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Application of Human Computer Interaction in Developing an IT-Supported Design Collaboration Process

Naeimeh Delavari[1]*, Muhamad Taufik Abdullah[2], Rahinah Ibrahim[3] and Normahdiah S. Said[4]

[1]Integrated Design Studies, Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[2]Faculty of Computer Science and Information Technology, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[3]Faculty of Design and Architecture, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[4]Faculty of Modern Languages and Communication, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ABSTRACT

Increasing globalisation and international collaboration have led to an increaseddemand for improvedcommunication within design collaboration processes. To address this issue, IT-supported design collaboration processes have been utilised, enablingprofessional design team members to work in a distributed design environment. However, IT-supported systems often lack human understanding, making such systems frustrating for professionals to use.The objective of this theoretical paper is to propose Human-Computer Interaction (HCI) integrated approaches that improve the interaction among professional design team members and collaborative technologies in a distributed design environment. This is particularly examined in the context of the building industry. For this purpose,this paper analysesthe related literature in design collaboration processes. This analysis is used toassess how earlier systems affect design team members' capabilitiesto accept and use collaborative technologies.It is found that in addition to impacting the ergonomic and cognitive capabilities of professionals, a system should also motivate professionals intrinsically and extrinsically. The findings of this study are essential forpromoting the utility of IT-supported design collaboration projects.In addition, this study supports further research to increase the level of engagement in collaborative team work and mitigate knowledge loss in a complex project lifecycle.

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E-mail addresses:
nami.delavari@gmail.com (Naeimeh Delavari),
taufik@fsktm.upm.edu.my (Muhamad Taufik Abdullah),
rahinah@putra.upm.edu.my (Rahinah Ibrahim),
norma@fbmk.upm.edu.my (Normahdiah S. Said)
* Corresponding author

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INTRODUCTION

Globalisation (Kolarevic *et al.,* 2000) has motivated building industries to increase the establishment of distributed design collaboration. On the other hand, the growing popularity of internet-based and collaborative technologies is creating a promising approach to non-collocated design collaboration processes. However, with regard to advances in collaborative technologies, such as 3D visualisation systems (Rahimian & Ibrahim, 2007), collaborative CAD and Computer Supported Collaborative Work (CSCW) tools (Christiansson *et al.,* 2001), Virtual Reality (VR) (Bouchlaghem & Whyte, 2000), Virtual prototyping (Li *et al.*, 2008) and Building Information Modeling (Popov *et al*., 2010),design team members prefer to communicate through conventional modes. Subsequently, e-collaboration is not yet the norm in design collaboration processes (Delavari & Ibrahim, 2009). As a result, design team members have to contend with the impracticality and inconvenience of having to exchange vast amounts of information among one another,who are usually located in different geographical areas. The authors believe that there is lack of understanding for building professionals in using collaborative technologies in IT-supported collaboration processes. Therefore, to reduce the problems in current conventional collaboration methods and to fulfil the vital need for globalised practice in construction industry (Kolarevic*et al.*, 2000),current IT-supported design collaboration systems should be supported with HCI.

Basically, HCI is the study of how humans use computer systems to simplify, perform or support a certain task (Dix & Finlay, 2004). Therefore, the human needs to present his/her requirements to the computing system. In this regard, the authors believe that to motivate building professionalsto perform their activities in IT-supported design collaboration methods and to satisfy their human need, there is an urgent need to integrate HCI into design collaboration processes. In this study, HCI is used to identify the variety of approaches to improve the interaction among design building professionalsandinteractive computing systems.

In this paperwe aim to lay the theoretical groundwork for HCI integration in IT-supported design collaboration processes. The paper is organised as follows. First, a brief introduction and background to the problem is presented. Next section defines HCI from different perspectives and analyses the earlier HCI frameworks, introduces design collaboration processes in building project teams and itsassociated challenges. The importance of HCI in design collaboration processes is also explained in this section and the last section presents a detailed analysis and discussion of related work in the area of IT-supported design collaboration process.

HCI AND ANALYSIS OF ITS FRAMEWORKS

The introduction of technology in organisations has had a significant effect on how information is stored, accessed, utilised and efficiently used in the work environment (Dix & Finlay, 2004). Traditionally, the major concern of computerised organisations is how to match the technology to the job constraints; however this scenario has changed. Subsequently, in modern IT-supported organisations, the main concern is with human aspects and requirements of system use other than job constraints. These issues are the concerns of HCI.

HCI is defined as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Sequin & Kalay, 1998). Subsequently, HCI is the study of how people use computer systems to perform certain tasks. It is a multidisciplinary science that brings together computer technology, psychology, sociology and anthropology, industrial design, ergonomics and linguistics. The goals of HCI are generally to make tasks easier, more effective, more satisfying to perform and safer, based on human dimension and understanding (Norman, 2004). According to Preece *et al.* (1994) HCI is the process of designing computer systems that support people so that they perform their activities safely and productively. Zhang *et al.* (2005) define HCI as the way that humans interact with information, technologies and tasks within various contexts.

