DEVELOPING HEURISTICS TO OPTIMIZE THE CONFIGURATION OF THE VIDEO-MEDIATED ENVIRONMENT

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Dissertation submitted to the Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Industrial and Systems Engineering

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April 11, 2001
Blacksburg, VA

Keywords: Distributed meetings, Room Design, Heuristics, Electronic Meeting Systems, Participatory Design, Participatory Ergonomics, Video Teleconferencing, Macroergonomics

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(ABSTRACT)

A study was conducted to determine the preferences for the design of distributed meeting rooms used for video enhanced electronic meeting systems (VEMS). Although there is a significant body of literature in the group communication domain, the research in this multidisciplinary area has paid minimal attention to users' environmental preferences in the design of a meeting space.

A basic science approach through three studies was used to explore the variables that defined the design of a distributed meeting space from the user's perspective. Twenty-five inexperienced college-enrolled participants and twenty-five experienced Naval professionals used foam-core pieces to create a design of their ideal distributed meeting space. Thirty-seven variables were used to categorize qualitative attributes of the designs. Three types of designs emerged from the sample population: v-shaped, conference (u-shaped or oval), and theater (auditorium) style.

A nonexperimental design was used to measure the impact of the heuristics on the users' physical design of their distributed meeting spaces. Post-meeting evaluation results were promising and indicated that the heuristics were usable and that participating in the design could have a positive impact on user's subjective rating of their meeting experience. Overall, inexperienced users did not believe that the heuristics were necessary to determine the best room design for their team's needs.

In the third study, six experts conducted an expert evaluation of a distributed meeting room site. Most experts were not able to identify context-specific design issues such as camera angle and lighting with the static information that they were provided. The experts subjective ratings indicated that the heuristics were usable and were useful for room designers.

The overall findings indicated that experience level had a significant impact on user's perception of important equipment in a distributed meeting room. Naïve users were more concerned with visual communication and assigned more importance to public displays ($p=.035$). Experienced users were more concerned with audio communication and assigned more importance to microphone control ($p=.024$). In addition, general findings from this research include a new methodology for generating participatory ergonomic tools.

This work received support from the Naval Surface Warfare Center in Dahlgren, Virginia.

Acknowledgements

I would like to thank my advisor Dr. Brian Kleiner for his assistance and guidance throughout this process -- especially for his constant reminders that finishing your graduate work is indeed an achievable goal. I would also like to thank my committee members Dr. Mary-Beth Rosson, Dr. Tonya Smith Jackson, and Dr. Robert Williges, who each gave me individual attention throughout the creation of this document. I would like to thank my colleagues at Navsea Dahlgren, Mr. James Hamburger, Mr. Jeff Thoren, Mrs. Sheila Fortner and especially Ms. Mila Denson who has played both the role of committee member and sponsor, for all of the time and hard work that they devoted to my project. I would also like to thank the management at Navsea Dahlgren for sponsoring and supporting my research.

Lastly, I would like to thank my family for their never ending support: To my sisters, Alisia and Deidre who always found interesting ways to remedy any of my "dissertation" moments. To Frank and Fay who spent a lot of their time proof reading and cheering me on. To Auntie Gene and Uncle Pat who always provide great encouragement. To my dear parents who just keep believing that everything is possible. And, to my husband, Kevin, who has lived with me patiently and lovingly throughout the final stages of this process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES AND FIGURES

CHAPTER 1 - INTRODUCTION

To date, there is little research on facility design of the distributed meeting environment where electronic meetings systems and videoconferencing are hosted in many organizations. The strongest factors determining the design of a distributed facility currently include:

(1) guidelines provided by vendors (Mittleman, 1999; Nunamaker, 1996),

(2) recommendations made by experts in the field (Daly & Hansell, 1999), and

(3) typical organizational constraints of budget and space (Neal, 1995).

User preferences in the design of the distributed environment are relatively uninvestigated and are usually discovered in studying other aspects of the video-mediated environment or distributed group communication. As technology limitations lessen, there is continued integration of distributed group communication in all facets of team collaboration providing a greater need to understand user preferences in the design of distributed work systems.

1.1 The current video-mediated environment

Electronic Meeting Systems (EMS) are often considered the communication infrastructure of distributed meeting environments. The term EMS originated from research conducted in the late 80's and early 90's (Nunamaker et al., 1991). According to Nunamaker and his colleagues (1991), the term EMS is used to broadly define meeting activity supported by computer software and hardware. The purpose of electronic meeting support is to develop and to enhance group interaction, productivity, and efficiency (Nunamaker et al., 1991).

Over the last two decades, definitions of EMS have been evolving, as both technology and usage evolve. According to Kraemer and King (1988), the EMS contains a subset of group decision support systems (GDSS). The components include group communication technology such as an electronic boardroom (computer and audiovisuals), group network (computer network and interactive conferencing), and an information centers generally composed of databases and retrieval tools. According to Scott (1999), the EMS can be also considered to be "a specific type of groupware providing support for mediated group meetings". Scott (1999) defined groupware as the set of technologies that provide communication, collaboration, and coordination used in distributed meetings.

Video teleconferencing (VTC) is the term used to describe meeting activity supported by the electronic transmission of visual images and sound for teams that do not share the same physical location. The visual images used in a VTC are characterized as being both multidirectional and synchronous (Daly and Hansell, 1999). In addition, some authors also describe the teleconferencing facility as a GDSS which utilizes computers to facilitate remote communication (Kraemer and King, 1988).

In Scott's (1999) definition of distributed technology EMS includes both group support systems and videoconferencing. His definition of an EMS is broad and does not distinguish between spatial (same place, different place) and temporal (same time, different time) dimensions often used to describe Computer-Supported Collaborative Work (CSCW). In the CSCW domain, videoconferencing becomes a special case of EMS where the computer-supported team is meeting at the same time but in different places. The CSCW approach is used in this research to ensure that the concept of spatial differentiation is maintained in the EMS terminology.

Therefore, VTC can be used in combination with an EMS to expand meeting capabilities. The combination of these two types of meeting support will be termed a video-enhanced EMS (VEMS) in order to distinguish this from other spatial temporal settings where EMS is also used. VEMS is an environment in which one or many participants can collaborate via software as well as conference with one or many participants in remote locations. These members form a distributed team and they can also share the same software applications on public or individual displays to support the meeting process. This class of meeting is described as a same time, different place meeting.

Organizational use of VEMS

Users of VEMS depend upon experts from the organization to perform tasks such as installation, trouble-shooting, and maintenance. Teams also depend on meeting facilitators and technology facilitators (technographers) to help with the organizational and technological components of the meeting process, respectively. Despite, all of the support from experts, human factors issues in both the social and technical subsystems often impact both meeting performance and meeting efficiency in the VEMS environment. From this perspective, success in a distributed meeting is a function of addressing human factors challenges.

Pitfalls of VEMS Design

Hendrick (1991, 1995) listed the following as human factors pitfalls in the traditional work system:

(1) Technology centered design or maintaining a technology perspective in design,

(2) Left-over approach to function and task allocation or automating first and assigning remaining tasks to human operators, and

(3) The failure to consider an organization's sociotechnical characteristics.

The pitfalls identified in traditional approaches to work system design were used as a framework to analyze and propose changes in VEMS design.

Technology-Centered Approach

The electronic boardroom, the teleconferencing facility, the decision conference and collaboration laboratory (Kramer and King, 1988) are all group decision support systems which provide the foundation of the current VEMS. These predecessors of VEMS were developed, all or in part, from a technology perspective where developers created technological aids they believed users needed instead of the tools users demanded (Kraemer and King, 1988).

Therefore, it not surprising that inherent failures which existed in only GDSS due to the technology-centered approach to design have emerged also in the VEMS. Three areas have been identified where users of VEMS are most impacted by technology-centered design. These are: (1) the impact on user's commitment to the distributed technology, (2) user's comfort-level with the distributed technology, and, (3) user interactions during distributed meetings.

First, many of the users of a VEMS lack commitment to the success of the technology (Grenville and Denson, 2000). These authors observed several meetings in which group members lacked the patience to overcome technical obstacles and were anxious to return to lower technology solutions (i.e. telephone conferencing). Law and Whittaker (1986) observed similar behaviors in their ethnographic account of a word processing system implementation in the early phases of office automation. Users in their study also expressed a willingness to abandon the advanced technology solution. In their opinion, "malleability" or the ability to successfully transform the organization with technology, is a tradeoff between the willingness of the personnel, and other resources to adapt to the new system and the capacity for the technology, and other resources to perform in the new surroundings (Laws and Whittaker, 1986).

Second, psychosocial factors contribute to the complexity of the existing technology-centered driven issues. Lack of computer self-efficacy may inhibit participants from fully engaging in the groupware and roomware available for meeting use. Performing work in an unfamiliar environment, such as a VEMS facility, may also be difficult. Both field and empirical studies of early technology used to support distributed groups such as media spaces (Bly, Harrison, Irwin, 1993) and desktop video conferences (Isaac and Tang, 1993) support this notion. One of the advantages of desktop video conferencing and media spaces was that meeting members worked in a familiar environment where needed materials were readily available.

Third, there are known effects of video-mediated communication on meeting interaction (see Isaac and Tang, 1993). For example, the video conference meeting tends to be more formal than face-to-face meetings. In addition, the need for microphones may inhibit turn-taking and reduce the number of times each member takes the floor. Furthermore, there are also time constraints, therefore, most meetings must adhere to an agenda. Lastly, both the time constraints and the technology limit informal discussion. The effects on meeting interaction are discussed in further detail in Chapter 2.

Leftover Function Allocation

The impact of technology centered design is often manifested as leftover function allocation. In so doing, the operator's responsibilities become defined by the functions that can not be automated in the system (Hendrick and Kleiner, 2001). For example, many of the responsibilities of the technographer are defined by those tasks which are not already automated through the VTC system controller. These include monitoring the audio-visual control panel and controlling groupware access during the meeting.

Kraemer and King (1988) described major GDSS elements in terms of a sociotechnical perspective (see Chapter 2 for details). It is important to discuss the role of people in the social subsystem in each GDSS to address the evolution of these roles in the VEMS. A description of the social subsystem is provided for each technology used in GDSS (Kramer and King, 1988).

- In the electronic boardroom, the role of people included participants and an audiovisual technician.
- In the teleconferencing facility, the role of people included distributed participants and a teleconference facilitator.
- In the role of group network or groupware, the role of people included participants (co-located or distributed) and a group leader.

In these early systems, the facilitator was identified as the "key distinguishing social component of GDSS (Kraemer and King, 1988, p.19)". The facilitation role has evolved minimally over the last decade. The responsibilities of the today's facilitator and participants are almost identical to those of the technology facilitators and participants in pioneer GDSSs. Although many technological advances have been made to computing hardware, software, interfaces, telecommunication in the last decade, similar advances have not been made in the personnel roles supporting and using these technologies.

Failure to Consider Sociotechnical characteristics

Traditional organizational design often fails to consider the organization's sociotechnical characteristics (Kleiner and Hendrick, 2001). It is therefore important to identify the VEMS sociotechnical elements of the system, to remain cognizant of them once identified (see Chapter 2), and to utilize change and performance improvement methods that cater to sociotechnical interrelationships.

In the late 80's, the use of GDSS was already far below expectation given the anticipated need and promise (Kraemer and King, 1988) and the empirical literature testing the performance of these system has remained decidedly ambivalent throughout the 1990s (Hollingshead and McGrath, 1995). The sociotechnical literature suggests that changes focused on jointly optimizing the VEMSs can be structured to address these problems and should result in: (1) the users (and support personnel) making an increased contribution to the meeting process and (2) better participant performance in VEMS environments (see Eason, 1988, Pasmore, 1990, Taylor & Felton, 1993 for examples).

Physical Environment

One area in which the sociotechnical characteristics have been marginally addressed in the VEMS work system is in the allocation of space in the physical environment. In the macroergonomic design of a physical work environment, space should be allocated to support the functions of the personnel and technical subsystems (O'Neill, 1998). Designers of groupware systems (e.g. Nunamaker, Briggs, Mittleman, 1995; Mittleman, 1999) have considered the allocation of social space in the meeting facilities. In the optimal configuration of physical space, space allocation should also adhere to constraints of the organizational and environmental subsystems and address higher-level objectives such as (O'Neill, 1998):

- the types of groups using the facility (organizational)
- amount of space available for facility (environment)
- the type of administrative support for the facility (organizational)
- the mission of the facility (organizational)

Roomware

The use of roomware, such as electronic whiteboards, is also another technology consideration in the design of an electronic meeting system environment. These devices can create an atmosphere where technology is omnipresent. The effects of this type of technology can be perceived as an advantage by the room designer however, availability may be perceived differently by participants. The end user may be delighted or overloaded by the existence of roomware depending on his/her level of computer self-efficacy. In field studies conducted at the Naval Surface Warfare Center in Dahlgren, Virginia, both sides of this position were expressed by VEMS participants (Grenville and Denson, 2000).

Few empirical studies addressed the physical environment design needs of this work environment. To this author’s knowledge there are no empirical studies that address room configuration of the collaborative meeting environment from the perspective of space allocation and physical environmental design. Devising guidelines from empirical studies is common practice in human factors. There an empirical approach will be applied in this research to develop design guidelines for the distributed meeting environment.

1.2 Implications for Change

Participatory Ergonomics (PE) is one of several prescribed methods which can be used to remedy design pitfalls in any work system (Hendrick and Kleiner, 2001). In this section, the PE method will be introduced. The review is followed by a proposition in the form of a possible organizational response to the design issues in the VEMS subsystem. This proposition forms the basis of design changes to the VEMS investigated in this research.

Participatory Methods

The movement to include users in the design process is well known in the field of human-computer interaction (Greenbaum, 1993). Participatory design and its precursor user-centered design (Norman and Draper, 1986) have evolved since the mid '80s as methods to ensure that the technological perspective does not dominate software system design (Greenbaum, 1993). Participatory ergonomics is a variation of the participatory design process focused on making changes in the physical environment. Since its inception in the late 80's (Imada, 1991), this technique has evolved in parallel with its computer science counterpart and is described as a crucial macroergonomic practice (O'Neil, 1998; Hendrick and Kleiner, 2001).

Greenbaum (1993) listed several benefits of participatory design techniques which also apply to participatory ergonomics. First, participatory design can be viewed as a management strategy to encourage teamwork. Second, participatory design increases the likelihood of worker participation and the likelihood of developing systems that actually fit the work environment. Third, participatory design can become a method for fostering communication within the team and within the organization.

McCreary, Reaux, Hood, and Rowland (1998) reported on the impact of participatory design on the ownership of a networked computer environment. McCreary et al. (1998) used a participatory design method to obtain an easy access layout of a classroom setting. In their field study, teachers were used to redesign a technology-supported classroom. Design alternatives were elicited from teachers via a low-tech solution which consisted of arranging scaled cutouts of desks and of the classroom. Through this process, the teachers were given authority over the physical design of their classroom. Their experiences resulted in a sense of ownership of the networked-classroom environment (McCreary et al., 1998).

McCreary et al.'s (1998) field study suggested that participation in room design has a positive effect on ownership of networked classroom. It is proposed that similar results may be possible if meeting participants were involved in the configuration of VEMS meeting rooms. Therefore, the participatory approach is offered as an organizational response to the technology-centered perspective to VEMSs and their meeting rooms.

1.3 Research Problem

The current human factors and CSCW literature is inconclusive about issues of user performance and satisfaction in the distributed meeting environment. Design and development of these systems have been primarily focused on achieving satisfactory technology capability. In the past, improving the experience for distributed meeting participants has often been a by-product of technological advancements. The early research in this area did little to de-couple aspects of performance with user's satisfaction with the technology. Although performance and satisfaction can improve with robust technology, less emphasis has been placed on ecological aspects of the distributed meeting room environment. Furthermore, even less emphasis has been placed on the relationship between user needs and the design of distributed meeting room environments. Therefore, more research is needed to determine which role users of distributed meeting environments can play in determining their interaction with the technology and physical environment. This research will attempt to fill the gap in the literature between users needs, the design of the distributed meeting room environment, and the user's satisfaction in distributed meeting spaces.

1.4 Research Goals

Thompson (1998) noted that the organizational shift from an "individual performer orientation to a team performer orientation" is a driving factor affecting how meeting rooms are used in organizations today. The purpose of meeting rooms has expanded beyond the traditional destination to discuss future work or to report about past work. In today's environment, teams intend to perform and achieve work in the rooms that they meet in. To that end, many team members are inter-disciplinary, inter-divisional, and inter-organizational. Although it is possible for many of the team members to be physically co-located for teamwork, it is the case more often than not with these large teams that most of the team members can not meet in one central location. Instead, many of the team members may congregate at physical locations or meeting rooms that can be connected by computer networks to create a shared virtual meeting room.

In 1998, Thompson posed this question to U.S. companies: "Do your meeting rooms work?" She received responses from 54 companies. When these organizations were asked to compare the current meeting room requirements to their requirements in the past, respondents reported a greater need for flexible furniture, a greater requirement for telephone and computer connections in the meeting room, a greater need for tackable walls, and a greater demand for multi-media capability. These changes are as a result of the usage adaptation to accommodate the team performer orientation.

Clearly, the shift in the work performance paradigm is affecting the requirements for team workspaces in the traditional meeting room. Thompson (1998) has identified many of those changes. As organizations evolve to accommodate team performer requirements for physically collocated teams, they will need to understand and satisfy these requirements in distributed or virtually collocated teams. The purpose of this research is to contribute to the body of knowledge concerning users' needs and contribute meeting users' needs in distributed team meeting rooms.

Therefore, the goals of this research are to:

1. Identify user needs and preferences of the configuration and equipment used in VEMS meeting room environment.

2. To test participatory ergonomic techniques as an approach to facility design and improving user satisfaction.
3. Provide ergonomic guidelines and heuristics for designers and technical support staff of video-enhanced distributed meeting facilities.

1.5 Conceptual Research Model

Both the macroergonomic and sociotechnical models provide a general framework used to view the organization as a composition of interdependent subsystems. Several authors (Kraemer and King, 1988; Taylor and Felton, 1995; Bikson & Eveland, 1997; Hendrick and Kleiner, 2001) have adapted the components of these frameworks to model the use of groupware and the underlying distributed meeting system. The combined efforts of these authors has been summarized in Table 1.1.

Table 1. 1 - Macroergonomic Sociotechnical Framework for Distributed Technology use in Organizations

Technical subsystem *Product and technology*	**Personnel subsystem** *People, their roles, interactions*
Components • Electronic hardware • Software • Networks • Applications • Tools • Physical systems and environment Interfaces: Human-computer, human-system	Components • Workgroups • Jobs, • Task interdependencies Interfaces: Human-computer, human-organization
Organizational Design subsystem *Support units, and their structure*	**Environmental subsystem** *Stakeholders, their policies outside work system boundaries*
Components • Information Technology • Organization Development Interfaces: Human-computer, human-system	Components • Customers • Suppliers • Government • Consortiums, Technical groups

Figure 1.1 is a graphical depiction the relationship between subsystems in a distributed meeting system (Cano, 1997). A distributed group is composed of a team that may have a number of differentiated elements, for example, spatial dispersion where the team is not located in the same room, geographic dispersion where the team is not located in the same region, and temporal dispersion where the team is not in the same time zone.

To overcome these challenges, teams require integrating mechanisms to support communication, coordination, and control within the team (Kleiner and Hendrick, 2001). In this research participatory design/ergonomics is proposed as the integrating mechanism of interest which can be used to reduce the impact of challenges due to spatial, geographic, and temporal dispersion.

The assertion in this research is that the participatory ergonomic approach can be used to allow users of VEMS to gain control over challenges in their work environment. The proposed hypothesis is that the end user can control the placement of equipment in the distributed workspace through a participatory ergonomics approach and that this practice can be merged with traditional meeting integrating mechanisms such as agenda setting and time management.

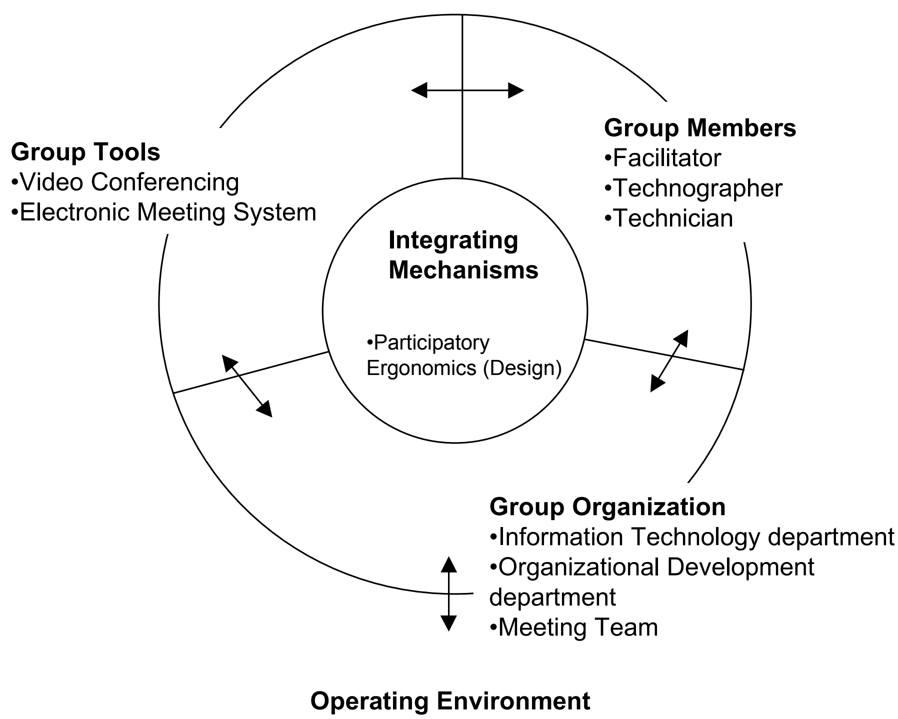


Figure 1. 1 - Conceptual Research Model for VEMS Work System

(after Cano, 1997; Hendrick, 1996)

1.6 Research Questions and Hypotheses

Research questions and hypotheses discussed in this section are based on the proposed relationships between variables selected from the literature and outlined earlier in the conceptual model. The research questions and hypotheses are formed to develop both known and proposed relationships among these variables. In this study, the interactions of interest are among the following variables: (1) group members and operating environment and (2) operating environment and satisfaction.

