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Changing Skills in Changing Environments: Skills Needed in Virtual Construction Teams

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1. Introduction

This book focuses on virtual reality. In the context of design, virtual reality is an emerging technology that not only allows designers and other stakeholders to gain a three-dimensional appreciation of the artifact being designed, it also has the potential to significantly alter the manner in which design occurs. Internet-based technologies have made it possible for designers in different locations to collaborate in developing and refining their designs. Virtual reality has contributed to this environment (Maher, 2005) by allowing designers in geographically-dispersed locations to interact with each other. Software applications have been developed to assist and facilitate these collaborative activities (including Shyamsundar and Gadh (2001) and Lau, Mak and Lu (2003)) but comparatively speaking, little research has been conducted into the people-related issues of collaboration via the Internet. Some of these are the issues addressed in this chapter.

Recent developments in virtual communication technologies have the potential to dramatically improve collaboration in the construction industry (Gameson & Sher, 2002). Furthermore, virtual teams "hold significant promise for organizations that implement them because they enable unprecedented levels of flexibility and responsiveness" (Powell, Piccoli, & Ives, 2004, p. 6). Some authors observe that virtual teams are here to stay (Bell & Kozlowski, 2002) and that organisations will be forced to "embrace virtual collaboration to enhance their competitiveness" (Abuelmaatti & Rezgui, 2008, p. 351). Indeed, current research proposes that "(g)lobally disbursed project teams are the new norm in every industry today" (Daim et al., 2012). However, the skills required to work productively in virtual environments have been theoretically defined but not assessed in the real world. Indeed, many of the studies that have been conducted (e.g. Hatem, Kwan and Miles (2011) and Rezgui (2007)) into virtual teamwork have involved tertiary-level students. Abelmaatti and Rezgui (2008) consider that the challenges of virtual teamwork in the real world substantially outweigh the relative ease with which academics can research and develop virtual team solutions. Furthermore, the differences between virtual and face-to-face teamwork means that an overt and explicit effort is needed to design new work processes to make it successful (Nunamaker, Reinig, & Briggs, 2009).

Our studies were part of a project which examined the use of information and computer technologies (ICTs) to facilitate design / construction team interactions. They were funded by the Australian Cooperative Research Centre for Construction Innovation (Maher, 2002) and focused on the early stages of design / construction collaboration where designs for a building are created, developed and revised. Three aspects of collaboration in virtual environments were investigated: (i) the technological processes that enable effective collaboration using these technologies; (ii) the models that allow disciplines to share their views in a synchronous virtual environment; (iii) the generic skills used by individuals and teams when engaging with high bandwidth ICT. The last strand of these investigations was investigated by the authors and is reported on here. Details of the other strands of this project may be found at the project website (Maher, 2002) and other publications (Bellamy, Williams, Sher, Sherratt, & Gameson, (2005) and Sherratt, Sher, Williams, & Gameson, 2010).

2. Virtual teamwork

There are numerous definitions of teams. For this paper teams are defined as a cluster of two or more people usually occupying different roles and skill levels that interact “adaptively, interdependently, and dynamically towards a common and valued goal” (Salas, Shawn Burke, & Cannon-Bowers, 2000, p. 341). At present the term “virtual teams” is used by different authors to mean different things. A more detailed exploration of the various facets of virtual teams is provided by Dubé and Paré (2004) and is summarised in Table 1. A number of other researchers have outlined the characteristics of or factors relating to virtual teams e.g. Berry (2011); Schumacher, Cardinal and Bocquet (2009) as well as the

CHARACTERISTICS		DEGREE OF COMPLEXITY LOW <————————> HIGH	
…related to the basics of virtual teamwork	Degree of reliance on ICT	Low reliance	High reliance
	ICT availability	High variety	Low variety
	Members’ ICT Proficiency	High	Low
…related to the complexity of virtual teamwork	Team size	Small	Large
	Geographic dispersion (physical proximity)	Local	Global
	Task or project duration	Long term	Short term
	Prior shared work experience	Extensive experience	No experience
	Members’ assignments	Full-time	Part-time
	Membership stability	Stable membership	Fluid membership
	Task interdependence	Low interdependence	High interdependence
	Cultural diversity (national, organizational, professional)	Homogeneous	Heterogeneous

Table 1. Key Characteristics of Virtual Teams

variables contributing to effective virtual teamwork (Gaudes, Hamilton-Bogart, Marsh, & Robinson, 2007; Peña-mora, Vadhavkar, & Aziz, 2009). Virtual teams may differ significantly depending upon these aspects and Dubé and Paré suggest that this table could also be used as a diagnostic tool to help assess the level of complexity in a virtual team.

3. Generic skills

There is still much discussion about the core set of knowledge, skills and attitudes that constitute teamwork (Salas, et al., 2000). We sought to contribute to this debate by identifying the skills that transferred from a traditional face to face (F2F) environment and the ones that required refining for virtual environments. Furthermore, we wished to identify if virtual teamworkers needed any new skills. As a starting point, we investigated the generic skills workers acquire and use on a daily basis. Generic skills are defined by Salas et al (2000: p, 344) as "the knowledge, skills and attitudes that a team member possesses when completing a task or communicating with fellow members, whether in a co-located or virtual environment". Generic skills influence both individuals and teams; they are skills which are "…transportable and applicable across teams" (Salas, et al., 2000, p. 344). A review of generic skills (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995) was used to identify those which are used by design team members and is summarised in Table 2.