Furthermore, extensive studies in HCI show that many studies have clearly proposed various building blocks and components of HCI. One of the earliest studies (Eason, 1991) presented a three-level model forHCI. The first level of the model presents HCI as the conversation between two participants capable of processing information. The second level examines user, task and environmental factors (physical environment in which computers are used) that may affect task performance. The third level presents the impact of the interaction between humans and computers on social life as a result of changes in the way people interact or organisations operate.

Hewett *et al*. (1992) proposed a framework that identifies the main building blocks and dimension of HCI as humans, use and context, computer techniques and process to design. Later, Preece*et al*. (1994) proposed an improved model of HCI that identifies all the components that would contribute to the design of HCI. This model considered users with cognitive processes and capabilities such as enjoyment, satisfaction, motivation, personality and experience. These components include organisational and environmental factors, users, comfort factors, health and safety factors, user interface, task factors, constraints, system functionalities and system constraints. The next framework proposed by Zhang and Li (2004) demonstrates the broad issues and concerns of HCI. They defined the components of HCI as human, technology, design/usability, use/evaluation/ impact, context and task/job.

Through a deep understanding of the HCI frameworks discussed in the previous section, this author identifies HCI as a broader subject beyond interface design that encapsulates all aspects related to the interaction between humans and technology. These models are comprehensive enough to identify the factors that contribute to HCI design. The similarity among all the models is that all the models demonstrate the major components and their relationships, as well as the main factors that play an important role in HCI.

HCI frameworks mainly focus on the collaboration and interaction betweenhumans and technology and define what a system should do from a human perspective. As a result, all the proposed models from as early as 1991 have demonstrated that humans are the core component of the proposed frameworks. They recognise the user as a complex being with cognitive capabilities. In this regard, this paper focusses on humans and briefly explains the human dimension in HCI among professional design team members.

The next section discusses and elaborates the collaboration among professional building design team members in design collaboration processes.

DESIGN COLLABORATION PROCESS

Design collaboration is an activity that requires the participation of individuals for accomplishing an agreed design task or addressing an agreed-on design goal (Chiu, 2002). This activity is performed by organising design tasks and resources and sharing expertise, ideas and design information among design team members. Similarly, a building project in collaborative work is normally divided into several parts and distributed among design team members (Ibrahim *et al.,* 2007). There are two types of design collaboration: structured collaboration and unstructured collaboration (Chiu, 2002). Structured collaboration refers to a collaborative design team that shares the same goals while unstructured collaboration refers to a collaborative design team without shared goals and minimal dependency among the team members.

According to Cross (1989) and Goel (1995) collaborative design stages include: i) analysis of the problem, ii) concept generation, iii) preliminary design and iv) detailed design. Yet, Chiu (2002) believes that the design process consists of i) architectural programme schematic design, ii) design development, iii) construction documentation and iv) construction. Similarly, Stellingwerff and Verbeke (2003) identify three distinct phases that always take place in collaborative design processes (Fig.1). These phases are design in early stages, collaborative design and completion of design specification. According to Stellingwerff and Verbeke's design process, the solution should be debated and exchanged in an open way without prejudgments and too many constraints. Then, the most fruitful solutions are selected. In this phase the implicit aspects of the design become explicit. Therefore, collaboration usually takes place when the implicit knowledge

DESIGN COLLABORATION PROCESS

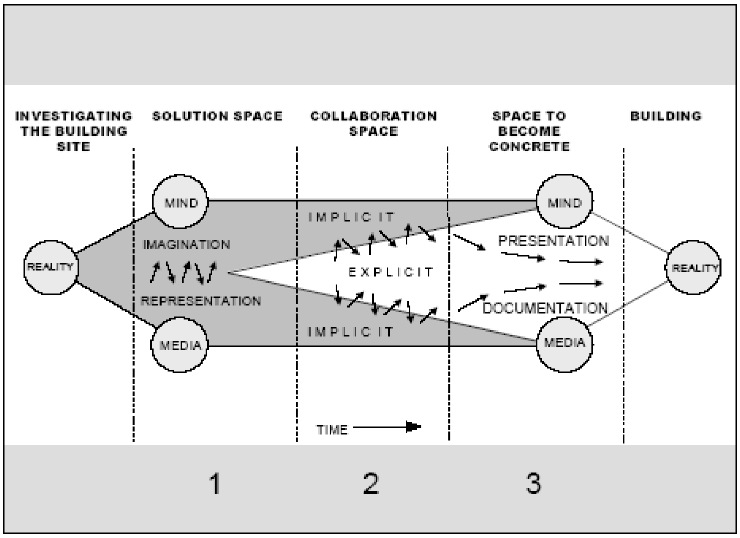

Fig.1: General Design Collaboration Phases (Stellingwerff and Verbeke, 2003)

of design team members is made explicit to produce a consistent design proposal. It is then finalised by standardisation of documents and optimisation of collaboration processes between design team members (Stellingwerff & Verbeke, 2003).

