THEORETICAL MODEL OF MEDIATED SHARED SPACE FOR SUPPORTING INFORMAL INTERACTION AT A DISTANCE

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DECLARATION

I hereby declare that this thesis is my original work and it has been written by me in its entirely. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Nguyen Thi Lan Truc

2 Sep 2015

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ABSTRACT

The focus of this study is on creating a mediated shared space for supporting natural informal interaction among geographically distributed people. Informal interaction mentioned in this study is the short conversation that occurs during face-to-face encounter when people are physically co-located in a shared environment.

In order to maintain the benefit of informal interaction at a distance, many technical systems were implemented to support distance-separated people to interact with their co-workers. However, problems were reported. Although informal interaction did occur at a distance through these systems, they mostly focus on supporting the content and context of the interaction in a specific stage of the interaction process (e.g. encounter stage, initiation stage or communication stage) and no system took into account the relation between spatial setting and interaction context of the whole interaction process: i.e. from encountering a person, to initiating a conversation with him/her, and then engaging in the conversation. When the whole interaction process occurs within a spatial setting, it will help people to be aware of each other's availability in order to avoid intrusiveness into the other person's current activity, reduce the effort in starting a conversation, and increase the probability of encounter and participation.

This research thereby argues that, to better support informal interaction at a distance, a mediated setting is required for supporting context awareness of the whole informal interaction process. Therefore, a theoretical model of Mediated Shared Space for supporting informal interaction at a distance using spatio-temporal approach is proposed. The model consists of three factors (continuously open, mutually shared, concurrently convergent) that characterize the function of the mediated spatial setting that enables informal interaction to occur throughout three

processes of interaction from encounter, to initiation and communication. Two instances of the model which support different degrees of Mediated Shared Space were then implemented as prototypes and tested among research students and alumni in a research lab of the National University of Singapore.

A comparative method was used to compare and test the effectiveness between the two prototypes. Participants were asked to try out the two mediated shared spaces in a given period of time. After the experiment, they gave feedback on their experience through an online survey. Collected data were analyzed through quantitative data analysis. Informal interviews and observations were also used to strengthen the hypothesis and clarify ambiguous issues in the quantitative data. The analyzed results showed that the prototype with a higher degree of Mediated Shared Space achieved better context-awareness in the three processes of informal interaction as compared to another.

The significance of this study is to provide a spatio-temporal approach to enhance context-awareness of informal interactions at a distance through the theoretical model of Mediated Shared Space. The usage of Mediated Shared Space is not constrained to supporting informal interaction. It could be open to support any co-located collaboration purpose whose situation contains interaction context-awareness.

CHAPTER 1
INTRODUCTION

1.1 Background

1.1.1 What is informal interaction?

According to Kraut et al. (Kraut et al., 1990), there is no stable defined concept for informal interaction. It is defined in this study as "conversations that take place at the time, with the participants, and about the topics at hand." In E.Campbell and A.Campbell's study (Campbell & Campbell, 1988), informal interaction is defined as "relatively unstructured information exchanges that tend to occur in face-to-face encounter during 'off-task' moments." In Whittaker et al's study, informal interaction is referred to as "taking place synchronously in face-to-face settings" (Whittaker et al., 1994). Therefore, physical proximity is an important factor for mediating informal interaction since face-to-face communication occurs when people are physically close to each other (Fish et al., 1992).

In this research, informal interaction is understood to be casual communication that occurs in face-to-face encounters when people are physically co-located in a shared environment in which they are able to share the physical content and context.

Different from scheduled meetings where communication is scheduled and predetermined and often take place in the conference room, the main characteristics

of informal interaction is that it is unplanned in advance by at least one party in terms of unscheduled timing, and it has undetermined participants and unprepared topics of conversation (Isaacs et al., 1997; Kraut et al., 1990). For example, the conversation could spontaneously occur when two people bump into each other in the hallway and a conversation is started on a topic not prepared by either party. The conversation could be intended by one party who seeks out the other to discuss a particular topic without informing the other party in advance. In both spontaneous conversations and intended conversations, the topics are varied and impromptu such as sharing interests, exchanging information, resolving problems or clarifying ambiguous issues to change understanding.

The other characteristics of informal interaction are "interactive", "expressive" (Kraut et al., 1990; Monge et al., 1985) and "rich" communication (Daft & Lengel, 1986; Kraut et al., 1990). Specifically, interactive communication allows the possibility for immediate giving and receiving of feedback thus people could tailor the conversation according to current circumstance. Expressive communication is the ability to use verbal and non-verbal expressions, and the full range of linguistic tools to communicate (Monge et al., 1985). And lastly, rich communication allows one to "clarify ambiguous issues to change understanding in a timely manner" (Daft & Lengel, 1986).

This type of informal interaction differs from asynchronous interaction such as email or Facebook since the interaction does not occur at the same time and in the same physical place. It also differs from synchronous informal interaction such as phone calls or Skype since the two parties are in different physical places and may not be aware of each other's availability when making the call. Hence a huge effort is required to make the connection if the recipient is either not available or is unable to take the call at this moment.

1.1.2 Informal interaction in organizations nowadays

Informal interaction in terms of interpersonal communication occurs most frequently in workplace areas among employees. Data from questionnaires and observations show that people often spend between 35% to 75% of their working time in face-to-face communication and the time spent depends on the particular job type (Kraut et al., 1990; Whittaker et al., 1994). Another study reported that about 83% to 93% of interpersonal interactions in the workplace are not preplanned but are unscheduled professional interactions (Isaacs et al., 1997). Why do informal interactions happen at such a high rate?

Previously, work efficiency was focused on the individual tasks such as typing, telephoning, writing reports, reading memos or participating in scheduled meetings. With this working process, the individual was "a key ingredient to productivity, rather than the team or group". Therefore, informal interactions were seen as wasting time in many companies. "Talking was all right as long as it occurred as part of a scheduled meeting. There, it could drone on for hours and still be real work, while a five-minute conversation at the water cooler was considered 'time-out' (Becker & Steele, 1995, p. 67). In today's world, this type of work practice is not suitable for tackling complex works such as information technology in banking, automobile manufacturing, etc. Solving issues in these industries require enormous amounts of information from different disciplines. Teamwork, collaboration and communication are indispensable in the working processes, and thus the workplace is no longer an individual desk but a place for teams to meet and hang out. They are "fundamental building blocks to organizational effectiveness" (Becker & Steele, 1995, p. 68). Communication in teamwork varies from planned meetings to spontaneous and unplanned conversations in order to coordinate activities. In unplanned meetings, communication occurs spontaneously in the hallways, on the stairs, at lunch or at the water coolers. According to (Grajewski, 1993), effective

ideas often originate from unplanned meetings rather than scheduled meetings. He states that "ideas are rarely created when you're sitting at your desk alone and tense, but [are generated] during creative encounters with other human beings". In this way, informal communication encourages the stimulation of creativity across project teams, disciplines and departments since high value, unexpected ideas and information arise from free-flowing and serendipitous face-to-face communication. Rather than distracting from work, informal interaction is recognized as a way to commit and share knowledge and skills which cannot be done through written tasks.

People in a team have benefited from informal interaction in promoting productivity and social function. Through casual conversations, they generate collaborative working relationships, foster and maintain existing memberships to sustain the group over time or help each other to achieve productive works such as developing an idea or making decisions. The experience of being "in" on organizational gossip serves to decrease feelings of alienation and isolation within the organizations (Fox, 2001). Informal interaction has also been shown to influence the rate of innovation in organizations and works with high uncertainty can make use of unscheduled communication to achieve better coordination to increase their effectiveness rather than using programmed ways (Allen, 1984; Argote, 1982).

When work practices changed from individual work to teamwork and collaborative work, the work environments also changed accordingly. Workplace settings are no longer simply one's desk but also include a pantry, conference, break rooms, recreational facilities and attractive lounges, whose purpose is to provide facilities for people to keep in constant communication with their teams in terms of planned and unplanned meetings every time and everywhere (Becker & Steele, 1995). Workplace settings are highly interconnected with maximized visibility, openness and accessibility to encourage chance encounter. These public areas also act as "activity magnet areas" and "activity generators" or shared resources to pull people

into these areas and hold them thus fostering communication and extending the opportunity for them to interact. Normally, informal communication often occurs at public or semipublic areas such as on the stairs, in the hallways, in the pantry during coffee breaks and is considered as the "bedrock of advanced work culture" (Becker & Steele, 1995, p. 72). This stimulates creativity across project teams, disciplines and departments as members discuss design, technology and marketing. It is a way to "create and reinforce organization culture"(Becker & Sims, 2001; Parker et al., 2002; Sundstrom, 1999).

Informal communication brings different types of people into closer contact and helps them to understand and accept different ways of thinking and working (Becker and Steele, 1995, p76). It also helps to build up trust among people over time as they are able to judge each other's competence through the conversations. This allows them to get more involved and work closer together in a project (Kraut et al., 2002).

1.1.3 Informal interaction in distributed teams

Informal interaction as mentioned in part 1.1.2 is only possible when people share a physical space together in which they are able to "see each other, hear each other speak, handle or look at the same thing or perceive anything about the place where others are or what they are doing" (Robertson, 1997). When people are physically co-located, chance interaction normally occurs through routine activities such as bumping into another along the corridor or meeting someone at the water dispenser. Informal interaction takes places from such repeat encounters or due to extended periods of contact. As such, physical proximity in terms of co-location and same time zone, particularly the space/time context, are crucial conditions for informal interaction to take place and for people in the organization to come into

contact and communicate (Monge et al., 1985; Olson, G. M. & J. S. Olson, 2000; Whittaker et al., 1994).

Team members may not be co-located all the time. They could be away on business trips or transferred to other departments for project tasks. To increase innovativity, organizations normally draw workers from multiple disciplines to work on projects, thus creating varying degrees of separation as team members may be scattered over floors, buildings and even different cities or countries. As the distance between people increase, the number of opportunities for informal interaction decrease accordingly. Since the people in a team are working under the condition of spatial dispersion and/or temporal dispersion, two questions at hand are raised as followed:

1. ***How to maintain the informal interaction among people who are located in scattered physical locations? and***
2. ***How to create a workplace setting that would afford such informal interaction?***

In order to answer the first question, researchers have developed many kinds of systems to enable synchronous informal interaction at a distance in order to maintain effective communication among geographically distributed people. These systems used five technical ways to facilitate informal interaction:

1) Video-based technologies (Albolino et al., 2005; Fish et al., 1990; Jancke, Gavin et al., 2001);

2) Collaborative Virtual Environments (CVEs)(Cheney et al., 2010; Sharma et al., 2011);

3) Buddy Lists (Andersen et al., 2006; Bravo et al., 2006; Lincoln et al., 2009),

4) Telepresence (Karahalios & Dobson, 2005; Lincoln et al., 2009); and

5) Ubiquitous information (Bravo et al., 2006; Mejía et al., 2010; Streitz et al., 2007; Wang et al., 2005).

Table 1 shows specific systems developed based on the five technical methods.

Video-based technologies	CVEs	Buddy List	Telepresence	Ubiquitous information
Cruiser(Root, 1988) **Video Window** (Fish et al., 1990) **Portholes**(Dourish & Bly, 1992) **RAVE** (Gaver et al., 1992) **Montage** (Tang & Rua, 1994) **OfficeWalker** (Obata & Sasaki, 1998) **Virtual Kitchen** (Jancke, Gavin et al., 2001) **Milk**(Albolino et al., 2005) **Telemural**(Karahalios, 2009)	**FreeWalk**(Nakanishi et al., 1998) **Valentine**(Honda et al., 1999) **Forum**(Phillip & Andrew, 2000) **3D Web World**(Nakano et al., 2004) **Mixed Reality** Architecture(Schnadelbach et al., 2006) **AET Zones**(Cheney et al., 2010) **VirtualOffice**(Sharma et al., 2011)	**ActiveMap**(McCarthy & Meidel, 1999) **iSocialize**(Andersen et al., 2006) **CoolBeans**(Dee et al., 2007)	**Chit Chat Club**(Karahalios & Dobson, 2005) **Shader Lamp Avatars**(Lincoln et al., 2009)	**ProxyLady**(Dahlberg et al., 2002) **IPAD** (Silva Filho, 2004) **Promocoto**(Wang et al., 2005) **RFID**(Bravo et al., 2006) **AmbientAgoras**(Streitz et al., 2007) **SOLAR** (Mejía et al., 2010)

Table 1: Systems for supporting informal interaction at a distance

Video conference systems are not considered as systems for informal interaction since the purpose of video conference is for planned meetings in which all participants are informed in advance to attend. Although the high quality audio-video conference systems such as Cisco Telepresence Video Conference (Cisco, 2008)

support good sense of co-presence and co-location, there are no unplanned factors at these meetings such as confirmed attendees or pre-arranged seating.

For the second question, technologies has made it possible for informal interaction with remote co-workers. For example:

1) Two or more public spaces can be linked together through video screens such as VideoWindow, Portholes (Dourish & Bly, 1992) and Virtual Kitchen (Jancke, Gavin et al., 2001). In this way, remote people can be aware of each other's presence and availability, and communicate together through the video screens.
2) Remote people can access the physical space through physical embodiments such as physical sculptures in Chit Chat Club(Karahalios & Dobson, 2005). In this way, remote people can interact with local people who are around in the physical space.
3) In a 3D replication of the real workplace, people can login as avatars and meet each other in these virtual workplaces. Examples include Virtual Office(Sharma et al., 2011) or AET Zones (Cheney et al., 2010).

1.2 Statement of the research topic

Although these systems have been developed to make informal interaction possible at a distance, some common issues tend to occur. As pointed out by Truc and Tan (Truc & Tan, 2011) these issues include intrusiveness, much effort required to make a connection, privacy concerns, low probability of encounters and participation. They tend to occur especially, in intended informal interaction. This study argues that these systems mostly focus on supporting the context content in a specific stage of the interaction process such as supporting presence awareness (Streitz et al., 2007), grounding (Clark & Brennan, 1991; Kraut et al., 2002), co-ordination (construct,

manage and maintain the conversation)(Elaine et al., 2004; Nakano et al., 2004) instead of supporting context awareness of the whole interaction process: i.e. from encountering a partner, to initiating a conversation with him/her, then engaging in the conversation.

According to Brown et al (Brown et al., 1997), context is defined as location, identities of people around the user, season, time of the day, temperature, etc. Schilit and Theimer (Schilit & Theimer, 1994) defined context as location, identities of people and objects nearby. In a similar definition, Ryan et al (Ryan et al., 1998) referred to context as location, environment, identity and time. From these definitions, the important aspects of context are who (identity), where (location), when (time) and what (relevant issues). In informal interaction, the aspects of the interaction context are who (the person involved in the interaction), where (the current location of this person), when (the appropriate time to initiate/start/end the interaction) and what (what is current activity of this person). These context aspects also show the whole interaction process from encountering a partner (who, where), to initiating a conversation (what, when) and engaging in the conversation (what, when).

Riva et al. (Riva et al., 2003) pointed out that applications for supporting context awareness should also look at the who's, where's, when's and what's of entities (people of the interaction) and use this information to answer why this situation is happening. Having this information, remote people could avoid being intrusiveness, reducing the effort needed to make a conversation, and increase the probability of encounter and participation.

To facilitate application developers in forming context of the application scenario, Lessiter et al (Lessiter et al., 2001) has defined context as "*the information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an*

application, including the user and the application themselves". With this definition, if a piece of information represents a situation involving interaction of an entity then this information is understood as context. In order to form the context of informal interaction at a distance, this information should put people within the range of each other's sense perceptions (see, hear, touch) and enable people to mutually perceive each other's presence, availability, current activity and willingness to interact.

As pointed out by Zhao and Elesh (Zhao & Elesh, 2008), this information is co-location and co-presence. Co-location puts people in each other's close proximity and thus provides the "distance over which one person can experience another with naked [or mediated] sense". Therefore, it provides the spatial relationship that places people within range of each other's sensory proximity. However, being "within range" is not the full condition for mutual accessibility and mutual contact (Goffman, 1966a) but just a prerequisite for social connectivity. In order to enable people to mutually perceive each other, co-presence "makes co-located people tune into one another" and renders them "mutually accessible" and therefore "allows for mutual contact". Therefore, co-presence is the condition needed for two-way human interaction to occur.

In order to build up social context for informal interaction to occur, the sense of co-location supports perception of co-participation and the sense of co-presence enables co-located people to be aware of the whole interaction process. Thus they are able to pick up the necessary information of other people's presence (who), their location (where) and each other's activity (what). This allows them to 'see at a glance' what is occurring in the space so they can take proper action (when) such as acknowledging people's greeting, determining the appropriate time to approach for a conversation when the party is free (when) or not disturbing when the party in being engaged in another activity (what).

Therefore, this study argues ***that the common problems of existing systems are that they do not properly support the sense of co-presence and co-location which are the two aspects necessary to build up shared social context of informal interaction***.

Section 3.1 will elaborate in details on the research gaps that cause by lack of supporting the sense of co-presence and the sense of co-location in the interaction process.

1.2.1 Research questions

When people are geographically distributed, they are only able to be co-located through a mediated space which is a computer-aided model of spatial setting that "uses the properties of space as the basis for mediating interaction" (Benford et al., 1994). In order to support better shared social context, the model should be a shared space that supports the feeling of being together in the same environment. Therefore, the main research question derived from the analysis above is:

What is a theoretical model of mediated shared space that affords a sense of co-location and co-presence in the whole process of informal interaction among geographically distributed people?

Sub-question 1: *What are the main factors of the mediated shared space for supporting a sense of co-location and co-presence in the whole informal interaction process?*

This question is addressed in chapter 3 where the theoretical model of mediated shared space with temporal and spatial factors is introduced.

Sub-question 2: *What are the possible spatial settings of mediated shared spaces that could be formed from these factors?*

This question is addressed in section 3.4 which describes an instance of mediated shared space that could be formed from the theoretical model factors.

Sub-question 3: *What is the difference in supporting the sense of co-presence and co-location between an existing virtual space and a prototype of the theoretical model of mediated shared space?*

This question is addressed in chapter 4 and chapter 6 where the research method and experiment to compare the two mediated shared spaces is introduced.

Sub-question 4: *How can the proposed prototype of mediated shared space be implemented using available technology?*

This question is addressed in chapter 5 which describes how the two mediated shared spaces used for the experiments are implemented with available technology.

1.2.2 Research objectives

This research starts with the following objectives.

- To develop a model of mediated shared space for workplace setting to support informal interaction at a distance through the sense of co-location and co-presence.
- To evaluate the effectiveness of the proposed model in supporting the sense of co-presence and co-location compared with an existing mediated shared space through the experiment prototype
- To identify possible computer-aided spatial settings that could be formed based on the model factors.

1.2.3 Research hypothesis

Existing virtual spaces have low degrees of supporting informal interaction. The higher the degree of any factor of mediated shared space, the higher the sense of co-presence and co-location supported.

1.3 Scope of the study

In this study, the issue of creating mediated shared spaces to support informal interaction at a distance focuses on creating a model of spatial setting which supports co-presence and co-location among geographically distributed people. Although there are various instances of mediated setting, this study only focuses on three-dimensional settings because spatial setting provides an intuitive spatial structure in which the geometrical arrangement could structure, constrain and enable certain forms of interaction (Harrison & Dourish, 1996). Specifically, spatial setting provides: spatial organization to orient people's interpretation and interaction; spatial relationship to relate people to activities and to each other; spatial distance to partition activities and the extent of interaction and spatial entities showing people's presence and the ongoing awareness of their activity that provides necessary information for structuring people's behavior and interaction (Figure 1).

Due to budget constraint, the model tested in this study used free and affordable tools and devices. Other possibilities were also considered however they are not affordable due to high technical implementation and costs. These possibilities are elaborated in chapter 3.

Since the focus of this study is for people who are working together in workplace environment, the sample population is restricted to co-workers including remote people and local ones. It was difficult setting up the experiment in a private company in Singapore, hence a research room in the Department of Architecture, National University of Singapore was chosen to test the proposed model. This

research room is a shared space for research scholars in which informal interaction could occur when 1) people are using the shared appliances (fridge, microwave, toaster, etc), 2) people have an issue to discuss so they seek another researcher in the room to talk about it, 3) people happen to see colleagues passing by their desk and realize that they have something to discuss with them, 4) people have the need to gossip. Since these informal interactions do occur in this research room, researchers could be considered as working people and thus this study assumes that the research room has sufficient workplace aspects to fit the scope of the study.

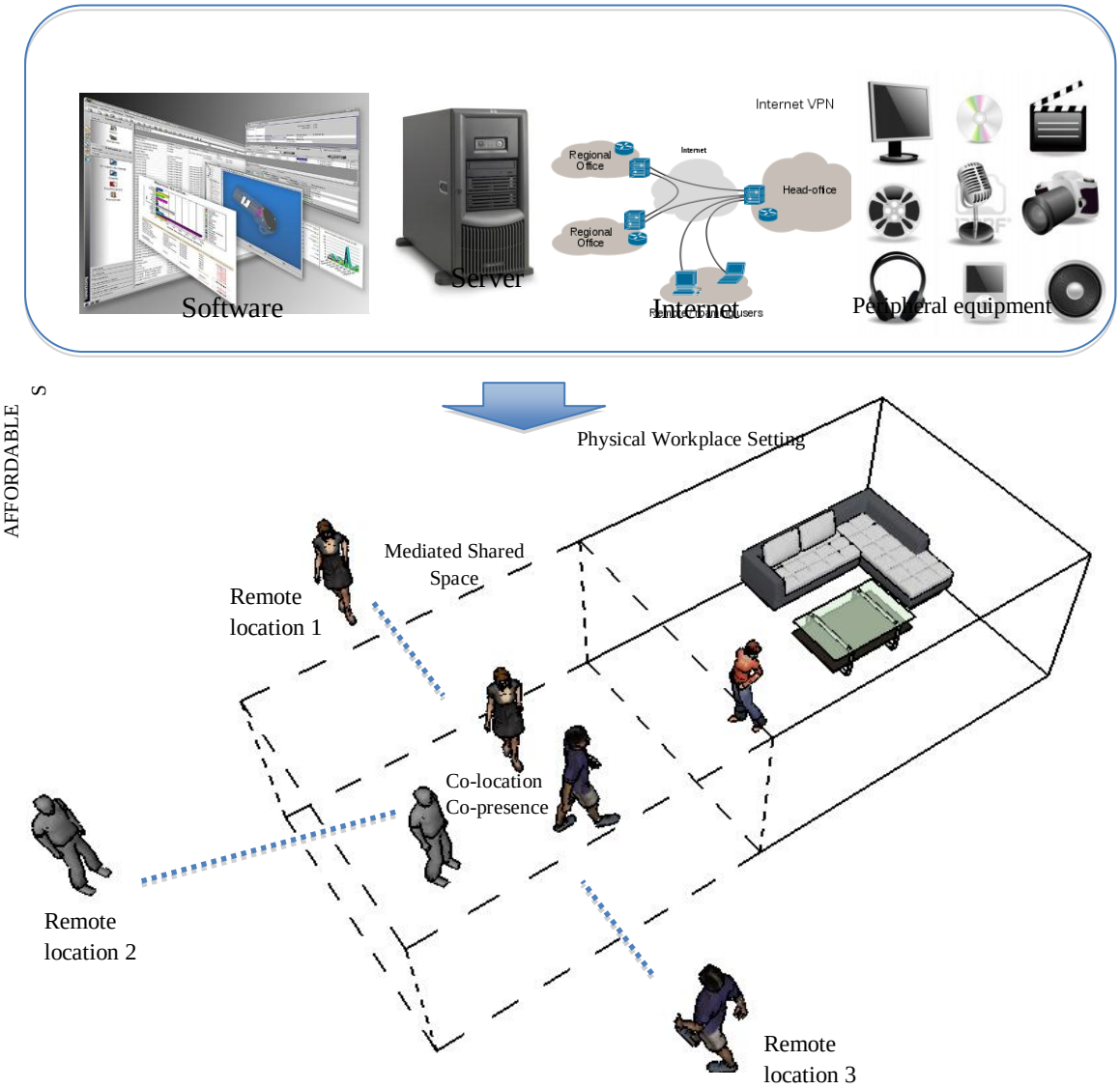


Figure 1: Scope of the study is on three dimensional setting, affordable tools and devices

1.4 Significance of the research

As mentioned in section 1.1.2, informal interaction in organizations is very important to organization outcomes. Since working environments normally involve collaboration across multiple disciplines, the issue of enabling informal interaction among remote co-workers is, indeed, significant to maintain working efficiency. Different from some systems which supports informal interaction at a distance through a virtual perception of the environment, this study provides a more realistic and natural way for geographically distributed co-workers to encounter, meet up and interact through the integrated shared space. The significance of this study is related to the important role of informal interaction in organizations and collaborative works as well as in the everyday interpersonal interaction of people. The functional features of the proposed shared space provide an appropriate environment for helping people to keep and maintain informal conversations as well as to stimulate informal interaction even though they are distance-separated. The model could be used to create interactive systems for stimulating informal interaction among people located in different buildings who have fewer chances of encountering one another.

1.5 Research framework

This study has been deployed in five phases as illustrated in Figure 2:

1. Find research gaps and formulate research statement
2. Review relevant literature and theories
3. Develop prototype
4. Experiment design
5. System evaluation
6. Analysis and discussion

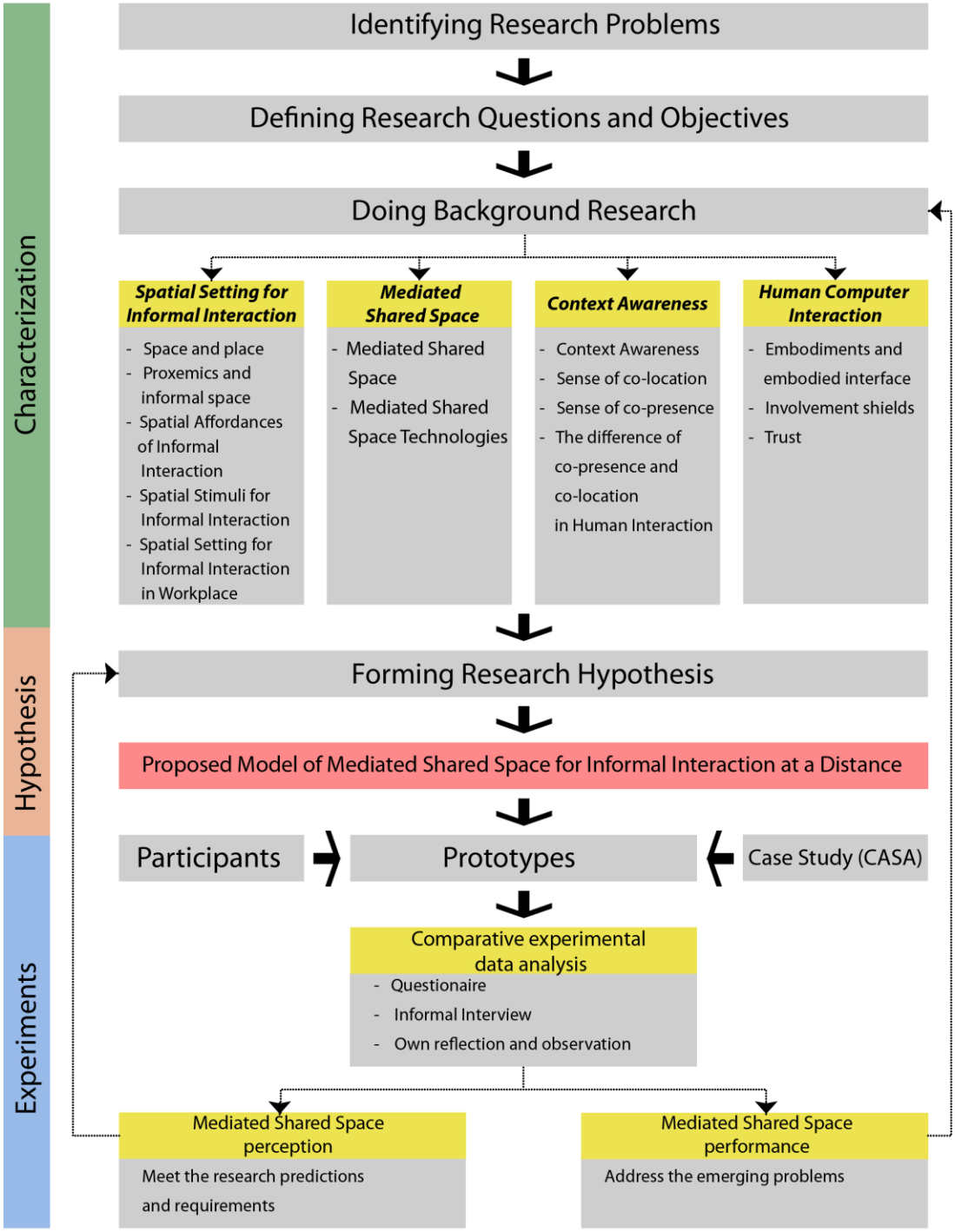


Figure 2: The research framework

1.6 Thesis organization

This thesis is organized into seven chapters.

Chapter 1 provides a general idea of the study, starting from the research background of the importance of having informal interaction in workplace. This is followed by the issues that tend to occur in the systems for supporting informal interaction at a distance. Research question, research hypothesis and research objectives are also stated in this chapter.

Chapter 2 reviews the related theories and practices of supporting informal interaction at a distance. The focus of this chapter is to find out the essential factors for supporting theoretical model creation in chapter 3 and the lack of existing theories and practices that need to be overcome.

Chapter 3 elaborates on the development of the theoretical model of Mediated Shared Space. Starting from the research gaps, this chapter introduces the spatio-temporal approach as a way to deal with these gaps and then proposes the conceptual model whose factors are developed based on the approach and the reviewed literature that was ascertained in Chapter 2. At the end of this chapter, possible solutions to construct implementable Mediated Shared Space are presented.

Chapter 4 explains the methodology used to validate the theoretical model in which dependent variables, independent variables, data collection and analysis method are elaborated in detail.

Chapter 5 describes the technical way to implement the experimental treatments which are developed as the prototypes of the proposed Mediated Shared Space. The implementation is done through three steps: choosing system architecture, system Mock-up and trial process and resolving technical problems.

Chapter 6 explains how the experiment data is analyzed and evaluated, and how the research findings are identified.

Lastly, **chapter 7** summarizes the major conclusions of the study and suggests future research directions.

CHAPTER 2
LITERATURE REVIEW

The main objective of this study is to develop a model of mediated shared space that could enable context awareness of the entire informal interaction process. Therefore, this chapter describes the scope and limitations of the current systems for supporting informal interaction at a distance while investigating state-of-the-art of shared space technology that could be applied for developing the study objective. This chapter also reviews the literature in relevant disciplines that could support the application of mediated shared space for informal interaction at a distance.

The first section provides the basic understanding of spatial setting for informal interaction. The second section reviews literature related to mediated shared space and available mediated shared space technologies. The third section explores the topic of context-awareness such as location awareness, presence awareness and context-aware computing. Lastly, this chapter discusses the knowledge obtained from the first three above sections.

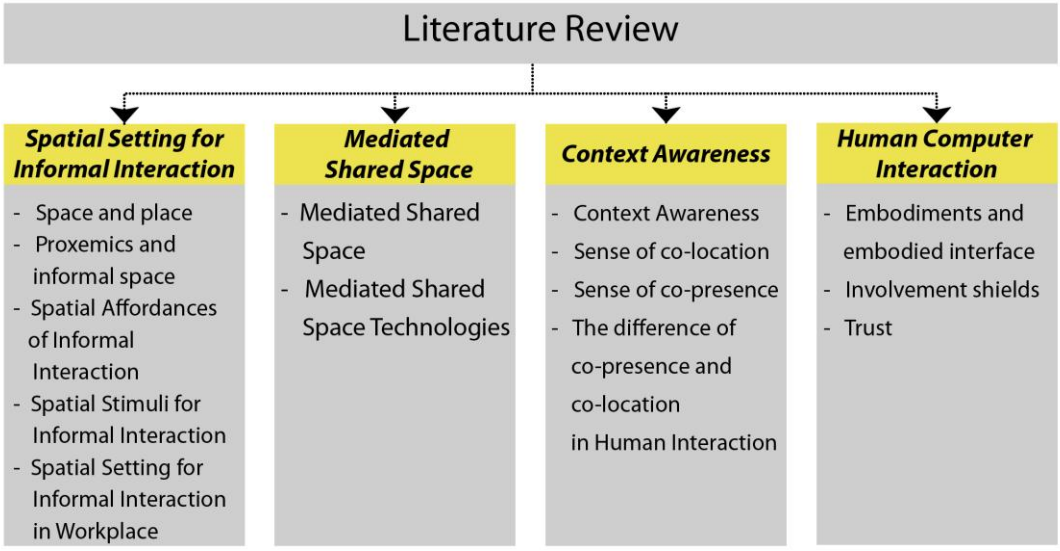


Figure 3: Literature review for Mediated Shared Space for informal interaction at a distance

2.1 Spatial setting for informal interaction

"Physical space helps people engage in conversation because when two people encounter each other, they are reminded of each other's existence, can assess each other's availability for communication, have a channel to signal intent for communication, and have the resources to carry it out*"* (Kraut et al., 2002).

Rashid et al (Rashid et al., 2006) had pointed out that there is a relationship between space and informal interaction so that different types of spatial settings could have direct or indirect positive effects on informal interaction. Therefore, the impact of increased interaction could also have positive effects on the organization outcomes such as improving coordination and innovation, building commitment, spreading ideas, sharing knowledge and skills beyond normal job requirements. Additionally, Giddens (Giddens, 1986) had shown that space acts as a key resource for "establishing and enabling an activity". In particular, the boundaries of space allow peripheral awareness of people's presence and current activities thus enabling them to "see at a glance" of who is around and what is occurring in the space. Therefore,

space could establish and enable informal interaction to occur as it provides awareness of the possibility of encountering people who are co-located and their availability before initiating the conversation. In order to understand how spatial setting supports informal interaction, what the suitable spatial settings for informal interaction are and what spatial elements could be used to design the setting for informal interaction, this section reviews literature related to the relationship between spatial setting and informal interaction such as the notion of space and place, proxemics and informal space, spatial affordances for informal interaction, spatial stimuli for informal interaction and, lastly, shared space for informal interaction in the workplace.

2.1.1 Space and place

2.1.1.1 The notion of space and interaction structuring

Space, in general, is defined and understood as a three-dimensional environment through Euclidean geometry with x, y, z dimensions (Gleeson, 1996). From a geographical approach, space is understood to be "neutral container, a blank canvas that is filled by human activity". From a regional and quantitative approach, the term "space" is conceived as "a surface on which the relationships between (measurable) things are played out" (Hubbard et al., 2004). The relationships could be explained through three related main concepts that are direction, distance and connection. While absolute or "empirico-physical" conception of space has treated space as "an absolute container of static" that is outside of human existence rather than playing an active role in shaping social life, the psychology approach believes that space is socially produced and consumed. According to Lefebvre (Lefebvre, 1991), there is no existence of absolute space since it is controlled by social activity

at a given time. Thus every society produces its own space which is made up by a "trialectics" of spatiality: cultural practices, representations and imaginations.

This study adopted the definition of space by Harrison and Dourish (Harrison & Dourish, 1996). It is understood to be the geometrical arrangements that could structure, constrain and enable certain forms of movement and interaction. It has four essential properties that could be used as spatial aspects for collaborative purposes. They are (1) relational orientation and reciprocity; (2) proximity and action; (3) partitioning, and (4) presence and awareness.

Relational orientation and reciprocity refers to the ways in which the spatial organization of space orients people's interpretation and interaction. For example, the spatial conventions such as up and down, left and right directions are used to guide people to refer to objects or other people that are located in the space easily. Therefore, the relationships between space, artifacts and people could be used in referential communication in which the spatial objects or frames serve as referential identities (Nova, 2005). For example, a man could be referred to as standing next to the entrance door so that the entrance door is the referential identity of the space. The second property of space is proximity and action. It refers to the spatial relationship that relates people to activities and to each other. For example, people tend to interact with those who are around them. The third property which is partitioning, refers to the spatial boundaries (walls, doors, windows, curtains) and spatial distance which could be used to partition activities and the extent of interaction. For example, rooms or partition walls might help to separate different kinds of activities. The extent of interaction among people is different when the distance between them is different (Hall, 1966). Partitioning through spatial boundaries also has an important role in influencing awareness and controlling movement as different effects of spatial boundaries (Giddens, 1986). The last property is presence and awareness; these are

two critical factors for interaction. Seeing the presence of others and their on-going activities provides necessary information for structuring people's behavior and interaction, unproblematically. Thus by being aware of who is around and what he or she is currently doing, people could manage their own activity according to the social situations or be able to predict the likely actions of others in order to structure their own activity. For example, initiating a conversation is not appropriate when someone is engaged in another activity.

2.1.1.2 The notion of place and appropriate behavior framing

As with space, place is understood in popular discourse as area, region and landscape. According to Hubbard (Hubbard et al., 2004), the theoretical specification of place has remained a matter of dispute. It is understood differently in different disciplines. From a psychological approach, place is conceived as "a particular form of space" which is created through "acts of naming" and "the distinctive activities and imaginings associated with particular social spaces". From a geographical approach, place is understood to be a "distinctive type of space that is defined by the lived experiences of people". In this way, place represents the "sense of belonging" for those who have ever lived there as well as represents a "locus for identity". From a regional and quantitative approach, the absolute conception of place refers to "a largely self-contained gathering of people in a bounded locale". Against these understandings of place in which people's activities occur in a framework of geometric relationships, a humanistic approach argues that the place people live is a world attached with meaning. A representative example of this approach is the conception of place by Yi-Fu Tuan (Tuan, 2001) in which an abstract space will become a concrete place if it is filled with meaning. In this approach, the identity of place is obtained from people's emotional attachment by "dramatizing the aspirations, needs, and functional rhythms of personal and group life". A social and cultural approach sees place as culturally produced, where "culture not only takes

place, but makes place" (Hubbard et al., 2004). A psychological and philosophical approach contends that place is involved with embodiment. Casey (Casey, 1993) emphasized that "place, by virtue of its unencompassability by anything other than itself, is at once the limit and the condition of all that exists … Place serves as the condition of all existing things".

Although the notion of place is explained in a variety of ways based on different perspectives, place could be understood as "authentic, close and lived space" which is formed through the arrangement of objects and spaces to support designated activities that convey the social and cultural relations of the inhabitants or of the wider society (Canter, 1977). By being "in place", people encounter a range of cognitive (mental) and physical (corporeal) performance with which appropriate behaviors are framed (Holloway & Hubbard, 2001). In line with this notion of place, Harrison and Dourish (Harrison & Dourish, 1996) noted that, "place is space which is invested with understanding of behavioral appropriateness, cultural expectations and so forth. We are located in space but we act in place". Through this statement, space acts as spatial organization with relative position and direction for holding and structuring activity while place is tied-up space added with something such as social meaning, culture, convention, etc. with which appropriate behavior is framed. Giddens (Giddens, 1986) also mentioned about the sense of behavioral framing in the term "locales" so that "locales" are more than simple spaces and "features of settings are […] used in a routine manner, to constitute the meaningful content of interaction." For example, a space furnished with a meeting table is often used for formal meetings while a space furnished with a sofa and low table is used for informal conversation purpose. As such, a space is a three-dimensional structure for events to occur and a place is a space for people to be (Harrison & Dourish, 1996).

2.1.2 Proxemics and informal space

With regard to how people use physical space in the conduct of daily interaction, a variety of studies have made use of Hall's conceptual framework called "proxemics". Hall defined proxemics in his book "*The hidden dimension*" as "the interrelated observations and theories of man's use of space as a specialized elaboration of culture" (Hall, 1966, p1). Proxemics research is based on territoriality studies in which territoriality is defined as "behavior by which an organism characteristically lays claim to an area and defends it against members of its own species" (Hall, 1966, p7). It provides a place for animals to play, learn and hide; a home to sleep, eat, nest and be protected; and a frame for keeping them within communicating distance of each other. Thus it encourages the activities of the group and holds the group together. In general, territoriality is "a basic behavioral system characteristic of living organisms including man" (Hall, 1966, p10). Since proxemics is about man's use of space, Hall investigated thermal space, tactile space and visual space in order to find out how sense of space is perceived by man through his receptors. Hall argued that "man's sense of space is closely related to his sense of self, which is an intimate transaction with his environment. Man can be viewed as having visual, kinesthetic, tactile, and thermal aspects of his self which may be either inhibited or encouraged to develop by his environment".

In Hall's book, proxemics has three manifestations which are infracultural level, precultural level and microcultural level. Infracultural level refers to the behavior at lower organizational levels that underlie culture. Infracultural level is behavioral and rooted in the past. Precultural level refers to the sensory base and the physiological base shared by all human beings to which culture gives structure and meaning. Precultural level is physiological and occurs very much in the present. Lastly, microcultural level refers to spaces formed by culture and is considered as building blocks for designing human spaces. There are three types of microcultural

level space: fixed-feature space (FS), semi-fixed feature space (SP) and informal space (IP).

Fixed-feature space is so termed based on the evidence that territoriality is relatively fixed. It is "one of the basic ways of organizing the activities of individuals and groups" including material manifestations as well as hidden and internalized designs that govern behavior. An example of fixed-feature space is buildings whose exterior and interior are built according to culturally determined designs. The important point about fixed-feature spaces is the mutual relationship between fixed-feature spaces and human behavior as Hall, quoting Sir Winston Churchill, says "*We shape our buildings and they shape us*". Semi-fixed-feature space is about space and furniture arrangements wherein activities are organized and objects are manipulated. The important point about semi-fixed feature space is that "the structuring of semi-fixed features can have a profound effect behavior and this effect is measurable." In other words, different arrangements can result in different behaviors and attitudes. Finally, informal space refers to the space or distance maintained between two parties for chance encounter. It represents the space around one's body which determines the interpersonal interaction distance among people. This space is dynamic because it moves together with the person when he/she moves. Hall argued that informal space is significant since the spatial settings can form an essential part of the culture. It is considered as the hidden dimension and contains four distance zones: (1) intimate distance; (2) personal distance; (3) social distance and (4) public distance. Each zone has a close phase and a far phase and the distance influences interpersonal interaction. The distance can vary depending on personality and environmental factors.

1. Intimate distance

Close phase (Distance: less than 15cm). This is the distance of love making and wrestling, comforting and protecting. Within this very close distance, physical

contact and physical involvement is uppermost in the awareness of both persons. In the maximum contact phase, one person's parts may be touching the other person's. Other channels for communicating are used instead of vocalization.

Far phase (Distance: 15cm-46cm). This distance is still intimate between two persons although their parts are not into contact. Communication is normally done through whispering.

Intimate distance is only for lovers and is not appropriate in public for those who are strangers. However, people are sometimes brought into intimate distance when they are in very crowded spaces such as in buses, trains or at crowded events.

2. Personal Distance

Close phase (Distance: 46cm - 76cm). This distance allows one to hold and touch the other, thus signaling a close relationship between the two.

Far phase (Distance: 76cm - 120cm). This distance is just beyond the point that one can "get his hands on" someone else.

Personal distance is mostly for interaction among family members and close friends.

3. Social Distance

Close phase (Distance: 1.2m – 2.1m). The close phase of social distance occurs in impersonal business relationships among people who work together. People keep this distance when they are in a casual social conversation.

Far phase (Distance: 2.1m - 3.7m). This distance also occurs in business and social contact but happens more formally than the close phase. The distance is used to separate strangers. For example a work desk is used to separate two people so that they can keep working in the presence of the other without appearing to be rude.

Social distance is for interaction among people who have social relationships such as acquaintances and colleagues.

4. Public Distance

Close phase (Distance: 3.7m – 7.6m). At this distance, people can see the presence of others but they are outside the circle of involvement. Therefore, people can easily ignore or take defensive action if threatened.