To examine the skills designers use it is necessary to understand the content of their interactions. A number of techniques facilitate such insights including Protocol Analysis and Content Analysis. Protocol Analysis attempts to infer cognitive processes by examining verbal interactions (Ericsson & Simon, 1993) but has been found to be a limited means of identifying non-verbal design cognition. Even where some comparisons are discovered, a large degree of interpretation is required (Cross, Christiaans, & K., 1996). The subjectivity of analysis and the length of time required to complete analysis also call into question the appropriateness of this method.

Content Analysis, according to (Wallace, 1987), involves coding transcripts of communications in terms of frequency analyses because the underlying assumption is that "the verbal content produced by the individual is representative of the thought processes at work in his or her mind" (p. 121).

Several content analysis techniques were used to identify and interpret these thought processes and thereby to investigate the generic skills our participants used. We explored micro-level communication processes because these "can provide valuable insights to managers and researchers alike about how to 'read' the health of teams" (Kanawattanachai & Yoo, 2002: p. 210). We identified quantitative content analysis as an effective means of identifying the generic skills of designers. This necessitated the development of a framework by which our data could be coded. Behavioural marker studies (Klampfer, et al., 2001, Carthey, de Leval, Wright, Farewell, & Reason, 2003) provided a template for our generic skills coding framework. Behavioural markers are observable non-technical "aspects of individual and team performance" (Carthey et al, 2003: p. 411) which are related to the effectiveness of an individual and team. The methods for creating behavioural markers informed the development of our framework. In accordance with Klampfer et al's (2001) recommendations, we devised a system that provided simple, clear markers, used appropriate professional terminology, and emphasised observable behaviours rather than ambiguous attitudes or opinions. The Anaesthetists' Non-Technical Skills (ANTS) (Fletcher, et al., 2003) system was informative and helped shape our coding system. Using the ANTS system allowed us to incorporate the skills in Table 2 into the Generic Skills coding scheme shown in Table 4.

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
Performance monitoring and feedback	Ability of team members to give, seek and receive task clarifying feedback.	Performance feedback Acceptance Mutual performance monitoring Procedure maintenance
Team management: Project management/leadership	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 Morale building
Co-ordination	Process by which team resources, activities and responses are organized to ensure that tasks are integrated, synchronized 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 most appropriate solution, and evaluate the consequences.	Problem assessment Problem solving Planning Implementation

Table 2. Integrated skills (as adapted from Cannon-Bowers et al 1995)

In addition to the Generic Skills analysis presented here, three other techniques were used to analyse the data:

1. **Bales's Interaction Process Analysis** (Bales, 1951) - to analyse the interactions between design team members, so that aspects such as decision-making, communication and control could be examined.
2. A **Communication Technique Framework** (Williams & Cowdroy, 2002) – to investigate the techniques which the designers used to communicate.
3. **Linguistic analyses** - to evaluate the communication occurring in teamwork. The approach adopted was derived from systemic functional linguistic theory (Halliday & Matthiessen, 2004).

The aims of this study were to identity and examine the generic skills which facilitate teamwork in three settings, ranging from face-to-face to 3D virtual environments. The teamwork which we studied occurred during the conceptual stages of designing construction projects.

3.1 Data collection

Video and audio recordings of designers collaborating in teams were collected using Noldus Observer Pro (Burfield, Cadee, Grieco, Mayton, & Spink, 2003) to store, code and analyse our data. Noldus is ethnographic video analysis software which facilitates the collection, management, analysis and presentation of observational data. It allows researchers to view video footage and score the frequency of specific behaviours, and to note how these behaviours interact with each other or with independent variables. The advantages of such recordings include: being able to review interactions and behaviours as well as being able to compare different coders' or viewers' interpretations (Guerlain, Turrentine, Adams, & Forrest Calland, 2004).

3.2 Participants

It is often the case that design team members are drawn from different backgrounds/cultures, ages, and experience (Marchman III, 1998), especially in multi-disciplinary design teams collaborating on an entire project. Stratified purposive sampling (Rice & Ezzy, 1999) was therefore used to select a heterogenous group of ten participants. This method of sampling ensured that the diversity of the participants was reflective, as far as possible, of the actuality of design teams in the real world. Participants were both male and female, of varying ages, cultures and had differing levels of experience and influence, ranging from higher management to junior staff. Due to constraints imposed by the funding body, recruitment of participants was limited to organisations within the Cooperative Research Centre for Construction Innovation (CRC-CI). The pool of eligible participants was further constrained by work pressures eventually resulting in participants being recruited solely from the discipline of architecture.

3.3 Task

Data were collected in three experimental conditions:

- **Traditional face-to-face** collaborative design between the design team members (including interactions such as talking and sketching).

- **Virtual design using a shared electronic whiteboard** (incorporating synchronous audio and visual communication) which allowed drawings, images and text to be shared.
- **Virtual design using a high bandwidth 3D virtual world** (Activeworlds-Corporation, 2008) (incorporating synchronous audio communication) which allowed drawings, images and text to be shared. This tool represents team members as "avatars" and allowed them to manipulate 3D representations of a design and to communicate using audio as well as text "chat" facilities.

Designers were grouped into five teams of two and asked to prepare conceptual designs that responded to various briefs. These briefs related to fictional projects on an actual site at Sydney University, Australia. Depending on the session, designers were asked to design an art gallery, a hostel, a library or a dance school for the site. The participants were then given 30 minutes to prepare their designs using one of the three experimental conditions. Prior to each design session the research team spent one to two hours coaching the designers in the capabilities of the whiteboard and 3D virtual world technologies. Once designers were familiar with the hardware and software, they were asked to prepare their designs. Typical characteristics of the virtual teamwork involved in these tasks are presented in Table 3 using Dubé & Paré's (2004) framework.