Research Question 1: *What requirements do users identify as important (or necessary) in a virtually collocated room?*

Poltrock and Englebeck (1997) identified a number of requirements for virtual collocation after studying distributed Integrated Product Teams (IPTs) at Boeing. They recommended that in order for teams to be successful in work-centered, people-centered, and meeting-centered activities in a virtual collocated setting, the following requirements should be met:

- Audio quality should be high and rival the co-located room experience. A room should support multiple microphones, stereo speakers, and noise suppression technology (p. 66).
- "Multiple methods of information sharing are needed (p.66)". The team should be able to edit, share, review, and secure both internal and external documents needed by the team. The team should be able to access meeting information at any time.
- People-centered activities should be supported by video conferencing allowing team members to create a sense of presence.
- Virtual team meetings may increase the required amount of meeting preparations to ensure that the supporting technology is functioning throughout the meeting. Therefore, teams should have pre-conference, in-conference, and post-conference procedures.

In this field, a small number of researchers have identified some of the requirements of the distributed meeting room environment. The requirements list generated by researchers are based on observational studies of users in virtually collocated meetings. Researchers such as Poltrock and Englebeck (1997) believe that there are sets of requirements that must be met in order to have a successful virtually collocated meeting. Because researchers have observed users enacting a consistent set of requirements when participating in distributed meetings, in this study, it is expected that aside from individual differences due to experience level, the following research hypotheses will be supported:

Research Hypothesis 1a: *There is a consistent subset of requirements (equipment, facility attributes, etc.) that users will identify.*

The notion of individual differences is a persistent and prevalent theme across many domains in human factors research. In the domain of human-computer interaction, there is sufficient evidence that naïve and expert users have different needs from a particular user interface. In order for distributed teams to become virtually collocated, computer support is required (i.e. telecommunication connectivity in a control room) and often the meeting is located in computer-supported room. Users of these rooms are required to have varying levels of interaction with the computer system and software that supports their virtual location. It may be reasoned that the type of interaction that users have with the systems that support virtual collocation will differ based on their level of experience with systems in the distributed meeting environment. Because the experiences of naïve users and expert users with the computer systems in this environment will differ, the following hypothesis was generated to support the impact of individual differences on design requirements:

Research Hypothesis 1b: *The requirements will differ based on the users' level of experience in a distributed meeting environment.*

Research Question 2: *What is the set of design rules users will engage to create their optimal design for a distributed meeting space?*

Olson, Covi, Rocco, Miller, and Allie (1998) reported that a dedicated project room was preferred by ideal teams in 9 Fortune 500 companies. In their analysis of the primary needs of collocated teams, the authors identified: (1) shared cognitive artifacts to make work visible, (2) editable such as flip chart sheets, and (3) to-do lists. These teams were studied to inform the author's design of future groupware and the authors reported the following minimum groupware requirements: "support large, persistent, shared visual displays, awareness of team members activities, and various signals to others about the importance of their work (p. 279)". The authors in this study observed team members interacting in these rooms. Their observations indicated that there is consistency in user needs in collocated spaces and the authors expressed that these needs can be generalized to virtually collocated groups. The authors' statements about consistency across companies is an indication that users in these teams have consistent needs regardless of their organizational setting. The aspect of consistency of user needs across organizations supports the notion that if asked to design a space for collocated or virtually collocated work, aside from individual differences, a set of similar design rules may emerge from users. Therefore, the following hypotheses were generated,

Research Hypothesis 2a*: There is a consistent set of rules users will engage to design a facility.*

Research Hypothesis 2b: *The rules will differ based on the users' level of experience in a distributed meeting environment.*

Research Questions 3: *What impact will the ability to control aspects of the operating environment have on users' report of satisfaction with the distributed meeting process?*

Several studies have been conducted in environmental human factors engineering to investigate relationship among team member performance, satisfaction, and control over their workspace (Vincente, 1999; O'Neill, 1998). Typically, these studies are conducted on co-located teams and elements of their workstations. Studies by O'Neill and his colleagues support the idea that teams work more effectively in an environment where they have control over their workspace. For example, in a study where workers were given training on the ability to fully adjust the configuration of their workstations and the control group was given no training, both subjective and objective data collected after three months with the new work facilities supported:

- Decision latitude and knowledge of control over the work environment were positive predictors of individual performance.
- Learning, decision latitude (job control), availability of control over work environment were positive predictors of group effectiveness.
- Availability of control over work environment and lighting were both positive predictors of group collaboration (i.e. shared support, even participation, and shared responsibility).

- As satisfaction with storage, privacy, and knowledge of control over work environment increases stress (reports of bother, worry, frustration and tenseness) decreases.

Therefore, it can be conjectured that increased control over the physical environment will positively impact its users. The following hypothesis was generated.

Research Hypothesis 3: *Users will report that having control of their environment increased their satisfaction with the distributed meeting experience.*

Research Question 4: *How do non-expert and expert users report on the usefulness and the usability of the distributed meeting room design heuristics*?

Preece et al. (1993, p.47) identified four key aspects of usability testing.

(1) learnability or ease of learning.

(2) throughput or ease of use or completion time as users experience level increases.

(3) flexibility or adaptability of the system as users experience level increases.

(4) attitude towards the system while using it.

In addition, Neilsen (1994) identifies usability and learnability as important metrics for techniques used to perform usability inspections. According to Neilsen, methods that are used to determine usability must be easy to apply efficiently and easy to learn. Therefore, the concept of usability not only describes the user's interaction with the system but also the evaluator's interaction with the method he/she is using to inspect the system.

The heuristics used to design a facility will create a method that can also be deemed "usable". Usability of the set of heuristics will be determined by user ratings of the heuristics on relevant usability components i.e. learnability, ease of use, flexibility, and attitude. It is expected that user ratings of usability of the heuristics will be consistent regardless of the expertise of the evaluator because adaptability or the ease at which the method accommodates users of different experience levels is a component of usability.

Research Hypothesis 4: Both experts and n*on-experts will report that user-centered design heuristics are usable and useful in the distributed facility design process.*

1.7 Operational Research Model

The operational research model was used to define the proposed interactions among the variables used in this research study. It also is the research model that is used to operationally define the variables considered in a research study.

For example, where the conceptual model (Figure 1.1) indicates a relationship between *group members* and other components of the distributed meeting work system. The operational model is used to further define the meaning of the term group members in the context of this dissertation. In the conceptual model, the term group members represents both group and member attributes while belonging to the input variables used in this research. Similarly, group tools are defined as task/projects/purposes and communication technology. This component of the work system is also considered an input variable in this research. Furthermore, operational definitions are provided for input variables, operating conditions, process variables, and outcome variables. Input variables and operating conditions are defined as independent variables and process variables and outcome variables are defined as dependent variables.

The following description of the system was illustrated in the conceptual model shown in Figure 1.1. The operational model is adapted from McGrath and Hollingshead (1995) model for studying flow effects in computer aided work groups. This model identifies a set of input, operating, process, and outcome variables for distributed team communication and interaction.

Of the set of variables presented in this model, the dependent and independent variables used in this study are group member attributes, task related outcomes such as heuristics and guidelines and time, participatory design, and group related outcomes such as user reactions, rated satisfaction, and rated effectiveness.

In this study, user's level of experience in the distributed meeting environment is used as an independent variable. The dependent variables are task-related outcomes, task product features or guidelines, and time to complete design of the ideal distributed meeting room. During the participatory and expert evaluation of user's guidelines user's level of experience remained the independent variable and participatory design/ergonomics methods, and heuristics were added independent variables, while the dependent variables were group related outcomes such as user reactions, rated satisfaction, rated effectiveness, and member relationships (applies to participatory evaluation only).

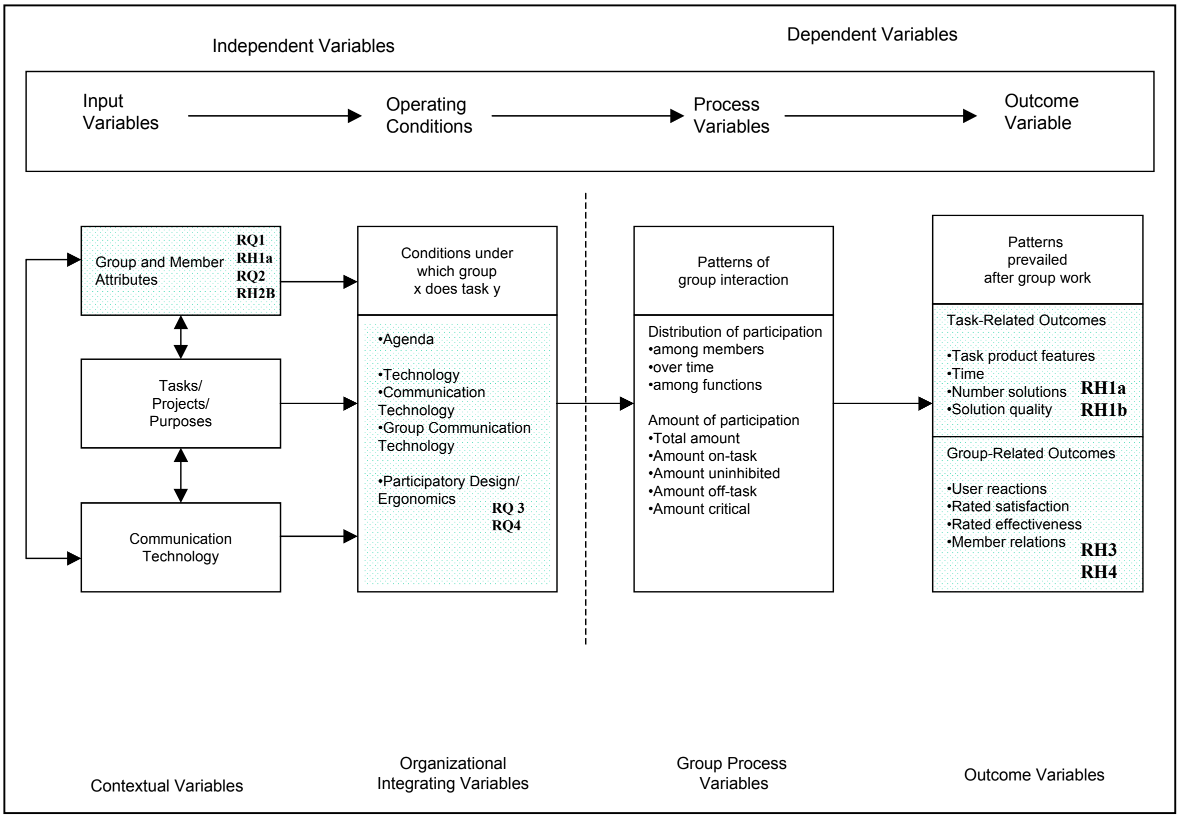


Figure 1. 2 -- Operational Research Model

Isolating issues in the physical environment of distributed meeting rooms and mapping them to their respective research domains or body of knowledge is a challenging one. There are architectural, ecological, fiscal constraints on the design of any meeting room. All of these aspects must be considered when crating an appropriate meeting space. Technical challenges such as scientific advancements in video compression or audio transmission reside in the domain of computer science and audio/video technology. Issues of group performance and satisfaction while using computerized technology reside in the domain of CSCW. The issues of organizational and technology change reside in the domains of organizational psychology and in terms of prescriptive solution in the domain of macroergonmics.

This research focused on the use of a prescriptive solution to enhance meeting room design for real world teams. Participatory ergonomics is the macoergonomic approach used to enable teams to select a design that is best for their meeting experience.

CHAPTER 2 – LITERATURE REVIEW

This chapter has been divided into four sections to address issues impacting participatory room design in a video-mediated environment. The first section is a review of the evolution of video conferencing. This section includes summary of the video-mediated environment compared to the traditional face-to-face meeting and a discussion of technology change over the last decade including the use of electronic meeting systems and other group communication technologies in concert with videoconferencing. It concludes with a discussion of the costs and benefits of video teleconferencing and the reality of VTC technology adoption in organizations.

The second section of this chapter adds to the historical review by expounding upon the theoretical framework used to describe video-mediated work. The perspective of complex sociotechnical systems, alternative input-output models, among other approaches are used to describe video-mediated collaborative work.

Existing guidelines for the design of computer supported meeting rooms and video teleconferencing centers are discussed and summarized in the third section. The purpose of this section is to orient the reader in the technical domain by providing information on established human factors practices in the video-mediated environment, practices appearing in the popular literature, and to provide information about possible limitations or constraints to any. The section is concluded by a discussion of the practice of developing heuristics. Examples are provided from heuristics developed for software evaluation.

The last section is a discussion of emerging trends in VTC systems, including augmented and virtual reality.

2.1 Video Mediated Communication

Evolution of Teleconferencing Technology

The purpose of this section is to provide background literature on the transition from desktop conferencing to larger video-enhanced electronic meeting systems. The studies reported in this section illustrate the current perspective on advantages and disadvantages of video-mediated communication. The studies are used to emphasize how these developments impact remote collaboration in design work.

Technological advancements in the communication modes for video transfer, developments in hardware to support both video and distributed computing, and enhancements in software to enable group communication and group decision–making have made video teleconferences (VTC) an alternative to face-to-face meetings in many work group environments. Despite these improvements, work groups in the VTC environment still report differences in their interactions in VTC versus face-to-face meetings. This is a concern because these interactions between group members help teams form, evolve, and perform.

The video-mediated meeting environment has evolved over the last decade from small distributed groups and single-camera, single monitor desktop video conferences (DVC) to state of the art video-enhanced electronic meeting systems with full audio and visual support. The early research in this area is focused on the DVC environment. Many DVCs in the early nineties were developed to support prototype groupware applications (see Isaccs and Tang, 1993 for example). As research and industry interest in DVCs grew, the concept was used to support a variety of meeting types including remote collaboration, remote design efforts, and group presentations (Isaac and Tang, 1993; Olson, Olson, and Meader, 1995; Isaccs, Morris, Rodriguez, and Tang, 1995).

Although the DVC environment provided another channel of information beyond the audio channel used in telephone meetings, users discovered some important cues were missing from distributed interaction. Sellen, Buxton, and Arnott (1992) addressed the issue of missing spatial cues in the DVC environment in the Hydra prototype system. Hydra supported four-way video conferencing where each member was represented by a separate camera/monitor system in a “simulated 4-way roundtable”. This system was designed “to preserve unique personal space” and to allow many of referential interactions as in face-to-face meetings. Sellen (1992) also addressed the difference of speech patterns between DVC and face-to-face meetings. In addition, she noted a host of subtle differences between DVC and face-to-face meetings. These differences included failure to make eye contact, principle of reciprocity (i.e. all participants can see and hear each other) not holding, a sense of how one's voice is perceived by listeners, and many more (see Sellen, 1992).

As the use of remote collaboration increased, the impact of video over the use of audio only was also studied. Isaac and Tang (1993) conducted an experiment to examine remote collaboration in face-to-face meetings, phone meetings, and DVCs. They found benefits of video over audio in the participants' ability to express understanding, forecast responses, use gestures, convey purely non-verbal information, express attitudes in posture, and manage pauses. They also found the following limitations in DVC over FtF meetings: turn taking, control of the floor, use of peripheral cues, side conversation, pointing, and manipulation of real-world objects. The two advantages of DVC over FtF found by the authors were that conversations were more efficient and devoid of the social content found in FtF meetings, and, because participants were at their desks, they had all of the necessary documents available to them close at hand.

Many studies were conducted which compared remote collaboration to distributed work to determine justifiable benefits for the use of the desktop video conferencing in work environments. Olson, Olson, and Meader (1995) found face-to-face groups produced work of the highest quality. However, in their study, the quality of work produced by groups supported with high quality video and audio was indistinguishable from that of face-to-face meetings. These authors also found that remote work without video (or audio only) was not as good as face-to-face interaction.

Issacs, Morris, Rodriguez, and Tang (1995) found differences between FtF and distributed desktop presentations. In their study, meeting participants used their time differently. This was determined by the level of attention participants focused on the presentation. Remote attendees often multi-tasked and paid specific attention only to aspects of the talk which interested them. The authors found there were significant differences in the perception of presentation quality as well. Audience and speakers both found co-located presentations to be better than their distributed counterparts. More spoken questions were asked in the FtF environment than in the distributed environment. However, when written questions from the remote sites were included into the pool of questions asked to speakers, the authors found no differences in number of questions asked by the audience.

The two previous examples compared differences in distributed meeting behavior. In an interactive setting, video appears to benefit meeting participants by providing an environment similar to FtF. In a presentation or one-way communication setting, desktop video appeared to benefit meeting participants by allowing them to multi-task and focus on the messages most important to them. The findings in the literature with regard to the benefits of video over audio-only are not consistent (Veinott et al., 1999 for example), instead, as in the earlier examples, the results tend to be situational.

Table 2. 1 - Summary of Findings for Video versus Face to Face Meetings

Comparison	Construct	Description
Video versus Face to Face	Cues (Missing)	• Defining personal space • Lack of referential interactions • Making eye-contact • Principle of reciprocity - unable to see and hear each other • Use of peripheral cues • Pointing • Manipulation of real world objects
	Speech patterns	• Turn taking • Control of the floor • Side conversations • lack sense of how one's voice perceived by listener
	Collaborative Work	• Quality indistinguishable if supported by high quality video and audio
	Efficiency	• Devoid of social content • Documents are close at hand in desktop conference
	Presentations	• Remote attendees multi-task • Pay specific attention to relevant parts of presentation • Subjective perception that FtF presentation is better • Less spoken questions are asked
Video versus Audio	Cues (Available)	• express understanding • forecast responses • use gestures • convey purely non-verbal information • express attitudes in posture • manage pauses
	Collaborative Work	• Quality of work less than FtF
Communication Setting	One-way	• DVC allows audience to multi-task
	Interactive	• Video provides environment similar to FtF

Group Communication Technologies (GCT)

Scott's (1999) review of communication technology and group communication begins where the earlier review of the video-mediated literature was ended. Scott examined a broad spectrum of communication technologies including EMS, GDSS, and groupware and summarized findings of empirical studies in the literature by comparing the performance of groups with communication technologies to performance of traditional face-to-face meetings.

This review of GCT literature, in particular the EMS domain, overlapped with the earlier discussion on video teleconferencing. The overlapping issues are characteristic of different place/same time meetings in general. They also included a number of relevant factors in the EMS literature such as group size, group proximity, time dispersion, type of activity, applicable software tools, etc. (Nunamaker et al., 1991).

Scott (1999) also presented and defended the input-output model as a "sense-making framework" for group support technologies such as EMS, GDSS, VTC, etc (Scott, 1999). In addition, an augmented input-process-output model provided a robust framework for theorizing on group communication and communication technologies. Scott reasoned that the framework's applicability is due to the fact that the model is not focused on the technologies themselves, their function, their features, nor their use (Scott, 1999). Instead, the input-process-output model presents a systematic approach to organizing findings according to processes and outcomes in the computer-assisted group work, group communication, and group technologies (Guzzo et al., 1995; Scott et al., 1999).

Scott's review identified a number of input-process-output models that described group communication technology. Each was developed to focus on a different aspect of the group work. His examples included models for (1) electronic meetings based on Dennis, George, Jessup, Nunamaker, and Vogel's (1988) work, (2) technology supported meetings based on Mennecke, Hoffer, and Wynne's (1992) work, (3) and variables that defined input factors, organizing concepts, process variables, and outcome factors based on McGrath and Hollingshead's (1994) framework. These examples along with the research model in Chapter 1 are shown in Table 2.2.

Table 2. 2 - Summary of Input- Output Models used in the CSCW

Model	Inputs	Mediating Variables	Process	Outcome	Feedback
1. Electronic Meeting Model (Dennis et al.,1988; Nunamaker, et al., 1991)	• Work group • Issues • Task concerns • External context • Technology	Process support Task support Task structure Process structure	Meeting process	Outcomes	
2. Technology Support Group Meeting (Mennecke et al., 1992)	• Task • Member • Group • Meeting characteristics		Facilitation Technological support Structural factors Sociotechnical issues	Groups performance and development Individual perceptions	From current to subsequent meetings or group learning Extra-meeting socialization (member interactions between a series of formal meetings)
3. Technology supported group model (McGrath and Hollingshead, 1994)	• Technology • Member attributes • Group attributes • Tasks/projects/purposes • Contextual factors	Organizing concepts: information processing system, Consensus-generating system, vehicle for motivating/regulating behavior	Participation Information processing effectiveness Consensus generating Normative regulation	Task performance/effectiveness User satisfaction Member relations	
4. Flow of Effects for Computer Aided Work Groups (Guzzo, Salas, et al., 1995)	• Group and Member Attributes • Task/projects/purposes • Communication technology	Operating Conditions: Condition under which group x does task y	Patterns of group interaction	Patterns prevailed after group work	
5. Meeting process-model (Scott, 1999)	• Context - laboratory, organizational • Group/Member Characteristics: gender, size, nationality, high/low coordination/collaboration, etc. • Task Characteristics: choosing (convergent) and generating (divergent) tasks. Complexity level, time tasks.		Meeting Process: Facilitation, climate, Leadership style, structured and unstructured decision process.	Outcomes	Feedback

The input-process-model framework was used to compare group performance, meeting efficiency, and member satisfaction for studies published within the last five years (Scott, 1999). For reviews of studies earlier than this period Scott referred readers to Bensabat and Lim (1993), Collins-Jarvis and Fulk (1993); and McGrath and Hollingshead (1994).

