A Comparison of Face to Face and Computer Mediated Collaboration

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Abstract. In the construction industry, the need for collaboration between people who are geographically remote is a reoccurring feature. The traditional way of dealing with this is collocation but this is expensive and disruptive and so increasingly, use has been made of remote collaboration using computational technology over networks. To assess whether or not such computer mediated collaboration is effective, a carefully controlled set of experiments has been undertaken using ten groups of two people who are required to work on a partially developed design task. The work is undertaken using computer mediated communication supported by a 3D CAD package. As a control, the same people have also undertaken a similar design task working face to face. The results show that, for the type of design task involved, people collaborating using computer mediated communication, at worst are as effective as people working face to face and probably are slightly more effective.

1. Introduction

IT technology to support communication and collaboration has witnessed a remarkable development during the recent years. This includes advances in both software and hardware. Design software has likewise witnessed a significant evolution, including some limited facilities to support Computer Mediated Communication (CMC).

Many researchers have focused on communication and collaboration systems and more specifically, how to use these systems in the construction industry. Straus and McGrath (1994) found that the overall effectiveness of face-to-face (FTF) groups was lower than that of CMC groups, particularly for tasks requiring higher levels of collaboration and decision making. Rocco (1998) asserted that the prior knowledge of other participants build strong trust in both FTF and CMC. Lantz (2001) examined the impact of a collaboration virtual environment on the performance of experienced individuals. Dawood et al (2002) developed a system that facilitates communication and data sharing. Luis et al (2009) illustrated the basic principles required for a collaborative network organisation. Kwok et al (2001) studied the impact of the various cultures of people using CMC. Hegazy et al (2001) described an information model that expedites design collaboration. Rezgui (2007) stated that the possibility of successful virtual team working in the construction industry depends not only on the adoption of effective ICT technology but also on an integrated analysis of social and organisational concepts. Akgun et al (2009) conclude that emotions are one of the most important factors in increasing the efficiency. Alel et al (2010) have used conceptual design type tasks to test the effectiveness of CMC compared to FTF. Their findings support the views of Lantz that CMC is an effective means of collaborative working.

Virtually none of the above work (except Lantz and Alel et al), used large scale experimentation and scientific methodologies to prove their hypotheses. This is significant and is an omission which the current work directly addresses, which has led to the development of a novel method of analysis that gives an in-depth view of the effectiveness of CMC and FTF.

2. Methodology

The aim of the current research is to assess the differences that occur between people who undertake engineering tasks FTF and people who do the same tasks when working remotely from each other via CMC. The tasks involve geometric alterations to several components of a building model. The task is not about creativity but problem-solving, and a group with good skills and experience would complete the task on time. The programme of experiments to investigate this has therefore involved teams of two people who are assigned two tasks, one FTF and the other using CMC. The order the tasks are performed is random to avoid any systematic bias in the results. For both tasks, the participants have to modify a building using a given 3D computer model of the building. The software used in both FTF and CMC experiments is Autodesk Revit Architecture, and since none of the participants was familiar with Revit, all of them had to be trained beforehand with identical training for all the participants.

At the start of each task, the two participants were given a list of instructions describing the necessary task. The instructions were individually given to, and different for, each team member. The instructions were carefully devised so that the tasks could not be carried out without assistance from the other participant. This approach enforces the need for collaboration and hence communication. For each experiment, there were four sections to the overall task which the participants were required to complete. Great care was taken before the experiments to ensure that all the participants were given identical verbal and written instructions and that the participants were not told anything about the purpose of the experiments. Likewise when the experiments were over, they were instructed not to discuss what had occurred with anybody else to avoid “contamination” of potential future participants.

The hardware used consists of a server coupled to two other computers, which are in separate rooms (see Fig. 1). For CMC, each participant worked remotely using one of the computers. For FTF, the participants sat together and jointly and simultaneously used a single computer, and were given freedom in choosing their own position in relation to the computer (see Fig. 2). Despite this freedom, the participants inevitably had only one of them (predominantly) controlling the mouse, and he/she was designated User 1. In CMC the participants worked on a single Revit model which was located on the server. Each user could “check out” a copy of this central file as a local file and changes on the local copy had to be updated in the central file. The designated User 1 in FTF remained User 1 in CMC, and the computer used in FTF became the computer for User 1 in CMC, i.e. it was always User 2 who moved to a new room.