Far phase (Distance: >7.6m). This distance occurs in public speaking such as between a speaker and the audience.

The four distance zones for interpersonal interaction are summarized in

Table **2** and illustrated in Figure 5.

Distance zones	Phase	Physical distance	Interaction
Intimate distance	Close	< 15cm	The distance for whispering and embracing
	Far	15cm – 46cm	
Personal distance	Close	46cm – 76cm	The distance for interaction in a close relationship such as with family members and close friends
	Far	76cm – 120cm	
Social distance	Close	1.2m – 2.1m	The distance for interaction among business associates and acquaintances.
	Far	2.1m – 3.7m	
Public distance	Close	3.7m – 7.6m	The distance for public speaking.
	Far	>7.6m	

Table 2: Four distance zones for interpersonal interaction (Hall, 1966)

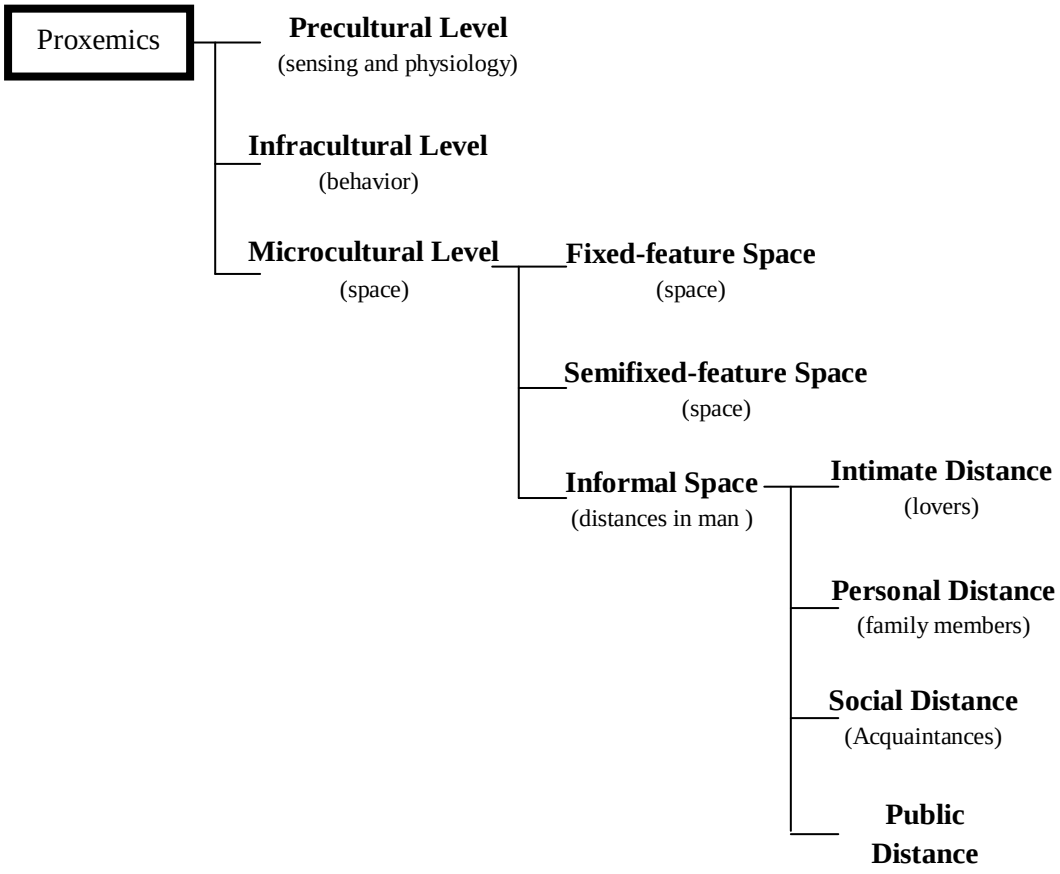


Figure 4: Proxemics structure (Hall, 1966)

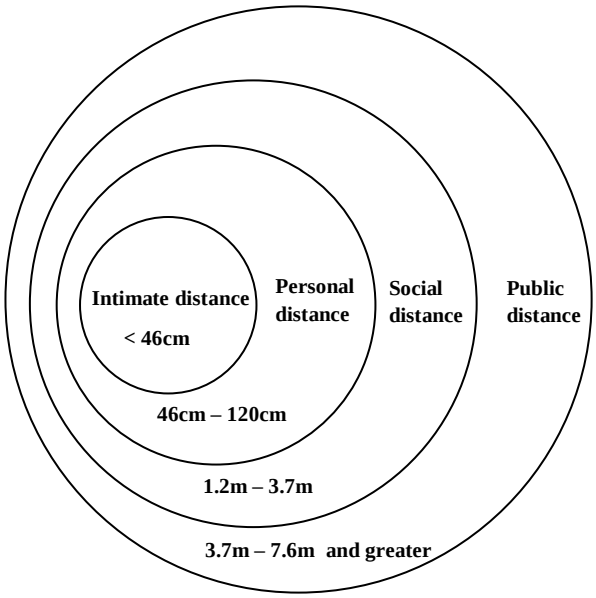


Figure 5: Hall's distance zones

While Hall (Hall, 1966) dealt with four distance zones for interpersonal interaction, Nishide (Nishide, 1985) categorized five distance zones appropriate for interpersonal conversation. They are: the zone of exclusion, the zone of conversation, the zone of proximity, the zone of mutual recognition and the zone of recognition. The five zones are summarized in Table 3 and illustrated in Figure 6.

Distance zones	**Physical distances**	**Action**
The zone of exclusion	< 50cm	Not appropriate for usual conversation
The zone of conversation	50cm – 150cm	Conversation is mandatory in this zone. Formal conversation occurs in distance more than 80cm.
The zone of proximity	1.5m – 3m	The zone for approaching a party for a conversation
The zone of mutual recognition	3m – 20m	The zone for recognition and greetings. Evasion is difficult in the range from 3m to 7m.
The zone of recognition	20m – 50m	The zone for recognition without greetings.

Table 3: Five distance zones for occurring conversation by Nishide (Nishide, 1985)

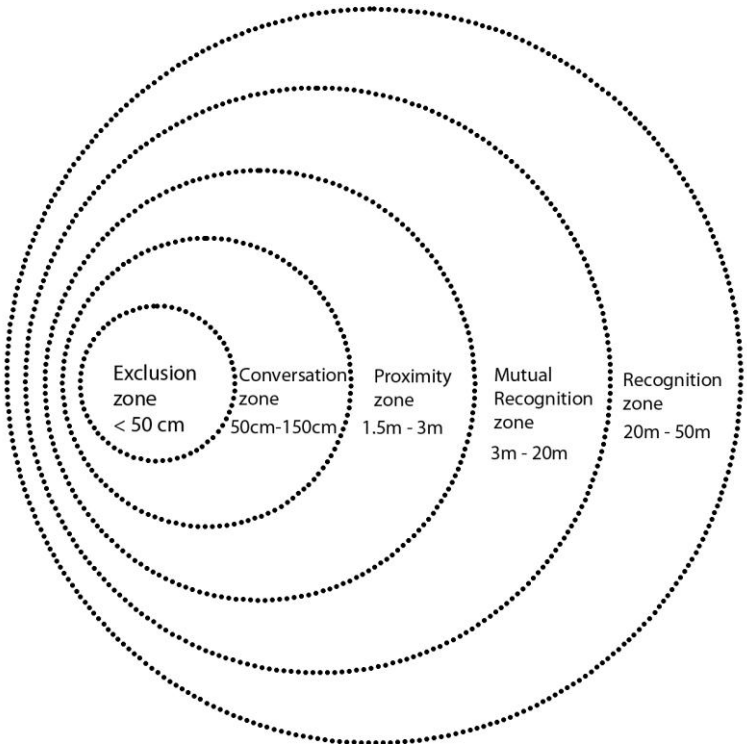


Figure 6: Nishide's distance zones

2.1.3 Spatial affordances for informal interaction

As mentioned in section 2.1.1.2, spatial setting could be used for informal interaction if the setting is arranged in a way to support designated activity thus providing meaningful content for informal interaction to take place. This section examines the environmental requirements to afford informal interaction that could be used to inform the design of the spatial setting for informal interaction activities.

In a physical environment, informal interaction often occurs in common spaces such as hallways, photocopy rooms, mail rooms, lounges or places where people often encounter each other (Albolino et al., 2005; Campbell & Campbell, 1988; Fayard & Weeks, 2007; Fish et al., 1990). "The more traffic that flows through and past a place, the greater the chance of encountering others there, and places that are central and that have a layout that makes them easy to enter and exit will have more traffic" (Fayard & Weeks, 2007).

Examining the example of the water-cooler around which the organization gathers, Fayard and Weeks (Fayard & Weeks, 2007) found that both physical settings and social construction of the space influence informal interaction that occurs around the water-cooler. They pointed out that there is no integrated framework or theory showing how both spatial settings and its social characteristics influence informal interaction. Hence they approached this issue by relying on the theory of affordances coined by Gibson (Gibson, 1979) to build social affordances of informal interaction. The affordances take into account social characteristics of the spatial setting in order to understand what appropriate behaviors are designated in the setting. Fayard and Weeks proposed a framework of social affordances which contains three main features which are ***propinquity, privacy*** and ***social designation.*** They are introduced as a necessity of a physical setting to afford informal interaction and environmental requirements for signaling and obligating behavior.

The first two environmental requirements come from two strands of existing theories regarding the relationship between informal interaction and spatial settings. They are theories of privacy and theories of propinquity. Theories of privacy indicate that "people feel most comfortable to interact informally when they can control the boundaries of their conversation". From these theories, walls, partitions and other forms of inaccessibility and privacy are presumed to increase levels of informal interaction. Closed spaces are preferred for informal conversation to take place. A typical example that supports this theory is the Hawthorne experiment (Gillespie & Schultz, 1993) where a move from an open plan to a smaller and more private space increases the level of informal interaction. In contrast, theories of propinquity emphasizes that "informal interactions occur in spaces that bring people physically closer to each other". From these theories, open spaces with the absence of walls and partitions increase visual opportunities for people to encounter each other thus fostering informal interaction. It seems that the two theories are contradictory

however they are two indispensable factors that support informal interaction. Consider an example where informal interaction is not supported due to the lack of privacy factor. The Scandinavian Air Systems (SAS) which is headquartered near Stockholm, created a lively interior "street" lined with shopping, recreational, eating, sport facilities as well as multipurpose lounges with shared facilities such as furniture for meetings, photocopying machines, fax, coffee facilities. The street was designed to foster informal interaction as SAS managers believed that "good ideas spring from impromptu meetings". However, the observation data showed that most interpersonal exchanges did not occur in the space specially designed for this. Little interaction occurred in the street. Instead, most of the interaction (64%) occurred in the individual offices where privacy could be maintained and were less intrusive (Markus & Cameron, 2002). Although the street provided sufficient opportunities for supporting propinquity, it failed to afford informal interaction due to the lack of physical privacy (Fayard & Weeks, 2007).

In order to reconcile the contradiction between privacy and propinquity, Fayard and Weeks have examined them in terms of the social construction of a setting. In this way, privacy is not only "a function of the visual and acoustic isolation of a space" but also "partly a function of the social definition of a place". For example, the same room may afford different levels of privacy. It could afford a higher level of privacy if it is a personal office, or a lower level of privacy if it is used as a public lounge. By examining in terms of social construction, propinquity is defined as "two people being in the same location where there is both opportunity and social obligation for face-to-face communication". For example, if two persons come to the mail room to collect their mail, the physical space of the mail room is small enough to obligate them to acknowledge each other's presence or even obligate them to exchanges greeting or start a short conversation.

In summary, the settings must have three environmental requirements to afford informal interaction that bring people into unplanned contact with others (propinquity), allow them to control the boundaries of their conversation (privacy) and provide socially "legitimate rationalizations" for people to stay and talk to each other in this setting (social designation). The three environmental factors are depicted in Figure 7.

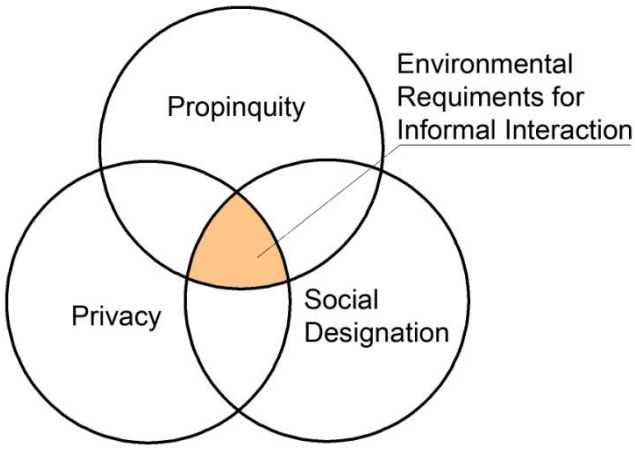


Figure 7: Three environmental requirements for informal interaction (Fayard & Weeks, 2007)

Although the three environmental requirements provide spatial facilities and spatial obligations to bring people together to interact as well as provide appropriate boundaries to enable people to control their interaction, people are still affected by certain cultural norms which dictate what is appropriate and accepted behaviors in such places. Take the example of LX Common at Xerox's Wilson Center (Horgen, 1999). A space was designed to support informal interaction among groups. The space contained a kitchen, a photocopier machine, a printer and important reference materials. It was located at the center of the labs so that people had to pass through this room in order to go to the other labs. Since different groups used the space for their meetings, some people who did not wish to join the meetings tried to avoid the groups by detouring through a rear door. The space became an actual place for

intended informal interaction after some rules were established to allow people to freely access and use the space for interacting informally.

Andre et al (André et al., 2006) have introduced a taxonomy for the design of workplace "break" spaces. The idea for this work was motivated by a fire which destroyed the café room where the social activities of teachers, staff and students occur daily. The authors analyzed three spaces: the ruin café room and two other substitute spaces for the ruined one (hallway kitchenettes, entrance foyer) in order to understand why the substitute spaces were problematic and the ruined one was successful. The taxonomy has seven values which are grouped in two categories: artifacts and activities. Artifacts are attributes of the space and activities are interactions supported by the space. In the artifact group, the "lure" value represents attractive things in the space such as good coffee and congenial colleagues and the "environment" value represents the design of the space. In the activity group, the activity of "breaking away from work" is a value that represents whether the space is suitable for taking a break and supports the feeling of breaking away from work; "serendipitous meetings", "semi-planned meetings" and "socializing" are three critical activities to be supported by the space for effective interaction. At the boundary of the artifact group and the activity group, "awareness of others" is a value that represents determining the presence of people in the space for one's act. The authors argued that the taxonomy provides a framework for the analysis of physical spaces to assess if they if they are appropriate as break spaces in terms of their affordances for social interaction. The analysis could be used to inform design requirements of the physical spaces or design of digital systems to better support rich social interaction occurring in the physical break spaces.

2.1.4 Spatial stimuli for informal interaction

While spatial affordances are required for informal interaction, spatial stimuli provide spatial aspects to trigger people's awareness and draw their attention (Becker & Steele, 1995; Davis, 1984). In the area for informal communication, spatial stimuli are understood to be places or "activity magnet areas" (Becker & Steele, 1995) which act as a magnet to attract and hold people, thus encourage them to come into unplanned conversations. Spatial stimuli are often examined together with spatial settings (building design and location) which increase the opportunity for establishing visual contact and awareness through open areas that maximize visibility. Spatial stimuli and spatial stimuli (functional areas and furniture) facilitate people's communication by providing the comfort and convenience for making conversations at designated places and utilities.

Fayard and Weeks (Fayard & Weeks, 2007) pointed out three key physical characteristics of spatial setting that could meet the three environmental requirements presented in section 2.1.3. They are spatial elements that have a positive or negative effect on privacy and propinquity and influence both the opportunity and the social obligation for interaction. These elements are classified in this paper into three groups, namely architectural elements, geographical elements and functional elements. Architectural elements concern elements of physical environments (walls, doors, windows, etc) and their characteristics (how accessible they are, how enclosed, how large). Geographical elements refer to where the setting is located and how it is situated, for example proximity to hallways. Functional elements concern the content or objects of the setting (photocopier, fax machine, printer, bulletin boards, supply cabinets and mail box) and their technical and social function.

In Davis's study (Davis, 1984), the architectural elements, geographical elements and functional elements are also highlighted as important features

influencing and regulating behavior in offices. In his paper, the three kinds of physical elements are investigated under three categories which are (1) building design and physical location, (2) furniture comfort, placement and seating arrangement and (3) open versus closed offices. Informal conversation areas often consist of a couch, small coffee tables, and visitors' chairs. The three categories are combined into one constituent feature known as physical structure. Together with physical structure, physical stimuli and symbolic artifacts are physical setting variables that influence the behavior of managers and organization members. Physical stimuli are those aspects of the physical setting that intrude into people's awareness and influence their behavior such as getting them to pay attention. Examples include mail, notes on the desk from others, different objects in the room, the smell of coffee or cigarettes. Symbolic artifacts are aspects of the physical setting that individually or collectively guide the interpretation of the social setting. Examples include the design of the office, the type and style of furnishings, the color of the walls, the presence or absence of carpeting or photographs displayed on walls or desks.

E.Campbell and A.Cambell (Campbell & Campbell, 1988) have investigated how informal interaction occurs among colleagues in education environments. Through two studies that examined the link between elements of the physical environment and informal social interaction in department lounges, E.Campbell and A.Cambell have categorized the spatial elements that increase informal interaction into three groups:

- ***Things that attract people:*** The more people are attracted the higher the probability for informal interaction to occur. Example: mail room, refreshment room and so on.

- ***Things that hold people***: Once people are attracted to an area, anything that will hold them in that location will extend the opportunity for them to interact. Example: up-to-date bulletin boards, coffee machines.
- ***Things that support informal communication***: Anything that makes conversation between people convenient should enhance interaction. For example: seats, blackboards.

In conjunction with E.Campbell and A.Cambell findings of environmental stimuli for generating and catalyzing informal interaction, Becker and Steele (Becker & Steele, 1995) pointed out three amenities which are activity generators and therefore act as magnets to attract and encourage people's participations.

- **Areas for food and communication**. Amenities such as small coffee tables, bar stools or coffee machines are suitable for short conversations, informal meetings or quick chats with others. Through drink and food, people could "easily join in and drop out of a conversation without stopping work altogether". A typical example is Apple's new R&D campus in Cupertino, California. Its activity area, where high-quality coffee and other beverages are provided, is located at the main entrance. Since coffee tables are placed at the center of the atrium, visibility is maximized and traffic flow is high, thus encouraging accessibility and increasing the possibility for unplanned meetings.
- **Areas for shared services**. Service facilities such as mail rooms, copy rooms and meeting areas are often used by employees regularly. Therefore, the likelihood for accidental encounters is high when people go to these areas to use the services.
- **Information centers and displayed thinking areas.** Facilities such as bulletin boards (normal and electronic), rotating displays are often used to share organizational activities with all members. These information displays

could act as gathering areas that attract people to come to obtain updated information, and in the process stimulate them to discuss what they are seeing and hearing.

2.1.5 Spatial settings for informal interaction in the workplace

Nowadays, work practices have changed from individual work to teamwork and collaborative work across multiple disciplines. It is recognized that multidisciplinary collaborative work encourages the stimulation of ideas and promotes creativity and innovation. Therefore, organizations have reshaped their workplace settings to meet the demands of changing work practices. The workplace is not simply one's desk, office, or work station in an office building but it also contains the cafeteria, the conference and break rooms, the project rooms, corridors, water fountains and the fitness center (Becker & Steele, 1995). These functional spaces constitute "the total workplace" (Becker & Steele, 1995) which provides facilities for people to keep in constant communication with their teams in terms of planned, spontaneous and unplanned meetings at all times and places. One of the principles guiding the design of the workplace is the ruby model of communication. It promotes the idea of a model of a basketball, or soccer game in which all players are brought together in a process to fulfill a task. Although each player takes different responsibility in the process, they all contribute to a common goal which is to move the ball somehow towards the goal. To keep constant communication, communication in the ruby model occurs dynamically on the stairs, in the hallways, at lunch, during coffee breaks. Informal interaction is taken into account in this model as the "bedrock of advanced work culture" (Becker & Steele, 1995, p. 72) to stimulate creativity across project teams and across disciplines and departments through enormous amounts of information such as design, technology and marketing. It brings different types of people into closer contact and helps them to understand and accept different

ways of thinking and working (Becker and Steele, 1995, p. 76). Figure 8 depicts a transformation of a boring hallway with closed offices to a lively stimulating street with open spaces for teamwork.

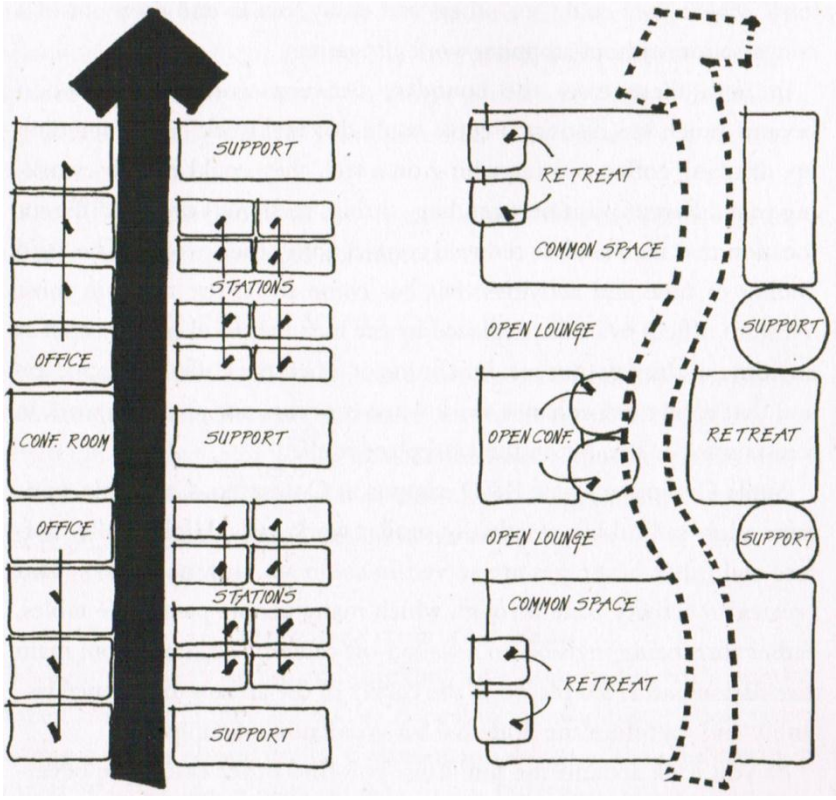


Figure 8: A transformation of a boring hallway with closed spaces to a lively stimulating street with open areas and permeable spaces (Becker & Steele, 1995, p. 80)

Two typical workplace design approaches are Main Street and Town Centre (Square) in which the workplace settings are designed to reflect the concept of ruby model for teamwork. Main Street is designed as a main spine to connect the whole organization together. Located along the street are "activity magnet areas" and "activity generators" or shared resources such as cafeteria, food and beverage areas, open discussion areas, service facilities (mail stations, copy center) and even real shops. These functional spaces act like magnets to pull people into these areas and hold them thus fostering communication and extending the opportunity for them to interact (Becker & Steele, 1995, p. 78). Informal interaction may occur when people

move along the street or use the services in the street. Although most of functional spaces are placed along the Main Street, they are distributed throughout the building rather than grouped together to minimize the distance traveled. The purpose is to encourage contact and communication among individuals and groups across disciplines based on functional inconvenience of physical settings. A typical example of Main Street is Waterside, the combined business center of British Airways. The idea of Waterside emerged from the problem of communication among people in the scattered buildings. They were prevented from interacting by closed private offices along boring corridors and communication and meetings mainly occurred through appointments. Therefore, people did not have the opportunities for rapid communication as well as making corporate decisions. "Waterside is designed for people to interact, to meet casually as well as formally. A grand covered street is the axis along which the six office buildings open, filled with coffee shops, bank, grocery store, and florist". The amenities bring people from different parts of the business center to the street so that they can "enjoy the ambient of the building", "know more about what is going on in the company" and "walk around more and bump into people". Open areas with tables and chairs are well used for solo work or informal meetings, both working and socializing purposes (Figure 9).

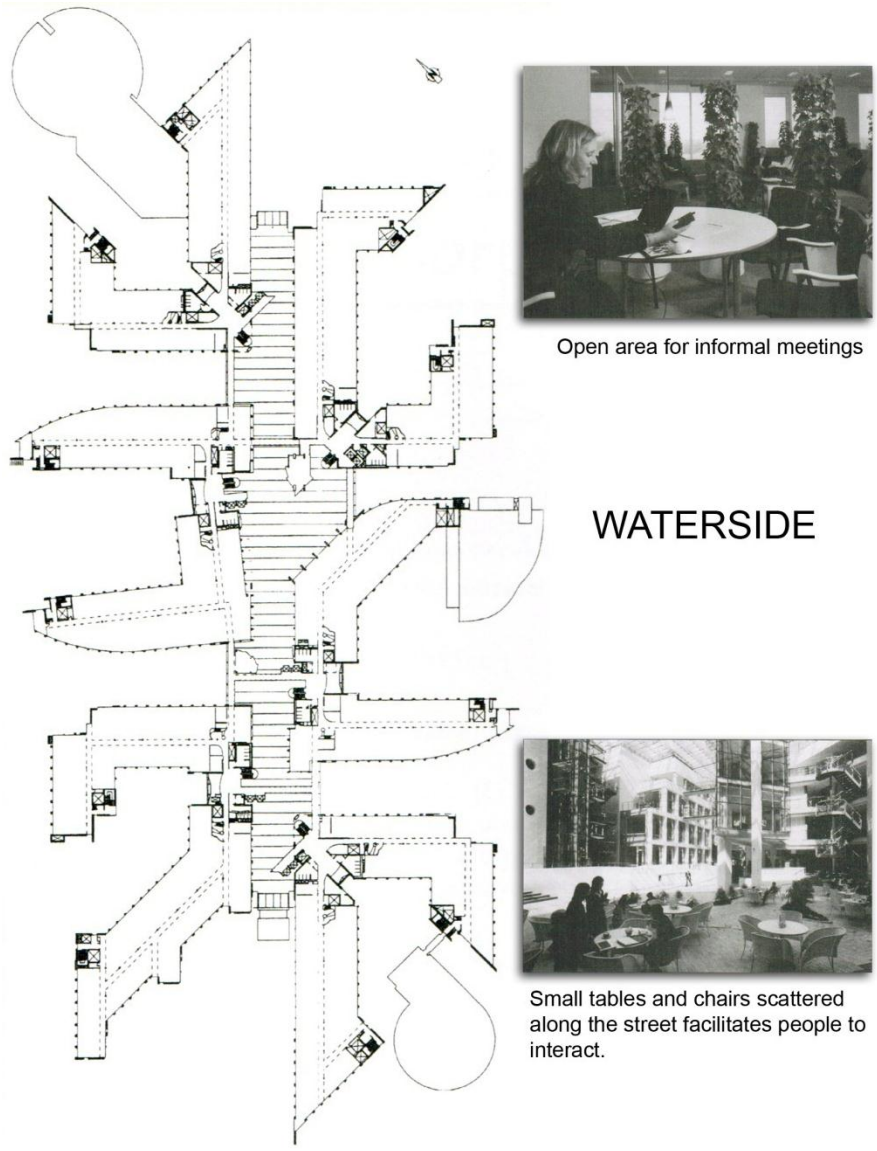


Figure 9: Waterside connects the six buildings to a grand street

Town Centre centralizes all shared activities and resources in a single magnet area that would become the corporate hub of group activity. For example, Apple's new R&D campus in Cupertino, California which was mentioned earlier in this chapter. It has a "work oasis" with high quality coffees and other beverages provided in the main entrance lobby. Café tables are placed in the center of the atrium to enhance visibility thus creating an activity zone for accidental meetings (Becker & Steele, 1995). Similarly, Bates USA, an international advertising agency, created a centre area to increasing interaction among many different teams. The centre contains

a space for staff to gather and has a traditional café bar with cybercafé benchtops to facilitate rapid communication and bring different groups together (Figure 10). In both Main Street and Town Centre, the spatial settings are designed to "maximize visibility" between floors, to the outside, and into private offices in order to establish visual contact and easy accidental encounters with other office workers and other work areas. Table **4** contains examples of Main Streets and Town Centres in some workplaces.

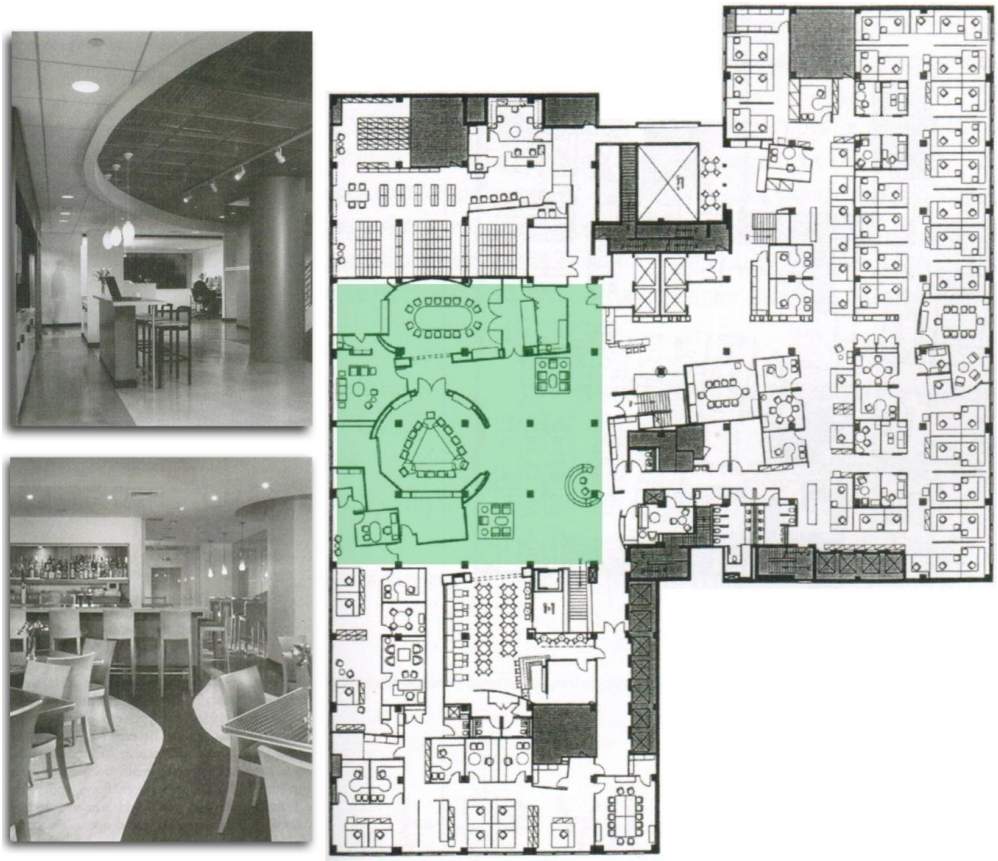


Figure 10: Centre area in Bates USA

Design Approach	Examples
Main Street	Scandinavian Airline System (SAS) headquarter (Becker & Steele, 1995, p. 81) Digital Equipment Corporation's British Headquarter (Becker & Steele, 1995, p. 81) LX laboratory in Xerox's Wilson Center (Horgen, 1999, p. 175) Waterside (Marmot & Eley, 2000, p. 281) First Data Investment Services Group (Marmot & Eley, 2000, p. 287) Nortel Networks (Marmot & Eley, 2000, p. 295) West Group (Marmot & Eley, 2000, p. 343) TBWA/Chiat/Day (Marmot & Eley, 2000, p. 401) Boeing Operations Fleet Support (Streitz et al., 1998, p. 2) Hexcel Corporation Headquarters (Becker & Steele, 1995)
Town Centre	Bates USA (Marmot & Eley, 2000, p. 333) Silicon Graphics, Inc (Marmot & Eley, 2000, p. 353) Excite Headquarters (Marmot & Eley, 2000, p. 445) Apple Computer's new R&D campus (Becker & Steele, 1995, p. 79)

Table 4: Examples of Main Streets and Town Centres in some workplaces

2.2 Mediated shared space technologies

2.2.1 What is mediated shared space?

Mediated shared space, in Gaver's paper (Gaver, 1992, p. 1), is described as an "encompassing space" which "is rich with perceptual information about objects and events that can be explored and manipulated". Similar to Gaver's definition,

Benford et al. (Benford et al., 1994) explained mediated shared space as the model of spatial setting that "uses the properties of space as the basis for mediating interaction". With regard to the issue of being there together (Efimova, 2010), a mediated shared space is a space that provides "excuses to be there", "opportunities to see what's going on and to be seen in a non-intrusive way" and "easy switching between inward- and outward-oriented activities". Billinghurst (Billinghurst et al., 1998) defined mediated shared space in the context of computer supported cooperative work (CSCW) as a three dimensional CSCW space that maintains the sense of continuity among existing users in the workspace. Therefore, technologies in the workspace should be seamlessly integrated in order to support remote collaborators to communicate in naturalistic ways.

2.2.2 Mediated shared space technologies

2.2.2.1 Groupware

The main purpose of this study is to support informal interaction activities at a distance between groups of people at remote locations through mediated shared space. This section examines how groupware could be used to support the study objective since the main purpose of groupware is also "to assist groups in communicating, in collaborating and coordinating". The term "groupware" was coined by Johnson Lenz and Johnson Lenz (Johnson-Lenz & Johnson-Lenz, 1982) and refers to computer-based systems used to support social group process toward a common goal. Ellis et al (Ellis et al., 1991) has defined groupware as "computer-based systems that support groups of people engaged in a common task (or goal) that provide an interface to a shared environment". In these definitions, shared environment is one crucial factor that "unobtrusively offers up-to-date group context and explicit notification of each user's action when appropriate". In other words,

shared environment is a bounded space where people are able to see and undertake joint activities. Shared environments can vary from 2D flat environments to 3D environments. In this research, 3D environments are used as the shared space for supporting joint informal interaction among distance-separated people. Table 5 classifies different types of groupware based on whether it supports synchronous or co-located features. As informal interaction at a distance is a real-time activity between geographically distributed people, it is considered a synchronous distributed interaction. The groupware that allows people to interact together at the same time but in different locations are called real-time groupware.

	Same time	Different times
Same place	**Face to face interaction** (e.g. meeting room technology)	**Asynchronous interaction** (e.g. physical bulletin board)
Different place	**Synchronous distributed interaction** (e.g. teleconferencing, IM)	**Asynchronous distributed interaction** (e.g. email)

Table 5: Groupware taxonomy

2.2.2.2 Applications of mediated shared space technologies for informal interaction

Informal interaction occurs when people are co-located and the physical proximity provides a chance for them to come into contact and communicate (Kraut et al., 2002). When people are physically separated, their interaction would have to be mediated by technology. To support informal interaction at a distance, researchers have come up with a variety of ways to mimic chance encounters thus encouraging physically separated people to engage in unplanned conversations. Shared spaces technologies have been employed to create shared environments so as to bring

geographically distributed people together across space and time. Figure 11 classifies the examples of mediated shared space for supporting informal interaction at a distance based on the four categories of shared spaces technologies introduced by Benford et al (Benford et al., 1998). They are media spaces, collaborative virtual environments (CVEs), telepresence systems and collaborative augmented environments (CAEs). Video conferencing systems are excluded because though they provide facilities for distance-separated people to communicate with one other, they are often used to serve planned and formal meetings rather than interaction by chance.

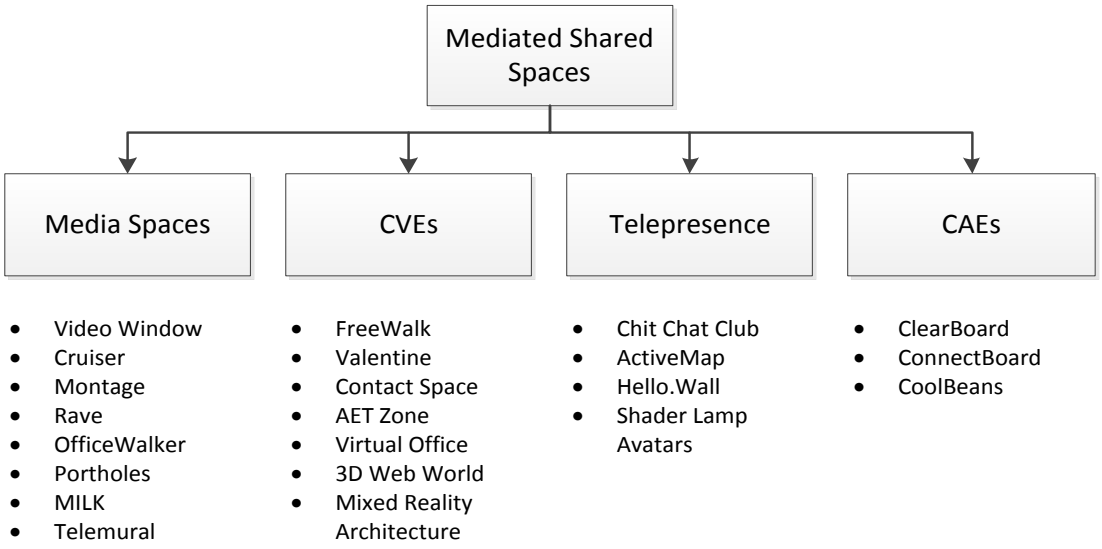


Figure 11: Mediated Shared Space Technologies classified by Benford et al (Benford et al., 1998)

Media spaces

Most of the examples employed media spaces for creating virtual shared space. VideoWindow (Fish et al., 1990) created a shared virtual lounge between two distance-separated public lounges through high bandwidth video channels and full-duplex four channel audio. By projecting the image on a three-foot high by eight-foot wide screen, the system allows nearly the whole lounge area to be seen together with

life-sized people. Informal interaction initiates when a person walks into the room, glances at the window and sees another at the other end. RAVE (Gaver et al., 1992) was developed as a shared virtual workspace with which people are able to maintain awareness of remote locations through viewing the selected location "background" and "sweep"-ing the locations (to find out who is around and what he or she is doing). The "glance" function allows one to check the availability of people at the remote location. Portholes (Dourish & Bly, 1992) approached the notion of virtual shared office by enabling people to keep a peripheral awareness in a variety of places through a matrix of slowly scanned continuous video images. Through these images one is able to know who is available and therefore establish are available thus establishes an audio-video connection with that person. The last type of shared space that has been used in many systems is the notion of shared virtual hallways. Typical applications are OfficeWalker (Obata & Sasaki, 1998), Cruiser (Root, 1988) and Montage (Tang & Rua, 1994) in which the mechanism of shared virtual hallways enables people to walk through and "peek" into offices to see who is there. The "hallway" is actually a path which contains a set of locations (offices, common areas) which the user might visit. By peeking into another's office, the parties can see each other and may initiate a conversation. Telemurals (Karahalios & Donath, 2004) introduced a sociable shared space which encourages social interaction between two remote physical spaces. The shared space is created by rendering the captured video images of people in each space into silhouette shapes, blending them together and projecting the blended images onto the walls of the respective spaces. The parties can interact via the audio channel and through the use of subtle cues of expression such as hand movement and body postures.

Collaborative virtual environments (CVEs)

Since virtual worlds have been shown to support social interaction through users' navigation and social positioning (the degree to which one related to the space they inhabit or others who shared it through movement and positioning (Jeffrey & Mark, 1998)) thus they could provide a structure for encouraging unintended interaction (Phillip & Andrew, 2000). According to Phillip and Andrew (Phillip & Andrew, 2000), the primary ways to support informal interaction focus on using media spaces instead of CVEs. However, CVEs are expected to provide a greater degree of social interaction than media spaces. Typical CVEs for supporting informal interaction include Forum (Phillip & Andrew, 2000), FreeWalk (Nakanishi et al., 1998), Mixed Reality Architecture (MRA) (Schnadelbach et al., 2006) and Valentine (Honda et al., 1999). Interactions among users in Forum happen in a shared information landscape where each user is represented in the form of an avatar. By placing the users' avatar close to each other based on what the users are working on, Forum provides opportunities for opportunistic informal interaction that fit the current activities of users. In FreeWalk, a 3D space is developed just like a virtual hallway or lobby to encourage accidental encounters in a more relaxed atmosphere with maximum freedom for the participants. A participant is represented as a pyramid on which his/her video is mapped on the rectangular plane. Participants can find others on the radar screen while wandering in the 3D environment, thus allowing for accidental encounters. Similar to FreeWalk, MRA links multiple diverse physical spaces in a shared virtual environment in which a Mixed Reality Architecture Cell displays the live video of a physical space and transmits the live audio captured from the physical space. Valentine (Honda et al., 1999) was developed as a 3D virtual office environment to enable home workers to come to work together. Participants are represented as avatars whose bodies are 3D polygons and heads bear the photos of

the users. This presents a more natural environment as the participants can recognise one another and feel the other's presence.

Telepresence systems

An example of telepresence systems for casual interaction is Chit Chat Club (Karahalios & Dobson, 2005). It is a mixed physical and virtual environment for casual communication among distributed groups of people. Remote participants could interact and communicate with local participants by logging into a physical telepresence sculpture which is created in an anthropomorphic form and placed at the table where local participants hang out. Differing from the concept of telepresence systems whose remote embodiments are able to navigate the space, the sculpture is installed as a fixed object and faces a fixed direction. Therefore, a remote participant who logs into the telepresence sculpture is unable to explore the physical environment and his/her field of view is constrained by the fixed direction as well as the field of view of the attached camera on the sculpture. Recently, more realistic robotic avatars such as Shared Lamps Avatars (SLA) (Lincoln et al., 2009) could support more natural conversations through dynamic motion (gesture and talking) and the appearance of real people.

Collaborative augmented environments (CAEs)

ClearBoard and ConnectBoard (Kar-Han et al., 2009) were developed as a seamless integration of interpersonal spaces and shared workspaces with which co-workers in two remote locations are able to talk through and draw on one transparent glass window (Ishii et al., 1993). The collaborative work represented as a shared drawing image is overlaid on the RGB video of the partner. While ClearBoard was designed as a drafting table which produces an unnatural view of the remote user, ConnectBoard supports a more natural interaction through an upright screen.

2.3 Context awareness

2.3.1 What is context-awareness?

Context was defined in section 1.2 as "the information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and the application themselves". In informal interaction, this information is co-location and co-presence. Co-location puts people in each other's close proximity thus providing the "distance over which one person can experience another with naked [or mediated] senses". Co-presence "makes co-located people tune into one another" and renders them "mutually accessible" and therefore "allows for mutual contact". As such, a sense of co-location and a sense of co-presence support the perception of co-participation and facilitate reciprocal orientation toward each other thus creating the social context for informal interaction to occur. In order to be aware of the interaction context at a distance, context-aware computing is used to detect, sense, interpret and respond to the information of the interaction context.

There are many definitions of context-aware computing; however, they all belong to either one of two categories: adapting to context and using context. Riva et al. (Riva et al., 2003) defined context-aware in a general way so that it could be applied to all types of context-aware applications. It is defined as a system that "uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task ".

Through this definition, context-aware applications for supporting informal interaction at a distance should provide two pieces of information which are sense of co-location and sense of co-presence as identified in section 1.2 to enable informal interaction to occur.

2.3.2 Sense of co-location

According to Zhao and Elesh (Zhao & Elesh, 2008), co-location is "spatial relationship, characterized by mutual presence in close proximity that puts people within the perceptual range of each other". In the physical world, co-location enables people to be within the range that they could perceive each other using their naked sense such as see, hear and touch. This perceptual sensory will be lost if the distance between people increase. However, it could be extended or mediated with the aid of electrical mediation such as video-based devices (teleconference, videophone), collaborative virtual environments, etc.

