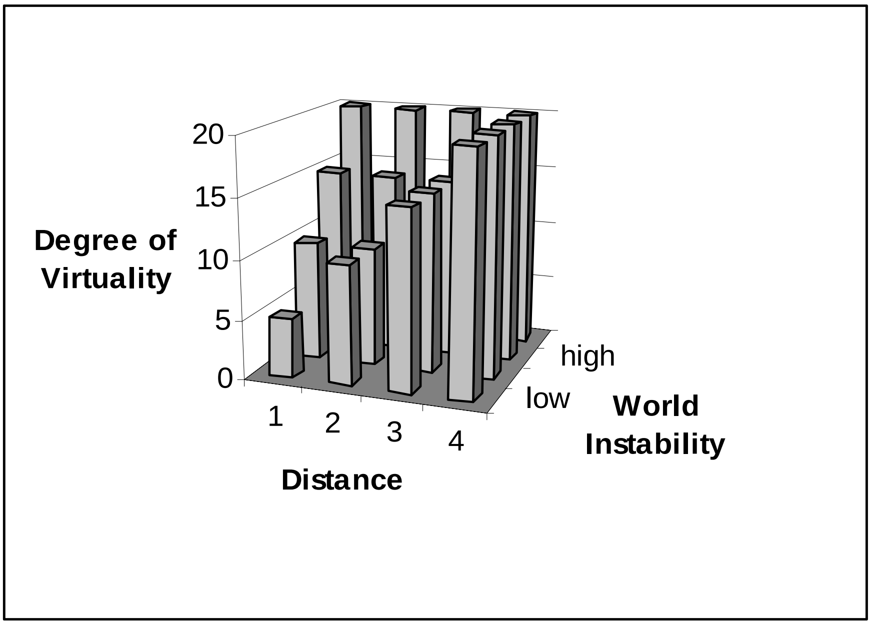
- The lack of personal contact minimising the ability to use social cues and body language
- A lack of leadership hierarchy within the remote groups
- Members being at the mercy of technology, as communication channels could be severed by a fault.

Ensuring that all members of a team have an appropriate level of technical expertise in terms of using communication media is also a challenge (Lahti, Seitamaa-Hakkarainen and Hakkarainen 2004).

Organisations are advised not to use existing management strategies for virtual teams. Different environments and constraints require different solutions if the full potential of such environments is to be met (Gameson and Sher 2002a). A clear definition of roles, responsibilities and objectives is needed. Virtual environments may constrain open discussion, and clear boundaries and procedures need to be created at all levels.

The move towards a virtual world is becoming ever more relevant in today's unstable world. The extent to which a team becomes virtual can be affected by a number of variables including the distance between members, the number of organisations the members represent, the length of time the team has functioned together (Ratcheva and Vyakaram 2001), and the experience (i.e. technical skills) of the members (Mcmahan 1998). As can be seen in Figure 5.3, the extent of a team's virtuality can also be affected by world instability (such as 9/11). As distance increases and people are reluctant to leave home, the degree of a team's virtuality increases (Kirkman *et al.* 2002).

Figure 5.3 Diagram illustrating the variables that can impact on a team's ability or willingness to become virtual (virtuality).



Design professionals have always collaborated with each other. Paradoxically, as ICT has reduced physical constraints, communication difficulties between team members remain. While new technologies and prices are making national and international travel easier, cost cutting and economic downturn have seen an increase in the number of virtual teams operating between and within organisations. The benefits faced by virtual teams seem to outweigh the challenges. In the long run virtual teams appear to be less expensive and more time efficient, as well as increasing the amount of knowledge and skills within these teams.

5.3 Issues of Generic Skills Arising from a Virtual Context

For the purposes of this review, generic skills are defined as the knowledge, skills and attitudes that a team member possesses when completing a task or communicating with fellow members (Salas, Burke and Cannon-Bowers 2000), whether in a co-located or virtual environment. It is argued that skills development and training should be viewed by management as an investment, creating valuable and skilled employees. Providing team members with the skills needed to communicate in a virtual environment is a long but necessary process (Goulding and Alshawi 2002) if errors associated with miscommunication are to be avoided.

This section presents information on teamwork dynamics in a broad sense, and analyses its relevance to organisations and industries. In Salas's research involving teams, generic skills have been defined as those that influence both individuals and teams (Salas, Burke and Cannon-Bowers 2000). They are skills which are *'…transportable and applicable across teams'* (Salas, Burke and Cannon-Bowers 2000). Table 5.4 illustrates the skills which form the basis of an effective team (Salas, Burke and Cannon-Bowers 2000).

Table 5.4 Integrated teamwork skills as adapted from Cannon-Bowers et al 1995 (Salas, Burke and Cannon-Bowers 2000).

Core Generic Skills	**Definition**	**Sub skills**
Adaptability	The use of compensatory behaviour and reallocation of resources to adjust strategies based on feedback	• Flexibility • Compensatory behaviour • Dynamic reallocation of functions
Shared situational awareness	When team members have compatible mental models of the environment within and outside of the team.	• Orientation • Team awareness • System awareness • Identity
Performance monitoring and feedback	Ability of team members to give, seek, and receive task clarifying feedback.	• Performance feedback • Acceptance • Mutual performance monitoring • Procedure maintenance
Leadership/team management	Ability to direct and co-ordinate the activities of other team members particularly pertaining to performance, tasks, motivation, and creation of a positive environment.	• Task structuring • Motivation of others • Goal setting • Goal orientation
Interpersonal relations	Ability to optimise the quality of team members' interactions.	• Conflict resolution • Assertiveness • Moral building
Co-ordination	Process, by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronised and completed within established temporal constraints.	• Task organisation • Task interaction • Timing
Communication	Information exchange between members using the prescribed manner and terminology.	• Information exchange • Consulting with others
Decision making	Ability to gather and integrate information, use sound judgment, identify alternatives, select the best solution, and evaluate the consequences.	• Problem assessment • Problem solving • Planning • Implementation

Notwithstanding the skills identified in Table 5.4, we have focussed on those which occur most frequently in the literature. These are now discussed below.

5.3.1 Core Generic Skills in a Virtual Context

The core generic skills listed in Table 5.4 are examined here in detail, and then analysed as they present in a virtual environment.

5.3.1.1 Adaptability

The skill of adaptability stems from the need to change to be efficient and/or work effectively in dynamic team situations. For teams moving from co-location to virtual environments, an ability to adapt and change can be a long process riddled with trial and error scenarios. This process is seen as necessary to encourage effective virtual teams (Kirkman *et al.* 2002).

It may be argued that the construction industry is struggling to adapt to newer technologies, changing its culture (Baldwin 2004), and the need for developing the IT skills of virtual teams. This emphasises the rationale underpinning this project.

5.3.1.2 Shared situational awareness

Shared situational awareness refers to the ability of team members to negotiate a common understanding of a situation and, on the basis of this, to interact and solve problems (Salas, Burke and Cannon-Bowers 2000). Sonnenwald and Pierce (2000) note that it is not only intra-group (within team members) shared situational awareness that teams need to develop skills in, but inter-group (between different teams) shared situational awareness as well (Sonnenwald and Pierce 2000).

5.3.1.2.1 Identity

When team members speak of a team identity, or an organisation to which they belong, they often refer to the information and knowledge a team shares and acts upon. In some cases this sharing of information may take precedence over the need for a shared physical space (Lipnack and Stamps 2000). With virtual teams, the fact that there is no 'physically' shared space is possibly not an issue, as there is only a need for ownership of knowledge which can easily be arranged in the virtual world through systems such as shared files. Team members do still need shared areas where the majority of their transactions occur. This is termed a 'place', and is where team members build a sense of community (Lipnack and Stamps 2000). A virtual system (such as a 'bulletin board') for building team identity would need to accommodate two 'places': a *product place*, where an actual project is designed and delivered, and a *process place*, where running of the teams and organisations occur (Lipnack and Stamps 2000). This combination allows team members to operate effectively across physical boundaries (Lipnack and Stamps 2000).

5.3.1.3 Performance monitoring and feedback

One the easiest ways to exercise the skill of feedback is to conduct feedback meetings, either at the end of a project or at the end of a phase of a project (Emmitt and Gorse 2003). The ability to provide feedback is essential if problems in future projects are to be identified (Emmitt and Gorse 2003).

Kirkman et al's (2002) case study of Sabre Inc, a travel innovation company, highlighted a number of skills that management recognized as important for a virtual team, and feedback was one of these. In the case of virtual teams, feedback must be a constant process, provided mostly by the team leader (Kayworth and Leidner 2000) as this person is generally the major coordinator. Within the construction domain feedback can be defined as clarification provided by a messenger to a receiver where an earlier message was not understood. If the communication skills of messengers are not sufficiently developed the use of a multi-channel communication system may be required, such as the combination of telephone, email, and a shared electronic whiteboard (Emmitt and Gorse 2003) [Section 5.5].

5.3.1.4 Team management

5.3.1.4.1 Project Management

The skills of project management have been recognized as essential as projects become more '…global and complex…' (Vitiello 2001). Project management uses a set of generic skills to deliver projects within time, scope, and cost, while providing clients with a quality product (Smart 2004). Vitiello (2001) outlines a list of skills necessary for effective project management (many of which have already been described above):

- Leadership skills
- Communication skills
- Conflict resolution skills
- Negotiation skills
- Listening skills
- Team building skills
- Relationship management skills

Smart (2004) also identifies the following project management skills:

- Planning skills
- Contract management skills
- Problem solving skills

The skills utilised by project managers in co-located teams are quite different to those used in a virtual team (Kayworth and Leidner 2000). The techniques used to negotiate, resolve conflicts, and communicate change are due to the different communication channels in place in these environments i.e. managers would not be able to negotiate one-on-one with a team member, nor would relevant information be close at hand; instead managers need to exercise more detailed and rich negotiation strategies through an electronic medium (Gameson and Sher 2002b). Furthermore, management of a global virtual team may also be challenged by language and cultural differences. This is particularly pertinent as it has been noted that managers spend almost 90% of their work time communicating with team members (Cleland and Ireland 2002).

5.3.1.4.2 Leadership

Project managers need skills in leadership regardless of whether the tasks they manage are virtual or not. Emmitt and Gorse's (2003) experiences show that a project manager who uses an open and inclusive leadership style, and allows a sense of ownership to develop is more effective than one who adopts an autocratic style. In the context of this research, a sense of ownership refers to the extent to which design professionals discuss problems and have ideas acknowledged by management, whilst maintaining high levels of commitment to their tasks (Emmitt and Gorse 2003). Whilst some authorities acknowledge that the leadership skills used in a co-located team are similar to those required in a virtual team (Dharmawardena 2003), there are also considerable differences. For example, to be effective in a virtual world it is necessary to create a more structured and formal environment (Dharmawardena 2003, Lurey and Raisinghani 2001). Newer technologies do not necessarily lead to greater team effectiveness; it is the implementation of the human aspects of a team (such as a positive and satisfying work environment) that leaders of virtual teams should seek to facilitate (Hoyt 2000, Lurey and Raisinghani 2001).

When leading a virtual team, proactive management skills are essential. Leadership involves taking the time and effort to contact and liaise with team members and to ensure that there are no clashes, be they cultural, personal or other (Cantu 1997, Kayworth and Leidner 2000). Lipnack and Stamps (2000) however, suggest that it is the ability of virtual team leaders to influence and guide teams, rather than leading by force that creates an effective virtual environment.

5.3.1.4.3 Goal setting

An integral part of leadership is the ability to establish goals for team members. Furst et al (1999) explain that goal setting is the ability to '…establish specific, challenging and accepted team goals'. Virtual team leadership is heavily founded on an ability to set clear goals for team members. The ability to deliver timely and appropriate feedback pertaining to these goals then follows (Dharmawardena 2003).

5.3.1.5 Interpersonal relations

Interpersonal skills have been cited (Hoyt 2000) as being of extreme importance to effective teams. These skills allow for the management of conflict and disagreements between members of teams (Stevens and Campion 1994). When attempting to use interpersonal skills (such as peer support) in a virtual team setting, the impact of body language may be lost because technologies such as email and telephone conferencing do not communicate them effectively (Hoyt 2000). Industry case studies, such as that of Sabre Inc mentioned Section 5.3.1.3, indicate that through trial and error, companies have realised the need for a balance between technical skills and interpersonal relations (Kirkman *et al.* 2002). It would be difficult in situations employing low bandwidth technologies for a team member to provide 'body language' cues to let, for example, a person know that they are being listened to or, for example, to congratulate them in a physical manner [such as a handshake] (Hoyt 2000).

5.3.1.5.1 Assertiveness

Assertiveness is the ability to allow others to recognise, by declaring clearly (Blair 1992), that a team member's…knowledge skills and ideas…' (Smith-Jentsch, Salas and Baker 1996) are available and important for a team discussion (Smith-Jentsch, Salas and Baker 1996). Effective assertiveness is about being 'quietly assertive'. Blair (1992) explains that one should acknowledge what other team members have said, clearly state one's point with some supportive evidence, and then attempt to resolve the issue. Assertiveness is about being diplomatic, and allowing all members to be heard. In virtual environments assertiveness can be associated with 'flaming' or online conflict (Alonzo and Aiken 2004). Alonzo and Aiken (2004) define 'flaming' in an online context as '…hostile intentions characterised by words of profanity, obscenity, and insults that inflict harm to a person'. The virtual online world creates an environment where team members may feel inhibited or invincible because they are able to be over-assertive without fear of actual physical harm. Skills in assertiveness involve members being able to state their point without creating unhealthy conflict.

5.3.1.5.2 Conflict resolution

Conflict within a team is not necessarily a negative element of team processes. Skills in conflict resolution centre around allowing a healthy amount and level of conflict that helps solve problems while discouraging unhealthy levels of conflict (Furst, Blackburn and Rosen 1999). Functional conflict management techniques (such as exploring differences) may be used in an attempt to solve disputes between team members or teams (Emmitt and Gorse 2003), while maintaining constructive relationships (Emmitt and Gorse 2003). Conflict is not necessarily the reason team members get into disputes; it is generally the result of poor management of conflict by project managers or team leaders (Emmitt and Gorse 2003) (for example '*I'll listen to your unreasonable demands, if you'll consider my unacceptable offer*' (Brilliant, 1970: cited in (Banner and Gagne 1995)). While social cues (such as menacing stares) make it simple to understand when unhealthy conflict is occurring in a co-located team, this diagnosis may be more difficult in virtual environments (Furst, Blackburn and Rosen 1999). If, when monitoring conflict in a virtual team, a late or rude reply to an email or phone message is discovered, it may be premature to suggest that conflict is becoming unmanageable. Virtual environments create an atmosphere of 'ambiguous' communication, where it can be difficult to interpret whether a person's communication is promoting unhealthy conflict (Furst, Blackburn and Rosen 1999).

5.3.1.6 Co-ordination

Co-ordinating the work of individuals is essential for the creation of an efficient and effective working team. It involves synchronising information and the tasks of each team member and controlling redundant work (Furst, Blackburn and Rosen 1999). The construction industry is highly fragmented and as a consequence there may be little or no co-ordination between members collaborating on a project (Mohamed 2003). As a result the construction industry has obtained a reputation for inefficiency (Mohamed 2003). In the context of the construction industry, co-ordination refers to the ability to deliver 'accurate and timely information' (Emmitt and Gorse 2003) for decision making and problem solving.

Emmitt and Gorse (2003) compiled a list of potential sub-skills that contribute to effective co-ordination:

- Ability to convey information with clarity and brevity
- Ability to report accurately
- Ability to be consistent
- Avoidance of redundant and repetitious information
- Checking ability
- Timing of information

The use of virtual technologies to co-ordinate construction processes should be beneficial to both team members and team management. Effective co-ordination of information can significantly reduce conflict (Emmitt and Gorse 2003) and an ability to record and transmit information aids the co-ordination and tracking of decision making.

5.3.1.7 Communication

Communication according to Chiu (2002) is: *'…the dynamic process in which one person consciously or unconsciously affects the cognition of another through materials or agencies in symbolic ways*'. Artefacts are the most simple of the types of communication, they 'allow the externalization and representation of objects, constraints, form, function, assembly, materials, and so on' (Perry and Sanderson 1998). They include such things as models or CAD visuals (Perry and Sanderson 1998). In Perry and Sanderson's (1998) study artefacts such as sketches, large scale printouts, and CAD visuals were used to communicate ideas between engineers and draftspeople.

When changes in a design are needed these are often presented in the form of a new artefact, so that when a faulty current design is withdrawn, a new sketch or CAD visual may be put in its place (Perry and Sanderson 1998). When these new artefacts are approved it is common practice for the majority of stakeholders initial the work to indicate those who have approved it. This allows a clear communication channel to be established for these stakeholders (Perry and Sanderson 1998).

Drawing is an important aspect of the communication process within design. Drawings can bridge differences of professional jargon (Laseau 2001). In a virtual environment drawings can be communicated as an attachment to an email or in a shared networked space (Maher, Simoff and Cicognani 2000).

Three dimensional (3D) virtual worlds have been defined as a '*…single computer-mediated dynamic environment which provides virtual team members with a sense of place'.* (Maher, Simoff and Cicognani 2000). They commonly use avatars (3D representations of team members), which allow the use of body language and emotion to a small degree. Most communication is still text based, with the text appearing along side the relevant avatar (Maher, Simoff and Cicognani 2000).

It is common practice for novice virtual teams to share space on a computer system. This facilitates the sharing of files, but does not allow for communication between individuals (Maher, Simoff and Cicognani 2000). Team members need more than an indication of what other are working on. They need a medium through which they can express thoughts and ideas on their own work as well as that of others.

Communication embodies a large area of research. This review divides communication skills into three areas: verbal communication, non-verbal communication, and receipt of communication. These areas may be affected by the virtual world, depending on the technologies and techniques utilised.

5.3.1.7.1 Verbal Communication

Learning and the majority of team interactions are primarily facilitated by conversation. It is through this skill that the beliefs and assumptions of team members that form the culture of a team are learnt (Gay and Lentini 1995).

When engaged in conversation in a face-to-face environment, it is important to be able to ask for feedback to ensure the person being communicated to is interpreting one's meaning correctly (Blair 1992). The current state of e-communication inhibits such interactions (for example, seeking reassurance would make the process of emailing extremely cumbersome). However, the rapid rate at which on-line communication has and is evolving indicates that more elegant solutions may become available.

In any virtual team the most common solution to conversation barriers is the telephone or, as it is known, tele-presence (Gabriel and Maher 1999). When teleconferencing is used in place of a co-located meeting, studies have indicated a large reduction in time spent socialising, as participants are better able to adhere to the task at hand (Cleland and Ireland 2002). However, without members being able to access the same visual information, there may large amounts of mis-communication because of the difficulties of translating three dimensional objects into words (Gabriel and Maher 1999, May and Carter 2001, Poltrock and Engelbeck 1999). Gabriel and Maher's (1999) study indicates that there are four types of verbal communication in the design process (Maher, Simoff and Cicognani 2000):

1. Communication control (interruptions, floor holding and handovers)
2. Communication technology (discussions of how to use the tools)
3. Social communication (time spent in social conversation, not related to design)
4. Design communication (discussion of design ideas, scope and task)

For effective collaboration in a design setting, a majority of 'design communication' would be advantageous. It is interesting to note that this occurred in a 3D virtual environment which encompassed an avatar, as opposed to the use of video conferencing (Maher, Simoff and Cicognani 2000).

5.3.1.7.2 Non-verbal communication

Gestures are an important element in the hierarchy of communication (Williams and Cowdroy 2002). Design teams often use gesture to indicate the manipulation of objects in a design (Perry and Sanderson 1998). In a team situation it is often the non-verbal cues which convey the most meaning; a wink, a raised eye brow, or an ear tug (Hoyt 2000). These cues, whether created on purpose or accidentally, can give secret or subtle information about project or team dynamics (Cleland and Ireland 2002).

In experimentation with types of verbal communication for virtual interactions, acknowledged in Section 5.3.1.7.1, communication via synchronous typed text rather than conversation (tele-presence) has been noted as more advantageous (Gabriel and Maher 1999, Maher, Simoff and Cicognani 2000). Typing conversations allowed more reflection on communication and greater concentration on the design communication. A written record was also generated which could be examined to clarify points of interest (Gabriel and Maher 1999).

5.3.1.7.3 Receiving communication

When considering the skills involved in the communication process, listening (or 'receiving) is not widely mentioned. Listening is the ability to understand communication (i.e. to be a receiver). As humans can lose up to twenty five percent of the information they listen to (Cleland and Ireland 2002), re-evaluation of this aspect is arguably necessary. There is little focus on listening skills in formal education. In addition one's ability to 'receive' can also be affected by emotional aspects relating to the information (Cleland and Ireland 2002, Emmitt and Gorse 2003), as '*…we only hear what we want to hear'*. The major hurdle with some virtual technologies is ensuring that team members actually receive a communication. Some bulletin boards and email systems do not provide a checking mechanism to indicate that the intended person has actually viewed the communication.

5.3.1.8 Decision Making

When making a decision, there are generally a limited number of alternatives from which to choose (Stempfle and Badke-Schaub 2002). Once an alternative passes a predetermined satisfaction point, a decision is made. Little regard is given to other alternatives (Stempfle and Badke-Schaub 2002). Decisions in the construction industry are often needed immediately and adequate time is rarely allowed for all data and perspectives to be considered (Emmitt and Gorse 2003). As a consequence decision-making by virtual teams is more difficult than when teams are co-located. This is because it may be necessary to clarify positions from a variety of different locations. Interestingly Gorse's (2002) research shows that the groups that are most effective are the ones that are able to utilise a broader range of communication techniques. This may contribute to a deeper understanding of contributors' opinions and be facilitated by the use of higher bandwidth technology (Emmitt and Gorse 2003). Most IT technologies have been created to encourage greater collaboration between members of a construction team (Emmitt and Gorse 2003). Industry case studies, such as Sabre Inc, have shown that for decision making in a virtual team, there needs to be on-going training (Kirkman *et al.* 2002). Some studies have suggested that the use of virtual teams can lead to an increase in the time it takes to make decisions and also results in a drop in team cohesion (Driskell, Radtke and Salas 2003).

5.3.1.8.1 Problem solving

Problem solving is a precursor to decision making and it is thus appropriate to categorise it as a sub-skill of decision making (Kirkman *et al.* 2002). It is the ability to highlight the problems or limitations within a task or team, and then subsequently to put in place appropriate action to remedy it (Furst, Blackburn and Rosen 1999). With respect to problem solving in the construction industry, it appears that project managers may take different approaches depending upon whom they are consulting (Emmitt and Gorse 2003). When interacting with those lower in their hierarchy (such as sub-contractors) an informal approach to problem solving is used. However, when solving problems with other professionals, such as engineers or architects, more formal processes are often used. Those involved frequently spend more time evaluating problems before making contact with each other (Emmitt and Gorse 2003). In the majority of these cases communication between the professions is via virtual methods such as fax or telephone (Emmitt and Gorse 2003). The use of high bandwidth technologies in problem solving would allow a quicker exchange of relevant information with increased richness and detail (Gameson and Sher 2002b).

5.4 Collaborative Design Activity

Lawson's research (1990) identified collaboration as a large component of a designer's working time. Since this acknowledgement of the profile of collaboration there has been a move toward applying research methods to gain a better appreciation of this activity and the skills required to effectively participate in collaborative design processes. In the process of gaining an understanding of design team activities, Muir (1995) defined collaboration as the activity of communication between parties involved on a project. Collaboration is an alliance to complete a mission or solve a problem (Kvan 2000).

Collaborative teamwork in a construction context historically refers to a short-term alliance (i.e. for a single project) between parties or companies. Cooperation is the term used to describe the relationship between companies that would exist for more than one project (Love *et al.* 2002), being a more informal arrangement (Kvan 2000). Collaboration (involving project teams) and cooperation (with operational teams) may have similar connotations but they are not interchangeable as they have fundamentally different definitions (Kvan 2000). Maher et. al. (2000a) report three different styles of design collaboration, within a collaborative design experiment, as shown in Table 5.5.

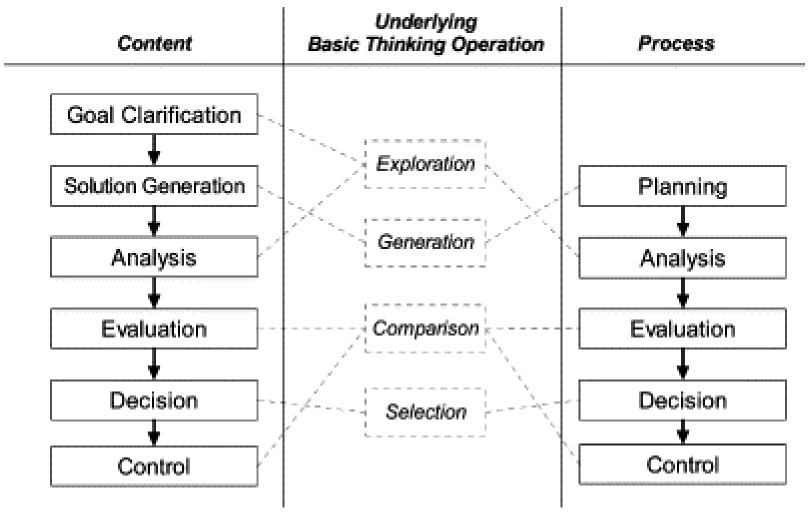
Table 5.5 Differing design collaboration styles (as indicated by Maher et al. 2000a)

Collaboration Style	Description
Constant collaboration	Designers work on the entire design entity while consulting with each other.
Intermittent collaboration	Designers work on different sections of the design, and check with each other intermittently.
Leader controlled collaboration	There is an establishment of a leader who directs the members to specific design tasks.

These types of collaboration all need to be supported in any mode of team, whether co-located, virtual or global virtual.

Professionals involved in team-related activities during the design process undertake a complex, multi-faceted process. The collaborative design process is different from traditional design processes undertaken by individual designers. The difference between individual designers and design teams is encapsulated in the collaboration between participants when creating a new artefact. To appreciate the complexity of this collaborative process requires an understanding of the process itself. Stempfle and Badke-Schaub (2002) developed a model, shown in Figure 5.4, which sets out the characteristics of both Tuckman's (1965) and Cornick and Mather's (1999) models of project team lifecycle.

Figure 5.4 Generic step model of design team activities (Stempfle and Badke-Schaub 2002).



Stempfle and Badke-Schaub's (2002) model, Figure 5.4, illustrates the steps which define the processes in which design teams engage. The content and process steps of the design team are linked via the cognitive processes underlying the actions of exploration, generation, comparison, and selection.

Similarly Thorpe's (2004) 'Generic Design and Construction Process Protocol' classifies the design collaboration process as a method of project management. Thorpe's project management process is based upon four broad stages:

- Pre-project

- Pre-construction
- Construction
- Post construction

To provide a level of detail of the activities which occur within and across these four stages, Thorpe (2004) identified the following phases of the process protocol:

- Demonstrating the need (Phase zero)
- Conception of need (Phase one)
- Outline feasibility (Phase two)
- Substantive feasibility study and outline financial authority (Phase three)
- Outline conceptual design (Phase four)
- Full conceptual design (Phase five)
- Coordinate design, procurement, and full financial authority (Phase six)
- Production information (Phase seven)
- Construction (Phase eight)
- Operation and maintenance (Phase nine)

The similarities between the construction process protocol, described by Thorpe (2004), and stages inherent in the design team lifecycle (shown in Figure 5.4) illustrate that a process protocol could be established solely for design. These models show that design and more importantly collaborative design, is a segmented process, punctuated by four to five stages that define design processes. From these similarities it is likely that design process protocols could be those ‘process’ steps noted by Stempfle and Badke-Schaub (2002) which consist of the stages proposed by Gay and Lentini (1995). To appreciate the diversity of activity which occurs in the team design process requires an understanding of the range of these activities. Gay and Lentini’s (1995) study of design processes in a collaborative virtual environment defined these activities. Their study identified ten specific activities which occurred in a virtual environment, and these are presented in Table 5.6:

Table 5.6 Design activities adapted from Gay and Lentini (1995).

Design Activity	Definition
Orientating	Establishing contact, familiarization with task and environment. Period in which members establish themselves and become comfortable in the new environment
Subdividing the problem	Defining tasks, objectives, requirements, and boundaries
Establishing roles	Assigning responsibilities, and leadership issues
Information seeking	Researching skills.
Information sharing	Sharing drawings, communicating pictures, gesturing, reporting on research and progress
Monitoring	Clarification of communication channels
Negotiating/ understanding	Explaining design, commenting and questioning, and justification
Designing	Sketching, visualizing, drawing, and manipulating materials
Building	Not relevant to this review of early design
Evaluating	Scrutinising the project in its duration. (Gay and Lentini 1995)

The similarities between the ‘Generic Design and Construction Process Protocol’ (Thorpe 2004), and Stempfle and Badke-Schaub (2002) and Gay and Lentini’s

(1995) descriptions of design team activity warrants further investigation to ascertain whether the creation of design team protocol stages is appropriate. This is outside the scope of this investigation.

5.4.1 Issues Impeding Design Team Collaboration

While research has been conducted to define the processes and activities of collaborative design teams, investigations have also been undertaken to define the processes of implementation and associated issues. In a practical design situation there are a range of difficulties and barriers which inhibit effective practice.

One of the strongest barriers to open and effective collaboration is the perception of professional stereotypes (Gil *et al.* 2001, Muir 1995). Muir and Gil observed different professions perceptions of other professions (for example, as the sports car driving architect) and noted that such narrow-mindedness could hinder effective design collaboration.

Unhealthy conflict (Furst, Blackburn and Rosen 1999) may be another major barrier often brought about by the abovementioned prejudices (Emmitt and Gorse 2003).

Distance between design team members is a further barrier. The design process is, in most cases (Emmitt and Gorse 2003), spread between several professions. Team members need only to be on different floors of a building for face-to-face contact to reduce significantly (Lipnack and Stamps 2000).

A prerequisite for effective collaboration is efficient project management. This involves the "setting and the achieving of mutually agreed goals, and the monitoring of the procedures set up to achieve them" (Muir 1995).

Effective inter-professional collaboration in the design and construction industry is founded on the following five objectives:

1. To stop stereotyped attitudes
2. To improve the flow of information
3. To improve the decision making process, through an understanding of other professionals' values and methods, and through effective channels of communication.
4. Avoiding abortive work through duplication
5. Increasing the cost effectiveness of design procedures (Muir 1995)

Collaboration in design teams poses a complex set of variables which require management by a design team manager to gain best outcomes.

5.4.2 The Generic Skills which Support Design Collaboration

A significant factor in collaborative design team environments is that 'expertise' is paramount and changes continually. If all 'experts' are narrow specialists they will tend to follow a rational, 'logical' sequential design process from the detail parts to the complex whole (Williams and Cowdroy 2002). The need is invariably for design to commence based on the identification of a defined outcome that is understood and shared by all members of the design team, including those who will be members for only part of the overall design project. To understand and share the concept of a completed product, each member of a team must be able to understand the 'position' of most or all other members, and must therefore have some understanding of the design challenges faced by other members.