		DEGREE OF COMPLEXITY LOW <———————> HIGH	
Degree of reliance on ICT	Low	Varies	High
ICT availability	High	X	Low
Members' ICT Proficiency	High	X	Low
Team size	Small	X	Large
Geographic dispersion	Local	X	Global
Task or project duration	Long term	X	Short term
Prior shared work experience	Extensive	X	None
Members' assignments	Full-time	X	Part-time
Membership stability	Stable	X	Fluid
Task interdependence	Low	X	High
Cultural diversity	Homo-geneous	Varies	Hetero-geneous

Table 3. Typical characteristics of the virtual teams engaged in this project (adapted from Dubé & Paré, 2004)

All tasks were conducted in an identical sequence (i.e. participants first worked "face-to-face", then used a "whiteboard" and finally designed in the "3D virtual world"). This procedure was prescribed by our research directorate and was designed primarily for the first two strands of our overall research project (Maher, 2002). We are conscious that participants may have become familiar with aspects of the tasks that they were asked to complete, and may also have become fatigued (Pring, 2005). As the designers gained experience of working together, one would assume they would be able to work more effectively over time. If this is so, their final collaboration would have been the optimal one and this would have occurred when they were designing in the 3D virtual world. Conversely, if they had become fatigued or bored, their last task performed would have been the one most affected. It is thus not possible to determine whether sequence affected the outcomes of this research.

3.4 Coding of data

All interactions were coded using the framework shown in Table 4 resulting in 4611 entries. Noldus provided each entry with a time stamp, and allowed entry of a subject code, an observable behaviour and a non-technical skill representative of that observable behaviour (see Figure 1).

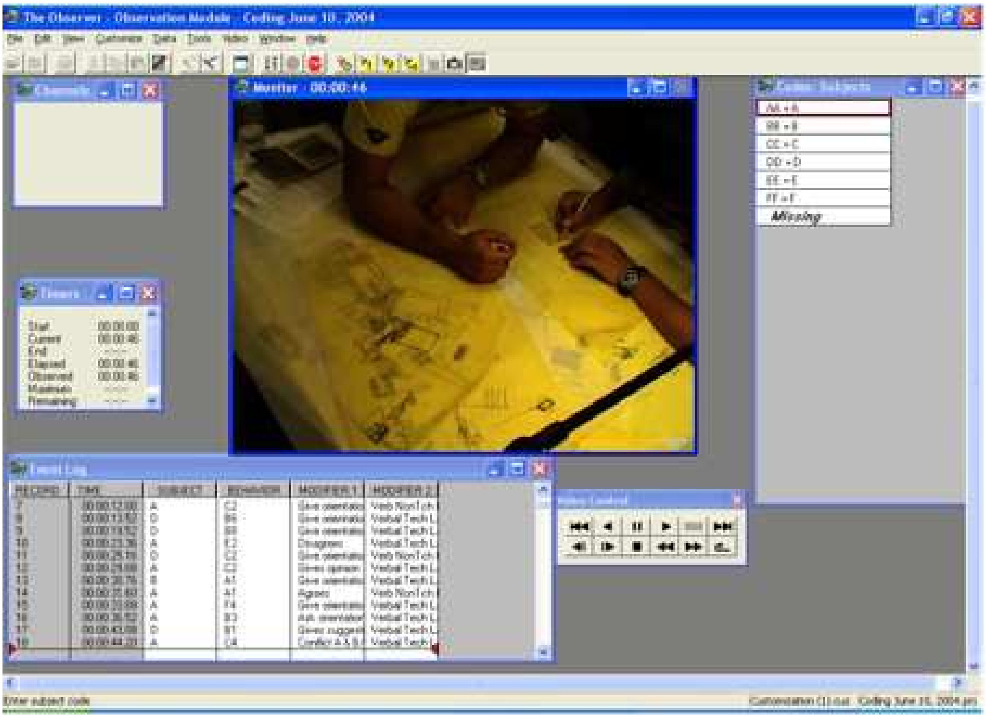

Fig. 1. Screen showing coding of video data in Noldus Observer Pro

The resulting scores were statistically analysed using a repeated measures ANOVA parametric test to establish the differences between participants' performance on the three tasks (traditional face-to-face design, virtual design using a electronic whiteboard, and virtual design using a high bandwidth 3D virtual world) (Riedlinger, Gallois, McKay, & Pittam, 2004). The results of the ANOVA tests were interpreted using Mauchly's Test of Sphericity which examines the covariance of the dependent samples. The data were also examined to determine which shift in condition (i.e. face-to-face to whiteboard or whiteboard to 3D virtual world) was responsible for any significance. SPSS Version 12 was used for all statistical analyses.