2.3.3 Sense of co-presence

Co-presence was coined by Goffman (Slater et al., 1994) as a form of co-location that makes people "accessible, available and subject to one another". So co-presence is the condition that is needed for two-way human interaction to occur as co-presence enables people to "sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived". In other words, co-presence enables one to actively perceive others and to feel that others are able to perceive him/her.

In the physical world, co-presence is face-to-face encounter and that takes place when people are in close proximity to each other and are visible to each other such as being in the same room or at a social gathering. When people are not in each other's range of recognition, co-presence is no longer physical "face-to-face" encounter. People can have the sense of being together with others through mediated space where all participants can be the sense of digitally co-located though not physically co-located. In this way, co-presence becomes "face-to-face mediation"

encounter (Wineman et al., 2009). According to Zhao and Elesh (Zhao & Elesh, 2008), the definition on co-presence when people are not co-located has been mentioned in the literature of presence in many ways, however the meaning of co-presence has not been fully addressed. These definitions are listed in Table 6.

Definition of co-presence	Defined in
The sense of being with others in a remote environment	(Lombard & Ditton, 1997; Schubert et al., 2001)
The sense of being with others in a shared virtual environment	(Biocca et al., 2003; Goffman, 1966a; Slater et al., 2000)
People who are visible from a path of observation	(Rashid et al., 2006)
The sense of psychological connection to and with another person	(Slater, 1999)

Table 6: Co-presence definitions as given by various researchers

In order to categorize and make sense of different types of human co-presence in the Internet era, Wineman et al. (Wineman et al., 2009) proposed a taxonomy of co-presence in which co-presence is mapped based on two dimensions: simulation (physical/digital) and proximity (physical/electronic). Table 7 shows four forms of co-presence in Zhao's taxonomy.

Simulation / Proximity	Physical Proximity	Electronic Proximity
Physical Simulation	Corporeal Co-presence (face – to - face)	Corporeal Tele-co-presence (face – to – device)
Electronic Simulation	Virtual Co-presence (physical simulation: robots)	Virtual Tele-co-presence (digital simulation: agents)

Table 7: Zhao's taxonomy of co-presence (Wineman et al., 2009)

- **Corporeal co-presence:**

Corporeal co-presence is a type of human co-location that occurs when one person is corporeally present in an environment and he is in close physical proximity with another. This type of co-presence enables people to perceive and reach each other through naked sense without any mediated sensory. To interact with someone in corporeal co-presence is to interact in terms of physical "face-to-face" and physical "body to body". Corporeal co-presence represents the full conditions of human co-presence as defined by Goffman (Casanueva & Blake, 2000) so that people could "sense that they are close enough to be perceived in whatever they are doing, including their experiencing of others, and close enough to be perceived in this sensing of being perceived". Examples of corporeal co-presence are being together in a party, meeting, etc.

- **Corporeal tele-co-presence:**

Corporeal tele-co-presence is a type of human co-location that occurs when one person is corporeally present in an environment and he is in electronic proximity to another. In this type of co-presence, people are unable to perceive each other using

their naked sense but through mediated means instead. To interact with a person in corporeal tele-co-presence is to interact in terms of "face-to-device" which means people use communication devices to get in touch with each other. For example, using the laptop for talking and chatting with remote people.

The difference between tele-co-presence and tele-presence is the possibility of reciprocal interaction that allows distance-separated people to mutually see, hear and communicate with each other. Tele-presence does not support reciprocal interaction. It only allows a person to be present at the remote location and to even manipulate an object located there, however this possibility is unavailable for the people at the remote location. For example, a TV viewer is able to see and hear the activities occurring in a stadium but people in the stadium are unable to see and hear what is happening in the place of the TV viewer.

- **Virtual co-presence**

Virtual co-presence is a type of human co-location that occurs when one person is virtually present in a physical environment and his embodiment (e.g. robot) is in close physical proximity to the local people who are physically located in this environment. Interaction in virtual co-presence could be considered as "face-to-face" interaction between the robot and the local person as the robot is located within range of the naked sense of perception of that person.

- **Virtual tele-co-presence**

Virtual tele-co-presence is a type of human co-location in which distance-separated participants are represented as digital agents to interact with each other. To interact in virtual tele-co-presence, participants have to use an electronic medium (e.g. computer) to mimic the human interaction of the digital agents. For example, interaction in a collaborative virtual environment (CVE) is a type of virtual tele-co-

presence in which avatars are digital agents and positioned at in electrical proximity with each other in the virtual environment.

2.3.4 The difference between co-location and co-presence in human interaction

Co-location and co-presence are two distinct concepts. Co-location refers to the close distance ”over which one person can experience another with naked [or mediated] senses” (Casanueva & Blake, 2000). Therefore, it provides the spatial relationship that places people within range of each other’s sensory proximity. However, being within range is not the full condition for mutual accessibility and mutual contact (Goffman, 1966a) but just a prerequisite for social connectivity. For example, although two people who have prior acquaintanceship are within range of each other, they may not come into contact as one person may be busy and is thus unreachable. Co-location could be established in the physical world by means of transportation and in the online world by means of mediated space.

Co-presence is a form of co-location that provides social connectivity among people. In co-presence, people are not only located within each other’s sense perception (can hear, see and touch each other) but also mutually accessible, oriented to each other and reciprocally ready to engage and be engaged. Therefore, co-presence enables people to be not only within each other’s range but also within reach. According to Zhao (Zhao & Elesh, 2008), co-presence could be established if people are willing to engage and be engaged as many “involvement shields” could be used to block access if people are unwilling to participate. For example, one could pretend to focus on reading the newspaper to avoid interacting with other co-located people.

In *Being and Time*, Heidegger (Heidegger, 1962) associated "co-location" and "co-presence" with using the terms "being in" and "being with", respectively. In "being in", people are in "location-relationship with something else" and in "being with", "the world is always the one that I share with others".

In order to make a clear distinction between co-location and co-presence, Zhao (Zhao & Elesh, 2008) compared key features of the two terms in Table 8.

Co-location (being in)	Co-presence (being with)
• Spatial relationship • Proximity • Mutual present • "within range"	• Social relationship • Reciprocity • Mutual accessible • In touch

Table 8: Key features of co-location and co-presence (Zhao & Elesh, 2008)

2.3.5 Embodiment and embodied interface: supporting sense of co-presence

According to section 2.3.3, co-presence in informal interaction at a distance is no longer in terms of "face-to-face" and is mediated through interfaces. There are different types of interface arrangement that could be used to form human co-presence that allow human sensory perception to be extended via electric mediation.

The interface used to engage human sensory channels is called embodiment. The general definition of embodiment in this approach is defined as the "biological and physical presence of our bodies, which is a necessary precondition for subjectivity, emotion, language, ... and social interaction" (Lamont, 2002). The term "embodiment" has been widely used in various areas such as philosophy tradition,

psychology, cognitive science and neuroscience, sociology and, lastly, Human Computer Interaction (HCI) and computer science (Farr et al., 2012). As mentioned in section 1.2, the aim of this study is to find a way to mediate a sense of co-location and sense of co-presence at a distance. Thus the concepts of embodiment from the HCI and computer science approach are of research interest.

In HCI, the definition of "embodiment" was first coined by Dourish (Dourish, 2001) in his book "*Where the action is: the foundations of embodied interaction*". It is defined as "the transition from the realm of ideas to the realm of everyday experience". It does not only include physical embodiment of objects such as desks or chairs but also extends to embodiment of interactions such as speech and conversation. Dourish used Heidegger's phenomenological approach about "ready-to-hand" and "present at hand" to explain embodied interactions, for example the use of a mouse. To him, the mouse is the extension of his hand as he is able to select objects and operate computer functions with it, so through the mouse is "ready-to-hand". The mouse when it is being used in an activity is "present-at-hand". In this research, Zhao's (Zhao, 2003) definition of embodiment is employed: it is the "involvement of human bodies in the process of communication". In corporeal co-presence, "face-to-face" interface allows fully embodied interaction whose embodiment is able to engage all human sensory channels (smell, taste, touch, hearing and vision). When the distance between individuals increases, embodiment could allow human sensory perception to be extended through electronic mediation or computer simulation that is used to generate artificially corporeal sensory cues. For example, Skype allows distance-separated people to see, hear and communicate with each other as if they are co-present. With the aid of advanced technologies, embodied interfaces could extend the sensory perception to haptic interaction (Bailenson & Yee, 2008; Goffman, 1966b) or even smell, taste and touch perception (Motherboard, 2014; Paradis, 2014).

The simplest embodied interface which is plain text message does not convey much corporeal information of people's co-presence.

2.3.6 Involvement shields: methods used for blocking engagement requests

2.3.6.1 Offline shields

According to Goffman (Goffman, 1966a), "involvement shields" refer to barriers that are used to block human perception for contact without being rude. In the real world, typical examples of "involvement shields" are architectural partitions such as walls, spatial partitions and whatever physical objects behind which individuals may feel safe of not to be involved in improperly situational context. Being in the right place for socializing, co-located people, by right, could easily establish co-presence for social contact through mutual accessibility and mutual contact. However, being in the right place for socializing and being co-located may not be a guarantee for co-presence to be established. People may use "involvement shields" to avoid engaging as they are not willing to participate and be engaged by others (Zhao, 2003). Besides hiding behind physical obstructions (walls, partitions) to keep others from being within range, people could use various strategies to shield access to them such as pretending not to see people or "woolgathering, daydreaming or autistic thinking" (Goffman, 1966a) so that they are able to render themselves inaccessible and unavailable for social contact.

2.3.6.2 Online shields

In physical "face-to-face" encounter, using "involvement shields" is sometimes not successful. However it is easier in the online world if the interaction is "face-to-interface". According to Zhao (Zhao & Elesh, 2008), "involvement shield" in the online world performs the same functions as in the real world but it takes

different forms. People often use four evading strategies for blocking engagement requests. They are “ignoring”, “hiding”, “blocking” and “relegating”.

Ignoring and hiding are often used in “face-to-interface” interaction as some levels of embodiment in the interfaces do not enable people to perceive each other thus one could easily ignore or hide if he/she is not willing to respond to an engagement request. For example, Skype users could easily ignore an incoming call by not picking up the call as they can identify the caller through icons. The users can also easily set their availabilty status and thus hide from callers.

Blocking is a way to prevent attempts from others requesting engagement. For example, Skype users are able to block people in their friend list from making contact.

Relegating is a way to control access through some modes of restriction in cases where engagement is not avoidable. For example, Skype users could choose either one of modes of interaction which are audio only and “face-to-face” in their interpersonal communication; audio-only is often used when people do not want others to see their current activity.

2.3.7 Trust: prerequisite for successful online interpersonal interaction

Ishaya and Macaulay (Ishaya & Macaulay, 1999) defined trust as “a characteristic for collaboration where members believe in character, ability, integrity, familiarity and morality of each other”. Meyerson et al (Meyerson et al., 1996) defined trust as the willingness to suspend doubt about others. In collaborative works, trust is a prerequisite for success as it is important when teamwork involves risky activities and the team lacks the ability to meet each other or monitor people’s

behavior (Nohria & Eccles, 2000). Trust is essential for teamwork as individualism and deceitful behavior of team members can cause a team to fail (Rocco, 1998).

In the real world, people trust those who "make a sincere effort to fulfill commitments, are honest in negotiating commitments and do not take advantage of another when the opportunity arises" (Cummings & Bromiley, 1996). When people are co-located, trust and identity are two interrelated aspects that are built up through physical recognition and face-to-face interaction. As Handy (Handy, 1995) pointed out that "trust need touch" and "trust is touch" because face-to-face meeting allows you to "create trust much quicker and, by establishing the trust, it allows the individual the opportunity to ask questions" (Healio, 2012). With the advent of Internet, communication is able to occur electrically however trust is still very fragile, (Rocco, 1998). Rocco found that trust is broken down in the online world, especially through text communication; however a pre-face-to-face meeting could help to establish the trust in online communication. Olson and Olson (Olson, J. S. & G. M. Olson, 2000) also found that trust is built up better if team members participate in online "get-acquainted activities" compared to doing nothing beforehand. With regard to the communication methods for building up trust, Bos et al. (Bos et al., 2002) examined four ways of communication which are face-to-face, video, audio and text chat and found that the level of trust is lowest in text chat. For video and audio conferencing, the level of trust is as good as face-to-face, however some issues arose such as "delayed trust" (slow progress to achieve cooperation) and "fragile trust" (vulnerability to opportunistic behavior). Through research studies, the relationship of trust and identification should be maintained to increase interpersonal trust in the online world s interpersonal interaction could be successful achieved.

2.4 Summary

The main purpose of this review was to find the relevant theories and practices that could support the development of the theoretical Mediated Shared Space in Chapter 3. Therefore, the review process went through the following literatures:

- ***Theories and practices of spatial setting designated for informal interaction:*** to get the basic understanding of how a physical spatial setting could facilitate the informal interaction process;
- ***Applications of mediated shared space:*** to find out what are the possible types of mediated shared space and the difference between previous applications of mediated shared space for informal interaction at a distance and this study;
- ***context awareness:*** to retrieve the essential information characterizing the situation of the informal interaction process; and
- **other related discipline** such as Human Computer Interaction (HCI): to increase the breadth of this study in this area.

Section 3.1 will discuss the identified research gaps in existing literature including theory gaps and practice gaps based on which the proposed theoretical model of Mediated Shared Space is built.

CHAPTER 3
PROPOSED THEORETICAL MODEL OF MEDIATED SHARED SPACE FOR SUPPORTING INFORMAL INTERACTION AT A DISTANCE

3.1 Research gap: supporting sense of co-location and co-presence in the context of informal interaction

As stated in section 1.2, the existing systems do not properly support a sense of co-presence and co-location which are the two necessary aspects to build up shared social context of informal interaction at a distance.

In order to understand how co-location and co-presence play important roles in supporting informal interaction, this study examines the actual context of sequence processes of informal interaction that often takes place in daily life, and points out the issues that occur when co-location and co-presence are supported by systems developed for supporting informal interaction at a distance.

3.1.1 Practice gaps

3.1.1.1 Co-location and co-presence in different stages of informal interaction

Informal interaction routine often occurs in three stages; namely encounter, initiation and communication.

In the encounter stage. The encounter stage starts when one person happens to see another when they are physically present together (co-location) in the same physical space (co-location). According to Nishide's definition of recognition distance, people are able to perceive the presence of others when they are within a distance of 20m to 50m (Nishide, 1985). In addition, Hall (Hall, 1966) pointed out that one could have a clear vision of up to 5 people who are within 7m distance. As such, when people are physically co-located within this range they are able to recognize each other; beyond this, identities fade and recognition is difficult. Therefore, co-location provides "the distance over which one person can experience each another with naked sense" (Goffman, 1966b)

Transcending the "location-relationship" of co-location, co-presence provides the feeling of "being with" others through recognizing and identifying the other parties who are "being in" the range. Recognition could be one or two ways depending on the recognition distance, environment exposure, people's viewpoint and location. Although two co-located people are near to each other, they could be apart if they are out of each other's focus. Co-presence removes this isolated feeling by bringing them into the periphery of each other. In summary, in the encounter stage, co-location enables people within the recognition zone (with or without greetings) and co-presence renders people's awareness of another's to be aware of other's presence thus providing them with the feeling of being together in a shared space instead of being isolated.

In the initiation stage. The initiation stage starts when a person has an intention to discuss and exchange information with the other party after encountering him/her. In this stage, co-location puts people in the zone of proximity whose distance (1.5m-3m) is appropriate for starting a conversation (Nishide, 1985). Before initiating the conversation, people need to be aware of what the other party is currently doing and whether he/she is ready to take part in the conversation. As such,

co-presence supports availability awareness so that the initiator could avoid intrusiveness if the other party is not ready for a conversation. The distance between people in the zone of proximity is as short as people could evade each other thus co-presence enables both parties to "pay close attention to each other, ready to engage and be engaged therefore make them unique accessible, available and subject to one another" (Casanueva & Blake, 2000). In other words, co-presence enables people to be mutually accessible for contact and take an immediate response when they are the subject of attention. Therefore, in the initiation stage, co-location enables people to be mutually present in the zone of proximity within which co-presence provides mutual accessibility to each other's availability and enables people to be reciprocally oriented toward each other and responsive for social contact.

In the communication stage. The communication stage starts when two persons start to engage in their interpersonal conversation and in a face-to-face manner. In this stage, co-location enables people to be in the zone of conversation within which conversation often occur. The distance between two parties in a social conversation is kept longer than the distance in a personal conversation as social conversation is between acquaintances while personal conversation is between close friends. When people are in each other's close proximity, co-presence draws them into communication and enables them to be engaged in the conversation thus fostering the development of trust (Goffman, 1971). According to a survey conducted by the Association for Manufacturing Excellence, a sense of mutual trust is established when people talk face-to-face because people could "foster for a willingness to work things out through mutual problem-solving"(Healio, 2012). In other words, they are willing to share information with their interaction partner. When people are within each other's interpersonal distance, co-presence could enable people to be aware of their partner's willingness to engage and contribute to the conversation, or disengage from it. In short, in the communication stage, co-location

puts people in the range of interpersonal communication and co-presence enables contact, supports engagement awareness and facilitates interpersonal communication including maintaining, disengaging and reinitiating the conversation.

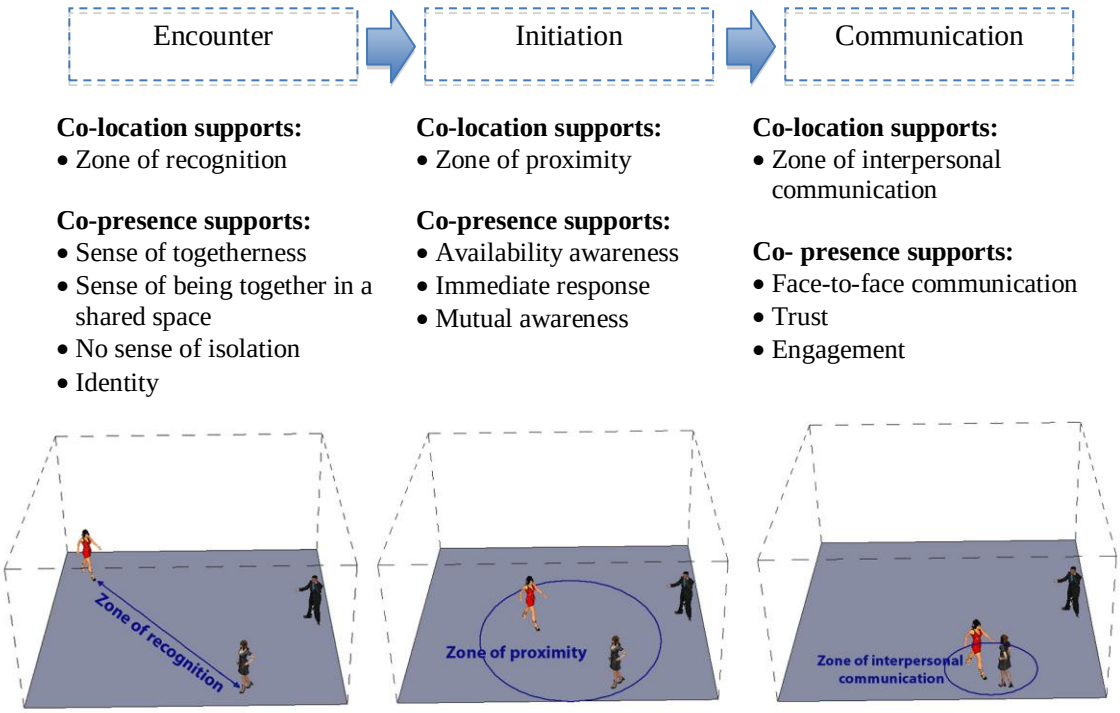


Figure 12: How co-location and co-presence supports three stages of informal interaction

3.1.1.2 Problems of existing systems in supporting co-location and co-presence awareness

In informal interaction, the co-presence factor supports perception of the presence of co-located people and facilitates reciprocal interaction such as exchanging information thus providing social context for informal interaction to occur (Rothenberg & King, 2006). According to Agrifoglio and Metallo (Agrifoglio & Metallo, 2011), informal interaction mediated by technology provides less "social indicators (cues)" than physical face-to-face communication; thus the interaction mechanism used in these mediated technologies support less "shared social context cues" and reduces communication efficiency.

Tu (Tu, 2002) pointed out that shared social context cues in mediated space refer to the user's characteristics and their perceptions of the online environment. It also refers to task orientation (Steinfield, 1986), the recipient's social relationships(Steinfield, 1986), access location of the online environment, trust (Cutler, 1995) and social process(Walther, 1992). Therefore, by enabling co-presence (being together) in the online environments, people could perceive the shared social context cues that facilitate their interpersonal interaction.

The three stages of informal interaction (encounter, initiation and communication) are three social processes occurring when people are co-present and co-located in the same environment. In order to know the extent of social context of informal interaction supported by mediated spaces, this section examines in detail the problems of the sense of co-location and the sense of co-presence in three stages of informal interaction supported by mediated technologies that affects the social context.

Problems of supporting co-location and co-presence in the encounter stage. In media space, although video and audio are very intuitive, natural and inexpensive ways to support highly realistic recognition, informal interaction sometimes does not occur as expected due to technical and usage issues (Jancke, G. et al., 2001). For example, multiple screens placed as tiled display such as in Virtual Kitchen (Jancke, G. et al., 2001) are often used to connect people in different locations. However the sense of co-location is weakly supported due to the spatial incongruity e.g. the different size, structure and perspective of the tiled display does not create the sense of co-location in a shared space and does not focus a person's attention enough to easily be aware of co-located partners. Some systems such as IM HERE (Elaine et al., 2004), support co-presence encounters through the use of online buddy lists so that people could encounter their friends when they go online. However, the probability of encounter is low as all parties have to make the effort to

log into the system at the same time in order to encounter each other. There is no sense of co-presence if nobody goes online or people set their status to invisible. The same issue also arises in a collaborative virtual environment which requires geographically distributed people to login to be co-located in a 3D shared space and provides co-presence through avatars or embodiments. Although avatars are able to easily encounter others as they are able to freely navigate, the co-presence encounter situation only occurs if people login to the 3D environment at the same time and are active in the environment activities such as walking around or participating in a get-together activity. People may feel lonely or isolated if only he/she is in the environment with nobody else around. Tele-presence uses robots as embodiments of the remote people. An example is Chit Chat Club (Karahalios & Dobson, 2005). The sense of co-presence is weak as robots (representing remote users) have the same appearance and cannot be customized according to one's preference thus lowering the chance of recognition.

Problem of supporting co-location and co-presence in the initiation stage. In some connection-based systems which use buddy lists as Skype, people may be located in a 2D environment, but it may be difficult to initiate a conversation by just looking at the other party's status e.g. online, busy, "not at my desk". Setting the status is a convenient way to inform others of one's current availability. However, it may not reflect one's actual availability. Initiating a connection may sometimes intrudes and interrupts the other party's current activity. For example, the remote user may set her status as available, but she is actually busy working on her computer at that time. Both caller and the recipient are not mutually aware of each other's current activities so an incoming call may interupt the recipient's current activity. If the receipient is not willing to accept the call, the caller will have to make an effort to try a few times to initiate the connection. The same problem also occurs in CVEs as participants are mediated by avatars and both parties are unable to be mutually aware

of each other's current availability though they could be mutually aware of what avatars are currently doing if they are all engaged in a CVE activity such as participating in a party.

Problems of supporting co-location and co-presence in the communication stage. Video-based communication media, especially high quality audio-video systems could support a high degree of engagement awareness and face-to-face communication due to interlocutors that are able to see real-time images of each other. Since the screen mainly shows the upper body of the remote interlocutor i.e. "talking head" video (Finn et al., 1997), less spatial environment is shared, and thus does not provide the context of co-location and being together. With regard to the tiled display, the feeling of face-to-face is less supported since people can only focus on talking with one person and easy miss looking at other screens while engaged in the conversation. In CVEs, the mechanism of face-to-face communication is supported by enabling avatars to stand and communicate face-to-face with each other through voice chat or text chat. Since participants are mediated through avatar embodiments, the extent of engagement awareness can only be felt through how responsive the voice and text chat are without seeing the actual participant's facial and body language.

3.1.2 Theory gaps

3.1.2.1 Lack of theory/literature in mediated shared space for informal interaction

With regard to the theoretical model of physical shared space for informal interaction, Fayard and Weeks (Fayard & Weeks, 2007) have outlined three affordances of a physical space for informal interaction which are propinquity, privacy and social designation. The three factors are used as a theoretical model for creating physical space designated for informal interaction in the workplace. Rashid

et al. (Rashid et al., 2006) have developed a workplace interaction model in which the spatial attributes (visibility, accessibility and openness) and spatial behaviors (movement, visible co-presence and face-to-face interaction) create a relationship among physical space, behaviors, and organization outcomes. This model could be used to create a mediated shared space to facilitate informal interaction, however these factors only indicate the attributes of the physical space but do not show how the space setting should be created as a shared space to afford mobile interaction.

Gibson (Gibson, 1979) discussed the affordances of everyday physical medium through the properties of earth, water and air – a solid, a liquid and gas. According to Gibson, the medium whose property: 1) has no resistance or less resistance, affords locomotion (movement); 2) transmits light, affords vision; 3) transmits vibrations or pressure wave, affords hearing; 4) allows chemical diffusion, affords smelling 5) contains oxygen, affords breathing; 6) has an intrinsic polarity of up and down, affords orientation. In fact, these features are too coarsely grained to be used to make a shared space for remote people but they can be useful to suggest the properties that the mediated space should have to afford the multiple human sensory modalities and actions.

In order to support remote people to obtain the common ground, Clark and Brennan (Clark & Brennan, 1991) proposed eight factors with which various media should have to accomplish grounding. They are: co-presence, visibility, audibility, contempolarity, simultaneity, sequentiality, reviewability and revisability. These factors focus on supporting the content and the process during the conversation rather than create a shared space to afford the social context in which informal interaction occurs from encounter to initiation and communication.

Gaver (Gaver, 1992) has outlined some affordances of media space for collaboration which is inspired by Gibson's six affordances of everyday medium and

developed on the Clark and Brennan's factors (Clark & Brennan, 1991). His affordances of media spaces include 1) affordances for vision, 2) affordances for listening, 3) affordances for movement, 4) affordances for interactive movement and 5) affordances for predictable interaction. Through the design implication based on these affordances, they could be used to make a mediated shared space for informal interaction using audio-video technologies. However, it can only support the creation of a shared space between two remote locations.

Olson and Olson (Olson, G. M. & J. S. Olson, 2000) have developed 10 characteristics that technologies should have for supporting co-located synchronous interaction. They are: 1) Rapid feedback; 2) Multiple channel; 3) Personal information; 4) Nuanced information; 5) Shared local context; 6) Informal "hall" time before and after; 7)Co-reference; 8) Individual control; 9) Implicit cues and 10) Spatiality of reference. These features only focus on supporting same-time and synchronous interaction that occurs either in the same place or at different places. They can be only to be used to support synchronous informal interaction but cannot be used to create a mediated shared space among remote people.

With regard to the practical works, the systems developed for supporting informal interaction at a distance are normally created based on the characteristics of the technologies that allow remote instead of on literature of mediated shared space for informal interaction.

Due to this inadequacy, the systems for supporting informal interaction are predominantly technology driven and task-specific rather than spatio-temporal driven.

3.1.2.2 Lack of technical guideline or technical implications for developing mediated shared space

Based on the affordances of media space for collaboration, Gaver (Gaver, 1992) has discussed technical implications and possibilities for designing media space to improve the shortcomings of each affordance. These implications are only useful and significant for developing systems for supporting informal interaction using audio and video technology. They cannot be applied to developing other mediated shared space such as virtual reality space and telepresence.

For virtual reality space and telepresence, there is no general guideline for developing either 3D virtual environments or telepresence systems for supporting informal interaction but there are guidelines tailored for specific systems such as design implications for future development.

3.2 Spatio-temporal approach

In order to minimize the problems presented in Section 3.1.1, this paper introduces a spatio-temporal approach whose spatial and temporal conditions enable geographically distributed people to encounter each other and interact together in the same place at the same time. In this way, the sense of co-presence among geographically distributed people increase as they are co-located in a shared environment. Spatial boundaries refer to the geographic differences among people and temporal boundaries refer to time zone differences (Cummings et al., 2007). In order to enable geographically distributed people to encounter each other, their spatial boundaries and temporal boundaries must overlap. In other words, people must share the same spatial setting and the same time zone in order to be aware of each other's presence and the social context of the interaction. Therefore, the spatio-temporal approach attempts to create a shared spatial setting which is the convergence space of

different spatio-temporal boundaries. Figure 13 illustrates the mechanism of how a mediated shared space for informal interaction among geographically distributed people is formed through spatio-temporal approach by making different remote spatio-temporal boundaries (rST) coincide.

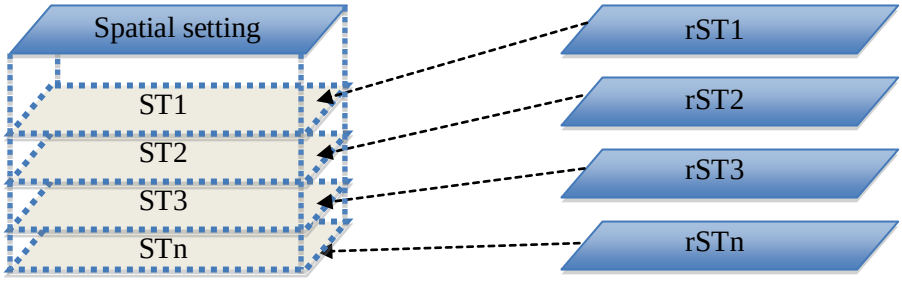


Figure 13: Spatio- temporal approach: Overlapping different remote spatial – temporal boundaries (rST) to become a shared space for facilitating concurrent informal interaction.

Figure 14 illustrates a possible spatio-temporal approach in which a collaborative virtual environment (CVE) is a shared space for remote participants. It is connected to the physical lounge to allow interaction among local and remote participants.

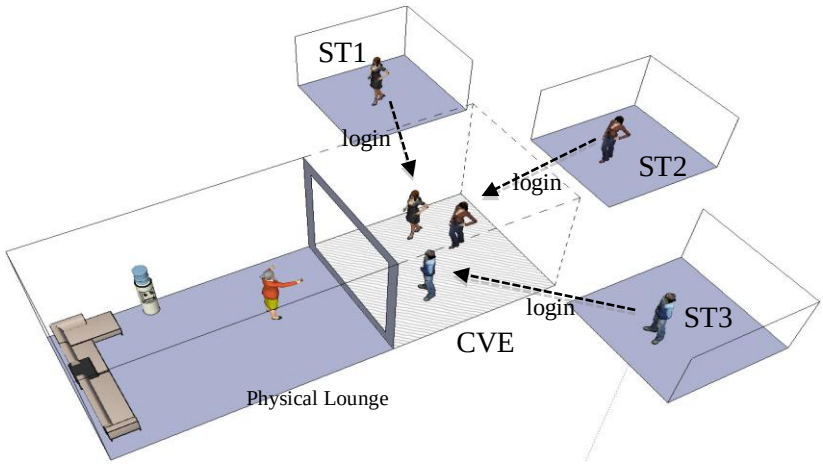


Figure 14: A connection of the CVE with a physical lounge creates a shared lounge for informal interaction with the participation of remote people

A model of mediated shared space which consists of spatial factors and temporal factors is needed to support naturally informal interaction. Spatial factors

are used to create visualization of the spatial boundary that provides a platform for facilitating social access and the gathering of geographically distributed people thus creating the stage for the three steps: encounter, conversation initiation and communication. Temporal factors provide real-time reciprocal information among participants in both awareness and communication processes, help participants to be mutually aware of who are currently around, where they are, what is currently occurring and what is going to occur in the surrounding environment. Therefore, temporal factors help to increase perception of co-presence while spatial factor supports a sense of co-location thus reducing the effort to encounter a communicative partner, reducing intrusiveness when initiating the conversation and encouraging interpersonal communication engagement.

3.3 The proposed theoretical model of Mediated Shared Space – Overall paradigm

Practical issues and theoretical gaps identified in section 3.1.1 and 3.1.2 have shown that existing theories and methods were not adequate to guide how a spatio-temporal mediated shared space could be constructed for supporting informal interaction at a distance. Specifically, the existing applications of mediated shared space were more task-specifically developed or technology driven, and thus they cannot be conceptualized as theoretical models. Similarly, literature review has shown that there is no theoretical underpinning that uses both spatial and temporal factors as grounding for the development of mediated shared space for informal interaction.

Drawing on the literature on spatial setting for informal interaction, previous applications of mediated shared space and related theories on context awareness, this study sets three objectives that a mediated shared space should obtain to enable social

context to be aware and shared among geographically distributed people. As such, informal interaction at a distance could naturally occur and common issues could be minimized. The three objectives are also used as indicators for assessing the effectiveness of the theoretical model of mediated shared space. They are:

- The sense of co-location and the sense of co-presence in the encounter stage
- The sense of co-location and the sense of co-presence in the initiation stage
- The sense of co-location and the sense of co-presence in the communication stage

In order to achieve the sense of co-location and the sense of co-presence in the three stages of informal interaction process, this research believes that if the mediated shared space has been built by the spatio-temporal approach, the spatial and temporal attributes will enable people to share the same spatial setting and interact in the same time zone, thus they will be easily "within range" (co-location) and "within reach" (co-presence) .

Within this focus, this research proposes three spatio-temporal factors that a mediated shared space should consider to achieve the sense of co-location and the sense of presence in the three stage of informal interaction. With these common issues could be minimized as mentioned in Section 3.1.1.2. These factors are: 1) Continuously Open; 2) Mutually Shared; and 3) Concurrently Convergent (Figure 15).

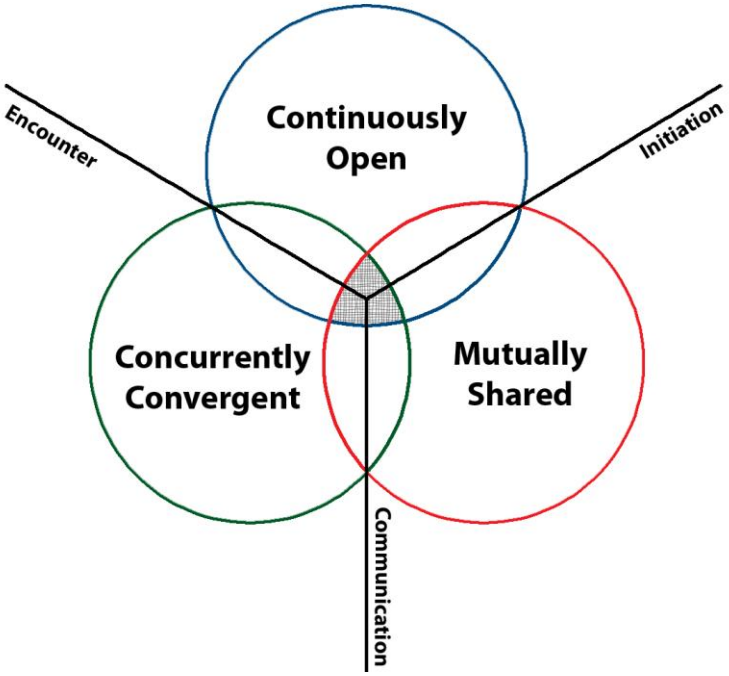


Figure 15: Theoretical model of Mediated Shared Space

3.3.1 Continuously Open

"***Continuously open***" refers to the characteristic of the mediated space that is "***open***" to facilitate people to join and interact at any time they want. As "***Continuously open***" is a spatio-temporal factor, it is constituted by a spatial factor and a temporal factor which are "*open space*" and "*continuously*" respectively.

Open space. In this study, the term "open space" refers to the common spaces in the workplace whose settings are designed in a way that allows visual accessibility across different parts of the space. As for common usage, the space is open for everyone to access e.g. lounge, pantry, cafeteria. For geographically distributed people, open space refers to the mediated space that allows accessibility of remote participants. Similar to the physical open space, the mediated spatial setting should be created with less obstruction to provide maximum visibility for geographically distributed people who access the space to be aware of each other's presence with ease. In addition, the system used to host the mediated space should be

operationally “open” so that enables remote users can login, populate and interact together.

Continuously. In this study, “continuously” is a temporal factor which refers to the condition of the space that is continuously open to facilitate people to come any time. For the mediated space, “continuously” means the system hosting the mediated space continuously operates for geographically distributed people to login anytime to interact with each other.

Why must the mediated space for informal interaction be “continuously open”?

Firstly, it is to increase the sense of co-presence through facilitating constant informal interaction as presented in the ruby model by Becker& Steele (Becker & Steele, 1995). The ruby model aims to design the workplace in a way that enables communication to occur dynamically everytime and everywhere such as on the stairs, in the hallways, at lunch, during coffee breaks. As “continuously open” makes mediated space “on” all the time, people in different time zones can access the space anytime at their convenience (unscheduled accessiblity) thus increasing the probability of people’s presence in the space at different points of time. As the probability of people in one place increase, the sense of co-presence will increase accordingly. Instead of interacting in scatterred locations as in the ruby model, an openly convergent space is provided for geographically distributed people to populate when they login, and people are brought into closer contact since they converge in one place.

Secondly, it is to ensure maximum visibility of the setting so as to provide visual contact for facilitating co-presence such as presence awareness, availability awareness, mutual awareness and engagement awareness. Specifically, in the context of the encounter stage, “continuously open” supports visual recognition and enables

participants to be aware of the presence of others who are co-located nearby, in a non-obstructive way. In the context of the initiation stage, "continuously open" allows visual access to each other's current activity to determine availability status which provides context for making interaction (Dourish & Bellotti, 1992) such as when and how to initiate the conversation or to respond to an interaction in an appropriate manner. In the context of communication, "continuously open" helps people to freely converse with each other while maintaining a visual awareness of their surroundings. They are then able to control the boundary of their conversation from privacy violation and intrusiveness. "Continuously open" also helps to establish interpersonal trust through visual contact in face-to-face meeting.

Thirdly, it is to increase high chance of encounter among participants. The freedom to access or login anytime will result in more visits to the space and a higher chance of encountering people, thus leading to more frequent informal inteaction and reducing the effort to interact due to spatial separation.

3.3.2 Mutually Shared

"Mutually shared" refers to the function of the mediated space that enables all visual information of the space including spatial and social features to be mutually seen by all participants. Spatial features include the spatial setting of the space and artifacts. Social features are social activities and people who are hanging around in the space. All "mutually shared" information is simultaneously seen by all. Therefore, the "mutually shared" function of the mediated space in a way could support "what you see is what I see" (WYSIWIS) for geographically distributed people. The spatial and temporal factors that constitute "mutually shared" are "shared space" and "mutually".

Shared space refers to the common space in the workplace whose spatial setting and spatial artifacts are designated for common usage, for example the lounge, pantry, corridor, etc. For geographically distributed people, "shared space" refers to the three dimensional space whose spatial setting "is rich with perceptual information about objects and events that can be explored and manipulated" together (Gaver, 1992). Therefore, "shared space" gives geographically distributed people "excuses to be there", "opportunities to see what's going on and to be seen in a non-intrusive way" and allows "easy switching between inward- and outward-oriented activities" (Efimova, 2010).

Mutually. In this study, "mutually" is the temporal condition that refers to reciprocal information exchange that allows the symmetric delivery of an individual's information (presence, activities) to another. According to (Harrison & Dourish, 1996), if a space supports reciprocity, it will orient people to refer to other people who are located in the space easily. In this study, "mutually" means "I can see and hear you if you can see and hear me" (Borning & Travers, 1991). As one's information is made available to the other and vice versa, this facilitates co-presence awareness in the three stages of informal interaction. In mediated space, "mutually" enables information of the space to be distributed at the same time over the internet to geographically distributed people. Therefore, the information of each other's presence in the space is also simultaneously distributed to those who are logged in, thus among those who are logon thus enabling co-presence awareness among them.

Why should the mediated space for informal interaction support "mutually shared"? Firstly, "mutually shared" allows reciprocal information exchange that symmetrically delivers an individual's information (presence, activities) to another. In other words, "mutually shared" enables one's information to be available to others and vice versa, thus reducing the effort to be aware of each other's presence and increasing mutual trust among each other.

Secondly, because people are physically located at a distance, their presence in the mediated space must be mediated through embodiments. As co-presence is the feeling that the people who are mediated by the embodiments actually exist and are active, therefore, the more the sharing of an individual's actual information with others, the more the sense of co-presence will be experienced.

3.3.3 Concurrently Convergent

"Concurrently convergent" refers to the function of the mediated space that enables people coming from different geographical areas to concurrently meet together in a common place. By being co-located at a place, people are in close proximity to each other thus co-location puts people who have the need for communicating in each other's presence and renders people mutually accessible for contact (Zhao & Elesh, 2008). "Concurrently convergent" is constituted by two spatio-temporal factors: "convergent space" and "concurrently".

Convergent space refers to the common space in the workplace that provides a rationalized setting that enables people to frequently come, populate and make casual conversation in this setting. Examples of convergent spaces in the workplace are pantry, printing room, cafeteria etc whose spatial artifacts (good food and drinks; public shared services) and spatial activities act as catalysts to attract, encourage and draw people to come, stay and converse. For geographically distributed people, convergent space refers to the mediated space that shortens the distance among geographically distributed people thus enabling them to be co-located even if they are living in different time zones.

Concurrently is defined in the Oxford Dictionary (Dictionary) as "taking place at the same time or the same location" or "occurring or existing simultaneously". In this study, "concurrently" is a temporal condition that indicates the possibility of being simultaneously present in a location. For geographically

distributed people, "concurrently" facilitates people scattered in different time zones to be able to access and populate the mediated space at the same time. By being concurrently present in one place, the sense of co-presence among them increases, thus also increasing the probability of chance encounter.

Why should mediated space for informal interaction support concurrently convergent? Firstly, being concurrently convergent is also being co-located as people are present at the same time in the same location. When people are co-located they are in close proximity to each other. Proximity is defined by Harrison & Dourish (Harrison & Dourish, 1996) as a property of space whose spatial relationship relates people to each other as well as to each other's activities. According to Nova (Nova, 2005), close proximity helps to maintain social awareness as it is easier for people to pick up information of each other's presence and current activities. As such, close proximity reminds one the existing of each other's presence when they are co-located thus increasing the chance for encounters to take place. It also puts people who have the need for communicating in the range of each other's presence thus facilitates people to pick up and "access to each other's availability for communication" and provides "a channel to signal intent for communication" (Kraut et al., 2002) in the initiation stage. As people are able to mutually access to each other's presence thus it is easy to stimulate conversation engagement and establish common ground due to the conversation utterance delivered and received simultaneously (Clark & Brennan, 1991; Kraut et al., 2002).

Secondly, mediated space is created based on spatial metaphor which contains the information about the spatial structure and social context. When geographically distributed people are co-located, this information is consistent to everyone thus providing a sense of spatial connectivity that connects each individual's spatial perception together to become a common shared space. The sense of spatial connectivity, in this way, supports visual continuity across different parts of the space

thus focusing attention and diminishing visual distraction when recognizing each other's presence. This concurrent convergence function could be used as a ruby model of informal interaction in physical space as mentioned in section 2.1.5 that brings people into closer contact and facilitates interaction with their remote colleagues in terms of intended, spontaneous and unplanned informal interactions whenever they login.

Thirdly, a convergent space that is designated for informal interaction could act as a place where people encounter a range of cognitive (mental) and physical (corporeal) performance that make their interaction more meaningful (Holloway & Hubbard, 2001).