There is a difference between types of problems in design, well-structured (defined and understood) versus ill-structured (less understood, larger ramifications) (Perry and Sanderson 1998). This review is restricted to an analysis of ill-structured problems which typically occur in the early stages (design development) of a project. Ill-structured problems require longer periods of communication and the use of a range of artefacts (Perry and Sanderson 1998). The early design process is an iterative form of problem solving, where solutions are formed and constantly revised or redefined to produce a satisfactory product (Lahti, Seitamaa-Hakkarainen and Hakkarainen 2004). The activities associated with the early design process include: orientating, subdividing the problem, defining roles and planning and analysing problems. The stages of design are not exclusive. Team members move between stages (Lawson 1997). May and Carter’s (2001) study into virtual teaming in the European automotive industry found that collaboration in early design phases of a product did not improve the quality of the product. Rather, quality was achieved in a shorter time period. The difference was an increase in “first time right decisions” (May and Carter 2001) which eliminated costly late production changes (May and Carter 2001). Design limitations are discovered through the sharing of information (Lahti, Seitamaa-Hakkarainen and Hakkarainen 2004) in the early design phase, making it one of the most important phases for collaboration.

The next section describes how the early design process affects specific skills when these are exercised in a virtual context.

5.4.2.1 Leadership

Leadership during early design is important because it influences the types of skills team members possess as well as the contributions they make (Baird, Moore and Jagodzinski 2000). The leader or leaders need to be able to create teams which identify important ‘social links’ between virtual team members (Baird, Moore and Jagodzinski 2000).

When forming a design team, team leaders need to maximize the skill levels of members. This process is constrained in a project operating on a short timeframe, and in such cases it is especially important for leaders to take advantage of the skills possessed by experienced team members. Advantage may also gained by involving experienced team members in familiar tasks for each new design team (Baird, Moore and Jagodzinski 2000). However, such actions postpone the training of junior staff. To address this leaders may require staff with limited experience to refer to senior staff for advice (Baird, Moore and Jagodzinski 2000).

In a virtual team the ability of partially trained designers to refer to an experienced source is potentially impaired because of the lack of face-to-face interaction. Baird et al (2000) suggest that leaders should allow initial face-to-face contact between parties very early in the life cycle as this allows a stronger social link to form and creates an environment where training and quality designing can occur.

5.4.2.2 Co-ordination

Co-ordination and structuring skills need to be exercised when designing collaboratively using a virtual medium (Lahti, Seitamaa-Hakkarainen and Hakkarainen 2004). Lahti et al’s study also highlighted the need for team members to discuss their designs. In this study facilities were not available to change other people's designs online as communication was effected using a web chat system and email. Participants felt that not having such facilities hindered their ability to communicate ideas.

5.4.2.3 Feedback

Due to the loosely defined nature of early design processes, it is important for team members to be able to seek and provide feedback. Vertical communication channels between junior team members and senior decision makers are important (Baird, Moore and Jagodzinski 2000). An ability to give feedback is crucial at this stage because large amounts of information need to be validated (Baird, Moore and Jagodzinski 2000). Early in the design process junior designers need to obtain clarification from their seniors. This interaction is critical.

5.4.2.4 Communication

Baird's (2000) study of collaborative engineering design reveals some interesting communication processes. An ability to build interpersonal relationships in an engineering team can be a slow process and this may be exacerbated when operating in virtual environments (Baird, Moore and Jagodzinski 2000). Baird et al (2000) suggest that these environments may not foster skills such as feedback.

Within the engineering domain it may take time to filter design or design processes communications (Baird, Moore and Jagodzinski 2000). This may be due to the method of dialogue used and may also be the result of a team member's lack of experience of working with others. In this connection, Williams and Cowdroy (2002) note that using analogies is easier in the early stages of design if team members have worked together previously.

5.4.2.4.1 Non-verbal Communication

In Baird et al's (2000) work, senior engineers are referred to as 'consultant engineers'. They observed that skills in communication, particularly non-verbal (such as smiles, nods and frowns) were important for consulting engineers providing feedback to juniors about their suggestions (Baird, Moore and Jagodzinski 2000). Communicating such non-verbal cues is difficult in virtual environments. As yet it is unclear whether video media or the use of extremely rich and detailed language could convey these cues virtually.

5.4.2.5 Interpersonal relations

The way in which team members collaborate during the early stages of design can impact on a team's ability to perform. Social collaboration appears to play an important part in the design process especially when researching and determining limitations.

Collaboration is fundamentally different to co-operation. Collaboration normally implies team members working together on a project while co-operation implies splitting a task and working individually. Collaborators generally work together on many projects, while team members co-operate on one project and then disband. Like project teams, design collaboration is defined by a series of steps. There are a number of theories regarding these steps but like project teams these are similar for both design and construction.

5.5 Collaborative Technology Facilitators

Technologies which facilitate virtual design teamwork are emerging in electrical engineering, materials science, and computer science disciplines (Milne 2000). These technologies considerably improve the quality of communications and interactions between remote stakeholders (Perry and Sanderson 1998). Examples of these technologies are provided in Table 5.3.

Virtual tools gaining prominence include **Shared Electronic Whiteboards** and **Multi-User 3D Virtual Worlds**.

1. **Shared Electronic Whiteboard** – A shared electronic whiteboard involves the use of a conventional electronic whiteboard but with the added capabilities of video and audio conferencing, and remote sketching (Gero *et al.* 2004). Remote sketching is the ability for team members to share and collaborate on drawn ideas and manipulate their designs across a network. It allows multiple users to work on a design in real time from remote locations (User Data Connections Limited 2005). Programs which support this form of collaboration include Group Board (User Data Connections Limited 2005) and Net Meeting (Microsoft Windows Technologies 2005).

2. **Multi-User 3D Virtual World** - This software allows synchronous collaboration between multiple members, where they may chat, speak, draw or build using a space facilitated by the internet (Maher, Simoff and Cicognani 2000). Interaction in the shared networked space is conducted through avatars which are 3D representations of the designers (Rosenman *et al.* 2005). Software which supports these forms of work includes Active Worlds (Activeworlds 2005) and Second Life (Linden Lab 2005).

When using a virtual environment it has been suggested by Gay and Lentini (1995) that the use of multiple channels in design, such as video conferencing, a chat box and a drawing tool, leads to a greater depth and breadth in communication, and also provides back-up systems should one channel fail (Gay and Lentini 1995, Kayworth and Leidner 2000). In terms of problem solving, however, other research has indicated that multiple channels provide minimal or no advantage (Chapanis 1975). Chapanis (1975) observed that restricting the number of channels had little effect on problem solving abilities, and argued that the communication process was all that was affected (Maziloglou et al, 1996; as cited in (Gabriel and Maher 1999, Maher, Cicognani and Simoff 1998).

5.6 Summary

Environmental and technological changes have impacted on the way construction teams function. A major driver of environmental change has been a move towards more collaborative contractual arrangements, such as alliancing and partnering, which, in turn, promote technological change. Longer term relationships between project team participants act as drivers for the uptake of new technologies. Investing time and money in new computer systems becomes attractive if such technologies can be used on many projects, with the same people.

Furthermore, technology (i.e. cost of technology, speed of information transfer and the associated costs) promotes moves from co-located to virtual team activities. However, the challenge of such moves is to incorporate aspects of co-location (for example, being able to see people whilst interacting with them, and being able to collaborate).

To function efficiently and effectively in a team environment (irrespective of whether it is a traditional or virtual team) team participants require '*appropriate skills*' (i.e. awareness, understanding, and abilities to apply). It cannot be '*assumed*' that all team members automatically possess all the necessary skills for virtual teaming. Previous research has shown that the introduction of new technologies can impact, both positively and negatively, on the performance of teams. Therefore the ability to map and measure the skills of individuals and teams is critical. Mapping and measuring these skills will facilitate targeted training. The development of skills mapping and measurement tools is a major outcome of this aspect of this research project.

The next section documents the development of a framework for the analysis of design team activity.

6 ANALYSIS FRAMEWORK LITERATURE

This section outlines a framework to support the identification of behaviours involved in design team collaboration. It is used as a basis for conducting protocol analyses of video data of design collaboration. In this section Content and Protocol Analysis are firstly discussed. Behavioural Markers are then examined as they offer a system by which behaviours associated with the generic skills, as taken from teamwork research, can be identified. Linguistic research to elicit themes within participants' speech and transcribed text is described next. Finally coding schemes for examining behaviours of design teams are presented.

The data analysis framework described in this report evolved in response to the nature and content of video data collected by the University of Sydney. Design activity using three different ICT arrangements (or 'stages') was video-recorded. The various set-ups made it possible to compare and contrast skills profiles when participants used different technologies. Three different 'bandwidths' were employed (where low bandwidth refers to simple technologies such as phone and fax, while high bandwidth includes complex solutions such as 3D virtual worlds). The three stages are as follows:

Stage 1: **Baseline level:** the technology used was a combination of face-to-face communication and sketching. These methods are representative of the majority of collaboration as currently conducted in synchronous design.

Stage 2: **Moderate bandwidth:** this method allows team members in different geographical locations to manipulate designs. The e-whiteboard consists of an electronic sketch pad, web camera, and 'chat facilities'. The software in use for the electronic whiteboard was 'group board' (User Data Connections Limited 2005).

Stage 3: **High bandwidth:** 3D virtual worlds (with team members being represented by 'avatars') were the next step in remote design/construction collaboration. Team members manipulated a 3D representation of a design using computer-based tools, and communicated through 'chat' facilities. All interactions were logged in the system.

6.1 Behavioural Markers

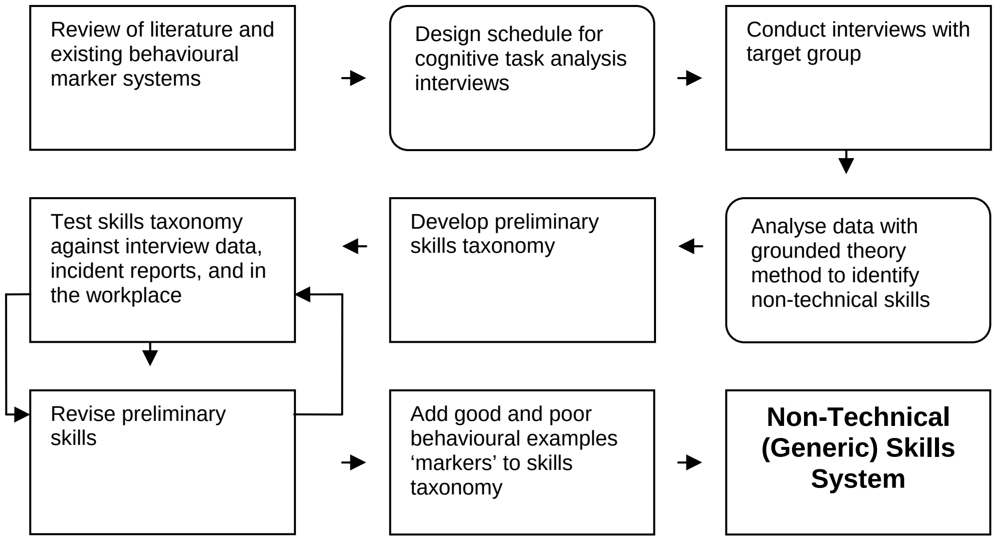
Behavioural markers are observable non-technical (Klampfer *et al.* 2001) *'…aspects of individual and team performance'* (Carthey et al, 2003: p, 411) which are related to the effectiveness of an individual and a team. Behavioural markers or, more specifically, the methods for creating behavioural markers, offer a physical description of non-technical skills [generic skills] (Kjellberg *et al.* 2003). Klampfer et al (2001) recommend simple and clear behavioural markers, which use appropriate jargon and terminology. Furthermore they note that emphasis should be placed on an observable behaviour rather than an ambiguous attitude or opinion. Generic skills behavioural markers from other industries, such as aviation and medicine need to be adapted for design team interactions.

6.1.1 Creating Behavioural Markers

The key to creating effective behavioural markers is eliciting opinions from multiple sources (Fletcher *et al.* 2003, Klampfer *et al.* 2001). In the context of this research project, it is necessary to identify factors which contribute to performance, and which lead to a positive or negative outcome (Klampfer *et al.* 2001).

Fletcher et al (2003) outline a specific time table for the creation of behavioural markers in Figure 6.1. The approach suggested is the most common method by which behavioural markers are defined.

Figure 6.1 Behavioural markers development process as adapted from Fletcher et al (2003).



6.1.2 Behavioural Marker Systems

The majority of behavioural marker systems have been developed for the aviation industry, and are now being transferred to other areas such as medicine (Helmreich 2003). They allow users to understand which generic skills are represented by certain behaviours. Table 6.1 provides an example of generic skills (Fletcher *et al.* 2003). The generic skills are presented in the 'categories' column, while their observable behaviour is displayed in the 'element' column.

Table 12.1 documents the 'Line Operation Safety Audit' (LOSA) behavioural markers used in the aviation industry. These provide an overview of behaviours indicative of different individual and team generic skills.

Table 12.2 and Table 12.3 provide a detailed physical description.

Some of the non-technical skills areas identified for aviation and medicine correlate with the generic skills found in design team literature. This supports using the behavioural elements of those skills to identify generic design skills.

Table 12.4 correlates behavioural markers for generic team skills with those presented in behaviour marker research.

Table 6.1 The Anaesthetists Non-Technical Skills (ANTS) system prototype describing skills (categories) and behavioural elements [adapted from Fletcher et al (2003)].

Categories	Element
Task Management	• Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilising resources
Team Working	• Co-ordinating activities with team members • Exchanging information • Using authority and assertiveness • Assessing capabilities • Supporting others
Situation Awareness	• Gathering information • Recognising understanding • Anticipating
Decision Making	• Identifying options • Balancing risks and selecting options • Re-evaluating

6.2 Content Analysis

Content Analysis (CA) refers to the coding (manual or automated) of communication content from drawn from transcripts, newspapers, or other communication recordings, such as audio and video media. Coding and subsequent frequency analysis provides insights into the cognitive processes of the communicator (Garson 2004, Wallace 1987).

'The underlying assumption in all the major reviews of content analysis is that the verbal content produced by the individual is representative of the thought processes at work in his or her mind' (Wallace, 1987: p, 121).

Content analysis was first used 50 years ago, and is now widely used by, for example, the disciplines of psychology, sociology, political science and communications (Baron 2001). The use of content analysis is not restrictive and may be conducted on a large range of communications (Baron 2001). A method of CA, Bales's Interaction Process Analysis (IPA), analyses interactions in group communication, and is used in this research. The conclusions drawn from content analysis can be based on the sender, the message, or the receiver (Weber 1990).

Weber (1990) lists the advantages of content analysis as:

- Methods associated with content analysis use those transcripts of verbal communication which are the usual for human interaction.
- Content analysis may utilise quantitative and / or qualitative methods.
- Reliable inferences may be drawn from texts regardless of age, and these may include factors such as culture, and socio-economic and political climate.
- Content analysis is a non-obtrusive process which avoids the pitfalls of experimental procedures.

Content analysis is not necessarily a quantitative process (Krippendorff 2004). Speech and communication are generally qualitative to begin with, so it is consistent to apply a method for analysing text which is based on direct qualitative interpretation

(Krippendorff 2004). The differences between quantitative and qualitative content analysis lies in the information they provide regarding communication. Quantitative content analysis gives the **what**, **where**, **when**, and **how** of the content (Mostyn 1987), while qualitative describes the **why** of content. The basic differences between the two forms are described by Mostyn (1987), and are set out in Table 6.2.

6.2.1 Quantitative Content Analysis

Quantitative content analysis is the most frequently defined form of CA. It is the process of investigating the content of interactions or communications to discover the frequency of ideas or themes. It is thought that examination of communications offers insights into peoples' cognitive processes. For example, if a person expresses a certain idea a number of times, that idea is central to their thought processes at that time (Krippendorff 2004, Wallace 1987). Methods of quantitative content analysis include Interaction Process Analysis [Bales, 1951], The Bettman-Park Typology [Bettman and Park, 1979], Evaluation Assertion Analysis [Osgood, 1956], The General Inquirer [Stone, 1962], The Gottschalk-Glesser Typology [Gottschalk, 1974], and Frequency and Concordance Analysis [Pool, 1959] (Wallace 1987).

Table 6.2 The major differences between Quantitative and Qualitative Content Analysis [adapted from Mostyn (1987)].

	Quantitative	**Qualitative**
Sample Size	Large	Small
Length of Interview	Short in length. Short answer or multiple choice	Long, to allow the gathering of deeper information beyond the superficial
Format of Questioning	Follows a standard format	Follows the participants reactions to various stimuli
Objectives	What, where, when, how	Why
Form of Analysis	Statistical	Content Analysis
Reporting	Based on statistical analysis	Based on theories of motivation
Reliability and Validity	Can always be determined	Can rarely be determined

6.2.2 Qualitative Content Analysis

Qualitative Content Analysis is sometimes known as 'Interpretive Content Analysis' and originates in disciplines such as social science and literary theory (Krippendorff 2004). It is the direct interpretation of human interaction or communication through an examination of messages within printed text or spoken words (Krippendorff 2004). Qualitative Content Analysis is akin to the way humans interpret speech and text (Wallace 1987). According to Mayring (2000) qualitative content analysis involves defining criteria from theory and the research question, and this determines which sections of the text are to be considered. Following this the text and criteria is trialled and the categories are carefully decided. A feedback loop allows these categories to be revised, resulting in main categories for analysis and these categories are checked for validity and reliability.

6.2.3 A Comparison between Quantitative and Qualitative Content Analysis

This comparison of quantitative and qualitative content analysis is based on their respective techniques, results, and reliability. Mostyn (1987) considers the following:

Quantitative:

- It is believed this method is more rigorous and systematic as it bases its analysis on numbers and frequencies as opposed to abstract judgements.
- It offers higher levels of reliability because different coders decide on the categories and have definitions for each. Analyses conducted using computer systems may result in high reliability.
- Analysis cannot be obstructed by one exception phrase. Researchers must examine all aspects of the text.

Qualitative:

- Any creation of categories will require some form of qualitative analysis.
- Qualitative analysis allows views of communications through 'peoples' understanding, rather than through computations of a computer.
- It is a more sensitive measure which allows for understanding of deeper issues.

After examining the differences between the two content analysis methods, it was decided that **'quantitative'** would best serve this study's purposes for the following reasons:

- This study only examines the interaction process (i.e. the message conveyed in the communication), not the actual content of meaning.
- It has a higher inter-coder reliability.

The next section examines Bales's Interaction Process Analysis (IPA).

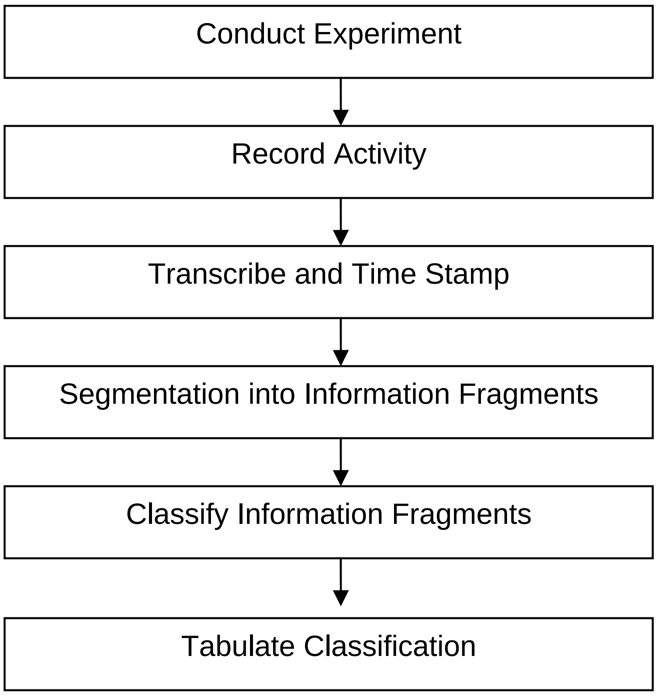
6.3 Protocol Analysis

Protocol analysis is a technique which allows researchers to infer cognitive process through analysis of the verbal behaviour of participants (Ericsson and Simon 1993). The most common method is the 'think aloud' approach which views participants being trained to voice their thoughts as they attempt to solve a problem. These thoughts are transcribed and graphs created which chart the progress of possible cognitive processes (Ericsson and Simon 1993). While the generic skills stream of this project did not require designers to 'think aloud' it is important to appreciate how this technique is used, as it is closely linked to content analysis.

The Delft Protocols Workshop conducted by Cross et al (1996) concentrates on protocol analysis of industrial design teams. These studies determined that protocol analysis may be the most effective method of identifying designers' cognitions. As Cross et al (1996: p, 2) explain *'…how else might we examine what is going on inside people's heads, other than by asking them to tell us what they are thinking'.* The experimental set up and procedure for this project is similar to that of the Delft protocol analysis workshops.

Baya and Leifer (1996) present a protocol analysis method in Figure 6.2.

Figure 6.2 Flowchart of the stages inherent within protocol analysis (from Baya & Leifer, 1996).



6.3.1 Protocol Analysis: A Segmented Process

When creating a protocol it is efficient to structure experimental interactions as shown in Figure 6.2. There appear to be several ways in which data may be segmented for analysis of design teams. These may be dependent on several factors including information and activity. They are presented below.

1. **Episode:** Episodes are defined after the encoding of the protocol. They are those periods which elicit a clear and identifiable behaviour (Baykan 1996). An episode is similar to an event. An event is a segment of time which begins when a new portion of information is mentioned or discussed, and ends when another different portion of information is raised (Dwarakanath and Blessing 1996). An event also changes when a different person starts speaking.
2. **Segments:** *'Segments are verbalisation units that correspond to units of heeded information, pauses, and syntactic information'* (Baykan, 1996: p, 134). Segments consist of verbalisations ranging from single words to entire phrases (Baykan 1996).
3. **Sentences:** A sentence is the smallest measure of verbalisation that represents a context (Gameson 1992). A sentence consists of 'recording units' which may be single words or terms. However, it is an entire sentence which puts these terms into a context and which allows analysis to occur.
4. **Utterance:** An utterance may vary from a single word to an entire sentence. It comprises those words which convey one single thought (Roter 2002).
5. **Drawing Packets:** These are made by one designer and end when focus is directed towards another drawing. Drawings are differentiated through appropriated special separation. Packets may be further divided into drawing acts (Mazijoglou, Scivener and Clark 1996), which can be further divided into categories such as symbolic and non-symbolic acts.

‘Utterances’ allow coders to deal with one thought or cognitive process at one time and were used as the metric for this research.

6.3.2 Advantages and Disadvantages of Protocol Analysis

The major advantage of protocol analysis is that it allows researchers to analyse the design process in a relatively closed setting, safe from interruptions. Protocol analysis also allows researchers to reduce the complexity of their studies as all variables do not need to be accounted for (Baya and Leifer 1996).

The Delft workshop study indicates that protocol analysis is extremely limited in its capacity to delineate non-verbal cognitions associated with design. Should some comparisons be discovered, a large degree of interpretation is needed (Cross, Christiaans and Dorst 1996). The subjectivity of analysis and the length of time required to complete an analysis on one dataset further undermine the appropriateness of this method. However, protocol analysis (Baya and Leifer 1996) and content analysis still offer a highly appropriate solution for the analysis of teams at work. These approaches facilitate an understanding of a preselected area of interest as participants can be asked to describe (‘think aloud’) their cognitions.

6.4 Bales Interaction Process Analysis (IPA)

Bales’s Interaction Process Analysis (IPA) may be used to understand the interactions of a group of people engaged in a task. It is a *‘…method of classifying direct, face-to-face interaction’* (Bales, 1951: p, 5) in an attempt to generate a set of categories which are sufficiently generic in nature to represent team/human interaction (Bales 1951). Our investigations did not attempt to gauge interactions based purely on transcripts of speech. Non-verbal interactions as well as gestures were included as well. As Bales (1951: p, 31) explains *‘The observation of social interaction and its situation is the common starting ground for all of the social sciences’*. Figure 6.3 illustrates the categories defined by Bales as indicative of interactions. Note that the “Key” describes where analysis of different concepts may be measured.

6.4.1 Studies which have used Bales’s IPA to study Computer Mediated Communication

Although IPA has traditionally been used in face-to-face situations, there have been many studies where it has been used to analyse Computer Mediated Communication (CMC). One such study was conducted by Hiltz and Turoff (1993) and examines the difference between face-to-face and ‘computer communication’ using IPA. This used IPA successfully to show that there might be differences between the two conditions in the ‘agreement’ and ‘disagreement’ categories.

Pena (2004) used IPA to study interpersonal communication between video game players using ‘chat’ (typed) communication within a multi-user system. He attempted to show that there was a difference between the amount of task-oriented communication and socio-emotional communication. He predicted that there would be a difference, but, in presenting two contradictory theories was unwilling to place more weight on one or the other. With regards to socio-emotional content he predicted that differences would be seen for valence (positivism and negativity) and for player experience.

Following the work of Rice and Love (1987), Pena added two extra categories which represented the giving and asking of socio-emotional questions such as ‘How old are you?’. These were considered to be positive in valence, in accordance with Rice and Love’s (1987) study. Four other categories were also included:

- Messages which fixed grammatical and other errors in previous messages
- Messages which were automatically created by the game for events such as players entering or leaving
- Messages which discussed technical difficulties
- Messages for undefinable messages

Pena’s (2004) study found that more socio-emotional communication occurred during game play than with task orientated work. He also noted that there were differences between socio-emotional messages.

Jaffe et al (1995) examined the use of pseudonyms in mixed gender group computer communication. Their hypotheses related to the experience of participants with CMC, use of pseudonyms by each gender, and the conditions that foster an environment where pseudonyms are used in CMC. This study acknowledges that Bales’s IPA may not account for *‘…multidimensional relational qualities’* and that its categories alone may be *‘…rigid’* (Jaffe et al, 1995: p, 411). Jaffe et al (1995) adopted extra categories used by Rice and Love (1987) including:

- Communications which refers to others communications.
- Communications which include ‘first-person pronouns’ such as ‘I’, and ‘me’.
- Communications which provide support, such as ‘…that’s true’.
- Emotional communication using an electronic symbol, such as an emoticon.

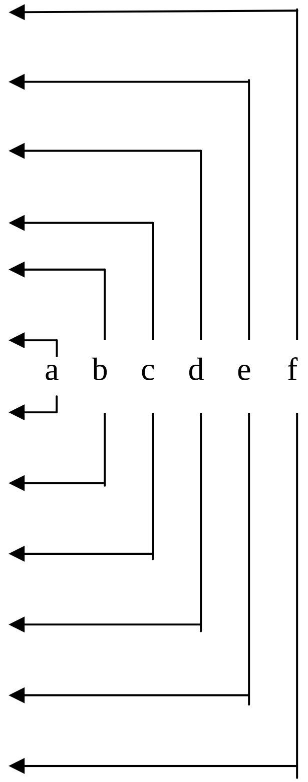
Using a revised version of Bales’s IPA, Jaffe et al (1995) established that under study conditions people using CMC felt more comfortable using pseudonyms instead of their true identity. They found no significance attached to the experience levels of participants (as those with little or significant experience of CMC participated equally).

Chou’s (2002) study compared the interactions which occur in both asynchronous and synchronous distance CMC learning. Bales’s IPA was expanded so that both the ‘gives orientation’ and ‘asks for orientation’ categories in the ‘task orientation’ section of the system included sub-categories. The sub-categories for the categories concern personal information, topic-related information, and technical information. Findings from this research included:

- More socio-emotional (SE) interactions occur in synchronous CMC compared with asynchronous CMC.
- There was an increase in one way communication in the asynchronous mode when compared to the synchronous CMC.
- There were gender interaction differences where females engaged in SE more often than males in both forms of CMC.

Figure 6.3 Interactions present within teams [adapted from Bales (1951)].

		Interactions	Description
	A	**Shows solidarity**	Raises other's status, gives help, reward
	A	**Shows tension release**	Jokes, laughs, shows satisfaction
	A	**Agrees**	Shows passive acceptance, understands, concurs, complies
E	B	**Gives suggestion**	Direction, implying autonomy for other
E	B	**Gives opinion**	Evaluation, analysis, expresses feeling, wishes
E	B	**Gives orientation**	Information, repeats, clarifies, confirms
E	C	**Asks for orientation**	Information, repetition, confirmation
E	C	**Asks for opinion**	Evaluation, analysis, expression of feeling
E	C	**Asks for suggestion**	Direction, possible ways of action
	D	**Disagrees**	Shows passive rejection, formality, withholds help
	D	**Shows tension**	Asks for help, withdraws out of field
	D	**Shows antagonism**	Deflates other's status, defends or asserts self.



KEY

a = Problems of communication
b = Problems of evaluation
c = Problems of control
d = Problems of decision
e = Problems of tension reduction
f = Problems of reintegration

A = Positive reactions (Socio-emotional area: positive)
B = Attempted answers (Task area: neutral)
C = Questions (Task area: neutral)
D = Negative reactions ((Socio-emotional area: negative)
E = Task area neutral

Gorse and Emmitt's (2003) study assessed three methodologies used with small groups to determine an appropriate method for analysing group interaction. The methods examined were: 'diaries and interviews', 'observation supported by audio recordings', and 'observation using Bale's IPA'. These researchers considered Bales's IPA to be effective and the least onerous for researchers and participants. The participants felt comfortable knowing that their interactions were not being analysed for what was being said, but rather for the content of their speech.

The major preliminary findings from this study indicated a lack of Socio-Emotional (SE) interaction between construction partners and that most interactions were task orientated. Gorse and Emmitt (2003) argue that this may account for the 'adversarial behaviour' dominating the construction industry today. However it was also observed that SE communication raised the alertness of team members, especially negative SE communication such as 'disagreeing'.

Bales's Interaction Process Analysis was selected as it specifically investigates the interaction and communication between team members. It has been used in a number of studies into the move from face-to-face to CMC.

6.5 Systemic Functional Linguistics

Systemic Functional Linguistics (SFL) (Halliday 1985, 1994) is a theory of language which is concerned with the practical or functional use of language. It considers language to be a system of resources from which every speaker makes choices, depending on who is being spoken to, about what and in what situation. Thus context has a critical effect on not only what is said but also what form it takes.

Context is considered to be a combination of three important dimensions, viz. field, mode and tenor. Field refers to the nature of the interaction that is taking place (e.g. a lecture/presentation, social conversation, management meeting). The mode reflects the part that language is playing in the interaction depending on what channel is used (e.g. oral, written, graphic, gesture). The tenor refers to the participants in the interaction (personal characteristics, status, and role). These three play a significant role in determining which aspects of language use are affected by particular dimensions of the context (Eggins, 1994). The contextual variables relating to this project are described in Table 6.3.

Table 6.3 Dimensions of context for design team collaboration.

Contextual variable	Description
Field	Team collaboration
Tenor	Architects and engineers, relatively equal status, varying levels of familiarity.
Mode	Three levels of ICT setup (reflecting different degrees of oral, written, graphic and non-verbal communication).