A number of conclusions can be drawn from Scott's review of the findings of 81 laboratory and 50 organizational studies. A summary of the relevant findings including the appropriate technology and setting are shown in Table 2.3.

Table 2. 3 - Summary of Relevant Findings in Group Communication Technology

Technology	Setting	Finding
(1) GSS	Organizational	Performance improves
(2) GCT	Laboratory	Task effect moderates performances
(3) GCT	Laboratory	Requires more time than FtF
(4) GCT/CC	Laboratory	Type of GCT impacts efficiency
(5) EMS	Laboratory	Divergent task performed better that FT. Better quality decision under time constraints

First, the findings across studies do not consistently support either GCT or FtF meetings as producing superior outcomes in meeting efficiency or communication. More importantly, the findings remain inconclusive when the focus is narrowed to videoconferencing and EMS.

Second, the findings in Scott's review indicate that there is some evidence of improved group performance when GDSS are used in an organizational setting. Moreover, task effects impact results of GDSS performance in the laboratory setting. And, lastly, GDSS are further impacted by the level of GCT. Therefore, whether a GDSS is combined with computer conferencing, audioconferencing, or videoconferencing impacts performance.

Third, the findings on meeting efficiency revealed that GCT groups nearly always required more time in laboratory studies than FtF groups. In the organizational context, GCT groups achieved greater efficiency than their FtF counterparts. Scott (1999) provided several reasons for the varied results across the two contexts:

1. Time on task: laboratory meetings were one-shot experiments whereas organizational experiments were conducted over longer projects.
2. Group history: laboratory meetings were GCT aided efficiency were similar to organizational groups in that the teams had a group history.
3. Technology features and capabilities: But most importantly for this research, studies where GCT were found to decrease efficiency or reported to show no difference generally involved a technology like Lotus Notes, emails, or some form of teleconferencing (Scott, 1999).

From the studies reviewed, there is evidence that teams which used GDSS systems in their meeting reported equal or greater satisfaction than FtF counterparts in both the laboratory and organizational setting. Scott stated that in 75% of the studies where FtF was reported better than GCT, there was always an additional component of CC involved in the study, such as, Lotus Notes or email. He also found another pattern in these studies, that GCT was compared to FtF but the GDSS component was not compared individually to FtF. These ambiguities in the design may also impact the existing findings.

In laboratory settings GDSS with robust technology capabilities resulted in better satisfaction than those with lesser capabilities. Scott reported that in the organizational setting, member satisfaction was measured over a broad range of technologies i.e. GCT, GDSS, etc. Member satisfaction in this context is linked to the long-term investment made in the technology and employees' awareness of the cost to the organization in both technical and human resources such as facilitators (Scott 1999; Neidermen, Biese, and Berenek, 1996).

In divergent tasks, such as brainstorming, EMS groups reported better performance than FtF groups. EMS groups also reported better quality decision making under time constraints in the laboratory setting, more implementable ideas, and higher quality contributions (Scott, 1999).

The components of task activities used in empirical studies of computer-supported group work are diverse. Scott argued that the task effect must be considered when assessing group performance in distributed settings. Cano (1997) reviewed non-supported group communication metrics and computer-supported group communication metrics. This review included task activities used in laboratory and field experiments to study decision-making tasks. Tasks varied from pilot simulations, case studies, and resource allocation and the tasks described suggested both divergent (idea generation) and convergent (decision-making) activities are required to evaluate group performance with distributed meeting technology.

In summary, there are a number of critical factors that must be considered in an empirical study of group communication in a distributed environment. These factors include setting, level of group communication technology, type of task, group history, available time on task, technology features and capabilities, and number of technologies used and compared. Although the reports on member satisfaction are less tentative, overall lack of conclusive results in meeting efficiency and communication indicates that researchers have yet to isolate all of the underlying factors affecting distributed teamwork.

Benefits, Costs, and Capabilities of the Current VTC Paradigm

The lack of conclusive results in the empirical literature has not had a direct impact on organizational optimism about Group Communication Technologies in general and Video Teleconferencing in particular. The perceived VTC benefits in organizations are generated primarily from an accounting, cost-benefits, or tradeoff analysis approach. The VTC benefits (after Schaphorst, 1999) shown in Table 2.4 are typical of benefits used to justify the significant capital expense associated with establishing VTC capabilities. Organizations are challenged by the task of quantifying all of the benefits of VTC. Therefore, reduced travel costs and meeting time are often used as the primary cost reduction to justify the investment in VTC's.

Table 2. 4 - Benefits and Costs of Video Teleconferencing (adapted from Schaphorst, 1999)

All the participants in a decision can be brought together without travel resulting in

- Faster decision making
- Better decisions
- Increased productivity

By eliminating the need for travel a team can

- Hold more meetings
- Increase employee safety (less risk assumed by travel)
- Ensure tighter security

The negative effects of travel can be avoided which can result in

- Improved employee morale
- Avoided travel costs
- Reduced fatigue
- More efficient use of key personnel

Video teleconferences are timed but can occur more frequently, therefore, realizing

- More disciplined, productive meetings
- Team building
- Interning (inclusion of non-participatory members)
- Reliability

The costs of VTC systems vary according to the complexity of the system. Schaphorst (1999) identified six components that can be used to define the complexity of a VTC system's physical configuration. These components are (1) physical layout, (2) typical display, (3) TV camera(s), (4) Lighting/Acoustics, (5) Typical Scene/Number of People, and (6) Microphone/Speaker. Schaphorst's *Table of Physical Configuration of VTC Systems* has been duplicated in Table 2.5. Among the essential characteristics that a facility designer must consider are: whether a dedicated facility is available or necessary, the number of people participating in a meeting, and whether documents and graphics must be integrated into the meeting (Schaphorst, 1999). Each of these decisions will impact the cost of the installation.

Table 2. 5 - Physical Configuration of VTC Systems*

VTC Configuration	Physical Layout	Typical Display	TV Camera(s)	Lighting Acoustics	Typical Scene; Number of People	Microphone/ Speaker
Customized room	Large conference room, large table, possible additional chairs. Electronic equipment is in a back room.	Rear screen projector(s) or multiple large TV monitors built into a wall.	Usually multiple cameras with pan, tilt, zoom.	Usually customized.	Large group of people; can be more than six.	Multiple microphones or one table top unit.
Rollabout	Self contained module(s), table within a conference room.	One or two large TV monitors built into a rollabout module; small TV window of self view.	One or two cameras with pan, tilt, zoom.	Usually normal room lighting and acoustics.	Small group of people up to six.	Typically one table top unit.
TV set top		One large TV monitor.	Integrated into the TV set top unit.	Normal room lighting.	Small group	Typically one table top unit.
Desktop	Camera/monitor on desktop; electronics in videophone or floor. Typically a PC.	One small TV monitor. PC display.	One small camera. No pan, tilt, zoom.	Usually normal room lighting and acoustics.	Talking head; head and shoulders; usually one person.	Handset or integrated videophone.

***From Schaphorst, 1999, p.13**

In a proposal to the Navy at Dahlgren to achieve compatibility among the systems used at the Macroergonomic and Decision Support Laboratory at Virginia Tech, and two locations in the U.S. Navy (NavSea Dahlgren, NavSea Panama City), four additional areas were considered when defining basic requirements for video teleconferencing systems (Grenville, 1998). As shown below in Figure 2.1, these requirements are the communication line, VTC system hardware, PC software and hardware, and video equipment. Each of these areas affects the quality of video transfer, both incoming and outgoing, in a VTC system. Each area also contributes to the cost of the system.

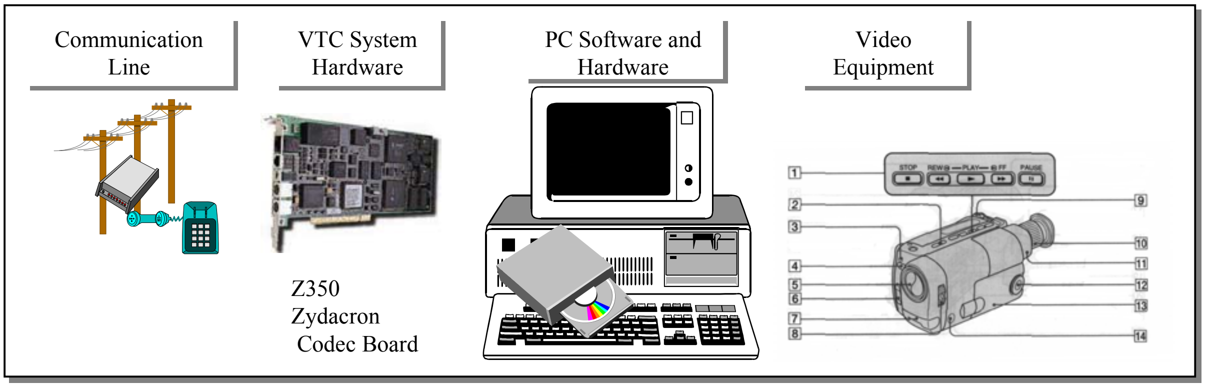


Figure 2. 1 - Components of a VTC System

The capability of the underlying communication network supporting the VTC systems is determined by the type of communication line. Transmissions rates range from 64-128 kbps – low end, to a mid-level of 128-384 kbps, and 768-1.5444 Mbps for high-end systems (Schaphorst, 1999). Current options, at the low end of bandwidth capabilities, include Ethernet, mid-range capabilities can be achieved with end-to-end digital solutions such as ISDN, and the maximum bandwidth capabilities can be achieved with ATM lines.

A standard VTC package has the following components as shown in the sample system in Table 2.6. VTC bundles include VTC system hardware, VTC software, and necessary video and audio equipment. The cost of this ISDN system in 1998 was approximately $6K (Grenville, 1998). Lower end systems with less flexibility in the components are available for as little as $2K and higher end systems can range in the multiple $10K range.

Table 2. 6 - Components of a typical VTC system

VTC Bundle
1. Codec board: (Primary VTC systems hardware. Required in order to encode out-going video and decode in-coming video. Resides in ISA slot in an IBM-PC compatible computer.)
2. IMUX: (Communication hardware. On-board multiplexer. Controls available bandwidth when multiple ISDN lines are used.)
3. Telephone: Standard telephone with keypad- Handset for privacy- DTMF for dialing
4. VTC software required for the hardware components
5. Camera: NTSC or PAL SVideo Pan-tilt-zoom with remote & on-screen control
6. Microphone: High quality tabletop mount Balanced output Phantom power supply
7. Speakers: Powered multimedia Volume & tone control

Application software allows the user to control the bandwidth and communication services used to make a VTC call. It also allows the host to manage point-to-point conferencing. There are a variety of choices for VTC system software, however, in order to avoid issues of compliance or proprietary methods of encoding and decoding the video and audio data, any chosen system must be capable of conferencing at the H.320 protocol. Measures of performance for VTC system software include frames per second in a window or full screen and compatibility with the remote system.

The debate about the cost-benefit tradeoffs for videoconferencing is multi-faceted. Researchers and users remain optimistic about the capability of group communication technology, in particular, videoconferencing and computer-supported work such as EMS, GDSS, etc. Organizations view videoconferencing and group communication technology as a pragmatic solution to the challenge of distributed team members. These technologies remain a practical solution to distributed team work; therefore, researchers continue to investigate the factors that will optimize performance for teams that achieve co-location and communication through the support of these technologies.

2.2 Work System Model

In the earlier section, the characteristics and variables of a VEMS were discussed in the context of the historical developments in pioneer systems. This work was used to provide background on the CSCW perspective of the evolution of these systems by examining the impact of GCT on satisfaction, performance, and efficiency. Although there was some discussion in Section 2.1 of physical environment design with respect to the current VTC paradigm, the discussion was limited to the impact of the physical environment on cost of installation.

In general, physical environment design is an important human factors consideration in the implementation of information technology systems. Eason (1988) identified lighting conditions as one of the critical aspects of the physical environment in computer work because participants must have adequate lighting to read both paper documents and computer terminals. In the VEMS environment, there is the added requirement of providing adequate lighting for transmission of a clear visual image to other locations.

A host of physical environment issues are important to the planning and design of computer-supported meeting environments. Some of these issues can impact the visual system such as lighting, table configuration, and work stations. Others may have impact on the auditory system such as room atmosphere, electrical and HVAC, and flooring (Mittleman, 1995; Daly & Hansell, 1999; Schpahorst, 1999).

The physical environment issues have implications beyond participant comfort during a meeting. In fact, deficiencies in the physical environment can impede the visual and auditory system. Impedance of the visual and auditory system can impact channels of communication. When participants are unable to hear or speak to one another clearly, the quality of collaboration during the meeting is degraded. Again, inadequacies in the physical environment can cause team members to lose focus on the meeting task and instead focus on aspects of the technical system which are not task related. When the team digresses by focusing on the technical system, group performance can be negatively impacted i.e. more time on task, increased frustration level, etc. (Grenville and Denson, 2000).

Office Environment

O'Neill (1998) described a process for macroergonomic design of a physical work environment in which the organization's social, technical, and environmental subsystems were examined in order to generate possible design alternatives. In the education and analysis phases of this approach, objectives, alternatives, and activities are generated and then considered by users and analysts during the design phase. It is recommended that the team be expanded during the design phase to include as many stakeholders as possible. Stakeholders can include suppliers such as vendors, technicians, and those directly involved with the meeting such as facilitators and participants. Finally, administrative support and observers can also be viewed as stakeholders because they can be considered customers or consumers of the process.

The design process involves participants envisioning the ideal future state (O'Neill, 1998). This is a participatory design exercise that is based on six principles of sociotechnical design (Cherns, 1987; Taylor & Felton, 1993; O'Neill, 1998):

1. Minimizing criteria generated in the solution alternatives,
2. Addressing physical and organizational boundaries,
3. Directing critical information towards those who need it,
4. Allowing workers control of environment,
5. Supporting designs that reinforce the mission of the organization,
6. Fostering an ongoing design process.

Several techniques are used in the design process to generate alternatives. First, a participatory scenario-based design process is used to generate a future state for the organizations. The scenario methodology involves role-play and addressing future-oriented questions to generate possible scenarios. Second, contextual inquiry is used while observing the current work process. Open-ended questions are posed to participants to elicit their contributions and expertise. Third, a computer-based group consensus process is used to facilitate voting, data collection and analysis. The software allows anonymity so that ideas can be discussed freely by all stakeholders in the meeting (O'Neill, 1998).

The macroergonomic design of the physical work environment expands beyond the user-centered approach into the participatory design approach where stakeholders in the environment participate in creating solutions.

Participatory Ergonomics

Both the human factors and computer science body of knowledge are replete with examples of participatory methods used to involve stakeholders in the design process. In general, participatory approaches have evolved from a set of techniques used by design experts. They are then modified to include stakeholder input and evaluation at designated stages of the design process.

Most recently, ergonomic challenges in industry have been addressed through participatory ergonomics. As this term implies, workers, operators, and all other job stakeholders participate in many of the evaluation and design steps involved in the redesign effort. Participatory approaches differ from the traditional ergonomic methods. The ergonomist no longer acts solely as a consultant in the design process with limited interaction with users, but instead the participatory approach requires shared decision-making with the stakeholders throughout the process.

Hendrick and Kleiner (2001) provided a detailed theoretical discussion of the participatory approach used in macroergonomics. A few of the relevant points have been summarized below. First, the participatory approach in macroergonomics can be applied to all levels of the organization, and the participants can range from teams to individuals. Second, there are two levels of involvement: (1) full direct participation which involves all stakeholders and (2) partial direct participation which involves a subset of the stakeholders. Third, the level of formality in the participatory approach can be determined by whether the team is permanent and is focused solely on addressing the participatory design problem or whether the team is temporary and has other responsibilities other than the participatory design problem.

Recent studies incorporating participatory ergonomic techniques each utilize different approaches to help the operator engage in shared decision-making involved in job redesign. Typical characteristics of these approaches include assessment questionnaires used to determine the current state of musculoskeletal disorders in the workplace (Joode, Burdof, and Vespuy, 1997; Reynolds, Drury, and Boderick, 1994);

conducting of ergonomic reviews or audits through checklists (Reynolds, et al., 1994) or observation techniques such as videotaping the operator while performing the task (Joode, et al., 1997; Latko, Armstrong, Foulke, Herrin, Rabourn, & Ulin, 1997); redesigning the job according to a theoretical framework which aids in the task allocation or job design to promote operator satisfaction (Imada, 1995). Other variations also include data analysis through simple optimization techniques (Reynolds, et al., 1997), computer simulation (Capodaglio, Capadoglio, and Bazzini, 1997), or comparison with guidelines (Joode, et al., 1997; Capodaglio, et al. 1997).

In addition to these techniques, Hendrick and Kleiner (2001) present four applications of the use of participatory ergonomics in organizations. These application areas can be used to categorize specific projects where participatory methods are used.

First, the organization may focus on participation in decision making and problem solving. There are two approaches used to achieve participatory decision-making. One method is for the organization to make adjustments in the personnel and organizational subsystem. Therefore, functional, cross-functional, and self-managed teams can engage in participatory decision making and can create recommendations or invoke their decisions depending on their level of decision authority.

Similarly, adjustments can be made to the technical subsystem by providing technology supporting participatory decision making. For distributed groups, a supporting technology is video teleconferencing. Electronic meeting systems which support convergent (consensus reaching) and divergent (idea sharing) decision making can also be used to support group decision making whether the team is co-located or distributed.

Second, the participatory approach can be used in product and system design. Usability evaluation for the design of software and systems is cited as one of the prime examples of this type of participation (Hendrick and Kleiner, 2001). One method for achieving user participation in the product design process is by the use of scenarios. Scenarios can be used to bridge the gap between designer and users. Chin, Rosson, and Carroll (1997) used scenarios to aid teachers, developers, and analysts through participatory evaluation of a user interface.

Third, the authors discussed training system design as an application of the participatory approach. Training is often categorized as an administrative control where the workers are taught to adapt to the limitations of their work system. However, training still presents an opportunity where workers can be involved. Workers can participate in both development and deployment of the training program.

Fourth, workers can participate in work system analysis and design. Hendrick and Kleiner (2001) provide a ten-step methodology which can be used to involve workers at all levels in job redesign. The ten phases of the work system analysis and design process systematically address all of the organization's subsystems. This approach, which can be used to guide consultants and workers through a participatory redesign effort, is as follows:

Interdisciplinary Systems Approach

Mittleman (1995) provided an interdisciplinary summary of the relevant planning and design literature for the collaborative meeting environment. The primary objective of this review was to establish some guidelines for a programmatic approach to the physical environment design of collaborative meeting facilities. In this paper, Mittleman organized his findings according to the systems approach used in architecture which includes (1) goal definition, (2) needs analysis, (3) information gathering, (4) requirements definition, (5) generation and testing of programmatic alternatives, (6) program decision, and (7) documentation. The approach he developed can be adapted to include the level of participation desired by the organization.

Mittleman identified the following areas as important when determining requirement definitions for collaborative meeting environments. These include table configuration; workstation design; adequate lighting in the workspace and meeting room; room atmosphere and how technology is emphasized in the room; the use of public display screens and determining how many and where they are positioned; building and OSHA specifications; electrical and HVAC systems; selection of flooring; the level of room security; and the allocation of social space in the meeting room.

The final section addressed by Mittleman was program decisions and documentation where an emphasis was placed on providing a clear linkage between the document and the needs analysis so engineers and architects using the document understand the rationale for each design decision.

Lastly, Mittleman did not address the generation and testing of the programmatic alternatives component of the architectural systems approach. This is not surprising because, as the author reported, there is a gap in the available literature of empirical studies on the design of collaborative meeting environments.

In this section several methods of modifying physical work environments were discussed. These methods ranged from participatory to programmatic. Each method demonstrated that the physical environment redesign is multi-faceted and requires a combination of techniques in order to generate and implement physical design alternatives.

2.3 Design Guidelines for the Collaborative Meeting Environment

The use of guidelines from a number of disciplines is necessary to address all of the objectives of the facility such as communication, presentation, and collaboration. Instructional facilities designed for distance learning can provide examples of one-to-many communication in video telephony. These facilities may provide solutions that can be applied to a meeting room. Guidelines from human factors and interior design can be used to select colors which are most pleasing and provide the most contrast in a video environment. Human factors guidelines can also be used to address ergonomic concerns such as computer work station design and furniture selection.

Audio

The audio system components include the microphone for signal capture, the amplifier for signal amplification, and the speakers for signal distribution (Woodson, Tillman, & Tillman, 1992). Only the use of microphones and speakers in the sound system will be discussed in this section because they are most relevant to human-system interaction in VTC meetings.

First, *microphones used for VEMS should operate in the wide frequency response range without distortion*). Video conferencing systems have a wider frequency range (50 Hz to 7 kHz) than the basic telephone system (50 Hz - 3.5kHz) Daly and Hansell, 1999.