3.3.4 Summary

The theoretical model of Mediated Shared Space has been proposed with three spatio-temporal factors. The factors and their spatio-temporal characteristics are summarized in Table 9.

Model factors			Characteristics
Continuously Open	Time	Continuously	Continue in time
	Space	Open Space	Space that provides maximized visibility and is accessible by anyone
Mutually Shared	Time	Mutually	Reciprocal information exchange in time
	Space	Shared space	Space that allows everyone to explore and manipulate together and enables their information to be shared among each other.
Concurrently Convergent	Time	Concurrently	Happening at the same time
	Space	Convergent Space	Space that enables people to be co-located

Table 9: Summary of spatio-temporal characteristics provided by the model factors

These three factors have been identified to support the sense of co-location and the sense of co-presence in the three stages of the informal interaction process, namely encounter stage, initiation stage and communication stage. The relationships between the model factors and the three stages of informal interaction are recapitulated in Table 10, Table 11 and Table 12.

	Continuously Open
Encounter Stage	- Provide maximum visibility for presence awareness - Provide maximum accessibility for high chance encounter
Initiation Stage	- Provide visual accessibility for availability awareness and mutual awareness
Communication Stage	Provide visual contact for engagement awareness and trust

Table 10: "Continuously open" factor and the three stages of informal interaction

	Mutually Shared
Encounter Stage	- Enable information sharing for presence awareness and identification
Initiation Stage	- Enable mutual accessibility to each other's actual information for availability awareness and mutual awareness.
Communication Stage	- Enable mutual recognition for mutual trust among each other

Table 11: "Mutual shared" factor and the three stages of informal interaction

	Concurrently Convergent
Encounter Stage	- Enable people to be co-located for presence awareness and identification. - Provide a sense of spatial connectivity for focalized attention thus enhancing chance encounter
Initiation Stage	- Provide close proximity for mutual awareness
Communication Stage	- Provide close proximity for stimulating conversation engagement.

Table 12: "Concurrently convergent" factor and the three stages of informal interaction process

3.4 Mediated Shared Space – Constructing mediated spatial settings

Figure 15 in section 3.3 provided an overview paradigm of the theoretical model of Mediated Shared Space whose spatio-temporal factors should be taken into account when creating a mediated space for supporting informal interaction. Figure 16 shows a more detailed version of this model in which each factor of the theoretical model is constructed by the possible solutions of the mediated spatial setting that are categorized by the degree of continuous opening, mutual sharing and concurrent convergence.

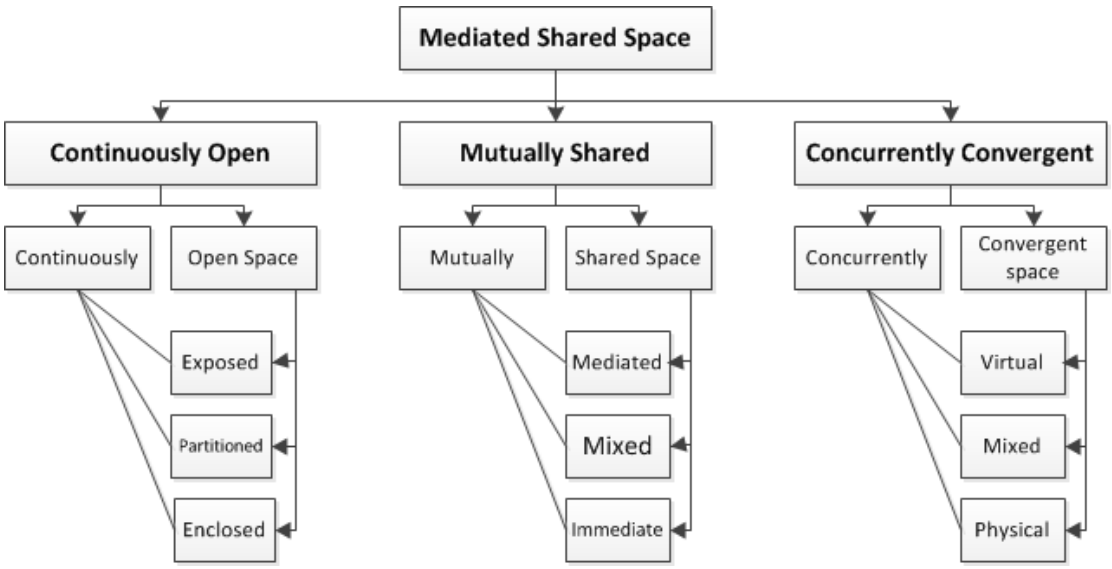


Figure 16: Detailed model of mediated shared space with specific types of mediated spatial settings

3.4.1 Mediated Shared Space for Continuously Open

In the workplace, the spaces for informal interaction are often created in an open manner that could maximize visual contact for those who are currently present in the space so that they can encounter their partners with ease. In mediated space, this condition is still appropriate and applied. However it is not fully dependent on the space content and perception but more influenced by the right to access the space. The degree of opening spreads along a continuum on which three types of mediated settings could be formed: 1) exposed space; 2) partitioned space and 3) enclosed space. Exposed space and enclosed space are the two extremes of the degree of opening continuum that shows the level of accessibility across the space boundary. Although there are different types of mediated settings for continuous open, participants who have the access right are allowed to access any time as this space is continuously open for them.

1) For exposed space, the mediated setting allows everyone to participate at anytime. There is no access restriction applied to participants. This mediated

setting supports the highest chance encounter as people could access anytime they want. As explained in Section 3.3.1, if the probability of people being in one place increases, the sense of co-presence will increase accordingly. This type of mediated setting is suitable for social interaction where privacy and trust are not taken into account.

2) For partitioned space, the mediated setting only grants access to a group of people who have certain relationships such as belonging to a community, working together in a company or participating in an event (e.g. virtual conference). The reason for this access restriction is that these groups of people need a certain level of privacy and trust when they interact with each other. In this case, the mediated setting could allow visual accessibility to a certain degree but only allow spatial accessibility to those who have the access right. Therefore, participants who are granted access could freely participate in the space anytime and the probability of chance encounters occuring for them is high.

3) For enclosed space, the mediated setting is restricted accessibility to everyone. People who would like to access must make a request to the administration. This type of mediated setting is not suitable for social space but more appropriate for groups that need a high level of privacy and who do not wish to be disturbed by outsiders.

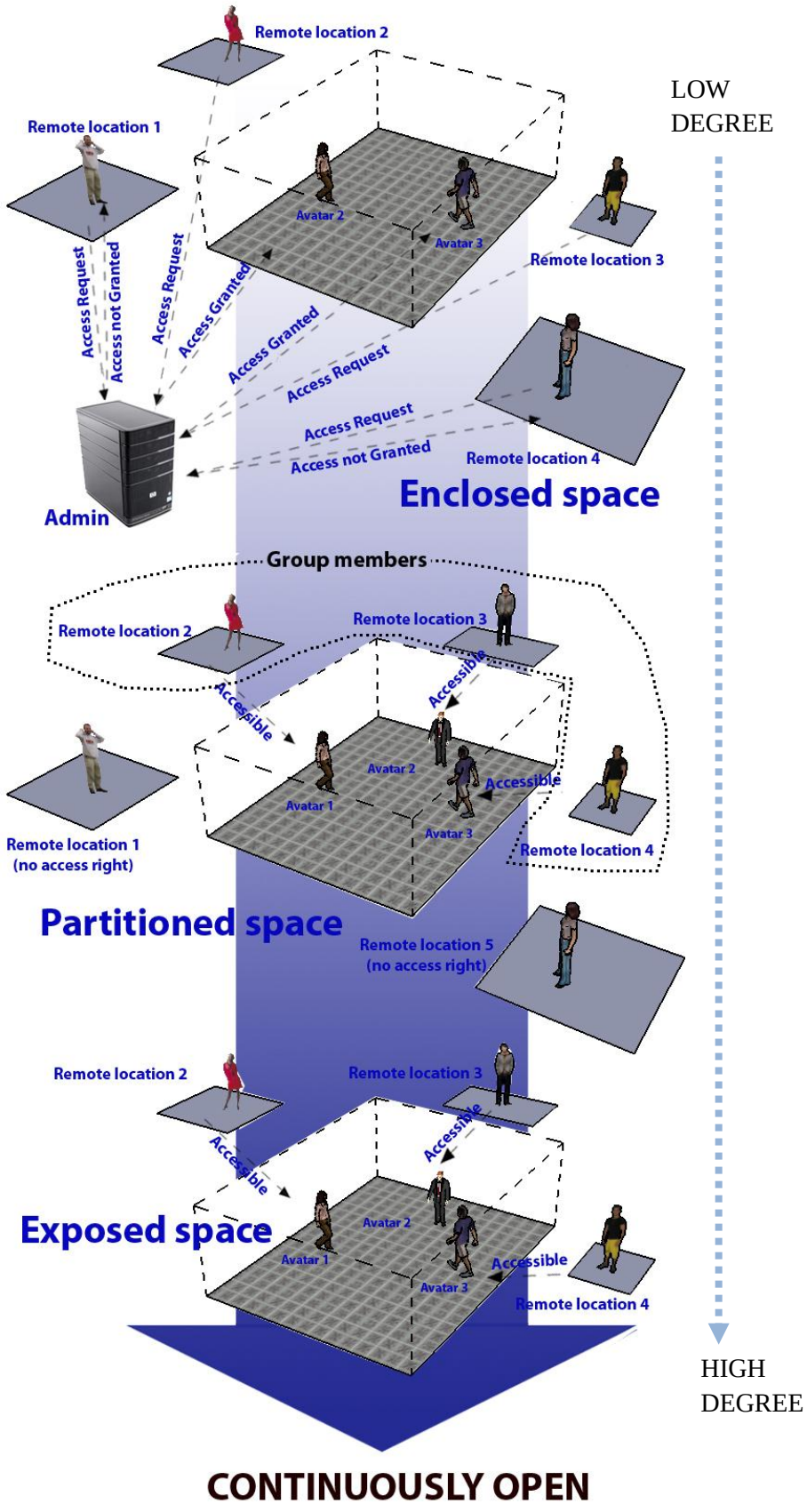


Figure 17: Spatial setting for continuously open

3.4.2 Mediated Shared Space for Mutual Sharing

In physical space, people are immediately aware of who are around and what is happening in the space as all information is exposed to them. As such, they are able to be mutually aware of each other when they are co-located. However, when people are at a distance, being mutually aware of each other in a physical space is impossible. They are only able to do so through technology mediation. The degree of sharing for mediated settings spreads along a sharing continuum on which three types of mediated spaces for mutually sharing could be formed: 1) mediated sharing; 2) mixed sharing and 3) immediate sharing. On the sharing continuum, mediated sharing and immediate sharing are the two extremes that show the status of indirect sharing and direct sharing, respectively.

1) For mediated sharing, actual information of every remote space is not shared among each other but is mediated through a virtual space in which participants and the spatial space are computer-generated representatives of the real ones. In this way, people of one space and not the actual information. As the information of people is mediated, their actual activities may not be reflected. For example, the embodiments may still be present in the virtual space but the actual people may not be there.
2) For mixed sharing, the actual information of one or more spaces is exposed while information of the remaining spaces is mediated. Mixed sharing can be done through two ways: 1) through the combination of video-based and virtual technologies: video-based technologies share the actual information of remote spaces while the virtual space shares the mediated information; 2) through the combination of physical space and mediated artifacts and embodiments of remote artifacts and people.
3) For immediate sharing, the actual information of every space is shared and therefore, everyone can immediately see what is happening in all other

spaces, such as, who is around and what they are doing. Immediate sharing can be done through the integration of multiple media spaces in which each shares the real scene of one remote space.

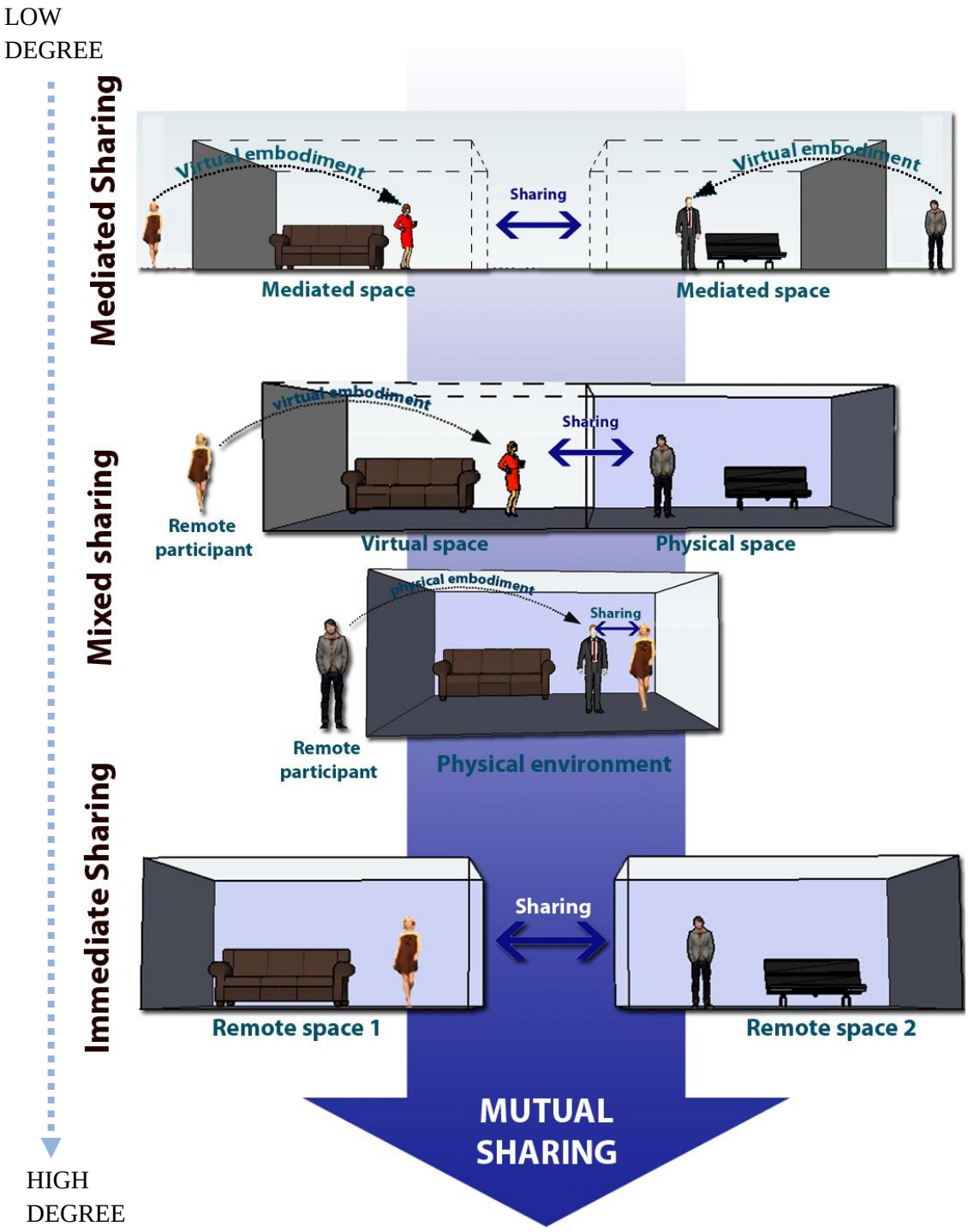


Figure 18: Spatial settings for mutual sharing

3.4.3 Mediated Shared Space for Concurrent Convergence

In the physical environment, as mentioned in section 2.1.4, the reason for people to converge in a space is because of the features offered by the space or the spatial stimuli such as good food and drinks, common services, etc. In mediated space, these features could be made as virtual features. However, they may not attract people to join the space as these features are not real and can only be seen but not used like the real ones. Mediated shared space should focus on having features that facilitate visual attraction that would bring participants frequently into a space and stay there. This study argues that the visual attraction for informal interaction in mediated shared space is co-presence. By being aware that the remote partners are present in the same space, people could be attracted by opportunistic and spontaneous conversations. This is the space to be if they need to talk with a certain party about a particular topic, or if they hope to bump into someone that they have not met for some time. Knowing that they could meet their friends in this space could be the draw for subsequent intended interaction or frequent intended interaction. When people are at a distance, they are only able to be convergent through a mediated space or a physical space with mediated features, therefore, this study categorizes mediated spaces that allow geographically distributed people to be concurrently convergent along a continuum on which three types of mediated spaces may be formed: 1) virtual reality space, 2) space with mixed reality boundary and 3) physical reality space. On the continuum, virtual reality space and physical reality space are the two extremes.

1) For the mediated space with virtual reality boundary, the spatial setting is created as a 3D virtual space in which remote people could be convergent by logging in. As people appear as graphically humanoid embodiments called avatars they could be aware of those who are co-located.
2) For mediated space with mixed reality boundary, the spatial setting is created with the combination of both physical setting and computer generated

features of the spatial setting. There are two types of mixed reality boundary: 1) virtual space embedded with real-time image of the physical space; 2) physical space extended with virtual space. The first type of mixed reality space supports the feeling of being convergent with participants of the virtual space (avatars) and the real people appearing in the real-time video. In the second type, real-world participants could meet their remote friends through the extended virtual space in which remote people populate as avatars. The degree of mixing between virtual and physical features is varied in this type, e.g. more virtual and less physical or more physical and less virtual. Therefore, a variety of mixed spaces could be created in this type of mediated shared space.

3) In the physical space, remote people could be convergent with real-world people through tele-presence such as being represented as physical embodiments e.g. robots, human-like sculptures or holograms.

Figure 19 shows the three types of mediated spatial settings for concurrent convergence. The settings are placed based on the degree of supporting convergence for remote people.

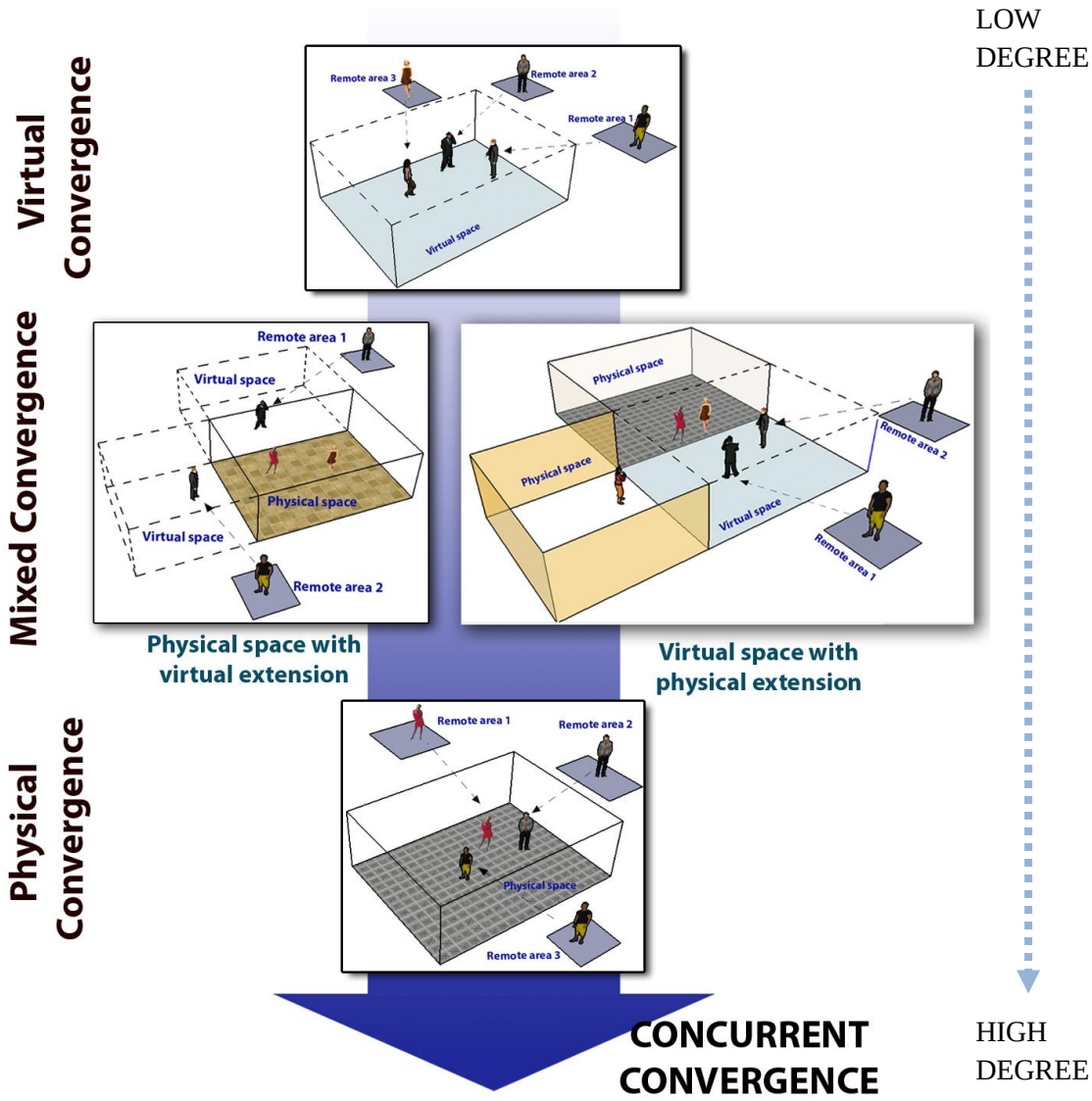


Figure 19: Spatial settings for concurrent convergence

3.4.4 Constructing Mediated Spatial Settings based on the Theoretical Model

Sections 3.4.1, 3.4.2 and 3.4.3 have identified different types of mediated spatial settings based on the degree of concurrent convergence, continuous opening and mutual sharing. As different factors consist of different types of mediated spatial settings, there are a variety of instances of Mediated Shared Space that could be formed from the three categories. Figure 20 shows the possible combinations of

instances of Mediated Shared Space. Although each factor is illustrated with three different instances, the number of instances of Mediated Shared Space created from these three factors could be more than 3x3x3=27 instances. This is because the mediated settings out of the two extremes of each factor is not just one instance but could vary along the continuum between the two extremes. For example, the mediated setting of partitioned space of continuous opening factor could vary depending on the degree of exposing the space content to the participants. Specifically, it depends on the degree of opening of spatial boundaries as well as the degree of the accessibility rights.

The ideal Mediated Shared Space that could achieve the highest level of support for informal interaction will be the one whose components are the mediated setting that are located at the highest extreme of the continuum. In this space, computer agents will look and act like humans to evoke a rich sense of co-presence that resembles the real life corporeal co-presence.

An example of how an instance of Mediated Shared Space is formed is illustrated in Figure 21. Specifically, a mediated setting from each factor of the theoretical model is selected to form the mediated shared space. In this case, the three selected mediated settings are virtual convergence, enclosed space and mediated sharing. Based on the available mediated shared space technologies presented in Chapter 2, 3D virtual space is more suitable to represent this type of mediated shared space as:

- The space allows remote participants to virtually converge as if they are co-located.
- The space is enclosed as it only allows those who are granted the access right to enter the space.

- The space allows participants to represent themselves to each other through the use of virtual embodiments or avatars with which participants could have a sense of co-presence and are able to interact with each other.

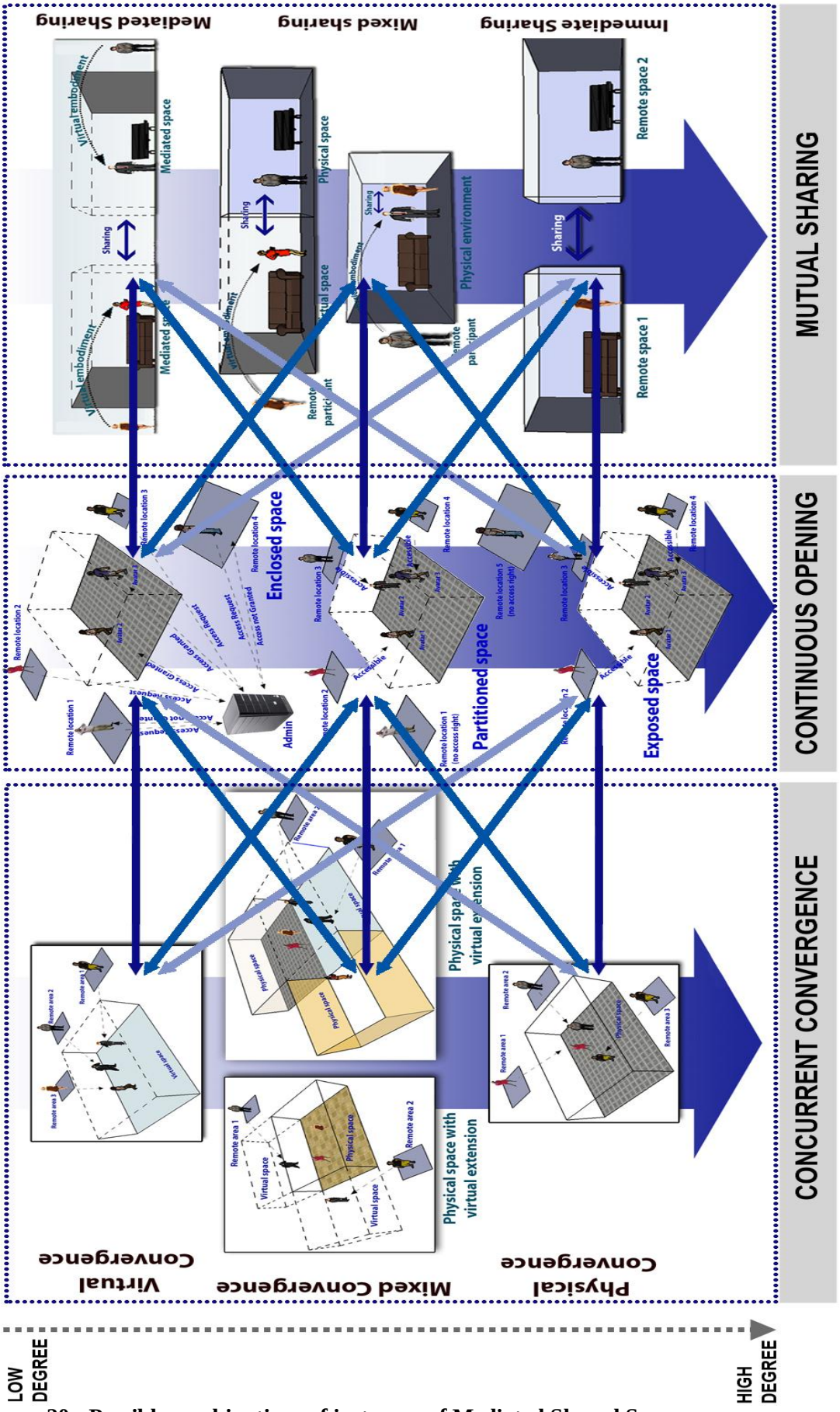


Figure 20: Possible combinations of instances of Mediated Shared Space

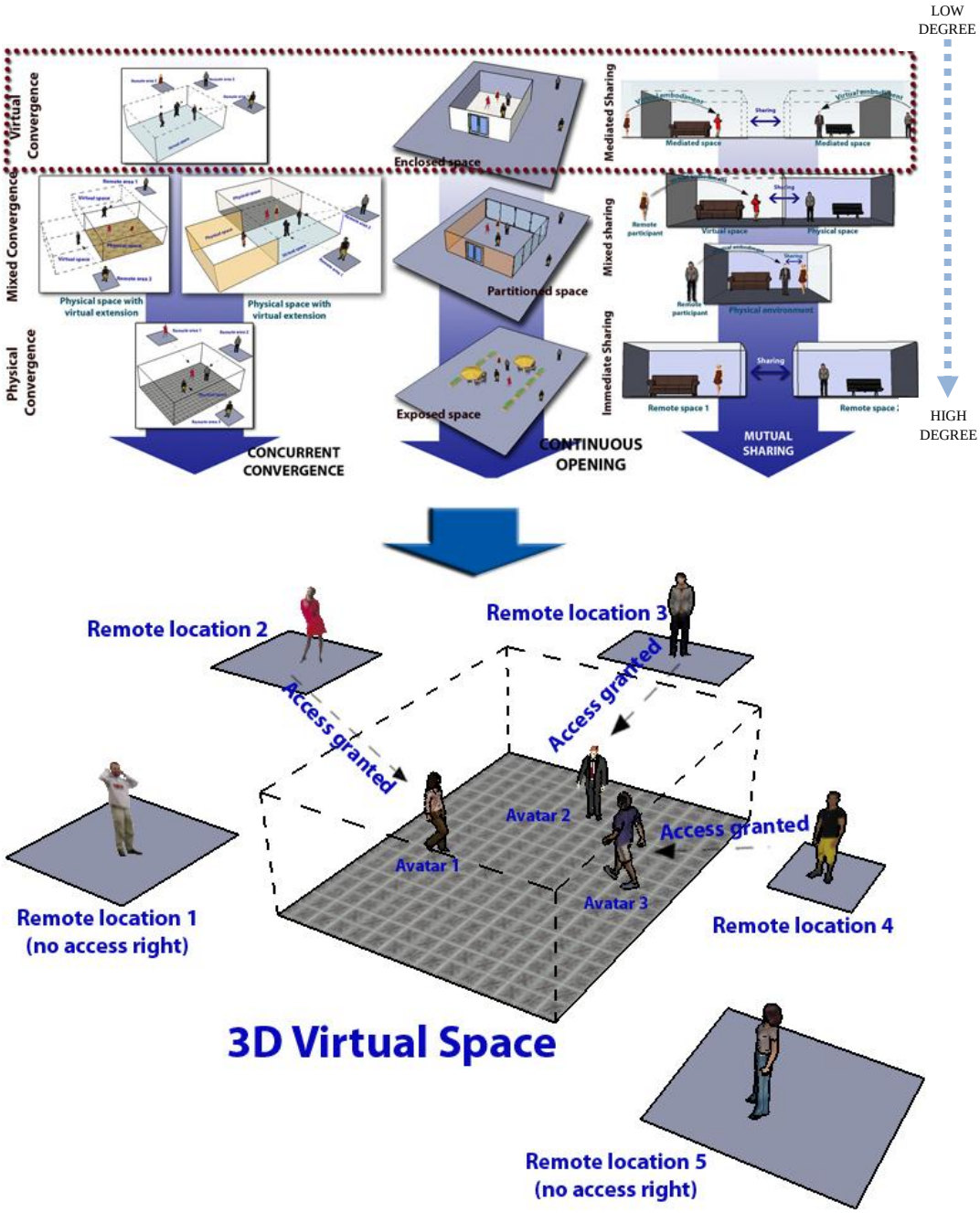


Figure 21: An example of forming an instance of Mediated Shared Space from the three factors of the theoretical model

3.5 Discussion

The theoretical model of Mediated Shared Space for supporting informal interaction at a distance has been conceptualized and developed based on the theoretical literatures of spaces for informal interaction and the gaps of practical case

studies which are the technical systems or prototypes that had been developed for supporting informal interaction at a distance. As the model of Mediated Shared Space is just a theoretical framework, it needs to be constructed with definite components in order to be implementable. Section 3.4.4 has shown the way to construct Mediated Shared Space by combining possible spatial settings that are derived from each factor of the theoretical model. There are multiple instances of Mediated Shared Space that can formed and their degree of supporting informal interaction are varied. Chapter 4 will explain the method and process to evaluate the prototype and then Chapter 5 will describe the technical method of how to implement the prototypes of Mediated Shared Space for the evaluation process.

CHAPTER 4
METHODOLOGY

A theoretical model of Mediated Shared Space was proposed in chapter 3 to support better co-presence and co-location in the three stages of informal interaction at a distance. This chapter introduces the research method which is comparative experimental design to evaluate the effectiveness of the proposed theoretical model. This chapter has four parts. The first part describes the experiment design including treatment design, population and sampling, group design and task, and gives an overview of the experiment. The second part introduces the experiment variables used to measure users' feedback and the process of preparing the experiment questionnaire for collecting data. The third part elaborates how data was collected and analyzed. The last part highlights the constraints and scope of the methodology.

4.1 Experiment design

In order to evaluate the effectiveness of the proposed model of Mediated Shared Space, a comparative experimental design method was chosen to compare the effectiveness of supporting co-presence and co-location between the two instances of the theoretical model. As shown in Chapter 3, there are many instances of the Mediated Shared Space that could be created from the three factors of the theoretical model from lowest degree to highest degree. In this experiment, two instances were

selected as two experimental treatments. One instance represents a mediated shared space with lower spatio-temporal degree. It also represents an existing type of mediated shared space that does support the sense of co-location and co-presence, to some extent. Another instance was created with higher spatio-temporal degree than the first one. The purpose of the experiment method selection was to test the research hypothesis that *the existing virtual spaces have low degrees of supporting informal interaction. The higher degree of any factor of mediated shared space, the higher the sense of co-presence and co-location supported.*

The first experimental treatment was created by combining virtual convergent space, partitioned space and mediated sharing space. In this experiment, a 3D virtual space was chosen to represent the first treatment as it allows virtual convergence among distant people, allows mediated sharing through avatars and is constructed with an enclosed boundary that isolates avatars from real-life people. Figure 22 illustrates how the first treatment of the experiment was created.

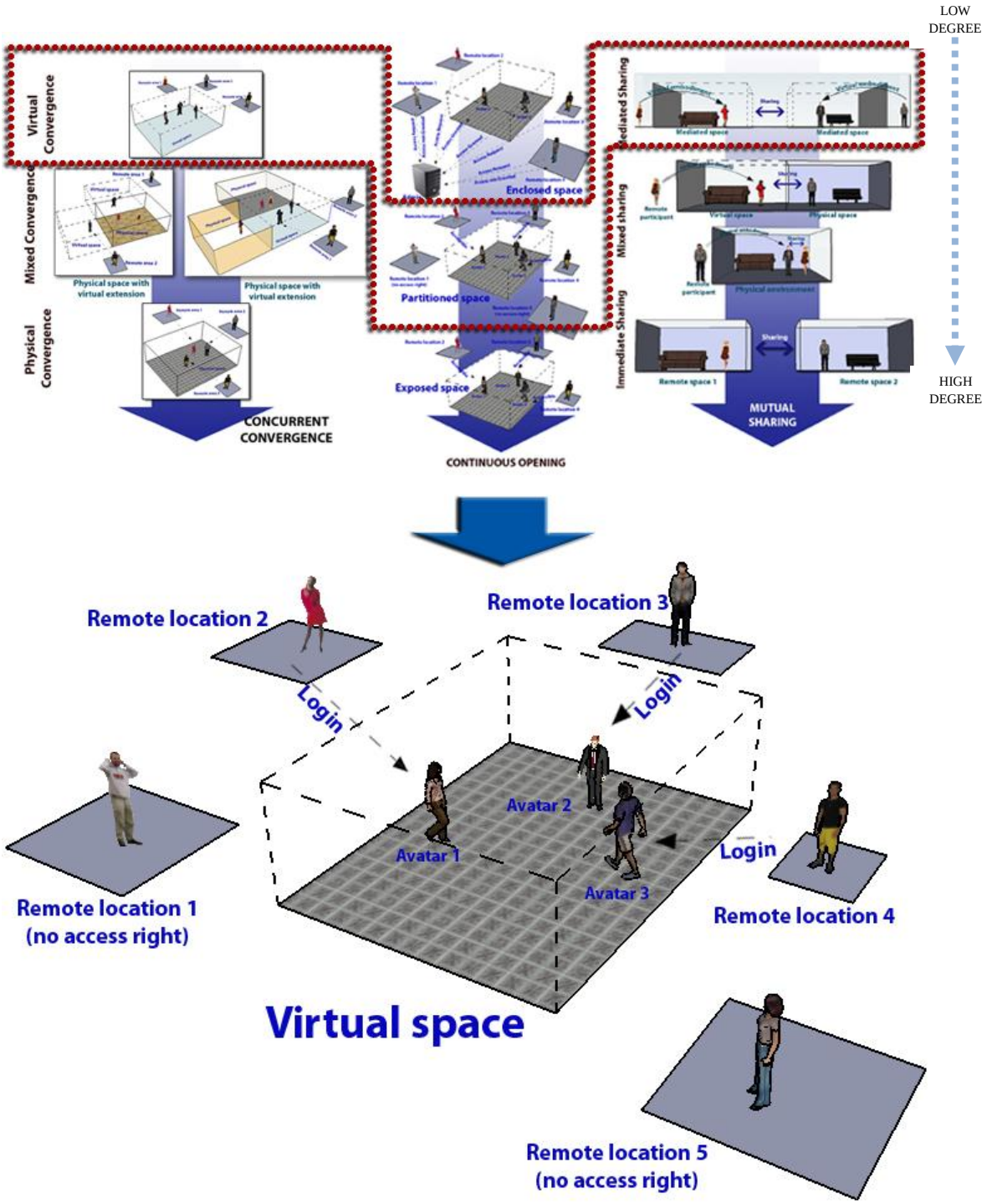


Figure 22: Constructing the first treatment of the experiment - Virtual CASA

The second treatment was created by combining mixed convergent space, partitioned space and mixed sharing space. In this experiment, a mixed reality space was chosen to represent the second treatment. It was created as a mixture of virtual space and physical space in which the virtual space is the extension of the physical

space and, conversely, the physical space is the augmentation of the virtual one. Figure 23 shows how the second treatment of the experiment was formed from the three factors of the theoretical model.

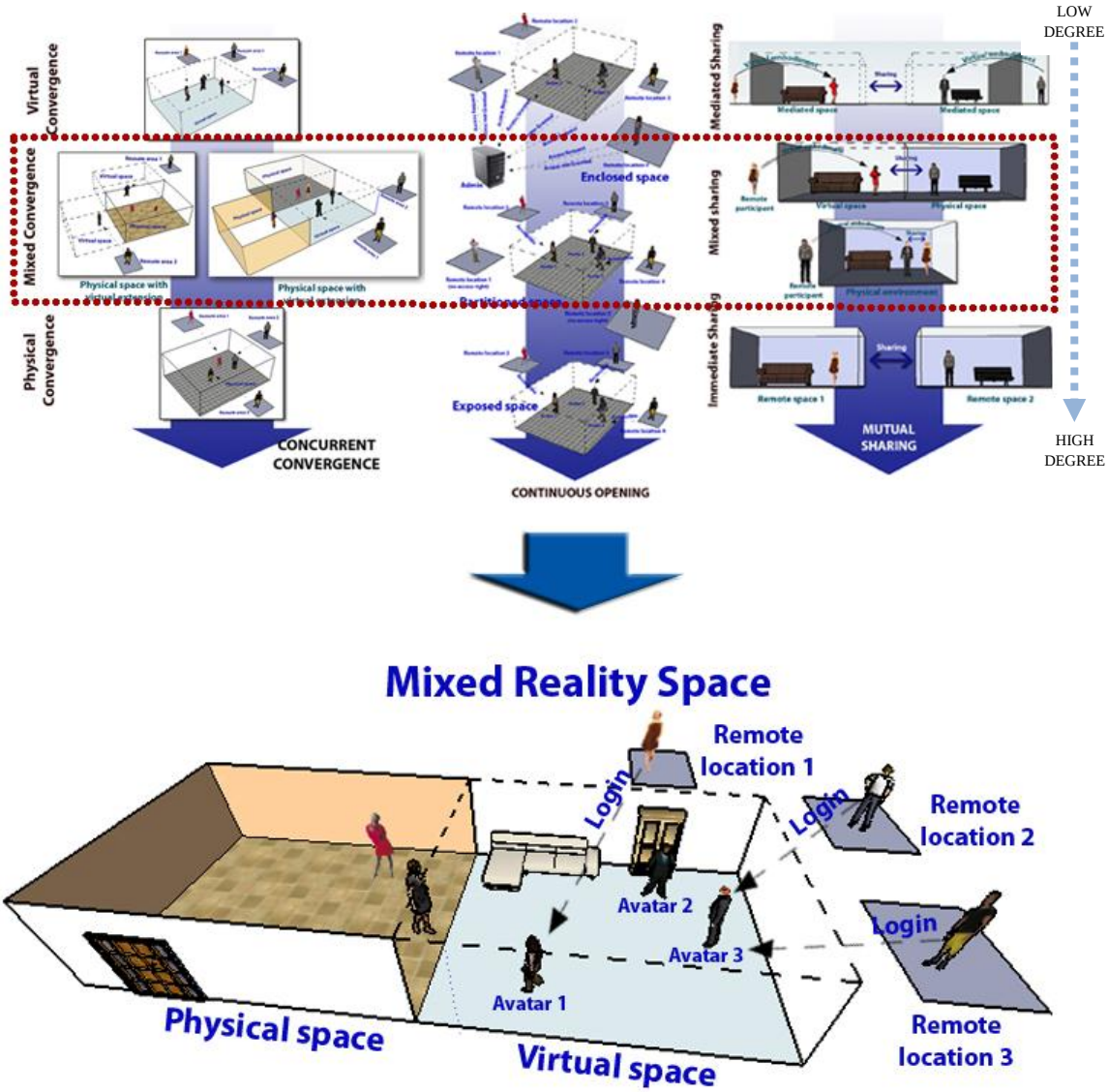


Figure 23: Constructing the second treatment of the experiment – Mixed Reality CASA

The experiment case study was implemented in Centre for Advanced Studies in Architecture (CASA) which is a research office at the school of Design and Environment, National University of Singapore. The study population is CASA's

current residents and alumni. They were invited to do the same interaction on both platforms. The two platforms are:

1) A virtual space called Virtual CASA which is a normal Collaborative Virtual Environment (CVE) created as a 3D virtual representation of CASA. (Figure 24)
2) A mixed reality space called Mixed Reality CASA which is a mixture of 3D virtual space extended with real-time video of real CASA and vice versa (Figure 25).

After the experiment, feedback was collected using a mixed method of questionnaire and informal interview. The collected data was analyzed to investigate the difference in the dependent variables for each platform through which the effectiveness of the proposed model could be specified. The experiment design is elaborated in details in the following sections.

Figure 24: Virtual CASA

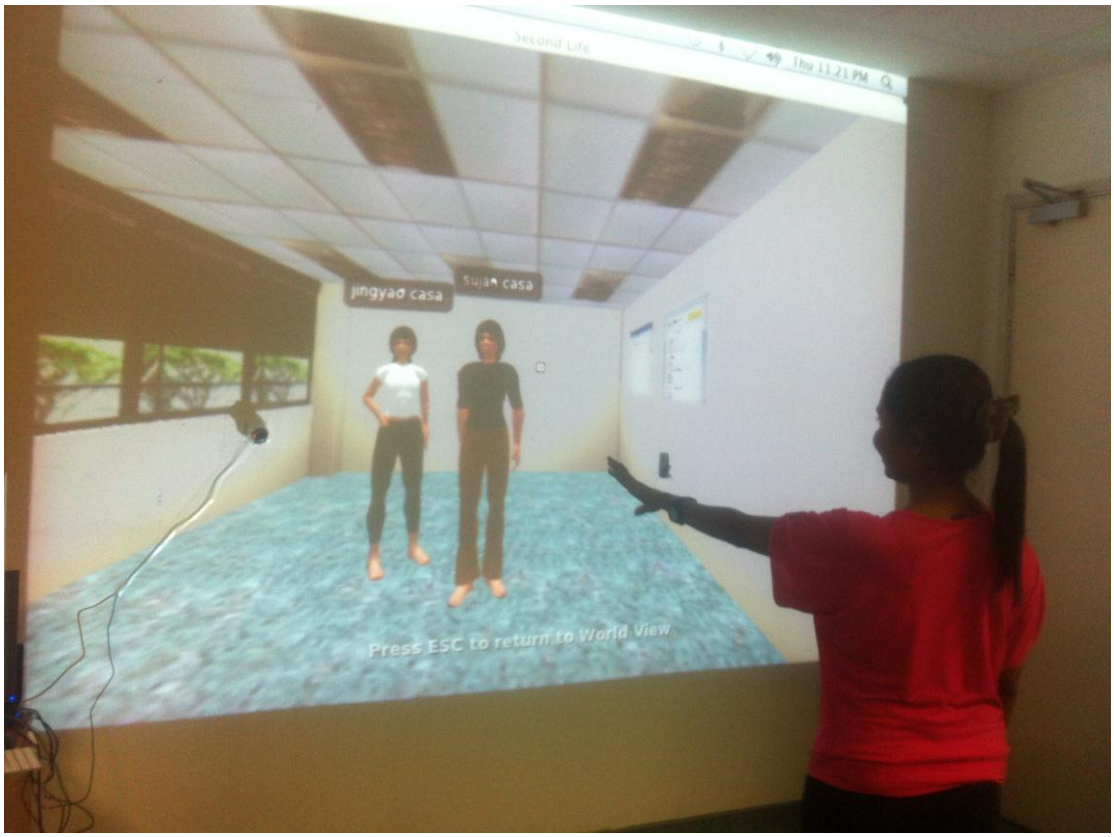


Figure 25: Mixed Reality CASA (physical space and virtual space)

4.1.1 Treatment design

In order to compare the effectiveness difference of the two platforms, CASA members were invited to try out, in turn, the two experimental spaces: Virtual CASA and Mixed Reality CASA.