Figure 1: Hardware arrangement for the experiments

Revit contained features which allowed multi-users simultaneous access on the same model but not on the same parts of the model. The responsibility for different areas of the model (e.g. exterior walls, plumbing, etc) were allocated to different users and if a user wished to modify something which impinged on an object they did not own, then they had to firstly request permission to do so. The tasks in the current work have been set up so that the work necessarily involved such requests. These designs which the users were asked to work on were also deliberately sub-standard so that the need for modification was relatively obvious.

For the CMC experiments, the communication between the participants was achieved using Skype for both audio and visual, the latter consisting of a small on-screen image of the other. At no time did participants share a desktop so all communication about the task had to be verbal or via the chat facility in Skype. In all experiments, the participants were video recorded, and the full session including the complete computer interaction and audio was also recorded. Once the experiments have been completed, the various data streams were synchronised and joined together using Corel Video Studio 12, and a detailed transcript of spoken words, non-verbal gestures, demeanour, etc. created and then analysed.

The analysis of the results was undertaken by extracting from the transcript of the experiment measures such as the total of task- and non-task related words, the total working time (i.e. time actually spent on the task), non-task related time, productivity, the number of exchanges (i.e. the number of times the discussion moved from one participant to the other) and the length of time when nobody spoke. Most of these measures were calculated for each individual and then aggregated where appropriate to obtain the team performance.

Figure 2: An FTF experiment

Figure 3: A CMC experiment

To demonstrate the differences in user behaviour during FTF and CMC, ten experiments were conducted for each, and each experiment consisted of two participants. (Further 20 experiments have also been conducted which reinforce the same findings.) Each group had different tasks with a similar concept; the task was not repeated so that the users did not become familiar with the tasks under FTF because this could then affect result reliability for CMC. Each experiment lasting 35 minutes was divided into seven intervals of 5 minutes in the analysis. The results for each experiment were fully studied and analysed and statistical results over ten experiments for each item were compiled to compare the differences between FTF and CMC.

The analysis allowed the comparison of the performance of individuals within each experiment plus a comparison of how each team performed in comparison to the other teams. As the participants had varying levels of experience from expert to novice, this allowed some interesting inferences to be drawn about how the various groups performed. The performance comparisons include:

- The productivity of each team regarding to the completion of various activities.
- Time spent on the task- and non-task time (i.e. unproductive) for groups and individuals.

- The number of words by each participant, which indicated the level interaction, or if one team member was more dominant. Likewise the number of non-task related words gave an indication of how effective and task-focussed the participants were.
- Various possible measures of collaboration had been examined in this work and the most robust and effective was been found to be the number of exchanges (percentage of interaction) between team members. This is further discussed below.

Most of the participants were Engineering PhD students from many different countries, with some experience in aspects of design and the construction industry, and 40% of them worked with total strangers. It has been found useful to classify the participants into groups according to their level of experience as follows: (A) Expert-Expert; (B) Expert-Junior Expert; (C) Expert-Novice; (D) Junior Expert-Novice; and (E) Novice-Novice, with two experiments per group type.

3. Results and Discussion

Many parameters have been measured and analysed in order to determine the performance of teams in both FTF and CMC, such as total number of words, different types of words, time spent working or wasted, productivity, number of exchanges and the degree of collaboration.

3.1. Total number of words, work and non work related words

It is obvious in Fig. 4 that total number of words in FTF was higher than in CMC and it is hypothesised that the higher number of words in FTF was possibly due to the need for more social interaction when people are collected. This can be confirmed by analysing the transcripts to determine the number of task related words, defined here as work-related words. As can been seen the trend of the curves for work related words is very similar to the curve for the total number of words, but the total number of work-related words in FTF is still higher than CMC. The percentage of work-related words out of the total is higher in CMC (FTF 92%, CMC 96%) but the number of work related words is higher in FTF (CMC 1847 words, FTF 2111 words). This indicates that participants say more about the task in FTF.