Generic skills	Sub-skills	Code	Observable Behaviour
Task Manage-ment	Planning or preparing a task	A11	Outlines and describes the plan/brief for a design
		A12	Reviews a design after changes are made
		A13	Describes actions required once design is completed
	Prioritising tasks	A21	Assigns priority to design tasks to be completed
		A22	Prioritises the segments within design tasks
	Providing direction and maintaining standards for the task	A31	Follows design protocols and briefs
		A32	Cross checks the completion of design tasks
	Identifying and utilising resources	A41	Identifies and allocates resources
		A42	Allocates tasks to team members
		A43	Requests additional resources
Team Working	Co-ordinating activities with team members	B11	Confirms roles and responsibilities of team members
		B12	Discusses design with others
		B13	Considers requirements of others before acting
		B14	Co-operates with others to achieve goals
	Exchanging information	B21	Gives updates and reports key events
		B22	Confirms shared understanding
		B23	Communicates design plans and relevant information
		B24	Clearly documents design
	Using authority and assertiveness	B31	Is appropriately and necessarily assertive
		B32	Takes appropriate leadership
		B33	States case for instruction and gives justification
		B34	Gives clear instructions
	Assessing capabilities	B41	Asks for assistance
		B42	Asks team member about experience
		B43	Notices that a team member does not complete a task to an appropriate standard
	Supporting others	B51	Acknowledges concerns of others
		B52	Reassures / encourages
		B53	Debriefs
		B54	Anticipates when others will need information

Generic skills	Sub-skills	Code	Observable Behaviour
Shared Situational Awareness	Gathering information	C11	Asks for information or artefacts relating to a design
		C12	Checks on the status of a project and tasks
		C13	Collects information regarding a problem
		C14	Cross checks and double checks information
	Recognising and understanding	C21	Describes seriousness or urgency of task
		C22	Pays close attention to advice of fellow member
	Anticipating	C31	Takes action to avoid future problems
		C32	Reviews effects of a change
Decision Making	Identifying options	D11	Discusses design options with clients/other designers
		D12	Discusses various techniques for the design
	Balancing risks and selecting options	D21	Weighs up risks associated with different designs
		D22	Implements chosen design
	Re-evaluating	D31	Re-evaluates chosen design technique after it has been chosen

Table 4. Generic Skills Coding Scheme

Intra-reliability between two raters was established for the generic skills coding scheme on a 35-minute 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 acceptable level of 80% (Kazdin, 1982).

4. Results

4.1 Generic skills

The generic skill *Shared Situational Awareness* increased significantly ($F(2, 8) = 4.903$, $p < .05$). The Within-Subject Contrasts test indicated a significant difference between face-to-face and whiteboard conditions ($F(1, 4) = 19.478$, $p < .05$).

For the skill of *Decision Making*, there was a significant decrease ($F(2, 8) = 42.431$, $p < .001$) in frequency as the design conditions moved from low to high bandwidth conditions. The Within-Subject Contrasts test demonstrated a significant difference between both the face-to-face to whiteboard and whiteboard to 3D virtual world ($F(1, 4) = 120.274$, $p < .001$ and $F(1, 4) = 8.685$, $p < .05$ respectively).

For the skill of *Task Management*, the decrease in frequency from face-to-face to whiteboard approached significance ($F(1, 4) = 4.799$, $p > .1$).

4.2 Observable behaviours

The following five observable skills (see Figure 2) were significantly affected by the experimental conditions:

- A11 ("Outlines and describes the plan/brief for the design" indicative of *Task Management*). There was a significant decrease ($F(2, 8) = 9.021$, $p < .05$) in the incidence of this behaviour from low to high bandwidth levels. The Within-Subjects Contrasts test indicates that the move from face-to-face to whiteboard was significant ($F(1, 4) = 7.943$, $p < .05$).

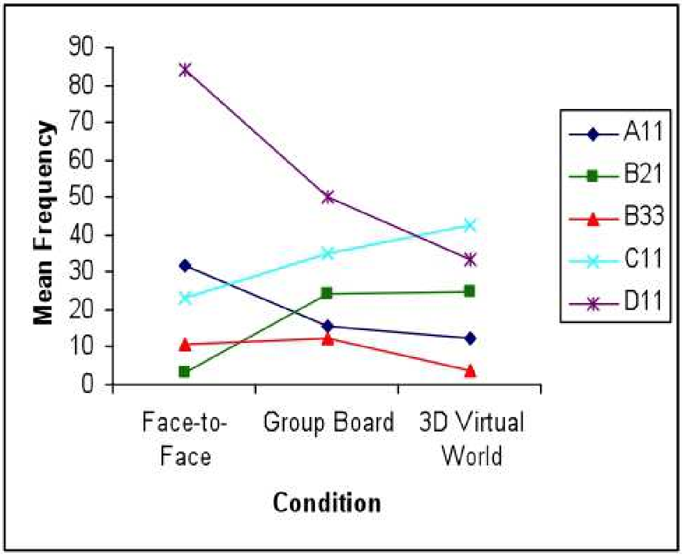

Fig. 2. Frequency of significant observable behaviours A11, B21, B33, C11, D11, in 3 conditions

- B21 ("Gives updates and reports key events", demonstrating *Team Working*). This behaviour increased significantly ($F(2, 6) = 6.343$, $p < .05$) as the design process moved from low to high bandwidth. Furthermore, the difference between *face-to-face* and *whiteboard* conditions was significant ($F(1, 3) = 16.734$, $p < .05$).
- B33 ("States case for instruction and gives justification", also demonstrating *Team Working*). The movement from low to high bandwidth demonstrated a significant decrease in this behaviour ($F(2, 6) = 5.362$, $p < .05$). A significant difference between *whiteboard* and *3D virtual world* was found to be approaching significance ($F(1, 3) = 5.642$, $p = .098$).
- C11 ("Asks for documents and/or information regarding a design" indicating *Shared Situational Awareness*). This increased significantly as the design process moved from low to high bandwidth ($F(2, 8) = 5.526$, $p < .05$). The Within-Subjects Contrasts test showed a significant change ($F(1, 4) = 15.751$, $p < .05$) for the shift from *face-to-face* to *whiteboard* conditions.
- D11 ("Discusses design options with clients/other designers" demonstrating *Decision-Making*). As the design collaborators shifted from low to high bandwidth, the frequency of the behaviour decreased significantly ($F(2, 8) = 25.383$, $p < .001$). In addition, significant differences were also found between *face-to-face* and *whiteboard* and *whiteboard* and *3D virtual world* ($F(1, 4) = 46.24$, $p < .05$ and $F(1, 4) = 8.095$, $p < .05$, respectively).