In the experiment with Virtual CASA, all participants were asked to experience a virtual environment of CASA in which they could login and appear as graphical humanoid embodiments called avatars through which they are able to communicate with others using text chat or voice chat. The virtual CASA environment offered navigation possibility that enabled avatars to navigate so that they could encounter and make conversation with others.

The same participants were then asked to try the Mixed Reality CASA as remote participants. The population size in CASA is small. Hence, in order to increase the sample size, some of the current local CASA residents had to play two

roles in this experiment: local CASA residents and remote people. Figure 26 illustrates how the participants were arranged for different experimental tasks.

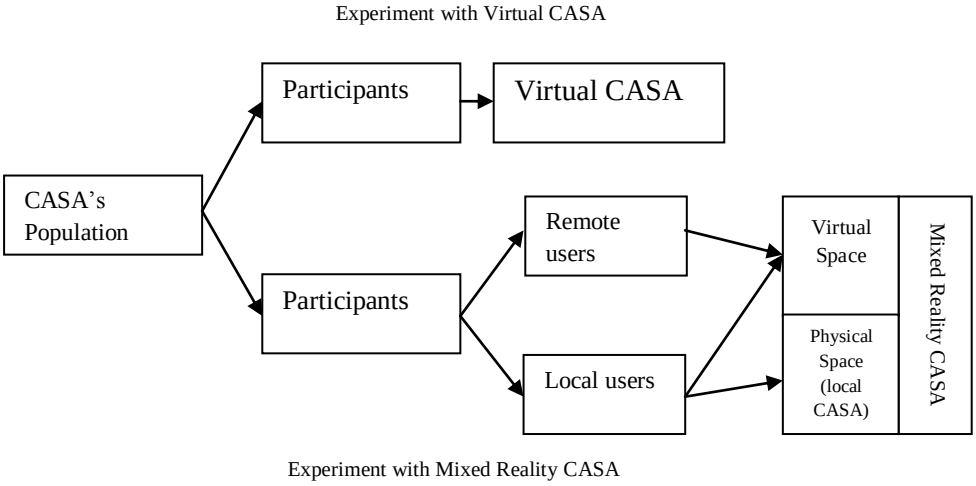


Figure 26: Experiment design

4.1.2 Population and sampling

The target participants of Mediated Shared Space are people who know each other such as co-workers in a workplace. Knowing each other is very important for trust and observing privacy in informal interactions. Specifically, trust is a criteria for sharing information and making new relationships (Kumar, 2010; Licoppe, 2004) and privacy is a societal criteria to indicate that "people feel most comfortable to interact informally when they can control the boundaries of their conversation" (Fayard & Weeks, 2007). In this experiment, the students of CASA who are current students and alumni were selected as experimental participants. They could be considered as co-workers since they have been working together in CASA for a long time, thus, they know each other quite well even though some of them have graduated. A total of 25 CASA students and alumni participated in the experiment. Among them, 13 participants are current CASA residents while the other 12 participants are alumni who graduated recently.

4.1.3 Experimental phases and group tasks.

There were two main phases in the experimental process: construction phase and evaluation phase. Each phase was divided into sub phases corresponding to the particular tasks that the group had to do. Table 13 elaborates the group tasks in each phase of the experiment followed by the result/outcomes of the sub phase. The specific instructions on how to implement each task are described and illustrated in Appendix A.

	Experiment phases	Participants		Group tasks		Results/outcome
Construction phase	Preparation (4 months)	Researcher		Setup the system Operate the system Prepare the structure questionnaire and informal interview question Work as moderator		Basic construction of experiment platform Preliminary of questionnaire prepared
	Pilot experiment (2 months)	15 participants		Test the system's functioning robustness and usage Test the questionnaire to see if it is understandable		Updated experiment system Updated questionnaire
Evaluation phase	Main Experiment 01 **Evaluating the Virtual CASA** (2 weeks)	25 participants	13 Overseas users	Install the system in their computer (laptop) Login to experience the system (encounter, approach partner and communicate) at any time in their convenience within 2-week stimulated timing (Must login at least twice). Complete the **online questionnaire** after finishing the 2-week Virtual CASA experiment.		End users experience data (Filled questionnaire)
			12 Singapore users	Install the system in their computer (laptop) or **using the pre-installed system** in moderator's laptop Login to experience the system (encounter, approach partner and communicate) at any time in their convenience within 2-week stimulated timing. (Must login at least twice). Complete the online questionnaire after finishing the Virtual CASA experiment.		End users experience data (Filled questionnaire)
	Main Experiment 02 **Evaluating the Mixed Reality CASA** (2 -week frame together with experiment 1)		25 Remote participants	Overseas participants	Experience the Mixed Reality CASA at the same time experiencing CVE. (Must login at least twice). Complete the online questionnaire for Mixed Reality CASA right after the 2-week stimulated time. Answer the interview question through skype or yahoo message	End users experience data (Filled questionnaire and audio recording of their interview answer)
				Singapore users	Experience the Mixed Reality CASA at any available time during 2-week. (Must login at least twice). Complete the online questionnaire for Mixed Reality CASA after the 2-week stimulated time.	
			11 CASA residents	Communicate with avatars Complete the online questionnaire for the local users Answer the interview question Swap with remote participants to act as remote participants		End users experience data (Filled questionnaire and audio recording of their interview answer)

Table 13: Overview of experiment

4.2 Experiment variables and questionnaire

The term "*social context*" represented by the sense of co-location and the sense of co-presence in informal interaction is a broad concept. In order to measure it, an operationalization process is required which converts the broad concept to indicators and then a set of variables corresponding to each indicator (Kumar, 2010). As mentioned in Section 2.3.3, co-location is a prerequisite for co-presence therefore the measurement of co-presence covers the measurement of co-location. This part elaborates the way indicators were derived from the sense of co-presence, then how experiment variables were developed from each indicator and later how the user's survey questions were formulated. Figure 27 shows the operationalization process of converting the concept of sense of co-presence in informal interaction into indicators and then to dependent variables.

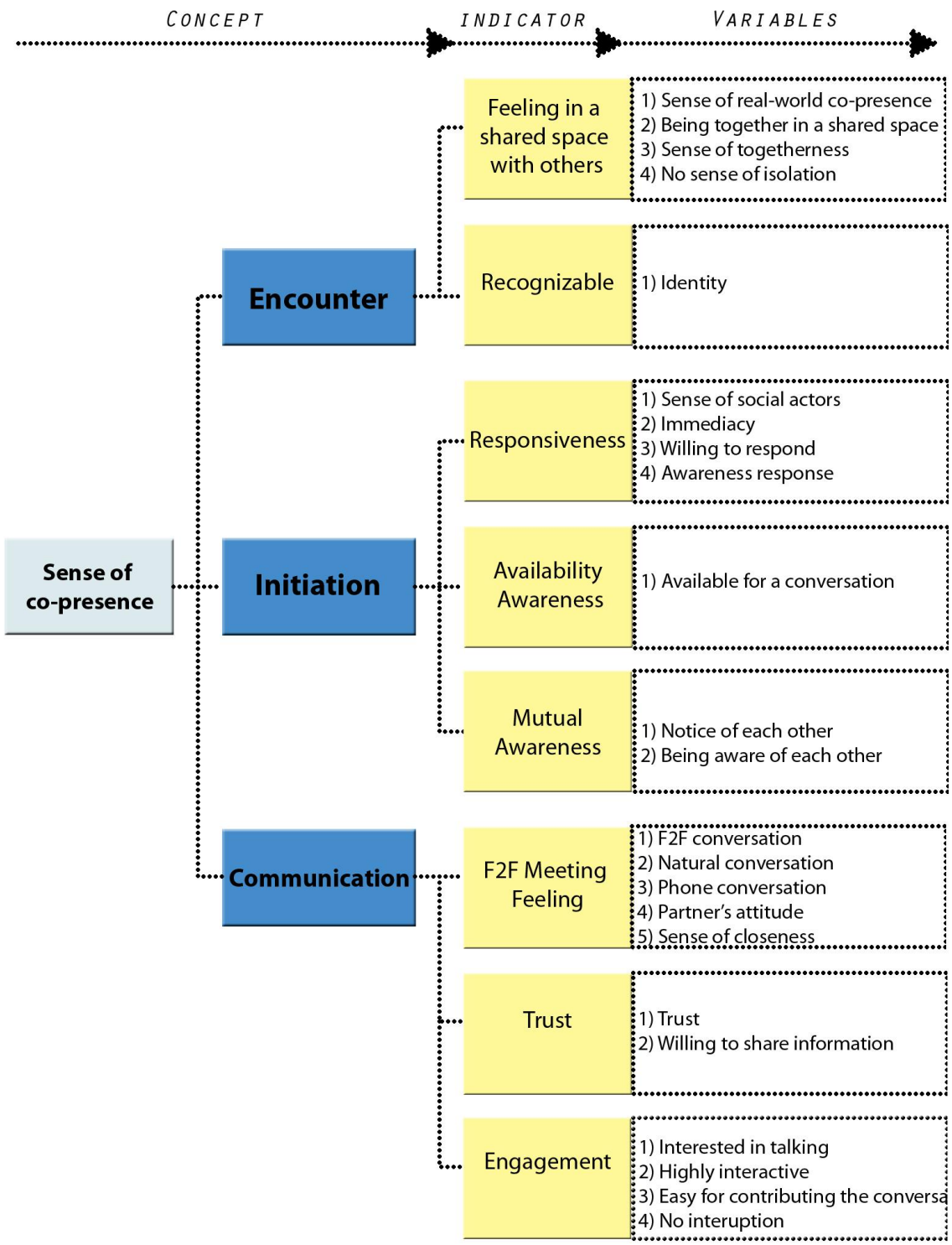


Figure 27: Operationalization process of converting the concept of sense of co-presence into indicators and dependent variables

4.2.1 Dependent variables

Dependent variables are used to measure the difference when the independent variables are manipulated. According to the study hypothesis, changes of mediated spaces will result in changes to the sense of co-presence in three processes of informal interaction at a distance**.** This study will measure the difference of sense of co-presence awareness supported by the two spaces Mixed Reality CASA and Virtual CASA. Therefore, variables used to measure the sense of co-presence awareness in the three processes are dependent variables.

4.2.1.1 Sense of co-presence in the encounter stage

There are two indicators that are identified as conditions for the sense of co-presence when people encounter each other in a shared space: 1) Feeling in a shared space with others and 2) Recognizable. The two indicators were derived from the research of supporting encounter in informal interactions among remote people in which the two indicators are the most concerned factors that have been taken into account in developing the supporting systems (Isaacs et al., 1997; Karahalios, 2009; Willis et al., 2010).

The first indicator for "feeling in a shared space with others" was constructed by four variables adapted from the experiment of Ho et al (Ho et al., 1998) on the sense of being together and the experiment of Slater et al (Slater et al., 2000) on co-presence. The second indicator "recognizable" is about the identity of the remote parties thus its variable is the extent to which the remote parties are recognized through the mediated system. Table 14 lists the indicators, variables, and corresponding questions to measure co-presence in the encounter stage.

Indicators	*Response Variables*	*Questionnaire*	*Scale*	*Informal interview question?*
Feeling in a shared space with others	Sense of real-world co-presence	Please rate how closely your sense of being together with others in a real world setting resembles your sense of being with them in Virtual CASA (Mixed Reality CASA) (Ho et al., 1998)	1.Not at all… 7. Very much	Interview questions are only used for clarifying research findings. e.g. What was your feeling when you encountered remote people in this space?
	Being together in a shared space	To what extent, did you have a sense of being in a shared space with your colleagues through avatar appearance (CASA folks) (Slater et al., 2000)	1.Not at all… 7. Very much	
	Sense of (togetherness) co-presence with more than one person	To what extent, did you have the sense of the other two people being together with you? (Ho et al., 1998)	1.Not at all… 7. Very much	
	No sense of isolation	I often felt as if I was all alone (Slater et al., 2000)	1.Not at all… 7. Very much	
Recognizable	Identity	How much were you aware of your friends through avatar appearance? (through the video)?	1.Not at all… 7. Very much	

Table 14: Selection of indicators, variables and questions for measuring sense of co-presence in the encounter stage

4.2.1.2 Sense of co-presence in the initiation stage

After being aware of the presence of remote parties, the conversation between them could be initiated by the initiator. In order to do so, the initiator must be aware of the actual availability of the remote party (Albolino et al., 2005) and their possible responses to the initiation (Goodwin et al., 2010). At the other side, the remote party also needs to know information about the initiator so that they can respond to the right person at the right time to avoid being intrusive (Elin et al., 1997; Schmidt, 1998). In this case, mutual awareness needs to be established among parties.

The first indicator "responsiveness" was constructed by four variables: 1) Sense of social actor; 2) Immediacy; 3) Willingness to respond and 4) Awareness response. According to Reeves et al (Reeves & Nass, 1996) and Bailenson & Yee (Bailenson & Yee, 2008), people respond to the medium as a social actor and have a feeling of co-presence with it even if the medium is just the simplest text-based

interface. However, different types of media bring different sense of co-presence and thus people respond to them as different types of "social actor". As such, "social actor" is selected as a variable for responsiveness. Although a medium could be responded to as a social actor, the degree of responsiveness could be different if there is a prior relationship between the two parties. In this case, the variable "awareness response" is used to measure the degree of awareness when they respond. Lastly, "immediacy" and "willingness to respond" are used to measure the degree of immediate response and response willingness to the conversation initiation between two parties, respectively.

The second indicator "availability awareness" was constructed by the "available for conversation" variable that is used to measure the degree of awareness of whether the other party is available for a conversation.

The last indicator "mutual awareness" was constructed by the "being aware of each other" variable. The questions for this variable are adapted from Biocca et al's research (Biocca et al., 2001).

Table 15 enumerates the indicators, response variables and corresponding questionnaire for measuring co-presence in the initiation stage.

Indicators	Response Variables	Questionnaire	Scale	Informal interview question
Responsiveness	Sense of social actor	When you first saw your colleagues (avatar/real people), did you respond to them as if they were: • *Real people* • *Character in a movie* • *Objects (e.g. a box)* • *I don't know*	Multiple choice	Interview questions are only used for clarifying research findings. e.g. How did you feel when you were trying to contact people in CASA?
	Immediacy	When other avatars greeted you or waved at you, your response to their greeting was?	1.Immediately… 7. Avoid	
	Willingness to respond	When you first saw avatars, was your first response to approach them or avoid them?	1.Approach… 7. Avoid	
	Awareness response	Did the CASA folks (avatars) respond like they: • Knew you • Didn't know you • I don't know • I didn't notice	Multiple choices	
Availability awareness	Available for a conversation	How much were you aware of whether your partner is available for conversation?	1.Not at all… 7. Very much	
Mutual awareness	Being aware of each other (Goodwin et al., 2009)	I hardly noticed another individual The other individual didn't notice me in the room I was often aware of others in the environment Others were often aware of me in the room	1.Not at all… 7. Very much	

Table 15: Selection of indicators, variables and questions for measuring sense of co-presence in the initiation stage

4.2.1.3 Sense of co-presence in the communication stage

The communication stage starts when two parties engage in the conversation. The sense of co-presence in this process was grounded by three indicators: feeling of face-to-face meeting, trust and engagement.

To measure the first indicator, three out of four variables which are face-to-face conversation, natural conversation and partner's attitude were adapted from 24 components proposed for the impact of mediated social actor in social environment

by Garau (Garau, 2003). The last variable, sense of closeness, was selected from out of six variables developed by Nowak et al (Nowak & Biocca, 2003) on the effect of agency on a user's sense of co-presence.

People only share information and engage in the conversation if they know whom they are talking to. Thus the degree of trust and engagement in the communication stage will indicate the level of co-presence in the mediated space. The variables used to construct trust and engagement were also adapted from the variable lists in the research of Garau (Garau, 2003) and Nowak et al (Nowak & Biocca, 2003).

The indicators, response variables and corresponding questionnaire for measuring co-presence in the communication stage are shown in Table 16.

Indicators	Response Variables	Questionnaire	Scale	Informal interview question
F2F meeting feeling	F2F conversation	This felt like a face-to-face conversation	1.Not at all… 7. Very much	Interview questions are only used for clarifying research findings. e.g. How did you feel when you were communicating with your partners?
	Natural conversation	This felt like a natural conversation This felt like a phone conversation	1.Not at all… 7. Very much	
	Partner's attitude	How did your colleagues in form of avatars (through the video) seem to respond to you?	• Extremely unfriendly • Unfriendly • Neither unfriendly or friendly • Friendly • Extremely friendly	
	Sense of closeness	I tried to create a sense of closeness between us (Nowak & Biocca, 2003)	1.Not at all… 7. Very much	
Trust	Trust	I trusted my partner My partner trusted me	1.Not at all… 7. Very much	
	Willing to share information	I was unwilling to share personal information with my interaction partner (Slater, 1999) My partner was unwilling to share personal information with me	1.Not at all… 7. Very much	
Engagement	Interested in talking	I was interested in talking to my interaction partner	1.Not at all… 7. Very much	
	Highly interactive	The conversation seemed highly interactive	1.Not at all… 7. Very much	
	Easy to contribute to the conversation	It was easy for me to contribute to the conversation	1.Not at all… 7. Very much	
	No interruption	There was frequent inappropriate interruption	1.Not at all… 7. Very much	

Table 16: Selection of indicators, variables and questions for measuring sense of co-presence in the communication stage

4.2.1.4 Sense of co-presence in high socially functional space

In order to find out whether the degree of socially functional space could have any impact on the sense of co-presence, this study adopted seven variables from the research of Andre et al (André et al., 2006) on the design attributes necessary for mediated space support of social presence interactions. According to Biocaa and Harms (Biocca & Harms, 2002), social presence is defined as the "moment-to-

moment awareness of co-presence" of a mediated body through which social presence could be considered as a higher level of co-presence with a more intense sense of accessibility of others. The extent that the sense of social presence is measured could reflect the sense of co-presence to some extent. Table 17 shows the list of variables and corresponding questionnaire.

Indicators	Response Variables	Questionnaire	Scale	Informal interview question
Social Function Space	Enticing factor	This space gives me a close sense of distance between me and my friends This space brings me into contact with my friends	1.Not at all… 7. Very much	Interview questions are only used for clarifying research findings. E.g. how did you feel about the social interaction in this space?
	Environment	This environment (space and artifacts) is designed as a social space	1.Not at all… 7. Very much	
	Awareness of others' presence	The space supports high degree of awareness of other	1.Not at all… 7. Very much	
	Taking a break	This environment could be used to take a break away from work	1.Not at all… 7. Very much	
	Afford unplanned meeting	This environment affords unplanned meeting such as spontaneous conversation	1.Not at all… 7. Very much	
	Afford semi-planned meeting	This environment affords semi-planned meeting by offering the ability to go there and meet your friend	1.Not at all… 7. Very much	
	Socializing	This environment affords socializing activities	1.Not at all… 7. Very much	

Table 17: Selection of variables and questions for measuring sense of co-presence in high socially functional space

4.2.2 Independent variables

The independent variables in this study are the different mediated shared spaces, namely Virtual CASA and Mixed Reality CASA.

4.3 Data collection and analysis

End user data collection and analysis were through questionnaire and informal interview.

Through questionnaire. As some of the participants who were involved in the experiments stay in different countries, we did not prepare and distribute the questionnaire in the conventional way i.e. in hard copy and by snail mail. Instead, we used an online survey platform to gather data from all the participants, both remote and local. There are many benefits to using online surveys. These include speed, cost, accuracy, quick analysis, ease of use for participants, and greater flexibility (Evans & Mathur, 2005; Kiesler & Cummings, 2002). Among these benefits, the reasons for using an online survey in our study was convenience and accuracy, as data could be collected from geographically distributed respondents in a shorter time with sufficient information. After assessing various online survey platforms, Monkey Survey was chosen for our study as its procedure for creating and publishing the questions, and then gathering the data was easy to use. Once the survey questions were ready, a URL link to the survey was emailed to every participant for their response.

Since the two experimental platforms, Virtual CASA and Mixed Reality CASA, were tested by the same population, paired-sample t-tests (with 95% confidence interval) was chosen to test the experimental hypothesis. The null hypothesis of the experiment is that Virtual CASA supports the sense of co-location and the sense of co-presence better than Mixed Reality CASA. Hence the null hypothesis will be rejected if the probability (p-value) is less than 0.05 (5% level that Virtual CASA is greater than Mixed Reality CASA).

Through observation. Based on preliminary observation from the pilot experiment, the main observations of this experiment focused on how informal interaction processes among participants occurred in the two spaces. Observation in

Virtual CASA was through moderator's avatar and observation in Mediated Shared Space was conducted by the moderator. The observation time was selected to coincide with the working time of research students in physical CASA which was from 9.30 am to 8pm. It was because, most of the interaction tended to occur during this period.

Through informal interview. As the population of this experiment is very small, the quantitative data gathered from the questionnaire may not give the correct result. Therefore, individual informal interviews were planned to get more information to consolidate the findings in the questionnaire. These interviews were carried out after the participants had finished the experiment and filled out the questionnaire. Through a preliminary analysis of the collected data, some people were selected and scheduled for an interview. Each interview session lasted 10 to 15 minutes, and sometimes more if the participant wished to share more information. According to Smith (Schreer & Sheppard, 2000), the reason for informal interviews is to "cover the areas of interest while remaining sufficiently flexible to allow the respondent to focus on issues of particular individual concern". The interviews allow participants to express and explain their interest in specific parts of the experiment. However, participants were re-directed back to relevant issues if they get too focused on other marginal interests.

CHAPTER 5
TECHNOLOGY APPROACH TO DEVELOP THE PROTOTYPES

This chapter describes the technical implementation of the experimental treatments which were developed as the prototypes of the proposed Mediated Shared Space. The implementation was done through the following steps: 1) Choosing the system architecture; 2) System Mock-up; and 3) Trial process and resolving technical problems.

5.1 Proposed system architecture

5.1.1 System architecture

5.1.1.1 System architecture of the Mixed Reality CASA

The real system set up was previously shown in Chapter 4 (Figure 25). The system architecture of the Mixed Reality CASA (as illustrated in Figure 28) contains software and hardware components to develop the two spatial parts of the prototype which are the collaborative virtual space (CVE) and a media space (real CASA) so that informal interaction could be enabled between participants of the two spaces. The system architecture of Mixed Reality CASA works as follows:

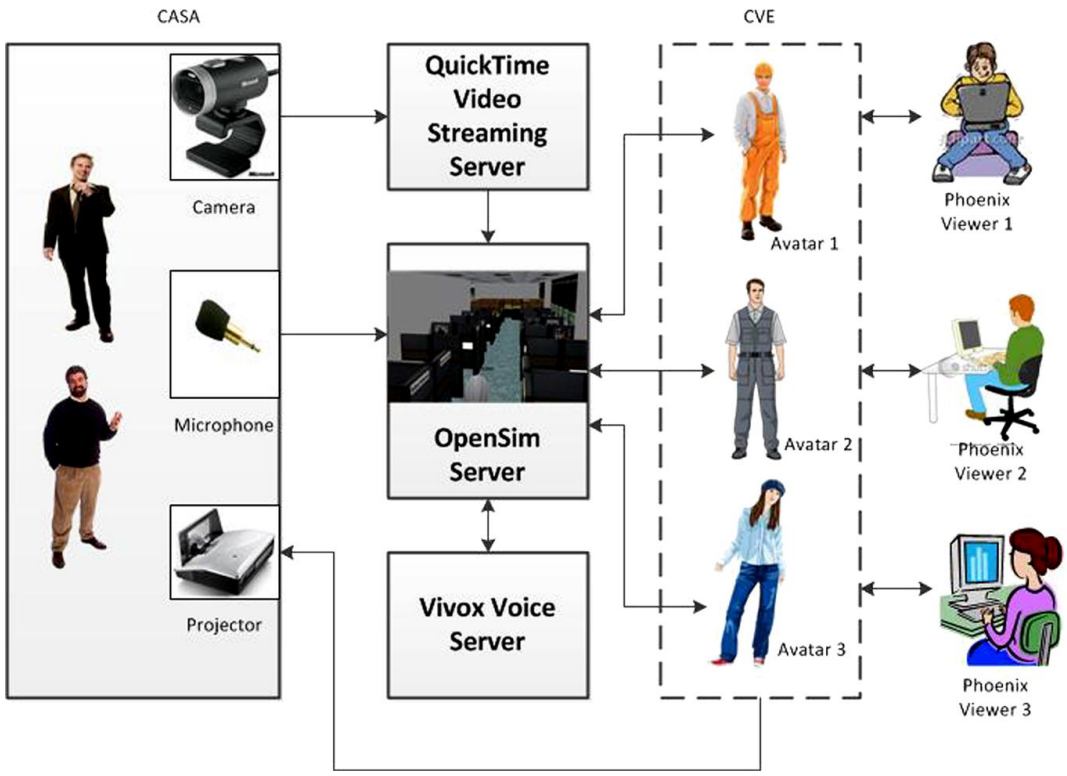


Figure 28: System architecture of the Mixed Reality CASA

Supporting informal interaction between participants of CVE and participants of local CASA. Remote people are able to participate in the Mixed Reality CASA by using Phoenix Viewer. They could use laptops or personal computers to launch the viewer and login to the CVE using a given username and password. Once the login process is successful, they are present in the CVE as avatars and are able to navigate and communicate with one another. The CVE is created as a 3D representation of the physical CASA and hosted by Open Simulator (OpenSIM) which is an open-source server platform for hosting virtual worlds. In order to support avatars to interact beyond the boundary of the virtual environment, CVE provides a video of CASA embedded on the surface of the virtual wall on which all activities inside physical CASA are captured and delivered inside the virtual world. As the OpenSIM does not support voice chat, Vivox Voice is used to enable voice

communication among participants including among avatars and between avatars and people in the local CASA.

Supporting informal interaction between participants of local CASA and CVE participants. People in the local CASA are aware of the remote people who are present the form of avatars in the CVE through the projection of CVE on the CASA wall. The projection is done using a projector. In order to communicate with avatars, a microphone and a speaker are installed in CASA. The microphone streams the voice to the CVE through Vivox Voice server and the speaker broadcasts the voice from CVE to the local CASA. Besides transferring the voice to the CVE, the image of all activities occurring in the local CASA is also real-time streamed to the CVE via a camera mounted on the CASA wall. Due to equipment constraint, this experiment uses only a webcam for this purpose. With the aid of QuickTime streaming server, the image could be streamed to CVE in real-time.

5.1.1.2 System architecture of the Virtual CASA

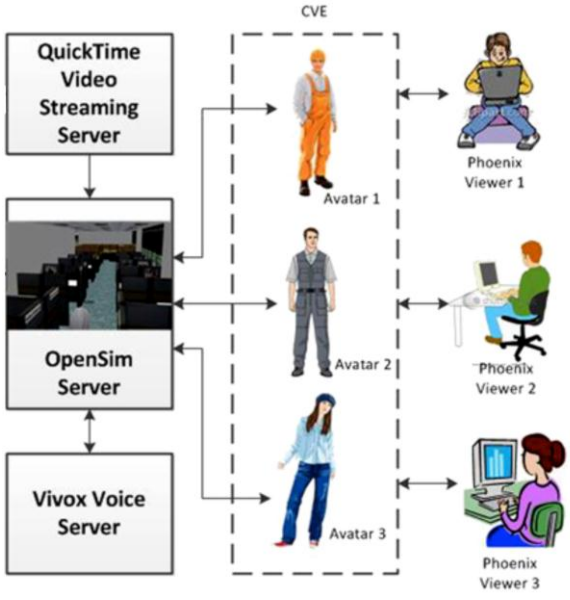


Figure 29: System architecture of Virtual CASA

Virtual CASA was built in the same system with Mixed Reality CASA so that they used the same servers to operate and the same type of CVE viewer to login to the system. It was shown in Figure 24 of Chapter 4 what the Virtual CASA looked like after set up. Here, Figure 29 shows the system architecture of the Virtual CASA.

5.1.1.3 Selection of Platforms

In this study, three types of platforms were used to implement Virtual CASA and Mixed Reality CASA. They are the platform for hosting the virtual world, the platform for video streaming and the platform for bridging voice.

The platform for hosting virtual world should support the following features:

- A server for hosting the virtual world which could act as a gaming engine for rendering 3D graphics (scene, participants,…), collision detection, real-time media (video, sound), animation, streaming, networking, memory management, and supporting different operation systems.
- A server for supporting real-time communication
- Open-source for enabling modification of the original configuration.
- Development sources for community-supported, shared resources and troubleshooting.
- Robust server for multiple connections and is compatible with different operation systems.

Several platforms were tried out in order to select the most suitable one that satisfies most of the above features. These platforms are presented in Table 18. As shown in the table, OpenSIM could support all the requirements, and was thus selected for this experiment.

Platform	Project Wonder Land	Germanium 3D	EON Reality	OpenSIM
Server for hosting virtual world	Project was shut down in 2010	Yes	Yes	Yes
Server for communication		No	No	Yes
Development sources		Yes	Yes	Yes
Open-source		Yes	NO	Yes

Table 18: List of platforms that were tested to select the best candidate for the experiment

This prototype requires real-time video streaming of the physical space so that remote people can be aware of who is currently present. Hence a platform for video streaming is needed to stream video images from the camera to remote participants over the Internet. A few streaming servers such as Ustream media server, Flash Media Server and Quicktime (Darwin) streaming server, were tested. Although all three servers were able to do the task, Quicktime was chosen because it was the only one that was compatible with OpenSim. It was also easier to set up than the other two.

Lastly, a voice bridging server is needed to enable real-time voice communication over the internet. Vivox voice server was chosen for this experiment because it is the only free online server and it does not require installation. All that was needed was to embed the server link into the OpenSim server. Although the Vivox server has been running smoothly thus far, should the server experience a problem in future, participants will be unable to communicate verbally.

Table 19 shows the three selected platforms used for implementing Mediated Shared Space prototypes in these experiments.

Platform	Roles
OpenSimulation (OpenSIM)	For hosting virtual world
Quicktime Streaming Server	For streaming real-time video to the virtual world
Vivox voice server	For streaming voice between virtual world and real world

Table 19: List of platforms used for implementing Mediated Shared Space prototypes in this experiment

5.1.1.4 Hardware and equipment selection

Hardware refers to the equipment that are used to capture the activities at one space, then deliver and make them visible to the people at the other spaces. The hardware used in this experiment includes 1) a projector for projecting the CVE space to the local people; 2) a microphone for capturing voice and sound; 3) a speaker for emitting sound from the Virtual CASA; 4) a camera to capture the activities of the local CASA for display in the CVE and 4) hosting servers to host the OpenSIM platform and stream the information (audio, video) over the network.

Due to the funding constraint, the hardware and physical equipments used in this experiment were re-cycled from existing resource of our lab. The types of hardware and their roles are listed in Table 20.

Space	Hardware and equipments	Roles
Mixed Reality CASA	Microphone	Capture live sound and voice from the physical space
	Speaker	Transfer sound and voice from the remote areas
	Projector	Display image of the CVE
	Camera	Capture live activities occurring in the physical space
	Quicktime Streaming server	Send video and sound stream over the Internet to the remote devices. Since Quicktime is Mac compatible, it has to run in different servers with OpenSIM whose platform is Windows-based.
Virtual CASA	OpenSIM Platform Server	Host the virtual world that allows multiple remote people to access.

Table 20: List of hardware used for implementing Virtual CASA and Mixed Reality CASA

5.1.1.5 Software requirements

Software is an important to make the system workable. They are used to create mockup of different parts of the system, to create the virtual space, to enable video broadcasting etc. The software used in this experiment are listed in Table 21.

Software needed	Software Selected	Role
3D Modelling tool	3DS Max	Create 3D spatial structure of the Mixed Reality CASA
Video broadcasting tool	Quicktime Broadcaster	Broadcast the live video stream to the remote machines
Video player	Quicktime player	Play the video stream at the remote machines
CVE viewer tool	Phoenix Viewers	View the Mixed Reality CASA at the remote machines

Table 21: Software used to develop Virtual CASA and Mixed Reality CASA

1. **3D Modelling tool**. A 3D modeling tool was needed to create the 3D virtual environments for the two prototypes. A number of tools were tried out such as AutoCAD, SketchUp and 3D Studio Max. The trial started with AutoCAD, then continued with SketchUp and finally ended with 3D Studio Max. There are two reasons why AutoCAD and SketchUp were dropped: (1) the size of the model and distortion of the geometrical model when it is imported into OpenSIM. The model built with AutoCAD generated a file that was too big to be imported. With SketchUp, size was not an issue. However, the model was distorted when imported into OpenSIM; (2) the texture mapping. As the 3D model should look like an extension of the physical model, the texture should be mapped in a nice way to illustrate the intention. SketchUp only provides a simple texture mapping – hence the model does not look realistic. Adding texture in AutoCAD makes the file size considerably large as the texture images are tiled and multiplied to cover the whole surface. All these problems were solved using 3D Studio Max. The model can be optimized, and therefore the size can be easily controlled, before it is imported into OpenSIM. Instead of multiple pieces of texture to cover the surface, 3D Studio Max uses baked texture where the images are consolidated into only one image.

2. **Video broadcasting tool.** In order to stream the video to the virtual world, a video broadcasting tool is needed to send the video data to the streaming server. In this study, Quicktime broadcaster was selected as it can deliver the video stream format to the Quicktime streaming server, and its Quicktime video format is the only format compatible with and supported by OpenSIM.

3. **Video player.** The video player is used to display the video at the end users space. To ensure interoperability within the system, the Quicktime player is used to display the Quicktime video format.

4. **CVE viewer tool.** In order to log in to the CVE, end users should have the CVE viewer installed in their computers. A number of viewers were tried such as Imprudence Viewer, Hippo OpenSIM viewer, Firestorm Viewer and Second Life viewer. Of these, Second Life allows the model to be imported into OpenSim with the least problem. However, at the end of the trial period of the experiment, Second Life no longer supported OpenSIM. Phoenix Viewer was then selected for the main experiment as it provided the same functions as Second Life.

5.1.2 System Mock-up

Although the experiment consists of two treatments, they were not developed separately but built together as one integrated system in OpenSIM. The steps to create the mock-up are as follows:

1. Create Virtual CASA
2. Create Mixed Reality CASA
    a. Create the CVE part embedded with video
    b. Create the media space part
3. Import Virtual CASA and Mixed Reality CASA to the OpenSIM by using CVE Viewer
4. Embed voice server to OpenSIM to enable voice communication in the system

5.1.2.1 Create Virtual CASA

The CVE environment was created as follows:

1. **Creating the 3D model of CASA**. After getting all the necessary dimensions of the CASA room, 3DS Max was used to create the 3D model. Texture of the model elements, such as the floor and ceiling were mapped with the photo of real materials of the corresponding elements. The texture was then baked and remapped to the 3D model to reduce the size of the model before it was imported into OpenSIM.

2. **Adding additional spatial elements**. If the size of the model exceeds the maximum size, then some parts of it may not be imported. To reduce the size of the model before it is imported into OpenSIM, some additional spatial elements (e.g. decorating elements) were created using the basic drawing tools of OpenSIM.

Figure 30 shows the entire process of how to create and develop Virtual CASA.

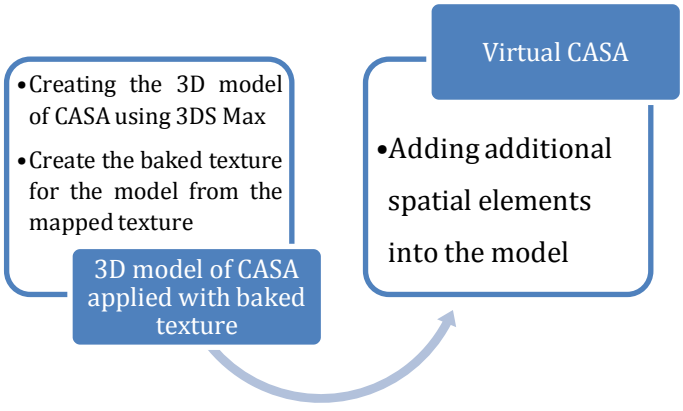


Figure 30: Process to create Virtual CASA

5.1.2.2 Create Mixed Reality CASA

Mixed Reality CASA is a mixture of virtual space and physical space, and is created from two parts: CVE and Media space. The process of creating Mixed Reality CASA is as follows:

1. **Creating the CVE part**. In this step, the CVE was technically modeled in a way that is similar to creating Virtual CASA (Section 5.1.1.1). In order to make a visual connection between the CVE part and the physical space so that the CVE looks like the virtual extension of the physical one and vice versa, the CVE setting was created in a way that is identical to the setting of the physical CASA.
2. **Adding video texture**. In order to enable real-time video connection between the virtual space and the physical space, a polygon was created in the virtual space and mapped with video texture. The polygon was then set up to link to the QuickTime video streaming server to stream the real-time video of physical CASA to the virtual space.
3. **Set up hardware and equipment at local CASA**. This step is to set up the media space at the local CASA to enable participants at the local CASA to interact with avatars on the CVE side. Hardware and equipment for the media space includes: a projector, a pair of speakers, a microphone and a webcam. The projector was set up to project the image of the CVE on the wall in such a way that the avatar sizes are as big as the real human size. The webcam was mounted on the wall at eye level so that the avatars can view the local CASA at the same viewing angle as the real human. All the hardware were connected to a Mac Mini as the video captured from the webcam needs to be streamed to the QuickTime streaming server which is a Mac OS application. The OpenSIM server was installed in a separate machine as it runs on in a Windows OS platform.

Figure 31 shows the process of creating Mixed Reality CASA.

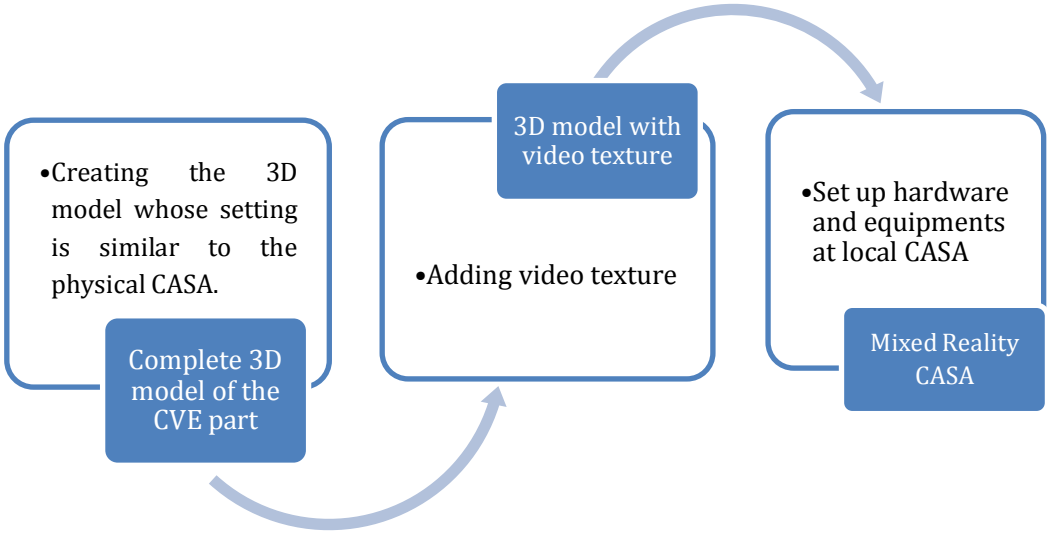


Figure 31: Process of creating Mixed Reality CASA

5.1.2.3 Import Virtual CASA and Mixed Reality CASA to the OpenSIM by using CVE Viewer

A CVE viewer (e.g. Phoenix viewer, Second Life Viewer) was used to import CVE model into the OpenSIM. Before importing, the CVE viewer was set up to link with the OpenSIM server by embedding the server address in the viewer login URL (details of the linking procedure are explained in Appendix C). When the server was successfully connected, the 3D model could be imported into OpenSIM server.

5.1.2.4 Embed voice server to OpenSIM to enable voice communication in the system

Vivox voice server was embedded into the open source file of the OpenSIM server to trigger voice communication at a distance (i.e. among avatars or between the virtual world and the physical world).

5.1.3 Re-solving technical issues during implementation of the prototypes and trial period

Although the types of experimental treatments have been clearly identified in Section 4.1.1, it still required a big effort to implement the two setups due to the following issues:

1. Suitable platforms, software and hardware for implementing the experiment.
2. Interoperability between platforms, software and hardware.
3. Quality of the prototypes to meet the research hypothesis.

This system is a combination of many components and each component needs to be built using different types of tools, software and hardware. Under budget and time constraints, it was important that the right tools were chosen that will meet quality expectations and allow interoperability among different types of software and hardware. Before implementation, the tools and software that, to some extent, met the above requirements were listed down and were tried one after another in order to select the most suitable ones that will work for the whole system. For example, many tools could be used to create the 3D model of CASA such as AutoCAD, SketchUp, 3DS Max, etc. Although SketchUp could create the model faster, it does not support light models with realistic texture mapping. In this case, 3DS Max could provide a good end result though the modeling procedure is more complicated. Additionally, 3DS Max generates a high interoperable model that could be imported into OpenSim with no geometric distortion. The same effort was also made for selecting the most suitable platforms (virtual world hosting platform, video streaming platform and voice platform) for the system.

After the system was mocked up, it was tested during the pilot experiment to see if the prototypes operated as expected. It was also checked to see if any technical

or usage issues might occur during the interaction process so that these problems could be resolved or minimized before the main experiment was conducted.

Below is a list of the main problems that occurred during the trial period:

1. Need for easy-to-use functional system for end users
2. Delay in video transmission
3. Low video resolution
4. Echo in sound transmission
5. Robustness of the system

As most of the CASA participants have only slight IT background and half of them are located remotely, the procedure for setting up and operating the system had to be simple and easy to understand for the end-users. Although the system was complicated at the admin side, end users should only need to download and install the CVE viewer in a few steps. Instructions were provided to facilitate the installation. In the pilot experiment, participants were asked to set up the system according to the preliminary instructions. The difficulties that they encountered were taken into account and steps were taken to further simplify the instructions and the installation procedure. In the operation process, frequent issues were also noted and the operational user's guide was made clearer for the main experiment. Details of the installation instructions and operational user's guide are shown in Appendix C, Appendix D and Appendix A, respectively.

The other technical issues found during the trial period that could significantly affect the quality of the interaction process were the low resolution of the real-time video and its latency. These issues could be technically resolved, to some extent, by reconfiguring some parameters of the system, for example removing the limit data rate in the QuickTime broadcaster to increase video solution and modifying XEngine parameters in OpenSim.ini to reduce video lag.