The main focus is the effect of the mode or channel of transmission of information on the interaction which takes place. The field remains the same across the three ICT levels. The tenor of the interactions will vary depending on the characteristics of the participants involved. SFL has been used to analyse the functional use of language in a wide variety of interactive situations. A few are classroom teaching (Lukin, 1995) treatment sessions (Ferguson & Elliot 2001) team meetings in the food industry

(Slade et al. 1995) and in hospitals (Iedema & Scheeres 2003) and in trade bargaining simulation (Carr et al 2004).

Two methods of analysis from SFL, particularly relevant to this project, supplement and complement the communication analysis provided by Bales's Interaction Process Analysis (Section 6.4).

6.5.1 Exchange Structure Analysis

All interactions are based around the demanding and giving of information or goods and services. An exchange is comprised of 'moves' (units of information) and each exchange is a sequence of moves (Martin, 1992). In an exchange, information is either being requested or provided, or actions are being requested or provided.

Exchange structure analysis has two types of moves:

- **Synoptic moves** - comprise the asking or providing of information/goods. Exchanges can be initiated by either participant. Therefore the roles of primary knower (the person who has the information/goods) and the secondary knower (the person to whom the information/goods are given) can be taken by any participant during different exchanges.

- **Dynamic moves** – perform the function of negotiating meaning (e.g. confirming, giving feedback, checking, clarifying,). These moves are used when the exchange of information is challenged or when speakers misunderstand each other.

Synoptic moves are thus used when the communication of information progresses smoothly whilst dynamic moves are needed when communication breaks down. The choice of language that participants make during information exchange depends on the context of the situation. For example, the choice of language may vary depending on the mode used (e.g. specific language needs to be selected to overcome the lack of nonverbal communication available in virtual worlds).

6.5.2 Mood and Modality

Politeness markers from SFL (Halliday 1985) are the linguistic choices of mood and modality. This analysis investigates how direct collaborators are during interactions. *Mood analysis* measures the degree of directness or certainty in speakers' utterances (e.g. more direct questions like 'Are you leaving tomorrow?' to less direct, more polite forms such as 'You're leaving tomorrow aren't you?'). *Modality* refers to the range of meaning between negative and positive which reflects uncertainty or directness. For example, the statements 'You forgot to add that detail' and 'I think perhaps you must have forgotten to add that detail' vary in directness.

These politeness markers reflect the relationships set up in the context and how information is exchanged to reflect the context (e.g. how requests are made and how the answers are given). Thus the choice of language that participants use reflects not only their relationship with each other (e.g. familiarity, status, role) but also the constraints placed on them by the different stages of ICT setup.

Effective design team collaboration requires trust-building between members. The use of politeness markers reflects the amount of trust that has been developed between collaborators. Although politeness markers reflect less direct communication and may therefore be less time efficient, they facilitate the communication of information by increasing the level of trust between collaborators. Furthermore, in dealing with team members of different cultures, the directness or definiteness of utterances may be of additional relevance in team-building (e.g. Chinese people tend to be less direct in their speech than Australians to avoid embarrassment – Mason & Murray 1999).

6.6 Reliability and Validity

Two major concerns with content analysis are reliability and validity. Reliability refers to the ability of the results to be replicable, so that if one coder analysed a section of interaction and then another did the same, they would obtain similar results (Weber 1990). Validity refers to the extent to which content analysis measures what the experimenter intends to measure (Weber 1990). It is possible to create a measure which is valid, but which is not reliable, however a measure which is not valid will never be reliable (Black 1993).

6.6.1 Reliability

Reliability is a measure how consistent two measures are in testing for the same thing. This includes using the same test twice or using two different coders (Black 1993). Ambiguity is the 'enemy' of reliability within any analysis system (Weber 1990). If the coding systems and definitions are ambiguous it may be impossible for separate coders to use the framework and reproduce similar results. Therefore reliability is associated with replicability (Winter 2000). Reliability for the researchers indicates that all precautions have been taken to eliminate bias, confounding variables, and that the data is significant in the same way for other researchers (Krippendorff 2004). Reliability allows researchers to apply an empirical result to their confidence in their data (Krippendorff 2004). There are three types of reliability that must be considered (Krippendorff 2004, Weber 1990):

1. **Stability** (weakest) (Weber 1990): Stability refers to those factors including ambiguity of the systems and definitions. This form involves 'testing and retesting' where the one 'observer' attempts to remove inconsistencies (tests intra-observer inconsistencies).

2. **Reproducibility** (medium): Reproducibility refers to the extent of similarity which may occur between the analyses conducted by two different coders. This involves 'testing and testing' where the method is repeated by a second independent coder (tests intra-observer inconsistencies and inter-observer disagreements).

3. **Accuracy** (strongest): Accuracy refers to how the coding may deliver similar results to an already established coding system. This is the strongest indication of reliability. It involves testing the coding against an external standard (tests intra-observer inconsistencies, intra-observer disagreements and deviations from a standard).

Others noted by Black (1993) include:

4. **Equivalence**: Administering two equivalent measures or tools to the same group twice in one day.

5. **Intra-judge** (scorer): This is appropriate when a large amount of data has been collected and the consistencies of the measures need to be examined. This involves taking a random sample from two points and calculating the reliability.

6.6.2 Validity

The most important aspect of validity is that coding systems actually relate to their *'…causes and consequences'* (Weber, 1990: p, 18), and that they measure what they set out to measure (Krippendorff 2004). Thus, validity is associated with the notion of accuracy (Winter 2000). For example in this study if a category were named DECISION, for it to be valid it would have to correspond with the concept of 'decision making in design team interaction'. There are many tests of validity, the most commonly used and probably the weakest is **face** [construct (Black 1993)] validity, as it relies on one single variable (Weber 1990). Face validity is basically a case of using common sense (Krippendorff 2004, Weber 1990). According to Weber (1990) there are four other more robust tests of validity which may be measured against external 'criteria':

1. **Content Validity** (Black 1993): refers to the extent to which a category correlates with an external measure of the same category. This allows categories and concepts to be generalised across analysis systems.

2. **Hypothesis Validity**: refers to the way in which a category relates to other external measures and theory. As the frequency of a category changes it results in changes to concepts and categories according to other measures and theory, so that, for example, as DECISION increases the amount of decision making in design increases, and subsequently there must be a decrease in CO-ORDINATION as an activity.

3. **Predictive Validity**: relates to the extent to which events or occurrences outside the influence of a content analysis study correlate to the events and occurrences within the study. Krippendorff (2004) states that predictive validity may be defined by two criteria:
   a) validating evidence for predictive validity need not be current; and
   b) predictions need to be specific.

4. **Semantic Validity**: Semantic validity refers to the experience of having different coders familiar with the language and texts, who upon examining the system agree that the components of a category have similar definitions or meanings. This refers to the amount of ambiguity in a system and is generally reserved for words which may have more than one meaning or connotation such as 'try'.

It is essential that reliability and validity is determined to ensure that the analysis framework consistently measures the generic skills identified.

6.7 Summary

An analysis framework for generic skills has been created. Protocol and content analysis provide a method by which design collaboration can be analysed, particularly the interaction between design team members. While content and protocol analysis facilitate human analysis, behavioural markers provide recorded observable behaviours which determine generic skill frequency. Skills are not easily measurable observable behaviours. However, behaviours can be recorded and may be indicative of specific generic skills.

7 ANALYSIS FRAMEWORK

This section describes the methodology of this study. The aim is to discover whether the generic skills used by design team participants are affected by the virtuality of the design process. The methodology is split into a *Pilot Methodology* and an *Experimental Methodology*. Both initially explore the requirements and subsequent choice of participants. Also included is an examination of the issues and techniques involved with video recording design teams and some technologies that facilitate this process.

This study analyses video data of design collaboration using three analysis frameworks:

1. Generic Skills Framework
2. Bales's Interaction Process Analysis (IPA), and
3. Systemic Functional Linguistics

This section outlines these three frameworks. They provide a basis for conducting protocol analyses on video data of design collaboration. The following sub-sections illustrate the format of this methodology:

7.1 Video Data Collection

Video is an attractive medium for recording team behaviours because it allows actions to be stored, reviewed and analysed over an extended timeframe. There are, however, some challenges associated with video recording (Mackenzie, Xiao and Horst 2004) including:

- technical complexity
- resource and time requirements
- need to use excellent equipment for meaningful data collection
- inability to identify behaviours which occur off camera

The advantages of video recordings outweigh the negatives. Videoed observations offer researchers opportunities to collect accurate data without having to rely on memory (Mackenzie, Xiao and Horst 2004). Furthermore the ability to revise researcher's observations of recordings allows for progressively finer grained analysis with each iteration (Guerlain *et al.* 2004, Xiao *et al.* 2004). The data extracted from video recordings is superior to that which could be collected through live observation and note taking (Xiao *et al.* 2004).

It was possible to address the potential shortcomings noted above. The design environment used was not dynamic, as most work was conducted at a stationary, central location. Movement of team members around their videoed environment was minimal. Video recordings replaced live observations thus avoiding the need to actually be on site (Guerlain *et al.* 2004)**.**

A clear advantage of this method is that researchers have a digital record which can be used in other ethically approved experimental work. For example, if researchers wished to investigate other aspects, the same data could be utilised (with the participants consent) as opposed to commissioning a new set of experiments.

Guerlain et al (2004) outline other ethical issues, such as regulatory and legal challenges, related to video recordings. In the context of this study, mock design briefs were used to address these concerns. Moreover, confidentiality issues bound the researchers to uphold the privacy of the participants. The final issue raised by Guerlain et al (2004) related to the ability of researchers to set up and operate the video recording technology successfully. Fortunately, experienced personnel employed by the University of Sydney collected all data.

7.2 Pilot Methodology

This methodology relates to a pilot study conducted using one design team. The results of this study informed the final generic skills coding scheme.

7.2.1 Pilot Study Participants

Participants needed to be involved in the design industry in some capacity and were recruited from an architectural practice. This firm is a multi-national organization with base offices in Sydney and Melbourne, and multiple offices in Asia and Europe as well as other Australian capital cities.

Contact with potential participants was organised through the city based managers and the CRC-CI contact. The participants were randomly chosen from design staff, based on their relative availability. They were of either gender and had a varying degree of experience and influence (power), with the range being from higher management to junior staff. They were of different ages. It was unknown what tertiary training or TAFE education the participants had engaged in, or whether they had any training in working in collaborative design teams or with collaborative technologies. This random assignment was appropriate because it represents the way design teams operate in practice. It is often the case that design team members are from very different backgrounds/cultures, ages, and experience (Marchman 1998), especially in multi-disciplinary design teams collaborating on a single project.

7.2.2 Pilot Research Design for Generic Skills Framework

To examine the generic skills used by design teams, relevant literature was examined and a generic skills framework was created. The generic skills selected as representative of team collaboration are shown in Table 7.1.

Table 7.1. Generic skills taken from literature (see 5.3)

Behaviour Class	Description	Elements
Generic Skills	Those non-technical skills which a team member uses when collaborating with team members.	Adaptability, Shared Situational Awareness, Performance Monitoring and Feedback, Leadership/Team Management, Interpersonal Relations, Co-ordination, Communication, Decision Making.

7.2.2.1 Description of Generic Skills

Each behavioural class consists of behavioural elements. The behavioural elements which contribute to the skills profile are listed in Table 7.2. The coding system i.e. the observable behaviours which represent these generic skills are shown in Table 13.1.

Table 7.2 Table of Generic Skills for Team Collaboration and descriptions as taken from *Behavioural Marker* research.

Generic Skill	**Description**
Adaptability	The use of compensatory behaviour and reallocation of resources to adjust strategies based on feedback.
Shared Situational Awareness	When team members have compatible mental models of the environment within and outside of their team.
Performance Monitoring and Feedback	Ability of team members to give, seek and receive task clarifying feedback.
Leadership/Team Management	Ability to direct and co-ordinate the activities of other team members pertaining particularly to performance, tasks, motivation, and creation of a positive environment.
Interpersonal Relations	Ability to optimise the quality of team members' interactions.
Co-ordination	Process by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronised and completed within established temporal constraints.
Communication	Information exchange between members using the prescribed manner and terminology.
Decision Making	Ability to gather and integrate information, use sound judgment, identify alternatives, select appropriate solutions and evaluate consequences.

7.2.3 Pilot Participant Methodology

While designers in co-located conditions were familiar with their surroundings and the techniques involved in collaborative design sessions, participants needed to be trained to use new collaborative software. Before each design session a substantial amount of time was spent familiarising designers with the technology. Once designers were suitably familiar with the software, they were allowed to participate in the design sessions. No briefs were provided. Each designer was asked to discuss a design they were currently working on with another designer working on the same project. They were given approximately 30 minutes to collaborate using each type of collaboration technology.

Data was collected to ensure the methodology and recording techniques were robust. These pilot sessions were conducted in the architect practice's offices in Sydney for the co-located stage, and at the University of Sydney for the second and third stages. The first co-located sessions used a small pool of participants who were designing a building in Canberra, ACT. This data provided an insight into the design sessions and enabled researchers to test the methodology. Of note are the following issues:

- Because of the timing of the project, researchers were unable to record data of designers engaged in conceptual design. Consequently the majority of design sessions consisted mostly of design explanation.
- Some of the camera angles were not ideal
- A member of the research group was a participant in stages two and three.

7.2.4 Reliability Analysis

Data collected for the pilot study was analysed to determine the reliability of the coding methods. Due to manpower restrictions, intra-rater reliability was initially established on twelve minutes of face-to-face data using the generic skill and interaction coding schemes. Point-by-point agreement was 57% and 56% on the two reliability tests conducted through Noldus Observer Pro (frequency of coding strings and frequency and sequence of the coding strings, respectively. These were both below the minimum level of acceptability of 80% (Kazdin 1982).

An examination of the coding revealed that two issues had contributed to the higher than acceptable percentage of disagreements, viz difficulty in differentiating between ‘shared situational awareness’ and ‘decision making’, and the large number of observations which may have occurred in one set of codes, but were not present in the other.

As a result, changes were made to the coding schemes. Firstly, Bales’s IPA was identified as a more valid and stable measure of decision making. Those observable behaviours (OB) for decision-making were subsequently merged with those for shared situational awareness. During this merger one OB from each was added to **performance monitoring and feedback**: explains a task and checks outcome of a design/solution against the problem. These changes to the generic skills coding scheme may be viewed in Table 13.2.

Secondly, the definition of a speech segment was clarified. Backchannelling was not included (as it was analysed using the Systemic Functional Linguistic coding) but single word responses to a direct question were.

Intra-reliability was again established on a complete session (35 minutes) using the revised coding scheme. Point-by-point agreement was 80% and 84% (frequency of coding strings and frequency and sequence of the coding strings, respectively), which is at or above the minimum acceptable level of 80% (Kazdin 1982b).

Further details of the reliability analyses can be found in Appendix 17.

7.3 Experimental Methodology

On completion of the pilot study and the creation of a robust generic skills coding scheme, some issues remained are required refinement. These are described below. A new generic skills coding scheme was created and this was then used to examine the remaining video data.

7.3.1 Experimental Participants

All participants were designers working in architectural practices. Ideally participants should have been recruited from a diverse range of disciplines (for example, structural engineering, construction or other similar professions) but engaging practitioners from more that one profession proved challenging. To attract sufficient participants it was necessary to recruit from our CRC-CI industrial partners as well as through the University of Sydney.

Five design teams were assembled, each consisting of two designers. Participants were grouped in pairs based on their availability, with preference being given to those who had worked together before. Participants were predominantly male (with only one female taking part) and had varying degrees of experience and influence (ranging from top management to junior staff).

7.3.2 Participants Methodology

Designers interacting in the co-located condition were familiar and comfortable with their surroundings and the collaboration techniques they used. However, in the second and third **stages** participants needed to be trained in the use of the new collaborative software. Before each session the research team spent 1-2 hours familiarizing designers with the technology. Participants were then allowed to participate in the design sessions.

Each designer received a brief for the architectural aspects of a project and instructions about their role in the design process. All projects were fictional and related on an actual site at Sydney University. Three different design briefs were provided. They were for the structural design of an art gallery, a library and a dance school. The collaborators were given 30 minutes to prepare each design using the different collaboration technology. The outline for the presentation of these briefs and schedule is presented in Table 7.3.

Table 7.3 Table showing schedule for experimental video recording of design collaboration. Including time length, interaction and design tools, and the design brief to be followed.

Experimental Stages	Length	Tools	Design Brief
Face-to-Face (Co-located) Experiment - Stage 1	30 min	Paper/pencil	Design of an Art Gallery
Shared E-Whiteboard (Group Board) Experiment - Stage 2	30 min	Group Board on Smart Board	Design of a Library
3D Virtual World (Active Worlds) Experiment - Stage 3	30 min	Active Worlds on desktop	Design of a Dance School

7.3.3 Experimental Coding Scheme

Once the design sessions were recorded, the data were analysed using the generic skills coding scheme. A pilot generic skills coding scheme was based on human factors research, specifically the area of behavioural markers. Behavioural markers are observable non-technical (Klampfer *et al.* 2001) *'…aspects of individual and team performance'* (Carthey et al, 2003: p, 411) which are related to the effectiveness of an individual and a team. Behavioural markers, or more specifically the methods for the creation of behavioural markers, were analysed because they offer a physical description of non-technical skills [generic skills] (Kjellberg *et al.* 2003). Klampfer et al (2001) enforce the need for simple and clear behavioural markers, which use appropriate jargon and terminology. They argue that emphasis should be placed on an observable behaviour rather than an ambiguous attitude or opinion. So if generic skills behavioural markers from other industries, such as aviation and medicine, are used to identify observable behaviours in design terminology, they will need to be adapted to be relevant for design team interactions. This adaptation means altering discipline specific terminology or other behaviours.

Further research into behavioural markers revealed that the pilot Generic Skills coding scheme could be simplified. The Anaesthetists' Non-Technical Skills (ANTS) (Fletcher *et al.* 2004) system was adapted for this purpose (see Table 7.4) . The nature of generic or non-technical skills implies that they are transportable between teams, as they are not directly involved in the technical aspects of the process. Using the ANTS system in the design domain allowed some of the skills previously mentioned to be merged, and resulted in a simpler coding scheme. Furthermore *decision-making* and *communication* are accounted for or incorporated within the ANTS scheme.

While effective communication would appear to be an essential component of team interaction, it is impossible to separate it from the observable behaviours associated with skills. Behavioural marker research indicates that communication is such an essential part of these non-technical skills that the nature of the analysis dictates that communication cannot be separated from these skills (Fletcher *et al.* 2004). Communication was thus excluded from the generic skills coding scheme as it is inherent in every other skill.

The skills included in the original and revised generic skills coding schemes were derived from behavioural marker research (Klampfer *et al.* 2001), so the transition and adaptation of these skills is well founded. Behavioural marker systems provide a rating system where the actual effectiveness of the skills is examined. However the requirements of this study are different and aim to detect whether the level of skill usage changes depending on the virtuality of the team. Searching for the presence and frequency of these skills is appropriate, and results in a set of behaviours recording effective skills usage. Interestingly, investigations in the design profession (Lewis and Bonollo 2002) into generic (or professional) skills showed that the skills identified related closely to the new generic skills coding system.

Table 7.4 Non-technical skills as presented by the ANTS system (Fletcher *et al.* 2004) and their adapted definitions.

Non-Technical Skill	**Definitions**
Task Management	"Managing resources and organising tasks to achieve goals, be they individual or team related"
Team Working	"Working with others in a team context, in any role, to ensure effective joint task completion and team satisfaction; focus is particularly on the team rather than the task"
Shared Situational Awareness	"Developing and maintaining an overall dynamic awareness of the situation based on perceiving the elements of the… environment"
Decision Making	"Making decisions to reach a judgement or diagnosis about a situation, or to select a course of action, based on experience or new information under both normal conditions and in time-pressured crisis situations"

Table 7.5 illustrates how the new skills are composites of the original skills, and also how the professional skills identified by Lewis and Bonollo (2002) were taken into consideration.

Table 7.5 Table showing the relationship between the ANTS generic skills, Salas's (2000) generic skills and Lewis and Bonollo's professional design skills.

ANTS Non-Technical Skills (Fletcher *et al.* 2004)	Generic Skills found in the Literature (Salas, Burke and Cannon-Bowers 2000)	Professional Design Skills (Lewis and Bonollo 2002)
Task Management	Leadership/Team Management	Project Management
	Performance Monitoring and Feedback	Acceptance of Responsibility
Team Working	Interpersonal Relations	Interpersonal Skills
	Co-ordination	
Situational Awareness	Adaptability	Negotiation
Decision Making	Decision Making	Problem Solving

Full descriptions and observable behaviours for the adapted ANTS coding scheme (Final Generic Skills Coding Scheme) can be viewed in Table 13.3.

7.3.4 Reliability Testing

Intra-rater reliability was established for the generic skills coding scheme on a 30-minute face-to-face session using Noldus Observer Pro. Point-by-point agreement was 81% and 80% on the frequency of coding strings and frequency and sequence of the coding strings, respectively. These were both at or above the minimum level of acceptability of 80% (Kazdin 1982b). Detailed reliability analysis of this session can be found in Appendix 18.

7.4 Additional Frameworks

Alternative frameworks employed in this study allow for the analysis of other informative aspects of design collaboration and contribute to the generic skills aspect of the study. They allow a deeper analysis of the concepts already being measured and of design team interactions as a whole. This study incorporates two additional forms of analysis 'Bales's Interaction Process Analysis' and 'Systemic Functional Linguistics'.

7.4.1 Bales's Interaction Process Analysis (IPA)

Bales's Interaction Process Analysis (IPA) provides an understanding of the interactions of a group of people engaged in a task. It provides a *'…method of classifying direct, face-to-face interaction'* (Bales, 1951: p, 5). Bales intended this system to generate a set of categories which are generic in nature and representative of team/human interactions (Bales 1951). It was not intended to measure interaction based purely on transcripts of speech as it includes non-verbal interactions, including gestures. Bales's Interaction Process Analysis was selected as it specifically investigates the interaction and communication between team members and has been used in a number of studies into the transition from face-to-face to 'computer mediated communication' (CMC) (Chou 2002, Gorse and Emmitt 2003, Jaffe *et al.* 1995, Pena 2004). As Gorse and Emmitt (2003) state, it is an extremely non-intrusive and simple method of content analysis. The framework for IPA is outlined in Figure 6.3.

7.4.2 Systemic Functional Linguistics

Systemic Functional Linguistics (SFL) (Halliday 1985, 1994) is a theory of language which is concerned with the practical or functional use of language. Two methods of analysis from Systemic Functional Linguistics (SFL) will be used to analyse the interaction between the participants during design team collaboration. These methods (exchange structure analysis and politeness markers) elaborate on Bales's Interaction Process Analysis (Bales 1951) to provide additional details on the interactions taking place within the three bandwidth levels.

From the *exchange structure* analysis (the first method), the efficiency of information exchange (i.e. the amount of time spent requesting and receiving information) and the amount of time needed to repair communication breakdown can be determined. The particular strategies which facilitate and hinder communication in different levels of ICT setup can therefore be ascertained. The categories to be determined are presented in Table 7.6.

Table 7.6 Categories of synoptic and dynamic moves

Type of move	**Code**
SYNOPTIC MOVES	
Person giving information	K1
Person receiving information	K2
Follow up move by K1	K1f
Follow up move by K2	K2f
Delayed K1 move	DK1
Person carrying out action	AC1
Person in receipt of action	AC2
Follow up move by AC2	AC2f
Follow up move by AC1	AC1f
Delayed ac1 move	Dac1
DYNAMIC MOVES	
Tracking moves	
Back channel	Bch
Forward channel	Fch
Replay request	Rprq
Response to replay request	rrprq
Confirmation request	Cfrq
Response to confirmation request	Rcfrq
Clarification request	Clrq
Response to clarification request	Rclrq
Confirmation	Cf
Clarification	clar
Check	Check
Collocational prompt	Cp
Self-correct	Sc
Response to check	rcheck
Challenging moves	
Challenge	Chall
Response to challenge	Rchall
Justification	Jst
Response to justification	Rjst
Additional	
Call	Call
Response to calling	Rcall
Greeting	Greet
Response to greeting	Rgreet
Exclamation	Ex
Response to exclamation	rex

The *politeness markers* analysis (the second method) was used to investigate the relationships built up between the collaborators in the three levels of ICT setup. The relationships established are critical to team building and trust within any situation. An analysis of politeness markers indicates how the different ICT levels affect the communication used to establish and develop these relationships. It therefore indicates aspects of communication which hinder or facilitate team-building within specific contexts. The markers examined are provided in Table 7.7.

Table 7.7 Politeness markers from SFL (Halliday 1985, Togher and Hand 1998).

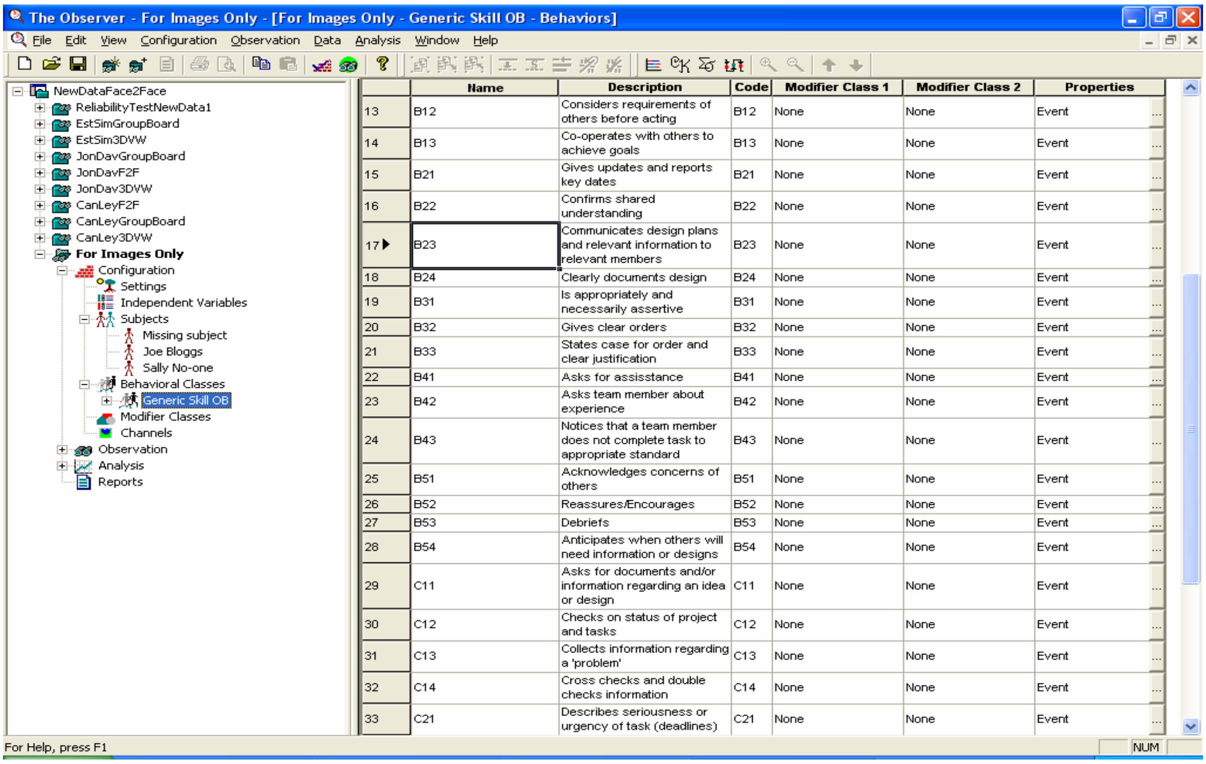
Politeness marker	**Example**
Finite modal verbs	Would, could, should, might, must
Modal adjuncts	Perhaps, probably, possibly
Comment adjuncts	I think, unfortunately
Yes/no tags	You brought that drawing didn't you?
Incongruent realizations of interrogatives	You don't know when the design will be completed or anything?

7.5 Coding Design Team Observations: Noldus Observer Pro Video Analysis Software

Noldus *'…Observer is a professional and complete manual event recorder for the collection, management, analysis and presentation of observational data…of humans and animals'* (Burfield, 2003: p, 21). This software allows researchers to view live behaviour or recorded video data, and score the frequency of specific behaviours, as well as how these behaviours interact with each other or independent variables. Once the video is coded, Noldus becomes a database for instances of the analysed video, allowing instances of interest to be packaged and played in any desired order. Noldus Observer Pro has been successfully used to study human interactions and communication (Blackler and Popovic 2003, Eide *et al.* 2003, Williams and Cowdroy 2002).

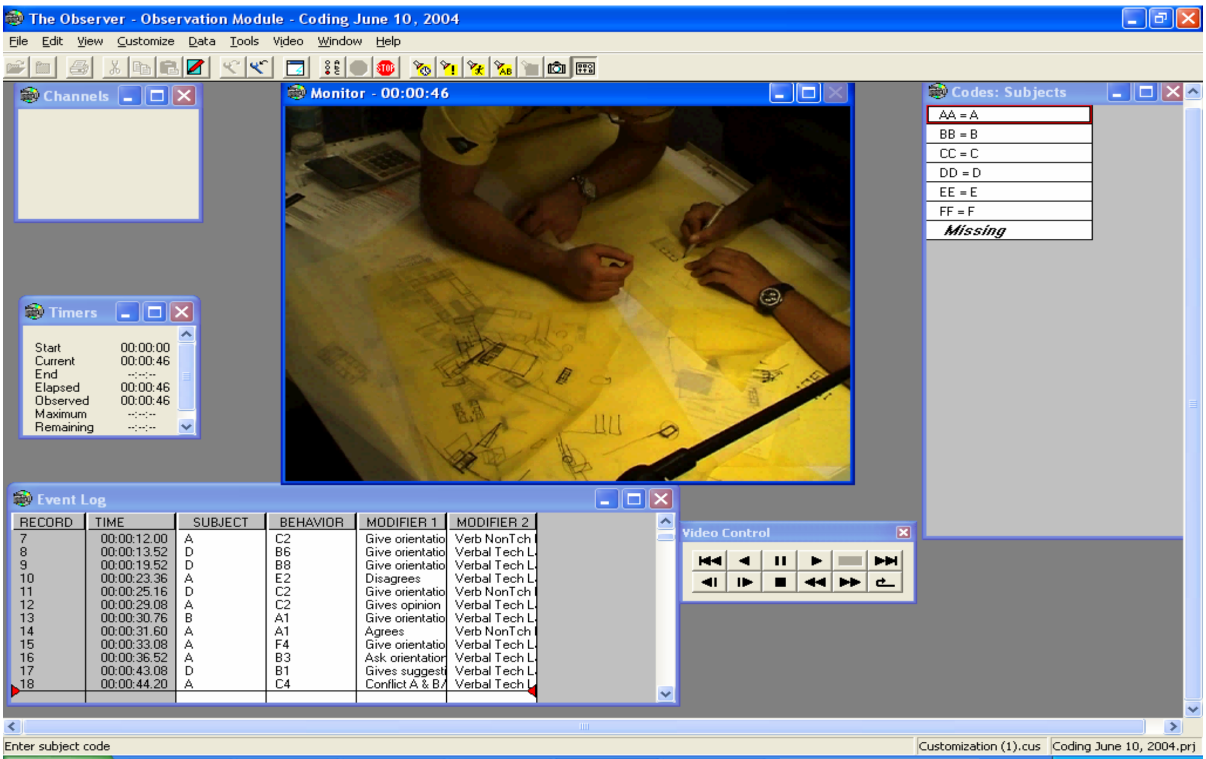
Figure 7.1 shows the generic skills coding scheme within Noldus. This study is limited to one behaviour class (that of 'generic skills') which is measured by inserting observable behaviours in Noldus chosen by a coder during video analysis. The frequency of these observable behaviours indicates the frequency of certain generic skill utilisation.