The authors believe that all collaborative design processes are more or less similar. Accordingly, this study focusses on a collaborative design process that starts with unlimited solution-space at the initial stage of the design process, allowing for close coordination among the professionals until the preliminary plan is finalised and the design is developed. This process supports a team of designers from non-collocated locations with different background knowledge, cultures, responsibilities and areas of expertise. Moreover, to facilitate communication among the members, this process is typically supportedby Internet-enabled agent technology, which uses IT-supported collaborative technologies.

In the next section, the current challenges in design collaboration process are briefly elaborated on.

Challenges in Design Collaboration Process

Design collaboration is implemented for organising design tasks and sharing experiences that requirethe participation of project team members (Nam & Wright, 2001). Nowadays, the non-collocated design collaboration process is motivated by globalisation and the trend of establishing enterprise design chain in construction industries (Li & Shen, 2008). Distributed or non-collocated design collaboration is a type of collaborative design process that aims to integrate geographically disperseddesign team members, design resources, services and systems. The successful establishment of non-collocated collaborative design has led to an increase in the demand for adaptation of IT/ICT in design collaboration processes. Therefore, it makes it possible for design team members to operate through an internet or intranet server and communicate with each other using collaborative tools and technologies beyond the boundaries of physical environment and time zone. An effective non-collocated design collaborative process should enable designers to cooperate and collaborate with each other conveniently using advanced communication technologies through accumulating new customised collaborative systems. Therefore, accelerating an effective establishment of global collaborative design is a challenging issue due to the complexity of technical and application requirements (Li & Shen, 2008).

Many studies indicate various efforts towards facilitating collaboration using IT/ICT in design collaboration and engineering (Rahimian *et al.,* 2008; Isikdag & Underwood, 2009; Scherer, 2007; Rosenman & Gero, 1999; Leeuwen & Zee, 2005). In addition, there are diverse numbers of software applications developed for collaborative product environment (Toye *et al.,* 1993) and communication in a distributed collaborative environment (Yee *et al.,* 1998; Wojtowicz, 1994).However, these types of collaborations are time-consuming and require extensive effort in terms of community building (Lahti *et al*., 2004).

Moreover, as IT-supported collaboration speeds up communication and the exchange of data among design team members, the current systems, however, do not help to establish mutual understanding among members. This contributes to increasing miscommunication and little understanding among design team members in the IT-supported design collaboration process. This is due to the fact that the interpretation of data produces many semantic ambiguities (Sequin & Kalay, 1998). On the other hand, it is a difficult task to train building professionals to collaborate using IT-supported technology quickly. Indeed, a long time is required to train design team members to use IT-supported technology.

The above challenges indicate that in the current collaborative design system, there is little efficient communication and collaboration, and this is caused by unfamiliarity of design team members in using IT-supported technologies. For instance, Construction Visual Prototyping (CVP) is used in the construction industry to provide a platform for designers to “try before building” by realistically simulating construction processes and capturing and reusing knowledge effectively (Li *et al*., 2008). However, the simulation outcome of a building project may seem doubtful at the beginning of a project, and designers view this technology as an animation tool that better illustrates their idea (Li *et al*., 2008).

The chief concern of design team members interacting with technology is technological support for collaboration enrichment and successful communication. These challenges suggest that there is a gap between an efficient and effective IT-supported design collaboration process and the understanding of design team members using the collaborative systems. To fill this gap, it is important to understand the requirements and behaviour of professional design team members who use these collaborative technologies. Such understanding can be achieved through integration of HCI in IT-supported collaborative design processes. Doing so will enable systems support professional design team members to perform collaboration on design, planning and development processesmore efficiently. Furthermore, acceptance of collaborative technologies in IT-supported collaborative design processes has improved.

In the following section, the authors identify the potential importance of HCI in the IT-supported design collaboration process. Through the analysis of previous studies, the varieties of approaches to improve the interaction among design team members with interactive computing systems using HCI are recommended.

Enhancing IT-Supported Design Collaboration Process Using HCI

Establishing a successful IT-supported design collaboration process in a distributed design environment requires an understanding of the requirements and behavioural aspects of design team members. As mentioned in earlier, the goals of HCI are generally to make tasks easier, more effective, more satisfying to perform and safer based on understanding human dimensions (Norman, 2004). Therefore, considering HCI in designing the system would utilisethe IT-supported design collaboration process by investigating the effects of the system on design team member's perception and their evaluation factors. HCI assists in definition of what a collaborative system should do from the perspective of professional design team members. As a result, integration of HCI in design collaboration processes enhances the collaboration between design team members and interactive computing systems.