In addition, two other statistical results from the generic skill Team Working are worth noting:-

- B23 ("Communicates design plans and relevant information" to relevant members). The Within-Subjects Contrasts test indicates that the mean frequency of B23 reduced significantly ($F(1, 4) = 23.774$ $p < .05$) between the *face-to-face* and *whiteboard* conditions.
- B52 ("Reassures/Encourages") was the only observable behaviour that approached significance ($F(2, 8) = 3.462$ $p < .1$). The decrease in frequency of this behaviour between *whiteboard* and *3D virtual world* ($F(1, 4) = 5.956$ $p < .1$) is also approaching significance.

Changes in the incidence of the remaining observable behaviours were non-significant, in some cases due to limited or non-existent data

5. Discussion

This study examined the generic skills of five design teams in three settings: face-to-face and two levels of virtual technology (viz. whiteboard and 3D virtual world). The behaviours underpinning the generic skills designers use during the conceptual stages of a variety of projects were recorded and analysed. The major findings were a significant increase in the frequency of Shared Situational Awareness and a significant decrease in Decision Making as bandwidth conditions increased.

5.1 Shared situational awareness

There was a significant and consistent increase in *Shared Situational Awareness* as the design process moved from low to high bandwidth as well as a significant increase between face-to-face and whiteboard conditions. This generic skill incorporates the sub-skills of gathering information, recognising and understanding as well as anticipating. One of this skill's observable behaviours (C11 "asks for documents and/or information regarding an idea or design") increased significantly as bandwidth increased and also between face-to face and whiteboard conditions. This behaviour is associated with information gathering and involves designers asking questions about a design, a site, an idea or an artefact. Shared goals and shared understandings are considered to be an intrinsic part of the team-building process (Berry, 2011). An increase in the frequency of this behaviour may indicate escalating levels of uncertainty (Gay & Lentini, 1995; Kayworth & Leidner, 2000) and it is conceivable that moving to unfamiliar design environments may have engendered such concerns. Furthermore, designing in 2D is markedly different from designing in 3D. Many designers traditionally work in 2D, and this approach is conveniently facilitated by whiteboard technologies. 3D virtual environments provide additional challenges because few designers have worked in them before. So, not only do 3D environments require designers to exercise their visualisation skills in a more complex way, they require them to use new tools (e.g. avatars, 3D geometric modelling tools etc) to express their conceptual designs. An increase in the incidence of C11 is therefore understandable. From this result, it could be extrapolated that design teams comprised of members from a variety of disciplines would have even greater difficulty in *Shared Situational Awareness*. Berry (2011) has suggested that increased requests for information may be the norm for virtual teamwork, i.e. it may be the normal pattern of communication, reflecting how different the virtual process is from the process of working in a face-to-face team. This increase may be due to the challenge of deciphering the ambiguity of remote communication (Nunamaker, et al., 2009). In addition, Berry (2011) reported that social communication in virtual environments tends to occur more slowly at first. Therefore, even if the amount of communication is similar, the rate may be different. Further research into team communication in these environments may elucidate this issue.

Virtual teams have a greater risk of communication breakdown due to the difficulties of establishing shared context of meaning (Bjørn & Ngwenyama, 2009). This breakdown can cause substantial difficulties as team members struggle to communicate and work with each other. This may also increase project delivery risks (Daim, et al., 2012). This increased need to establish a shared awareness suggests that design collaborators became unsure of their interpretation of communication and so requested additional confirmation. We suggest that design collaborators need to supply more detailed descriptions of what they are proposing or attempting to do and continually relate this to the specific task at hand. Additionally, Nunamaker et al (2009) have also recommended having clear rules and expectations when using certain types of technology and also having a clear definition of effective work completion. Virtual environments make it possible to communicate but the efficiency of such interactions and the level of shared understanding between individuals is not always assured. A way to enrich such communications is to use multiple communication channels or modes simultaneously (Gay & Lentini, 1995; Kayworth & Leidner, 2000). Instead of relying on a single mode of communication it is advantageous to support such communication with artefacts, such as sketches, as designers do in face-to-face situations. Verbal commentary is another way to enhance virtual communication. Where these environments support audio communication, verbal commentary and / or explanation provides valuable supplementary support. Berry (2011) suggests that virtual team members should be encouraged to seek out information when misunderstandings occur. We also recommend that multiple modes of communication be used concurrently to increase shared understanding between design team members in virtual conditions.

5.2 Decision making

There was a significant and consistent decrease in the frequency of *Decision Making* as design processes moved from low to high bandwidth and also between face to face and whiteboard, and between whiteboard and 3D. The sub-skills associated with this generic skill are identifying options, balancing risks and selecting options, and re-evaluating. The behaviour “discusses design options with clients/other designers” demonstrated a similarly significant decrease. The reduced frequency of such interactions suggests that designers using virtual environments more readily accept design proposals as solutions and do not explore as many alternatives as they would have had they been communicating face-to-face. Research on group style characteristics has reported similar findings; virtual teams were described to be less effective at team work, with decision-making being more difficult, resulting in poor decisions (Branson, Clausen, & Sung, 2008). It would seem that, because of the sometimes cumbersome nature of virtual communication, designers working in virtual environments find it more convenient to accept ideas rather than engage in discussions to explore alternative solutions. We therefore speculate that in virtual environments some designers’ perspectives may not be offered for discussion, that when they do their ideas may not be acknowledged and / or explored, and that as a consequence, the quality of their solutions may suffer. It is therefore important for designers working in virtual contexts to recognise the potential limitations of their solutions, and to challenge the proposals of their colleagues.