Figure 7.1 Screen showing the creation of a coding scheme within Noldus Observer.



Once the coding system had been entered into Noldus, observation and coding began. Figure 7.2 shows a screen as the coding process occurs. The coder is presented with the visual and audio data from a design session and is then able to record time, subject, observable behaviour (generic skill) and interaction. These coding strings appear in the 'event log' in the bottom left hand corner of Figure 7.2.

Figure 7.2 Screen showing the video coding window in Noldus Observer.



When the coder has completed the video analysis, Noldus generates a set of results. One of the outputs available is a list of the coded strings as shown in Table 7.8. These strings maybe placed into Excel or other statistics programs for testing.

Table 7.8 Example of Coded Data for analysis (Generic Skill)

Time Stamp	Subject	Generic Skill
17.64	E	Task Management
19.52	S	Team Working
30.56	E	Team Working
50.08	E	Task Management
80.52	E	Task Management
93.88	S	Task Management
99.64	E	Task Management
140.24	E	Task Management

7.6 Generic Skills in Relation to Information and Communication Technology (G-SICT) Questionnaire

Another aspect of this study gathered information on industry's perceptions of ICT and generic skills. A questionnaire was used to gauge designers' perceptions.

The questionnaire is shown in Figure 16.1. It is divided into five sections:

A. Demographics (including current use of virtual technology)
B. Importance of generic skills to simple (current) design collaboration
C. Importance of generic skills to virtual technologies
D. Importance of generic skills and their perceived use in current collaborative design situations.
E. Open questions on the management and useability of virtual technologies.

The questionnaire was administered electronically using the Sphinx Survey. Sphinx Survey is '…an all-in-one program for the design, administration, processing and analysis of surveys…' (Sphinx Development Uk 2005). The system facilitated the creation of an on-line questionnaire and the collection and analysis of respondents' data. Participants were recruited from CRC-CI industry partners and professional institutions via email. Managers were asked to email an "Information Sheet" to employees or members and to request assistance to complete the survey. Completion of the questionnaire by a participant was taken as their consent.

7.7 Summary

The video analysis methodology was tested with the pilot generic skills coding scheme. The scheme was modified to improve reliability but it was found that it did not address the full range of skills identified in the literature. A new coding scheme was developed based on behavioural markers research (the ANTS behavioural marker system). This new generic skill coding scheme was found to be reliable and was adopted as the final scheme. In support of this coding scheme Bales Interaction Process Analysis and Systemic Functional Linguistics were also used to analyse the non-technical aspects of design collaboration.

8 RESULTS

The results of the three areas 1) Generic skills (and associated observable behaviours), 2) Bales's Interaction Process Analysis and 3) Systemic Functional Linguistics are presented separately.

8.1 Data Analysis

The coded data, shown in Table 8.1 and Table 8.2, for generic skills and Bales's IPA, and systemic functional linguistics respectively, illustrate the output of Noldus Observer Pro. The aforementioned tables document every interaction recorded. For example, there were 4611 lines of code for generic skills and Bales's IPA. Each line of code provided a time stamp, subject code, and generic skill, interaction or systemic functional linguistic behaviour. The data was then arranged into contingency tables in order to complete the appropriate statistical tests.

Table 8.1 Example of Coded Data for analysis (Generic Skill and Bales's IPA)

Time Stamp	Subject	Generic Skill	Interaction
17.64	E	Task Management	Give orientation
19.52	S	Team Working	Agrees
30.56	E	Team Working	Tension release
50.08	E	Task Management	Give orientation
80.52	E	Task Management	Give orientation
93.88	S	Task Management	Give orientation
99.64	E	Task Management	Give orientation
140.24	E	Task Management	Gives suggestion
141.48	E	Team Working	Give orientation
143.24	E	Team Working	Asks opinion
144.20	S	Team Working	Agrees
148.28	E	Task Management	Gives suggestion

Table 8.2 Example of coded data for the Systemic Functional Linguistics Coding Scheme

Time Stamp	Subject	SFL Behaviour
55.91	A	tags
56.08	A	check
58.87	A	check
60.83	B	rcheck
62.58	A	K1
64.95	A	fv
66.45	A	K1
233.12	A	check
233.12	A	tags
235.41	B	rcheck
236.00	A	2kf
236.00	A	K1
236.79	A	ca

8.2 Statistical Tests

The data for the generic skills and Bales interactions were analysed using a Repeated Measures Analysis of Variance parametric test. This method assumes that the performance of participants on the three conditions will be intercorrelated so that a better participant would perform more highly during the three conditions while a poorer participant would perform to a lesser degree over the three conditions (Howell 1997). The results of the repeated measures ANOVA were interpreted using Mauchly's Test of Sphericity which examines the covariance of the dependent samples. This test applies the assumption that all covariance is equal (for independent samples covariance is always zero). A significant result ($p < .05$) for the test of sphericity indicates that this assumption has been violated (Howell 1997). In this case, a correction is needed and this is in the form of the Greenhouse-Geisser. If the value of the Greenhouse-Geisser has an Epsilon value greater than 0.75 then the more sensitive Huynh-Feldt is used. This test indicates which p value in the Within-Subjects Effects table is important in the determining the significance of the effect. The data were also examined using a test of 'Within-Subjects Contrasts'. This test determined which design process (bandwidth) shift; *face-to-face* to *group board'* or *group board* to *3D virtual world* is responsible for any significance.

Due to the distribution of the results, non-parametric statistical tests were employed (Cramer 1998) for the Systemic Functional Linguistics coding scheme. Although these tests are usually considered to be less powerful than parametric tests, this has been widely debated (Howell 1997). Non-parametric tests have been shown to be as powerful as their parametric counterparts (Doehring 1996, Howell 1997). In addition, non-parametric tests (particularly those employed in this study which use rankings) are not affected by a few outliers (Howell 1997). The non-parametric Friedman test for related samples was used to analyse the data.

For all statistical analyses, SPSS Version 12 was used. The complete tables for the statistical analyses can be found in the appendices.

8.3 Generic Skills

The results for each generic skill will be presented separately.

8.3.1 Shared Situational Awareness

The level of activity defined as '*shared situational awareness*', as the design process moved from face-to-face collaboration (low bandwidth) to 3D Virtual World (high bandwidth) design collaboration, increased significantly ($F(2, 8) = 4.903$, $p < .05$) (see Figure 8.1).

The Within-Subject Contrasts test indicated that *shared situational awareness* was being significantly influenced by the move from '*face-to-face to group board*' ($F(1, 4) = 19.478$, $p < .05$).

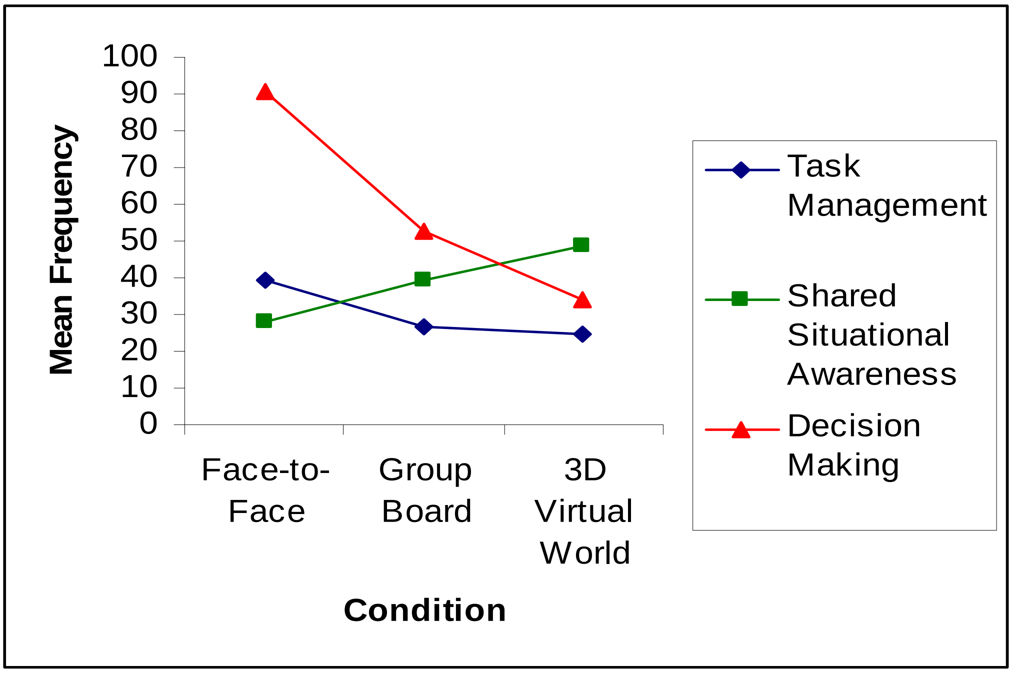
8.3.2 Decision Making

For Decision Making, there was a significant decrease ($F(2, 8) = 42.431$, $p < .001$) (see Figure 8.1) as the design setting moves from low to high bandwidth levels. The Within-Subject Contrasts demonstrated that the overall significance is being driven by the significant changes between two moves, '*face-to-face* to *group board'* and '*group board to 3D virtual world'* ($F(1, 4) = 120.274$, $p < .001$ and $F(1, 4) = 8.685$, $p < .05$ respectively). However there was a noticeable reduction in the frequency of *task* *management* skills as the design process moved from low to high bandwidth, so it has been included in Figure 8.1.

8.3.3 Task Management and Team Working

The generic skills of task management and team working did not change significantly between the three bandwidth levels ($F(2, 8) = 4.043$, $p > .05$ and $F(2, 8) = 0.45$, $p > .05$ respectively). However there was a noticeable reduction in the frequency of *task management* skills as the design process moved from low to high bandwidth, so it has been included in Figure 8.1.

Figure 8.1 Frequency of generic skills in three levels of bandwidth



8.4 Observable Behaviours

The frequencies of the Observable Behaviours were analysed again using the Repeated Measures ANOVA test and interpreting the results using Mauchly's Test of Sphericity. In most cases, the sphericity assumption was not violated and no corrections needed to be applied. The analysis of some observable behaviours was not performed due to their limited incidence.

In the interests of clarity, only those behaviours which changed significantly are presented below.

8.4.1 Outlines and Describes the Plan/Brief for the Design (A11)

There was a significant decrease ($F(2, 8) = 9.021$, $p < .05$) in the incidence of this behaviour as the design process moved from low to high bandwidth levels.

The Within-Subjects Contrasts shows that the specific move which is driving the overall significance for A11 is the move from '*face-to-face* to *group board*' ($F(1, 4) = 7.943$, $p < .05$). Therefore, although the generic skill Task Management was not significant, this observable behaviour A11 (which manifests Task Management) was.

8.4.2 Gives Updates and Reports Key Events (B21)

The observable behaviour '*gives updates and reports key events (B21)*' was found to have increased frequency significantly ($F(2, 6) = 6.343$, $p < .05$) as the design process moved from low to high bandwidth (see Figure 8.2). The move from '*face-to-face* to *group board'* conditions for this behaviour was found to be significant ($F(1, 3) = 16.734$, $p < .05$). As previously, the generic skill (Team Working) demonstrated no significant results but this specific behaviour (B21), which manifests Team Working, was significant.

8.4.3 States Case for Order and Gives Justification (B33)

As the design process moved from low to high bandwidth, the change in frequency of the observable behaviour '*states case for order and gives justification (B33)*' was significant ($F(2, 6) = 5.362$, $p < .05$) (see Figure 8.2). The decrease in B33 for the move from '*group board* to *3D virtual' world* conditions was found to be approaching significance ($F(1, 3) = 5.642$, $p = .098$), and so would suggest that the overall significance is being driven by this move.

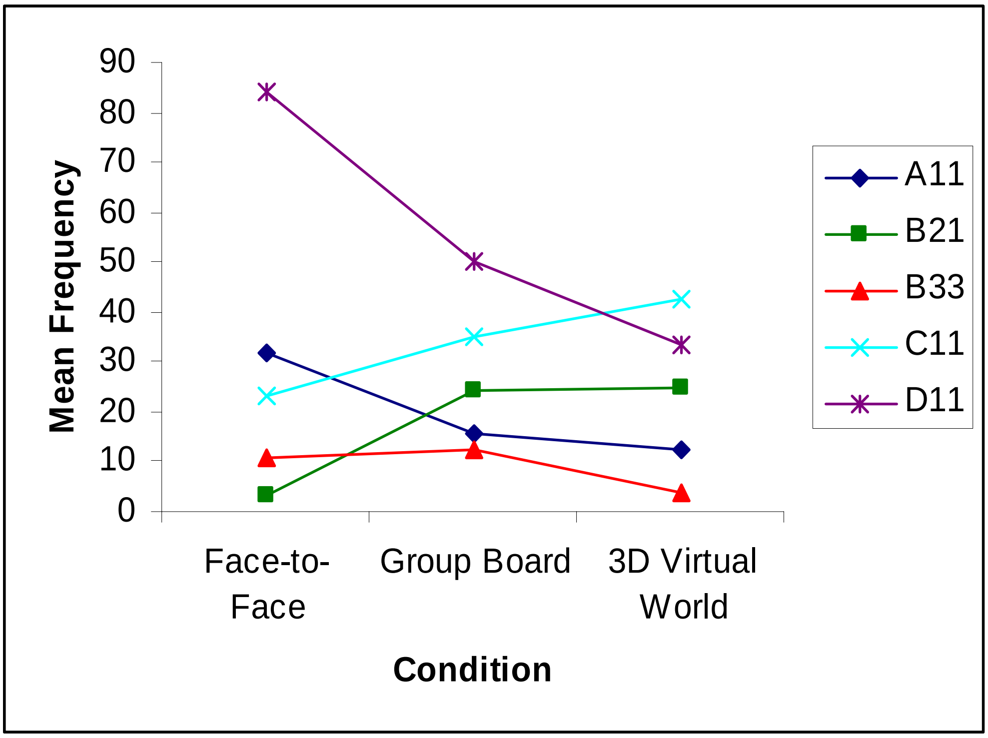
8.4.4 Asks for Documents and/or Information Regarding an Idea or Design (C11)

The observable behaviour '*asks for documents and/or information regarding an idea or design (C11)*' was found to have increased significantly ($F(2, 8) = 5.526$, $p < .05$) as the design process moved from low to high bandwidth (see Figure 8.2). The Within-Subjects Contrasts test showed a significant value ($F(1, 4) = 15.751$, $p < .05$) for the initial shift from '*face-to-face* to *group board'* conditions.

8.4.5 Discusses Design Options with Clients/Other Designers (D11)

As the design collaborators shifted conditions from low to high bandwidth, the frequency of the behaviour '*discusses design options with clients/other designers (D11)*' decreased significantly ($F(2, 8) = 25.383$, $p < .001$) (see Figure 8.2). The Within-Subject Contrasts test indicated that both shifts (*face-to-face* to *group board'* and *group board* to *3D virtual world) were significant (*$F(1, 4) = 46.24$, $p < .05$ and $F(1, 4) = 8.095$, $p < .05$, respectively).

Figure 8.2 Frequency of significant observable behaviours: A11, B21, B33, C11, D11, in 3 bandwidth conditions



8.5 Bales Interaction Process Analysis

The Repeated Measures ANOVA (discussed above) was used to examine the differences in the interaction profiles between the three different conditions. The interaction profile 'Shows antagonism' was not analysed due to its low incidence. The low number of this interaction may however point to other interesting areas within design collaboration.

For the sake of clarity, only those interactions which were significant are presented below. The complete tables for the statistical analyses can be found in the appendices.

8.5.1 Agrees

As the design collaborators moved from low to high bandwidth conditions, it was found that there was a significant decrease in frequency ($F(2, 8) = 8.457$, $p < .05$) in the category of interaction (see Figure 8.3). There was a significant change in the frequency of this category between the *group board* and *3D virtual world'* conditions ($F(1, 4) = 7.81$, $p < .05$).

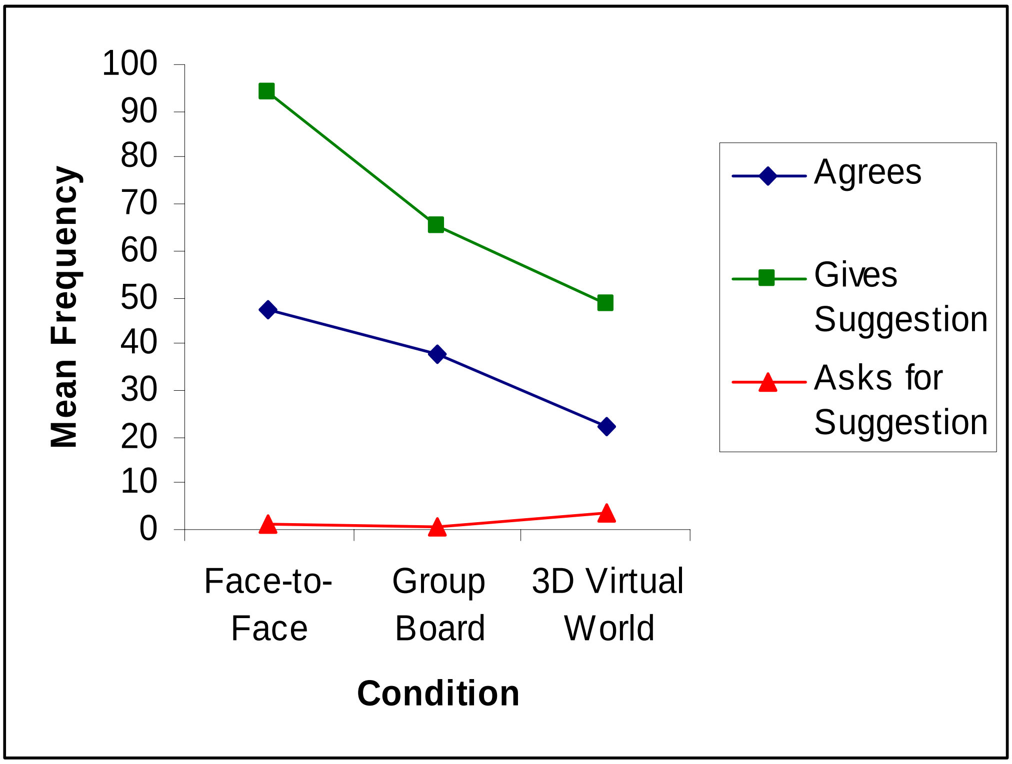
8.5.2 Gives Suggestion

A significant decrease in frequency ($F(2, 8) = 19.836$, $p < .05$) was also found for the interaction '*gives suggestion*' as the design collaborators moved from low to high bandwidth (Figure 8.3). The Within-Subjects Contrasts test indicated that the move from '*face-to-face to group board'* conditions was significant ($F(1, 4) = 22.3$, $p < .05$).

8.5.3 Asks for Suggestion

As the designers moved from low to high bandwidth conditions, there was a significant increase in the frequency of '*asks for suggestion*' interaction ($F(2, 4) = 12.182$, $p < .05$) (Figure 8.3). The increase from '*group board* to *3D virtual' world* conditions was also found to be significant ($F(1, 2) = 27.0$, $p < .05$).

Figure 8.3 Frequency of significant interactions: Agrees, Gives Suggestion and Asks for Suggestion, in three bandwidth conditions



8.6 Systemic Functional Linguistics

The following section presents the results for the linguistic aspects of the design teams under the three experimental conditions. The results of the two aspects analysed, exchange structure analysis and politeness markers, will be presented separately.

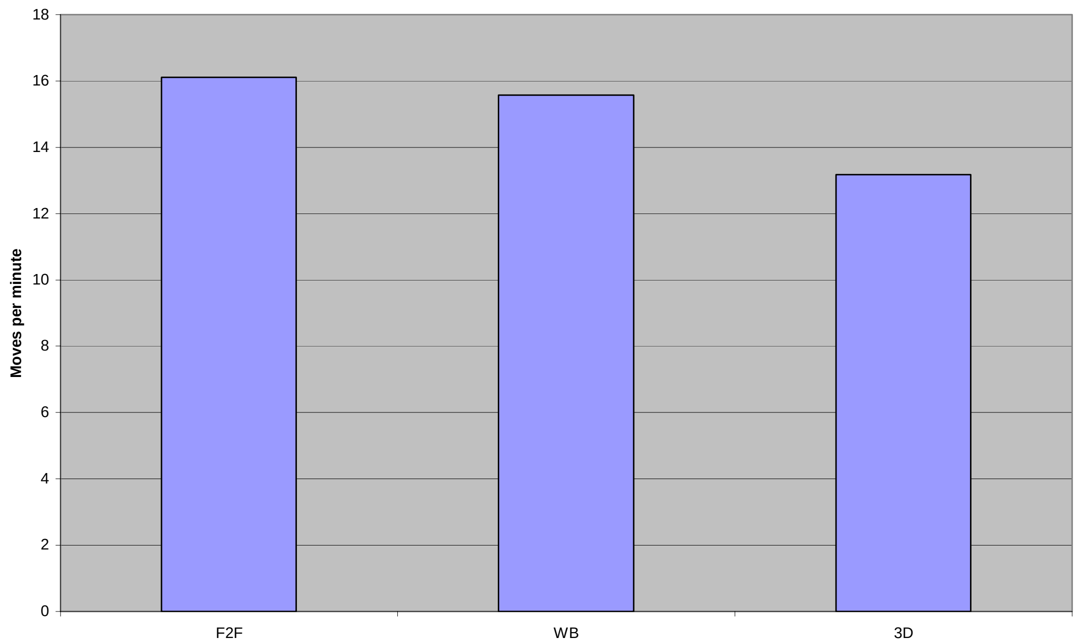
8.6.1 Exchange Structure Analysis

Exchange structure analysis is a measure of how efficient the exchange of information is between parties. The aspects of information exchange presented below include: total units of information exchanged, synoptic and dynamic moves (i.e. giving and receiving information, tracking and challenging moves and active repair of meaning versus feedback)..

8.6.1.1 Total units of information exchanged

Friedman's test (p= .074) indicated a trend towards a significant effect of condition on the total units of information exchanged (see Figure 8.4). Similar amounts of information per minute were exchanged in the F2F and group board condition but less in the 3D setting. Therefore the least amount of interaction occurred in the 3D condition.

Figure 8.4 Total units of information exchanged in three conditions



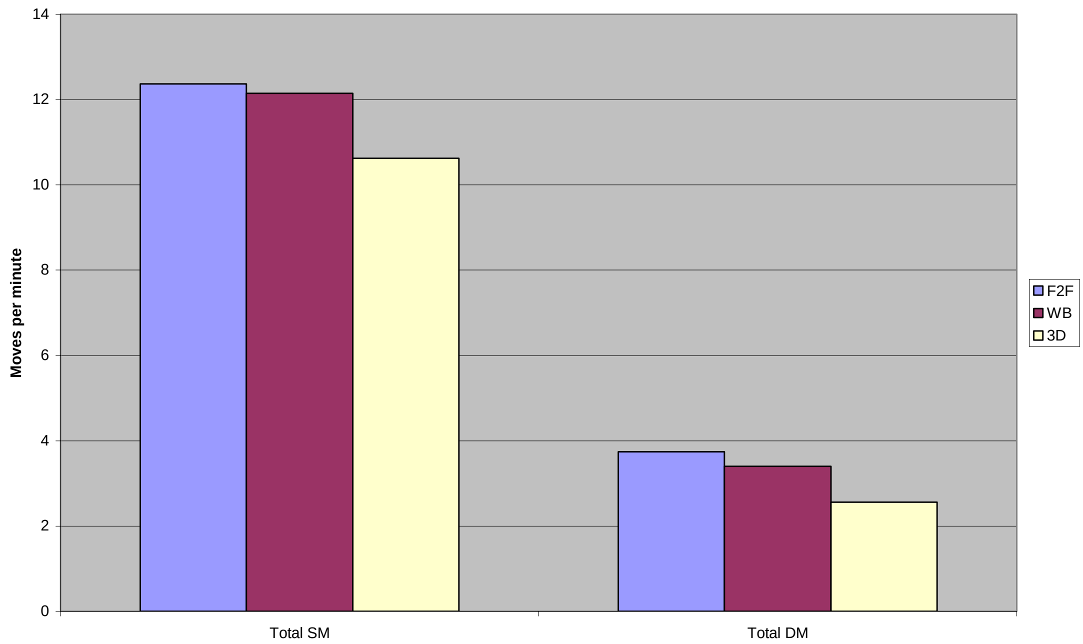
8.6.1.2 Synoptic and dynamic moves

As well as the quantity of interaction, the efficiency with which information is exchanged and the amount of time spent repairing communication breakdowns needs to be considered.

Synoptic moves (i.e. moves that request and provide information or action) were used more frequently in the F2F and group board conditions than in the 3D conditions (Figure 8.5), but no significant difference was found (p= .247). Therefore more information or action was requested or provided (relative to time) in the F2Fand group board conditions.

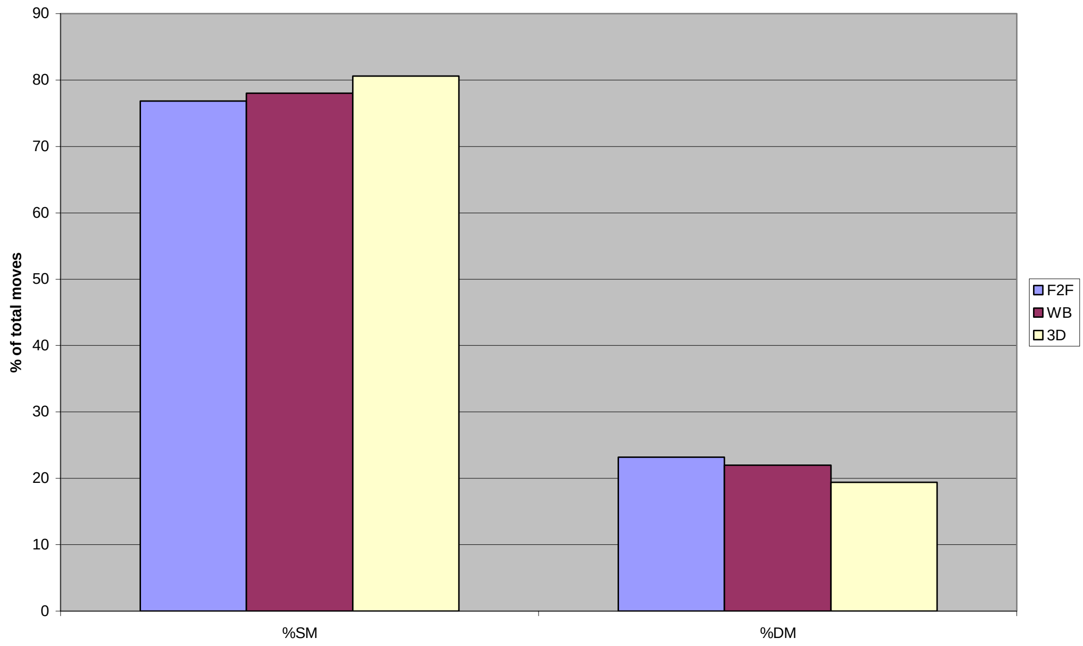
There was a trend towards a significant effect of condition for the dynamic moves (i.e. moves that help to negotiate the meaning exchanged) (p= .091). The frequency of dynamic moves was greater in the F2F and group board conditions than in the 3D session (Figure 8.5).

Figure 8.5 Total synoptic and dynamic moves in each condition



A closer examination of the relationship between synoptic and dynamic moves in each condition revealed that dynamic moves formed a progressively smaller proportion of total moves as the virtual technology level increased. (see Figure 8.6).

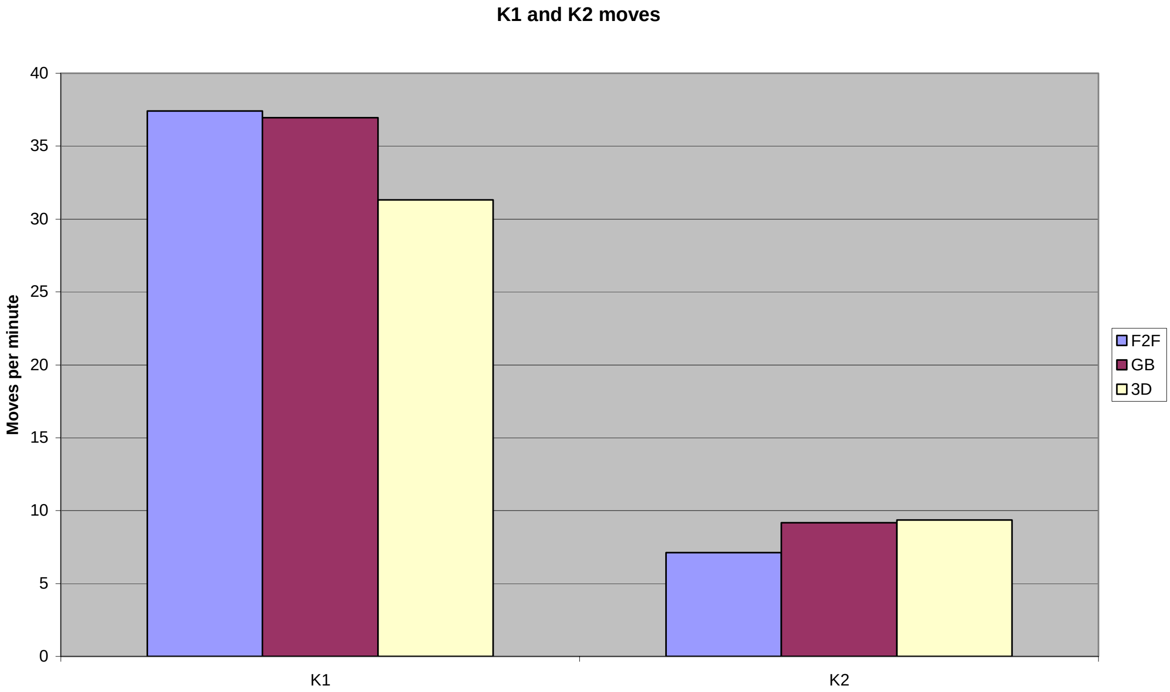
Figure 8.6 Relative percentages of synoptic and dynamic moves



8.6.1.3 *Synoptic moves: giving and receiving information*

No significant difference between the number of K1 or K2 moves was observed in the three conditions (p= .165 and p = .247, respectively). K1 moves indicate that information is being given whereas K2 moves show that information is being received (either with or without being requested). The results for giving and receiving information can be seen in Figure 8.7.