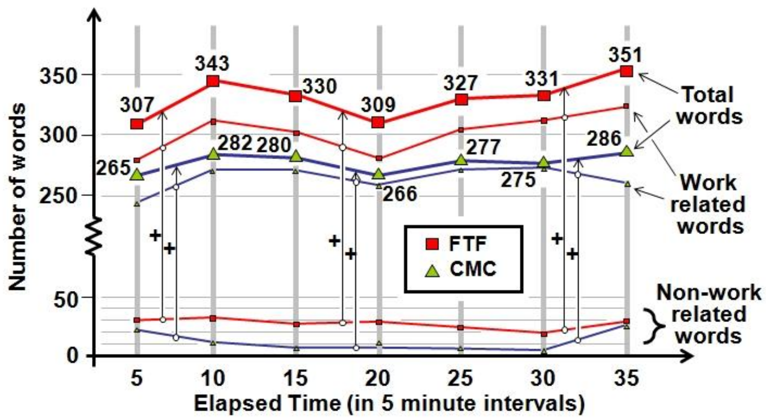

Figure 4: Total, work-, and non-work related words in FTF and CMC experiments

They could be looking more at the details which should result in a higher design quality, but conversely, the discussion might be non-productive. The examination of productivity helped to indicate which these scenarios are more plausible. Figure 4 also shows the average non-work related words is relatively few their distribution with time is interesting. The number of non-work related words in FTF is 186 (8.1% of total) and 82 in CMC (4.2% of total). As expected, non-work related words in FTF exceed that in CMC for all time intervals. However these two curves show a different pattern to those for work-related words, where there are a relatively high number of non-work related words at the start. This includes a high degree of social interaction, which can be reasonably expected at the start of any interaction.

Non work-related words remain approximately constant in FTF, but rapidly diminishes in CMC until the final five minutes when there is the number is almost the same as that in FTF, i.e. social interaction as the end of the task as approached. An additional feature noted is that the total number of non-work related words is higher between participants who already knew each other as compared to those who are strangers.

3.2 Working Time

Working time for any user is defined as the time is spent by user talking about and working on the task. Figure 5 illustrates the average working time spent by users in FTF and CMC. In FTF, User 1 (with mouse control) spent more time working during the first half of the experiment than user 2, but User 2 is more active in the second half of the experiment. This indicates User 1 was consistently more domineering at the start of the experiment but with time, User 2 takes more control in the experiment. On average, User 1 spends 1002s working time in FTF, compared to 785s for User 2.

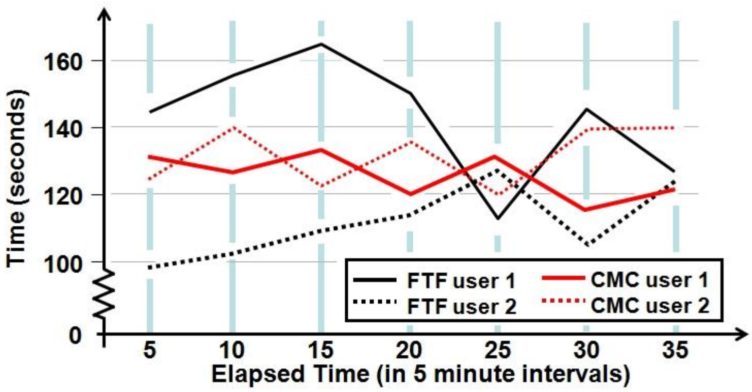

Figure 5: Working time spent by users in FTF and CMC

In CMC, there is much greater uniformity in working time between the same Users 1 & 2. This strengthens the previous impression that CMC removes the ability of one participant to dominate the other and so could possibly be a good way of making the best of all available expertise in a team without one person dominating the decision making. On average, User 2 spends 926s working in CMC, while User 1 spends a similar amount with 880s.

3.3. Wasted and Non-specific Time

Wasted time is here defined as the time on uttering non-work related words and the pauses in experiment. This figure is calculated from analysis the video recording directly. The measure cannot be absolutely precise because participants could have been thinking during the pauses. Figure 6 shows the wasted (and non-specific) time, which is consistently higher in FTF than in CMC. This indicates that CMC promotes a more task related use of the time. As stated above, the reason could be that the participants find CMC a more difficult way of working, or that they feel less of a need for social interaction in CMC. The average wasted time is 265s for FTF and 190s for CMC.

Non-specific time in Figure 6 is defined as the time that cannot, on initial appearance from study of the video recording, be clearly identified as either working or wasted. However, analysis of the characteristics (especially productivity in next section) of the non-specific time can show it is better aligned with working- than wasted-time. Non-specific time is consistently higher in CMC in throughout except towards the end of the experiments.