Second, *the microphone pick-up area impacts the seating arrangement.* Tabletop microphones have a cone-like pick up area of 120^{o}. The voices of about 3-4 people can be picked up within a 2.5-3 ft range from the conference table and allow for some movement while speaking. The pick-up area should be narrower in desktop environments because of office noise (Daly and Hansell, 1999). Important considerations include: ensuring that each person's voice can be distinguished from multiple voices in the group (Woodson et al., 1992), and ensuring that microphones should be adjustable to account for individual preference in seating position (Woodson et al., 1992).

Third, *aesthetics and practicality should also be selection criteria for microphones in distributed meeting rooms*. There are a number of recommendations in this area. Conspicuous tabletop microphones might be found intimidating whereas inconspicuous microphones can be inadvertently hidden by participants with their documents (Daly and Hansell, 1999). Ceiling mounted microphones are all less conspicuous and intimidating, however, they require special wiring and will impact on portability (Daly and Hansell, 1999). Lapel microphones and wireless microphones may be appropriate for participants who are observing the meeting because they can be easily turned on and off.

Fourth, *it is important for the designer to determine the number of microphones needed for the conferencing facility*. For smaller systems, once a second microphone is needed, there is an impact on cost because a microphone mixer is needed to manage the sound input from multiple microphones.

Fifth, *microphone placement can contribute to background noise in the system*. Because microphones are often focused in the direction of the rear wall, engineering considerations made to treat the acoustic environment at such a site should be applied to the rear wall only. Acoustic panels can be mounted into the rear walls of the room to deaden reverberation. Also, a less expensive alternative is to cover the rear wall with double pleated and lined full length drapes. The recommended room reverberation is 3-5 seconds and the room absorption coefficient should be in the .25-.45 range.

Finally, the following human factors recommendations on speakers are relevant to both small or large VEMS meeting rooms. First, the sound from the loudspeakers should be directed at the listener. Second, several loud speakers should be used in large spaces to maintain audio-visual position integrity. Third, audio-visual position integrity is also important for the single lecturer. In the case of the individual at a podium, the speaker should be positioned so the voice appears to originate from the speakers location. The loud speaker should be directed towards the audience and located either above or inside the lectern. (see Woodson et al., 1992 for more details)

Video

Visibility of remote meeting participants can affect team performance in the VEMS environment.). The recommendations provided here are based on concerns that meeting participants sometimes have difficulty in distributed communication because of the lack of visual cues (Sellen, Buxton, and Arnott, 1992). Therefore, the main objectives for video performance are that (1) participants should be aware of who is visually attending to them and (2) participants should be able to read facial cues, establish eye contact, or utilize gaze (Daly and Hansell, 1999).

First, *facial detail is limited if the number of remote participants imaged on one display is too large*. A single fixed camera is sufficient if the meeting involves up to four people. A single movable camera or multiple cameras are required for imaging larger groups. Camera presets can be used to store pre-selected camera positions which show smaller groups of up to four people. The movement of the camera can then be voice-activated or handled by the system controller.

Second, *higher frame rates may be required to image facial cues and other subtle movements in any given camera position*. Kies (1997) used a talking head image to investigate the impact of limited bandwidth on acceptable image quality. His findings showed that for talking head scenes significant differences in acceptable image quality were recorded for bandwidth up to 28 fps.

Third, *for larger groups multiple cameras can be used to achieve continuous presence through a split screen technique*. Because the upper and lower quarter of the video image provides no meaningful information, the center half of the camera output can be used to stack the images from two cameras for display on a single monitor. The Images from two cameras can also be displayed on dual monitors.

Fourth, *although lower end cameras can be used for a VTC meeting, they are not preferred*. Lower end cameras are preset to image the participants from a predetermined distance. Single fixed cameras without variable focal length afford the meeting participants very little flexibility. They must sit at a predetermined distance from the camera. A camera with variable focal length can be manually zoomed in and out on the participants. With lower end cameras, the light setting of the camera is usually manually adjusted and is fixed for the duration of the meeting.

Fifth, *remote camera control can be used for a more flexible design where the participants can reposition during the meeting*. An improved camera allows the system controller to handle zooming, focusing, brightness, horizontal position and vertical position of the camera. The authors suggested using this design to provide close-ups of pairs of individuals as necessary in the meeting (Daly & Hansell, 1999).

Sixth, *poor lighting at the meeting site can interfere with communication, therefore, participants should be well lit* (Daly & Hansell, 1999). The use of fluorescent lighting with an intensity at the table of about 1000 lux is recommended, however, computer monitors should not be in direct light. The rear wall should be lit in the same color temperature but at half the intensity of the participant lighting. For more details about lighting, the reader should refer to Daly and Hansell (1999).

Finally, the optimal solution for video is to use a combination of camera presets, remote camera control, split screen to image participants and appropriate lighting (Daly and Hansell, 1999).

Furniture and other considerations can also enhance the quality of the meeting environment. For example, chairs of medium blue color density will improve contrast between participants and background (Daly & Hansell, 1999). Carpeting is recommended for sound absorption.

Figure 2.2 provides a summary of design guidelines used to enhance audio and video capabilities in videoconferences.

Audio

1. Microphones used for VEMS should operate in the wide frequency response range without distortion.
2. The microphone pick-up area impacts the seating arrangement. Wider pick up areas are appropriate for conference rooms. Narrow pick up areas for desktop environments.
3. Aesthetics and practicality should also be selection criteria for microphones in distributed meeting rooms. Dimensions of practicality include: degree of conspicuousness, degree of intimidation, appropriate placement, degree of portability, cost of wiring, and ability to power on/off either by participant or by facilitator.
4. The appropriate number of microphones must be determined for the facility. Multiple microphones require a sound mixer and impact costs.
5. Microphone placement can contribute to background noise, therefore, treat the acoustic environment at the site to deaden reverberations.
6. Place speakers in room to maintain audio-visual position integrity.
7. Use carpets for sound absorption.

Video

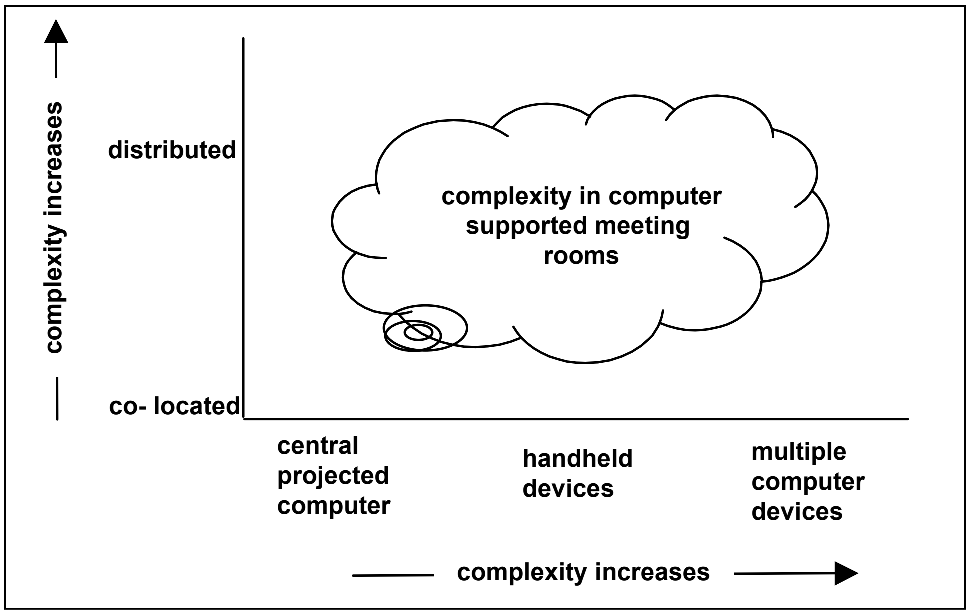
8. In order to retain facial details, limit the number of participants imaged on one display
9. For larger groups multiple cameras can be used to achieve continuous presence (all members are visible at all times) through a split screen technique
10. Lower end cameras can be used for a video conferencing but they are not preferred due to limited capabilities in adjusting lighting and focal length.
11. Remote camera control can be used for a more flexible design where the participants can reposition during the meeting
12. Higher frame rates may be required to image facial cues and other subtle movements in any given camera position
13. Poor lighting at the meeting site can interfere with communication, therefore,
14. participants should be well lit and the appropriate amount of rear lighting should be used to create contrast and to avoid shadows.
15. Avoid direct lighting on the computer monitors.
16. Select furniture color and table color and surface to improve contrast between participant and meeting environment.

Figure 2. 2 - Summary Audio and Video Design considerations in the VTC environment

Computer Supported Meeting Rooms

The final set of design guidelines which will be reviewed in this section are for computer supported meeting rooms. In the VEMS environment, teams expect to collaborate on their computers while simultaneously communicated via videoconferencing. Neal (1995) examined the challenges to design and development of productive computer supported meeting rooms.

Figure 2. 3 - Complexity in computer supported meeting rooms



According to Neal (1995), computer supported meeting rooms vary along two dimensions as shown in Figure 2.3: the number of computer devices per participant, and the location of the participants. At the low end of the spectrum, computer supported meeting rooms incorporate a projected computer, or electronic whiteboard in the traditional meeting space. Intermediate capabilities can include handheld devices used for participant voting. At the high end, each participant has his own computer specialized software tools for group interaction to support tasks such as collaborative writing, decision making, and planning. Lastly, Neal viewed the incorporation of participants who were not co-located as another level of technological complexity in computer supported meeting room design. In this case, remote members require the addition of audio and visual channels.

Neal identified group size, type of meeting, and type of technology as variables that determine the optimal room design. These variables are constrained by available space and funding. Physical architecture variables are also important in computer meeting room design. These include: material and color choices for the floor and ceiling, engineering considerations such as acoustic panels, lighting, and ventilation (Neal, 1995).

Neal warned that computers impact communication and the feel of the room and therefore affect group process. She argued that people rely on face-to-face contact in meetings. Therefore when the view is blocked by computers people can not use their meeting skills effectively. The sense that the inclusion of computers means that these skills are bypassed or rendered ineffective can make people unwilling to utilize an electronic meeting system in the co-located or distributed environment.

Neal provides a number of design guidelines to optimize usage meeting process in a computer supported meeting room. These guidelines are summarized in Figure 2.4.

Guidelines

- Consider how people feel.
- Consider how they feel when attending a long meeting.
- Configuration possibilities.

    1. **Central table** or Long tables placed to form a "U" or square - Both allow team members to see each other and see the facilitator. These configurations also allow the greatest flexibility to accommodate different size groups.

    2. **Tier configuration** - allows better view of screen and meeting leader. Leads to more formal meetings because of the lack of eye contact among the participants and the focus on the meeting leader.

- Select items such as furnishings and any peripherals conducive to the type of meeting that will take place. For example if executives are meeting, furnishing should emulate those of the typical executive board room (Neal, 1995).
- Do not block people's view of one another with computers.

Figure 2. 4 - Guidelines for computer supported meeting rooms (Neal, 1995)

Designing Guidelines

Mittleman (1995) reported a gap in the available literature of empirical studies on the design of collaborative meeting environments. His observation remains true today. No recent empirical studies were found in human factors literature, environmental psychology, or CSCW literature on the design of VEMS environments.

Devising guidelines from empirical studies is a common practice in human factors. As shown in the upcoming examples, the approaches used in the human factors domain, in particular in the Human-Computer Interaction (HCI) literature, are appropriate for developing design guidelines for the collaborative meeting environment.

In Neilsen and Mack (1994), there are three descriptions concerning the development of heuristics from empirical evaluation for the purpose of enhancing software design. The first example is Neilsen and Molich's (1990) usability heuristics. Neilsen and Molich first developed a checklist of usability considerations based on the authors' personal experience with user interface design. The nine-item checklist were developed to assist designers and programmers to evaluate a software user interface without referring to lengthy guideline documents. The authors tested the checklist for construct validity by evaluating the responses of 77 industrial designers to a design exercise where the participants identified problems with a simple human computer dialogue. They found that all usability problems fit well into one of the categories on their checklist. Therefore, one approach is to create a list of heuristics based on experience, to collect data from participants who have not been exposed to the heuristics on how to solve the particular design problems, and to categorize their responses based on the initial checklist. This is an inductive approach to generating heuristics.

Kahn and Prail (1994) developed a set of methodology design heuristics which are used "to assess the design of a methodology (p. 166)". They developed these heuristics based on a user needs analysis, prior methods, and their experience. They also distinguished between the different task performance models where the emphasis is placed on what a person should do or where they should look versus a heuristic where the emphasis is placed on the type of things to look for. An example of the contrast between the two approaches is taken from Kahn and Prail (1994):

1. Task performance model: Does the user see the information he needs? (p. 147)

2. Task-based heuristics: Minimize actions to accomplish tasks (p. 150)
3. User-based heuristics: Speak the user's language (p. 150)

In this case, the user needs analysis played a principle role in defining the heuristics. The authors established who the users were, what their goals were, and what their needs were, along with their responsibilities, a description of their roles, a description of the process, and the number of each type of user generally required to accomplish each task. These authors used a more descriptive approach to quantify the parameters involved in usability inspection. Their findings were used to generate a set of heuristics.

In this final example, Neislen (1994) used a database of 249 existing usability problems and generated explanations for the problems based on published sets of heuristics. He then used factor analysis on the explanations to derive a new set of heuristics. His method of heuristic development in this example was deductive.

Table 2. 7 - Heuristic examples from the HCI literature

Usability Heuristics (Molich and Nielsen, 1990)	Methodology Design Heuristics (Kahn and Prail, 1994)	Usability Heuristics (Nielsen, 1994)
• Simple and natural dialogue • Speak the user's language • Minimize the user's memory load • Be consistent • Provide feedback • Provide clearly marked exits • Provide shortcuts • Provide good error messages • Error prevention	• Minimize time cost to engineers who are on the critical path • Maximize involvement of engineers who will implement changes. • Create a method that is an "even" in the usability lifecycle. • Team-base approach • Adapt existing methods—help do what is done better • Leverage the language and structure of well-established methods solving similar problems • Task orientation • Clear potential integration with other parts of the usability engineering life cycle	• Visibility of system status • Match between system and the real world • User control and freedom • Consistency and standards • Error prevention • Recognition rather than recall • Flexibility and efficiency of user • Aesthetic and minimalist design • Help users recognize, diagnose and recover from errors

These three examples demonstrate that there is no established method of generating heuristics. The approach can be descriptive, inductive, or deductive and the heuristics can be validated be empirical studies as in Nielsen and Molich (1990) or Molich and Nielsen (1990).

2.4 The Future of Videoconferencing and Distributed Meeting Spaces

It is likely that augmented reality and virtual reality will be more readily combined with videoconferencing as network bandwidth increases in the future. Augmented reality (AR) is defined as computer generated objects represented in 3-D in physical space. In virtual reality (VR), the entire scene and its objects are computer generated and users experience and navigate the virtual world with variety of input devices such as tactile gloves and haptic joysticks, while wearing head helmets that provide an immersive virtual display.

The earlier discussion of roomware in Chapter 1 dealt with a number of the limited bandwidth solutions of today's conventional technology. For example, electronic whiteboards that can be used to share information in the distributed space while the users write on the physical board at their Site Belong to this toolset. Conventional roomware solutions in many ways are a precursor to AR solutions, however, they only scratch the surface of possibilities that scientists and researchers believe will exist in future collaborative co-located and distributed workspaces.

Buscher, Christensen, Gronbaek, Krogh, Mogensen, Shaprio, and Orbaek (2000) described on example of an AR roomware tool that is being developed to take advantage of incremental levels of bandwidth as they become available. They envision a roomware tool that is both spatially and temporally accurate that will allow participants to interact with a physical and digital model of text documents, CAD drawings, etc. Furthermore, they envision a digital conference room as a component of their augmented reality capability. In their model, a user would join "the discussion when his/her avatar [digital representation of his/her physical form] gets sufficiently close to the [augmented reality conference] table (Buscher et al., p. 47)".

Objects in AR can be passive or active and can be shared in a digital environment (p. 58). According to Buscher et al., these objects can be used to overcome the limitations of the physical environment such as boundedness and inflexibility (p. 58). It is important to note, however, that their environment assumes a level of participation and control not currently a part of the conventional VEMS. In terms of facilitating design, the authors believe synchronous sharing and design is composed of these four levels of ‘design and use’:

1. Populating and arranging a single workspace,
2. Inhabiting many parallel workspaces at a time,
3. Supporting and collaborating between several users,
4. Bridging between physical and virtual workspaces.

If AR is to be used successfully to bridge the distributed environment, the levels of design and use will have to become more practiced among users in distributed environments. Currently, users in a distributed environments often require a significant amount of technical support to populate and arrange their own workstations, to connect with others in the distributed environment, and to engage in distributed collaboration (see Bikson and Eveland, 1996).

Roehl (1995, p. 39) listed a number of obstacles to achieving Distributed Virtual Reality (DVR). The intent of this technology is for people to share the same virtual world using computers over a network. The obstacles at that time were:

- limited bandwidth,
- latency in the delivery, and,
- portability.

By 1998, Jackson, Taylor, and Winn reported success in using DVR to support virtual learning for sixth graders. Sixth graders were able to collaborate with peers in a virtual environment while wearing head-mounted display helmets which allowed voice communication via an intercom system. Students were able to communicate and gave high ratings to a sense of presence in the environment. These authors reported the following technical enhancements that could have improved the VR experience for their students (Jackson et al., 1998, p. 124):

- 3 - D localized sound,
- improved input devices,
- less cumbersome HMDs,
- simpler wands, and,

- introduction of haptic devices.

As of 2001, haptic (forced feedback) devices are common in virtual reality environments, and development is ongoing for input devices and display devices such as HMDs in virtual environments. A recent article in the *San Francisco Chronicle* (Rosch, 2001) indicated that future distributed meetings will be supported by cell phones, and virtual avatars will be used to represent the participants.

From this short chronology of advances in distributed meeting spaces, it is possible to understand the impact of increasing network bandwidth on achieving more sophisticated AR and VR in distributed meeting environments. These technologies will increase the level of "design and use" for participants and will demand that users have more control and interaction with their meeting space. The transition necessary to integrate these advanced technologies with more conventional technologies such as videoconferencing may require empowerment of users in order to increase their level of design and use in distributed meeting environments.

CHAPTER 3 - STUDY 1
USER VEMS PREFERENCES

One of the primary challenges of this dissertation is to go beyond the studies in the existing literature and to attempt to untangle aspects of user performance that have been previously coupled with users' satisfaction with VEMS technology. Therefore, this research is focused on understanding the impact of physical environment control on satisfaction with distributed technology. This problem is complex and little data exist in the literature to provide an empirical foundation for users' needs in this environment. Therefore, more than one study was required to collect the necessary data.

The first study was organized to gather data on users' needs in distributed meeting environments. The study was designed so that users could focus on designing the ideal distributed meeting room and in doing so data could be collected on user requirements and design rules. A manual task solution was used to reduce training and to ensure that participants would not be distracted by having to master a computer program such as CAD.

The purpose of the second study was two-fold: to test the heuristics representing the design strategies users articulated in the first study and to test the approach for applying room design or configuration heuristics in the physical environment. The target participants in this study were naïve users who were asked to configure a meeting room with and without heuristics and then to participate in a distributed meeting. Participatory ergonomics was the approach used to apply the room design or configuration heuristics. The overall purpose of this study was to investigate the impact of control of the operating environment on satisfaction with the distributed meeting process.

The third study was designed to gather data from experts on the heuristics and their usability. The experts were asked to evaluate the configuration created by the distributed team in the second study with and without heuristics. With the data gathered from this study, a comparison was made on the perceptions of usefulness and usability between experts in this study and non-experts from Study 2.

The intent of this three part design was:

- to gather data from the users at the extremes of the spectrum of distributed meeting room environments,
- to compile and to articulate the data collected from these users in the form of heuristics,
- to implement the heuristics using a participatory ergonomic approach, and
- to compare the opinions of non-experts and experts on the usability of the heuristics and their impact on satisfaction with the VEMS meeting room design.

3.1 Pilot Study

A. A pilot study was conducted with two graduate students to ensure that the final procedure for the user preference study would be easy to understand and that the task could be completed in a reasonable time period. This study has been included in this chapter to maintain the topical division of chapters.

B. The pilot study is presented first in Section 3.1. The remaining sections in this chapter pertain to the final study conducted on user preferences.

3.1.1 - Introduction

Snow, Kies, Neale, and Williges (1996) presented a case study of the participatory design of a usability laboratory where different tools were used in different phases of the design process. This case study was used as an example of a possible mapping of design tools (or technology) to a specific design phase (see Table 3.1).

Table 3. 1 - Summary of Design Tools used in Participatory Design Process of a Usability Lab (Adapted from Snow, Kies, Neale, and Williges, 1996)

Phase	Planning	Tool	Outcome
1. Planning	High-level goal setting, description of principles and constraints.	Computer aided design (CAD) drawings.	Identifying critical functions.
2. Preliminary Design	Allocation of workspace to a critical function.	Computer aided design (CAD) drawings. Scenarios of use.	Consensus on functional requirements.
3. Dynamic Space Manipulation	Owner/user manipulation of room structure and layout of workspace.	Scaled paper cutouts, transparencies, markers.	Functional specifications document and floor layout.
4. Physical Walkthrough	Envision renovated space. Acquire a sense of the physical space and its dimensions. Confirmation of outcomes from Phase 3.	Mark off walls in physical space.	Construction blueprints and cost estimation by architects.
5. Virtual Mockup and Walkthrough	Integrating, spatializing, visualizing in determining accessibility, furniture and equipment placement etc.	Superscape Virtual Reality Toolkit, 2-D layout.	3-D blueprint. Identification of usability issues before construction.