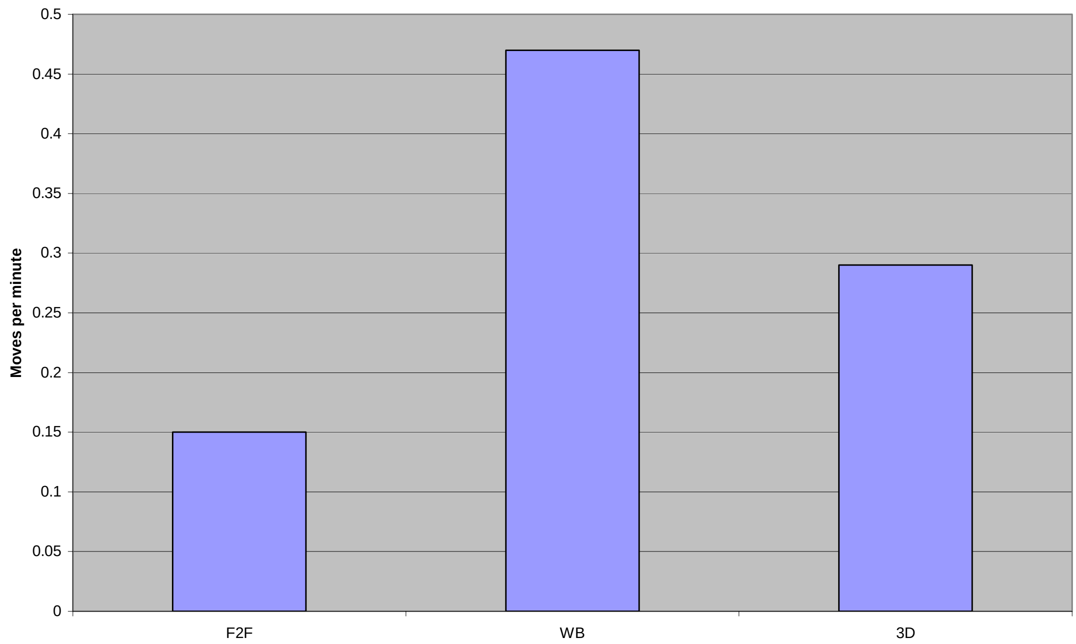
Figure 8.7 Incidence of K1 and K2 moves in each condition



8.6.1.4 *Synoptic Moves: Exchanging action*

These are moves in which action is requested or provided. There was a trend towards significance (p = .074) in the effect of condition of these action exchanges (see Figure 8.8). The fewest action exchanges occurred in the F2F condition, with the WB demonstrating the most.

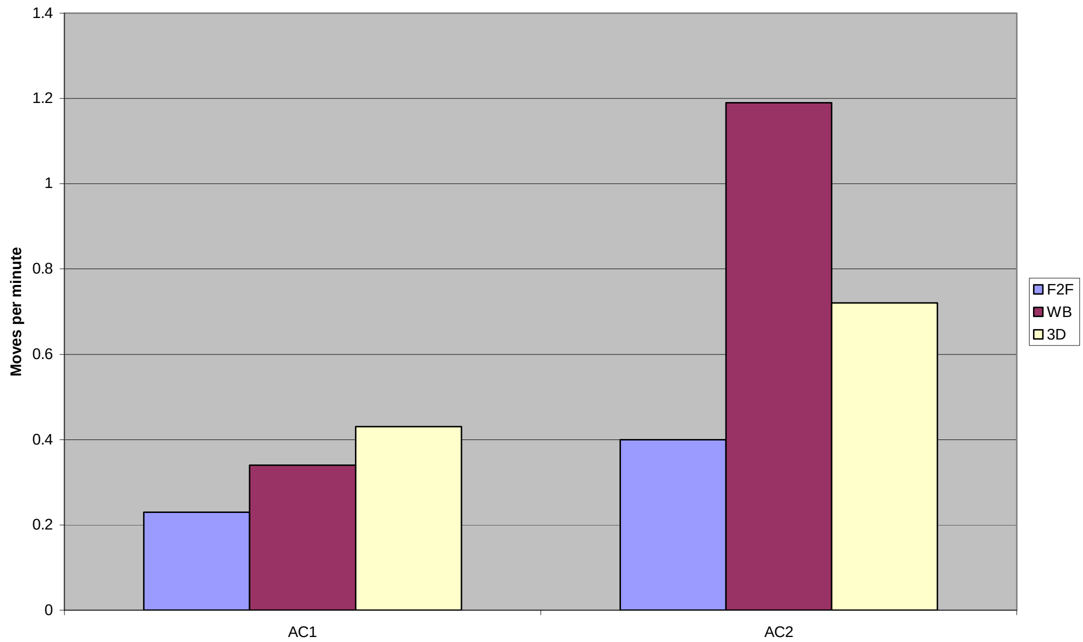
Figure 8.8 Action exchange in the three conditions



8.6.1.5 *Requesting versus providing action*

The virtual conditions did not have a significant effect on either requesting (AC2) or providing (AC1) actions ($p = .678$, $p = .196$, respectively) (Figure 8.9).

Figure 8.9 Requesting versus providing action in each condition

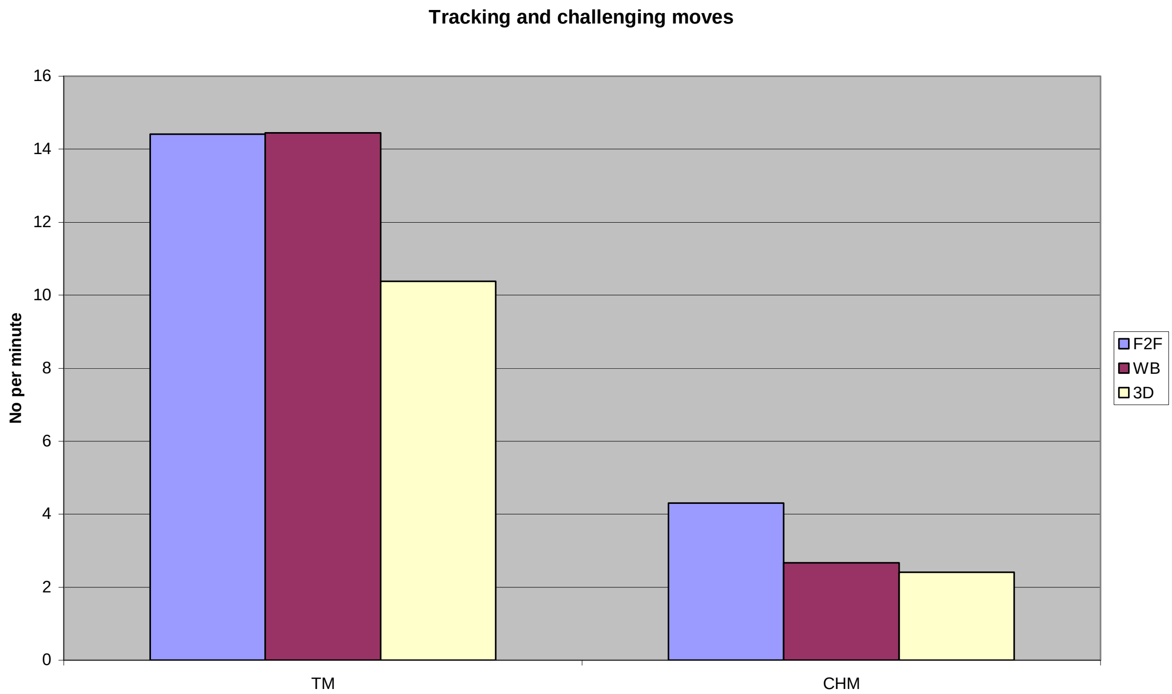


AC1 = providing an action AC2 = requesting an action

8.6.1.6 *Dynamic moves: Tracking and challenging moves*

Dynamic moves can be divided into two categories (tracking and challenging) which were also examined (Figure 8.10). Tracking moves, which indicate that the information has been conveyed successfully and also that the participants agree on the meaning being exchanged, occurred equally as frequently in the F2F and group board setting but less frequently in the 3D world. There was a trend towards a significant effect of condition on this category (p= .074). No significant effect of condition was found for challenging moves (p= .247). These moves, which indicate that the participants are not able to agree on the meaning of the exchange, occurred most frequently in the F2F condition.

Figure 8.10 Tracking and challenging moves in each condition.

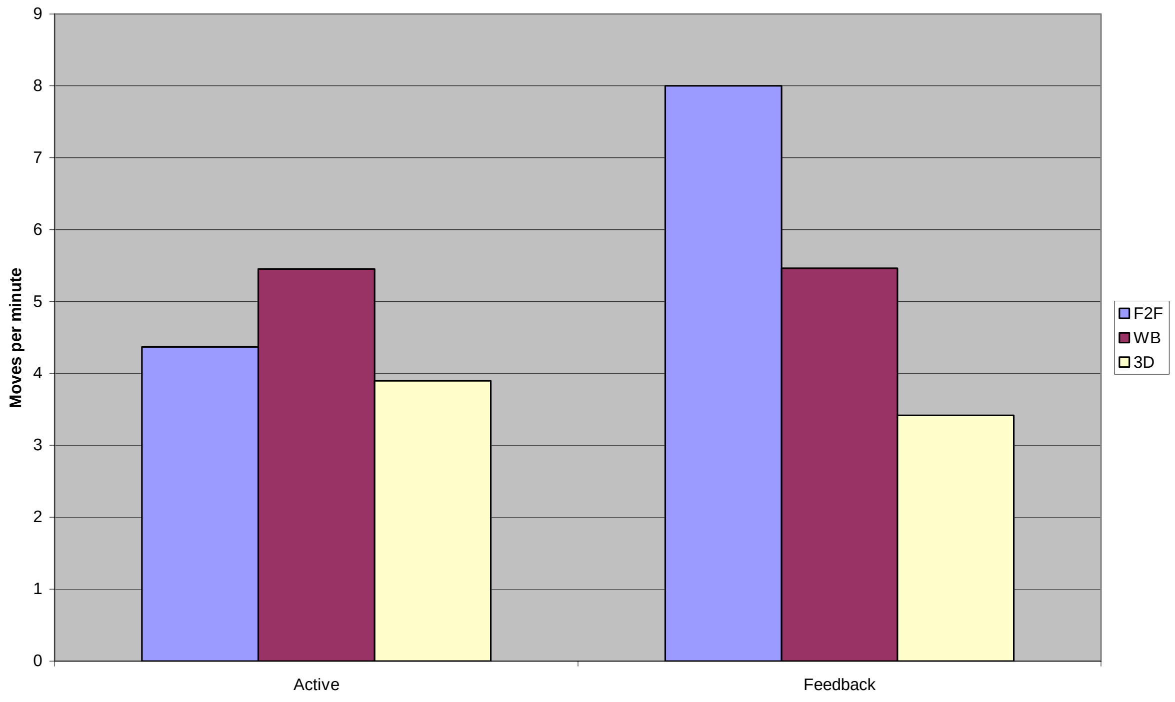


8.6.1.7 *Active repair of meaning versus feedback*

The tracking move categories which indicate a need to active repair of miscommunication (requests for confirmation or clarification, or checking) demonstrated a trend towards significance (p= .074). [Figure 8.11] These are moves that the listener uses because the information being conveyed is not clearly understood. The greatest quantity of these moves was displayed in the group board and the least in the 3D virtual world.

Tracking move categories which provide feedback that information has been conveyed successfully (by confirmation or backchannelling), in, Figure 8.11 demonstrated a significant difference between conditions (p= .041). Confirmation statements are moves where the listener repeats part of a message to confirm its accuracy. Backchannelling indicates that the information giving is proceeding smoothly (Togher no date). In the F2F condition, team members used the greatest amount of these feedback moves, with the 3D condition demonstrating the least.

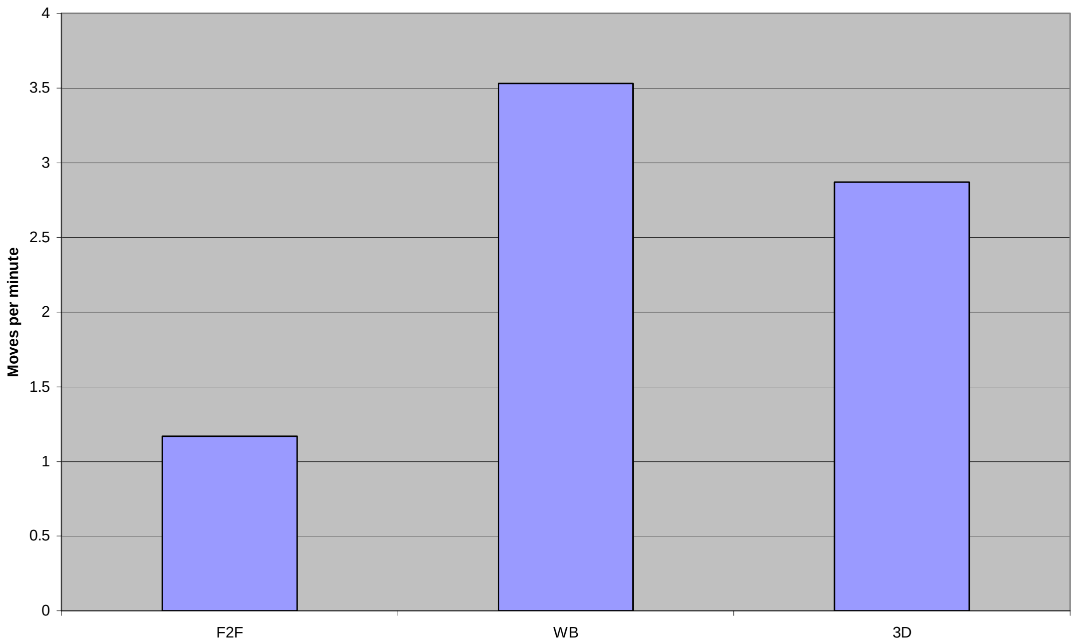
Figure 8.11 Active repair and feedback moves in each condition



8.6.1.8 *Naming and exclaiming moves*

This category includes the use of exclamations, greetings and vocatives (using the listener's name or other term of address e.g. "mate"). There was a significant effect of condition on this category (p = 0.15), with the F2F condition generating the least and the WB the most (Figure 8.12).

Figure 8.12 Naming and exclaiming moves in each condition

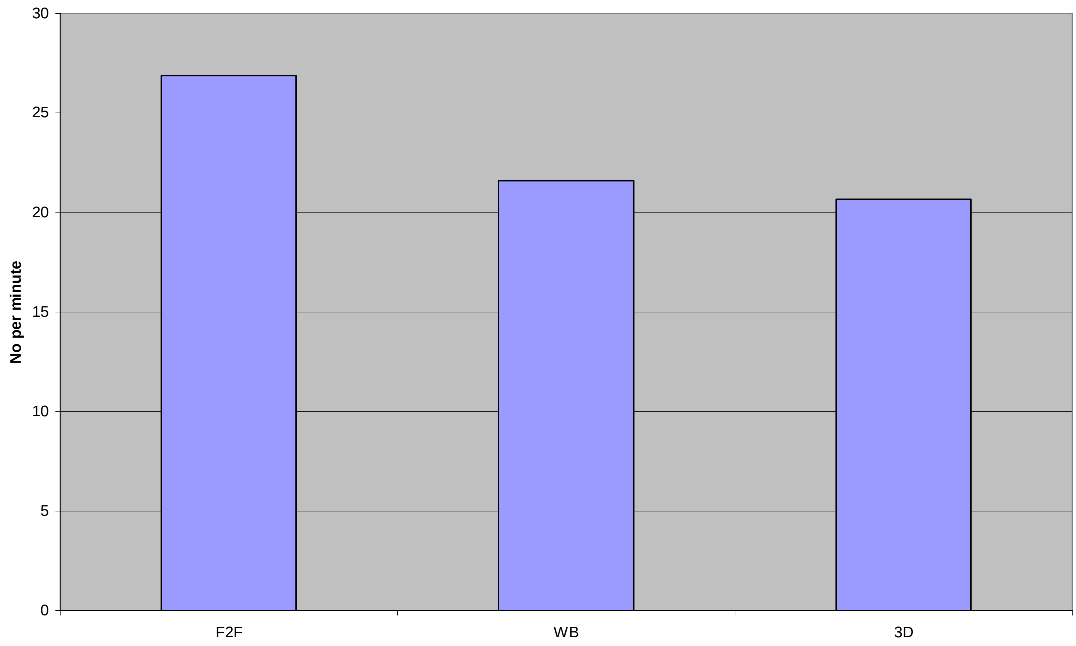


8.6.2 Politeness Markers

Politeness markers indicate how polite the team members were to each other during their interaction. The degree of directness or certainty is in inverse proportion to the amount of politeness markers used; therefore more direct language incorporates fewer politeness markers. These markers also reflect the range of meaning between negative and positive.

No significant effect of condition on the occurrence of these politeness markers was found ($p = .247$). However, more markers were used in the F2F setup than in the virtual conditions as shown in Figure 8.13. So, even though the participants in the F2F setup were able to use nonverbal communication (e.g. facial expression, gaze, gesture), they indicated greater politeness to each other verbally than in the non face-to-face conditions.

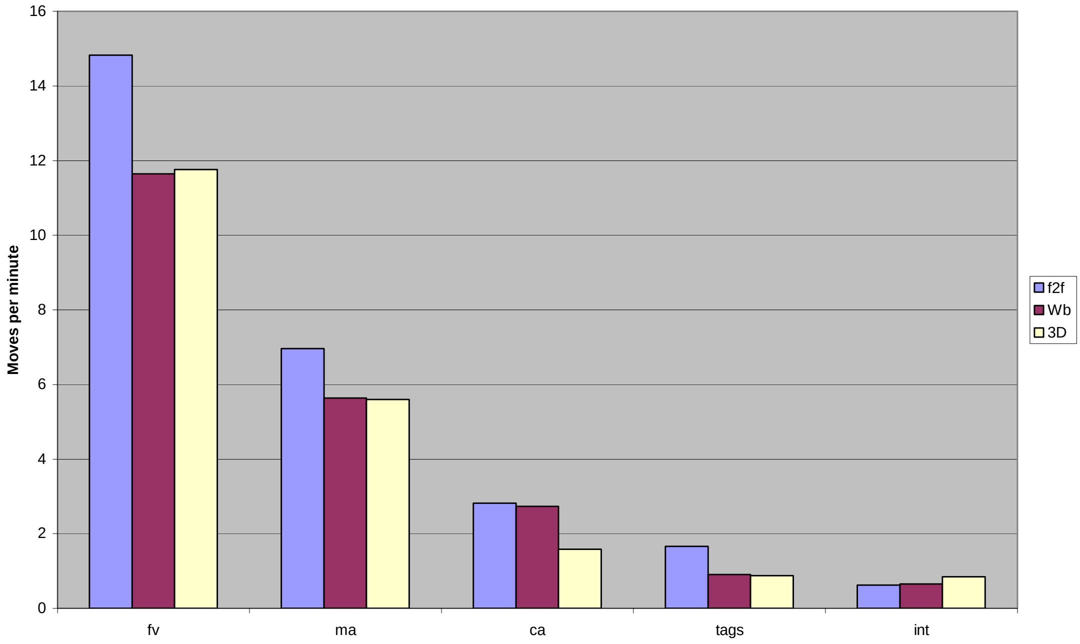
Figure 8.13 Total politeness markers in each condition



8.6.2.1 Politeness marker categories

No significant effect of condition was found for the five politeness marker categories (finite modals: $p = .247$, modal adjuncts: $p = .165$, comment adjuncts: $p = .819$, tag questions: $p = .165$, interrogatives: $p = .692$) (see Figure 8.14). Although the quantity of politeness markers differed between each condition, the types used were proportionally similar. The F2F condition elicited the greatest amount of politeness markers in most categories. Of the categories used, the category of finite modals (e.g. can, may shall, would) were used most frequently, whereas tag questions and interrogatives were used the least.

Figure 8.14 Politeness marker categories in each condition



8.7 Results for the G-SICT Questionnaire

Data were collected after two months. At this time only 28 participants had completed the questionnaire. Of these 3 were only partially complete and were discarded. For these reasons the results could not be included in the description of the main study. The following is a brief description of the findings:

1. The average age of respondents was between 30 and 50 years
2. The occupations of the respondents varied from Architecture (37.5%), Engineers (25%), Construction Management (16.7%) and Computer Science (12.5%).
3. The majority of the respondents were university educated with some having postgraduate qualifications.
4. The use of virtual technologies occurred in this order (often>never): 1) Email, 2) Phone, 3) Fax, 4) Other Software, 5) Text/Chat/Electronic Whiteboard, and 6) Video Conference.
5. The majority of respondents agreed that those generic skills identified from the literature were important for virtual collaboration; however they were unsure whether industry was lacking in these skills.

9 DISCUSSION OF RESULTS

This study examined the skills and interaction of five design teams in three settings: face-to-face and two levels using virtual technology (Group Board and 3D virtual world). The behaviours were analysed in terms of:-

1. **Generic skills** and those **observable behaviours** which are indicative of the skills.
2. **Bales's Interaction Process Analysis**, which examines the interactions used by design collaborators.
3. **Systemic Functional Linguistics**, which examines the linguistics aspects of designer's interactions.

Firstly, two of the generic skills, *shared situational awareness* and *decision making*, demonstrated a significant change in frequency in the three bandwidth levels; *shared situational awareness* increased whilst *decision making* as collaborators moved from low to high bandwidth levels.

While *task management* and *team working* were found to have not changed significantly, some of the observable behaviours manifesting these skills did change significantly as the bandwidth increased. The observable behaviours '*outlines and describes the plan/brief for the design*' (*task management*) and '*states case for order and gives justification*' (*team working*) had decreased significantly whilst '*gives updates and reports key events*' (*team working*) behaviour had increased significantly, as the bandwidth of the design process increased.

Within the generic skills that had significantly changed there were overriding observable behaviours driving that change. For *shared situational awareness,* the observable behaviour '*asks for documents and/or information regarding an idea or design (C11)*' was found to increase significantly. For *decision making,* the observable behaviour '*discusses design options with clients/other designers (D11)*' was found to decrease significantly.

Secondly, of the twelve interactions examined by Bales's IPA, only three were found to have significantly changed as the design process moved from low to high bandwidth. The frequency of both '*agrees*' and '*gives suggestion*' were found to have significantly decreased as the bandwidth of the design process increased, while the '*ask for suggestion*' interaction significantly increased. The possible links between the significant interactions and the generic skills will be discussed further below.

Thirdly, the Exchange Structure Analysis revealed a trend towards significance in the amount of information exchanged, with the F2F and WB settings exchanging more than the 3D condition. Regarding synoptic and dynamic moves, the F2F and WB conditions elicited a higher incidence of both these moves than the 3D setting. There was a trend towards significance in the effect of different settings on the dynamic moves. There was also a trend toward significance in the amount of action requested or provided with the greatest number occurring in the WB condition. A trend towards significance was found in the incidence of tracking moves, which indicate that the information has been conveyed successfully; these occurred less frequently in the 3D world. No significant effect of condition was found for the challenging moves. The frequency of some tracking moves changed with bandwidth; active repair moves demonstrated a trend towards significance whilst feedback moves were significantly different. The use of names and exclamations differed significantly with the F2F setting generating the least.

For politeness markers, there was no significant effect of condition although a higher incidence was observed in the F2F setting. Although quantitatively different, a similar ratio of politeness marker categories occurred in each setting.

9.1 Generic Skills/Observable Behaviours

9.1.1 Shared Situational Awareness

There was a significant and consistent increase in *situational awareness* as the design process moved from low to high bandwidth. In terms of the **observable behaviours** which are indicative of this generic skill, the observable behaviour '*asks for documents and/or information regarding an idea or design (C11)*' was found to significantly increase in frequency of use.

The observable behaviour '*asks for documents/or information regarding an idea or design*' is related to gathering information and involves one designer asking another a question regarding the design, the site, an idea or even artefacts. An increase in the frequency of this behaviour may indicate escalating levels of uncertainty (Riedlinger *et al.* 2004).

9.1.2 Decision Making

There was a significant and consistent decrease in the frequency of *decision making* as the design process moved from low to high bandwidth. The observable behaviour which scored most frequently for this generic skill, '*discusses design options with clients/other designers (D11)*', showed a significant decrease in frequency.

'*Discusses design options with clients/other designers (D11)*' involved one designer proposing design ideas to another designer. Therefore a decrease in this activity indicates that the designer, and subsequently the team, devoted significantly less time to developing possible solutions through the activity of brain storming as the design activity moved from low to high bandwidth design environments.

9.1.3 Further Conclusions

The shift in the bandwidth from '*face-to-face* to *group bo*ard' for the conduct of the design activity contributed most to the significance of the frequency changes for *shared situational awareness* and *decision making*. This suggests that introduction of even a low bandwidth virtual environment has the potential to affect the application of these generic skills, particularly the initial move. It is possible that a greater cultural and procedural adjustment was experienced with the move from '*group board* to *3D virtual world*'.

9.2 Bales's Interaction Process Analysis

9.2.1 Agrees

There was a significant and consistent decrease in the frequency of *agrees* interaction as the design process moved from low to high bandwidth. According to Bales (1951), *agrees* refers to confirmation or affirmation at the end of another's discussion. Thus this may indicate a decrease in positive affirmations between designers and a decrease in shared understanding as the virtuality of the team increased.

9.2.2 Gives Suggestion

There was a significant and consistent decrease in frequency of *gives suggestion* interactions as the design process moved from low to high bandwidth conditions. Bales (1951 p. 181) defines '*giving suggestion'* as '…attaining a desired goal by…proposing a solution…or suggesting where to start'. A decrease in this interaction would indicate a decrease in proposing solutions and creating ideas, perhaps an overall drop in creativity as the virtuality of design collaboration increased.

9.2.3 Asks for Suggestion

There was a significant increase in the frequency of '*asks for suggestion*' interactions as the design process moved from low to high bandwidth. The interaction '*asks for suggestion*' describes those interactions which '…question or request…suggestions as to how an action shall proceed' (Bales, 1951 p. 188). An increase in asks for suggestion may indicate that, as the design process changes to incorporate higher bandwidth technologies, the designers are having increasing difficulty forming ideas and need the input of others. This could be related to the increased levels of uncertainty in the virtual conditions.

The two suggestion categories can indicate problems with control. An increased amount of '*giving suggestion*' when compared with '*asks for suggestion*' can indicate that one person is attempting to seek control over the other. It can be seen that the frequency of 'gives suggestion' is high, while the frequency of '*asks for suggestion*' is low. However, as the bandwidth increases the levels of these interactions becomes more similar with '*gives suggestion*' decreasing and '*asks for suggestion*' increasing. This would suggest that as the bandwidth increases, more dominant designers may become less dominating.

9.3 Systemic Functional Linguistics

9.3.1 Exchange Structure Analysis

9.3.1.1 Total units of information exchanged

There was a decrease in '*total units of information exchanged*' as the design process moved from low to high bandwidth. This reflects previous research findings that information exchange may be less frequent (Potter and Balthazard 2002) and more concise using ICT (Gabriel and Maher 1999, Maher, Simoff and Gabriel 2000). Although more concise exchange of information may be of benefit, in terms of trust building a high frequency of communication is reportedly one of the keys to establishing "swift" trust (Jarvenpaa, Knoll and Leidner 1998).

9.3.1.2 Synoptic and dynamic moves

There was no significance found for the frequency of synoptic moves but fewer occurred in the 3D virtual world condition. However, compared to the total incidence of synoptic moves, a relatively greater proportion of moves in the 3D condition were synoptic moves, compared to the other settings. The frequency of synoptic moves may indicate the smooth exchange of information. In other words, information is provided clearly and, if a request for information is given, an appropriate response is received. Furthermore, participants also need to indicate that they have received, understood and/or accepted the information. Hawisher and Moran (1993) state that there is an intense need for response in computer-mediated communication and one of the major hurdles is ensuring that team members actually receive and understand a communication. Thus the number of synoptic moves reflects not only the amount of information provided but also the amount of information given that has been received by the other participant. Providing a response is also considered to be a trusting behaviour (Jarvenpaa and Leidner 1998) that would reinforce team-building. It was an unexpected finding that relatively more synoptic moves would occur in the 3D condition and this may reflect the effect of other factors (e.g. order/practice effects, previous team experience, similarity of the projects, discussed in Limitations below).

For dynamic moves, there was trend towards a significant decrease in frequency as bandwidth increased. Dynamic moves are used to perform the functions of negotiating meanings; this may involve checking or clarifying the exchange of information or when speakers misunderstand each other and attempt to overcome or repair this communication breakdown. Not only were there fewer dynamic moves in total in the 3D condition, these moves also comprised a smaller percentage of the total number of moves used. Therefore, the amount of time needed for negotiating meaning and the repair of communication breakdown was smaller in the 3D condition. This is a surprising finding in that communication in the 3D setting could be considered to be more complex and more prone to misunderstandings. This will be discussed further below.

9.3.1.3 Synoptic moves: giving or receiving information

Whilst not significant, the relative contribution of K1 (requesting information) and K2 (giving information) moves is of interest. In the F2F condition, more information was given than requested. This is in direct contrast to the 3D condition where less information was given and more requests for information were made, relative to the other two groups. This may indicate that the team members had more difficulty in obtaining the information they required in the 3D condition and therefore had to request more information.

9.3.1.4 Synoptic Moves: Exchanging action

There was a trend towards significance in the number of moves requesting or providing action. The fewest action exchanges occurred in the F2F condition, with the WB demonstrating the most. Fewer requests for or provision of action would be expected in the F2F condition than in the two virtual conditions; in the F2F condition, team members were less likely to ask or provide an action (e.g. drawing, writing) as they would simply carry out the action that was needed. In the two virtual conditions, team members would request or provide actions because they could not determine initially who would be doing the task. For example, in the WB condition, a team member might ask the other member to work on a specific aspect of the plan so that they both did not simultaneously work on the same aspect.

9.3.1.5 Dynamic moves: Tracking and challenging moves

Tracking moves are related to conveying information successfully with a shared understanding. There was a significant decrease in the frequency of tracking moves from the F2F and group board conditions to the 3D virtual world. Challenging moves include challenges to the content or relevance of the content, or a challenge to the authority of the speaker to say it. Fewer challenging moves occurred in the two virtual conditions; this may indicate that team members may have felt more comfortable challenging each other in a face-to-face situation in which they could use non-verbal cues to downplay the challenge. It can be hypothesized that a challenge taking place within a virtual environment may be perceived in a more threatening manner if the listener is relying solely on the verbal message. The relatively low incidence of both types of dynamic moves in the 3D condition may appear surprising. However, this may be explained by previous research which has noted that participants using computer mediated communication used a more commanding manner and gave more precise instructions (Newlands, Anderson and Mullin 2003). If information is exchanged in this way, there may be less need or fewer opportunities for interaction to negotiate meaning. Team members therefore may feel less able to challenge each other, particularly if one member takes on a more authoritative stance.