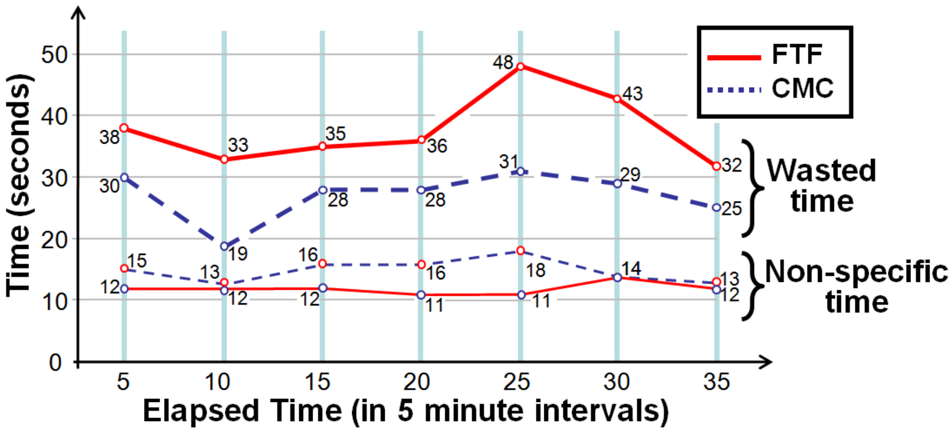

Figure 6: Wasted and Non-Specific Time in FTF & CMC

3.4. Productivity and Cumulative Productivity

The results presented so far have been largely focused on human factors. In this section, the productivity of the participants is presented. The productivity can be measured for the team or for each participant by totalling up the points allocated for successful completion of various features of the design modification task, according to the instructions given. The points for productivity of each task (i.e. for both FTF and CMC) are in four worksets where each workset has five items. Generally each workset is allocated 2.5 points and each item has 0.5 points so the maximum team productivity is ten points. Every effort has been made to make the point allocation procedure as consistent as possible but it has to be recognised that there is inevitably a degree of personal judgement involved.

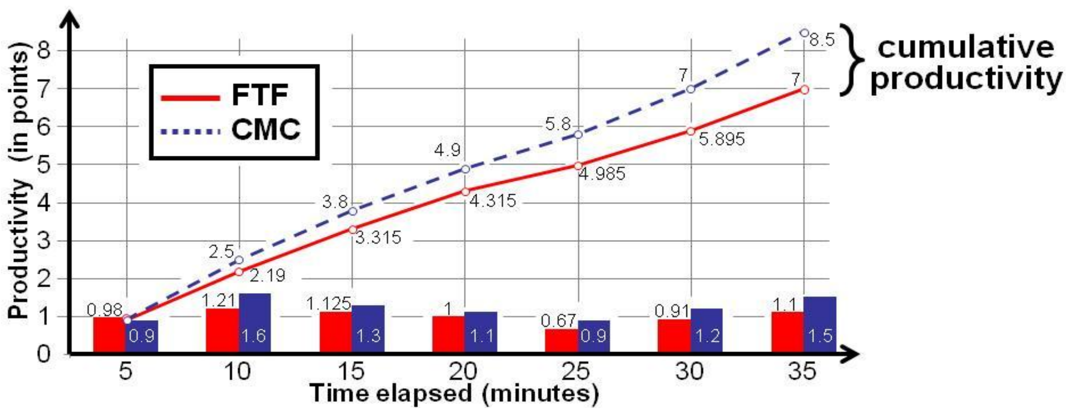

Figure 7: Comparison between Productivity and Cumulative Productivity in FTF & CMC

The results for productivity averaged over all the experiments are presented in Figure. 7. Rather surprisingly, after the initial 5 minutes, productivity for CMC is then higher than for FTF. Since none of participants had previously undertaken any technical tasks using CMC, nor had experience with Revit, it is remarkable that the unfamiliar form of communication in CMC should still result in higher productivity. The cumulative productivity is 8.5 for CMC and 7.2 for FTF.