5.3 Other notable results

The generic skill of Task Management demonstrated a decrease between face-to-face and whiteboard conditions that approached significance whilst there was a significant decrease in the behaviour of outlining and describing the plan/brief for the design/s. *Task Management* incorporates the sub-skills of planning or preparing a task, prioritising tasks, providing direction and maintaining standards for the task, and identifying and utilising resources. The management of virtual teams is acknowledged as being challenging (Kayworth & Leidner, 2000) and it may well be that the results apparent here relate to the small team size and personal management style of those involved.

Team Working skills incorporate co-ordinating activities with team members, exchanging information, using authority and assertiveness, assessing capabilities and supporting others. In demonstrating this generic skill, team members increased the frequency of giving updates and reporting key events significantly; however they significantly less frequently stated the case for instruction or gave justification as they worked in higher bandwidth conditions. The change in condition from face-to-face to whiteboard resulted in significantly more updates and reports of key events, as well as significantly fewer design plans and relevant information being communicated to relevant members. In contrast, the move from whiteboard to 3D virtual environments resulted in some changes that approached significance (fewer reassuring or encouraging comments, and more stating of the case for instruction and giving justification). This skill thus appears to present opportunities for further investigations. There are clearly many factors influencing designers' behaviours and further investigations to distil participants' contributions and interactions should provide interesting insights.

6. Limitations

The following are the main limitations of this study:

- Whilst the number of interactions analysed was large, the number of design teams analysed was relatively small (5). Each set of design tasks took 3.5 to 4 hours (including training and preparation) and proved challenging to organise. The fact that only five design teams took part is indicative of the difficulties involved in arranging the sessions. Although the number of teams was relatively small, the use of purposive sampling has permitted an exploration of the diverse nature of design teams.
- The data were collected under laboratory conditions. Because of confidentiality and logistics, it was not possible to video designers working at their normal place of work, nor was it possible to record their work on real-life design projects. Although the designs the participants were asked to work on were fictitious, they represented realistic design projects. It is difficult to determine the relative differences in complexity between the five projects provided.

- Due to the fact that participants were selected from a restricted pool of design professionals, all participants were from one discipline (architecture). Whilst our results may reflect the teamwork culture of the architectural profession, multi-disciplinary design teams may have experienced even more difficulty in exercising generic skills in virtual environments.

7. Implications for future research

An ability to map and measure the generic skills of individuals and teams is crucial for the construction/design industry because it allows specific training needs to be identified. Without a direction, those seeking to improve virtual teamwork may or may not succeed.

Virtual environments do not support non-verbal interactions as effectively as co-located conditions do and this deficiency inevitably leads designers to use different skills and / or skills in a different manner. A number of future research directions stem from this, including further examination of non-verbal interactions, team protocols and the possible impact of prior experience of ICT systems.

It is essential that designers understand the characteristics of the different environments in which they find themselves working. Specific generic skills may be needed for team members to function efficiently and effectively, particularly in virtual, high-bandwidth design environments. By examining the effects of technology on these generic skills, the particular strategies which facilitate and hinder teamwork 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 make greater use of electronic whiteboards, 3D virtual worlds and other technologies. In this context it is pertinent to note that currently training usually focuses on the use of new software and hardware, rather than on the generic skills that facilitate communication and collaboration. There is clearly a need to raise designers' awareness of the skills required for effective virtual collaboration, and to this end we have developed an interactive CD to assist those new to working in virtual environments (Newcastle, 2008; Williams & Sher, 2007). Additional skills development tools would provide valuable continuing professional development opportunities for design professionals.

8. Conclusions

The major conclusion drawn from our analysis of design collaboration is that there are significant differences for the generic skills profiles between the three operational conditions; face-to-face, whiteboard and 3D virtual world. This was true for the overall design activity of the five teams. As Daim et al (2012) concludes, the basic fundamentals of team building are still valid, but "new dimensions of technology and global economy are making matters complicated and challenging for the managers" (p. 9). While it is clear that the introduction of virtual technologies has implications for designers, the challenges are not solely technical. Ebrahim, Ahmed and Taha (2009) consider that the successful implementation of virtual teamwork is "more about processes and people than about technology" (p. 2663). However, technology has traditionally been the focus of investigation in virtual teamwork without taking into account social and economic considerations

(Rezgui, 2007). In addition, small-medium companies may be at an advantage because they can more flexibly change and adapt to new technology (Rezgui, 2007).