9.3.1.6 Active repair of meaning versus feedback

Although only demonstrating a trend towards significance, the incidence of active repair of miscommunication occurred most frequently in the WB setting. These moves indicate that the information being conveyed is not clearly understood. It is not clear why communication in the WB setting should required more active repair; a possible reason is that in the ordering of the settings, the WB was the first of the two virtual worlds to be experienced. Therefore increased need for active repair may reflect the team members' adjustment to working with reduced visual contact with each other.

There was a significant decrease in the frequency of usage for '*feedback*' in the 3D virtual world condition. This reduction in the amount of feedback in the 3D condition raises a number of questions. Backchannelling (one type of feedback) is a common feature of telephone conversations (Togher no date) when no visual cues are available. The reduction observed in this study in the 3D virtual world may be due to the fact that even in this condition, team members could observe each other via a video monitor. It may also provide support for previous research that participants using computer mediated communication used a more commanding manner and gave more precise instructions (Newlands, Anderson and Mullin 2003). Thus in the 3D environment, team members may have considered it less necessary to provide feedback to each other. However, it is of concern that more feedback was not provided. Research has demonstrated that there is an intense need for responses in computer-mediated communication (Hawisher and Moran 1993) and responses contribute to trust building (Jarvenpaa and Leidner 1998).

9.3.1.7 Naming and exclaiming moves

The experimental condition had a significant effect on the use of exclamations, greetings and vocatives (using the listener's name or other forms of address e.g. "mate"). The F2F condition generated the least and the WB the most. The incidence of these moves can be explained in terms of the three types of moves involved. The incidence of greetings was negligible in all conditions, reflecting the nature of the interaction. Regarding vocatives, their use is redundant in a situation in which there are only two conversational partners. Therefore, the incidence of vocatives should be constant across all three conditions. However, the use of vocatives tends to indicate an attempt by speakers to establish a closer relationship with each other (Eggins & Slade, 1997). Therefore, the quantity of vocatives may increase in the two virtual conditions in order to attract the listener's attention and compensate for the remoteness afforded by the technology. The form of the vocative (the use of titles, surnames, first names, nicknames, terms of endearment or abuse) was not examined in this study. Nonetheless, a brief qualitative examination of the data revealed that whilst predominantly first names were used in the WB condition, the general Australian-male vocative “mate” or “man” was used in the 3D condition. The use of the latter terms may indicate greater familiarity between speakers (Eggins & Slade 1997) or attempts to establish closeness.

Exclamations may include expressions such as “wow” or “great” but may also incorporate swear words or slang. The use of these expressions may indicate the casualness or formality of the interaction, and in this study, informality (and therefore the incidence of these expressions) may increase as the team members become more familiar with each other (i.e. in the virtual conditions). Furthermore, more dominant team members may use more swearing to reinforce their role in an interaction (Eggins & Slade, 1997). Thus the increased incidence of vocatives and exclamations in the two virtual conditions may reflect the level of technology being used as well attempts to enhance familiarity with each other.

9.3.2 Politeness Markers

Politeness markers reflect the relationships set up in the context (Togher and Hand 1998) and also the constraints placed on the participants by the technology setup. A greater use of politeness markers may indicate the speaker’s awareness of the power balance, familiarity and also the effect of the context. Thus the greater politeness expressed in the F2F may reflect the increased level of collaboration on information sharing. Although politeness markers reflect less direct communication and may therefore be less time efficient, their use will facilitate teamwork and trust between the participants.

There was no significant effect of the three conditions on the types of politeness markers used. Although different quantities of each politeness marker were used in the three conditions, the proportion of each type used was similar in each condition, possibly indicating the naturally occurring frequency of types in this type of team work. The F2F condition elicited the greatest amount of politeness markers in most categories, reflecting their greater total use of these markers. Of the categories used, the category of finite modals (e.g. can, may shall, would) were used most frequently, whereas tag questions and interrogatives were used the least.

For all three conditions, the main type of politeness marker used was the finite modal verb (would, could etc). For example, a direct request for action is “Get that drawing” whereas a less direct, more polite means (using a modal verb) is “Could you get that drawing?”. Modal adjuncts were the second most commonly used in both settings e.g. the use of perhaps, probably, possibly. Tag questions and incongruent realizations of interrogatives were used the least in all conditions.

It is perhaps surprising that the participants in the two virtual environments, with their limited access to nonverbal communication, used fewer politeness markers. Even though the participants in the F2F setup were able to use nonverbal communication (e.g. facial expression, gaze, gesture) in addition to verbal politeness markers, they indicated greater politeness to each other verbally than in the two virtual conditions. It is even more surprising in the light of the fact that in both virtual conditions, they were able to interact using a web camera. However, as Hoyt (2000) has indicated, even in this type of set-up, non-verbal interaction may be inhibited. It could have been hypothesized that the participants in the virtual environments would have at least used similar amounts of verbal politeness markers to overcome the effect of the technology. These markers indicate the degree of directness used by the participants when requesting or providing information or action from each other. It may be that more direct and therefore less polite language was used more frequently in an attempt to overcome the difficulties in communicating clearly using the technology and also the distancing effect that the technology may exert. Using fewer politeness markers can also be a way of controlling the interaction (Togher and Hand, 1998). Thus, to avoid miscommunication in the virtual environments, group members may have considered it more efficient and expedient to use more direct speech in transmitting and requesting information or action.

9.4 Limitations

Five limitations were identified in the study and are discussed below. :

1. Small sample size – whilst the number of interactions analysed was large, the number of design teams analysed was small (5). The data collection required designers to find time in their and their companies' schedule to participate in 1.5 hours of mock design. With the addition of training and travelling time, the designers provided about 3.5 to 4 hours. Also the priority of their own urgent design tasks may relegate experimental sessions to second place. The fact that this report analyses only five design teams is a direct result of these difficulties and it is thus difficult to generalise the findings to the wider population.

2. Sequence in which the participants operated using the experimental conditions i.e. face-to-face, group board and 3D virtual world was not randomised. In the data collection, all the design participants moved through the different levels in the same order of increasing virtuality. Therefore the participants are affected by factors of practice/familiarity or fatigue (Pring 2005). It is not possible to determine how and to what extent these confounding variables affect the research outcomes. As the designers devote half an hour to each method face-to-face, group board and 3D virtual world, they are gaining experience working together. As a result one would assume they would be able to work more effectively as their time together increased. If this is the case their time of optimal collaboration will be when they are designing in the 3D virtual world. On the other hand, if fatigue or tedium set in, the last task performed (viz 3D virtual world) would be the most affected.

3. The data was collected in a laboratory setting. In addition, the construction designs which the designers were discussing were fabricated designs i.e. they were fictitious and did not hold intrinsic meaning for the designers. What this research attempted to do was to make the conditions as close to real world as possible so that the results and conclusions reached here could be generalised to the real world design setting. Another issue associated with the data is that, because the designs were not real, the designers had some difficulty at times acting as they would in a real world setting. For example, designers were able to skip over parts of the design that were difficult.

4. All participants were architects and therefore, the results may be influenced by the culture of the architecture profession. The concept of a designer encompasses many different professions including architecture, engineering and construction management. To have representation from only one professional source limits the extent to which the results can be extended to all designers. Furthermore, by investigating team interaction within one profession, it is difficult to generalise the findings to teams which comprise various professions (e.g. an architect, a construction manager and an engineer).

5. The participants comprised a heteregenous group in terms of gender, age, qualifications, experience, language and culture. Although their various

backgrounds can be considered to reflect the real world of remote/virtual teamwork, it is not clear how these factors individually have contributed to the results. It is difficult to hypothesise how a combination of, for example, relatively limited proficiency in English, little experience of technology and the effects of the technology itself would affect generic skills or the interaction that occurs.

9.5 Recommendations

The recommendations arising from this project are organised into four categories
1) Recommendations for design collaborators,
2) Recommendations for design team management,
3) Recommendations for educational development and 'continuous professional development', and
4) Directions for future research.

9.5.1 Recommendations for Design Collaborators

These recommendations are those which are specific to individual designers.

9.5.1.1 Shared Situational Awareness

The increase in the need to establish a shared awareness as virtuality increases suggests that design collaborators become more uncertain in their interpretation of the communication and so request more and more confirmation of information. It can be concluded that design collaborators need to supply a more detailed description of what they are proposing or attempting to do and continually relate this to the specific task with which they are directing their design activity. It will always be possible to obtain information in a virtual world, but what is a potential concern is the efficiency of this transfer and the level of shared understanding within groups at a point of time. To achieve high quality virtual communication it is necessary to use multiple channels or modes of communication simultaneously to enrich the design concept being communicated. Instead of relying on a single mode of communication, e.g. verbal communication, it is necessary to support verbal communication with non-verbal artefacts, such as sketches, as designers do in face-to-face situations. Such communication enhancements make it possible to, for example, indicate areas being referred to.

> **Recommendation 1**: Use multiple modes of communication concurrently to increase shared understanding in design teams

9.5.1.2 Decision Making

Evidence of a decrease in design solution generation and brainstorming as virtuality increases suggests that design collaborators are more ready to accept a design proposal and assign it the status of a solution, without offering alternatives. Because of the at times cumbersome nature of communication in a virtual world (described above), the perception is that it is easier to accept an idea without conducting a discussion for the purpose of extrapolation, multiple outcome generation, or other potential solutions. However it would seem that in virtual environments many perspectives are not acknowledged and the solution generation phase of designing consequently suffers.

> **Recommendation 2**: Designers should ensure appropriate brainstorming and design option generation is conducted when working in a virtual context.

> **Recommendation 3**: Designers should encourage all team members to acknowledge each design proposal and offer their opinions and design ideas.

9.5.2 Recommendations arising from SFL analysis

9.5.2.1 Exchange of information

Within the context of a team involved in producing a design, a key criterion for a successful outcome is their ability to communicate effectively. However, in this study, fewer units of information were exchanged (i.e. the amount of interaction decreased) as the level of virtual technology increased. Although previous research (discussed above) has had similar findings, the rate of interaction in virtual environments should be similar to that of F2F settings for a number of reasons. Firstly, common ground is built and rebuilt through the moment-to-moment interactions of the team members. Negotiation, which team members need to engage in to establish shared understanding, is an active process. The challenges to negotiation increase as team members build common ground with people from different professions, cultures, languages and educational backgrounds. Thus the need for interaction is constant in any collaborative team setting. Secondly, for teams to collaborative successfully, trust needs to be built. Because teams are often required to collaborate efficiently but also rapidly, trust needs to be built up quickly. A high frequency of interaction has been found to establish trust (Jarvenpaa, Knoll and Leidner 1998). The building of trust in remote teams may be more difficult to establish than in F2F settings and therefore the amount of interaction is of even greater importance when using virtual technology.

> **Recommendation 4:** Design team members should interact with each other frequently in order to establish common ground and trust.

9.5.2.2 Ease of information exchange

The quality and ease of information exchange needs to be taken into account. This study indicated that there was less negotiation of meaning (i.e. dynamic moves) in the 3D setting, suggesting that there was less need for checking, clarifying or repairing miscommunication. Whilst this may be a positive finding for the use of virtual technology, it must be placed in the context of less interaction overall in the 3D setting. Furthermore, previous research (discussed above) indicated that participants may be more authoritative in their communication when using virtual technology, possibly preventing other team members from challenging a decision or an action. However, for the building of trust and teamwork in virtual environments, as well as collaboration, team members should feel comfortable checking, clarifying and challenging the information provided to them.

> **Recommendation 5:** To establish trust and collaborate effectively, design team members should be encouraged to participate actively in the design process rather than passively accepting one member’s decisions.

9.5.2.3 Giving and receiving information and action

A greater number of moves requesting, rather than providing, information or action was observed in the virtual settings. From this it is apparent that more time was spent by team members obtaining the information or action necessary for them to continue with the project. Regarding the provision of information, it can be concluded that team members working in the virtual settings did not adapt to the conditions by increasing the information given to each other. The incidence of requests for action may have been the result of the technology or the participants' level of experience of the technology. In both virtual settings, the drawing or writing of one team member was not immediately visible to the other team member. This meant that team members would request an action that was already being completed by the other team member. In addition, because of the technology, group members asked for action on specific aspects of the project (e.g. you do…. and I'll do …) to avoid both team members working on the same aspect.

> **Recommendation 6:** In virtual technology settings, team members should increase the flow of information to each other and be explicit in action requests to compensate for the restrictions placed on them by the technology.

9.5.2.4 Providing feedback

Providing feedback is a necessary mechanism in environments where there are no visual cues to indicate that communication giving is proceeding smoothly. Contrary to expectations, less feedback was provided in the virtual settings than in the F2F setting in which the speakers had access to non-verbal cues. Previous research (discussed above) has stressed the need for feedback in computer-mediated environments. In addition, feedback contributes to trust building.

> **Recommendation 7:** In virtual technology settings, team members should provide verbal feedback to indicate to the speaker that the information has been clearly received.

9.5.2.5 Naming and exclaiming

The incidence of names and exclamations was greater in the virtual settings than in the face-to-face condition. Whilst the use of names in F2F interaction between two conversational partners is redundant, their increased use in virtual settings is appropriate in getting a team member's attention if there is limited visual contact. The greater use of names in the two virtual settings may have been an attempt to overcoming the distancing effect of the technology and increase familiarity with each other. Both first names and terms such as "mate" were used. Although in principle the use of increased naming is appropriate in virtual settings, the form of the vocative may need to be considered to take into account cultural variables when working in culturally diverse global teams. Although some of the team members were not Australian-born, they would have been accustomed with the use of Australian terms of address and would therefore not have taken offence.

Regarding exclamations, the increased use of exclamations in the virtual settings may indicate greater familiarity (due to increased experience working together or to overcome the effect of the technology) or may stress informality. Whatever the motivation, the use of swearing may be considered problematic by other team members, whether of the same culture and language or not.

> **Recommendation 8:** Team members should be circumspect about the use of names, particular familiar vocatives, and the use of swearing when interacting in global teams, particularly with people from different cultures.

9.5.2.6 Politeness markers

More verbal politeness markers were used in the face-to-face setting than in the two virtual conditions, even though the team members were able to use non-verbal politeness markers in the former condition. The need for verbal politeness markers should increase as the use of non-verbal cues becomes more difficult. More direct communication may have been used to overcome the difficulties in communicating in the virtual environments; as discussed above, team members may take on a more authoritative stance when using technology. The use of politeness markers results in less direct communication but their use builds trust and may reflect an increased level of collaboration and they are therefore of importance in any team work setting.

> **Recommendation 9:** Team members should use less direct, more polite communication within the virtual settings to build trust and increase collaboration, particularly when interacting with team members of different cultures. This may only be possible as technology or team members experience of the technology improves.

9.5.3 Recommendations for Design Team Management

Recommendations for design team management refer to specific aspects of design team management which could be improved.

Some form of leadership or team management is vital for virtual design collaboration. An increase in uncertainty (shared situational awareness) and a decrease in solution generation (decision making) indicates that an environment managed by a clear set of guidelines would benefit such collaboration. It is clear that the activity of collaboration within design teams presents a complex set of variables which require effective management. The challenges faced by design team managers require a specific mix of experience, knowledge and understanding. The recent introduction of 'architectural design management programs' in UK universities (e.g. BSc Architectural Engineering and Design Management at Loughborough University at http://www.lboro.ac.uk/departments/cv/prospstud/undergrad/aedm/index.html) is evidence of a perceived need for professional education in this sector.

In addition, the need for effective management highlights the benefits that would accrue from a dedicated protocol system (similar to the *Process Protocol* described by Thorpe (2004)). Such a document would assist the management of design collaboration within virtual teams. A designated leader would need to be appointed to manage design sessions, something that was lacking from the experimental sessions.

To combat the increase in uncertainty within virtual teams design leaders would need to ensure that the design process was structured so that all design team members were able to contribute to discussions. Teams need to be managed to ensure that members provide information in a clear concise manner with an appropriate level of detail.

Furthermore, it would appear that the style of management appropriate to virtual environments warrants further investigation. Clearly an advantageous strategy would be to encourage input during the solution generation phase so that adequate designs were not accepted without discussion.

> **Recommendation 10:** Virtual design teams operate under the guidance of a designated leader or project manager.

Recommendation 11: A protocol to be established for virtual team working to be implemented by design team leader.

9.5.4 Recommendations for Educational Development

In creating University courses for design related degrees in the area of design management and virtual technologies emphasis should be placed on the skills and areas identified above. One way these skills could be utilised in education is through ePortfolios (such as the NURAPID system established at Loughborough University in the UK (Sher *et al.* 2005)). NURAPID stands for **N**ewcastle **U**niversity **R**ecording **A**cademic, **P**rofessional and **I**ndividual **D**evelopment Progress File. NURAPID is a system which allows students to record and audit their skills sets as outlined by professional and industry bodies for their chosen field. It also helps students manage the attainment of skills relevant to their disciplines and creates records which are useful for CV's. This project has found that there are differences in the skills which are needed during virtual design collaboration. If these differences are incorporated in student skills auditing and recording, it would better prepare them for the increasing demands of high bandwidth technologies within the design/construction industry.

Recommendation 12: Findings concerning generic skills be implemented into ePortfolios for recording and auditing student skill profiles.

9.5.5 Directions for Future Research

There are many directions for future research into the generic skills and the interactional styles within virtual design teams. Many of these relate to investigating the recommendations provided above.

It would be prudent to determine whether the increase in uncertainty and the decrease in solution generation in the virtual condition affected the outcome of the design session. This would establish whether an increase in *shared situational awareness* and a decrease in *decision making* generic skills had an impact on the efficiency of the design process and the quality of design solutions.

Recommendation 13: Investigate the relationship between generic skills and communication in virtual environments, and the efficiency and quality of the design process.

This report describes differences in the use of generic skills as virtuality of design collaboration increases. Future research into the effects generic skills could have on the use of a design management protocol within virtual teams would be important for design management education. Being able to expand on the issues cited above would contribute to the creation of a skills audit which students and industry professionals could use to align themselves with industry skill standards.

Recommendation 14: Research the creation of a protocol for virtual design team management.

The limitations described above indicate the possible presence of an order or practice effect as the move from low to high bandwidth conditions was not randomised. This effect may be countered by the familiarity the designers had with one another prior to the experimental design sessions. A future direction for this area of research may focus on whether there is a different effect seen between the generic skills used by designers who know or have previously worked with each other and those who do not/have not. In globally dispersed virtual teams, there may always be designers who have not previously met each other. The experience designers have working with each other may promote the use of different skills in the virtual domain thus presenting different generic skills and interaction profiles.

> **Recommendation 15:** Research into the effect of prior experience with team members on the generic skill and interaction profiles of virtual teams.

While limited conclusions can be drawn from the results from the G-SICT questionnaire, some issues are apparent.

- It is convenient for researchers to develop and administer questionnaire surveys using secure websites hosted by third parties. However, it this convenience may be at the expense of participants. Recipients of email requests appear to pay scant attention to yet another email (even when these receive the endorsement of managers or peers).
- Achieving a high response rate for an on-line survey is not easily achieved. Ways of engaging recipients (such as contacting them personally and requesting them to complete the survey online) need to be considered.

> **Recommendation 16:** Mix the modes of survey presentation. Much like virtual teams, begin with face-to-face contact and ease into the online situation.

As noted above, the participants appeared to agree that all of the generic skills identified were of importance. However they were unsure whether they were in use in the design/construction industry at present. Perhaps in future iterations of the G-SICT it would be necessary to incorporate definitions of these generic skills so as the participants would be sure of what researchers were asking of them. At present participants are answering these questions on their own understanding of these skills.

> **Recommendation 17:** Provide definitions of generic skills in future iterations of the G-SICT.

Due to the small number of participants it would be necessary once these recommendations are put in place to complete further work into industry perceptions of virtual technologies and generic skills.

> **Recommendation 18:** Further research to be conducted into industry perceptions of generic skills necessary for virtual design collaboration using the G-SICT.

9.6 List of Recommendations

A summary of the recommendations is presented below:

> **Recommendation 1**: Use multiple modes of communication concurrently to increase shared understanding in design teams.

Recommendation 2: Designers should ensure appropriate brainstorming and design option generation is conducted when working in a virtual context.

Recommendation 3: Designers should encourage all team members to acknowledge each design proposal and offer their opinions and design ideas.

Recommendation 4: Design team members should interact with each other frequently in order to establish common ground and trust.

Recommendation 5: To establish trust and collaborate effectively, design team members should be encouraged to participate actively in the design process rather than passively accepting one member's decisions.

Recommendation 6: In virtual technology settings, team members should increase the flow of information to each other and be explicit in action requests to compensate for the restrictions placed on them by the technology.

Recommendation 7: In virtual technology settings, team members should provide verbal feedback to indicate to the speaker that the information has been clearly received.

Recommendation 8: Team members should be circumspect about the use of names, particular familiar vocatives, and the use of swearing when interacting in global teams, particularly with people from different cultures.

Recommendation 9: Team members should use less direct, more polite communication within the virtual settings to build trust and increase collaboration, particularly when interacting with team members of different cultures. This may only be possible as technology or team members experience of the technology improves.

Recommendation 10: Virtual design teams operate under the guidance of a designated leader or project manager.

Recommendation 11: A protocol to be established for virtual team working to be implemented by design team leader.

Recommendation 12: Findings concerning generic skills be implemented into ePortfolios for recording and auditing student skill profiles.

Recommendation 13: Investigate the relationship between generic skills and communication in virtual environments, and the efficiency and quality of the design process.

Recommendation 14: Research the creation of a protocol for virtual design team management.

Recommendation 15: Research into the effect of prior experience with team members on the generic skill and interaction profiles of virtual teams.

Recommendation 16: Mix the modes of survey presentation. Much like virtual teams, begin with face-to-face contact and ease into the online situation.
Recommendation 17: Provide definitions of generic skills in future iterations of the G-SICT.

Recommendation 18: Further research to be conducted into industry perceptions of generic skills necessary for virtual design collaboration using the G-SICT.

10 CONCLUSIONS

It is clear that the introduction of virtual technologies has implications for designers. The challenges are not solely technical. These technologies impact on the ways designers work and collaborate. This research has identified some goals which need to be addressed if virtual technologies are to be effective and successful. The generic skills and Bales's IPA data have shown that some areas are unaffected by the implementation of ICTs, but others signal significant differences. Areas which warrant further attention include a drop in frequency of idea generation and solution forming, and an increase in uncertainty as virtuality increases.

The ability to map and measure generic skills of individuals and teams is crucial for the construction/design industry. This mapping and measurement can contribute to training in deficient areas. The major deficiency highlighted by literature was the lack of non-verbal capabilities in the virtual world compared to co-located conditions. This deficiency will inevitably lead to different skills and interactions being used.

The major conclusion drawn from analysis of the coded design collaboration is that there are significant differences between the operational conditions; face-to-face, group board and 3D virtual world, for the generic skills, Bales's IPA and the two Systemic Functional Linguistics profiles. This was true for the overall design activity of the five teams.

Using two linguistic analyses to investigate team interaction in more depth has provided additional information, not only on the communication itself but also on the contribution of communication to trust-building and collaboration. Only a fine-grained analysis of interaction can provide the type of information needed to determine the effect of virtual technology on communication in design teams.

Collaboration in team work is not only concerned with the transmission of information but also with the building of trust. The more frequent interaction and increased politeness markers in the F2F setting are both factors found to contribute to trust building (Jarvenpaa and Leidner 1998, Jarvenpaa, Knoll and Leidner 1998). Teams which are high on trust have been found to be able to solve problems and resolve conflicts (Jarvenpaa and Leidner 1998).

It is essential that designers understand the characteristics of the different environments in which they may find themselves working. Specific communication skills may be needed for team members to function efficiently and effectively, particularly in virtual, high-bandwidth technological, environments. By examining the effects of technology on communication, the particular strategies which facilitate and hinder communication when different levels of technology are used, can be ascertained. These strategies can then be incorporated into the briefing and training sessions provided to construction design teams as they move to greater use of group board, 3D and other technologies. In this context it is pertinent to note that currently training usually focuses on the use of new software and hardware technology, rather than on the interpersonal communication skills that will facilitate communication and collaboration.

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12 APPENDIX I – BEHAVIOURAL MARKER SYSTEMS

Table 12.1 Table of Behavioural Markers and descriptions taken from LOSA [adapted from (Klampfer *et al.* 2001)]

Marker	Positive description of marker	Behaviour
Briefing	The required briefing was interactive and operationally thorough	• Concise, not rushed, and met requirements • Bottom lines were established
Plans stated	Operational plans and decisions were acknowledged and communicated	Shared understanding about plans
Workload assignment	Roles and responsibilities were defined for normal and non-normal situations	Workload assignments were acknowledged and communicated
Contingency management	Members developed effective strategies to manage potential issues	• Issues and their consequences were anticipated • Used all available resources to manage issues
Monitor/Crosscheck	Team members actively crosscheck activities and other members	Verification of team activities
Workload management	Tasks were prioritised and properly managed to handle primary duties	• Avoid task fixation • Did not all work overload
Vigilance	Team members remain aware of the status of the project	Team members maintain situational awareness
Automation management	Automation was properly manage to balance situational and workload requirements	
Evaluation of plans	Existing plans were reviewed and modified when necessary	Team member decisions and action were openly analysed to make sure the best existing plan was the best plan
Inquiry	Team members ask questions to investigate and/or clarify current plans of action	Team members not afraid to express a lack of knowledge
Assertiveness	Team members stated critical information and/or solutions with appropriate persistence	Team members spoke up without hesitation
Communication environment	Environment for open communication was established and maintained	Good cross talk
Leadership	Project leader showed leadership and co-ordinated team activity	In command, decisive, and encouraged team participation,

Table 12.2 Non-Technical Skills (NOTECHS) behavioural markers and descriptions [adapted from (Klampfer *et al.* 2001)].

Categories	Elements	Example Behaviours
Cooperation	Team building and maintaining	Establishes atmosphere for open communication and participation
	Considering others	Takes condition of other team members into account
	Supporting others	Helps other team members in demanding situation
	Conflict solving	Concentrates on what is right rather than who is right
Leadership and Managerial Skills	Use of authority and assertiveness	Takes initiative to ensure involvement and task completion
	Maintaining standards	Intervenes if task completion deviates from standards
	Planning and co-ordinating	Clearly states intensions and goals
	Workload management	Allocates enough time to complete tasks
Situation Awareness	System awareness	Monitors and reports changes in system states
	Environmental awareness	Collect information about the environment
	Anticipation	Identifies possible/future problems
Decision Making	Problem definition/diagnosis	Review causal factors with other team members
	Option generation	• States alternative courses of action • Asks other team members for options
	Risk assessment/Option choice	Considers and shares risks of alternative courses of action
	Outcome review	Checks outcome against plan

Table 12.3 Assessment of communication and interaction skills, domains and items [adapted from Kjellberg et al (2003)].

Theoretical Domain	Skill	Description
Physicality	Contacts	Makes physical contact with others
	Gazes	Uses eyes to communicate and interact with others
	Gestures	Uses movements of the body to indicate, demonstrate or add emphasis
	Manoeuvres	Moves one's body in relation to others
	Orients	Directs one's body in relation to others and/or occupational forms
	Postures	Assumes physical positions
Information Exchange	Articulates	Produces clear, understandable speech
	Asserts	Directly expresses desires, refusals and requests
	Asks	Requests factual or personal information
	Engages	Initiates interactions
	Expresses	Displays affect/attitude
	Modulates	Employs volume and inflection in speech
	Shares	Gives out factual or personal information
	Speaks	Makes oneself understood through the use of words, phases or sentences
	Sustains	Keeps up social action or speech for appropriate durations
Relations	Collaborates	Co-ordinates one's action with others toward a common end goal
	Conforms	Follows implicit and explicit social norms
	Focuses	Directs conversation and behaviour to ongoing social action
	Relates	Assumes a manner of acting that tries to establish a rapport with others
	Respects	Accommodates to other people's reactions and requests

Table 12.4 Generic Skills – Behaviour Marker Correlation showing that previous behavioural marker research can provide insight into those behaviours which contribute to the generic skills for teamwork taken from the literature.