There are diverse groups of professionals in design collaboration processesdistributed across various geographical, functional and cultural boundaries.This means that the criteria for the system's quality evaluation may be seen differently bythe different groups. For example, culture affects how people interact with computers (De Souza & Dejean, 2000; Ess & Sudweeks, 2000; Dunckley & Jheita, 2004). Therefore, in order for various design team members to collaborate effectively, the system designers who develop the system need to consider whether the system designed for one group will work for other groups. Therefore, it is necessary to consider HCI in designing systems to improve the interaction among various groups of design team members located in different geographical area and with diverse backgrounds.

In considering the above statements, this paper analyses and evaluates the human dimensions and constraints that potentially have a great impact on professionals' interaction with computing systems. As a means to motivating building professionalsto perform their activities in IT-supported design collaboration, satisfy their human need and sustain their level of engagement in the collaborative work environment, this study supports the integration of HCI in design collaboration processes.

The next section elaborates on earlier studies in design collaboration, and analyses how these studies can be enhanced to improve collaboration and communication among building professionals in IT-supported design collaboration process.

ANALYSIS AND DISCUSSION OF IT-SUPPORTED DESIGN COLLABORATION STUDIES

To achieve a sustainable design collaboration process, many studies suggest improvement to communication and collaboration among professional design team members. For example, Chiu (2002) attempted to present the role of the organisation in design collaboration and its impact on communication and collaboration. Chiu suggested that a structured organisation can facilitate design communication and consequently contribute to the success of a design project. The study does, however, lack a proper computational system in the organisation to evaluate and improve the communication level among design team members. Nevertheless, it is possible to achieve a sustainable design collaboration process through integration of collaborative technologies. This has been the subject of a number of studies. There are, however, a number of challenges associated with such technologies (see Challenges in Design Collaboration Process) which prohibit professional design teams from readily utilising the processes. In this paper,a summary analysiswhich can aid in the acceptance of collaborative technologies in IT-supported design collaboration processes (refer to Table 1) is presented by analysing the studies in the literature that treat collaborative technologies as a means for improving communication. The earlier studies are analysed based on identifying what aspects of human dimensions might have been involved in designing the system. This analysis is usefulto identify what is lacking in the earlier studies and how to improve them accordingly. Consequently, this paper proposes how the earlier studies can be improved on by considering human needs in designing the system in order to make it more satisfying for the utilisation of design team members.

As presented in the above summary, various IT-supported design collaboration studieshave influencedthe cognitive and ergonomic capabilities of professionals. For example, one of the earlier studies (Haymaker & Keel, 2000) proposed a new approach called ‘Filter Mediated design’ in which this mechanism is augmented using agents for achieving coherence and innovation in remote design collaboration. The new approachserves to reformulate the construction and flow of information in collaborative design. The intent is to reduce some of the verbal communication to improve efficiency and allow for more people to participate in the design process. From the abovestudy, the authors identify that the use of a schematic design in this study which has reduced the ambiguity among design team members can potentially affect their cognitive capabilities. Therefore,influences affecting human cognitive perspective can simplify collaboration among design team members. However, from the HCI viewpoint human interaction with technologies should be driven by the different levels of human needs and goals (Zhang *et al.*,2005). However, althoughthe use of computerised filter mediated systems has simplified collaboration among design team members by affecting their cognitive capabilities, it has also decreased their creativity level. Thus, this studywill identify how a computational medium would simplify design collaboration processes. In addition, the study will also consider how the acquisition of skills through the ease of use of that system which affects the movement of cognitive capabilities from motor skills to mental model skills (Said, 2004) will increase the level of engagement of collaborative members while maintaining the creativity and attraction of experts.

Erickson and Kellogg (2000) focus on designing socially translucent systems in collaborative design. In fact, these systems are the design digital systems that support human-human communication and

TABLE 1
Analysis of IT-supported Design Collaboration Studies

Developments in IT-supported Design Collaboration Process	Analysis Based on Study's Effects on Human Dimension	Supporting References	
		year	Authors
Designing social translucent system in collaborative design	Cognitive and ergonomic capabilities	2000	Erickson and Kellogg
Developing filter-mediated design for design collaboration process	Cognitive capabilities	2000	Haymaker and Keel
Designing real-time collaboration system using indexical representation	Cognitive and ergonomic capabilities	2003	Larsson
Facilitating re-interpretation and reflection-on-action capabilities to design collaboration	Cognitive capabilities	2007	Hailpern *et al.*
Facilitating TUI to improve the collaborative design environment by table-top systems	Cognitive capabilities	2008	Kim and Maher
Determining the technological and social routines of individuals using devices and sharing information across spaces	Cognitive capabilities	2009	Plaue *et al.*
Proposing VR-based design interface	Cognitive capabilities	2010	Ibrahim and Rahimian
Developing CoSpacesCollaborativeWorking Model (CCWM)- a descriptive human factors model of collaboration	Cognitive and ergonomic capabilities	2012	Patel *et al.*