The problem of sound echo could only be partially resolved as the admin rights of the voice server was not provided. In this case, the sound volume was kept at medium level to minimize the sound echo.

Last but not least is the robustness of the system that refers to the sudden quitting of the CVE viewer at the end-user sides. In order to solve this problem, several viewers were tested in this trial period to find out which was the most stable viewer that could operate well with OpenSIM platform and other software.

5.2 Discussion

Although the two prototypes looked simple, the implementation process was neither simple nor easy. It was circumscribed by some technical limitations which are discussed below.

5.2.1 Technical limitations

The technical limitations of this study are limited resources (e.g. tools, software, money) for implementing the system; and time and manpower constraints for further developing and enhancing the system.

As the budget for this study was very limited, the only resources that were available were free software and re-cycled equipment from other research studies. Because of this, some technical issues were not fully addressed, for example the quality of the video transmission and even the robustness of the system. Video quality was poor because the re-used webcam does not have a high resolution or a large viewing angle. On the issue of system robustness, the use of freeware caused technical interoperability issues among different types of software. Some software did not function well when handling data from other sources. In addition, some

freeware did not have technical support for all the available functions and therefore required highly experienced programmers to handle complicated issues (Dafli et al., 2009).

Time and manpower constraints were also big issues for technical implementation of the system. The time allocated to implement this system was short, and building the structure required expertise from different areas (e.g. modeling, software and hardware programming and mockup). All these contributed to the technical shortcomings that were not fully addressed in this experiment.

CHAPTER 6
DATA ANALYSIS AND EVALUATION

The purpose of this chapter is to analyze and evaluate the research question and find out whether Mixed Reality CASA or Virtual CASA supports better the sense of co-presence and sense of co-location in the three processes of informal interaction (encounter, initiation and communication). Participants were asked to try out two experimental platforms which were created based on different degrees of supporting "continuously open", "mutually shared" and "concurrently convergent". The two platforms are Mixed Reality CASA and Virtual CASA in which Mixed Reality CASA was assumed to support a higher degree of the three factors above. This chapter uses quantitative and qualitative methods to determine the significant difference between the two spaces in order to prove the experiment assumption. The data was obtained from participants through questionnaire survey and informal interview. Since the questionnaire was self –completion, this study assumes that all participants gave honest answers.

In the analysis part of this chapter, the two spaces were compared based on the difference between two means of measurement variables. Since the two experimental platforms were tested by the same population, paired-sample t-test (with 95% confidence interval) was chosen to test the experimental hypotheses. This study employed statistical functions in Statistical Package for the Social Sciences (SPSS) to

calculate the independent sample t-test and the conclusion was drawn from the output.

In the discussion part, data from informal interviews was used to strengthen the statistical finding in the analysis parts and to clarify and explain the vague points in the statistical results.

6.1 Pilot experiment

Prior to the main experiment, a pilot experiment was implemented whose purpose is to 1) test how the system works and how robust it is and 2) test the questionnaire to see whether it is understandable. A total of fifteen participants who are current CASA students and alumni were invited to participate in this pilot experiment. There were no tasks for them during the pilot experiment. They were just asked to install the system onto their laptops or desktops and try out both Virtual CASA and Mixed Reality CASA at their convenience within one month.

The two methods to evaluate the pilot experiment were observation and obtaining feedback. Information obtained from observation included whether the space design and the given functions of the space met the interaction purpose, whether the system afforded user's interaction regarding robustness and satisfaction and whether unforeseen issues such as social issue or technical issues, occurred during the interaction. Information obtained from user feedback included user satisfaction when using the system, problems occurring during their interaction and unclear points in the questionnaire.

Information gathered from this pilot experiment were considered and used to redesign the space structure, add more useful functions and remove ambiguities in the questionnaire.

6.2 General information of participants

In the main experiment, this study invited 25 participants to participate in the experiment. The participants included current CASA students, CASA alumni and a faculty member. As the online survey was set to require that participants answer all questions before submitting, all the participants are deem to have fully completed questionnaire.

Since most of the participants are working on social topics in architecture their level of IT competence is not that high. The level of IT competence among participants is significant as it could influence their performance during the experiment. In order to regulate the level of IT competence in performing the experiment prototypes among the participants, all of them were trained individually on the general techniques before they participated in the main experiment. They were trained how to log in to the system, how to use the keyboard to navigate, how to use communication tools to make conversation, and how to turn on the video of the real CASA, etc.

6.3 Evaluating the sense of co-location and the sense of co-presence in the encounter stage

This section analyses how participants perceived the sense of co-presence in the encounter stage. As elaborated in Section 4.2, the sense of co-presence in the encounter stage was measured by 2 indicators which are 1) Feeling in a shared space with others and 2) Recognizable.

6.3.1 Feeling in a shared space with others

The feeling in a shared space with others was measured by four variables which are 1) Sense of real-world co-presence; 2) sense of being together in a shared space; 3) Sense of togetherness; 4) No sense of isolation. The variables were reflected through four questions in the survey.

For the sense of real-world co-presence, the experiment question is "Was the sense of real-world co-presence significantly higher for Mixed Reality CASA than for Virtual CASA?"

The research hypothesis for this question is: Sense of real-world co-presence is significantly higher for Mixed Reality CASA than for Virtual CASA. $\mu_{\text{Mixed Reality CASA}} - \mu_{\text{Virtual CASA}} > 0$

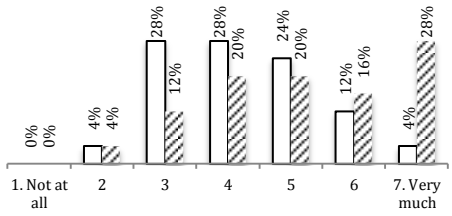
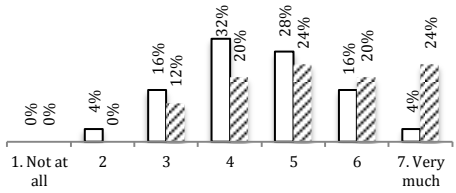
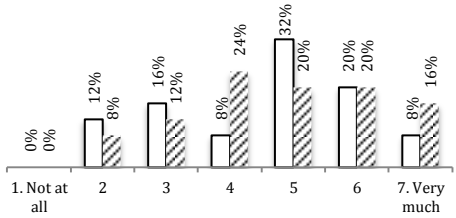
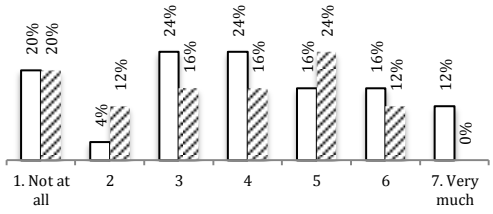
As such, the null hypothesis is: The sense of real-world co-presence was the same or lower for Mixed Reality CASA than for Virtual CASA. $\mu_{\text{Mixed Reality CASA}} - \mu_{\text{Virtual CASA}} \leq 0$

This is a one-tail hypothesis test since the difference between means must be sufficiently greater for Mixed Reality CASA than for Virtual CASA in order to reject the null hypothesis. According to the results presented in Table 22, the mean number of sense of real-world co-presence in Mixed Reality CASA was 5.16 and the mean of this variable for CVE was 4.24. The two-tailed significance level of this test was 0.027. As this is a 1-tailed hypothesis, the two-tailed must be divided by half which gives 0.0135. The null hypothesis was rejected since the probability of getting the observed sample is less than 0.05 ($p = 0.0135 < 0.05$). Therefore, the result shows that "the sense of real-world co-presence" was higher for Mixed Reality CASA than for Virtual CASA.

The same analysis is also used for other variables which are the sense of being together in a shared space", "sense of togetherness" and "no sense of isolation".

A significantly higher difference was also reported for Mixed Reality CASA than for Virtual CASA for "the sense of being together in a shared space" ($p = 0.027 < 0.05$) and "no sense of isolation" ($p=0.0095<0.05$). However, the "sense of togetherness" was not significantly higher for Mixed Reality CASA ($p = 0.202 > 0.05$) even though the mean value of Mixed Reality CASA ($\mu = 4.8$) was higher than the mean value of Virtual CASA ($\mu = 4.44$).

Table 22 shows the output of the SPSS calculation for the observed sample results of the "feeling in a shared space with others" in Mixed Reality CASA and Virtual CASA.

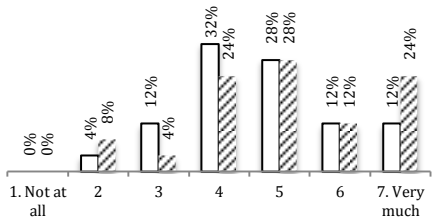
Indicators	Variables	Response	Means (μ)	1-tailed S level/2 (p)	H_o
Feeling in a shared space with others	Sense of real-world co-presence		4.24 5.16	0.0135	Rejected
	Sense of being together in a shared space		4.48 5.24	0.027	Rejected
	Sense of togetherness		4.44 4.80	0.202	Accepted
	No sense of isolation		3.48 4.40	0.0095	Rejected

Virtual CASA

Mixed Reality CASA

Table 22: Paired sample t-test for "feeling in a shared space with others" in Mixed Reality CASA and Virtual CASA

6.3.2 Identity

Indicators	Variables	Response	Means (μ)	1-tailed S level/2 (p)	H_o
Identity recognizable	Identity		4.68 5.04	0.2085	Accepted

Virtual CASA

Mixed Reality CASA

Table 23: Paired sample t-test for "identity recognizable" in Mixed Reality CASA and Virtual CASA

As for the ability to recognize colleagues who been working or have worked together through mediated shared space, there was no significance difference found between the two spaces ($p = 0.2085 > 0.05$) although the mean of this variable was greater for Mixed Reality CASA than for Virtual CASA.

6.3.3 Discussion

The sense of co-presence and co-location was reported by two indicators which are "the feeling in a shared space with others" and "identity recognizable". The findings showed that Mixed Reality CASA has better supported "the feeling in a shared space with others" as three out of four variables for this indicator had produced the results that yield towards Mixed Reality CASA. Only one variable of this indicator "***sense of togetherness***" was not significantly higher for Mixed Reality CASA ($p = 0.202 > 0.05$) even though the mean value of Mixed Reality CASA ($\mu = 4.8$) was higher than the mean value of Virtual CASA ($\mu = 4.44$). In order to find out

how participants actually felt about the sense of togetherness when they experienced the two spaces, data from informal interview was used. Below are the participants' feedback and comments when they were asked: "What was your feeling when you encountered remote people in the Mixed Reality CASA?".

- "*I could see people in CASA moving towards me. It gives me the feeling that they are aware of me standing here*".
- "*When I saw Mary*[1] *standing over there, I have the feeling of coming back to CASA to visit you guys".*
- *"I really miss CASA, …, this system is fantastic as I could login to visit CASA and talk with everyone".*

An interesting comment from Bob when he first used the system really supported the two variables "sense of being together in a shared space" and "sense of togetherness":

- *"It is much better than Skype as the spatial setting is connected between real world and the virtual world thus gives me the feeling that people are co-located in just one space. It's good for my team to use such kind of system when we need to have a meeting as the free version of Skype only supports one-to-one connection".*

Bob is a local CASA participant located in CASA. His comment showed the point of view of the local participant on how the system supports this function.

The comments above showed that some people actually have the feeling of being together when they are in the Mediated Shared Space. However, the low rating may come from people who encountered the following situations:

[1] *All names have been changed for privacy reasons*

- *"People are usually hiding inside their cubicles, very difficult to know who are around"*
- "*CASA is always quiet. They only turned up when I called them*".

This feedback is not negative experience for the system. As mentioned, CASA is actually a research room for research students instead of a public space for hanging out. Therefore, people are mostly in their individual cubicle[2] doing their research work. Interaction among them only happens when they have things to discuss or share.

When they were asked the same question for Virtual CASA, their comments about the "***sense of togetherness***" mainly concerned the avatar's presence as they only have this feeling when the avatar was logged in or active.

- *"I was very happy to meet Cindy[1] there. However, I still feel alone as I tried to chat with her but she didn't reply".*
- *"The space is very interesting as I could meet many CASA people in your space yesterday. Today, I have been hanging out from morning until now but haven't met anyone yet".*

These comments show that the "***sense of togetherness***" is actually supported in Mixed Reality CASA more than in Virtual CASA as people in local CASA responded when the avatars called them.

The second variable which is "recognizable" was also not reported to be significant higher for Mixed Reality CASA even though the mean of this variable was greater for Mixed Reality CASA than Virtual CASA. Through qualitative data, Mediated Shared Space could support real identity recognition through real-time video while Virtual CASA only allows one to identify through the avatar's name floating above the avatar's head.

[2] *Individual cubicles: low height of 1.2m*

- *"Grace[3] has changed her appearance which looks like yours thus I thought you were hanging around there yesterday."*

The low rating for Mixed Reality CASA may be due to its virtual part; here, remote people also appear as avatars, so people had to figure out the avatar's identity.

6.4 Evaluating the sense of co-location and the sense of co-presence in the initiation stage

In the initiation stage, there are three indicators for measuring the sense of co-presence. They are 1) responsiveness, 2) availability awareness and 3) mutual awareness.

6.4.1 Responsiveness

The way that people respond to the conversation initiated by the other party was measured by four variables: 1) Sense of social actor; 2) Immediacy; 3) Willing to respond and 4) Response awareness.

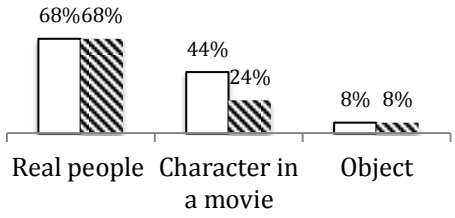
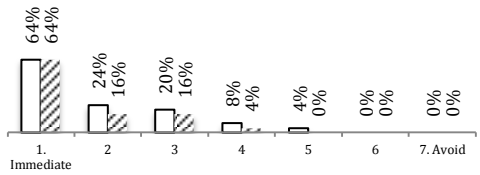
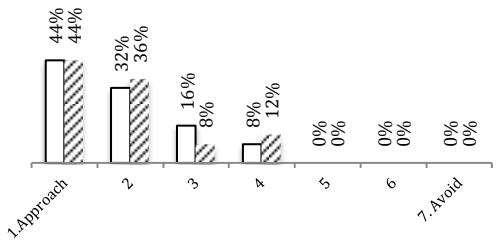
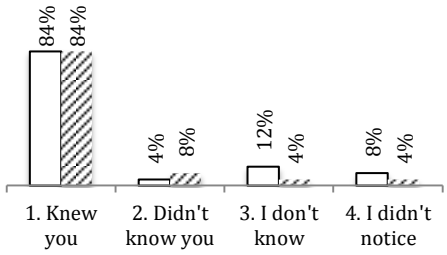
For the sense of social actor, the respondents were asked whether the way they responded to the other party in Mixed Reality CASA or Virtual CASA was like the way they would respond to 1) real people; 2) a character in a movie; or 3) an object. 68% of the respondents for Mediated Shared Space thought that the parties they were interacting with are real people. The percentage for Virtual CASA is 32%. As to whether the other party is like a character in a movie, the response for Mixed Reality CASA was 24%, while that for Virtual CASA was 60%. When respondents were asked whether the remote parties look like an object, the same percentage of 8% was reported for both Mixed Reality CASA and Virtual CASA.

[3] *All names have been changed for privacy reasons*

The immediacy variable was measured by the question on whether the remote party responded to their greeting immediately. There is a statistically significant difference reported for Mixed Reality CASA than for Virtual CASA with $p = 0.023<0.05$ as shown in Table 24. Based on this statistical result, Mixed Reality CASA could support immediate response better than Virtual CASA.

On the matter of whether the other party was willing to respond to the greeting, there is no difference for the two spaces ($p=0.5>0.05$). According to the collected data shown in Table 24, most of the response yielded towards immediate response to the party's greeting.

For the "response awareness" variable, 84% of participants reported equally for the two spaces that their partners responded as if they knew who was trying to contact them. Only 4% thought that the partners in Mixed Reality CASA did not know them, while the rate for Virtual CASA was higher at 8%. The rate that people did not know if their partners knew them or not was 12% for Mediated Shared Space and 4% for Virtual CASA. Finally, the rate that people did not notice about this issue was 8% and 4% for Mediated Shared Space and Virtual CASA, respectively.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Responsiveness	Sense of social actor		1.60 2.60	0.0142	Rejected
	Immediacy		1.60 2.04	0.023	Rejected
	Willing to respond		1.88 1.88	0.5	Accepted
	Response awareness		1.52 1.28	0.1235	Accepted

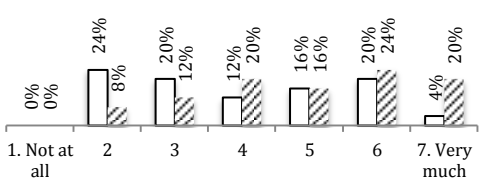
Virtual CASA

Mixed Reality CASA

Table 24: Paired sample t-test for "*responsiveness*" in Mixed Reality CASA and Virtual CASA

6.4.2 Availability awareness

The statistical data collected when respondents were asked whether they were aware of their party's availability for a conversation showed that Mixed Reality CASA supports availability awareness better than Virtual CASA with $p=0.0215<0.05$.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Availability awareness	Available for a conversation		3.88 4.96	0.0215	Rejected

Virtual CASA

Mixed Reality CASA

Table 25: Paired sample t-test for "*availability awareness*" in Mixed Reality CASA and Virtual CASA

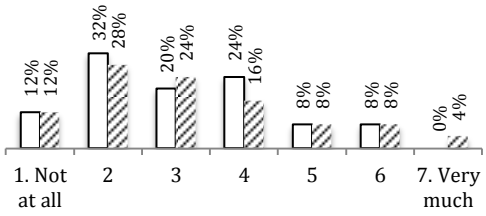
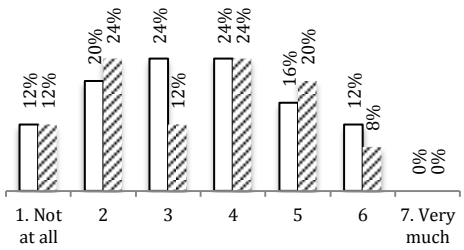
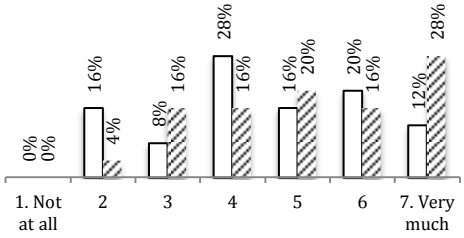
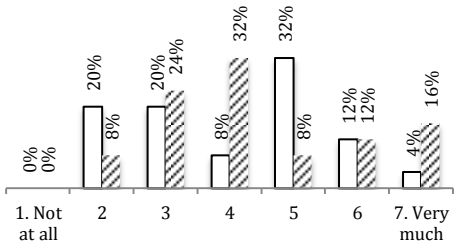
6.4.3 Mutual awareness

Mutual awareness in the initiation stage was measured by four variables which are 1) Hardly notice others; 2) Others hardly notice me; 3) Often being aware of others and 4) Others often being aware of me.

For the first variable, respondents were asked whether they notice others. Most of the responses yielded towards the answer that they noticed other parties however there is no statistically significant difference in the response for the two spaces since $p=0.4605>0.05$.

The second question asked whether they noticed or were aware of other parties. The answers were divided on both sides – showing that some of them were aware of other parties while some of them were not. Although the responded mean for Mixed Reality CASA (μ=3.64) was greater than for Virtual CASA (μ=3.4), no statistically significant difference was found for the two spaces due to $p=0.254>0.05$.

In the third and the fourth questions, respondents were asked whether they are often aware of others in these spaces and have the feeling that others also are often aware of them. The result in the Table 26 shows that no statistical difference was found for Mixed Reality CASA and Virtual CASA for both variables.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Mutual awareness	Hardly notice others		3.16 3.20	0.4605	Accepted
	Others hardly notice me		3.64 3.40	0.254	Accepted
	Often being aware of others		4.52 5.12	0.054	Accepted
	Others often being aware of me		4.08 4.40	0.1675	Accepted

Virtual CASA

Mixed Reality CASA

Table 26: Paired sample t-test for "*mutual awareness*" in Mixed Reality CASA and Virtual CASA

6.4.4 Discussion

The sense of co-presence and co-location in the initiation stage were measured by three indicators which are “responsiveness”, “availability awareness” and “mutual awareness”.

According to the quantitative data analyzed in Section 6.4, two out of four variables of “responsiveness”, namely “sense of social actor” and “immediacy“ showed that Mixed Reality CASA had a higher rating than Virtual CASA. The remaining two variables of this indicator, namely “willing to respond” and “response awareness” showed Mixed Reality CASA had a lower significant difference.

For the “willing to respond” variable, the reported rate was not significantly higher for Mixed Reality CASA ($p=0.5>0.05$) and the mean was equal for both Mixed Reality CASA and Virtual CASA. Although the quantitative data did not support Mixed Reality CASA, the qualitative data which includes observation and interview data was quite positive. Specifically, the observation of how local people responded to the greetings of their remote colleagues showed that most of people who were walking or showing up in CASA often stopped and responded to the greeting by saying “Hi” to the avatars even though there was no further conversation after that. They always tried to be polite with the avatars as they know that the avatars might be their friends. Perhaps, involvement shields, as mentioned in Section 2.3.6, might occur when someone was not willing to respond to those who were not close to them. Data from the interview was also in line with the observation data. When people were asked “How did you feel when you were trying to contact people in CASA?” They said their interest grew when their greetings were responded.

- "*Paul*[4] *said 'Hi' and talked to me. Although the conversation was short but made us keep in touch"*

For the "response awareness" variable, both spaces had a high response of 84% on the degree of awareness that their partners knew who was the people interacting with them. It showed that people often respond to those whom they know even when they appear as avatars. The observation data in the local CASA also supported this finding. Specifically, people in the local CASA usually stopped, looked at the name floating on the avatar's head in order to identify who the avatar is, then responded and had a conversation with this avatar. Therefore, the same rating from the two spaces could be due to people knowing that the experiment is only for those who come from CASA, and thus they presume that the avatar is also the person with the corresponding name.

For the "availability awareness" variable, it is easy to understand why Mixed Reality CASA significantly supported this feature better than Virtual CASA as it used video for detecting availability. According to (Isaacs et al., 1997; Whittaker, 1995), video could help parties stay aware of each other's availability when the remote people appear inside the camera range, or provide the context with useful information on whether the other party is open for an interaction.

In Table 26, the statistical data of "mutual awareness" showed that both variables "notice each other" and "being aware of each other" did not provide quantitative result to show that Mixed Reality CASA supports better "mutual awareness" than Virtual CASA although the variable means of Mixed Reality CASA was greater than the corresponding means of Virtual CASA. Participants were asked in the survey whether they "hardly noticed" their remote friends who are present in the space and whether they felt that their friends "hardly noticed" them. According to

[4] *All names have been changed for privacy reasons*

the graphical distribution of the data in Table 26, only a minority of participants rated that they "hardly noticed their remote friend" while a majority of them noticed the presence of others. This trend was the same for the two spaces. In order to explain this data, the qualitative data showed that some participants "hardly noticed" their partners in the local CASA or Virtual CASA due to the fact they did not encounter anyone when they logged in. Details for the qualitative data for this reason were already mentioned in Section 6.3.3. In fact, people were around, however, they did not notice about the avatars' presence, Specifically, local CASA people were so focused on their work inside their cubicles, that they may have overlooked the presence of remote people. In Virtual CASA, this issue is because of the inactiveness of the avatars as the users of the avatars were engaged in other tasks but still left the avatars logged in. For the second variable of "mutual awareness" which is the feeling of two-way awareness between each other, the quantitative distribution of data also showed that a majority of the participants were aware of the other's presence but did not know whether their partners were aware of them.

Although, the quantitative result of two variables did not differentiate which space supported "mutual awareness" better, Mixed Reality CASA was shown to support slightly better than Virtual CASA through qualitative data and observation. Specifically, in the Mixed Reality CASA, local CASA people did respond when they were called by the avatars. However, in Virtual CASA, some avatars were idle and did not respond when other avatars communicated with them as the users of the avatars were not actually engaged. This finding also explains for the data distribution in Table 26 so that participants could be noticed and be aware of others' presence but they were not certain how others felt about them. The reason could be that the avatar's appearance did not reflect the actual status of the avatar's user.

6.5 Evaluating the sense of co-location and the sense of co-presence in the communication stage

In the communication stage, co-presence was measured through three indicators which are 1) face-to-face meeting; 2) Trust; 3) Engagement.

6.5.1 Feeling of face-to-face meeting

Four variables were used to measure "face-to-face meeting": 1) face-to-face conversation, 2) Natural conversation, 3) Phone conversation, 4) Partner's attitude and 5) Sense of closeness.

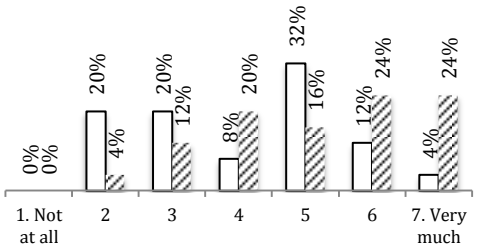
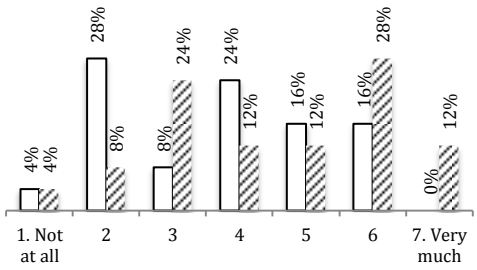
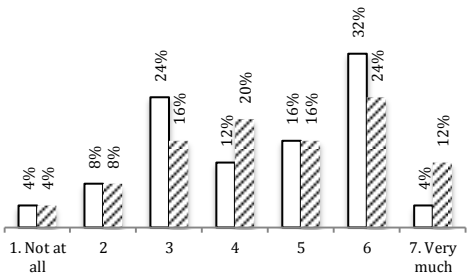
The data collected for "face-to-face conversation" showed that respondents had the feeling of face-to-face conversation when they were talking in Mixed Reality CASA more than in Virtual CASA ($p= 0.001<0.005$).

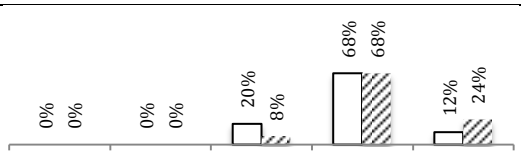
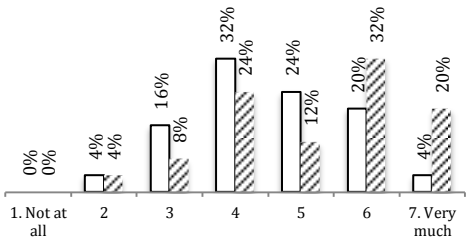
Responses for the second variable also supported the first variable since respondents felt that Mixed Reality CASA could support natural conversation better than Virtual CASA ($p=0.019<0.05$).

Surprisingly, when respondents were asked whether the conversation was like a phone conversation, the percentage for Mixed Reality CASA and Virtual CASA was quite equal. This was possibly due to the sound coming from the speakers being similar to the sound coming from a phone.

With regard to the partner's attitude, respondents were asked whether the way their partner responded to them were in one of these ways: 1) Extremely unfriendly; 2) Unfriendly; 3) Neither friendly or unfriendly; 4) Friendly or 5) Extremely friendly. Based on the responding data, 94% of respondents rated the partner's attitude in Mixed Reality CASA as either friendly or extremely friendly while the percentage in Virtual CASA was only 80%.

For the last variable, respondents were asked to rate the extent of sense of closeness when they were in the two spaces. The statistical result in Table 27 showed that Mixed Reality CASA could better support a "sense of closeness" than Virtual CASA with p=0.0145<0.05.

Indicators	Variables	Response	Means	1-tailed S level/2	H_0
Face-to-face meeting	F2F conversation		3.96 5.16	0.001	Rejected
	Natural conversation		3.60 4.52	0.019	Rejected
	Phone conversation		4.40 4.56	0.3645	Accepted
	Partner's attitude		3.92 4.16	0.028	Rejected

					
	Sense of closeness		4.52 5.20	0.0145	Rejected

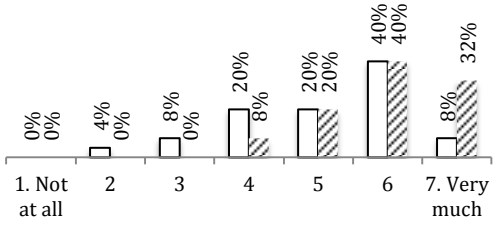
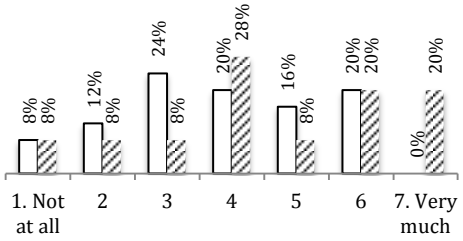
Virtual CASA

Mixed Reality CASA

Table 27: Paired sample t-test for "*face-to-face meeting*" in Mixed Reality CASA and Virtual CASA

6.5.2 Trust

In this section, respondents were asked whether they trusted their partners and were willing to share information with them when they were talking with each other. The data in Table 28 indicates that the extent of trust and willingness to share information was more when communicating in Mixed Reality CASA than for Virtual CASA.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Trust	Trust		5.08 5.96	0.01	Rejected
	Willing to share information		3.84 4.60	0.022	Rejected

Virtual CASA

Mixed Reality CASA

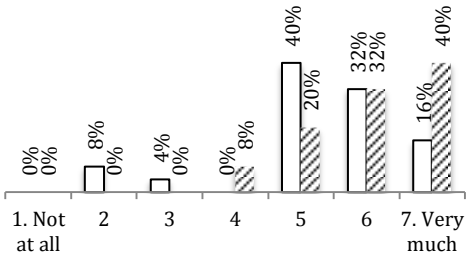
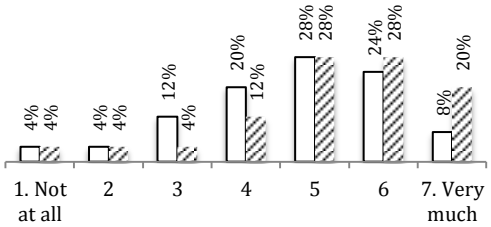
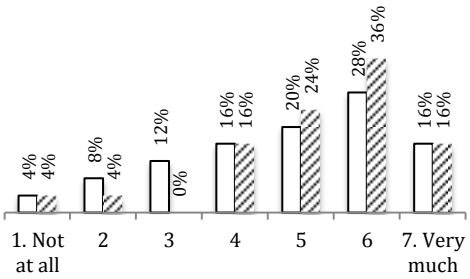
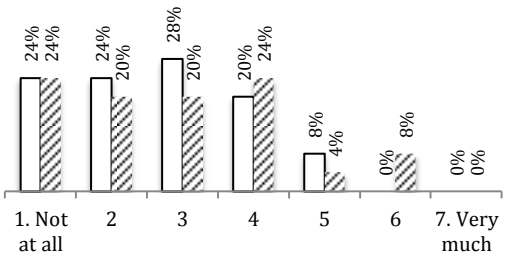
Table 28: Paired sample t-test for "*trust*" in Mixed Reality CASA and Virtual CASA

6.5.3 Engagement

In this section, respondents were asked to rate the extent of engagement in their conversation through four variables: 1) Interested in talking, 2) Highly interactive, 3) Easy for contributing and 4) No interruption.

For the first variable, participants were asked whether they were interested in talking with their partners. The statistical result in Table 29 shows that Mixed Reality CASA had a higher rate than Virtual CASA with $p=0.0205<0.05$ indicating that participants were more interested in talking with each other in Mixed Reality CASA than in Virtual CASA.

In the last three variables, respondents were asked whether they felt that the conversation was highly interactive, easy to contribute to and had no interruption. Interestingly, there was no significant difference found between the two spaces, as shown in Table 29, although the variable means of Mixed Reality CASA were all greater than the corresponding variable means of Virtual CASA.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Engagement	Interested in talking		5.32 6.04	0.0205	Rejected
	Highly interactive		4.68 5.20	0.5415	Accepted
	Easy for contributing		4.96 5.64	0.044	Accepted
	No interruption		2.72 2.88	0.346	Accepted

Virtual

Mixed Reality CASA

Table 29: Paired sample t-test for "*engagement*" in Mixed Reality CASA and Virtual CASA

6.5.4 Discussion

The sense of co-presence and co-location in the communication stage were measured by three indicators, namely "feeling of face-to-face meeting", "trust" and "engagement".

For the "feeling of face-to-face meeting", statistical data showed that Mixed Reality CASA supported this factor better than Virtual CASA as four out of the five variables produced results that yielded towards Mixed Reality CASA. Interviews also strengthened this result when participants were asked "How did you feel when you were communicating with your partners?". Most of the feedback showed that they felt as if they were communicating with real people.

- *"I could see Grace talking with me with gesture as if she was talking in front of me"*

Further to the sharing from remote participants, Bob related his experience as a local CASA participant when he was communicating with remote CASA people.

- *"The avatar is about the human size thus gave me the feeling of standing and talking with him like you and me are talking now."*

However, the issue of natural conversation was not well supported as participants still felt that their conversation was not as good as a normal conversation but more like a phone conversation. This finding is shown quite clearly in the data distribution in Table 27, although the mean of Mixed Reality CASA for "phone conversation" was greater than Virtual CASA. The reason could be due to the limitation of the equipment used for this communication which produced an audio sound similar to an audio conference call system with some echo interference during the conversation.

With regard to "trust" amongst each other, the quantitative results showed that participants trusted their partners more in Mixed Reality CASA, because they could see who was the person talking with them. Therefore, they were also willing to share information with each other more in Mixed Reality CASA although the degree of sharing was not too high. This could be due to the conversation being limited to exchanging greetings only between each other as they did not want to disturb people working.

- *"It was just a quick conversation as it may affect people in CASA."*
- *"Paul*[5] *said 'Hi' and talked to me. Although the conversation was short but made us keep in touch"*

For the extent of engagement in the conversation, as analyzed in Section 6.5.3, there was no significant difference found for the two variables of "engagement" which are "highly interactive", and "no interruption". Looking at the data distribution of the two variables, participants rated both spaces as highly interactive with little interruption occurring. According to the interview data, the reason that the variable mean of Virtual CASA is lower than Mixed Reality CASA is because the conversation was sometimes not as responsive as normal conversation. For example, the user of the avatar was interrupted after a while (e.g. to do some other work) but his avatar was unable to continue the conversation even though it was still hanging in the Virtual CASA.

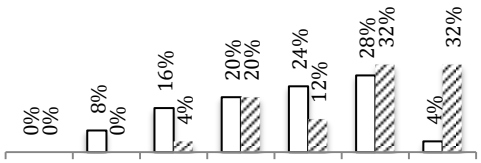
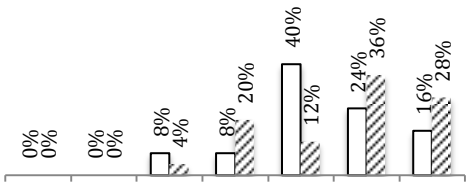
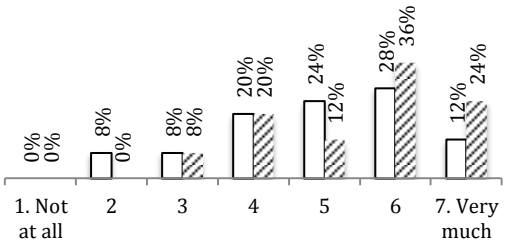
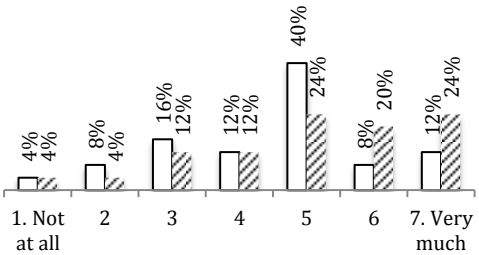
6.6 Evaluating the sense of co-presence in high social function space

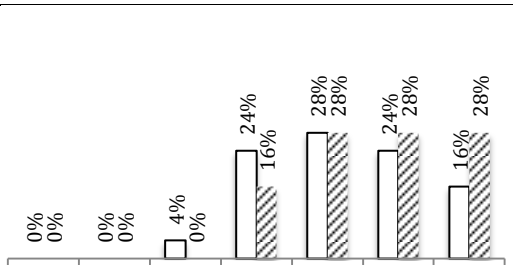
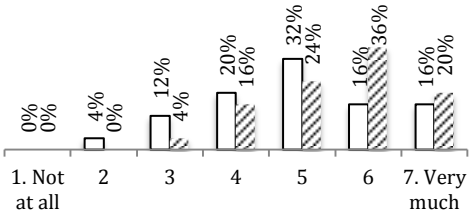
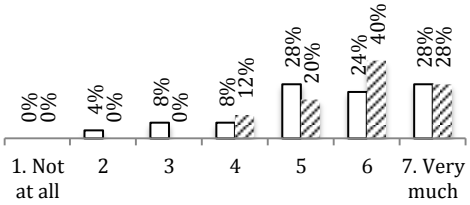
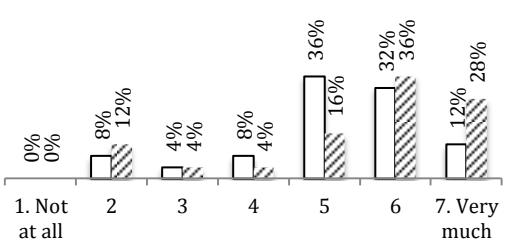
This part presents the data for the answer to the last research question which is "*Does the sense of co-presence increase if the mediated shared space supports a high social function in which human activity often takes place?*"

[5] *Real name has been changed for privacy*

Eight variables were used to measure “social function space”. They are: 1) “close sense of distance with friends”; 2) “brings into contact with friends”; 3) “environment”; 4) “awareness of friend’s presence”; 5) Taking a break; 6) Afford unplanned meeting; 7) afford semi-planned meeting; and 8) socializing.

The statistical data collected showed that Mixed Reality CASA significantly supported a “close sense of distance with friends”, a space for “taking a break” and “afford unplanned meetings” more than Virtual CASA. For the other variables, the results did not clearly indicate any significant difference however the means of these variables for Mixed Reality CASA were all greater than the means of the corresponding variables for Virtual CASA.

Indicators	Variables	Response	Means	1-tailed S level/2	H_o
Social function space	Enticing factor (Close sense of distance with friends)		4.60 5.68	0.0015	Rejected
	Enticing factor (brings into contact with friends)		5.16 5.64	0.0535	Accepted
	Environment		4.92 5.48	0.05145	Accepted
	Awareness of friend's presence		4.48 5.04	0.05375	Accepted
	Taking a break		5.08	0.0145	Rejected

			5.68		
	Afford unplanned meeting		4.92 5.52	0.0245	Rejected
	Afford semi-planned meeting		5.44 5.84	0.1265	Accepted
	Socializing		5.16 5.44	0.212	Accepted

Virtual CASA

Mixed Reality CASA

Table 30: Paired sample t-test for "social function space" in Mixed Reality CASA and Virtual CASA

6.6.1 Discussion

The purpose of measuring sense of co-presence in social space is to verify whether the introduction of augmented video in the Mixed Reality CASA could act as a stimuli (as mentioned in Section 2.1.4) to trigger people's awareness and attract remote people to participate in the space frequently. The more people participating in this space, the more co-presence is supported.

As analyzed in Section 6.6, only three out of eight variables statistically showed that the social function of Mixed Reality CASA space significantly supported a higher sense of co-presence than Virtual CASA. Data of the other five variables also showed the higher value for Mixed Reality CASA but was not significantly different.

As explained in Section 6.3.3 and 6.4.4, CASA is a research room, and thus, does not have social activity. People only come to CASA to do research work and social interaction only occurs when they have the need to exchange information or gather for an annual welcome party. This is the reason why statistical data did not much yield toward Mixed Reality CASA in the two variables "socializing" and "environment" as participants did not think of this place as having much social function or appropriate social environment.

The reason that the variables "awareness of friend's presence" and "enticing factor (bringing into contact with friends)" did not produce expected results could be explained in the same way as in the discussion in Section 6.3.3 and 6.4.4, that is, due to people in local CASA not being around remote people did not encounter anyone when they logged into the Mixed Reality CASA.

6.7 Summary

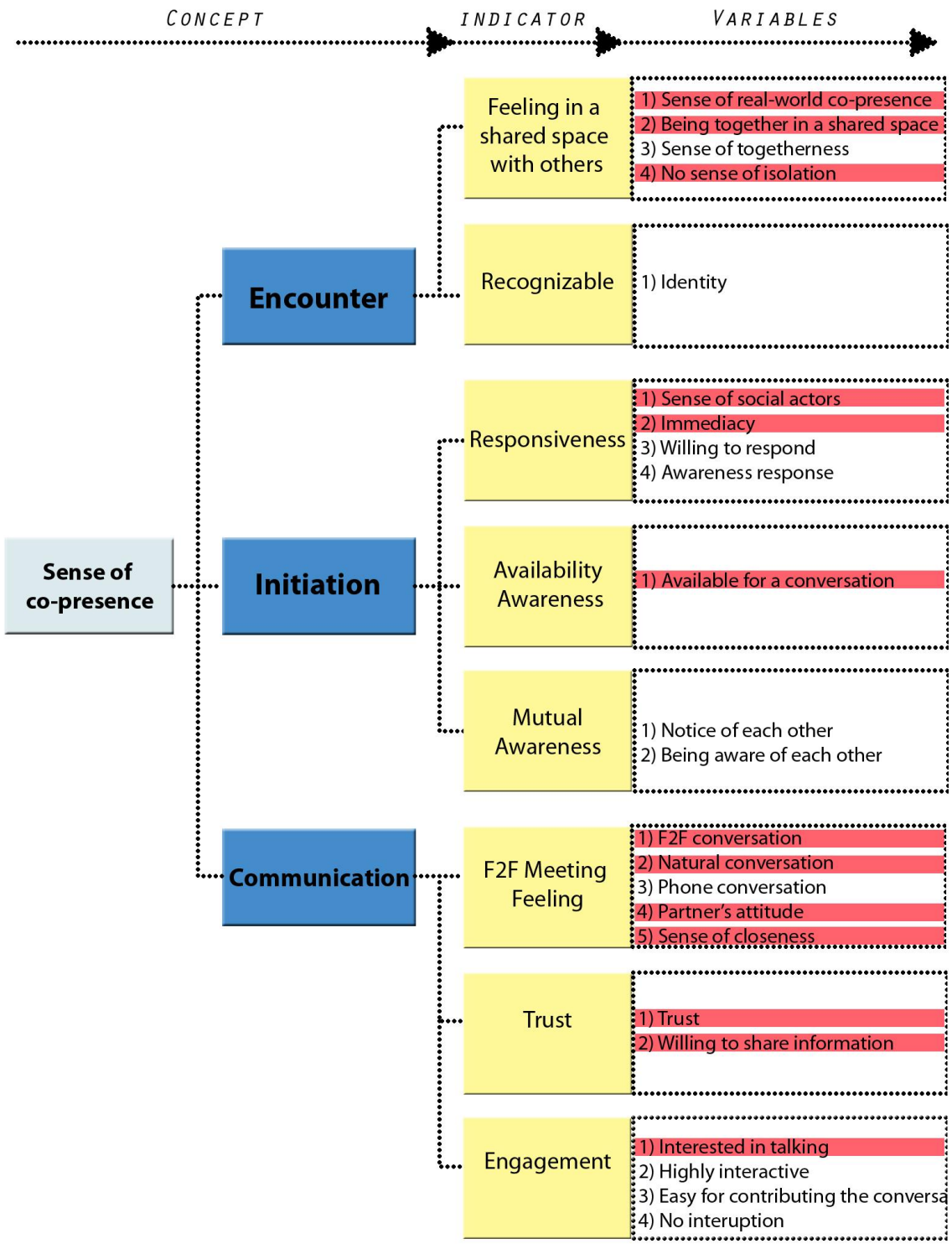


Figure 32: Summary of quantitative data for Mixed Reality CASA and Virtual CASA

Figure 32 gives the summary of the quantitative data in which the highlighted variables are the features that Mixed Reality CASA supported better than Virtual CASA.