Generic Skill	Behavioural Marker	Behavioural Element (Observable Behaviour)
Adaptability	Taken from other research	
Shared Situational Awareness	Situation Awareness (Klampfer *et al.* 2001)	• System awareness
		• Environmental awareness
		• Anticipation
	Vigilance (Klampfer *et al.* 2001)	• Team members remain aware of the status of the project
	Situation Awareness (Fletcher *et al.* 2003)	• Gathering information • Recognising understanding • Anticipating
Performance Monitoring and Feedback	Monitor/Crosscheck (Klampfer *et al.* 2001)	• Team members actively crosscheck activities and other members
	Evaluation of plans (Klampfer *et al.* 2001)	• Existing plans were reviewed and modified when necessary
	Inquiry (Klampfer *et al.* 2001)	• Team members ask questions to investigate and/or clarify current plans of action
Leadership/Team Management	Task Management (Fletcher *et al.* 2003)	• Planning and preparing • Prioritising • Providing and maintaining standards • Identifying and utilising resources
	Leadership (Klampfer *et al.* 2001)	• Project leader showed leadership and co-ordinated team activity
	Leadership and Managerial Skills (Klampfer *et al.* 2001)	• Use of authority and assertiveness
		• Maintaining standards
		• Planning and co-ordinating

		• Workload management
Interpersonal Relations	Assertiveness (Klampfer *et al.* 2001)	• Team members stated critical information and/or solutions with appropriate persistence
	Relations (Kjellberg *et al.* 2003)	• Collaborates
		• Conforms
		• Focuses
		• Relates
		• Respects
	Cooperation (Klampfer *et al.* 2001)	• Team building and maintaining
		• Considering others
		• Supporting others
		• Conflict solving
Co-ordination	Workload management (Klampfer *et al.* 2001)	• Tasks were prioritised and properly managed to handle primary duties
	Workload assignment (Klampfer *et al.* 2001)	• Roles and responsibilities were defined for normal and non-normal situations
Communication	Because of the nature of team work, finding exact communication behaviours would be difficult, so communication is thought better measured by other techniques.	
Decision Making	Decision Making (Klampfer *et al.* 2001)	• Problem definition/diagnosis
		• Option generation
		• Risk assessment/Option choice
		• Outcome review
	Decision Making (Fletcher *et al.* 2003)	• Identifying options • Balancing risks and selecting options
		• Others

13 APPENDIX II – GENERIC SKILLS CODING SCHEMES

Table 13.1 Coding scheme for examining generic skills within design teams

Generic Skills	Code	Observable Behaviours	Example
Adaptability	A1	Subject is directed towards a problem during design session, and solves before moving on	“Well why don’t we move x closer to y”
	A2	Subject recognises a problem during the design phase, and solves it before moving on	“Because of the dimensions of x we should move it closer to y”
Shared Situational Awareness	B1	Monitors changes in the environment or brief	“If x changes, it will result in a change in y”
	B2	Reports changes in the environment or brief	“x will need to change”
	B3	Collects and distributes relevant information	“To change x you will need to know y”
	B4	Identifies future problems	“If x is changed now it will effect y in the future”
	B5	Subject finishes other peoples sentences	
	B6	Subject gives information or representation before the team member has finished requesting it	
	B7	Identifies a possible source of information	“What if we ask the neighbour?”
Performance Monitoring and Feedback	C1	Checks the form and status of team members current activities and tasks	“Your drawing x aren’t you?”
	C2	Asks a question to clarify action plans	“Is this what you want me to do?”
	C3	Asks for description or representation of a team member’s task to check for appropriateness	“Could I check that x you created is correct?”
	C4	Provides comment on the appropriateness of a current or completed task, either through agreement/disagreement, suggestions, or opinions	“I think x needs to be more like y”
	C5	Gives positive response	“Yes”
	C6	Gives positive response with affirmation	“Yes, that’s really good”
	C7	Gives negative response	“No”
	C8	Asks for feedback or confirmation on task	“Does this look right”
Leadership / Team	D1	Gives priority to tasks	“We organise a timeline for completion

Management			of tasks”
	D2	Provides standards for team operation and task completion	“x needs to be double checked before it is signed off”
	D3	Planning and preparing of tasks and workload	“I think a plan should be created for tasks and workload”
	D4	Use of authority or assertiveness to assign tasks to team members	“You will do both x and y”
	D5	Identification and utilisation of resources	“Use that paper there to create x”
Interpersonal Relations	E1	Team building and getting team members involved	“I would like to get everyone’s opinions on x”
	E2	Confirms other team members, and encourages them	“That’s a really great idea”
	E3	Solving conflict between team members, by providing information	“You may understand our point of view if you view x from this angle”
	E4	Solving conflict between team members by listening to both arguments	“Please lets just hear both arguments, them form a decision”
	E5	Interrupts another team member, showing disrespect. Not in a form of anticipation	
Co-ordination	F1	Refers to the time available or left to complete the task	“There is only 10 minutes left to complete x”
	F2	Checks the progress of tasks, and their priority.	“I think you should complete tasks x and y soon”
	F3	Checks the workload status	“Will you be able to complete both tasks in the next 10 minutes”
	F4	Asks or questions the timing of the next task	“What’s next?”
	F5	Organising tasks or artefacts	“There is drawing number 1”
Communica-tion		This is better measured by the Bales IPA, as most of the behaviour within a team could be interpreted as communication	
Decision Making	G1	Generates a list of options from which a decision will be made	“We have a choice of x, y, z”
	G2	Questions the use of a solution, whether it is accepted or rejected.	“What if we do x”
	G3	Before a solution is created to a problem, the subject questions the factors that need to be considered	“We need to consider x, y, z before can resolve the issue”
	G4	Checks the outcome of a solution against the problem	“If we implement x, how will that change y”
	G5	Defines the problem in light of a solution	“We need to accomplish x, y, z”
	G6	Presents a single solution	“What about we do x”

Table 13.2 Table Changed initial coding scheme illustrating generic skills and the observable behaviours used by coders to identify generic skills

Generic Skills	Code	Observable Behaviours	Example
Adaptability	A1	Recognises areas for improvement in design or solution	"Maybe I should change the size of X"
	A2	Directs attention of the designer to a possible improvement for the design or solution	"Maybe you could should change the size of X"
	A3	Physically fixes or improves a design within 10 seconds of the flaw being nominated	
Shared Situational Awareness	B1	Explains a design/solution	"This bit represents that service area"
	B2	Asks for confirmation on a design/solution or aspect	"So this is the service area here?"
	B3	Asks a question regarding a design/solution or aspect	"Where is the service area?"
	B4	Finalises a design/solution	"OK that's that drawing done"
	B5	Distributes relevant written or physical information	
	B6	Identifies future problems	
	B7	Uses anticipation to complete other team member's sentences. Usually followed by agreement from the team member	
	B8	Identifies a possible source of information	
Performance Monitoring and Feedback	C1	Questions or asks for a description of a task	"What scale are you going to sketch X at"
	C2	Provides comment on the appropriateness of a current or completed task, or a design either through agreement/disagreement, suggestions, or opinions (More general; overall comment)	"I think this is good, really good"
	C3	Asks for feedback or confirmation on task	"Your drawing X at a ration of 100:1 aren't you?"
	C4	Explains a task	"I created a cross sectional drawing at the service level"
	C5	Checks the outcome of a design/solution against the problem	"OK the size of the service area is in line with the brief"
Leadership/Team Management	D1	Communicates the instructions and standards described in the design brief (formal)	Reads from brief
	D2	Suggests a new task	"I think we should make a new drawing of section X"

	D3	Gives priority to tasks	"We should draw a cross section first"
	D4	Assigns tasks to team members	"OK you can do that and I will do this"
Interpersonal Relations	E1	Spontaneously asks a team member for their opinion on a task or design	"Hey Pete, what do you think of X"
	E2	Interrupts another team member with a statement which goes against what the member is expressing or changes the focus	
	E3	Conflict/conflict solving	Arguing/Taking control of an argument
	E4	Joking, gossip/non-design discussion	"What are you doing after work?"
	E5	Polite remark	"Thanks", "Sorry"
Co-ordination (task related)	F1	Checks or monitors the progress of tasks against time	"We have to finish X by the end of the day"
	F2	Checks or monitors workload against time	"OK you have 10 minutes to finish X"
	F3	Asks a question regarding an artefact	"Where is that drawing going?"
	F4	Explains the presence or destination of an artefact	"I am putting X over here with the other drawings"
Communica-tion		This is better measured by the Bales IPA, as most of the behaviour within a team could be interpreted as communication	
Decision Making		This is better measured by the Bales IPA, which has a system for the measurement of decision making	

Table 13.3 Final Generic Skills Coding Scheme

Non-Technical Skill	Observable Behaviour	Example
Task Management	Planning or preparing a task	• Outlines and describes the plan for the design • Reviewing the design after changes are made • Describes what actions are to take place once he design is completed
	Prioritising tasks	• Assigns priority to design tasks to be completed • Prioritises the segments within design tasks
	Providing direction and maintaining standards for the task	• Follow design protocols and briefs • Cross checks the completion of design tasks
	Identifying and utilising resources	• Identifies and allocates resources • Allocates tasks to team members • Requests additional resources
Team Working	Co-ordinating activities with team members	• Confirms roles and responsibilities of team members • Discusses design with others • Considers requirements of others before acting • Co-operates with others to achieve goals
	Exchanging information	• Gives updates and reports key events • Confirms shared understanding • Communicates design plans and relevant information to relevant members • Clearly documents design
	Using authority and assertiveness	• Is appropriately and necessarily assertive • Takes appropriate leadership • Gives clear orders • States case for order and gives justification
	Assessing capabilities	• Asks for assistance • Asks team member about experience • Notices that a team member does not complete task to appropriate standard
	Supporting others	• Acknowledges concerns of others • Reassures/Encourages • Debriefs • Anticipates when other will need information or designs
Situational Awareness	Gathering information	
	Recognising and understanding	
	Anticipating	

Decision Making	Identifying options	• Discusses design options with clients/other designers • Discusses various techniques for the design
	Balancing risks and selecting options	• Weighs up risks associated with different design options • Implements chosen design
	Re-evaluating	• Re-evaluates chosen design technique after it has been chosen

14 APPENDIX III – COMPLETE TABLES OF REPEATED MEASURE ANOVA

Table 14.1 Complete Mauchly's Test of Sphericity table for Generic Skills

GenSkill	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
1.00	conditio	.049	9.070	2	.011	.512	.525	.500
2.00	conditio	.558	1.748	2	.417	.694	.945	.500
3.00	conditio	.253	4.128	2	.127	.572	.652	.500
4.00	conditio	.338	3.250	2	.197	.602	.719	.500

Table 14.2 Complete Test of Within-Subjects Effects table for Generic Skills

GenSkill	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
1.00	conditio	Sphericity Assumed	644.800	2	322.400	4.043	.061
		Greenhouse-Geisser	644.800	1.025	629.119	4.043	.113
		Huynh-Feldt	644.800	1.050	613.938	4.043	.111
		Lower-bound	644.800	1.000	644.800	4.043	.115
	Error(conditio)	Sphericity Assumed	637.867	8	79.733		
		Greenhouse-Geisser	637.867	4.100	155.589		
		Huynh-Feldt	637.867	4.201	151.834		
		Lower-bound	637.867	4.000	159.467		
2.00	conditio	Sphericity Assumed	1114.533	2	557.267	.450	.653
		Greenhouse-Geisser	1114.533	1.387	803.380	.450	.592
		Huynh-Feldt	1114.533	1.889	589.875	.450	.643
		Lower-bound	1114.533	1.000	1114.533	.450	.539
	Error(conditio)	Sphericity Assumed	9904.133	8	1238.017		
		Greenhouse-Geisser	9904.133	5.549	1784.778		
		Huynh-Feldt	9904.133	7.558	1310.459		
		Lower-bound	9904.133	4.000	2476.033		
3.00	conditio	Sphericity Assumed	1063.600	2	531.800	4.903	.041
		Greenhouse-Geisser	1063.600	1.145	929.256	4.903	.081
		Huynh-Feldt	1063.600	1.304	815.781	4.903	.071
		Lower-bound	1063.600	1.000	1063.600	4.903	.091
	Error(conditio)	Sphericity Assumed	867.733	8	108.467		
		Greenhouse-Geisser	867.733	4.578	189.532		
		Huynh-Feldt	867.733	5.215	166.388		
		Lower-bound	867.733	4.000	216.933		
4.00	conditio	Sphericity Assumed	8348.933	2	4174.467	42.431	.000
		Greenhouse-Geisser	8348.933	1.204	6936.066	42.431	.001
		Huynh-Feldt	8348.933	1.437	5809.674	42.431	.001
		Lower-bound	8348.933	1.000	8348.933	42.431	.003
	Error(conditio)	Sphericity Assumed	787.067	8	98.383		
		Greenhouse-Geisser	787.067	4.815	163.468		
		Huynh-Feldt	787.067	5.748	136.922		
		Lower-bound	787.067	4.000	196.767		

Table 14.3 Complete Test of Within-Subjects Contrasts table for Generic Skills

GenSkill	Source	conditio	Type III Sum of Squares	df	Mean Square	F	Sig.
1.00	conditio	Level 1 vs. Level 2	819.200	1	819.200	4.799	.094
		Level 2 vs. Level 3	20.000	1	20.000	1.026	.368
	Error(conditio)	Level 1 vs. Level 2	682.800	4	170.700		
		Level 2 vs. Level 3	78.000	4	19.500		
2.00	conditio	Level 1 vs. Level 2	768.800	1	768.800	.559	.496
		Level 2 vs. Level 3	2205.000	1	2205.000	.540	.503
	Error(conditio)	Level 1 vs. Level 2	5499.200	4	1374.800		
		Level 2 vs. Level 3	16342.000	4	4085.500		
3.00	conditio	Level 1 vs. Level 2	627.200	1	627.200	19.478	.012
		Level 2 vs. Level 3	441.800	1	441.800	1.571	.278
	Error(conditio)	Level 1 vs. Level 2	128.800	4	32.200		
		Level 2 vs. Level 3	1125.200	4	281.300		
4.00	conditio	Level 1 vs. Level 2	7372.800	1	7372.800	120.274	.000
		Level 2 vs. Level 3	1656.200	1	1656.200	8.685	.042
	Error(conditio)	Level 1 vs. Level 2	245.200	4	61.300		
		Level 2 vs. Level 3	762.800	4	190.700		

Table 14.4 Complete Mauchly's Test of Sphericity table for Observable Behaviours

Generic Skill (numeric)	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
A11	conditio	.834	.546	2	.761	.857	1.000	.500
A21	conditio	.	.	2	.	.	.	.500
A41	conditio	.	.	2	.	.	.	.500
A42	conditio	.408	.897	2	.639	.628	1.000	.500
A43	conditio	.000	.	2	.	.500	.	.500
B21	conditio	.303	2.388	2	.303	.589	.745	.500
B22	conditio	.629	1.390	2	.499	.729	1.000	.500
B23	conditio	.118	6.403	2	.041	.531	.564	.500
B31	conditio	.	.	2	.	.	.	.500
B32	conditio	.041	3.200	2	.202	.510	.542	.500
B33	conditio	.478	1.478	2	.478	.657	.965	.500
B41	conditio	.000	.	2	.	.500	.	.500
B43	conditio	.	.	2	.	.	.	.500
B51	conditio	.510	1.347	2	.510	.671	1.000	.500
B52	conditio	.358	3.079	2	.214	.609	.735	.500
C11	conditio	.445	2.432	2	.296	.643	.816	.500
C14	conditio	.	.	2	.	.	.	.500
C31	conditio	.051	2.976	2	.226	.513	.554	.500
D11	conditio	.251	4.147	2	.126	.572	.651	.500
D12	conditio	.	.	2	.	.	.	.500
D21	conditio	.000	.	2	.	.500	.000	.500

Table 14.5 Complete Test of Within-Subjects Effects table for Observable Behaviours

Generic Skill (numeric)	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
A11	conditio	Sphericity Assumed	1096.933	2	548.467	9.021	.009
		Greenhouse-Geisser	1096.933	1.715	639.762	9.021	.014
		Huynh-Feldt	1096.933	2.000	548.467	9.021	.009
		Lower-bound	1096.933	1.000	1096.933	9.021	.040
	Error(conditio)	Sphericity Assumed	486.400	8	60.800		
		Greenhouse-Geisser	486.400	6.858	70.920		
		Huynh-Feldt	486.400	8.000	60.800		
		Lower-bound	486.400	4.000	121.600		
A21	conditio	Sphericity Assumed	4.667	2	2.333	.	.
		Greenhouse-Geisser	4.667	.	.	.	.
		Huynh-Feldt	4.667	.	.	.	.
		Lower-bound	4.667	1.000	4.667	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
A41	conditio	Sphericity Assumed	.000	2	.000	.	.
		Greenhouse-Geisser	.000	.	.	.	.
		Huynh-Feldt	.000	.	.	.	.
		Lower-bound	.000	1.000	.000	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
A42	conditio	Sphericity Assumed	33.556	2	16.778	1.948	.257
		Greenhouse-Geisser	33.556	1.256	26.711	1.948	.286

		Huynh-Feldt	33.556	2.000	16.778	1.948	.257
		Lower-bound	33.556	1.000	33.556	1.948	.298
	Error(conditio)	Sphericity Assumed	34.444	4	8.611		
		Greenhouse-Geisser	34.444	2.512	13.709		
		Huynh-Feldt	34.444	4.000	8.611		
		Lower-bound	34.444	2.000	17.222		
A43	conditio	Sphericity Assumed	1.333	2	.667	1.000	.500
		Greenhouse-Geisser	1.333	1.000	1.333	1.000	.500
		Huynh-Feldt	1.333	.	.	.	.
		Lower-bound	1.333	1.000	1.333	1.000	.500
	Error(conditio)	Sphericity Assumed	1.333	2	.667		
		Greenhouse-Geisser	1.333	1.000	1.333		
		Huynh-Feldt	1.333	.	.		
		Lower-bound	1.333	1.000	1.333		
B21	conditio	Sphericity Assumed	1206.167	2	603.083	6.343	.033
		Greenhouse-Geisser	1206.167	1.179	1023.461	6.343	.072
		Huynh-Feldt	1206.167	1.490	809.490	6.343	.053
		Lower-bound	1206.167	1.000	1206.167	6.343	.086
	Error(conditio)	Sphericity Assumed	570.500	6	95.083		
		Greenhouse-Geisser	570.500	3.536	161.361		
		Huynh-Feldt	570.500	4.470	127.626		
		Lower-bound	570.500	3.000	190.167		
B22	conditio	Sphericity Assumed	630.000	2	315.000	.964	.422
		Greenhouse-Geisser	630.000	1.459	431.832	.964	.404
		Huynh-Feldt	630.000	2.000	315.000	.964	.422
		Lower-bound	630.000	1.000	630.000	.964	.382
	Error(conditio)	Sphericity Assumed	2613.333	8	326.667		
		Greenhouse-Geisser	2613.333	5.836	447.826		
		Huynh-Feldt	2613.333	8.000	326.667		
		Lower-bound	2613.333	4.000	653.333		

B23	conditio	Sphericity Assumed	336.933	2	168.467	.866	.457
		Greenhouse-Geisser	336.933	1.063	316.998	.866	.409
		Huynh-Feldt	336.933	1.128	298.576	.866	.414
		Lower-bound	336.933	1.000	336.933	.866	.405
	Error(conditio)	Sphericity Assumed	1556.400	8	194.550		
		Greenhouse-Geisser	1556.400	4.252	366.078		
		Huynh-Feldt	1556.400	4.514	344.804		
		Lower-bound	1556.400	4.000	389.100		
B31	conditio	Sphericity Assumed	2.000	2	1.000	.	.
		Greenhouse-Geisser	2.000	.	.	.	.
		Huynh-Feldt	2.000	.	.	.	.
		Lower-bound	2.000	1.000	2.000	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
B32	conditio	Sphericity Assumed	80.889	2	40.444	1.689	.294
		Greenhouse-Geisser	80.889	1.021	79.241	1.689	.323
		Huynh-Feldt	80.889	1.085	74.555	1.689	.321
		Lower-bound	80.889	1.000	80.889	1.689	.323
	Error(conditio)	Sphericity Assumed	95.778	4	23.944		
		Greenhouse-Geisser	95.778	2.042	46.913		
		Huynh-Feldt	95.778	2.170	44.139		
		Lower-bound	95.778	2.000	47.889		
B33	conditio	Sphericity Assumed	158.167	2	79.083	5.362	.046
		Greenhouse-Geisser	158.167	1.314	120.397	5.362	.080
		Huynh-Feldt	158.167	1.930	81.944	5.362	.049
		Lower-bound	158.167	1.000	158.167	5.362	.104
	Error(conditio)	Sphericity Assumed	88.500	6	14.750		
		Greenhouse-Geisser	88.500	3.941	22.455		

		Huynh-Feldt	88.500	5.791	15.283		
		Lower-bound	88.500	3.000	29.500		
B41	conditio	Sphericity Assumed	7.000	2	3.500	3.000	.250
		Greenhouse-Geisser	7.000	1.000	7.000	3.000	.333
		Huynh-Feldt	7.000	.	.	.	.
		Lower-bound	7.000	1.000	7.000	3.000	.333
	Error(conditio)	Sphericity Assumed	2.333	2	1.167		
		Greenhouse-Geisser	2.333	1.000	2.333		
		Huynh-Feldt	2.333	.	.		
		Lower-bound	2.333	1.000	2.333		
B43	conditio	Sphericity Assumed	.000	2	.000	.	.
		Greenhouse-Geisser	.000	.	.	.	.
		Huynh-Feldt	.000	.	.	.	.
		Lower-bound	.000	1.000	.000	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
B51	conditio	Sphericity Assumed	2.000	2	1.000	.300	.751
		Greenhouse-Geisser	2.000	1.342	1.490	.300	.677
		Huynh-Feldt	2.000	2.000	1.000	.300	.751
		Lower-bound	2.000	1.000	2.000	.300	.622
	Error(conditio)	Sphericity Assumed	20.000	6	3.333		
		Greenhouse-Geisser	20.000	4.027	4.967		
		Huynh-Feldt	20.000	6.000	3.333		
		Lower-bound	20.000	3.000	6.667		
B52	conditio	Sphericity Assumed	67.733	2	33.867	3.462	.083
		Greenhouse-Geisser	67.733	1.218	55.598	3.462	.122
		Huynh-Feldt	67.733	1.471	46.053	3.462	.107
		Lower-bound	67.733	1.000	67.733	3.462	.136

	Error(conditio)	Sphericity Assumed	78.267	8	9.783		
		Greenhouse-Geisser	78.267	4.873	16.061		
		Huynh-Feldt	78.267	5.883	13.304		
		Lower-bound	78.267	4.000	19.567		
C11	conditio	Sphericity Assumed	955.600	2	477.800	5.526	.031
		Greenhouse-Geisser	955.600	1.286	743.216	5.526	.060
		Huynh-Feldt	955.600	1.632	585.647	5.526	.043
		Lower-bound	955.600	1.000	955.600	5.526	.078
	Error(conditio)	Sphericity Assumed	691.733	8	86.467		
		Greenhouse-Geisser	691.733	5.143	134.498		
		Huynh-Feldt	691.733	6.527	105.983		
		Lower-bound	691.733	4.000	172.933		
C14	conditio	Sphericity Assumed	.667	2	.333	.	.
		Greenhouse-Geisser	.667	.	.	.	.
		Huynh-Feldt	.667	.	.	.	.
		Lower-bound	.667	1.000	.667	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
C31	conditio	Sphericity Assumed	2.667	2	1.333	.258	.784
		Greenhouse-Geisser	2.667	1.026	2.599	.258	.666
		Huynh-Feldt	2.667	1.107	2.408	.258	.680
		Lower-bound	2.667	1.000	2.667	.258	.662
	Error(conditio)	Sphericity Assumed	20.667	4	5.167		
		Greenhouse-Geisser	20.667	2.052	10.070		
		Huynh-Feldt	20.667	2.215	9.331		
		Lower-bound	20.667	2.000	10.333		
D11	conditio	Sphericity Assumed	6743.333	2	3371.667	25.383	.000
		Greenhouse-Geisser	6743.333	1.144	5896.978	25.383	.005

		Huynh-Feldt	6743.333	1.301	5181.322	25.383	.003
		Lower-bound	6743.333	1.000	6743.333	25.383	.007
	Error(conditio)	Sphericity Assumed	1062.667	8	132.833		
		Greenhouse-Geisser	1062.667	4.574	232.323		
		Huynh-Feldt	1062.667	5.206	204.128		
		Lower-bound	1062.667	4.000	265.667		
D12	conditio	Sphericity Assumed	2.667	2	1.333	.	.
		Greenhouse-Geisser	2.667	.	.	.	.
		Huynh-Feldt	2.667	.	.	.	.
		Lower-bound	2.667	1.000	2.667	.	.
	Error(conditio)	Sphericity Assumed	.000	0	.		
		Greenhouse-Geisser	.000	.	.		
		Huynh-Feldt	.000	.	.		
		Lower-bound	.000	.000	.		
D21	conditio	Sphericity Assumed	52.333	2	26.167	2.754	.266
		Greenhouse-Geisser	52.333	1.000	52.333	2.754	.345
		Huynh-Feldt	52.333	.000	.	.	.
		Lower-bound	52.333	1.000	52.333	2.754	.345
	Error(conditio)	Sphericity Assumed	19.000	2	9.500		
		Greenhouse-Geisser	19.000	1.000	19.000		
		Huynh-Feldt	19.000	.000	.		
		Lower-bound	19.000	1.000	19.000		

Table 14.6 Complete Tests of Within-Subjects Contrasts table for Observable Behaviours

Generic Skill (numeric)	Source	conditio	Type III Sum of Squares	df	Mean Square	F	Sig.
A11	conditio	Level 1 vs. Level 2	1312.200	1	1312.200	7.943	.048
		Level 2 vs. Level 3	57.800	1	57.800	.729	.441
	Error(conditio)	Level 1 vs. Level 2	660.800	4	165.200		
		Level 2 vs. Level 3	317.200	4	79.300		
A21	conditio	Level 1 vs. Level 2	1.000	1	1.000	.	.
		Level 2 vs. Level 3	9.000	1	9.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
A41	conditio	Level 1 vs. Level 2	.000	1	.000	.	.
		Level 2 vs. Level 3	.000	1	.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
A42	conditio	Level 1 vs. Level 2	65.333	1	65.333	2.481	.256
		Level 2 vs. Level 3	27.000	1	27.000	1.286	.374
	Error(conditio)	Level 1 vs. Level 2	52.667	2	26.333		
		Level 2 vs. Level 3	42.000	2	21.000		
A43	conditio	Level 1 vs. Level 2	2.000	1	2.000	1.000	.500
		Level 2 vs. Level 3	.000	1	.000	.	.
	Error(conditio)	Level 1 vs. Level 2	2.000	1	2.000		
		Level 2 vs. Level 3	.000	1	.000		
B21	conditio	Level 1 vs. Level 2	1722.250	1	1722.250	16.734	.026
		Level 2 vs. Level 3	4.000	1	4.000	.011	.921
	Error(conditio)	Level 1 vs. Level 2	308.750	3	102.917		
		Level 2 vs. Level 3	1046.000	3	348.667		
B22	conditio	Level 1 vs. Level 2	45.000	1	45.000	.063	.815
		Level 2 vs. Level 3	720.000	1	720.000	.749	.436

	Error(conditio)	Level 1 vs. Level 2	2872.000	4	718.000		
		Level 2 vs. Level 3	3844.000	4	961.000		
B23	conditio	Level 1 vs. Level 2	672.800	1	672.800	23.774	.008
		Level 2 vs. Level 3	145.800	1	145.800	.235	.653
	Error(conditio)	Level 1 vs. Level 2	113.200	4	28.300		
		Level 2 vs. Level 3	2477.200	4	619.300		
B31	conditio	Level 1 vs. Level 2	4.000	1	4.000	.	.
		Level 2 vs. Level 3	1.000	1	1.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
B32	conditio	Level 1 vs. Level 2	161.333	1	161.333	1.710	.321
		Level 2 vs. Level 3	33.333	1	33.333	1.099	.405
	Error(conditio)	Level 1 vs. Level 2	188.667	2	94.333		
		Level 2 vs. Level 3	60.667	2	30.333		
B33	conditio	Level 1 vs. Level 2	6.250	1	6.250	.216	.674
		Level 2 vs. Level 3	272.250	1	272.250	5.642	.098
	Error(conditio)	Level 1 vs. Level 2	86.750	3	28.917		
		Level 2 vs. Level 3	144.750	3	48.250		
B41	conditio	Level 1 vs. Level 2	.500	1	.500	.111	.795
		Level 2 vs. Level 3	12.500	1	12.500	25.000	.126
	Error(conditio)	Level 1 vs. Level 2	4.500	1	4.500		
		Level 2 vs. Level 3	.500	1	.500		
B43	conditio	Level 1 vs. Level 2	.000	1	.000	.	.
		Level 2 vs. Level 3	.000	1	.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
B51	conditio	Level 1 vs. Level 2	1.000	1	1.000	.231	.664
		Level 2 vs. Level 3	1.000	1	1.000	.231	.664
	Error(conditio)	Level 1 vs. Level 2	13.000	3	4.333		
		Level 2 vs. Level 3	13.000	3	4.333		

B52	conditio	Level 1 vs. Level 2	28.800	1	28.800	.920	.392
		Level 2 vs. Level 3	135.200	1	135.200	5.956	.071
	Error(conditio)	Level 1 vs. Level 2	125.200	4	31.300		
		Level 2 vs. Level 3	90.800	4	22.700		
C11	conditio	Level 1 vs. Level 2	696.200	1	696.200	15.751	.017
		Level 2 vs. Level 3	288.800	1	288.800	1.189	.337
	Error(conditio)	Level 1 vs. Level 2	176.800	4	44.200		
		Level 2 vs. Level 3	971.200	4	242.800		
C14	conditio	Level 1 vs. Level 2	.000	1	.000	.	.
		Level 2 vs. Level 3	1.000	1	1.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
C31	conditio	Level 1 vs. Level 2	1.333	1	1.333	.093	.789
		Level 2 vs. Level 3	1.333	1	1.333	4.000	.184
	Error(conditio)	Level 1 vs. Level 2	28.667	2	14.333		
		Level 2 vs. Level 3	.667	2	.333		
D11	conditio	Level 1 vs. Level 2	5780.000	1	5780.000	46.240	.002
		Level 2 vs. Level 3	1445.000	1	1445.000	8.095	.047
	Error(conditio)	Level 1 vs. Level 2	500.000	4	125.000		
		Level 2 vs. Level 3	714.000	4	178.500		
D12	conditio	Level 1 vs. Level 2	.000	1	.000	.	.
		Level 2 vs. Level 3	4.000	1	4.000	.	.
	Error(conditio)	Level 1 vs. Level 2	.000	0	.		
		Level 2 vs. Level 3	.000	0	.		
D21	conditio	Level 1 vs. Level 2	72.000	1	72.000	2.250	.374
		Level 2 vs. Level 3	.500	1	.500	1.000	.500
	Error(conditio)	Level 1 vs. Level 2	32.000	1	32.000		
		Level 2 vs. Level 3	.500	1	.500		

Table 14.7 Complete Mauchly's Test of Sphericity table for Bales IPA

Interaction	Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon(a)		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
1.00	conditio	.000	.	2	.	.500	.	.500
2.00	conditio	.852	.480	2	.787	.871	1.000	.500
3.00	conditio	.915	.267	2	.875	.922	1.000	.500
4.00	conditio	.905	.299	2	.861	.913	1.000	.500
5.00	conditio	.219	4.550	2	.103	.562	.629	.500
6.00	conditio	.213	4.644	2	.098	.559	.624	.500
7.00	conditio	.790	.707	2	.702	.827	1.000	.500
8.00	conditio	.673	1.189	2	.552	.753	1.000	.500
9.00	conditio	.074	2.599	2	.273	.519	.580	.500
10.00	conditio	.611	1.477	2	.478	.720	1.000	.500
11.00	conditio	.808	.641	2	.726	.839	1.000	.500

Table 14.8 Complete Tests of Within-Subjects Effects table for Bales IPA

Interaction	Source		Type III Sum of Squares	df	Mean Square	F	Sig.
1.00	conditio	Sphericity Assumed	7.000	2	3.500	7.000	.125
		Greenhouse-Geisser	7.000	1.000	7.000	7.000	.230
		Huynh-Feldt	7.000	.	.	.	.
		Lower-bound	7.000	1.000	7.000	7.000	.230
	Error(conditio)	Sphericity Assumed	1.000	2	.500		
		Greenhouse-Geisser	1.000	1.000	1.000		
		Huynh-Feldt	1.000	.	.		
		Lower-bound	1.000	1.000	1.000		
2.00	conditio	Sphericity Assumed	3.733	2	1.867	.404	.680
		Greenhouse-Geisser	3.733	1.742	2.143	.404	.656
		Huynh-Feldt	3.733	2.000	1.867	.404	.680
		Lower-bound	3.733	1.000	3.733	.404	.559
	Error(conditio)	Sphericity Assumed	36.933	8	4.617		
		Greenhouse-Geisser	36.933	6.970	5.299		
		Huynh-Feldt	36.933	8.000	4.617		
		Lower-bound	36.933	4.000	9.233		
3.00	conditio	Sphericity Assumed	1617.600	2	808.800	8.457	.011
		Greenhouse-Geisser	1617.600	1.843	877.623	8.457	.013
		Huynh-Feldt	1617.600	2.000	808.800	8.457	.011
		Lower-bound	1617.600	1.000	1617.600	8.457	.044
	Error(conditio)	Sphericity	765.067	8	95.633		