collaboration by utilising properties of the physical world. Their designed system is called 'Babble' and it is designed to make the participants and their activities visible to one another in a collaborative network so that they can make inferences about one another's activities and imitate one another. This socially translucent system integrates three characteristics i.e. visibility, awareness and accountability. However, the study focusses merely on three characteristics of a socially translucent system which support the usability concern and ergonomic aspects of human-human communication. Therefore, the authors believe that a socially translucent system can be further examined by focussing a human-centred view to more completelymeet the emotional needs of professional design team members.

Another study by Larsson (2003) successfully presents an observational study of the essence of a true collaboration in which design team members 'think together' rather than just exchanging information. This study gives a broader view of how a collaborative design team member communicates and negotiates common ground in collocated collaboration effectively, subtly, fluently and effortlessly such as negotiating by telling stories and using indexical representation. He uses a wide variety of tools including physical prototype, sketches, verbal languages, gesture, chairs, even his own body and all possible types of objects to visualise and describe meaning. However, the study does not present a global design team where the collaboration is applied using the IT-supported technologies in more natural and user-friendlier ways, for example, where the "physical objects live in one place" (Everitt *et al.*, 2003) or only one of the site has access to a physical prototype and the other collocated members negotiate shared understanding about concepts of "comfort" and "ease of use". The authors believe that the collaboration practice of using a variety of collaboration tools extends design team members' ergonomic capabilities in perceiving the communication. In addition, other collocated members who perceive the system's usability factors, the collaborative IT-supported system potentially affect their cognitive capabilities.However, developing a sustainable collaborative design process is beyond emphasising professionals' cognitive and ergonomic aspects. Although the use of indexical representation facilitates communication among design team members, it does not seek to retain and motivate the design team members to continue in the collaborative environments. Therefore, this study addresses HCI to integrate a human-centred collaborative system that satisfies design team members' emotional and aesthetic needs.

Hailpern *et al.* (2007) facilitate creative design processes by providing re-interpretation and reflection-on-action capabilities. Their study developed a novel system that satisfies the requirement of real-time collocated design collaboration that supports creative group work collaboration, namely, keeping multiple design ideas visible simultaneously, providing clearly delineated personal and group spaces, allowing multiple levels of sharing, shared idea should always remain in the collective consciousness, allow rapid access to personal and shared designs, minimise social inhibitors of group work. From this study, it can be identified that a collaborative system which provides an environment for design team members to share design ideas as well as access personal information would potentially improve professional cognitive strength in perceiving design communication. However, the system is mainly based on real-time collaboration needs rather than human needs. Therefore, to have an effective real-time collaboration the authors believe that HCI can be potentially used to intrinsically and extrinsically motivate design team members in global real-time collaboration.

Apart from improving the collaborative technologies in design collaboration such as display sharing abilities, Plaue *et al.* (2009) present the importance of social and technology routines as well as technology improvement. They present the analyse behaviour of designers and determine the technological and social routines of individuals using devices and sharing information across spaces and multiple meetings. They describe social and technological routines of users as: i) device arming, ii) ephemeral personal device usage, iii) at-a-glance information is important, iv) physicality comfort and reassures, v) non-technical factors are critical for success, and vi) rooms must be versatile. The authorsidentify that these routines address cognitive aspects of system use. Therefore, the authors believe that in IT-supported design collaboration the realisation of the human psychological dimension is more than just physical and cognitive aspects; as Tractinsky*et al.* (2000) state, "beautiful things are easy to use," and as Norman (1998) states, "pleasant things work better."

In addition, many studies present the more natural and direct use of 3D digital modelling and Tangible User Interface (TUI) in collaborative design processes(Tang, 1991; Bekker *et al*., 1995; Scott *et al*., 2003; Kim & Maher, 2008). TUIs are useful to construct internal and external design representations for designers, therefore strengthening their spatial cognition. Kim and Maher (2008) improve the collaborative design environment by table-top systems which employ TUI through an empirical study. They present the impact of TUI in changing the designer's spatial cognition and therefore improving their problem-finding behaviour. This potentially improves the design process. From this study, it can be identified that TUI directly impact designers' spatial cognition by perceiving external representations. However, there is still a lack of emphasis on the human aspects of system use.