In the design process outlined by these authors, Phase 3 Dynamic Space Manipulation, utilized a manual task solution of scaled paper cutouts, transparencies and markers. In this phase, stakeholders in the process used the scaled cutouts to support and to describe their design ideas to others on the team (Kies et al., 1996). In other studies where the primary design goal was for the participant to create a mock-up, similar low-technology design solutions were used (see McCreary et al., 1998; Green et al., 1992).

Therefore, in Study 1, a low-tech design solution was used to determine user preferences for VEMS room design. From the reports of Kies et al. (1996), it was expected that users would be able to use their final product to describe their design ideas. Survey instruments were used to collect demographic information and subjective information about equipment type and position in the optimal facility.

3.1.2 - Participants

Two female graduate students were solicited from the Industrial and Systems Engineering Department from Virginia Tech to participate in the pilot study. Both participants had limited experience in videoconferencing and groupware, however, they had considerable experience in email distribution lists and online chat applications.

3.1.3 - Materials and Equipment

Two studies from the literature were used to determine the appropriate number of available foam core pieces required to manually mock-up a VEMS facility. Green et al. (1992) created a vehicle prototype which used 1000 switches representing 250 types of switches to evaluate user preferences for dashboard cruise-control designs. The researchers provided a 4 to 1 ratio for selections of mock-up switches in order to allow users to create their envisioned design. In McCreary et al. (1998), teachers were asked to arrange a classroom mock-up with cutouts that represented the available furniture. In this study, the numbers of available cutouts were limited.

There may be a trade-off between the number of available parts and the potential to create a future state that is not based on an existing set-up (Green et al., 1992). Because the intent in this study was to allow the users to create their envisioned VEMS set up, a 110-piece kit was provided for the mock-up design with no restrictions on the user of any pieces.

3.1.4 - Facility

The pilot study was conducted in the Macroergonomic and Group Decision Systems Laboratory (MGDSL). More information about the layout of the facility is provided in the description of facilities for the final experiment.

3.1.5 - Procedure

The experimental procedure was divided into two phases: (1) experimental training and (2) experimental session. The procedure is described in detail in the remainder of this section.

Each participant signed a consent form and was asked to complete a short demographic questionnaire [Step 1]. The researcher spent a short period of time orienting participants to the experimental task. The orientation included a brief description of videoconferencing and groupware systems, which was given in conjunction with a video clip of a typical meeting [Step 2]. The purpose of this orientation was to ensure each participant had basic knowledge about the applications in the meeting room environment.

Participants were asked to review a list of possible meetings that could take place in distributed meeting room [Step 3]. In addition, participants were shown how to use the foam core pieces in the kit to mock up the room shown in the video clip [Step 4]. They also viewed a timed presentation of eighteen example meeting rooms representing a variety of possible room configurations [Step 5].

Once the training was completed, each participant was given a summary sheet based on the material covered in Step 2. They were given the instructions for the experimental session [see Appendix A] and asked to begin the session. Participants were asked to focus on three areas of the room design: floor layout, wall layout, and ceiling layout. They were given as much time to complete the experimental session as needed. Each design session was video recorded.

Once the participant finished their room mock-up [Step 6], he or she completed a work station preference survey [Step 7]. Participants were asked to rate the importance of type and position of equipment used in a distributed meeting room and participate in a post-session interview[Step 8]. A 7-point Likert type scale was used where (1) was assigned very unimportant and (7) was assigned very important. The entire survey instrument is provided in Appendix A, however, a sample question is shown below in Figure 3.1.

In a VEMS meeting, rate the importance of selecting the position of the **monitor:**						
1	2	3	4	5	6	7
Very Unimportant	Unimportant	Somewhat Unimportant	Indifferent	Somewhat Important	Important	Very Important

Figure 3. 1 - Sample Rating Question

Similarly, participants were asked to rank the importance the equipment which should be accessible to changes or redesign by users. An example question has been provided below in Figure 3.2:

Mark in order the equipment which you think is most important for meeting participants to be able to arrange. Assign the number 1 to the equipment you think is most important

Audio/Visual Equipment	
Cameras	____
Displays (Public)	____
Microphones	____
Overhead Projectors	____
Speakers	____
Computer Equipment and Roomware	
Computers	____
Document Readers	____
Whiteboards	____
Workstation	
Privacy Shields	____
Seating	____
Tables/workstations	____

Figure 3. 2 - Sample Ranking Question

3.1.6 - Summary of Pilot Study

Both graduate students involved in pre-testing completed the experimental session in less than 90 minutes. Their sessions were conducted with an early version of the experimental protocol which was modified for the final study based on their feedback. In the pilot study, all of the segments of the experiment were completed including the training, design session, post-experimental survey and post-session interview.

Several changes were made to the original design as a result of the pilot study: First, questions 17 and 18 were added to the survey (see Appendix A). Second, Plexiglas was preferred as a mock-up surface to the foam board material used in the pilot session. Both graduate students asked that more foam core pieces be added to the kit. The original kit had approximately 110 pieces and the number of pieces were increase to about 25%. Third, the camera position was changed to ensure that the frame captured hand movements in the entire design space and the foam core kit. Questions in the post-experimental interview were revised and were more direct.

In addition, two other changes were made the experimental protocol. First, one phrase related to computer security was simplified. Second, there was more emphasis placed on the instructions reminding participants that use of the foam core pieces in their design should be fully described in the post-experimental interview.

Finally, during the pre-testing phase, the training clip and presentation used in Step 2 were reviewed by an expert evaluator. Minor modifications were made to the presentation based on the reviewer's comments.

3.2 - Study 1 - User Preferences in Distributed Meeting Room Environment

3.2.1 - Participants

Twenty-five college-enrolled students and twenty-five naval employees participated in the user preferences study. The number of participants used in the sample was based on the recommendation that a large sample size of 50-100 subjects is required in user preference mock-up studies (Green et al., 1992).

Subjects were solicited from two sources. First, email distribution lists were used to send flyers throughout the college campus. Undergraduate or graduate students who had no prior participation in video teleconferencing or distance learning were asked to contact the researcher. Student participants were paid at a rate of $8 per hour.

Second, an organizational memo was distributed via email to all previous participants in meetings at the Decision Support Center at the Navel Surface Warfare Center in Dahlgren, VA. Subjects were asked to have prior experience in the VEMS environment either in a distance learning setting or as attendees in a video teleconference. No financial compensation was given to Naval participants.

3.2.2 - Experimental Design

The study was a one-factor between-subjects design. Previous experience in the VEMS environment was selected as the independent variable. There were two levels of experience: level 1 - naïve users and level 2 - experienced users. This factor is representative of the potential users of these facilities. The experimental design matrix is shown in Figure 3.3.

Experience Level	
Naïve	**Experienced**
S1..S25	S26..S50

Figure 3. 3 - Experimental Design Matrix for Study 1

3.2.3 - Materials and Equipment

An enhanced version of the room design kit (Figure 3.4) described in the pilot study was used during the experiment. This kit contained close to 140 foam core pieces. These pieces had a recommended use but no piece was specifically designated to represent any of the equipment in the room (Table 3.2). The participants were allowed to use the pieces without restriction to complete their design.

Figure 3. 4 - Foam Core Pieces used for Room Design

Table 3. 2 - Recommended Use for Room Design Kit Pieces

Tables	Roomware	Seating
4 triangle	3 squares	26 seats
8 rectangle	2 triangles	
8 semi-circular	3 rectangles	Lighting
4 quarter circle	2 semi-ovals	7 teardrop
8 fence post		
3 large rectangle	Public Displays	Microphones
3 squares	2 equilateral triangles	26 small circles
6 circles	4 isosceles triangles	
1 oval	4 squares	Miscellaneous
		4 oval
		3 large circle

3.2.4 - Facilities

Twenty-five college-enrolled students were observed during experimental sessions in the Macroergonomic and Group Decision Systems Laboratory (MGDSL) in the Human Factors Engineering and Ergonomics Center at Virginia Polytechnic Institute and State University (Virginia Tech). This facility was designed to host controlled experiments between individuals and groups with or without computer support. In its normal configuration, the facility consists of three experimental rooms and a control room. In this study, only the main experimental room and control room were used.

A Hi-8 camera was placed behind the two-way mirror in the control room to video record participants unobtrusively during their sessions. An additional microphone was connected to the camera and located in the experimental room to increase the sound capture on the video.

There were three focal areas in the experimental room in the MGDSL (Figure 3.5). The first area was the PC workstation where participants completed an online demographic questionnaire at the beginning of the session. The participants also returned to the PC workstation later on in the session to complete online surveys about workstation preferences. The PC workstation was a Pentium II computer with a 17" SVGA monitor connected to the T1- LAN for Internet access.

The second focal area was the video viewing station. Participants were shown a video clip on the 60" projection TV connected to a VHS Video Cassette Recorder. Participants were allowed to watch the video as many times as they wished to in the viewing area.

The third focal area was the design workstation where the room design kit, Plexiglas work surface, and the remote video microphone were placed. The workstation was located so the participant's hands and design could be taped during the session.

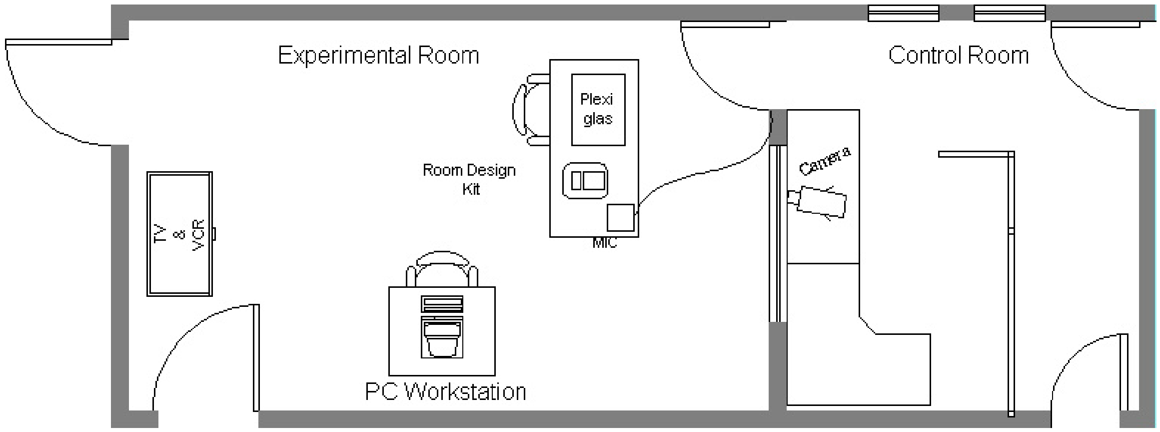


Figure 3. 5 - Layout at Virginia Tech Facility

The facility at the Dahlgren laboratory was a large conference room (Figure 3.6). A canon VC-C3 camera attached to a Sony Hi-8 recorder were placed on a mobile cart across from the participant's work area. One section of the large conference table was designated as a design work area (see location of Plexiglas and room design kit). A PC Pentium II laptop with a 15" SVGA monitor was located in the adjacent to the design work area. Participants used the PC to complete experimental training and online surveys. No viewing area was required in this facility because participants were experienced and did not need to view the videotape of a sample distributed meeting.

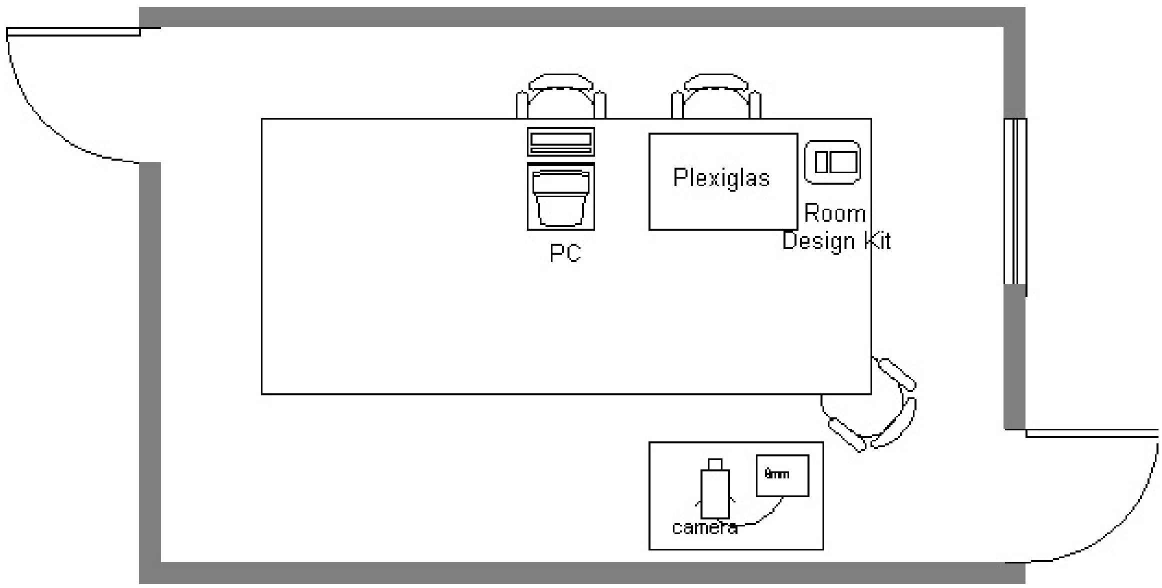


Figure 3. 6 - Layout at Dahlgren Laboratory

3.2.5 - Procedure

The procedure described in the detail in the pilot study was followed during the experiment with the exception of one modification. Step Two of the procedure was omitted for experienced users. Experienced users had participated at least one meeting in a videoconferencing facility and were familiar with the equipment and set up of at least one facility.

Both naïve and experienced users were shown the example meeting rooms during Step 5. All users may have developed biases in their design preferences due to their past experiences (experienced users) or due to the introductory video (naïve users). Therefore, it was important that the all users were exposed to a presentation of eighteen example meeting rooms. The example meeting rooms presented users with novel design ideas from other facilities.

The steps involved in the experimental procedure are summarized in Table 3.7.

Experimental Training

Step 1 - Demographic Survey…answer a few short questions about yourself

Step 2 - Tour of the Decision Support Center at Dahlghren, Navsea [*A sample facility for naïve users only.*]

Step 3 - Types of meetings

Step 4 - VTC Room Kit

Step 5 - Example Meeting Rooms

Experimental Session

Step 6 - Generate a Design

Step 7 - Workstation Preferences

Step 8 - Opinions [questionnaires and interview]

Figure 3. 7 - Experimental Procedure

3.3 - Data Analysis Methods

Due the variety of data collected and the exploratory nature of the study several data analysis methods were considered and used to answer the research hypotheses stated in Chapter 1. Prior to discussing how data were analyzed for each research question it is important to report which data were collected. This information is provided in Table 3.3.

Table 3. 3 - Definitions and Sources of Research Variables for Study 1

Variable Type	
Independent Variables	
Naïve versus Experienced Level of Experience in a Videoconferences	
Control Variables	Source of Data
Age	Pre-experiment questionnaire
Education Level	Pre-experiment questionnaire
Background (Academic or Work Related)	Pre-experiment questionnaire
Gender	Pre-experiment questionnaire
Experience with Videoconferencing	Pre-experiment questionnaire
Experience with Chat (Computer Communication)	Pre-experiment questionnaire
Experience with Groupware	Pre-experiment questionnaire
Dependent Variables	
Task Performance	
Completion Time	Videotape counter
Workstation Preferences	
Color of Chairs	Post-Task Questionnaire
Color of Floor	Post-Task Questionnaire
Color of Tables	Post-Task Questionnaire
Color of Walls	Post-Task Questionnaire
Privacy Shields	Post-Task Questionnaire
Type of Floor	Post-Task Questionnaire
Type of Microphone	Post-Task Questionnaire
Type of Seats	Post-Task Questionnaire
Type of Table	Post-Task Questionnaire
Meeting Room Preferences	
Configuration of Tables	Foam Core Design/ Post-Task Interview
Gallery Seating	Foam Core Design/ Post-Task Interview
Aisles	Foam Core Design/ Post-Task Interview
Use of a Technology facilitator	Foam Core Design/ Post-Task Interview
Placement of Technology facilitator	Foam Core Design/ Post-Task Interview
Configuration of Displays	Foam Core Design/ Post-Task Interview
Configuration of Roomware	Foam Core Design/ Post-Task Interview
Configuration of Lighting	Foam Core Design/ Post-Task Interview
Placement of Microphones	Foam Core Design/ Post-Task Interview
Computer Preferences	Foam Core Design/ Post-Task Interview
Other rooms	Foam Core Design/ Post-Task Interview
Other support people	Foam Core Design/ Post-Task Interview
Other support equipment	Foam Core Design/ Post-Task Interview
Importance of Equipment	
Order preference for flexible equipment	Post-Task Questionnaire
Importance ranking on position of equipment	Post-Task Questionnaire
Importance ranking on color of equipment	Post-Task Questionnaire
Importance ranking of type of equipment	Post-Task Questionnaire
Importance of group size	Post-Task Questionnaire
Importance of individual vs. group work	Post-Task Questionnaire
Heuristic	
Design Principles	Post-Task Interview

3.3.1 - Analysis Method for Research Question 1

The focus of this question was to determine the requirements users identify as important or necessary in a virtually co-located room. The demographic data on the characteristics of users were nominal with exception to the age data which is ratio data. Mode analyses such as frequency counts were used to analyze these demographic data. Descriptive statistics such as mean and standard deviation were calculated with the age data.

The rating data collected for importance were interval and based on a Likert-type scale. The ranking data collected for importance were ordinal. Both data sets were analyzed by using non-parametric statistical methods to compare:

- Differences in the importance rankings between naïve and experienced users by conducting a Mann-Whitney U test.
- Patterns in the importance rankings among naïve and experienced users by conducting Friedman and Wilcoxon tests.
- Factors (or patterns) in the rating data were determined by calculating inter-item correlation.
- Differences among factors in the rating were compared by conducting a Kruskal-Wallis test.

Finally, users' requirements for a virtually co-located room were also determined by extracting and coding data from the foam core room designs created by each participant. The features in each design were coded from the participant's design or from his/her responses to the post-session interview using nominal data. The requirements coded form each design were categorized by using cluster analysis as classification technique.

3.3.2 - Analysis Method for Research Question 2

The focus of this research question was to determine the set of design rules users engaged while creating the ideal design for a distributed meeting room. The data for the design rules were extracted from each participant's post-task interview. Content analysis was used to extract themes in each interview. The themes were named and the occurrence of each theme was counted. Themes were also ordered by how frequently they occurred. Heuristics were developed from these analyses.

3.4 - Results

Four methods were employed to identify user needs and preferences for flexible equipment in a VEMS meeting room. First, users were asked to rate and rank the importance of arranging equipment in the distributed meeting room. The results of this part of the study are summarized in Sections 3.4.1 to 3.4.5. Second, users were asked to design their ideal VEMS meeting room configuration. The results of the design session are summarized in Section 3.4.6. Third, users were asked to complete a web-based questionnaire that addressed room décor and workstation preferences. The results of this part of the study are summarized in Section 3.4.7. Finally, each user participated in a structured interview following the design session. The results of the interviews are discussed in Section 3.4.8.

In addition, to accommodate the needs of both naïve and experienced users, the data were analyzed with respect to shared patterns of agreement between the two user groups.

3.4.1 - Description of the Sample Population

The data collected on user preferences came from two groups comprised of twenty-five participants. Group 1 consisted of 13 undergraduate and 12 graduate students who were naïve users. This sample of naïve users consisted of 11 males and 14 females ranging in age from 21 to 43 years ($N=25$, $X = 24.88$, $s=6.35$).

Twelve of the students were from an Engineering background, ten from an Arts and Sciences background, two from Human Resources, and one from Business. One student reported having little experience with video teleconferencing. All of the others reported having no experience. When screened, all the students responded that they had never participated in a video teleconference or distance learning classroom.

Sixteen of the students reported extensive experience with chats, emails, and distribution lists. Six students reported some experience. One student reported little experience. Two students did not respond to the question.

One student reported extensive experience with group collaboration software. Three reported little experience with group collaboration software. The remaining twenty-one students reported no previous experience.

Group 2 consisted of experienced users who were Naval employees. This sample of experienced users consisted of eighteen males and seven females ranging in age from 24 to 62 (N = 24, X = 44.58, s = 8.87). One person did not report his age. Twelve of the employees were engineers. Nine employees were upper-level managers. Four employees were administrators. One employee was an organizational psychologist.

Three employees reported extensive experience with video teleconferencing. Twenty-one employees reported some experience. One employee reported little experience. When screened, all the participants responded that they had previously participated in a video-teleconference or distance learning session.

The level of experience with chats, emails, and distribution lists varied among the group. One person reported no experience, two employees reported little experience, five employees reported some experience, and seventeen employees reported extensive experience.

The sample also contained various levels of experience with group collaboration software. Four employees reported having no experience, eight reported some experience, eleven reported some experience, and two reported extensive experience.

The data on experience levels with video teleconferencing; chats, emails, listservs: and, group collaboration software has been summarized in Table 3.4.