		Assumed					
		Greenhouse-Geisser	765.067	7.373	103.771		
		Huynh-Feldt	765.067	8.000	95.633		
		Lower-bound	765.067	4.000	191.267		
4.00	conditio	Sphericity Assumed	5326.533	2	2663.267	19.836	.001
		Greenhouse-Geisser	5326.533	1.827	2916.238	19.836	.001
		Huynh-Feldt	5326.533	2.000	2663.267	19.836	.001
		Lower-bound	5326.533	1.000	5326.533	19.836	.011
	Error(conditio)	Sphericity Assumed	1074.133	8	134.267		
		Greenhouse-Geisser	1074.133	7.306	147.020		
		Huynh-Feldt	1074.133	8.000	134.267		
		Lower-bound	1074.133	4.000	268.533		
5.00	conditio	Sphericity Assumed	31.600	2	15.800	.301	.748
		Greenhouse-Geisser	31.600	1.123	28.133	.301	.635
		Huynh-Feldt	31.600	1.257	25.139	.301	.657
		Lower-bound	31.600	1.000	31.600	.301	.612
	Error(conditio)	Sphericity Assumed	419.733	8	52.467		
		Greenhouse-Geisser	419.733	4.493	93.422		
		Huynh-Feldt	419.733	5.028	83.479		
		Lower-bound	419.733	4.000	104.933		
6.00	conditio	Sphericity Assumed	22.533	2	11.267	.034	.967
		Greenhouse-Geisser	22.533	1.119	20.137	.034	.886
		Huynh-Feldt	22.533	1.248	18.058	.034	.906
		Lower-bound	22.533	1.000	22.533	.034	.864

	Error(conditio)	Sphericity Assumed	2688.133	8	336.017		
		Greenhouse-Geisser	2688.133	4.476	600.566		
		Huynh-Feldt	2688.133	4.991	538.562		
		Lower-bound	2688.133	4.000	672.033		
7.00	conditio	Sphericity Assumed	838.533	2	419.267	3.383	.086
		Greenhouse-Geisser	838.533	1.653	507.276	3.383	.102
		Huynh-Feldt	838.533	2.000	419.267	3.383	.086
		Lower-bound	838.533	1.000	838.533	3.383	.140
	Error(conditio)	Sphericity Assumed	991.467	8	123.933		
		Greenhouse-Geisser	991.467	6.612	149.948		
		Huynh-Feldt	991.467	8.000	123.933		
		Lower-bound	991.467	4.000	247.867		
8.00	conditio	Sphericity Assumed	1.600	2	.800	.658	.544
		Greenhouse-Geisser	1.600	1.507	1.062	.658	.510
		Huynh-Feldt	1.600	2.000	.800	.658	.544
		Lower-bound	1.600	1.000	1.600	.658	.463
	Error(conditio)	Sphericity Assumed	9.733	8	1.217		
		Greenhouse-Geisser	9.733	6.027	1.615		
		Huynh-Feldt	9.733	8.000	1.217		
		Lower-bound	9.733	4.000	2.433		
9.00	conditio	Sphericity Assumed	14.889	2	7.444	12.182	.020
		Greenhouse-Geisser	14.889	1.039	14.335	12.182	.069
		Huynh-Feldt	14.889	1.161	12.827	12.182	.059
		Lower-bound	14.889	1.000	14.889	12.182	.073

	Error(conditio)	Sphericity Assumed	2.444	4	.611		
		Greenhouse-Geisser	2.444	2.077	1.177		
		Huynh-Feldt	2.444	2.321	1.053		
		Lower-bound	2.444	2.000	1.222		
10.00	conditio	Sphericity Assumed	8.400	2	4.200	1.135	.368
		Greenhouse-Geisser	8.400	1.440	5.833	1.135	.360
		Huynh-Feldt	8.400	2.000	4.200	1.135	.368
		Lower-bound	8.400	1.000	8.400	1.135	.347
	Error(conditio)	Sphericity Assumed	29.600	8	3.700		
		Greenhouse-Geisser	29.600	5.760	5.139		
		Huynh-Feldt	29.600	8.000	3.700		
		Lower-bound	29.600	4.000	7.400		
11.00	conditio	Sphericity Assumed	14.533	2	7.267	3.206	.095
		Greenhouse-Geisser	14.533	1.677	8.664	3.206	.109
		Huynh-Feldt	14.533	2.000	7.267	3.206	.095
		Lower-bound	14.533	1.000	14.533	3.206	.148
	Error(conditio)	Sphericity Assumed	18.133	8	2.267		
		Greenhouse-Geisser	18.133	6.710	2.702		
		Huynh-Feldt	18.133	8.000	2.267		
		Lower-bound	18.133	4.000	4.533		

Table 14.9 Complete Tests of Within-Subjects Contrasts table for Bales IPA

Interaction	Source	conditio	Type III Sum of Squares	df	Mean Square	F	Sig.
1.00	conditio	Linear	.250	1	.250	1.000	.500
		Quadratic	6.750	1	6.750	9.000	.205
	Error(conditio)	Linear	.250	1	.250		
		Quadratic	.750	1	.750		
2.00	conditio	Linear	1.600	1	1.600	.561	.495
		Quadratic	2.133	1	2.133	.334	.594
	Error(conditio)	Linear	11.400	4	2.850		
		Quadratic	25.533	4	6.383		
3.00	conditio	Linear	1587.600	1	1587.600	18.493	.013
		Quadratic	30.000	1	30.000	.285	.622
	Error(conditio)	Linear	343.400	4	85.850		
		Quadratic	421.667	4	105.417		
4.00	conditio	Linear	5198.400	1	5198.400	31.814	.005
		Quadratic	128.133	1	128.133	1.219	.332
	Error(conditio)	Linear	653.600	4	163.400		
		Quadratic	420.533	4	105.133		
5.00	conditio	Linear	28.900	1	28.900	.489	.523
		Quadratic	2.700	1	2.700	.059	.820
	Error(conditio)	Linear	236.600	4	59.150		
		Quadratic	183.133	4	45.783		
6.00	conditio	Linear	22.500	1	22.500	.047	.839
		Quadratic	.033	1	.033	.000	.990
	Error(conditio)	Linear	1925.000	4	481.250		
		Quadratic	763.133	4	190.783		
7.00	conditio	Linear	722.500	1	722.500	5.255	.084
		Quadratic	116.033	1	116.033	1.051	.363

	Error(conditio)	Linear	550.000	4	137.500		
		Quadratic	441.467	4	110.367		
8.00	conditio	Linear	.400	1	.400	.615	.477
		Quadratic	1.200	1	1.200	.673	.458
	Error(conditio)	Linear	2.600	4	.650		
		Quadratic	7.133	4	1.783		
9.00	conditio	Linear	8.167	1	8.167	7.000	.118
		Quadratic	6.722	1	6.722	121.000	.008
	Error(conditio)	Linear	2.333	2	1.167		
		Quadratic	.111	2	.056		
10.00	conditio	Linear	8.100	1	8.100	1.385	.305
		Quadratic	.300	1	.300	.194	.683
	Error(conditio)	Linear	23.400	4	5.850		
		Quadratic	6.200	4	1.550		
11.00	conditio	Linear	4.900	1	4.900	2.579	.184
		Quadratic	9.633	1	9.633	3.658	.128
	Error(conditio)	Linear	7.600	4	1.900		
		Quadratic	10.533	4	2.633		

15 APPENDIX IV – SYSTEMIC FUNCTIONAL LINGUISTICS STATISTICAL DATA

Total exchange moves

NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
ESAF2F	5	16.1120	5.21980	12.08	21.99
ESAWB	5	15.5700	5.05487	9.81	21.61
ESA3D	5	13.1820	6.58711	6.88	21.22

Friedman Test

Ranks

	Mean Rank
ESAF2F	2.60
ESAWB	2.20
ESA3D	1.20

Test Statistics[a]

N	5
Chi-Square	5.200
df	2
Asymp. Sig.	.074

a. Friedman Test

Synoptic moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
SMF2F	5	12.3680	3.59685	9.40	16.90
SMWB	5	12.1480	3.72259	8.36	16.41
sm3d	5	10.6240	5.26075	5.62	17.74

Friedman Test

Ranks

	Mean Rank
SMF2F	2.40
SMWB	2.20
sm3d	1.40

Test Statistics[a]

N	5
Chi-Square	2.800
df	2
Asymp. Sig.	.247

a. Friedman Test

Dynamic moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
dmf2f	5	3.7440	1.79311	2.10	6.35
dmwb	5	3.4220	1.60837	1.45	5.83
dm3d	5	2.5580	1.48539	1.23	4.65

Friedman Test

Ranks

	Mean Rank
dmf2f	2.40
dmwb	2.40
dm3d	1.20

Test Statistics[a]

N	5
Chi-Square	4.800
df	2
Asymp. Sig.	.091

a. Friedman Test

Tracking Moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
tmf2f	5	2.8820	1.17289	1.74	4.39
tmwb	5	2.8900	.98196	1.42	4.09
tm3d	5	2.0760	.85824	1.17	3.02

Friedman Test

Ranks

	Mean Rank
tmf2f	2.20
tmwb	2.60
tm3d	1.20

Test Statistics[a]

N	5
Chi-Square	5.200
df	2
Asymp. Sig.	.074

a. Friedman Test

Challenging moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
chmf2f	5	.8620	.93213	.29	2.49
chmwb	5	.5320	.70485	.03	1.74
chm3D	5	.4820	.79279	.00	1.86

Friedman Test

Ranks

	Mean Rank
chmf2f	2.60
chmwb	1.60
chm3D	1.80

Test Statistics[a]

N	5
Chi-Square	2.800
df	2
Asymp. Sig.	.247

a. Friedman Test

Naming and exclaiming moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
addf2f	5	.2340	.25481	.00	.67
addwb	5	.7060	.56421	.25	1.57
add3d	5	.5740	.45643	.09	1.29

Friedman Test

Ranks

	Mean Rank
addf2f	1.00
addwb	2.80
add3d	2.20

Test Statistics[a]

N	5
Chi-Square	8.400
df	2
Asymp. Sig.	.015

a. Friedman Test

Politeness markers
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
pmf2f	5	5.3760	.95348	4.29	6.32
pmwb	5	4.3180	1.00457	2.59	5.09
pm3d	5	4.1320	2.34798	2.19	8.09

Friedman Test

Ranks

	Mean Rank
pmf2f	2.40
pmwb	2.20
pm3d	1.40

Test Statistics[a]

N	5
Chi-Square	2.800
df	2
Asymp. Sig.	.247

a. Friedman Test

Information giving moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
K1F2f	5	7.4840	4.86065	.06	12.53
K1WB	5	7.3880	2.59085	4.36	11.04
k13d	5	6.2620	3.24098	3.13	10.08

Friedman Test

Ranks

	Mean Rank
K1F2f	2.60
K1WB	2.00
k13d	1.40

Test Statistics[a]

N	5
Chi-Square	3.600
df	2
Asymp. Sig.	.165

a. Friedman Test

Information requesting moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
k23d	5	1.8700	.57546	1.23	2.47
k2f2f	5	1.4220	.32614	.93	1.74
k2wb	5	1.8320	.47662	1.49	2.58

Friedman Test

Ranks

	Mean Rank
k23d	2.20
k2f2f	1.40
k2wb	2.40

Test Statistics[a]

N	5
Chi-Square	2.800
df	2
Asymp. Sig.	.247

a. Friedman Test

Backchannelling
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
bchf2f	5	.9320	.95774	.10	2.47
bchwb	5	.6900	.61368	.21	1.51
bch3d	5	.3260	.38566	.06	.99

Friedman Test

Ranks

	Mean Rank
bchf2f	2.60
bchwb	2.40
bch3d	1.00

Test Statistics[a]

N	5
Chi-Square	7.600
df	2
Asymp. Sig.	.022

a. Friedman Test

Tag questions
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
tagsf2f	5	.3320	.22687	.12	.65
tagswb	5	.1800	.06000	.10	.24
tags3d	5	.1740	.07668	.09	.23

Friedman Test

Ranks

	Mean Rank
tagsf2f	2.60
tagswb	2.00
tags3d	1.40

Test Statistics[a]

N	5
Chi-Square	3.600
df	2
Asymp. Sig.	.165

a. Friedman Test

Finite modal
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
fvf2f	5	2.9640	.50023	2.54	3.77
fvwb	5	2.3300	.77482	1.13	3.11
fv3d	5	2.3520	1.28745	1.45	4.58

Friedman Test

Ranks

	Mean Rank
fvf2f	2.40
fvwb	2.20
fv3d	1.40

Test Statistics[a]

N	5
Chi-Square	2.800
df	2
Asymp. Sig.	.247

a. Friedman Test

Modal adjuncts
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
maf2f	5	1.3920	.69305	.54	2.42
mawb	5	1.1280	.53635	.70	2.01
ma3d	5	1.1200	.81247	.29	2.37

Friedman Test

Ranks

	Mean Rank
maf2f	2.60
mawb	2.00
ma3d	1.40

Test Statistics[a]

N	5
Chi-Square	3.600
df	2
Asymp. Sig.	.165

a. Friedman Test

Comment adjuncts
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
caf2f	5	.5640	.29938	.17	.97
cawb	5	.5460	.18902	.33	.82
ca3d	5	.3160	.19398	.09	.62

Friedman Test

Ranks

	Mean Rank
caf2f	2.00
cawb	2.20
ca3d	1.80

Test Statistics[a]

N	5
Chi-Square	.400
df	2
Asymp. Sig.	.819

a. Friedman Test

Interrogatives
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
intf2f	5	.1240	.09965	.00	.27
intwb	5	.1300	.15297	.03	.40
int3d	5	.1700	.10416	.03	.29

Friedman Test

Ranks

	Mean Rank
intf2f	1.80
intwb	1.90
int3d	2.30

Test Statistics[a]

N	5
Chi-Square	.737
df	2
Asymp. Sig.	.692

a. Friedman Test

Total action moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
actf2f	5	.9660	.36794	.75	1.62
actwb	5	1.1840	.31572	.89	1.70
act3d	5	.8320	.54486	.26	1.58

Friedman Test

Ranks

	Mean Rank
actf2f	1.80
actwb	2.80
act3d	1.40

Test Statistics[a]

N	5
Chi-Square	5.200
df	2
Asymp. Sig.	.074

a. Friedman Test

Feedback moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
feedf2f	5	1.6000	1.11090	.56	3.19
feedwb	5	1.0920	.65629	.41	1.95
feed3d	5	.6840	.63991	.12	1.52

Friedman Test

Ranks

	Mean Rank
feedf2f	2.80
feedwb	2.00
feed3d	1.20

Test Statistics[a]

N	5
Chi-Square	6.400
df	2
Asymp. Sig.	.041

a. Friedman Test

Providing action moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
Ac1F2f	5	.0460	.05079	.00	.10
AC1wb	5	.0680	.07259	.00	.18
Ac13D	5	.0860	.17601	.00	.40

Friedman Test

Ranks

	Mean Rank
Ac1F2f	1.80
AC1wb	2.30
Ac13D	1.90

Test Statistics[a]

N	5
Chi-Square	.778
df	2
Asymp. Sig.	.678

a. Friedman Test

Requesting action moves
NPar Tests

Descriptive Statistics

	N	Mean	Std. Deviation	Minimum	Maximum
AC2F2f	5	.0800	.04950	.00	.13
AC2wb	5	.2380	.14412	.03	.43
AC23D	5	.1440	.22098	.00	.53

Friedman Test

Ranks

	Mean Rank
AC2F2f	1.50
AC2wb	2.60
AC23D	1.90

Test Statistics[a]

N	5
Chi-Square	3.263
df	2
Asymp. Sig.	.196

a. Friedman Test

16 APPENDIX V – G-SICT QUESTIONNAIRE

Figure 16.1 Generic Skills in relation to Information and Communication Technologies Questionnaire (G-SICT)

The UNIVERSITY
of NEWCASTLE

Generic-Skills in relation to Information and Communication Technologies Questionnaire

(G-SICT)

Project Team:

Mr T. Williams
Mr W. Sher
Dr S. Sherratt
Mr T. Bellamy

The School of Architecture

and the Built Environment

The University of Newcastle
Architecture Building
University Drive
Callaghan, NSW 2303
Australia

16.1.1.1 Introduction:

Please read the following before you complete the questionnaire.

Please note:

1. Your name is not required as this questionnaire is totally anonymous.
2. Please complete this questionnaire in private. Do not discuss your answers with your colleagues.
3. Give your initial response to the questions, and do not consider the statements too deeply
4. Some of the statements may appear to be similar, but this is a complex area and a number of statements are required to cover each aspect of ‘generic skills’ and ICTs.

Generic-Skills in relation to Information and Communication Technologies Questionnaire (G-SICT)

Section A

Please answer all the questions by ticking the answer most relevant to you

1. Are you:

1. Male 2. Female

2. How old are you?

1. Under 20 yrs 2. 20 to 30 yrs 3. 30 to 40 yrs 4. 40 to 50 yrs 5. 50 to 60 yrs 6. Ov

3. Which choice best represents your occupation?

1. Architect 2. Construction Management 3. Industrial Designer 4. Graphic Designer

5. Computer Scientist 6. Engineer 7. Other: Please Specify ______________________

4. In which state or territory is your office?

1. NSW 2. QLD 3. VIC 4. SA

5. WA 6. NT 7. TAS 8. ACT

5. Years in your present occupation?

1. 0-5 2. 6-10 3. 11-20 4. 21 plus

6. How many hours a week would you spend working?

1. 0-30 2. 31-40 3. 41-50 4. 51+

7. What was the highest educational level you have achieved?

1. Year 10
2. Year 12
3. Tafe
4. University (undergraduate)
5. University (postgraduate)

8. Could you please indicate what technologies you use in design collaboration (you may tick more than one) and indicate how often you would use these technologies:

Phone

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Fax

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Email

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Video Conference

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Text Chat/Bulletin Boards

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Electronic Whiteboard

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Other Net Based Collaborative Software

1. All the time 2. Regularly 3. Sometimes 4. Seldom 5. Never

Section B

Below are a number of statements relating to collaborative skills. Please respond to these statements in relation to your experience as a member of collaborative teams which have used face-to-face contact, email, or telephone as methods of communication. Please tick the boxes.

9. The ability to identify areas for improvement in designs is important for design team members.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

10. The ability of team members to explain their design solutions to the entire group is not an essential skill for design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

11. Performance feedback to designs and tasks is a necessary aspect of design collaboration

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

12. It is crucial for a leader to suggest and assign design tasks to team members for effective design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

13. Conflict resolution is not vital for effective design team collaboration

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

14. It is not critical to monitor the time design tasks take for effective design teamwork.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

15. The ability to exchange information effectively is important for design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

16. Evaluating and selecting appropriate solutions is vital for design teams.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

17. The ability to amend or include design improvements quickly is necessary for effective design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

18. The ability of team members to question and confirm design aspects is important for design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

19. Questioning and confirming design tasks is not essential for design team members

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

20. It is critical for a leader to prioritise design tasks within design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

21. Social interaction between design team members is important for design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

22. It is vital to monitor and track the movement of physical artefacts such as drawings during design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

23. It is critical to consult other team members when involved in design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

24. The ability to evaluate consequences is not essential when collaborating in a design setting.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

Section C

The following statements relate to your experience of design collaboration using **ICTs**. Please read the statements and indicate your level of agreement or disagreement by ticking the appropriate boxes.

25. The ability to recognise areas for improvement in designs is important for design team members.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

26. The ability of team members to explain their design solutions to the entire group is not an essential skill for design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

27. Performance feedback to tasks and designs is a necessary aspect of design collaboration

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

28. It is crucial for a leader to suggest and assign design tasks to team members for effective design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

29. Conflict resolution is not vital for effective design team collaboration

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

30. It is not critical to monitor the time design tasks take for effective design teamwork.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

31. The ability to exchange information effectively is important for design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

32. Evaluating and selecting appropriate solutions is vital for design teams.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

33. The ability to amend or include design improvements quickly is necessary for effective design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

34. The ability of team members to question and confirm design aspects is important for design team collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

35. Questioning and confirming design tasks is not essential for design team members

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

36. It is critical for a leader to prioritise design tasks within design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

37. Social interaction between design team members is important for design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

38. It is vital to monitor and track the movement of physical artefacts such as drawings during design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

39. It is critical to consult other team members when involved in design collaboration.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

40. The ability to evaluate consequences is not essential when collaborating in a design setting.

1. Strongly disagree 2. Disagree 3. Don't know 4. Agree 5. Strongly agree

Section D

The follow two questions relate to statements. Please indicate you level of agreement/disagreement by ticking only one box for each skill.

41. “These generic skills are important for effective collaborative design teams”, respond to this statement by ticking one box only for each:

Adaptability **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Shared Situational Awareness **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Performance Monitoring and Feedback **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Leadership/Team Management **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Interpersonal Relations **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Co-ordination **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Communication **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Decision Making **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

42. “Collaborative design team members are often lacking in these generic skills” respond to this statement below by ticking one box only for each:

Adaptability **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Shared Situational Awareness **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Performance Monitoring and Feedback **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Leadership/Team Management **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Interpersonal Relations **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Co-ordination **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Communication **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Decision Making **Strongly Agree☐ ☐ ☐ ☐ ☐ ☐ ☐ Strongly Disagree**

Section E

Below are some questions on your views on the use of generic (non-technical) skills in design teams. There are no right or wrong answers; simply write down how you feel about each of the areas raised.

43. How does management deal with training employees for the use of Information and Communication Technologies (ICTs)

44. What has been your experience with the useability of any new ICT's used in design collaboration?

45. Do you think ICT's will become a critical element of design teams in the future?

46. Would you be prepared to complete more training for the use of new collaborative technologies?

47. What do you consider the 5 most important non-technical skills essential for the use of virtual technologies in design collaboration. Please put them in order of importance in descending order:

48. From your experience do you think there is difference in the skills required to participate in Virtual Teams, explain your reasons.

17 APPENDIX VI – RELIABILITY DATA FOR INITIAL (VERSION 1 & 2) GENERIC SKILLS CODING SCHEME

This appendix provides the results for reliability test conducted on the initial (version 1) generic skills coding scheme.

Data initially collected were intended to be used in the experimental study. However upon examination it was deemed more appropriate as pilot data from which a coding system could be established. Reliability was first sought to determine whether the coding system was definitive and replicable. Because of manpower restrictions Intra-Rater reliability was sought to confirm that the coder was being consistent in their coding and that codes were sufficiently defined. Two reliability analysis tests conducted through Noldus Observer Pro ethnographic software were based on the frequency of coding strings and also on the frequency and sequence of the coding strings from two observations of the same video data. Video data used was from a recording of face-to-face design collaboration using a generic skill and an interaction coding scheme.

17.1 Frequency Based Reliability Analysis

The first reliability test undertaken for the sample Face-to-Face video data was a frequency based analysis. This method is based only on the total number of each string of behaviour, so that if one string of code in the first observation occurs *X* number of times, this is compared with the number for that string of code in the second observation (must be the same video data). While this is a relatively crude indicator of consistency, it is helpful as a starting point because of the latitude it has with respect to the timing and order of the observed behaviours. It is especially useful for video data with an increased rate of interaction or behaviour.

17.2 Frequency/Sequence Based Reliability Analysis

The second test of reliability is based on the frequency and sequence of the coded data. It attempts to match specific behaviour events by code and time (Burfield *et al.* 2003). Because of the obvious time differences between matching codes when operating using milliseconds a tolerance window of must be defined. The 2 second window is the default suggested by Noldus Observer, meaning that when the software attempts to match a code from one observation to another the time recorded for the second observation may be ±2 seconds from the first observation to record a match.

17.3 Reliability Results: Initial Video Data Coding Scheme

As an initial attempt approximately the first 12 minutes of a face-to-face video was coded. The results yielded were based on the frequency and frequency/sequence reliability analysis calculated within the Observer.

17.4 Frequency Based Reliability Results: Initial Video Data Coding Scheme

Table 17.1 shows that intra-coder observations were the same only 57% of the time, when sequence was not accounted for. Pearson's Rho indicates whether there is any correlation between the two observations. Rho's value exists between -1 and 1 with high negative correlation and high positive correlation being represented respectively. Perhaps due to the small number of observations used in the analysis Pearson's Rho was found to be significant, so that there was a significant high positive correlation between the two sets of observations $t(-2) = 18.6$, $p < .01$.

Table 17.1 Frequency Based Reliability Analysis: Sample Face-to-Face Test 1 verses Sample Face-to-Face Test 2 using the initial Coding Scheme

Measure	**Value**
Number of Agreements	49
Number of Disagreements	37
Percentage of Agreements	56.98
Pearson's Rho	0.93

17.5 Frequency/Sequence Based Reliability Results: Sample Video Data Coding Scheme

When faced with results of the frequency/sequence reliability test it became clear that there was a large difference between the two observations, not just for the recorded behaviours but also for the sequence in which they were recorded. Table 17.2 indicates that like above that there was approximately a 44% disagreement rate. Pearson's Rho indicates that there was a trend towards a positive correlation between the observations $t(-2) = 4.1$, $p < .1$ however this was not significant.

Table 17.2 Frequency and Sequence Based Reliability Analysis: Sample Face-to-Face Test 1 verses Sample Face-to-Face Test 2 using the initial Coding Scheme

Measure	**Value**
Number of Agreements	41
Number of Disagreements	32
Percentage of Agreements	56.16
Pearson's Rho	0.48

17.6 Changes/Differences between Coding Schemes

The initial coding system was changed as a result of the following issues:

1. In the generic skills coding scheme, definitions for the observable behaviours of 'shared situational awareness' and 'decision making' were difficult to differentiate between. In the main this was caused by difficulties distinguishing between interaction regarding design or environment.

2. There were a large number of observations which may have occurred in one set of codes, but were not present in the other. These anomalies were attributed to the undefined nature of the speech segments.

17.7 Generic Skills Coding Scheme Changes

The generic skill observable behaviours which remained unchanged were *adaptability, leadership/team management, interpersonal relations,* and *co-ordination*. The main areas reconsidered were **decision making** and **shared situational awareness**. It was decided that discussions on environment were a necessity as this is a major factor in design. Coupled with this, Bales's IPA was identified as a more valid and stable measure of decision making. The observable behaviours (OB) for decision making were subsequently merged with those for shared situational awareness. The changes to the generic skills coding scheme are shown in the revised coding scheme (Table 11.6).

17.8 Speech Segment Changes

In the initial version of the coding scheme the speech or behavioural segments which were analysed and coded individually were based on Roter's (2002) definition of an 'utterance'. This definition stated that an 'utterance' was a group of words which conveyed a single thought. It became apparent that this definition was not sufficiently explicit. The follow factors required consideration:

- Back channelling was not to be coded. These included a team member saying 'yes, yes, yes' to encourage someone else. Back channelling was analysed using Systemic Functional Linguistics.
- Single word responses (such as 'yes') were included when in response to a direct question from another design team member.
- Inaudible segments of the video data were excluded
- The University of Sydney provided transcripts of the video data. Where discrepancies between the transcripts and the researchers interpretation of the audio recording occurred, the coder relied on the audio data.

Once these changes had been made to the initial version, the final version was used to re-examine the sample face-to-face video data.

17.9 Reliability Results: Version 2 Initial Video Data Coding Scheme

The final version of the coding scheme was implemented for the entire 35 minutes of video data from the sample face-to-face design session. Once again frequency and frequency/sequence based reliability were sought using the Observer.

17.10 Frequency Based Reliability Results: Version 2 Video Data Coding Scheme

The frequency based reliability analysis revealed that Version2 of the initial coding scheme allowed a much larger percentage of agreements at 80% in

Table 17.3. This high percentage of agreement implies that the coding scheme has reached a satisfactory level for intra-rater reliability. Pearson's Rho indicates that there is a high level of positive correlation between the two sets of observations, and the t-test shows that this reached a significant level $t(-2) = 46.67$, $p < .001$.

Table 17.3 Frequency based reliability results showing the number and percentage of agreements and disagreements, and the Pearson's Rho.

Measure	**Value**
Number of Agreements	157
Number of Disagreements	40
Percentage of Agreements	79.70
Pearson's Rho	0.98

17.11 Frequency/Sequence Based Reliability Results: Version 2 Video Data Coding Scheme

Like the results for the frequency based reliability analysis, the frequency/sequence analysis describes a large increase in the number of agreements between the two observations. Table 17.4 indicates that the number of matches in sequence and code has increased to approximately 84%. Pearson's Rho was also found to be significant indicating a high positive correlation between the two data sets $t(-2) = 32$, $p < .001$.

Table 17.4 Frequency/Sequence based reliability results showing the number and percentage of agreements and disagreements, and Pearson's Rho.

Measure	**Value**
Number of Agreements	151
Number of Disagreements	29
Percentage of Agreements	83.89
Pearson's Rho	0.96

For both tests of reliability, frequency and frequency/sequence, intra-rater reliability of .80 or above was found. This meant that the level of agreement between the two sets of codes for the same video data was 80% or above which is the acceptable level (Kazdin 1982a) for reliability testing. It was also found that there was a significant positive correlation between the two data sets, which also indicates reliability for the coding.

18 APPENDIX VII – RELIABILITY RESULTS FOR THE FINAL GENERIC SKILLS CODING SCHEME

This appendix provides the results for reliability test conducted on the FINAL generic skills coding scheme.

The methods used to test the reliability of the proposed coding scheme are the same as that for the pilot coding scheme. The coding scheme was implemented for the entire 30 minutes of a face-to-face video design session. Frequency and frequency/sequence based reliability were obtained using Noldus Observer Pro (Section 7.5).

18.1 Frequency Based Reliability Results: Face-to-Face Data Coding

The frequency based reliability analysis revealed that the coding scheme provided a large percentage of agreements at 80% in Table 18.1. This high percentage of agreement implied that the coding scheme had reached a satisfactory level for intra-rater reliability. Pearson's Rho indicated that there was a high level of positive correlation between the two sets of observations, and the t-test showed that this reached a significant level $t(-2) = 119.51$, $p < .001$.

Table 18.1 Frequency based reliability results showing the number and percentage of agreements and disagreements, and the Pearson's Rho.

Measure	Value
Number of Agreements	262
Number of Disagreements	61
Percentage of Agreements	81.11
Pearson's Rho	0.99

18.2 Frequency/Sequence Based Reliability Results: Face-to-Face Video Data Coding

Like the results for the frequency based reliability analysis, the frequency/sequence analysis resulted in a large number of agreements between the two observations. Table 18.2 indicated that the number of matches in sequence and code had reached approximately 84%. Pearson's Rho was also found to be significant indicating a high positive correlation between the two data sets $t(-2) = 83.87$, $p < .001$.

Table 18.2 Frequency/Sequence based reliability results showing the number and percentage of agreements and disagreements, and the Pearson's Rho.

Measure	Value
Number of Agreements	240
Number of Disagreements	61
Percentage of Agreements	79.73
Pearson's Rho	0.98

For both tests of reliability, frequency and frequency/sequence, intra-rater reliability of .80 or above was found. This means that the level of agreement between the two sets of codes for the same video data was 80% or above which is the acceptable level (Kazdin 1982a) for reliability testing. It was also found that there was a significant positive correlation between the two data sets, which indicates robust reliability for the coding.

Cooperative Research Centre for Construction Innovation
9th Floor, L Block
QUT Gardens Point
2 George Street
BRISBANE QLD 4001
AUSTRALIA
Tel: +61 7 3138 9291
Fax: +61 7 3138 9151
Email:
enquiries@construction-innovation.info
Web:
www.construction-innovation.info

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