The quantitative data showed that Mixed Reality CASA is better than Virtual CASA for all the features, but not all of them. Still, Mixed Reality CASA was proven to support co-presence better than Virtual CASA. Specifically, three out of five variables were credited for Mixed Reality CASA in encounter stage and seven out of eleven variables were credited to Mixed Reality CASA in the communication stage. Hence, to some extent, Mixed Reality could support co-presence better than Virtual CASA in the encounter and communication stages. As discussed in Section 6.4.4, although the quantitative data was not evident to Mixed Reality CASA in the initiation stage, however, qualitative data and observation provided additional evidence and reason to clarify the ambiguity and to explain why Mixed Reality CASA did not work for some features. The analysis showed that Mixed Reality CASA supported co-presence slightly better than Virtual CASA for "willingness to respond" and "being aware of each other". Therefore, with five out of seven variables credited to Mixed Reality CASA in the initiation stage, it could be proven that Mixed Reality CASA also supports sense of co-presence better than Virtual CASA in this stage. As elaborated in Section 4.1, Mixed Reality CASA was created as an instance from the three factors of the theoretical model of Mediated Shared Space. Because it was not constructed from the highest degree of each factor and its spatial setting is the combination of a virtual space and a physical space, thus, to some extent, participants who visited the virtual space of Mixed Reality CASA might have some feelings similar to when they were visiting the Virtual CASA. Therefore, it could be the reason why Mixed Reality CASA did not fully support a sense of co-presence in all three interaction stages.

While the sense of co-location is a prerequisite for co-presence, it had been reported more apparently for Mixed Reality CASA in the three stages of the interaction process by both quantitative and qualitative data. Specifically, it had been reported by the “feeling in a shared space with others” in the encounter stage, the “availability awareness” in the initiation stage and the “feeling of face-to-face meeting” in the communication stage.

CHAPTER 7
CONCLUSION

7.1 Mediated shared space for informal interaction: considerations

Through the review of theories and previous case studies, this study has come up with the theoretical model of "mediated shared space for informal interaction at a distance" whose features support the shared social context represented by the sense of co-location and the sense of co-presence in the three stages of the interaction process which are encounter stage, initiation stage and communication stage. The model was proposed to enable natural and intuitive interaction and overcome the problems that tend to occur in the current systems. The model recommended three main spatio-temporal factors: continuously open, mutually shared and concurrently convergent.

In most systems that were built to support informal interaction at a distance as described in Section 2.2.2.2, the sense of co-location and co-presence were supported to enable informal interaction to occur to limited extent. Some common problems were found such as intrusiveness, putting much effort into making a connection, privacy concerns, low probability of encounters and participation. They tended to occur, especially, in intended informal interaction when one person attempted to interact with another remote person. The problems were due to the fact that the sense of co-location and co-presence was not properly supported in the shared social context The literature review has shown that many studies have

attempted to enable informal interaction to occur remotely in different ways, however, they only focused on supporting the context content in a specific stage of the interaction process such as presence awareness, grounding, co-ordination instead of supporting context awareness of the whole interaction process: i.e. from encountering a partner, to initiating a conversation and then engaging in the conversation. Knowing this shortcoming and in the light of knowledge gained from the notion of space and place, context awareness and mediated shared space technologies, this study suggested three spatio-temporal factors for mediated shared space to support context awareness of the entire informal interaction process through the sense of co-location and the sense of co-presence. These factors are:

a) **Continuously Open**: this refers to the characteristic of the mediated space that is "***open***" to facilitate people to join and interact at any time they want. In this study, the term "open" is about the right to access the space whose degree of accessibility is varied depending on the spatial usage. This study proposed the following three types of "continuously open" whose order is based on the increment of the degree of "open":
    - Enclosed space: Full access to those who make a request
    - Partitioned space: Full access to groups of people
    - Exposed space: Full access to everyone at anytime
b) **Mutually Shared**: this refers to the characteristic of the mediated shared space that enables all information of the space to be visually shared among participants. Because participants join the space at a distance, the degree of sharing is different and dependent on the use of technology. This study categorized "mutually shared" into the following three types whose order is based on the increment of the degree of "sharing":

- Mediated sharing: actual information of each space is not immediately shared between each other but mediated through a computer-generated virtual space.
- Mixed sharing: actual information of some spaces is immediately shared while some spaces are mediated through computer-generated virtual spaces.
- Immediate sharing: actual information of every space is immediately shared with each other

c) **Concurrently Convergent**: this refers to the characteristic of the mediated shared space that enables remote people to be concurrently co-located. To support this characteristic, this study proposed three types of convergent space:

- Virtual reality space: people virtually converge in a 3D virtual space
- Space with mixed reality boundary: people converge in a mixed reality space
- Physical reality space: people converge in a real physical space

As each factor of the model consists of different types of mediated setting, a variety of Mediated Shared Space instances could be formed by combining these mediated settings. The maximum number of instances is not restricted to 3x3x3=27 cases but could be more because mixed settings are flexible and varied depending on the different types of media and tools used (more details were explained in Section 3.4.4).

Two instances have been chosen for testing the research hypothesis stated in Section 1.2.3. One instance, called Mixed Reality CASA, was developed with a higher degree of spatio-temporal factors which supposedly supports a higher degree of sense of co-location and co-presence. A second instance, called Virtual CASA, was built with a lower degree of spatio-temporal factors. It also represents the existing type of mediated shared space. The results show that Mixed Reality CASA supported the sense of co-location and the sense of co-presence better than Virtual

CASA. Therefore, it has proved the research hypothesis. The results also show that the two instances built with spatio-temporal factors did enable the sense of co-location and co-presence, each to different extent, in the three stages of the informal interaction process. Therefore, these instances have also validated the theoretical model.

In addition, in order to construct a better Mediated Shared Space, having clear implementation objectives and explicit development intentions are very important to set the desired achievement of the spatial setting based on which proper tools and media are selected for the implementation purpose. Therefore, these instances are technology dependent and based on the developer's intention.

7.2 Contributions

This study has two major contributions: contributions to academics and contributions to practices

7.2.1 Contributions to academics

Through a comprehensive literature review, Section 3.1.2 showed that previous systems developed for supporting informal interaction at a distance were predominantly technology driven and task-specific instead of being created based on a certain literature. There is no literature specifically focused on the issue of creating mediated shared space for informal interaction. Due to this inadequacy, this study contributed to the research in this area the development of a theoretical model of Mediated Shared Space which shows the theoretical foundation of how a mediated shared space should support context awareness of the whole informal interaction process. The model will serve as a theoretical guide to other researchers who are looking for theoretical support for setting clear development objectives of their

systems before they are implemented. This will help minimize the issues that tend to occur in these system as pointed out by Truc and Tan (Truc & Tan, 2011).). It also provides a theoretical approach for researchers who wish to develop their own systems for supporting informal interaction with the use of spatial settings. They could create mediated settings which accommodate and facilitate remote participation and achieve co-located informal interaction in a natural and intuitive way.

The other contribution of this study to academics is the comprehensive development of the theoretical model. The development started from the issues that tended to occur in previous systems. This was followed by the creation of the conceptual model for enhancing the interaction process, and finally the implementation of a prototype which is a technical possibility of the model in order to evaluate the effectiveness of the model. This comprehensive development of the theoretical model implied that the model had undergone a comprehensive study to become a workable model that could help to prevent typical issues and provide maximum support for the interaction process from encounter to initiation and then communication.

7.2.2 Contributions to practices

As discussed in Section 3.1.1 and Section 3.1.2.2, literature had shown that there was no specific design implementation or guideline for implementing mediated shared space for informal interaction at a distance. There were just general technical implications for implementing specific systems with the use of certain technologies and some technical implementation guidelines for future development purpose. Therefore, the practical contribution of this study is on the practical construction of the Mediated Shared Space that provides a guideline for constructing a variety of Mediated Shared Spaces from the provided set of mediated settings derived from the

three factors of the theoretical models that are continuous opening, mutual sharing and concurrent convergence. Through the findings in Chapter 6, the degree of supporting informal interaction of the Mediated Shared Space depends on the selected spatial settings that are used for constructing it. As mentioned in Section 3.4, each factor could consist of many types of mediated spatial settings whose degree of support for this factor spreads along its incremental continuum. Hence the greater the degree of support for this factor the higher the degree of supporting informal interaction achieved.

7.2.3 Other contributions

Besides the major contributions given above, this study also made the other significant contributions to the research in this area. These are summarized as follows:

- The identified theoretical and practical knowledge gaps in this study could be used in other research to develop other research directions
- The methodological approach for evaluating effectiveness of the proposed model contributes an evaluation process from experimental setup to data collection and data analysis that could be used as a reference for other research that have the same or similar purpose or needs.

7.3 Opportunity and future development

An obvious fact of informal interaction is that it is more efficient when it is conducted physically rather than through remote connection. With the aid of advanced technology, the distance between people can be shortened and they can be

brought together in one setting to interact as if they are co-located, e.g. talking over a video-based system, hanging out and interacting in a collaborative virtual environment, or being visualized and interacting in other physical spaces through holography. As technology is still being improved, the level of corporeal co-presence among remote participants is currently not at its peak. However, using technology to facilitate informal interaction is still the best solution to overcome the issue of distance, time and transportation costs. Moreover, if the technology-aided interaction could help participants to be aware of the interaction context before and during interaction, as if they are co-located, that could help to enhance natural interaction.

In this study, the Mixed Reality Space which is a prototype of the Mediated Shared Space model was constructed and implemented using available resources. Due to technical limitations it could not be the ideal solution of Mediated Shared Space. As explained in Section 3.4.4, there are a variety of Mediated Shared Space instances that could be formed from the three factors. Construction to achieve the desired result depends on the proper selection of tools and media for implementing the system (as elaborated in Section 2.2.2). This presents an opportunity for future research to implement these instances with other types of technology. For example, if holographic tele-presence was used instead, it might have a different impact on the participants of the experiment.

The other impact factor is the environment used for conducting the experiment. The experiment environment used in this study is a research room where people have little need to discuss. The response might be different if the experiment was conducted in other places, such as, a lounge in a professional company where informal interaction is a necessity and frequently occurs. In this case, research on different experiment environment is also a possible research opportunity for the future.

The aim of the Mediated Shared Space is not to create a substitution for face-to-face interaction but rather a new visual mode of informal space in the workplace such as a hallway, lounge or pantry that is not only for people locally but also affords the participation of remote people. By converting physical space into Mediated Shared Space, the physical space could be a hub for informal interaction whose setting affords the role of social space for informal encounter and casual communication among local and remote people. Therefore, the usage of this theoretical model is not constrained to supporting informal interaction. It could support any co-located collaboration whose working tasks need informal interaction in the collaboration process. In this case, it could be an extended research direction for researchers to explore.

Based on observation during the experiment, the Mixed Reality CASA prototype is more suitable for *intended* informal interaction when remote people have the need to interact with their co-workers. In this case, the degree of co-presence is higher as the remote ones will hang around in the system to wait to meet their partners. From the collected data, *opportunistic* and *spontaneous* informal interactions did occur through the implemented prototype but the rate was not high. It is an issue that needs to be further investigated.

Although local participants were involved in the experiment of Mixed Reality CASA, they were not taken into account in the quantitative analysis but their comments were used to strengthen the research findings. This is because the research would like to compare the same pool of participants' feedback when they made the same effort to experience the two platforms. Interaction at the physical side is quite complex as the encounter is effortless when remote people are hanging around in the space as avatars. It is effortful for local people to meet the remote ones when no remote people log in to the space. Therefore, another type of mediated shared space should be investigated to support effortless encounters.

Lastly, in addition to supporting normal informal interaction, this theoretical model could be used to serve other development objectives, such as, collaboration meetings or coordination meetings. For example, the "Big Room" collaboration meeting of a construction project often consists of multiple stakeholders (owners, designers, main contractors and subcontractors) who meet together to identify, discuss and address issues in order to enable a smooth project delivery process. As the meeting is on a daily basis and people have to gather in one big room for their discussion, this model could help to form a mediated space where people could meet virtually together. However, in order to support better collaboration process, shared tools or interactive artifacts, e.g. shared drawings for discussion, should be provided. As the main objective of this study is only to provide a shared space for remote people to be co-located to informally interact with each other, the shared features for collaboration are still under development and not integrated in the theoretical model. It is also a factor that needs to be considered if this model is to be used for collaboration purposes.

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APPENDICES

APPENDIX A: EXPERIMENT TASKS FOR REMOTE USERS

The experiment tasks have 4 parts:

1. Setting up the system
2. Experiment Phase 1: Exploring and communicating in the Virtual CASA
3. Experiment Phase 2: Exploring and communicating in the Mixed Reality CASA
4. Responding questionnaire and interviews

Part	Task details
Setting up the system	- Install Phoenix Viewer. Please refer to the attached instruction file. - Contact me, Truc (Bamboo), for helping to set up the system • Email: ivorybamboo@yahoo.com, g0800518@nus.edu.sg • Skype: truc_bamboo • Mobile: +6581435803 • Yahoo messenger: ivorybamboo
Phase 1 Experience Virtual CASA	After installing the system, the experiment task details for phase 1 are as follows: • Perform **Phase 1** (for details of the task click here). Please log in the virtual CASA as many times as possible. • After that, please respond to the questionnaire in this link: https://www.surveymonkey.com/s/B3Y7N7S

Phase 2 Experience Mixed Reality CASA	- After Phase 1, perform **Phase 2** (for details of the task click here). Please log in the virtual CASA as many times as possible. - Then, please respond to the questionnaire in this link: https://www.surveymonkey.com/s/T9YDRWK
Interview	After finishing the experiment task, I will contact you for 15-minute interview about how you experience the experiment. For those who are not in Singapore, the interview could be carried out through Skype or Yahoo messenger in your convenience.

Phase 1: Exploring and communicating in the Virtual CASA

1. Login to Phoenix Viewer

- After login to Phoenix Viewer, you will arrive to the virtual room as shown in Figure 33.
- Adjust your viewpoint (scroll up middle button of your mouse) to have a proper view.

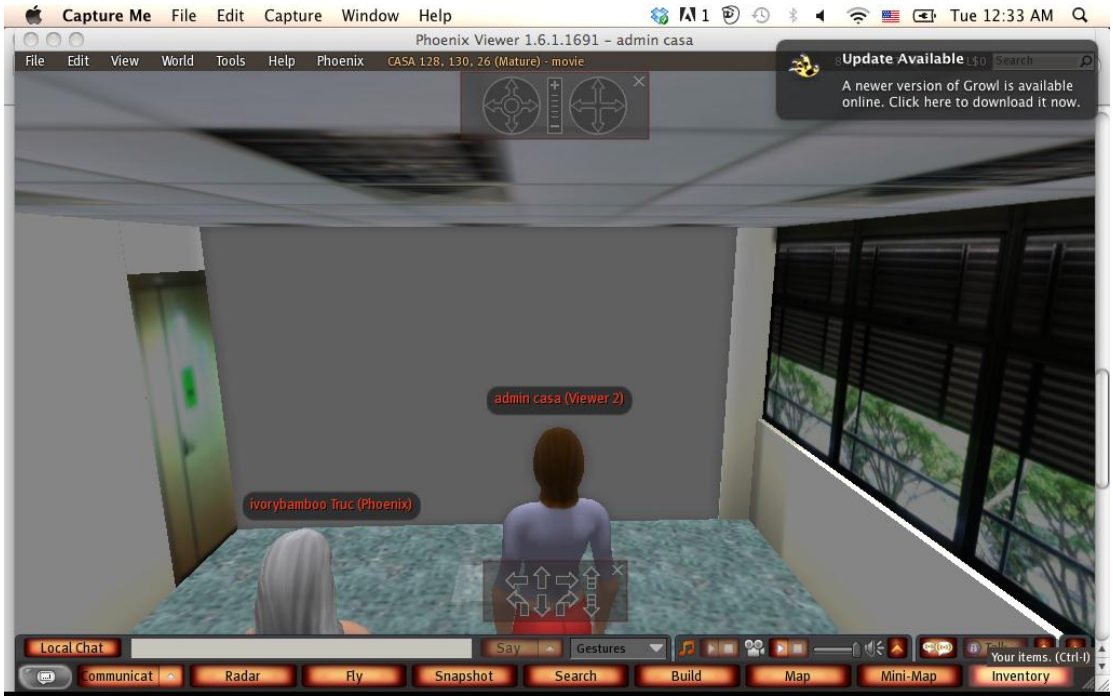


Figure 33: Arrival room

2. Enter the Virtual CASA

    - Press the up navigation arrow located on the navigation icons on your screen to cross the grey virtual wall as shown in Figure 34.

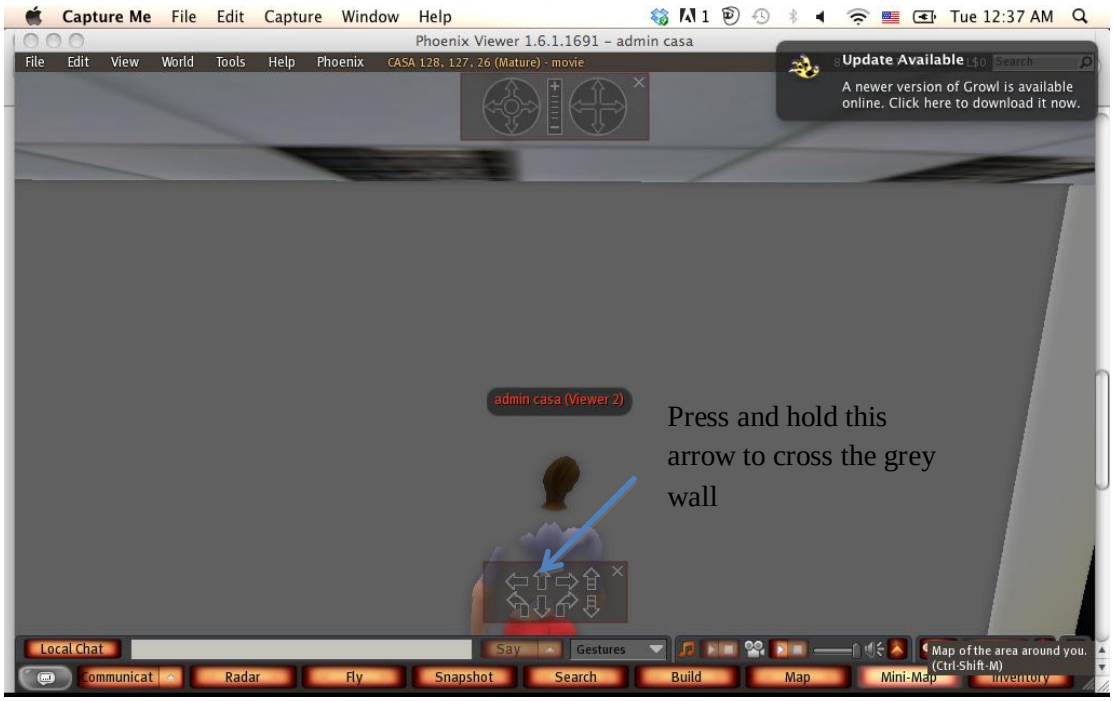


Figure 34: Crossing the gray wall

- Keep pressing the arrow until you enter the virtual CASA as shown in Figure 35.

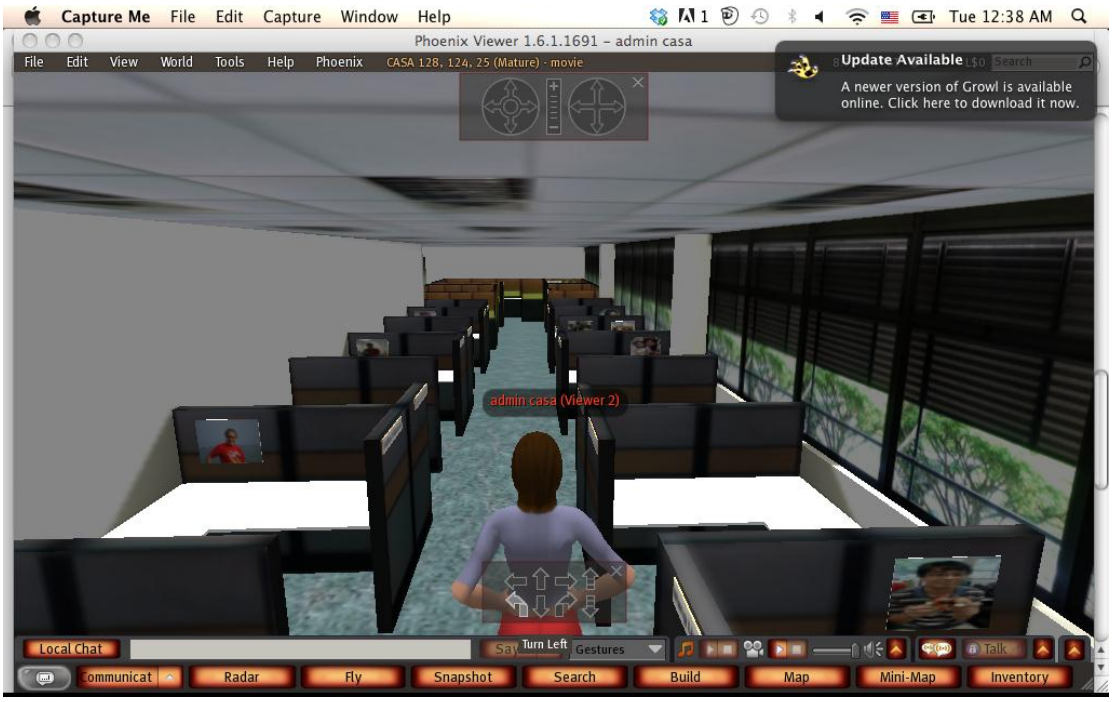


Figure 35: Virtual CASA

- When you meet someone inside the world, please try to communicate with them using text chat and voice chat as shown in Figure 36.

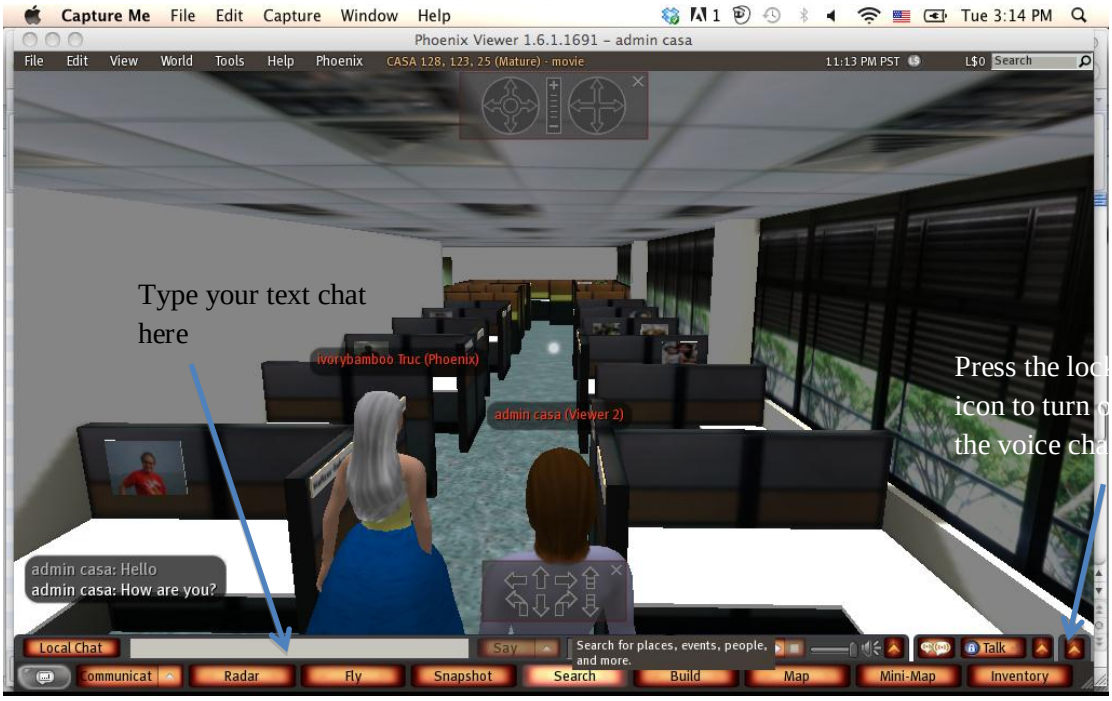


Figure 36: Communicating in virtual CASA

- When you are hanging out in Virtual CASA, you could change your appearance by right clicking on your avatar and choosing appearance on the pop-up window (Figure 37).

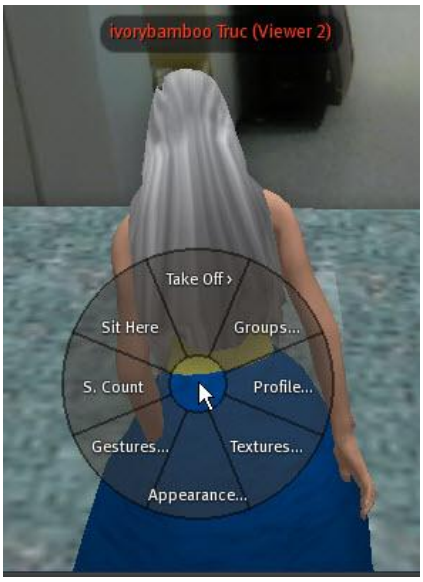


Figure 37: Changing appearance

Phase 2: Exploring and communicating in the Mixed Reality CASA

1. Come back to the arrival room

    - Turn your avatar around by pressing and hold the turn left (or right) navigation arrow (Figure 38).

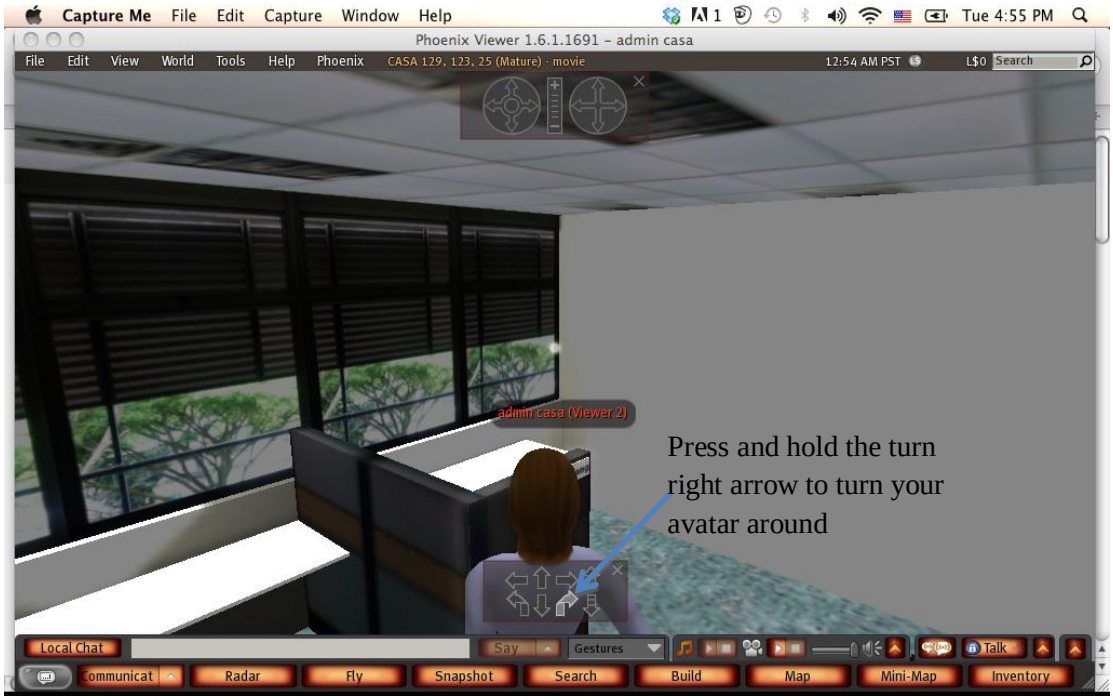


Figure 38: Turn your avatar back by pressing and holding the turn right arrow

- Keep turning until your avatar to face the grey wall (Figure 39)

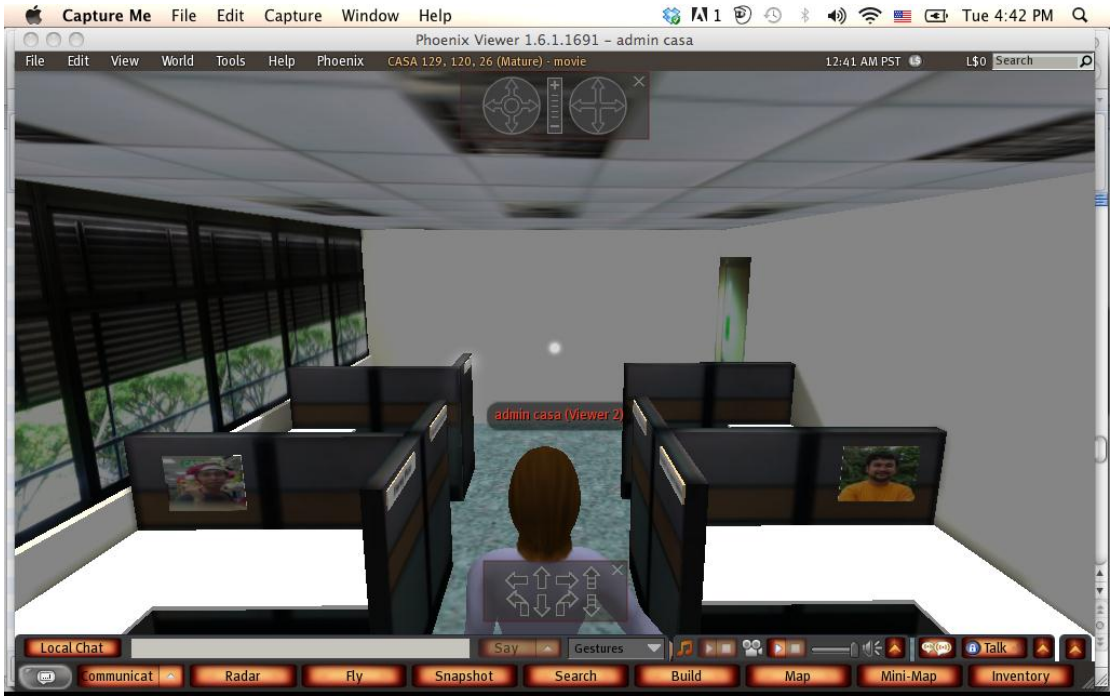


Figure 39: Turn around until your avatar faces the grey wall

- Press and hold the up arrow to cross the grey wall until you enter the arrival room (Figure 40)

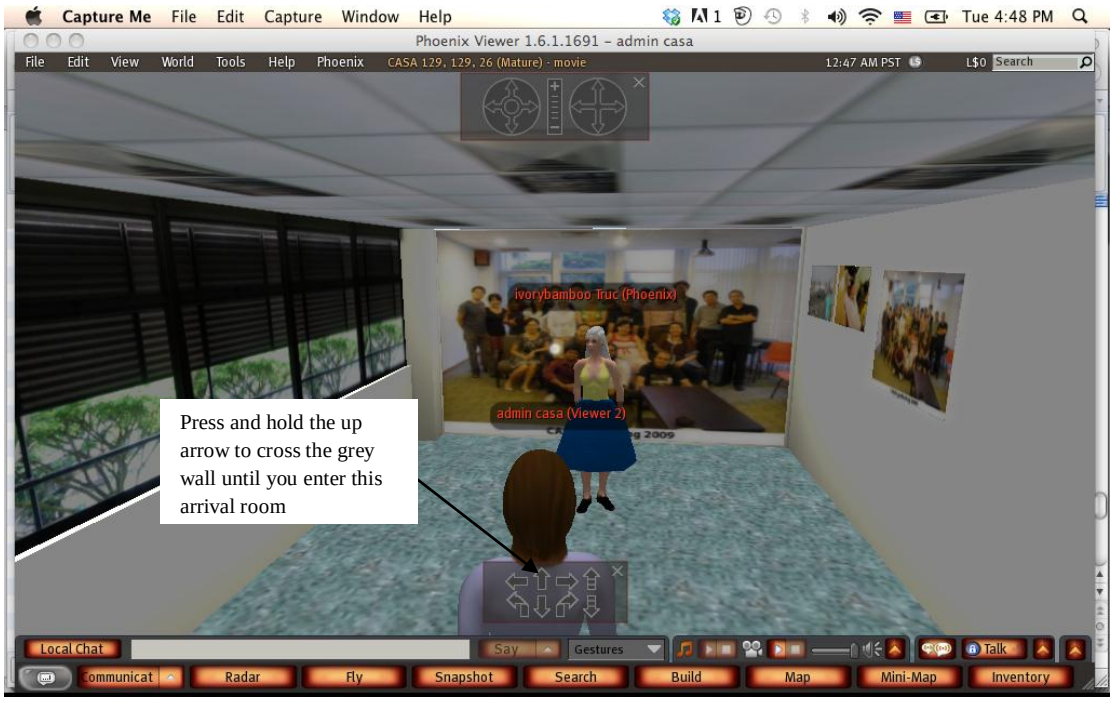


Figure 40: Keep pressing and holding the up arrow to cross the grey wall until you enter the arrival room

- Press the turn left (or turn right) arrow to turn back to the grey wall

Figure 41: Press and hold the turn left arrow (together with right and left arrow) to face to the grey wall

- Turn on the real-time video of CASA by clicking the **Play button** and **Allow button** on the pop-up message (Figure 42)

Figure 42: Turn on the play button and allow button to load the real-time video of CASA

- After click the Allow button, you can see the real-time video of the physical CASA as shown in (Figure 43)

Figure 43: The real-time video of the physical CASA

APPENDIX B: QUESTIONNAIRE FOR CASA PARTICIPANTS

Thank you for your kindness to voluntarily participate in my study which aims to examine whether Virtual CASA could support more chance of informal interaction among geographically distributed people

Please read through the below information for system installation and interaction guideline. If you have any question, please feel free to ask.

You will be asked to do the following procedures:

1. Set up the system in your computer (if you are not staying in Singapore). If you are staying in Singapore, you can use my computer instead.

2. Have a brief introduction and practice of using the system.

3. Have a brief explanation of your task.

4. Login the system at informed time

5. Communicate with your CASA's partners

6. Answer a questionnaire

7. Answer a short interview which is a discussion about experiencing the system

The whole study is expected not longer than 1 hour.

For guidance and interview, I will directly work with you if you are in Singapore at

your convenient time. Otherwise, we could make it through Skype or other instant messengers like Yahoo, MSN, …

Please note:

1. Participant's identification, questionnaire answers and interview response will be kept confidential

2. Please kept login to the system 1 to 2 times a week and during 1 month in your convenient time after the experiments so that I could have a better observation of how the system could support remote people at a distance

3. You could withdraw from participating the study without giving any reason.

My contact:

My name: Nguyen Thi Lan Truc (bamboo)

Skype: truc_bamboo

Email: g0800518@nus.edu.sg

Yahoo messager: ivorybamboo

CONSENT FORM

Please read the questions below carefully and circle Yes or No as your answer:

1. Have you read the information sheet about this study?

- Yes
- No

2. Have you had an opportunity to ask questions about the procedure?

- Yes
- No

3. Have you received enough information about this study?

- Yes
- No

4. Do you agree to take part in this study?

- Yes
- No

5. We would like to videotape when you are interacting in the experimental environments and also during the interview. The videotape is only used for the data analysis purposes and will be kept entirely confidential.

Do you agree to be videotaped?

- Yes
- No

6. General information

- **Gender:**
  - ✓ Male
  - ✓ Female

7. My status is as follows:

- Current CASA students
- Graduated CASA students
- Faculties
- Other (please specify)

8. Are you currently living in Singapore?

- Yes
- No

If No (please specify which country you are living now)

9. What is your name?

……

10. Please rate how closely your sense of being together with others in virtual CASA resembles your sense of being with them in a real world setting?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

11. To what extent, did you have a sense of being in a shared space with your colleagues when you were in the virtual CASA?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

12. In the last conversation, to what extent, did you have the sense of the other people being together with you?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

13. To what extent, did you often feel as if you were alone in virtual CASA?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

14. How much were you aware of your colleagues?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

15. When you first saw your colleagues, did you respond to them as if they were:

- Real people
- Character in a movie
- Objects (e.g. a box)
- I don’t know

16. When your colleagues said greeting to you or wave hands, your response to their greeting is?

- Immediate
- 2
- 3
- 4
- 5
- 6
- Avoid

17. When you first saw your colleagues, was your first response to approach them or avoid them?

- Approach
- 2
- 3
- 4
- 5
- 6
- Avoid

18. Did the colleagues respond like they:

- Knew you
- Didn’t know you
- I don’t know
- I didn’t notice

19. How much were you aware of whether your colleagues are available for a conversation?

- Not at all
- 2
- 3
- 4
- 5

- 6
- Very much

20. When you were in the virtual CASA, were you and others often aware of each other as follows:

	1. Not at all	**2**	**3**	**4**	**5**	**6**	**7. Very much**
I hardly noticed another individual							
The another individual didn't notice me							
I was often aware of others in the environment							
Others were often aware of me in the room							

21. To what extent, did you feel your conversation with colleagues is like a face-to-face conversation?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

22. To what extent, did you feel your conversation with colleagues is like:

	1. Not at all	**2**	**3**	**4**	**5**	**6**	**7. Very much**
A natural conversation							

A phone conversation							

23. How did your colleagues seem to respond to you?

- Extremely unfriendly
- Unfriendly
- Neither unfriendly or friendly
- Friendly
- Extremely friendly

24. To what extent, did you try to create the sense of closeness between you and colleagues?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

25. In the conversation with your colleagues, your feeling was

	1. Not at all	**2**	**3**	**4**	**5**	**6**	**7. Very much**
I often trust my colleagues							
I were willing to share personal information with my colleagues							

26. Were you interested in talking to colleagues?

- Not at all
- 2
- 3

- 4
- 5
- 6
- Very much

27. Did the conversation seem highly interactive?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

28. Was it easy for you to contribute to the conversation with colleagues?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

29. Was there any frequent inappropriate interruption?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

30. This space brings me close sense of distance between me and my remote colleagues?

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

31. This space brings me the contact with my remote colleagues

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

32. This space and its artifacts are designed as a social space

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

33. This space supports high degree awareness of other

- Not at all
- 2
- 3
- 4
- 5

- 6
- Very much

34. This space could be used to take a break away from work

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

35. This space affords unplanned meeting such as spontaneous conversation

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

36. This environment affords semi-planned meeting by offering the ability to go there and meet your remote colleagues

- Not at all
- 2
- 3
- 4
- 5
- 6
- Very much

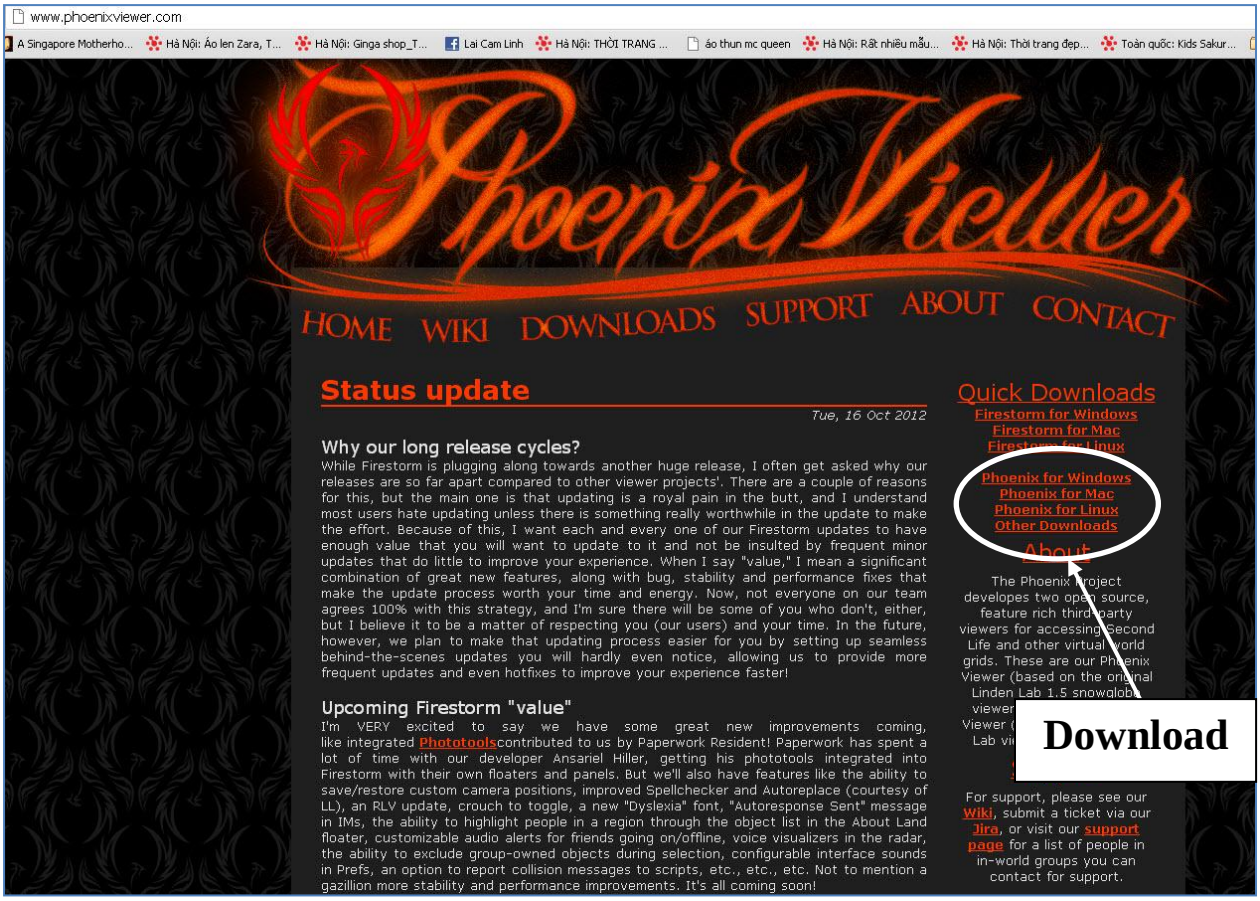
37. This space affords socializing activities