Table 3. 4 - Distributed Meeting Room Experience Levels

	None	Little	Some	Extensive
Naïve Users				
Video Teleconferencing	24	1	0	0
Chats, Emails, and Lists*	0	1	6	16*
Group Collaboration Software	21	3	0	1
Experienced Users				
Video Teleconferencing	0	1	21	3
Chats, Emails, and Lists	1	2	5	17
Group Collaboration Software	4	8	11	3

*missing data

3.4.2 - Comparison of Importance Rankings for Naïve and Experienced Users

The first research goal was to identify user needs and preferences for equipment in VEMS meeting room environment and to answer research questions about the rules and requirements users will specify for these environments. These questions were addressed by comparing importance rankings and opinions of users on the location of equipment and the type of equipment in the physical meeting space.

A Mann-Whitney U test was conducted to explore whether naïve users and experienced users reported different importance rankings for the equipment which must be flexible in a VEMS meeting room. The results of the test were significant for two types of equipment: microphones and public displays. The results also approached significance for computer equipment. See Appendix A for detailed test results.

Experienced users assigned greater importance to arranging the microphones than naive users, $z = -2.25$, $p = .024$ (Figure 3.8). Naive users assigned more importance (lower mean ranks indicate higher importance) to arranging the public displays than experienced users, $z = -2.10$, $p = .035$ (Figure 3.9).

Results indicated a trend between the two groups with respect to their assignment of importance in arranging computers in the room. Although non-significant, naive users tended to assign greater importance to being able to arrange the computer equipment in the room, $z = -1.71$, $p = .086$ (Figure 3.10).

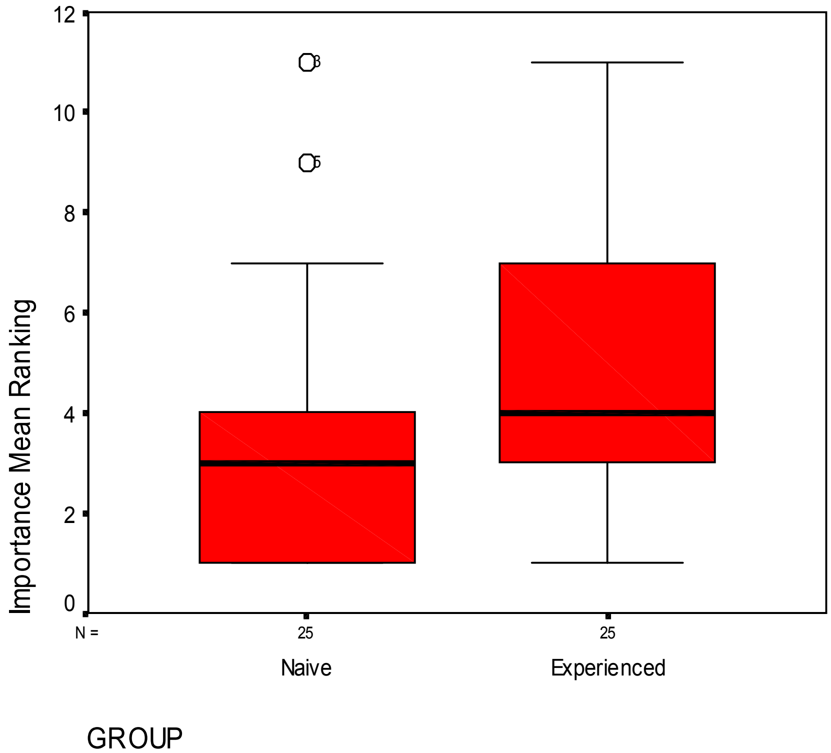


Figure 3. 8 - Between Group Comparison of Importance Ranking for Public Displays

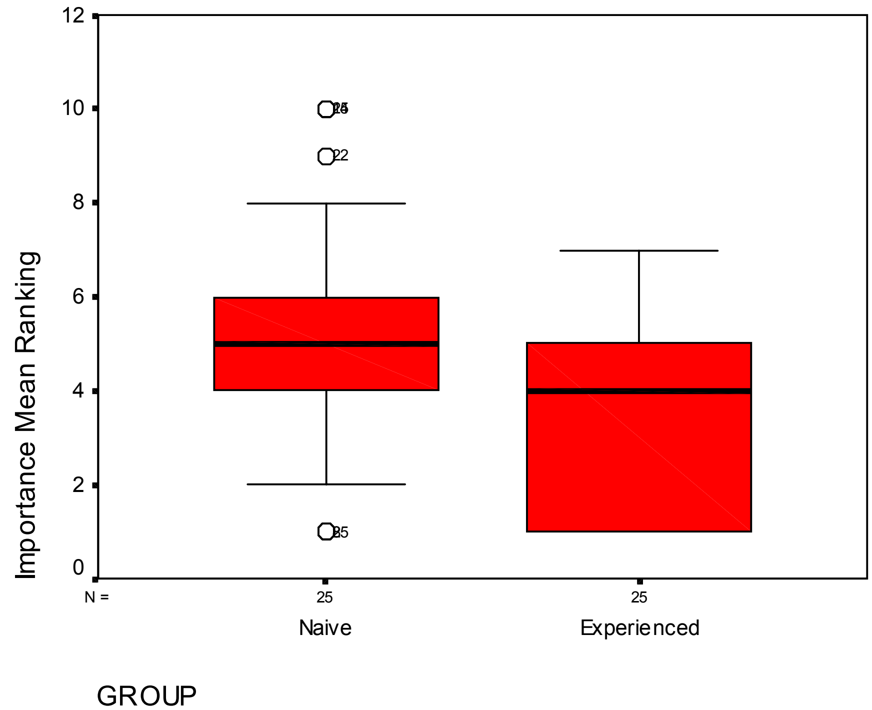


Figure 3. 9 - Between Group Comparison of Importance Ranking for Microphones

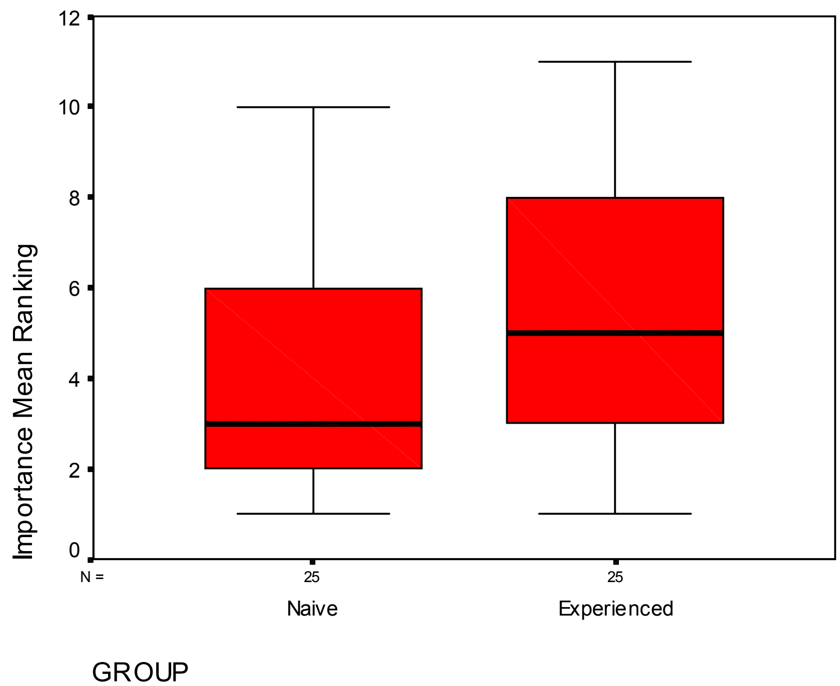


Figure 3. 10 - Between Group Comparison of Importance Ranking for Computer

The difference in importance mean ranking for microphones is further supported by the type of microphones preferred by naïve versus experienced users (see Figure 3.11). Sixteen of the naïve users preferred flexible neck microphones which are mounted to the desktop and the remainder preferred less obtrusive microphones (flat tabletop [3], wireless [4], or other customized microphones [2]). The majority of experienced users, however, preferred less obtrusive microphones (flat tabletop [7], ceiling mounted [5], wireless [1], or other customized microphones [3]) and only nine of the experienced users preferred flexible neck microphones.

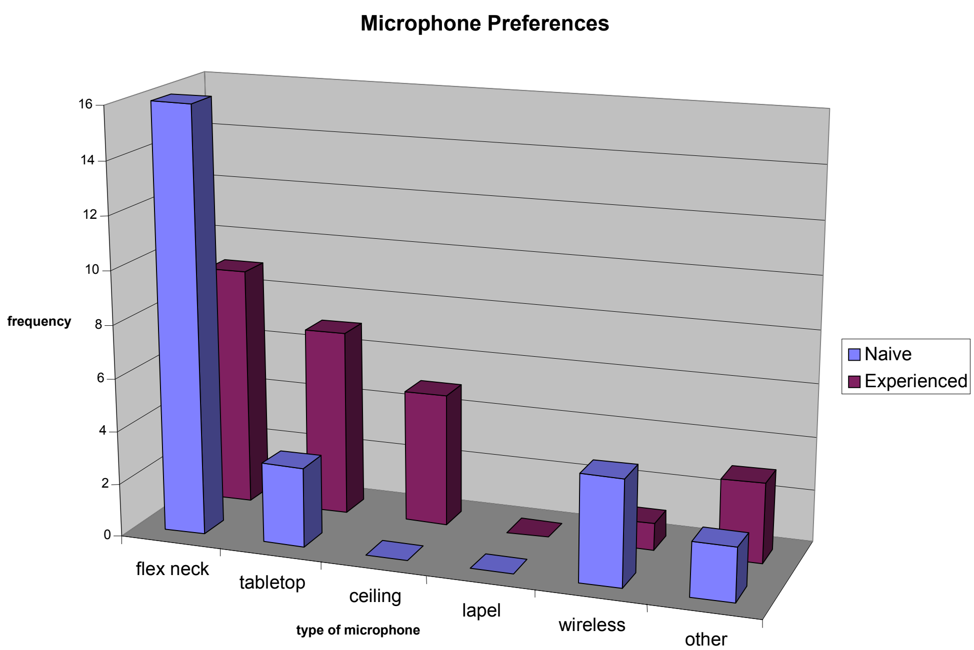


Figure 3. 11 - Microphone Preferences by Experience Level

3.4.3 - Patterns of Importance Ranking among Naïve Users

A Friedman test was performed to evaluate differences in the means for importance rankings (shown in Table 3.5) among the naïve users. The test was significant, $\Pi^2_{(10,\ \underline{N} = 25)} = 64.91$, $\underline{p}=.001$ indicating that there were differences between pairs of mean rankings among naïve users.

Table 3. 5 - Naïve Users - Mean Importance Rankings for equipment in a distributed meeting room

	Mean Rank
Display	3.32
Computer	4.32
Camera	4.88
Microphone	5.24
Seating	5.28
Workstation	5.80
Overhead	6.32
Speaker	6.40
Whiteboard	7.12
Document Reader	8.16
Privacy Shields	9.16

Follow-up pairwise comparisons were conducted using a Wilcoxon test to determine which pair(s) of importance mean ranks were significantly differently. The mean importance ranking for the public display was significantly greater than the importance ranking for any other criteria. There were no significant differences between the importance ranking for the display and the computer (Table 3.6).

Table 3. 6 - Pairwise Comparison (Displays)

	Z	p (2-tailed)
Display		
Computer	-1.70	0.090
Camera	-1.99	0.047*
Microphone	-2.25	0.024*
Seating	-2.01	0.044*
Workstation	-2.52	0.012*
Overhead	-3.29	0.001*
Speaker	-3.36	0.001*
Whiteboard	-3.57	0.0001*
Document Reader	-3.95	0.0001*
Privacy Shields	-3.72	0.0001*

The mean importance ranking for the computer was significantly greater than the importance ranking for the overhead, speaker, whiteboard, document reader, and the use of privacy shields (Table 3.7).

Table 3. 7 - Pairwise Comparison (Computer)

	Z	p (2-tailed)
Computer		
Camera	-0.59	0.553
Microphone	-0.99	0.324
Seating	-1.23	0.217
Workstation	-1.61	0.108
Overhead	-2.30	0.022*
Speaker	-2.04	0.042*
Whiteboard	-3.03	0.002*
Document Reader	-3.67	0.0001*
Privacy Shields	-3.39	0.001*

The mean importance ranking for the camera was significantly greater than the importance ranking for the overhead, speaker, whiteboard, document reader, and privacy shields (Table 3.8).

Table 3. 8 - Pairwise Comparison (Camera)

	Z	p (2-tailed)
Camera		
Microphone	-0.76	0.448
Seating	-0.39	0.696
Work Station	-0.88	0.381
Overhead	-1.84	0.066
Speaker	-2.07	0.039*
Whiteboard	-2.43	0.015*
Document Reader	-3.28	0.001*
Privacy Shields	-3.17	0.002*

The mean importance ranking for the microphone was significantly greater than the importance ranking for the whiteboard, document reader, and privacy shields (Table 3.9).

Table 3. 9 - Pairwise Comparison (Microphone)

	Z	p (2-tailed)
Microphone		
Seating	-0.16	0.871
Workstation	-0.68	0.499

Overhead	-1.51	0.130
Speaker	-1.93	0.053
Whiteboard	-2.38	0.017*
Document Reader	-3.21	0.001*
Privacy Shields	-3.61	0.0001*

The mean importance ranking for seating was significantly greater than the importance ranking for the whiteboard, document reader, and privacy shields (Table 3.10).

Table 3. 10 - Pairwise Comparison (Seating)

	Z	p (2-tailed)
Seating		
Workstation	-0.26	0.795
Overhead	-1.47	0.141
Speaker	-1.20	0.229
Whiteboard	-2.04	0.041*
Document Reader	-2.86	0.004*
Privacy Shields	-3.23	0.001*

The mean importance ranking for workstations, overhead projectors, and whiteboards were all significantly greater than the importance ranking for the document reader, and privacy shields. No other pairwise comparisons were significant (Table 3.11).

Table 3. 11 - Pairwise Comparisons (Remaining Equipment)

	Z	p (2-tailed)
Workstation		
Overhead	-0.51	0.608
Speaker	-0.57	0.571
Whiteboard	-1.53	0.127
Document Reader	-2.10	0.035*
Privacy Shields	-3.18	0.001*
Overhead		
Speaker	-0.14	0.892
Whiteboard	-1.21	0.228
Document Reader	-2.61	0.009*
Privacy Shields	-2.60	0.009*
Speaker		
Whiteboard	-1.08	0.278
Document Reader	-2.42	0.016*
Privacy Shields	-2.37	0.018*
Whiteboard		
Document Reader	-2.27	0.023*
Privacy Shields	-2.32	0.020*
Document Reader		

Privacy Shields	-1.62	0.105

The Kendall coefficient of concordance of W (10 df) = .26, p=.0001 indicated common patterns among the eleven choices. This result confirmed that there was agreement among naïve users in the order that they ranked the eleven types of equipment.

3.4.4 - Patterns of Importance Rankings among Experienced Users

A Friedman test was performed to evaluate differences in the means for importance rankings among the experienced users (Table 3.12). The test was significant, $\Pi^2_{(10,\ \underline{N}\ =\ 25)} = 47.78$, $\underline{p}$=.001 indicating that there were differences between pairs of importance rankings among experienced users.

Table 3. 12 - Expert Users - Mean Importance Rankings for equipment in a distributed meeting room

	Mean Rank
Microphone	3.56
Seating	4.48
Display	5.00
Camera	5.16
Computer	5.76
Whiteboard	6.08
Workstation	6.20
Speaker	6.28
Overhead	7.08
Document Reader	8.08
Privacy Shields	8.32

Follow-up pairwise comparisons were conducted using a Wilcoxon test to determine which pair(s) of importance mean ranks were significantly differently. The mean importance ranking for microphones was significantly greater than the importance ranking for the public displays, cameras, computers, whiteboards, workstations, speakers, document reader, and privacy shields (Table 3.13). There were no significant differences between the importance ranking of microphones and seating.

Table 3. 13 - Pairwise Comparison (Microphone)

	Z	*p* (2-tailed)
Microphone		
Seating	-1.331	0.183
Display	-1.990	0.047*
Camera	-2.185	0.029*
Computer	-2.522	0.012*
Whiteboard	-2.526	0.012*
Workstation	-2.457	0.014*
Speaker	-3.641	0.000*
Overhead	-3.709	0.000*
Document Reader	-4.019	0.000*
Privacy Shields	-3.660	0.000*

The mean importance ranking for seating (Table 3.14) was significantly greater than the mean importance ranking for workstations, speakers, overheads, document readers, and privacy shields.

Table 3. 14 - Pairwise Comparison (Seating)

	Z	*p* (2-tailed)
Seating		
Display	-0.689	0.491
Camera	-0.580	0.562
Computer	-1.473	0.141
Whiteboard	-1.713	0.087
Workstation	-2.375	0.018*
Speaker	-2.122	0.034*
Overhead	-2.562	0.010*
Document Reader	-3.302	0.001*
Privacy Shields	-3.424	0.001*

The mean importance ranking for displays (Table 3.15) and cameras (Table 3.16) were significantly greater than the mean importance ranking for overheads, document, readers, and privacy shields.

Table 3. 15 - Pairwise Comparison (Display)

	Z	*p* (2-tailed)
Display		
Camera	-0.014	0.989
Computer	-1.026	0.305
Whiteboard	-1.310	0.190
Workstation	-1.366	0.172
Speaker	-1.447	0.148
Overhead	-2.130	0.033*
Document Reader	-2.951	0.003*
Privacy	-2.481	0.013*

Table 3. 16 - Pairwise Comparison (Camera)

	Z	*p* (2-tailed)
Camera		
Computer	-0.702	0.483
Whiteboard	-1.285	0.199
Workstation	-1.201	0.230
Speaker	-1.283	0.200
Overhead	-2.221	0.026*
Document Reader	-2.939	0.003*
Privacy	-2.549	0.011*

The mean importance ranking for computers, whiteboards, workstations, and speakers (Table 3.17) were significantly greater than the mean importance ranking for document, readers, and privacy shields. There were no significant differences among the importance rankings for overheads, document readers, and privacy shields.

Table 3. 17 - Pairwise Comparison (Computer)

	Z	*p* (2-tailed)
Computer		
Whiteboard	-0.502	0.616
Workstation	-0.757	0.449
Speaker	-0.567	0.571
Overhead	-1.540	0.124
Document Reader	-2.713	0.007*
Privacy shields	-2.200	0.028*
Whiteboard		
Workstation	-0.135	0.893
Speaker	-0.216	0.829
Overhead	-1.216	0.224
Document Reader	-2.487	0.013*
Privacy Shields	-1.994	0.046*
Workstation		
Speaker	-0.095	0.925
Overhead	-0.864	0.388
Document Reader	-1.850	0.064*
Privacy Shields	-2.105	0.035*
Speaker		
Overhead	-1.150	0.250
Document Reader	-2.174	0.030*
Privacy Shields	-2.140	0.032*
Overhead		
Document Reader	-1.162	0.245
Privacy Shields	-1.179	0.238
Document Reader		
Privacy Shields	-0.594	0.553

The Kendall coefficient of concordance of W (10 df) = .19, p=.0001 indicated common patterns among the eleven choices. This result confirmed that there was agreement among expert users in the order that they ranked the eleven types of equipment.

3.4.5 - Underlying Factors in Distributed Meeting Room Design

Item analyses were conducted on the 23 items hypothesized to assess user preferences in the importance of selecting the type of equipment, position of equipment, color of equipment, and the ability to regroup or reconfigure in the environment. Each item was correlated with its own scale (with the item removed) and with remaining scales. The detailed reliability analyses for each scale are shown in Appendix A.

In the corrected item-total correlations for the position of equipment of scale, three items (position of computer, table or work area, and document reader) were removed from the original scale. The remaining items in the scale were the positions of the camera, microphone, lights, displays, speakers, and whiteboard (i.e. audio visual). Cronbach coefficient alpha for the corrected scale was .74.

One item, the type of computer (tools), was removed from the type of equipment scale. The remaining items were type of display, tables, whiteboard, lights, seats, microphones, floors, and walls (i.e. fixtures). Cronbach coefficient alpha for the corrected scale was .82.

Table 3. 18 - Item Correlations with Scales

Items	Factors			
	Position	Type	Color	Regroup
1. Position of the public display(s)	0.55	0.51	0.16	0.01
2. Configuration of the tables, desks, or workstations	0.26	0.22	-0.10	0.02
3. Position of the electronic whiteboard(s)	0.44	0.39	0.03	-0.03
4. Position of the document reader(s)	0.23	0.41	0.46	0.12
5. Position of the camera(s)	0.49	0.40	0.20	-0.05
6. Position of the computer(s)	0.17	0.09	0.16	0.00
7. Position of the lights	0.55	0.58	0.19	0.03
8. Position of the speakers	0.51	0.55	0.28	0.06
9. Position of the microphones	0.71	0.54	0.01	-0.10
10. Type of public display(s)	0.41	0.45	0.17	-0.22
11. Type of the tables, desks, or workstations	0.18	0.47	0.51	0.19
12. Type of the electronic whiteboard(s), document readers or other roomware	0.55	0.62	0.50	-0.03
13. Type of the computer(s)	0.17	0.16	0.05	0.15
14. Type of the lighting	0.74	0.53	0.23	-0.01
15. Type of the seating	0.39	0.52	0.30	0.19
16. Type of microphones	0.75	0.62	0.40	-0.01
17. Type of flooring	0.31	0.52	0.46	-0.14
18. Type of wall covering	0.40	0.62	0.56	0.00
19. Color of the furniture	0.26	0.58	0.55	0.30
20. Color of the wall coverings	0.11	0.47	0.55	0.04
21. Being able to work in privacy during a group meeting	-0.06	0.03	0.18	0.52
22. Being able to reconfigure the room easily to allow for individual or private work	-0.01	0.02	0.20	0.67
23. Being able to reconfigure the room easily to allow different groups to work in the space	0.01	-0.08	0.07	0.57

* underlined data indicates a significant correlation.