Recent studies present more advanced methods for improving communication among groups ranging in size fromsmall to larger enterprise. Ibrahim and Rahimian (2010) propose an alternative VR-based (Virtual-Reality-based) design interface to conventional CAD tools for novice designers working on conceptual design projects. VR-based interfaces can potentially affect the designers' cognitive capabilities during the conceptual design phase.Moreover, Patel *et al.* (2012) develop a descriptive human factors model of collaboration,CoSpaces CollaborativeWorking Model (CCWM). The factors involved in this model are context, support, tasks, interaction processes, teams, individuals and other overarching factors. Patel *et al.* highlight the variety of tools for supporting teams and individuals in performing tasks during the interaction processes,for instance,networks of virtual reality such as Cave Automatic Virtual Environments, teleconferencing and shared workspaces. These technologies do, however, still need good support systems such as user supportive interfaces and complementary job design. The study emphasises the importance of the above-noted factors for successful collaboration, but there is still a lack of understanding from the people in collaboration (individuals andteam). On the other hand, while the existing collaborative tools would directly or indirectly affect the human cognitive and ergonomic capabilities,the impact of the collaboration technologies on the entire scope of human needsshould be taken into account.

It is deduced from the above studies thatthe computerised filter mediated system, collaborative environments for sharing design ideas, VR-based design interface and TUIs to construct internal and external design representations would potentially affectthe cognitive capabilities of design team members. On the other hand, facilitatingdesign collaboration with a variety of novel tools, such as teleconferencing, extends the ergonomic capabilities of design team members in perceiving communication. The authors, however, believethat to motivate professionals to collaborate using technologies, it is necessary to take the entire scope of human needs into account.This is because the ultimate concern of design team members interacting with technology is for supporting their experience with technology for collaboration enrichment and successful communication.Therefore, the study recommends that in addition to the cognitive and ergonomic human dimensions, the collaborative system should intrinsically and extrinsically motivate design team members in global real-time collaboration. For example, one possible solution may be to improve the design of TUIs to encourage professional design team members to utilise it due to the attractiveness of the systemwhen it satisfies their aesthetic and emotional needs. Moreover, TUI can be improved to encourage professional design team members by extending their ability, supporting their individual tasks or providing rewarding capabilities to them. The earlier design improvement intrinsically motivates design team members while the latter design improvement extrinsically motivates professionals to TUI. This translates to an improvement in the acceptance of collaborative technologies in IT-supported design collaboration.

Finally, it is hypothesised that identifyingthe specific human dimension in design collaboration processcan be implemented using grounded theory (Strauss

& Corbin, 1998; Creswell, 2009). This methodology can be used to inductively construct and then describe a theory of how professional design team members collaborate in an IT-supported design collaboration process. This is an area of research which merits further investigation and is the subject of our future work.

CONCLUSION

In an effort to provide motivation towards advancing design collaboration processes via HCI, in this paperstudies making utility of computerised systems more attractive to professionals. It is argued that from the HCI point of view, human interaction with technologies should be driven by the needs and goals of professionals. In particular, it is found that the use of indexical representation or designing TUI can facilitate communication among design team members and influencetheir spatial cognition. They do not, however, maintain the attention and motivation of the team members to the collaborative technologies. Due to this, the authors believe that in IT-supported design collaboration the realisation of the human psychological dimension concerns more than just the physical and cognitive aspects. The study recommends thatIT-supported design collaboration systemsshould fit the entire capabilities of design team members,encompassing cognitive, ergonomic and intrinsic and extrinsic motivational aspects. The results of this study is expected to close the gapin knowledge loss due to discontinuity in complex projects (Ibrahim & Paulson, 2008) by providing documentation facilities in IT-supported collaboration.

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REFERENCES

Bekker, M., Olson, J. S., & Olson, G. M. (1995). *Analysis of gestures in face-to-face design teams provides guidance for how to use groupware in design*. In The Symposium on Designing Interactive Systems (DIS)’95, pp. 157-166.

Bouchlaghem, N., & Whyte, J. (2000).Virtual reality as a visualization tool, benefits and constraints, *International Journal of Integrated Design and Construction, 2*(4), 216– 224.

Chiu, M. L. (2002). An organizational view of design communication in design collaboration. *Journal of Design Studies*, *23*, 187–210.

Christiansson, P., Svidt, K., Skjærbæk, J. O., & Aaholm, R. (2001). User requirements modeling in design of collaborative virtual reality design systems. In G. Coetzee, & F. Boshoff. (Eds.), *Proceedings of IT in Construction in Africa,* South Africa, Vol. 40, pp. 1–14.

Creswell, J. W. (2009). *Research Design Qualitative, Quantitative and Mixed Methods Approaches (Seconded).* Los Angeles: SAGE.

Cross, N. (1989). *Engineering design methods. Strategies for Product Design.* New York: Chichester.