4. Degree of Collaboration Measurement

It is not easy to measure the "degree of collaboration" in the collaboration process, because it is neither quantitative nor tangible, and there is no recognised formula for its evaluation. A number of possible measures and combinations of measures were studied, and the findings have led to one main indicator that is most reliable and unequivocal, and that is the number of (verbal) exchanges between the team members. It is clear that, at one extreme, if there is no collaboration then one could expect a monologue (i.e. zero exchange) from the dominant participant with the other "participant" taking not part at all. In contrast, if there is genuine collaboration then one would expect a significant number of continual exchanges although it is recognised that there must be an upper limit beyond which each speech transaction is so short and fragmented as to be of no or little use.

In Table 1 the number of exchanges for FTF and CMC for each of the 10 groups of participants is presented. It can be seen that for eight experiments the number of exchanges is higher for CMC than for FTF. It is clear that the interaction, in terms of number of exchanges, is slightly better in CMC even though the differences are not big.

Table 1: "Number of exchanges" in FTF and CMC (**bold** for CMC > FTF)

Experiment Number	1	**2**	**3**	**4**	5	**6**	**7**	**8**	**9**	**10**
Number of exchanges in FTF	155	**112**	**108**	**168**	150	**165**	**120**	**130**	**107**	**122**
Number of exchanges in CMC	146	**122**	**131**	**171**	140	**176**	**127**	**149**	**115**	**146**

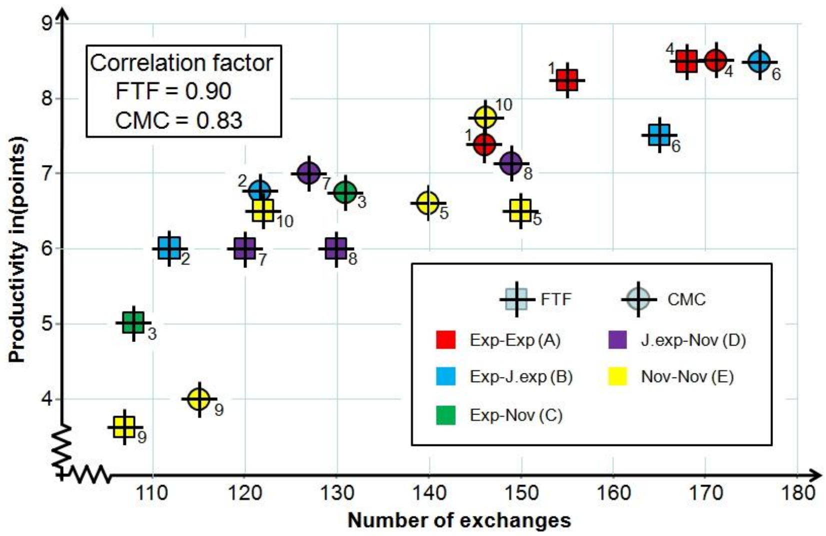

Figure 8: Relationship between Number of Exchanges and Team productivity in FTF & CMC

Figure 8 shows a good correlation between the team productivity and number of exchanges for both FTF and CMC. The correlation factor is slightly stronger in FTF but it is good for both cases. Figure 8 also shows that the expertise in a team has clear advantage in both greater team collaboration and team productivity.

5. Conclusion

In this paper the difference between CMC and FTF communication has been discussed thoroughly through analysis of experiments have done by participants. It has been concluded that, for the type of design exercise studied, the efficacy of CMC is much better than that of FTF in many aspects. CMC is better than FTF from a practical point of view, since users usually avoid "side conversations" and concentrate on their task. As compared to FTF, the total number of non-work related words is lower in CMC and this indicates that the time wasted is less in CMC, and CMC is better than FTF from a time management point of view. Additionally, it has been also found that total number of non-work related words is higher among users who know each other as compared to newly met users. The time-spent distribution was found to be more even in CMC as compared to FTF; remarkably, the time spent by each user was divided almost evenly (unlike FTF) giving strong indication that in CMC each participant can take participate fairly and freely regardless of any other factors like age group, experience, emotional factors, etc.

Productivity in CMC was also found to be higher in CMC which gives a good indicator that CMC is better than FTF from productivity point of view. Correspondingly, the working time was higher in CMC while wasted time was higher in FTF. The same participants thus seem to better task time management in CMC than in FTF. The degree of collaboration, as measured by the number of exchange, was also better in CMC. Overall, it has been found that for the type of collaborative design task tested, CMC has distinct advantages over FTF for team collaboration (especially with unequal team members), and ultimately for productivity.

6. References

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