All items in both the Color of Equipment scale and the Ability to Regroup or Reconfigure the Environment scale were highly correlated. Cronbach coefficient alphas for the corrected scales were .70 and .75 respectively.

Initially, each item was correlated with its own scale (with the item removed) and with the other three scales. In several cases, items were more highly correlated with one or more of the other scales than their own scale (as shown in Table 3.18). Based on these results and additional item analyses (see Appendix A), the scales were redefined. Seventeen items related to the fixtures and their type, position, and color were regrouped into a scale renamed as Importance of Fixture Criteria. The Cronbach coefficient alpha computed for this scale was .88.

Three items were not correlated to any of the factors. These were (1) the configuration or position of the tables, desks, and workstations; (2) the position of the computers; and (3) type of computers. These items dealt with specific equipment needs related to the work processes. For example, table configuration affects co-located teamwork, individual work, video-mediated work, and distributed collaborative work. Similarly, the type and the position of computers affects the ability to work in a distributed environment and the ability to work privately (i.e. laptops or large monitor desktops).

Lastly, the three items in the Ability to Regroup or Reconfigure the Environment scale remained in their original scale where the computed Cronbach coefficient alpha was .75

Comparison of Factor Scores for Naïve versus Experienced Users

A non-parametric one-way ANOVA was conducted to determine whether there were differences between importance scores of naive and experienced users. A Kruskal-Wallis test was conducted on the Fixture Criteria and the Ability to Regroup or Reconfigure the Environment scores for the two groups. The test showed no significant differences between either of the groups for their scores on the Fixture Criteria scale Π^2 (1, N = 25) = 1.982, p=.159. The test also showed no significant differences between either group's scores on the ability to regroup or reconfigure the environment scale Π^2 (1, N = 25) = 1.554, p=.213.

3.4.6 -Patterns of Similarities in Room Designs

Coding Scheme for Room Designs

Each design was divided into two areas: (1) inner area or core and (2) outer or gallery area (see Figure 3.12). This division was consistent with the way participants described their designs in their follow-up interviews and was often representative of the participant's intended use of the room by smaller versus larger groups.

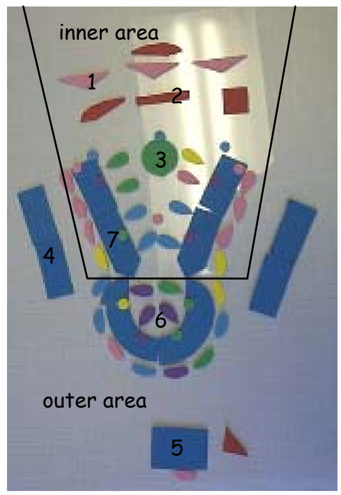


Figure 3. 12 - Design by Participant 1

Participant had no previous exposure to distributed meeting or video teleconferencing (naïve experience level). Description of the design as labeled: 1- Public displays; 2 - Audiovisual/Whiteboard; 3- Presentation Station; 4 - Gallery Seating; 5 - Technographer; 6 - Lighting; and 7 - Microphones. Inner area is V shaped. Outer area is semi circular. Gallery seating coded as auditorium style.

The coding for the inner and outer area of each design was based on the presence or absence of ten possible table configurations. The set of configurations was determined by those used in by participants in their designs (see Table 3.19). The descriptor used for each design was based on the coding scheme; each design was described according to its inner area followed by an underscore and then its outer area. For example, Design 1 shown in Figure 3.12 was coded VAud_Semi.

Table 3. 19 - Shape Coding for Room Designs

Shape Features in Distributed Room Designs	
C shaped	Rows
V shaped	Semi Circle
U shaped	Full Circle
U shaped-modified	Oval
L shaped	Pentagon

Comparison of Designs created by Naïve versus Experienced Users

There were no significant differences (p=.70; F=.15) between the mean design completion times of naïve users (x = 13.9 minutes, s = 4.3 minutes) versus experienced users (x = 14.5 minutes, s = 7.4 minutes).

A non-parametric one-way ANOVA was conducted on the coded shape data for designs of naïve versus experienced users. These data were frequency and non-parametric ANOVA is appropriate for count data. The results indicated that there were no significant differences in the frequency of occurrences of the ten possible table configurations in both the inner and outer area. These results are summarized in Table 4.16.

The comparison of completion time and design shape features among naïve versus expert users indicated that the are no significant differences. The lack of differences between groups was an interpreted as a measure of similarity between the two sets of designs, therefore, all of the designs were grouped together for the purpose of the cluster analysis.

Table 3. 20 - Summary of Non-Parametric ANOVA for Designs by Shape Feature

Inner Area	Naive	Experienced	Chi-Square	df	Asymp. Sig.
Row	5	4	.133	1	.716
C	5	3	.583	1	.445
V	1	3	1.065	1	.302
U	11	8	.749	1	.387
Oval	3	1	1.065	1	.302
Semi circle	2	3	.218	1	.641
Full circle	2	4	.742	1	.389
L	0	0	.000	1	1.000
Pentagon	0	1	1.000	1	.317
T Shape	0	0	.000	1	1.000

Outer Area	Naive	Experienced	Chi-Square	df	Asymp. Sig.
outer row	6	4	.490	1	.484
outer c	5	4	.133	1	.716
outer v	0	3	3.128	1	.077
outer u shape	3	3	.000	1	1.000
outer oval	0	0	.000	1	1.000
outer semi circle	1	2	.348	1	.556
outer full circle	2	2	.000	1	1.000
outer l shape	1	1	.000	1	1.000
outer pentagon	3	1	1.065	1	.302
outer T shape	0	0	.000	1	1.000

a Kruskal Wallis Test
b Grouping Variable: level of experience

Classification of Designs

Cluster analysis was performed to explore the data set and classify the designs. This method is used by researchers to determine the similarities between pairs of things (Romesburg, 1984). According to Romesburg, the results of a cluster analysis should be reported with information on how the application of the analysis was framed and validated. Framing refers to providing key information on the selection of the "specific methods to address your research goals (Romesburg, 1984, p.194)". Whereas validation refers to "how you have determined you have attained your research goal (Romesburg, 1984, p. 194)".

The purpose of this analysis is to further address Research Question 2 and to determine whether there are sets of rules that users engage when designing a distributed facility. Several variables were used to code the meeting room preferences expressed by participants in their foam core designs and their post task interviews. The data in the coded designs were nominal data. However, in order to perform a cluster analysis on this data set, each feature had to be coded in binary notation. Therefore, the variable representing the Configuration of the Inner Area of Tables (INNRAREA) which could have been coded as one variable with 10 possible values (see Table 4.15) on a nominal scale was instead coded as 10 separate variables with binary notation. For example, in Figure 3.12 where the Inner Area was coded as a V-Shape, the variable INNER_V was coded as 1 in binary notation to indicate the presence of that feature in the design.

Similarity between pairs of designs is determined by the presence or absence of coded variables in the data set. However, it is difficult to determine which variables are relevant for the cluster analysis. A number of iterations through the data were necessary to determine that shape data was most important to establishing a set of design rules engaged by users. This decision was further supported by the post-task interviews. Users often emphasized how they achieved their design objectives by creating the appropriate table configuration for the room. Therefore, in this study, the coded variables used in the analyses were those describing shape data in the inner and outer areas of each design.

The type analysis that was performed on this data set was a Q-analysis. This is a cluster analysis among objects (Design 1, Design 2, Design 3, …Design 50). This differs from an R-analysis which is a cluster analysis among attributes or coded shape variable in this case (i.e. INNER_V, INNER_C, …etc).

The clusters were determined using the average linkage method and simple matching measures. The average linkage method uses Euclidean distance to minimize distances between pairs. The simple matching coefficient measures the proportion of agreements either 1-1 (feature present) or 0-0 (feature absent) in a set of comparisons (Romesburg, 1984). Although other candidates for clustering methods and resemblance coefficients were considered, the combination of the average linkage method with simple matching resemblance coefficients had the highest cophenetic correlation coefficient of .950 (See Table 3.21). The cophenetic correlation coefficient was used as the selection criterion because it is a measure of "how well the tree [cluster dendogram] represents the data matrix (Romesburg, 1984, p. 24)".

Table 3. 21 - Comparison of Cophenetic Correlation Metric

Resemblance Coefficients	Average Linkage Cluster Method
Simple Matching	.950
Jaccard	.610
Pattern Difference	.874

The number of clusters determined in a data set can be subjective and is at the discretion of the researcher (Romesburg, 1984). The researcher must decide on the level of detail required and the purpose of the classification in order to determine the appropriate number of clusters. Once these decisions are made, the attribute space can then be divided by cutting the cluster tree (or dendogram).

As shown in Figure 3.13, three clusters emerged from the shape feature data representing the configuration of each room (see cut 1). Figure 3.13 is a cluster tree of the design shapes created by the participants. Each group or cluster represents configurations that share some degree of likeness. The degree of similarity for each design in a group is represented by the rescaled distance between designs or the vertical axis. Cut 1 represents high-level similarities among designs and was selected in order to create a broad categorization of designs. Cut 2 represents similarities among designs at a lower level of detail. This cut was created to represent subgroups within the major categories generated by Cut 1:

1. V shaped (4 designs)
2. Theater (12 designs)
3. Conference (34 designs)

These clusters were divided into descriptive subgroups (see Cut 2). The subgroups within each cluster are also shown in Table 3.22 and are summarized below.

Table 3. 22 - Main Clusters and Subgroups from the Cluster Tree

	Cut 1		
Cut 2	V-Shaped	Theater	Conference
V-shaped	4	-	-
Rear- Curved	-	7	-
Rear –Straight	-	5	-
Boardroom	-	-	4
Horseshoe	-	-	19
Circular	-	-	11
Major Categories	4	12	34

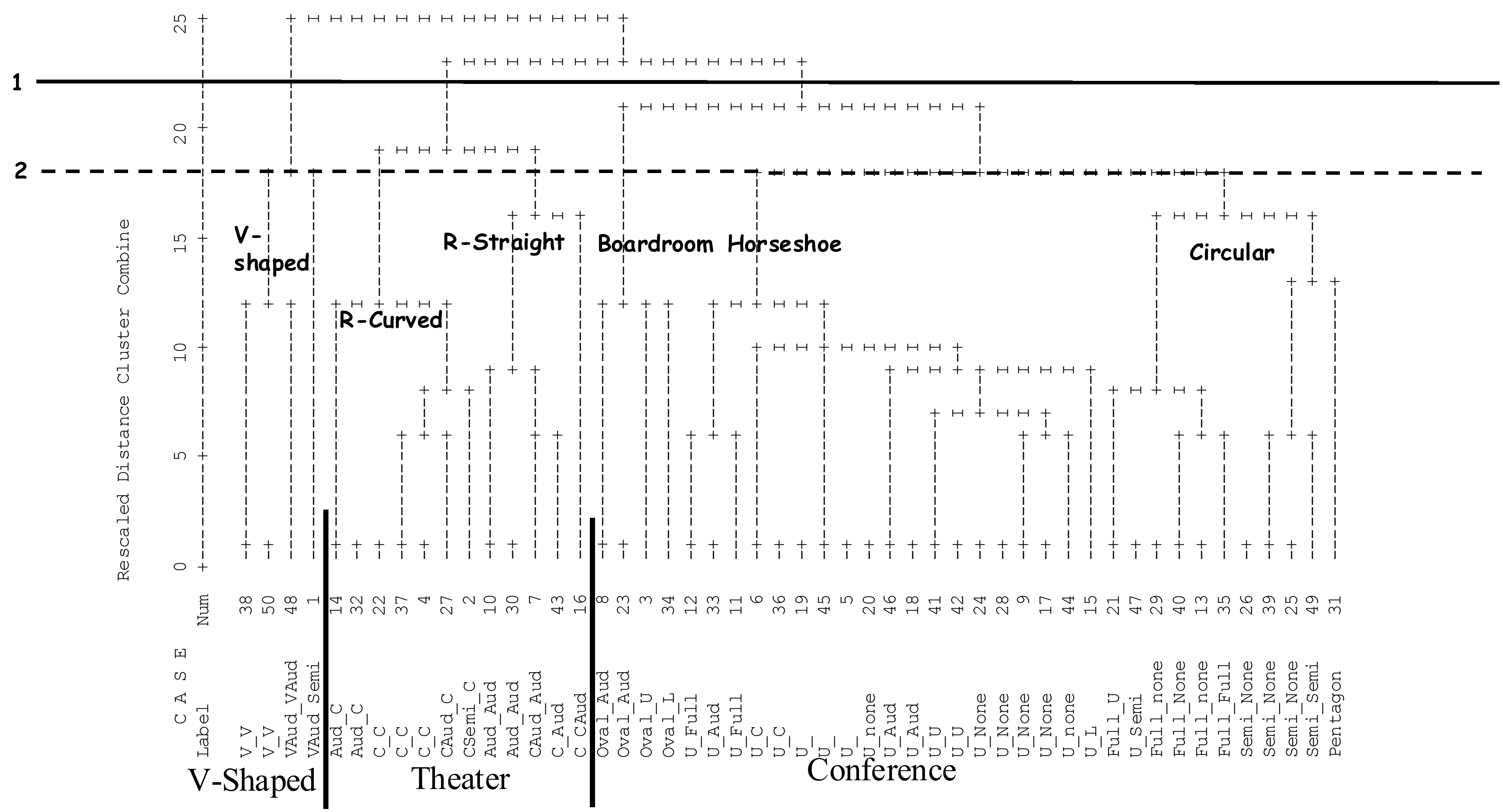


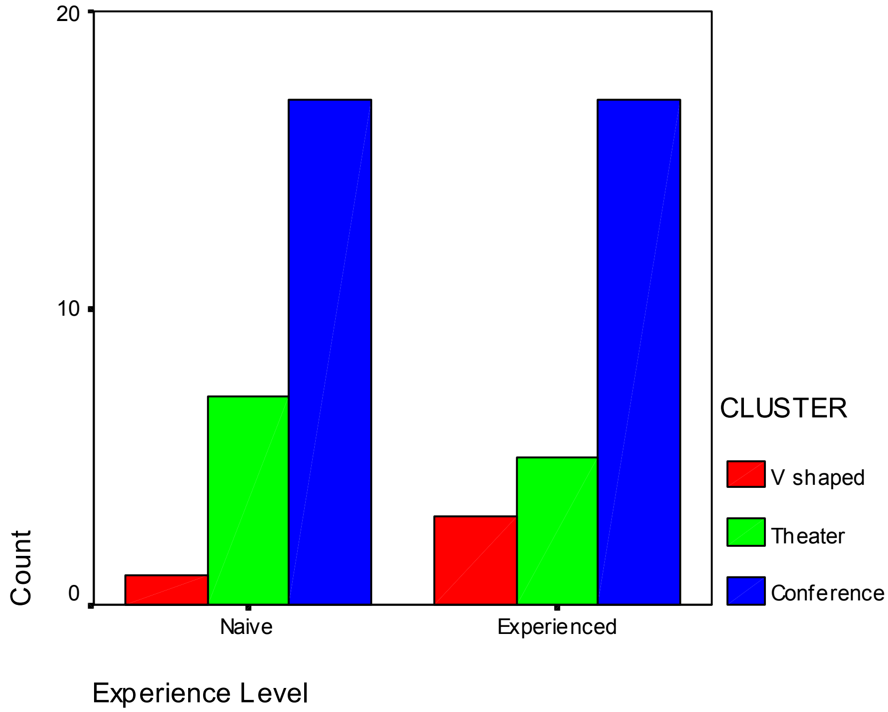
Figure 3. 13 - Cluster Tree (or Dendogram) for Categorization of Room Configurations

Patterns of Similarity among Users in Design Clusters

Demographic data were classified according to the clusters to explore patterns and similarities among clusters. The distribution of designs in each cluster for naïve and experienced users was similar. The pattern was consistent with the overall distribution of designs. In overall distribution, 8% of the designs were V-shaped, 24 % of the designs were Theater style, and 68 % of the designs were Conference style (Figure 3.14).

In each discipline area, the majority of participants preferred conference style rooms (Figure 3.15). Similarly, participants preferred conference style rooms regardless of prior experience with groupware (Figure 3.16).

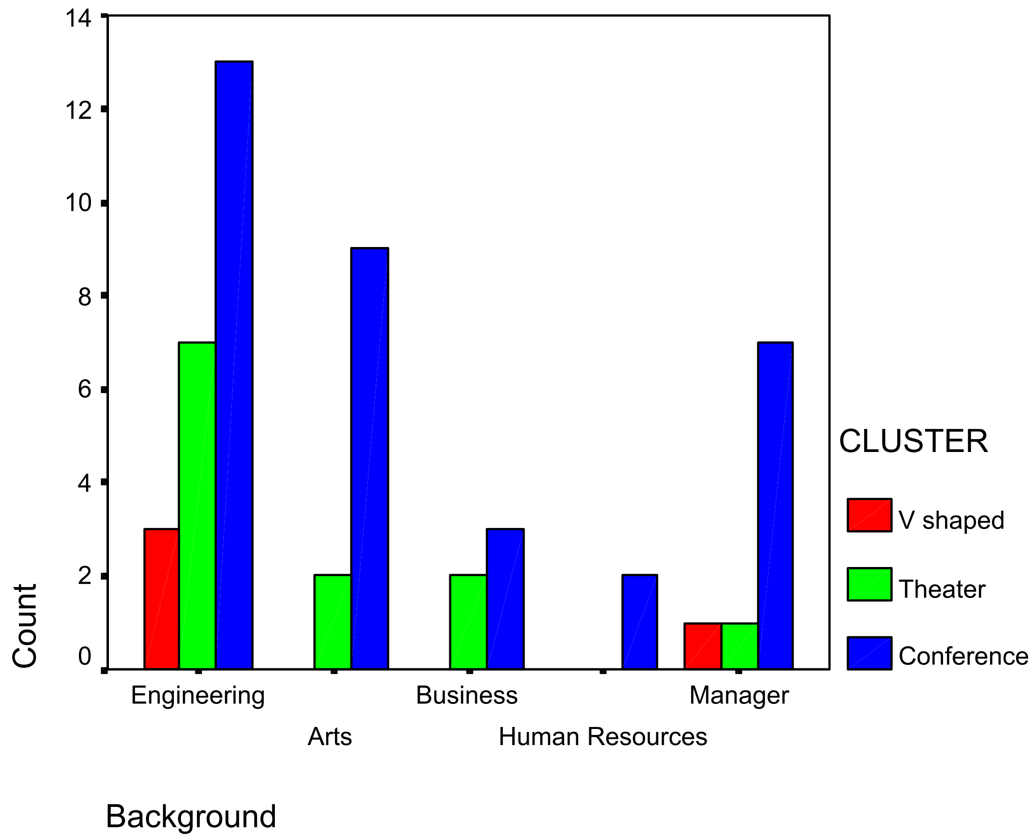
For those participants with no, some, or extensive experience in video teleconferencing, two out of three participants created a conference style meeting room. There were only two people who reported having little experience with video teleconferencing. One created a Theater style design, and the other created a Conference style design (Figure 3.17).