Designers bring with them a range of generic skills acquired over the years from a multitude of different activities. These need to be adapted to the new environments they find themselves working in. This is succinctly summarised by Larsson (2003) who states that since "design involves communication and interaction between individuals and groups in complex social settings, the social character of design is not separated from the technical results" (p. 153). Virtual technologies impact on the way designers work and collaborate and hence impact on the skills that need to be brought to bear. The investigations documented in this chapter contribute to this body of knowledge by identifying the generic skills of design professionals, profiling some of the impacts of different virtual communication technologies on these skills and identifying some goals which need to be addressed if virtual technologies are to be effective and successful. As Carletta, Anderson and McEwan have stated (2000, p. 1250), technologists are less interested in "social and organizational concerns than in equipment mechanics". The performance of virtual teams is far below their potential despite their rapid growth (Abuelmaatti & Rezgui, 2008). Therefore the investigation of these teams takes on a new urgency, particularly as virtual communication has been shown to have advantages over face-to-face interaction during problem-solving (Hatem, et al., 2011). Without taking into account the impact of these new design environments, advanced technologies that allow teams to collaborate at a distance may have a deleterious effect on teamwork and productivity.

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Sher, W., Sherratt, S., Williams, A., & Gameson, R. (2009). Heading into new virtual environments: what skills do design team members need? Journal of Information Technology in Construction, 14, 17-29.

10. References

Abuelmaatti, A., & Rezgui, Y. (2008). Virtual teamworking: Current issues and directions for the future. In L. M. Camarinha-Matos & W. Picard (Eds.), Pervasive Collaborative Networks (Vol. 283, pp. 351-360). Boston: Springer.

Activeworlds-Corporation (2008). Active Worlds Retrieved 28 Sept 2008, from http://www.activeworlds.com/

Bales, R. (1951). Interaction process analysis. Cambridge: Addison-Wesley Press Inc.

Bell, B. S., & Kozlowski, S. W. J. (2002). A typology of virtual teams: Implications for effective leadership. Group and organization management, 27(1), 14 - 49.

Bellamy, T., Williams, A., Sher, W., Sherratt, S., & Gameson, R. (2005). Design communication: issues confronting both co-located and virtual teams. Paper presented at the 21st Association of Researchers for Construction Management

(ARCOM). Berry, G. R. (2011). Enhancing Effectiveness on Virtual Teams. Journal of Business Communication, 48(2), 186-206.

Berry, G. R. (2011). Enhancing Effectiveness on Virtual Teams. Journal of Business Communication, 48(2), 186-206.

Bjørn, P., & Ngwenyama, O. (2009). Virtual team collaboration: building shared meaning, resolving breakdowns and creating translucence. Information Systems Journal, 19(3), 227-253.

Branson, L., Clausen, T. S., & Sung, C.-H. (2008). Group Style Differences Between Virtual and F2F Teams. American Journal of Business, 23(1), 65-70.

Burfield, I., Cadee, N., Grieco, F., Mayton, T., & Spink, A. (2003). The observer: Reference manual ver 5.: Wageningen, Neth: Noldus Information Technology.

Cannon-Bowers, J., Tannenbaum, S., Salas, E., & Volpe, C. (1995). Defining competencies and establishing team training requirements. In R. A. Guzzo & E. Salas (Eds.), Team effectiveness and decision making in organisations (pp. 333 - 380). San Francisco, CA: Jossey-Bass.

Carletta, J., Anderson, A. H., & McEwan, R. (2000). The effects of multimedia communication technology on non-collocated teams: a case study. Ergonomics, 43(8), 1237 - 1251.

Carthey, J., de Leval, M. R., Wright, D. J., Farewell, V. T., & Reason, J. T. (2003). Behavioural markers of surgical excellence. Safety Science, 41(5), 409-425.

Cross, N., Christiaans, H., & K., D. (1996). Introduction: The Delft protocols workshop. Analysing Design Activity. Chichester: John Wiley and Sons.

Daim, T. U., Ha, A., Reutiman, S., Hughes, B., Pathak, U., Bynum, W., et al. (2012). Exploring the communication breakdown in global virtual teams. International Journal of Project Management(0). Volume 30, Issue 2, February 2012, Pages 199-212

Dubé, L., & Paré, G. (2004). The Multifaceted Nature of Virtual Teams. In D. J. Pauleen (Ed.), Virtual teams: projects, protocols and processes: Idea Group.

Ebrahim, N. A., Ahmed, S., & Taha, Z. (2009). Virtual teams: a literature review. Australian Journal of Basic and Applied Sciences, 3(3), 2653-2669.

Ericsson, K., & Simon, H. (1993). Protocol analysis: Verbal reports as data (Revised version). Cambridge: MIT Press.

Fletcher, G., Flin, R., McGeorge, P., Glavin, R., Maran, N., & Patey, R. (2003). Anaesthetists' Non-Technical Skills (ANTS): evaluation of a behavioural marker system{dagger}. Br. J. Anaesth., 90(5), 580-588.

Gameson, R., & Sher, W. (2002). An investigation into perceptions of project team dynamics and the utilisation of virtual environments, Association of Researchers in Construction Management (ARCOM) (Vol. 1, pp. 177 - 186). Northumbria University, UK.

Gaudes, A., Hamilton-Bogart, B., Marsh, S., & Robinson, H. (2007). A framework for constructing effective virtual teams. The Journal of eWorking, 1(2), 83-97.

Gay, G., & Lentini, M. (1995). Use of Communication Resources in a Networked Collaborative Design Environment. Journal of Computer-Mediated Communication, 1(1), 0-0.

Guerlain, S., Turrentine, B., Adams, R., & Forrest Calland, J. (2004). Using video data for the analysis and training of medical personnel. Cognition, Technology and Work, 6, 131 - 138.

Halliday, M. A. K., & Matthiessen, C. M. I. M. (2004). An Introduction to Functional Grammar (3rd ed.). London: Hodder Arnold.

Hatem, W. A., Kwan, A. S., & Miles, J. C. (2011, July 6th - 8th). A comparison of face to face and computer mediated collaboration Paper presented at the 2011 eg-ice Workshop, University of Twente, The Netherlands.