Delavari, N., & Ibrahim, R. B. (2009). *IT/ICT Integration for Design Collaboration in the Construction Industry.* Second Construction industry research achievement international conference (CIRAIC2009). Malaysia.

Delavari, N., Ibrahim, R. B., Said, S. N., & Abdullah, T. M. (2010). *HCI Potential in Sustainable Design Collaboration Process*. International Conference of SusTed. Malaysia.

De Souza, M., & Dejean, P. (2000). Cultural Influence on Design. In D. Day, E. Del Galdo, & G. Prabhu (Eds.). *Designing for global markets 2: IWIPS' 2000 Proceedings.* The Second International Workshop on Internationalization of Products and Systems. Backhouse Press. Baltimore, Maryland, USA, 13-15 July 2000, pp.125-136.

Dix, A., & Finlay, J. (2004). *Human-computer interaction*. Third Edition. Pearson, Prentice Hall.

Dunckley, L., & Jheita, K. (2004).Formative evaluation of international user interfaces based on sorting techniques. In V. Evers, E. Del Galdo, D. Cyr & C. Bonanni (Eds.). *Designing for Global Markets 6: Culture, Trust and Design Innovation: IWIPS' 2004 Proceedings.* The Sixth International Workshop on Internationalization of Products and Systems.BondRepro Publication. Vancouver, Canada, 8-10 July 2004, pp.91-102.

Eason, K. D. (1991). Ergonomic perspective on advances in human–computer interaction. *Ergonomics*, *34*(6), 721–741.

Erickson, T., & Kellogg, W.A. (2000).Social translucence: An approach to designing systems that support social processes. *ACM Transactions on Computer-Human Interaction*, *7*(1), 59–83.

Ess, C., & Sudweeks, F. (2000).The Preface. In F. Sudweeks, & C. Ess (Eds.).*Cultural attitudes towards technology and communication: CATaC' 2000 Proceedings.*The Second International Conference on Cultural Attitudes toward Communication andTechnology.Murdoch University Publication. Perth, Australia, 12-15 July 2000, pp. vi-vii.

Everitt, K. M., Klemmer, S. R., Lee, R., & Landay, J. A. (2003). *Two worlds apart: Bridging the gapbetween physical and virtual media for distributed design collaboration*. In Proceedings of CHI'03, Ft. Lauderdale, FL, USA, ACM Press.

Goel, V. (1995). *Sketches of Thought*. Cambridge, MA: MIT Press.

Hailpern, J., Hinterbichler, E., Leppert, C., Cook, D., & Bailey, B. P. (2007). *TEAM STORM: Demonstrating an interaction model for working with multiple ideas during creative group work.* Proceedings of the 6th ACM SIGCHI conference on Creativity & cognition, pp. 193 – 202.

Haymaker, J., Paul, K., Ackermann, E., & Porter, W. (2000). Filter mediated design: generating coherence in collaborative design. *Journal of Design Studies*. *21*, 205–220.

Hewett, T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., Perlman, G., Strong, G., & Verplank, W. (1992). *ACMSIHCHI curricula for human–computer interaction. Association for computing machinery. ACM*. New York, NY: U.S.

Ibrahim, R., R. Fruchter, & R. Sharif. (2007). Framework for innovative architectural-construction integration design studio for cross-borders transdisciplinaryeducation. *Archnet-IJAR: Intl. J. of Architectural Research*, *1*(3), 88-100.

Ibrahim, R., & B. C. Paulson, Jr. (2008). Discontinuity in organizations: Identifying business environments affecting efficiency of knowledge flows in PLM. *Intl. J. of Product Lifecycle Management*, *3*(1), 21-36.

Ibrahim, R., & Rahimian, F. P. (2010). Comparison of CAD and manual sketching tools for teaching architectural design. *Automation in Construction, 19*, 978–987.

Isikdag, U., & Underwood, J. (2009). Two design patterns for facilitating Building Information Model-based synchronous collaboration. *Automation in Construction, 19*(5), 544-553.

Kim, M. J., & Maher, M. L. (2008). The impact of tangible user interfaces on spatial cognition during collaborative design. *Journal of Design Studies*, *9*, 222-253.

Kolarevic, B., Schmitt, G., Hirschberg, U., Kurmann, D., & Johnson, B. (2000). An experiment in design collaboration. *Automation in Construction*, *9*, 73-81.

Larsson, A. (2003). *Making sense of collaboration: The challenge of thinking together in global design teams.* Conference on Supporting Group Work Proceedings of the 2003 international ACM SIGGROUP conference on Supporting group work, pp. 153–160.

Leeuwen, J. P. V., & Zee, A. V. D. (2005). Distributed object models for collaboration in the construction industry. *Automation in Construction*, *14*(4), 491–499.