- Not at all
- 2

- 3
- 4
- 5
- 6
- Very much

APPENDIX C: INSTRUCTION TO INSTALL PHOENIX VIEWER

1. **Download Phoenix viewer** at this page: http://www.phoenixviewer.com/



If you are Windows user, please click: **Phoenix for Windows**

If you are Mac user, please click: **Phoenix for Mac**

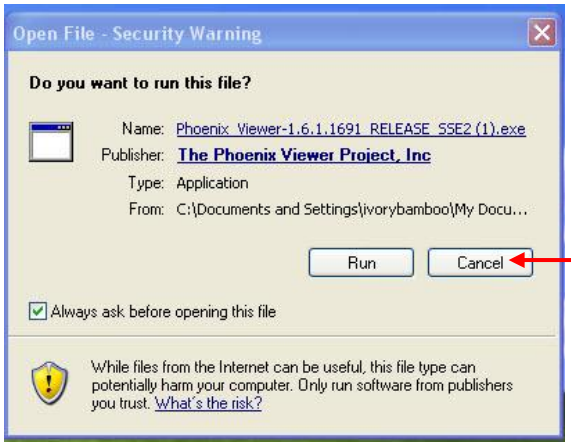
2. Run the downloaded file to install Phoenix Viewer

a. If you are using Windows, the downloaded file could be found in

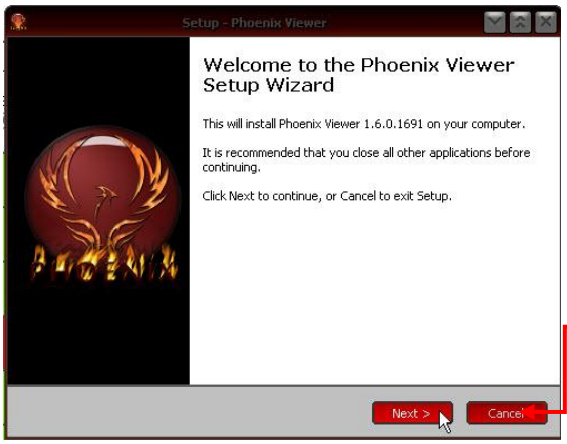
C:\ Documents and Settings\<USER>\My Documents\Downloads

For example:

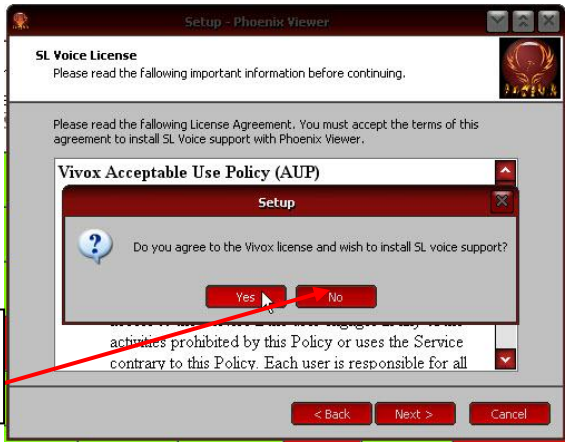
C:\ Documents and Settings\Truc\My Documents\Downloads



Press Run to install Phoenix



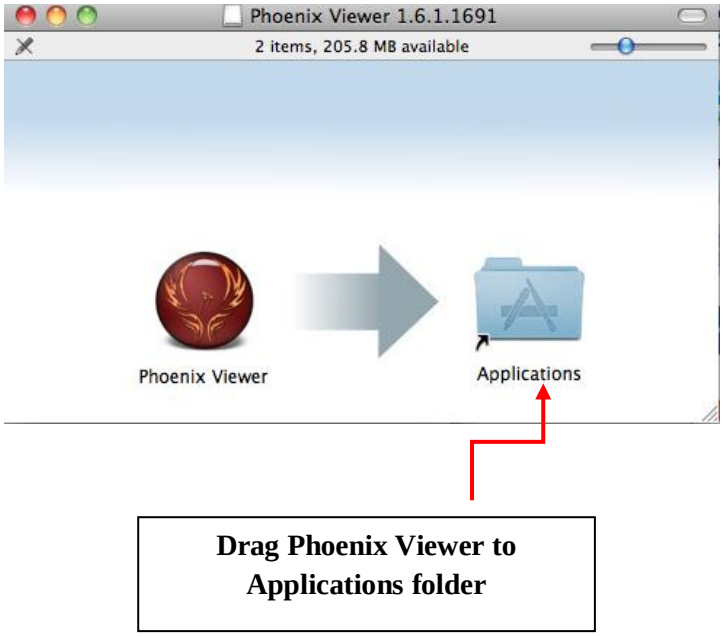
Press Next at each step



Click Yes to install Vivox voice

b. If you are using Mac, the downloaded file could be found in <USER>/ Downloads/

For example: Truc/Downloads

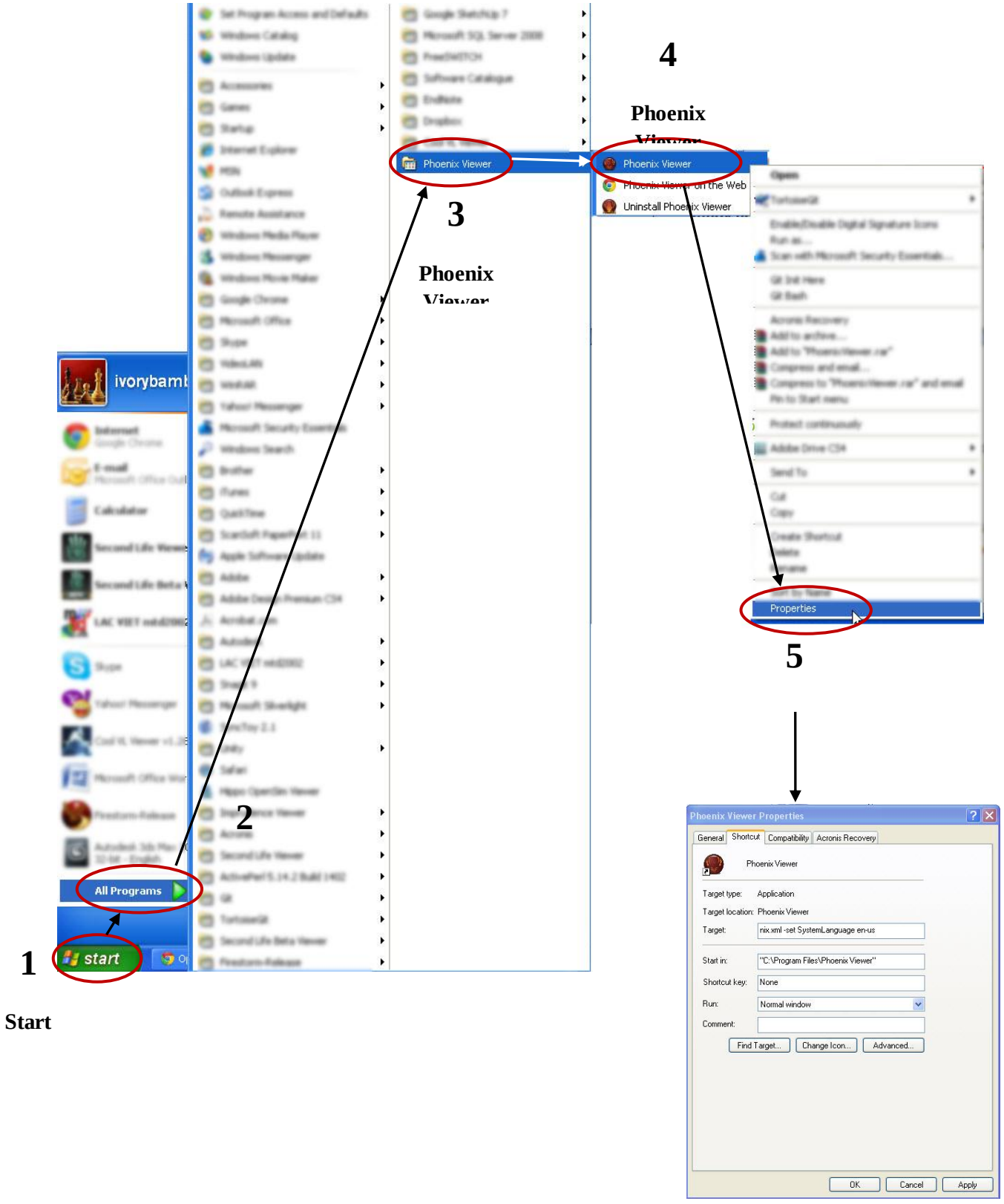


Drag Phoenix Viewer to Applications folder

3. **Connect to server after installing process,**

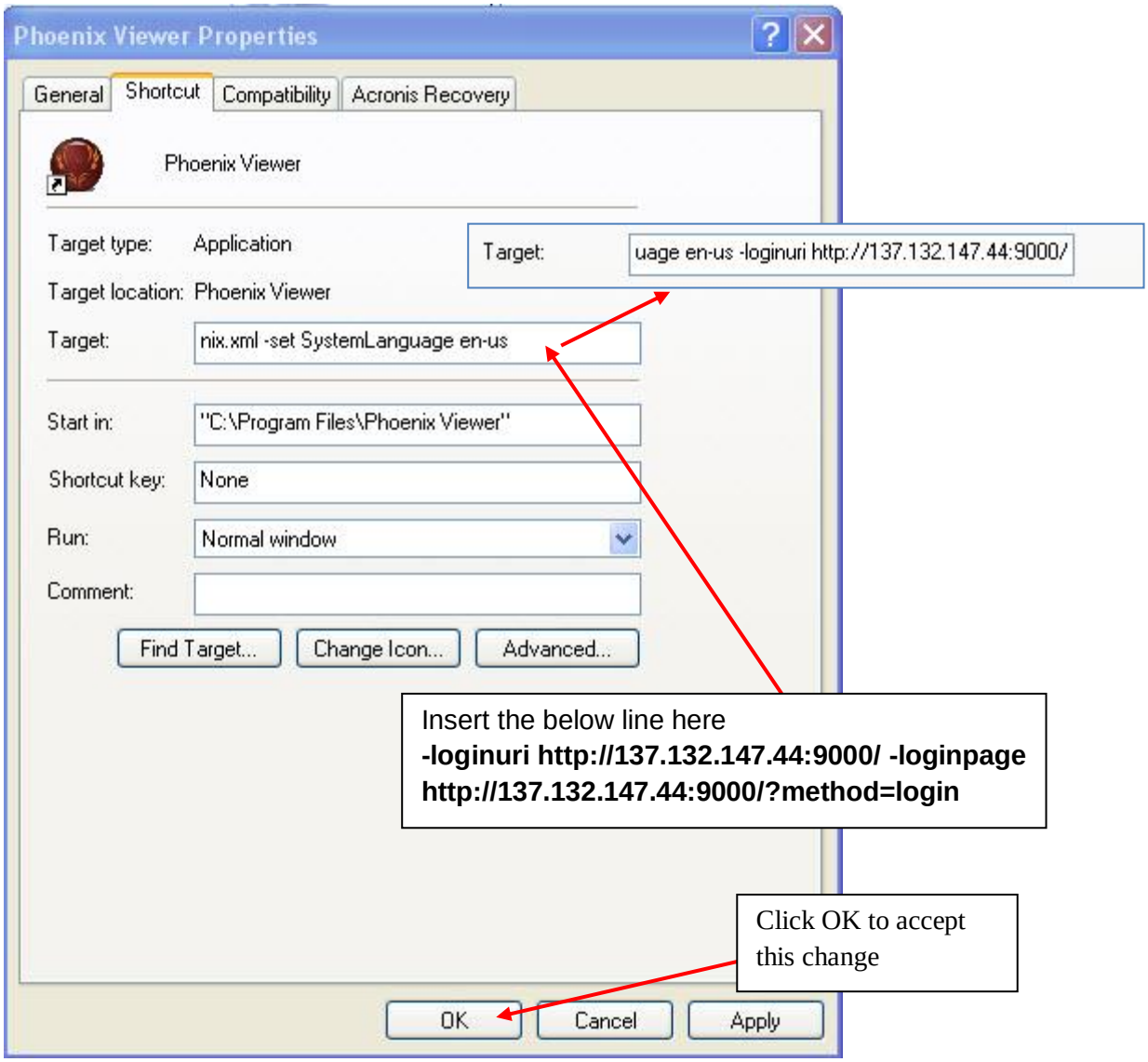
    a. **For Windows users**,

    - Go to **Start -> All Programs -> Phoenix Viewer**, **right click** on Phoenix Viewer icon and choose **Properties** on pop-up menu


4
Phoenix
3
Phoenix
Viewer
Phoenix Viewer
Uninstall Phoenix Viewer
Properties
5
2
All Programs
start
1
Phoenix Viewer Properties
General
Shortcut
Compatibility
Acronis Recovery
Phoenix Viewer
Target type: Application
Target location: Phoenix Viewer
Target: nix.xml -set SystemLanguage en-us
Start in: "C:\Program Files\Phoenix Viewer"
Shortcut key: None
Run: Normal window
Comment:
Find Target...
Change Icon...
Advanced...
OK
Cancel
Apply

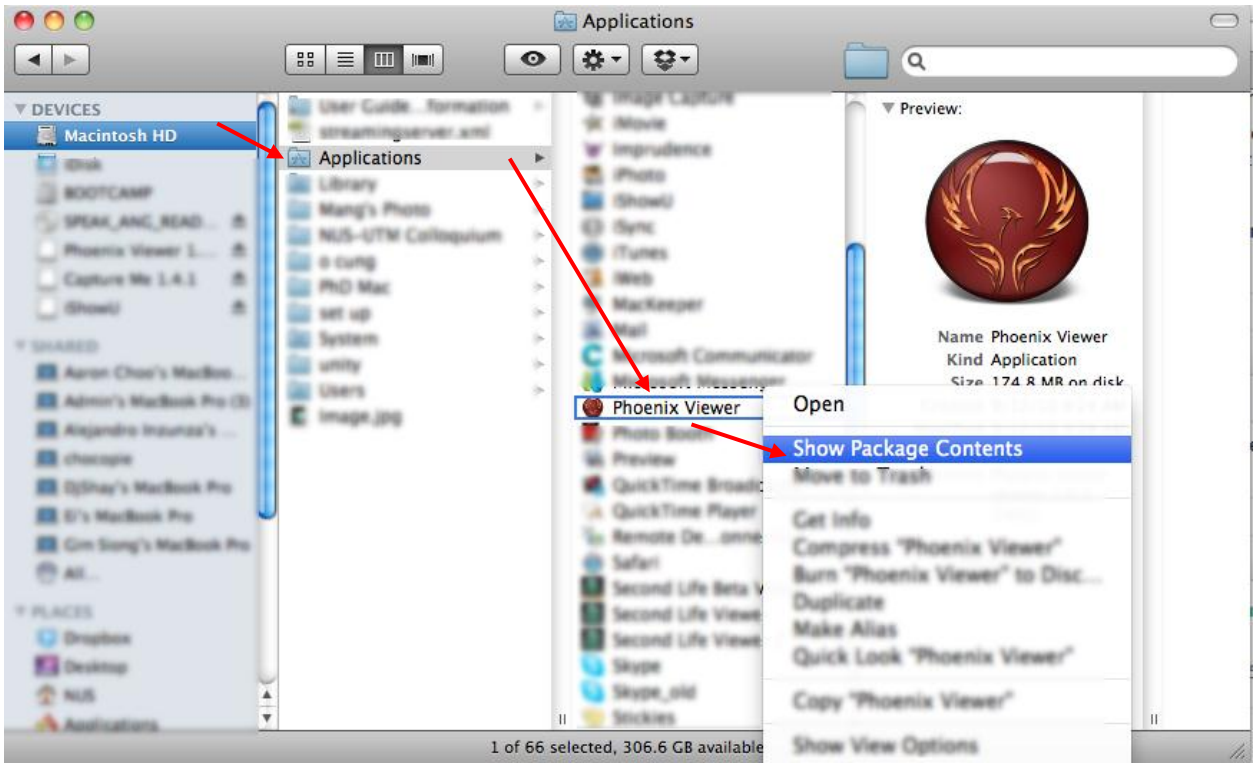
Start

- Go to Shortcut tab, in Target box
    - Place the cursor at the end of the text line
    - Make a space by pressing the space bar
    - Paste this following line:

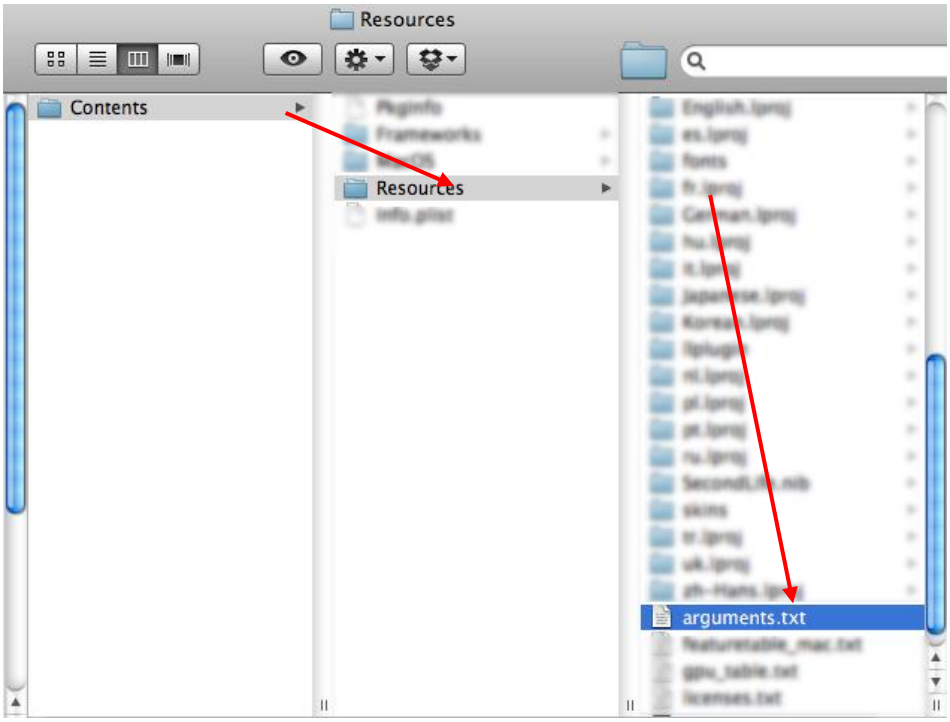


b. **For MAC users**,

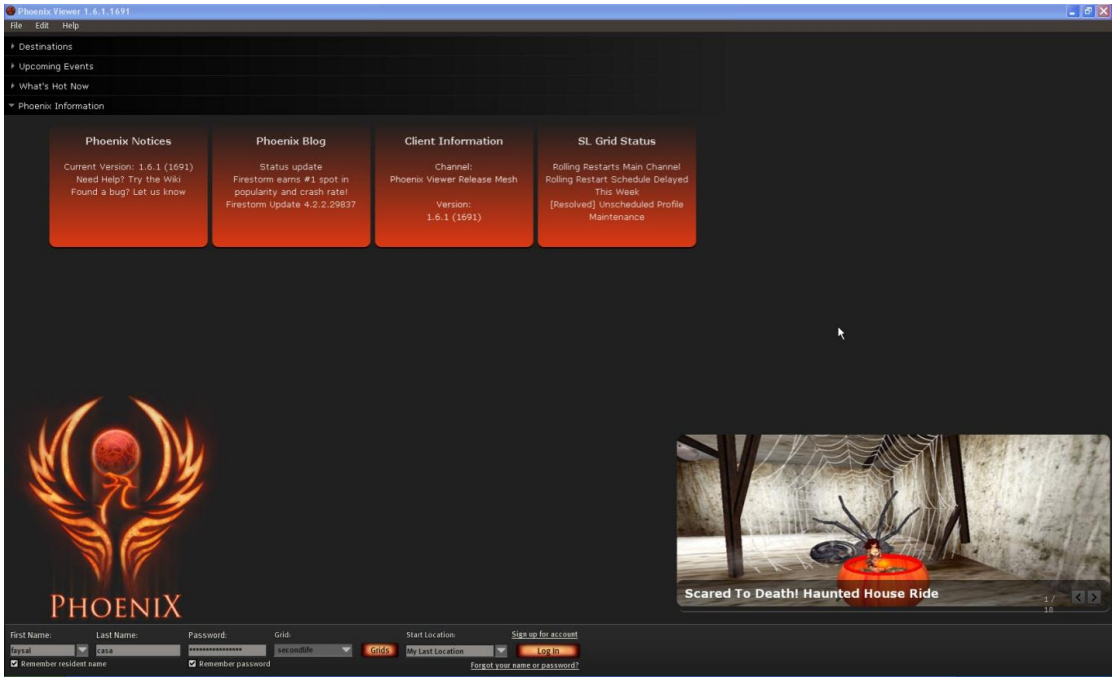
- Macintosh HD-> **Applications** -> **Phoenix Viewer**, **right click** on Phoenix Viewer icon and choose **Show Package Contents** on pop-up menu



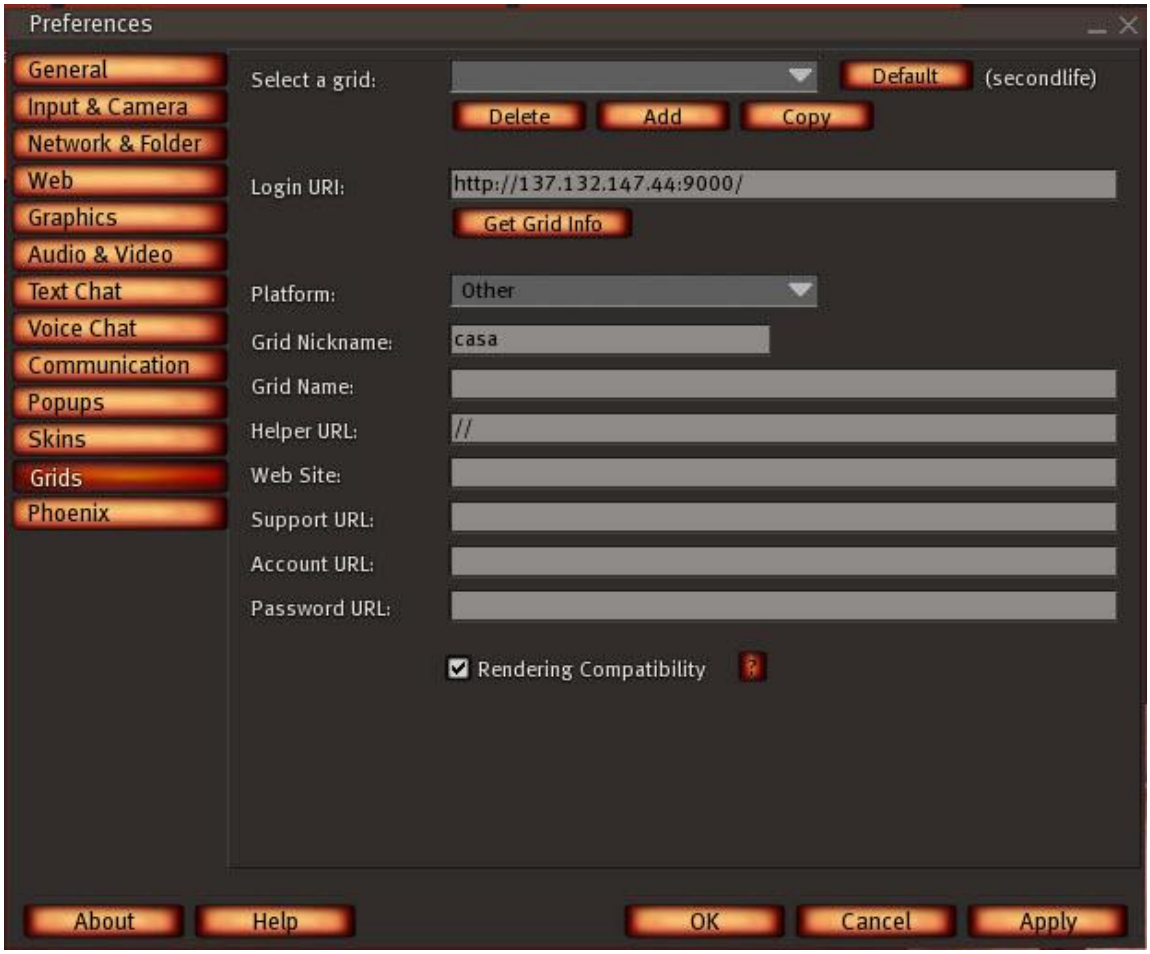
- In Contents folders, go to Resources and open **arguments.txt** file



4. **Launch the Phoenix Viewer.**



5. **Locate server path**



6. Login

- Key in your username into First Name and Last Name text box. Your username will be provided in a separate email.

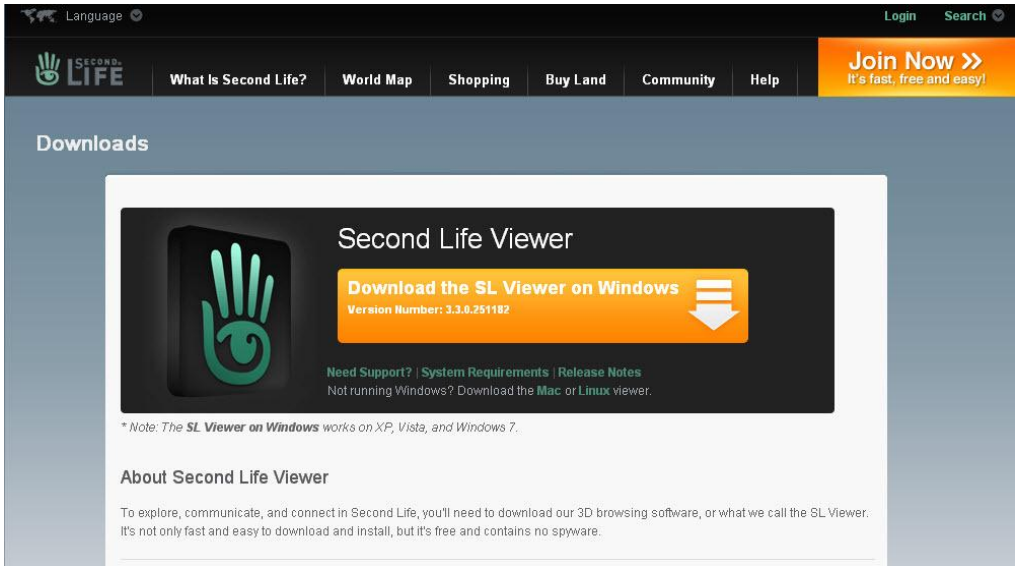
  For example: your username is **faysal casa** so that **faysal** will be the first name and **casa** is the last name

- Key in your password. Your password will be provided together with your username.
- Select casa in the list
- Press login to enter the world

APPENDIX D: INSTRUCTION TO INSTALL SECOND LIFE

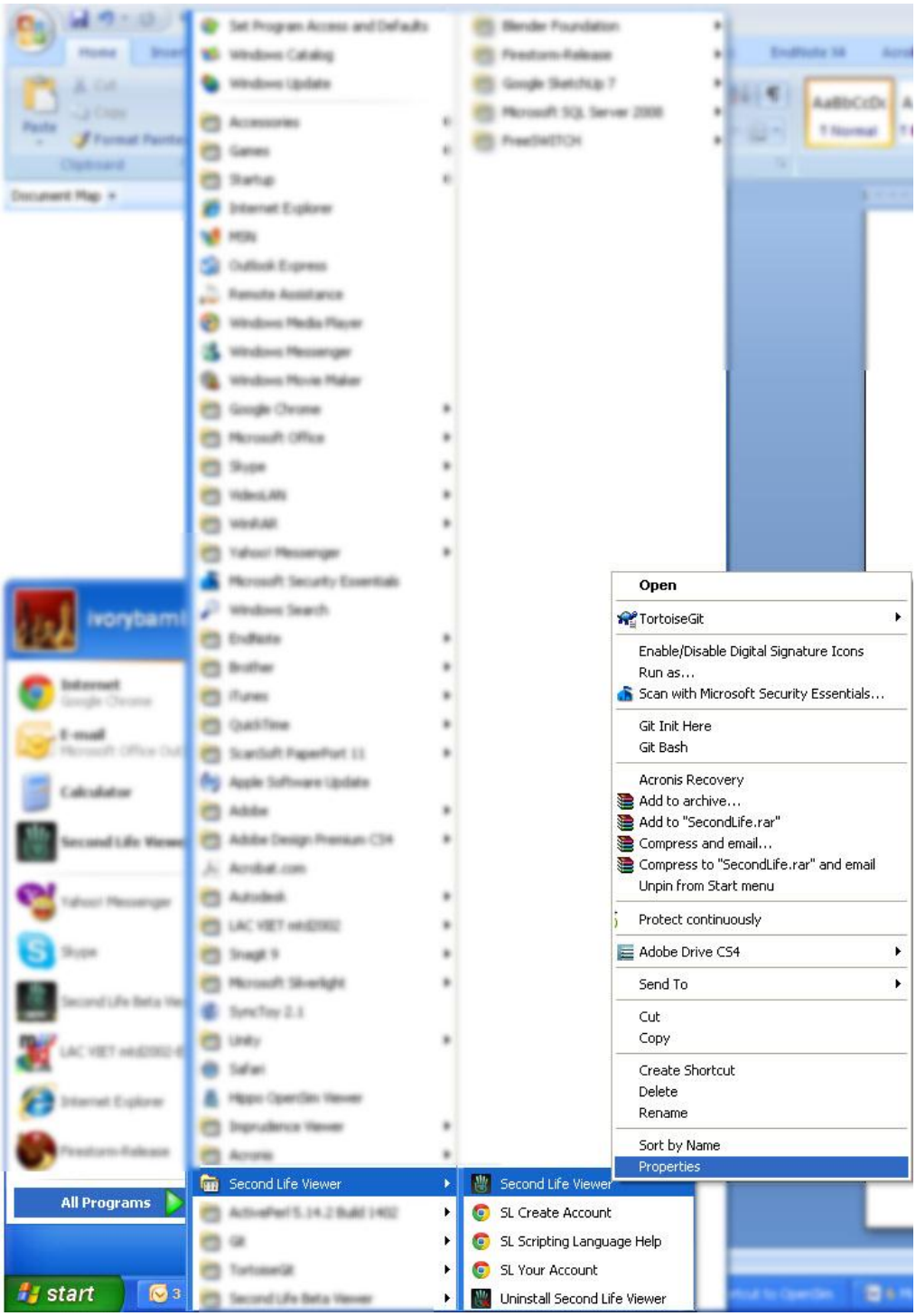
1. **Download Second Life viewer here:**

   http://secondlife.com/support/downloads/?lang=en-US

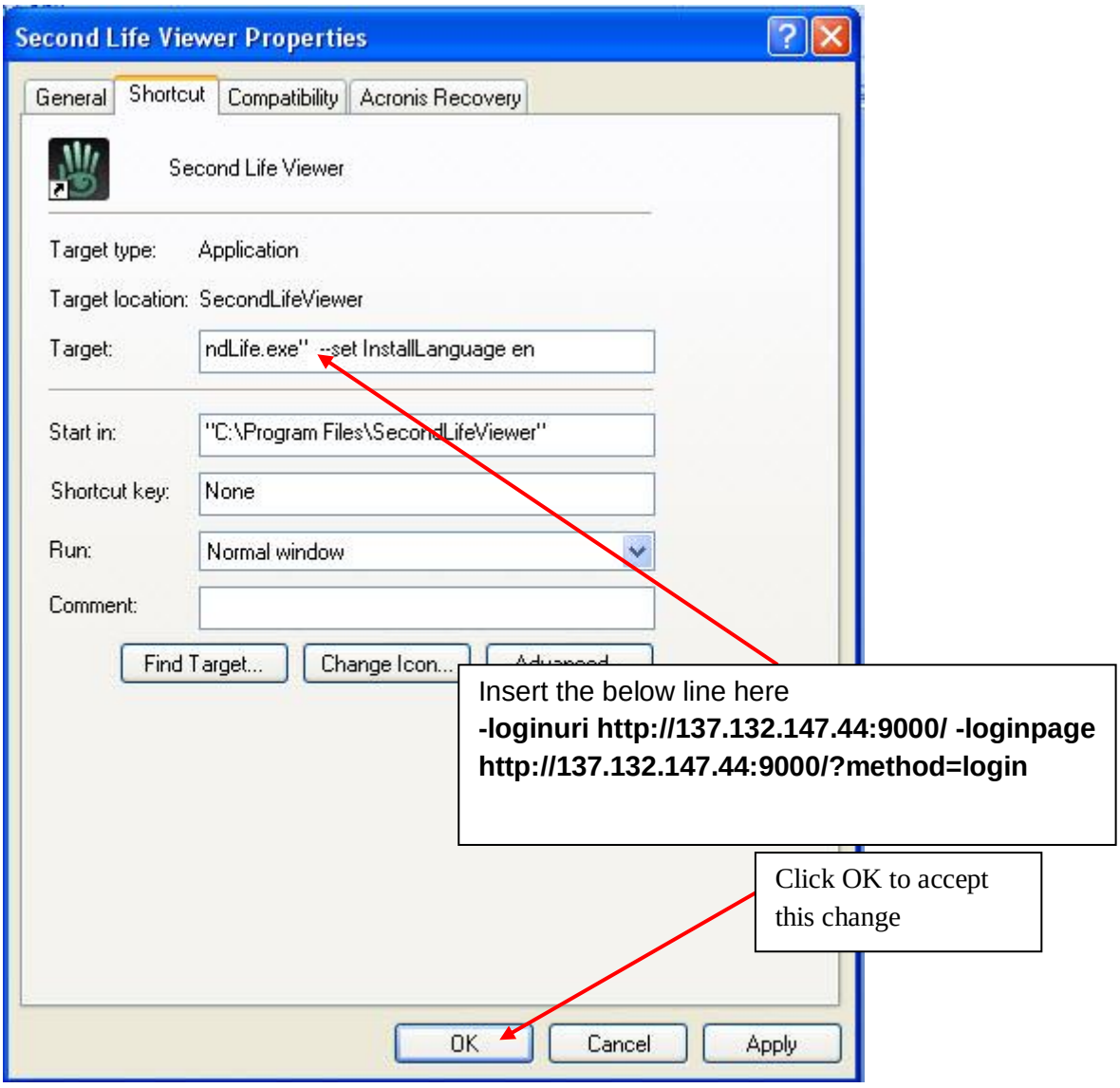


2. **Run the downloaded file and install Second Life Viewer**

3. Go to **Start -> All Programs -> Second Life Viewer**, **right click** on Second Life Viewer icon and choose **Properties** on pop-up menu



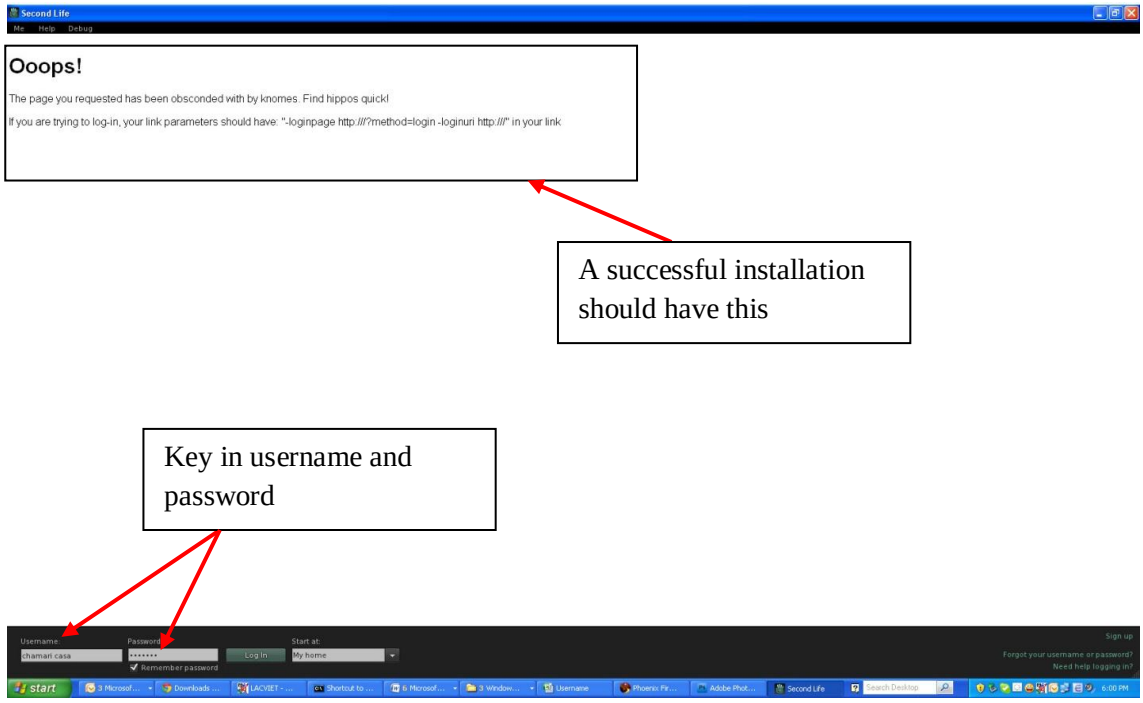
4. Go to **Shortcut tab, in Target box**, paste this following line: ***-loginuri http://137.132.147.44:9000/ -loginpage http://137.132.147.44:9000/?method=login*** into this box



5. **Click OK** to accept this change

6. **Run the Second Life viewer**. Start-> All Programs-> Second Life Viewer-> Second Life Viewer

7. **Key in your provided Username and Password**



APPENDIX E: RESULTS OF THE PAIRED SAMPLE T-TEST

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	sense of real-world co-presence - sense of real-world co-presence	-.920	1.956	.391	-1.727	-.113	-2.352	24	.027
Pair 2	Being together in a shared space - Being together in a shared space	-.760	1.877	.375	-1.535	.015	-2.024	24	.054
Pair 3	Sense of togetherness - Sense of togetherness	-.360	2.119	.424	-1.235	.515	-.849	24	.404

Pair 4	No sense of isolation - No sense of isolation	.920	1.824	.365	.167	1.673	2.522	24	.019
Pair 5	Identity - Identity	-.360	2.177	.435	-1.259	.539	-.827	24	.417
Pair 6	Sense of social actor - Sense of social actor	.200	.913	.183	-.177	.577	1.095	24	.284
Pair 7	Immediacy - Immediacy	.440	1.044	.209	.009	.871	2.107	24	.046
Pair 8	Willing to respond - Willing to respond	.000	1.354	.271	-.559	.559	.000	24	1.000
Pair 9	Awareness respond - Awareness respond	.240	1.012	.202	-.178	.658	1.186	24	.247
Pair 10	Available for a conversation - Available for a conversation	-1.080	2.532	.506	-2.125	-.035	-2.133	24	.043
Pair 11	Being aware of each other - Being aware of each other	-.040	1.989	.398	-.861	.781	-.101	24	.921

Pair 12	Being aware of each other - Being aware of each other	.240	1.786	.357	-.497	.977	.672	24	.508
Pair 13	Being aware of each other - Being aware of each other	-.600	2.217	.443	-1.515	.315	-1.353	24	.189
Pair 14	Being aware of each other - Being aware of each other	-.320	1.626	.325	-.991	.351	-.984	24	.335
Pair 15	F2F conversation - F2F conversation	-1.200	1.826	.365	-1.954	-.446	-3.286	24	.003
Pair 16	Natural conversation - Natural conversation	-.920	2.100	.420	-1.787	-.053	-2.190	24	.038
Pair 17	Phone conversation - Phone conversation	-.160	2.285	.457	-1.103	.783	-.350	24	.729
Pair 18	Partner's attitude - Partner's attitude	-.240	.597	.119	-.487	.007	-2.009	24	.056

Pair 19	Sense of closeness - Sense of closeness	-.680	1.464	.293	-1.284	-.076	-2.322	24	.029
Pair 20	Trust - Trust	-.880	1.236	.247	-1.390	-.370	-3.561	24	.002
Pair 21	Willing to share information - Willing to share information	-.760	1.786	.357	-1.497	-.023	-2.128	24	.044
Pair 22	Interested in talking - Interested in talking	-.720	1.671	.334	-1.410	-.030	-2.154	24	.041
Pair 23	Highly interactive - Highly interactive	-.520	1.896	.379	-1.302	.262	-1.372	24	.183
Pair 24	easy for contributing the conversation - easy for contributing the conversation	-.280	1.990	.398	-1.101	.541	-.704	24	.488
Pair 25	No interruption - No interruption	-.160	1.993	.399	-.983	.663	-.401	24	.692

Pair 26	Sense of distance with friends - Sense of distance with friends	-1.080	1.605	.321	-1.743	-.417	-3.364	24	.003
Pair 27	Bringing contact with friends - Bringing contact with friends	-.480	1.661	.332	-1.166	.206	-1.445	24	.161
Pair 28	Social space design - Social space design	-.560	1.781	.356	-1.295	.175	-1.572	24	.129
Pair 29	Awareness of others - Awareness of others	-.560	2.002	.400	-1.386	.266	-1.399	24	.175
Pair 30	Break away from work - Break away from work	-.600	1.291	.258	-1.133	-.067	-2.324	24	.029
Pair 31	Unplanned meeting - Unplanned meeting	-.600	1.443	.289	-1.196	-.004	-2.078	24	.049
Pair 32	Semi-planned meeting - Semi-planned meeting	-.400	1.708	.342	-1.105	.305	-1.171	24	.253
Pair 33	Socializing activities - Socializing activities	-.280	1.720	.344	-.990	.430	-.814	24	.424

APPENDIX F: PARTICIPANTS' CONSENT TO PARTICIPATE IN THE EXPERIMENT

Dear Casa friends,

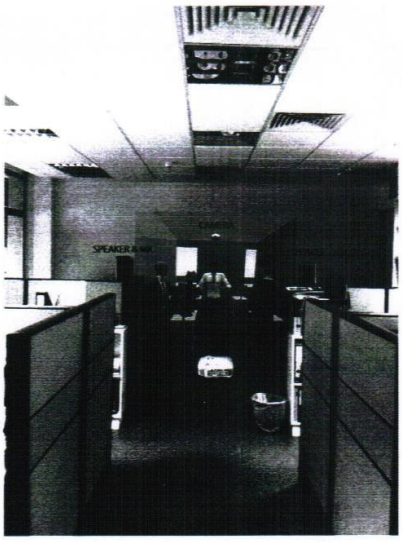
I am doing a research which is to create a shared space for supporting informal interaction at a distance among collaborative people. The shared space is constituted by two connected worlds: a physical space and its 3D virtual space. Since the two spaces could share their world content to each other thus residents of one world are able to see what happen in another world. The 3D virtual space is created for geographically distributed people to login and populate therefore they are able to see, encounter and make informal conversation with their counterparts who are located in the physical location.

In my pilot experiment, I would like to choose CASA as the physical space and invite all of you to participate in the testing. The experiment may look like the below figure. The system could provide a chance for us and our remote friends such as Chiu Kuowei, Timoticin Kwanda, etc or our graduated friends such as Ngo Minh Hung, Khanh Van, Wang Qing, Jungho or those who are not located in CASA such as Su Jan, Hannah to encounter and make conversation with each other as if all are co-located in CASA. In order to enable our remote friends to encounter people in CASA, a camera will be mounted on the back wall (as shown in the figure) and capture the real-time scene of CASA. However, our CASA authorities have concerned that the camera may create a nuisance to you and affect your privacy. In fact, the camera is just a webcam camera with normal resolution and used for capturing the walk way not focusing on anyone's place. Therefore, I would like to seek your understanding for my installation. The tentative period for the experiment will be from 15-Feb to 15-Mar (1 month). I will inform you when the camera is in operation in advance.

Thank you very much for your understanding and cooperation.

Regards,

Truc



I agree with this installation. & good luck to your experiment. Jiang Hao Feb 3rd. 2012

I agree Faysal Kabir Shu

Ü Happy with that. (Hafizur Rahaman)

APPENDIX G: PUBLICATIONS

1. Nguyen Thi Lan Truc and Tan Beng Kiang (2011) "Understanding and constructing shared spaces for supporting informal interaction at a distance". Proceedings of the 16th International Conference on Computer-Aided Architectural Design Research in Asia CAADRIA 2011, 2011.

2. Nguyen Thi Lan Truc and Tan Beng Kiang (2011) "Shared space at a distance: a model of integrated shared space for supporting informal interaction at a distance". (Full paper accepted to include in CAADFutures 2011 proceedings)