Kanawattanachai, P., & Yoo, Y. (2002). Dynamic nature of trust in virtual teams. The Journal of Strategic Information Systems, 11(3-4), 187-213.

Kayworth, T., & Leidner, D. (2000). The global virtual manager: a prescription for success. European Management Journal, 18(2), 183-194.

Kazdin, A. (1982). Single-case research designs. New York: Oxford University Press.

Klampfer, B., Flin, R., Helmreich, R., Hausler, R., Sexton, B., Fletcher, G., et al. (2001, 5 - 6 July 2001). Enhancing Performance in High Risk Environments: Recommendations for the use of Behavioural Markers. Paper presented at the Behavioural Markers Workshop, Swissair Training Centre, Zurich.

Larsson, A. (2003). Making sense of collaboration: the challenge of thinking together in global design teams. Paper presented at the GROUP '03 Conference.,

Lau, H. Y. K., Mak, K. L., & Lu, M. T. H. (2003). A virtual design platform for interactive product design and visualization. Journal of Materials Processing Technology, 139(1-3), 402-407.

Maher, M. L. (2002). Team Collaboration in High Bandwidth Virtual Environments Retrieved 6 Sept 2008, 2008, from http://www.construction-innovation.info/index.php?id=63

Maher, M. L. (2005). Collaborative Processes: Research Report on Use of Virtual Environment. Brisbane: Cooperative Research Centre for Construction Innovation.

Marchman III, J. F. (1998). Multinational, Multidisciplinary, Vertically Integrated Team Experience in Aircraft Design. International Journal of Engineering Design, 14(5), 328 - 334.

Newcastle, U. o. (2008). Training and CPD Retrieved 13 Oct 2008, 2008, from http://www.construction-innovation.info/index.php?id=1107

Nunamaker, J. F. J., Reinig, B. A., & Briggs, R. O. (2009). Principles for effective virtual teamwork. Communication of the ACM, 52(4), 113-117.

Peña-mora, F., Vadhavkar, S., & Aziz, Z. (2009). Technology strategies for globally dispersed construction teams ITcon: Special Issue Technology Strategies for Collaborative Working, 14, 70-80.

Powell, A., Piccoli, G., & Ives, B. (2004). Virtual teams: a review of current literature and directions for future research. SIGMIS Database, 35(1), 6-36.

Pring, T. (2005). Research Methods in Communication Disorders. London: Whurr Publishers.

Rezgui, Y. (2007). Exploring virtual team-working effectiveness in the construction sector. Interacting with Computers, 19(1), 96-112.

Rice, P. L., & Ezzy, D. (1999). Qualitative Research Methods: A Health Focus. South Melbourne (Australia): Oxford University Press.

Riedlinger, M. E., Gallois, C., McKay, S., & Pittam, J. (2004). Impact of social group processes and functional diversity on communication in networked organizations. Journal of Applied Communication Research, 32(1), 55 - 79.

Salas, E., Shawn Burke, C., & Cannon-Bowers, J. A. (2000). Teamwork: emerging principles. International Journal of Management Reviews, 2(4), 339-356.

Schumacher, M., Cardinal, J. S.-l., & Bocquet, J.-C. (2009). Towards a methodology for managing competencies in virtual teams - a systemic approach. Paper presented at the IFIP AICT 307 - PRO-VE 2009.

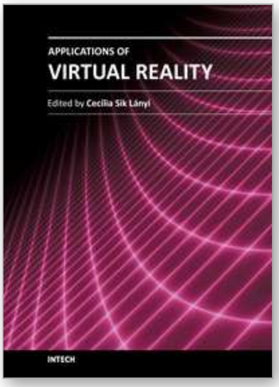
Sherratt, S., Sher, W., Williams, A., & Gameson, R. (2010). Communication in construction design teams: Moving into the virtual world. In R. Taiwo (Ed.), Handbook of Research on Discourse Behavior and Digital Communication: Language Structures and Social Interaction. Hershey, PA: IGI Global.

Shyamsundar, N., & Gadh, R. (2001). Internet-based collaborative product design with assembly features and virtual design spaces. Computer-Aided Design, 33(9), 637-651.

Wallace, W. (1987). The influence of design team communication content upon the architectural decision making process in the pre contract design stages. Edinburgh: Department of Building. , UK, Heriot-Watt University.

Williams, A., & Cowdroy, R. (2002). How designers communicate ideas to each other in design meetings. Paper presented at the Design 2002, International Design Conference.

Williams, A., & Sher, W. (2007, 12 - 15 Nov). The Alignment of Research, Education and Industry Application. Paper presented at the IASDR 07: International Association of Societies of Design Research, Hong Kong Polytechnic University.



Applications of Virtual Reality
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Information Technology is growing rapidly. With the birth of high-resolution graphics, high-speed computing and user interaction devices Virtual Reality has emerged as a major new technology in the mid 90es, last century. Virtual Reality technology is currently used in a broad range of applications. The best known are games, movies, simulations, therapy. From a manufacturing standpoint, there are some attractive applications including training, education, collaborative work and learning. This book provides an up-to-date discussion of the current research in Virtual Reality and its applications. It describes the current Virtual Reality state-of-the-art and points out many areas where there is still work to be done. We have chosen certain areas to cover in this book, which we believe will have potential significant impact on Virtual Reality and its applications. This book provides a definitive resource for wide variety of people including academicians, designers, developers, educators, engineers, practitioners, researchers, and graduate students.