Li, H. Huang, T. Kong, C. W. Guo, H. L., Baldwin, A. Chan, & N. Wong, (2008). Integrating design and construction through virtual prototyping. *Automation in Construction*, *17*, 915–922.

Li, W., & Shen, W. (2008). Collaborative design: New methodologies and technologies. *Computers in Industry*, *59*, 853–854.

Nam, T., & Wright, D. (2001).The development and evaluation of Syco3D: a real-time collaborative 3D CAD system. *Journal of Design Studies*, *22*, 557–582.

Norman, D. A. (2004). *Emotional design: Why we love (or hate) everyday things*. Cambridge, MA: Basic Books.

Norman, D. (1998). *The invisible computer*. Cambridge. MA: MIT Press.

Patel, H., Pettitt, M., & Wilson, J. R. (2012). Factors of collaborative working: A framework for a collaboration model. *Applied Ergonomics, 43*, 1-26.

Plaue, C., Stasko, J., & Baloga, M. (2009). *The conference room as a toolbox: Technological and social routines in corporate meeting spaces. C&T'09*, ACM 978-1-60558-601-4/09/06.

Popov, V., Juocevicius, V., Migilinskas, D., Ustinovichius, L., & Mikalauskas, S. (2010). The use of a virtual building design and construction model for developing an effective project concept in 5D environment. *Automation in Construction*, *19*(3), 357-367.

Preece, J., Rogers, Y., Sharp, H., Benyon, D., Holland, S., & Carey, T. (1994). *Human–computer interaction*. Addison-Wesley.

Rosenman, M. A., & Gero, J. S. (1999). Purpose and function in a collaborative CAD environment. *Reliability Engineering and System Safety*, *64*(2), 167–179.

Rahimian F. P., & Ibrahim, R. (2007).*Using 3D visualization in educational trans-disciplinary collaboration among non-collocated professional members*. Paper presented at the World Engineering Congress 2007, Penang, Malaysia, pp. 5 – 9.

Rahimian, F. P., Ibrahim, R., & M. N Baharudin. (2008). *Using IT/ICT as anew medium toward implementation of interactive architectural communication cultures*. Paper presented at the International Symposium on Information technology. Kuala Lumpur Convention Center, Malaysia, IEEE.

Said, N. S. (2004). *An engaging multimedia design model*. In the Proceedings of the 2004 conference on Interaction design and children: building a community, pp.169-172, June 01-03, Maryland. ACM digital Library, New York.

Scott, S. D., Grant, K. D., & Mandryk, R. L. (2003). *System guidelines for co-located, collaborative work on a tabletop display*. In the Proceedings of the European Conference Computer-Supported Cooperative Work, pp. 24

Scherer, R. J. (2007). Product model based collaboration. In Rebolj, D. (Ed.). *Proceedings of 24thW78 Conference: Bringing ITC Knowledge to Work, Maribor*, pp. 11–20.

Sequin, C. H., & Kalay, Y. (1998). A suite of prototype CAD tools to support early phases of architectural design. *Automation in Construction*, *7*, 449–464.

Strauss, A., & Corbin, J. (1998). *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory.* London: Sage.

Stellingwerff, M., & Verbeke, J. (2003). Collaborative architectural design supported by an information and knowledge pump. In Harris, D., Duffy, V., Smith, M.&Stephanidis, C. (Eds.). *Human Centered Computing- Cognitive, Social, and Ergonomic Aspects, Vol. 3*. Lawrence Erlbaum Associations, Inc.

Tang, J. C. (1991). Findings from observational studies of collaborative work International. *Journal of ManeMachine Studies*, *34*, 143-160.

Toye, G, Gutkosky, M, Leifer L, Tenenbaum, J., & Gilcksman, J. (1993). SHARE: A methodology and environment for collaborative product development". *Post-Proceedings of the IEEE Infrastructure for Collaborative Enterprises*, pp. 1–16.

Tractinsky, N., Katz, A. S., & D. Ikar. (2000). What is Beautiful is Usable. *Interacting with Computers*, *13*, 127-145.

Wojtowicz, J. (Ed). (1994). *Virtual Design Studio*. Hong Kong: Hong Kong University, Press.

Yee, S., Mitchell, W., Naka, R., Morozumi, M., & Yamaguchi, S. (1998). *The Kumamoto–Kyoto–MIT collaborative project: A case study on the design studio of the future*. Proceedings of CoBuild' ,Vol. 98, pp. 80–93.

Zhang, P., & Li. N. (2004). An assessment of human–computer interaction research in management information systems: Topics and methods. *Computers in Human Behavior, 20*, 125–147.

Zhang, P., Carey, J., Te'eni, D., & Tremaine, M. (2005). Integrating human computer interaction development into the systems development life cycle: A Methodology. *Communications of the Association for Information Systems*. *15*, 512-543.