Count

		CLUSTER			Total
		V shaped	Theater	Conference	
GROUP	Naive	1	7	17	25
	Experienced	3	5	17	25
Total		4	12	34	50

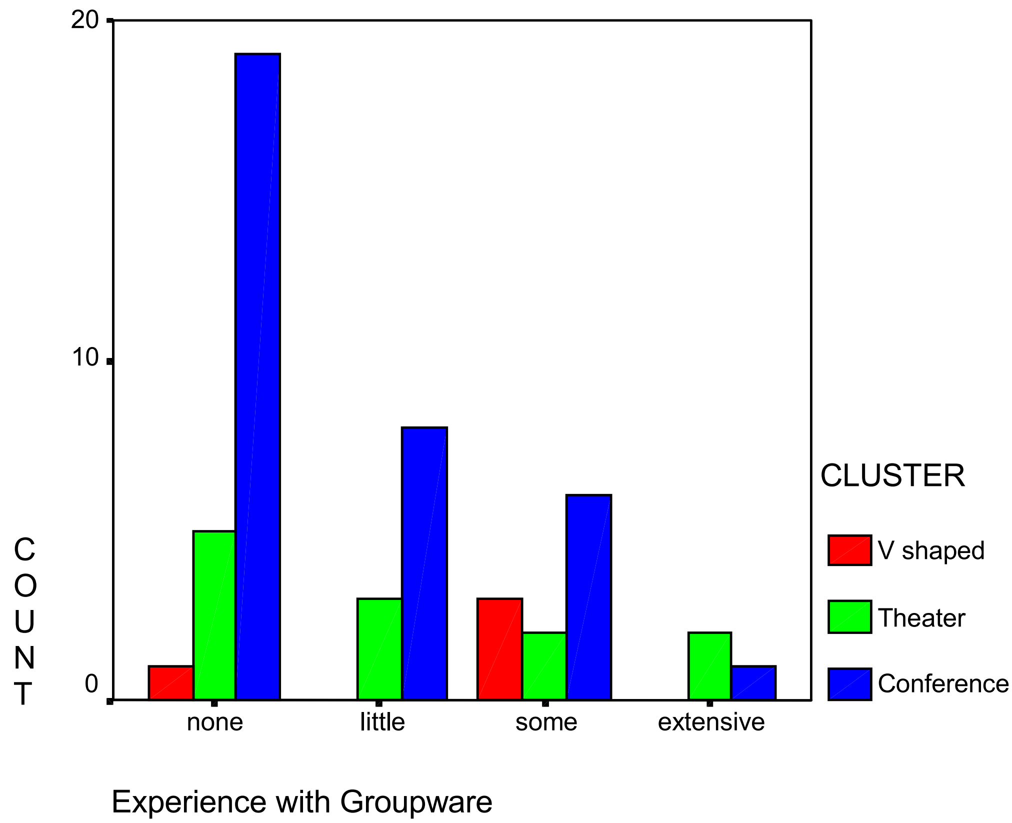
Figure 3. 14 - Experience Level by Cluster



Count

		CLUSTER			Total
		V shaped	Theater	Conference	
BKGROUND	Engineering	3	7	13	23
	Arts		2	9	11
	Business		2	3	5
	Human Resources			2	2
	Manager	1	1	7	9
Total		4	12	34	50

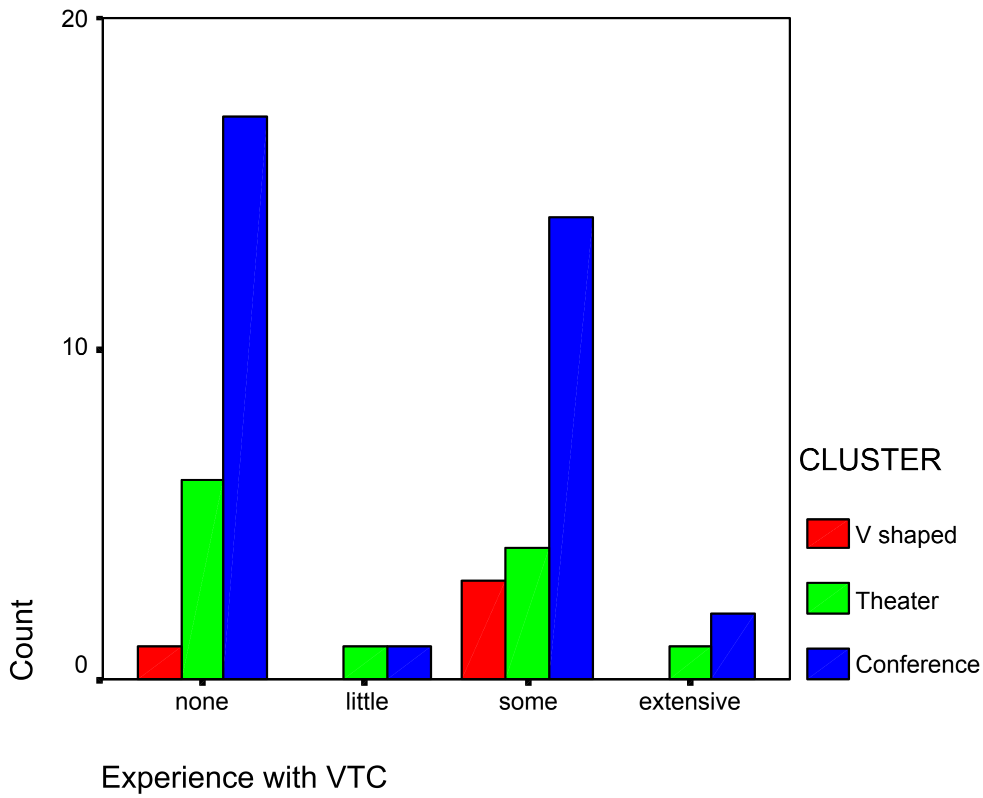
Figure 3. 15 - Background by Cluster



Count

		CLUSTER			Total
		V shaped	Theater	Conference	
Groupware	none	1	5	19	25
	little		3	8	11
	some	3	2	6	11
	extensive		2	1	3
Total		4	12	34	50

Figure 3. 16 - Figure 4.10. Experience with Groupware by Cluster



Count

		CLUSTER			Total
		V shaped	Theater	Conference	
VTC	none	1	6	17	24
	little		1	1	2
	some	3	4	14	21
	extensive		1	2	3
Total		4	12	34	50

Figure 3. 17 - VTC Experience by Cluster

3.4.7 - Room Decor and Work Station Preferences of Naïve versus Experienced Users

Seven categories or color descriptions emerged from the wall color preference data provided by naïve and experienced users. These were gray, blue, beige, white, any light color, any dark, and other. Naïve users had a strong preference for blue walls. Expert users indicated strong preferences towards both blue or gray colored walls. See Table 3.23 for details.

Table 3. 23 - Wall Color Preferences

	Naive	Experienced
Gray	2	7
Blue	9	6
Beige	5	3
White	4	2
Any dark	3	1
Any light	0	2
Other	2	4
Total	25	25

Participants were asked to select one of two floor types for their room designs. Three of the twenty-five naïve users preferred a tiled floor, while the remainder preferred carpeting. All of the experienced users preferred a carpeted floor. See Table 3.24.

Table 3. 24 - Floor Material Preferences

	Naive	Experienced
carpet	22	25
tile	3	0
Total	25	25

Participants were asked to specify their preferred floor color for the room. Eight color or color categories emerged from their responses. These were gray, blue, green, tan, black, white, any dark color, and other. For the most part, the preferences for floor color matched the preferences for wall color. Naïve users had a strong preference for blue. Expert users had strong preferences for blue or dark colored carpeting. See Table 3.25.

Table 3. 25 - Floor Color Preference

	Naive	Experienced
gray	3	4
blue	9	7
green	5	1
tan	6	1
black	1	1
white	1	1
dark	0	6
other	0	4
Total	25	25

Participants were asked to specify a preferred table surface to be used in their room design. Over 80% of participants in each category selected a wooden surface (i.e. cherry, oak, etc). The rest selected either plastic or specified other surfaces (such as marble or non-reflective surface). See Table 3.26.

Table 3. 26 - Table Surface Preference

	Naive	Experienced
wood	20	21
plastic	4	1
other	1	3
Total	25	25

Participants were also asked to specify a preferred color for the table surface in their room design. Sixty percent of both naïve and experienced users had a strong preference for dark wooden surfaces. Users in both categories who preferred red as a surface color had also specified cherry wood as the type of material. The rest of the users preferred a light colored table surface. See Table 3.27.

Table 3. 27 - Table Color Preference

	Naive	Experienced
dark	15	15
light	6	3
red	4	7
Total	25	25

Participants were given the option to select standard office seating for their design or to further specify the characteristics of the seating. Sixteen of the naïve users and ten of the experienced users specified standard office seating. Of the nine naïve users who specified additional characteristics for the seating used in their design, eight preferred mobile chairs, seven preferred cushioned, three preferred reclinable, and six preferred adjustable. Similarly, of the fifteen experienced users who specified additional characteristics for the seating used in their design, eight preferred mobile chairs, thirteen preferred cushioned chairs, two preferred reclinable chairs, and 13 preferred adjustable chairs.

In addition, participants were asked to specify whether privacy shields were used in their design. Nineteen of the twenty-five experienced users did not use privacy shields. However, eleven of the twenty-five naïve users did use privacy shields in their design. See Table 3.28.

Table 3. 28 - Privacy Shield Preference

	Naïve	Experienced
no	14	19
yes	11	6
Total	25	25

3.4.8 - User-Centered Rules for Distributed Meeting Room Design

The purpose of this section is to analyze the interview data provided by each participant. The data coded in the interviews are used to determine if there is a set of design rules that users will engage to create their optimal design for a distributed meeting space. The goal of the data analysis method used for the interviews was:

- To extract key words or principles used to describe the design and the design process and to examine these data according to the design classification.
- To develop heuristics from the processes described by the participants and the coded data from each design.

<u>Content Analysis</u>

At the end of each experimental session, participants were asked a series of questions about their design. Their responses were transcribed so that the text could be content analyzed.

In the first question, participants were asked to describe their design to a real world team and to tell them why they made the design decisions they did. Responses included the description of the design as shown in the examples below.

> P7: Basically these are four tables, four tables (pointing to the blue shapes on the left and right in the front) and an elevated table (pointing to the long blue shape in the back). Over here (pointing to the blue square in the back corner) is the technology advisor he/she has room, and that's the monitor that only he/she can see (pointing at the red square beside the blue one).
>
> P9: The table configuration is basically a "U" shape, which I saw on a lot of the designs and it would make a U so that everyone focuses on the subject. I put the speaker station down in here (motioning to a red block at the end of the "U" shaped table) for a person making a presentation or whatever.
>
> P31: The center portion, which is a pentagon shape, has five seats per table each table is a break away table.

Participants also included the reasoning for the design shape they chose:

> P7: I chose this design to give a combination of both privacy [and] almost individuality for each member of the group, but also give a feeling of group togetherness. I feel that other designs, which were like horseshoes, were too much away from interacting with the other group. I picture that these are not cameras but that there is actually another group on the other side and you had to design a room which would make that work in a group setting. That is why this doesn't fill up almost like a circle itself which makes the group interact too much on it's own.
>
> P32: The reason why I went with this type of layout is it uses all the tables and it still allows you to move stuff around for a different type of meeting. For instance, this configuration would be more of a

VTC type of configuration. Then if there were going to be a regular standard meeting then you could just move these table from here, and they of course would stay there, over to here and then swing this table around and the microphones are just table top microphones so they can just slide along with them. You can make a circle or broom type configuration.

P36: First and foremost, let me say that the design is kind of a fixed design. I'm less interested in having the participants arrange the room or move the furniture.

P43: First, of all I'm gonna [expect] a lot of interaction. I don't like too many people involved so I've sort of limited it to a reasonable amount with a small U that's not deep down the sides so there can be interaction and the cameras can catch people at about the same level, rather than having a long U. I've found that those haven't worked.

Participants described the workstation setup and other features in their room:

P7: I have a microphone with the overhead projector, there is no station there but it's easy to access since it's in the middle. There is a microphone for each person here (pointing to the front blue tables). Almost to give the idea that if you need to speak it's there but not that you have to speak all the time. There are lights shining on the displays.

P43: A whiteboard is important to have. Location is not as important. Other than it be movable so that you can get it where at least people in the one room can see it. I like the lighting over top, not on the table. I like to keep the tables as clear as I can for being able to put in use for your own writing and keeping notes and keeping your own documents that you may have brought with you.

P30: Well, we have a couple of displays up here, actually 4 displays across the front and two located in the center. Just for dual presentations or whatever. That's our camera so it's nice and in the center of the room. This display is also a whiteboard, so it's kind of a whiteboard slash display all in one. This over here is the table with the document reader on it, doesn't really have to be that close.

The next two questions were asked to help participants engage in further discussion of their designs. Participants were asked: What was the most challenging part of creating their design? They were also asked: What was easiest about creating their design? In general, the responses to these questions were short phrases.

Most challenging:

P2: Focusing on a wall (location of displays) having central viewing.

P18: Coming up with a layout where everybody can see everybody. I thought that the circular would be good but unless you find out how to have a 360-degree TV the people in the front are going to have to turn around.

P26: For me it was breaking out of the models that I use everyday and thinking beyond the models that I use in the DSC.

Easiest:

P17: The public screen.

P22: The set up. Everyone can see everything with the stadium seating.

P29: Probably the placement of the displays.

And, in many cases, these questions also provided an opportunity for participants to emphasize the reasoning used to create their design.

In some cases, these questions prompted a discussion of critical incidents in the design process. For example, Participant 31 restarted his design mid-stream in the design session and Participant 35 discussed limitations he found with the kit of materials which influenced his design. Participant 38 stated that his greatest challenge was creating a design in a timely fashion even though there was no time limitation given for the design process.

> P31: The table itself I thought was very easy, but once I had to start putting in the peripherals it was [more difficult]. For instance, I forgot about the speakers themselves. I knew I needed speakers but I had forgotten about them, but I had already placed the cameras and well I said the cameras can go in the same place as the speakers and that would work fine.

> P35: Well, using this particular kit of materials there wasn't enough of the pieces for me to do what I wanted to convey for a large meeting. Other than that, you know, I had no way to show windows, but just about everything else was fine.

> P38: I would say time, strangely enough the issue is time. I never thought about this before I walked in the room… I enjoyed thoroughly the eighteen examples, very… very good examples, and they got the creative juices flowing, but on the other hand I would say if you let me go home and think about this I might come up with slightly different, you know, configuration. So the point is I wanted to get you something in a timely [fashion] but I also want to go home and think about this for a week and try to come up with something more incredible. So, that's just the way I work.

In the fourth question, participants were asked how different sized groups could be accommodated in their design.

> P5: [*For a smaller group*], I would make this a circle [move tables] with a kind of a "U" shape. (Now referring to her original design). Maybe I would take these back (motioning to the "U" shape) and put these sideways [move tables] (motioning to the tables in the middle).

> P31: So at anytime if you wanted to break up into five different groups you could and spread out throughout the room and you each have your own little mini conference room. Where you can speak or talk in privacy about what your particular deal is or whatever matter you are discussing.

> P45: What I was trying to do was the inside piece would be for smaller meetings [in design] and ideally this would be stadium seating. This would be raised a little bit for larger meetings. The one thing I was trying to keep it from getting was too long.

The final question was asked to help participants close the discussion about their design and elicit discussion about any critical incidents encountered during the design process. Participants were asked to discuss any issues that they would have liked to address in their design but could not.

P39: I couldn't talk about the monitors. I think, you know, the computers are not that important. What is really important is the monitors, I think. I'd like fairly large flat screen displays. You know, either dual or rather large wide screen because I think that you should have a large display space or something particularly for design work.

P40: I can't think of any now. I guess it would have been… it would have been easier if I had the 3D part of it, you know, put … there were probably other things that I would have thought about in that level.

3.4.9 - Summary of Design Characteristics

In their interviews, participants described features of their designs that were coded and summarized below.

Display Location

The majority of participants located the display at the front of the room. Forty-seven designs had at least one display up front. Three designs had displays in the back of the room. Five designs had displays located in the center of the room. One design had a display location on the left/right side of the room. Although the majority of the displays were at ground level, six designs were conceived with displays that were elevated and located in raised sections of the room. Twenty-two designs were conceived with curved alignment as opposed to a straight alignment. The data about display location preferences is summarized in Table 3.29.

Table 3. 29 - Summary of Display Location Preferences

Group	Front	Rear	Center	Left/Right	Elevated	Curved
Naïve	24	0	0	1	2	9
Expert	23	3	5	0	4	13
Total	47	3	5	1	6	22

Technology Facilitation

Forty-three of the designs were created with a specific location for a technology facilitator. The position of the technographer with respect to the room and group varied. The technographer was located in the front of the room in eighteen designs, in the rear of room in nine, in the center of the room in one, at the main table with the group in four, and to the side of the room in one. The data about technology facilitation preferences is summarized in Table 3.30 below. For detailed data, see variables TECHNOG, TECHFRNT, TECHREAR, TECHMID, TECHGRP, and TECHSIDE in Appendix A.

Table 3. 30 - Summary of Technology Facilitation Preferences

Group	Technographer Required	Front	Rear	Center	With Group	Left/Right
Naïve	23	6	10	1	4	1
Expert	20	12	9	0	0	0
Total	43	18	19	1	4	1

Lighting

Many participants felt that the lighting in the room was important. Thirty-five participants felt that ceiling lighting was appropriate. Thirteen participants felt that the lighting should be focused on the over the desk or workstation area. Six participants wanted the lighting or lighting control to be at the desk or workstation area itself. See variables CEILLITE, DESKLITE, ATDESKLT in data table. See Table 3.31.

Table 3. 31 - Summary of Room Lighting Preferences

Group	Ceiling	Over Desk	At Desk
Naive	18	6	2
Expert	17	7	4
Total	35	13	6

Mobility of Furniture

Twelve participants believed that it was important for the furniture to be easily moved. They specifically stated that the furniture in their design was mobile (i.e. on casters) and easily reconfigured. See variable MOBILE in Table 3.32.

Table 3. 32 - Summary of Furniture Mobility Preferences

Group	Mobile Furniture
Naive	4
Expert	8
Total	12

Twenty-four participants responded that their design would accommodate smaller (or larger) groups by moving tables and making modifications to their original configuration. Nineteen participants responded that their configuration was designed to accommodate groups of different sizes by using a section of the room. The remaining 7 participants expected the room to be used by groups of all sizes without any further modification. See variables MOVETABL and INDESIGN (also shown in Table 3.33).

Table 3. 33 - Summary of Design Accommodation for Different Sized Groups

Group	Move Tables	In Design
Naïve	13	8
Expert	11	11
Total	24	19

<u>Zoning Supplemental Tasks: Administration Station and Presentation Station</u>

Twenty participants believed it necessary to zone devices in their design. Specifically, two types of zones were mentioned. First, seven participants created an administration station or zone in their designs where all of the administrative support equipment was located for the team's use. The devices mentioned included fax machines, printers, filing cabinets, meeting support documents, etc. Second, twelve participants created a presentation station or zone where all of the support devices required to present to the group were located. The devices mentioned includes a whiteboard, overhead projector, mobile microphones, document readers, pointers, etc. The data for zones in the design configuration is summarized in Table 3.34 below. See variables ADMINSTN and PRES_STN.

Table 3. 34 - Summary of Consolidation

GROUP	Administration Station	Presentation Station
Naïve	3	7
Expert	4	8
Total	7	15

Seating and Configuration

Participants mentioned a variety of concerns in their response to the first interview question where they were asked to describe their design. These concerns were often captured in specific design features and are summarized in Table 4.27 below. One concern was traffic flow within the room. Five participants created designs with aisles so that the room could easily accommodate the flow of participants within the room. One participant (see design 19) specifically mentioned accommodating participants with disabilities in her design.

Another issue of accessibility was space. In particular many participants were concerned about accommodating larger groups in the meeting facility. Several variables were used to capture this issue in the design. Forty-two participants believed gallery seating or auxiliary tables were a requirement for accommodating larger groups. In the majority of the designs, participants placed tables close together in order to address concerns about space in the facility. Fifteen of the tables in the core configuration (CC) were placed together and twenty-nine of the tables of the tables in the gallery seating (GS) were placed together.

The final issue captured in design configurations was the ability to see the display easily when larger groups were in the room. This was often addressed in the participant's design by stadium seating. Twenty-two participants envisioned stadium seating as a necessary part of their design. See variables AISLE, AUXTBLS, INNRTOG, AUXTOG, SEATING for detailed data on seating and configuration (Table 3.35).

Table 3. 35 - Summary of Seating and Configuration

GROUP	Aisle	Gallery Seating	Tables Together (CC)	Tables Together (GS)	Stadium Seating
Naive	3	22	7	15	11
Expert	2	20	8	14	11
Total	5	42	15	29	22

3.4.10 - Patterns of Commonalty in Design Themes

A preliminary content analysis was performed by reviewing all of the participant interviews and identifying no more than two design themes in each interview. These design themes represented the underlying reasoning for each participant's selection of room features in their design. The themes are listed Table 3.36. The results form the preliminary content analysis were used to develop a list of 14 recurring design themes stated by participants in their follow-up interviews. The criteria used to define each design theme are discussed in the upcoming paragraphs.

Theme 1 was named **Visibility of Displays**. Instances of this theme included statements where the participant stated that people using the room could see the displays, focus on the center (where displays were located), or focus on the wall (where displays were located). Other statements related to clearly seeing the displays were "I don't want them blocked by seating" [P4], "high enough to see over the people in front of you to the public display"[P6], "I think everyone can see it [the display] where they are' [P7], "everyone focuses on the subject" [P9].

Theme 2 was named **Ability to see Each Other**. Instances where participants made statements such as "They can actually see and look at each other" [P36] and "whenever speaking you want to be able to see the person without turning around" [P18] addressed the situation where team members were collocated. Participants also specifically discussed seeing distributed team members in statements such as "you can still see who's who in the room and who is talking" [P37]. Both of these scenarios were coded as theme 2.

Theme 3 was named **Privacy**. Participants made statements about the visual privacy gained by using laptops [P2], gained by using privacy shields [P33], and privacy accomplished by a specific seating arrangement [P3]. Some participants also commented on auditory privacy that could be controlled by the type of microphones used in their design [P33]. Three participants commented that privacy should not be a concern in the VEMS environment [P27, P33, and P40].

Theme 4 was named **Accommodating Participants**. There were two ways that participants spoke about accommodating team members in their design. First, the majority were concerned with using the space to hold as many participants as possible.

Often, this discussion led to how the person envisioned the use of gallery seating in the space. One participant stated that his design was created to specifically accommodate the number of people in his mock-up representation [P39]. He believed that it was difficult to achieve goals in distributed meeting spaces when the number of participants was too large and therefore, chose to limit the number of participants.

Second, participants were concerned about accommodating team members that had physical disabilities in their design. One participant [19] purposely created wide spaces in her configuration to ensure that the room had wheelchair access.

Theme 5 was named **Multi-purpose Configuration**. Three naïve participants and four expert participants created a design space where they envisioned a variety of team needs being easily accommodated in the meeting space. The level of detail provided by each participant differed from a general approach to specific design solutions which accommodated multiple activities. For example, "Trying to make it multi purpose because you want the room to be able to be used for different things [P27]". One participant [P34] tailored his design to multipurpose activities by creating different zones of activity in his configuration. He had a larger meeting space with a table that could be converted to an oval table for collocated teams or a half-circle for distributed teams. He created several presentation areas. Finally, he used an L-shaped space in the back of the room for presentations with co-located or distributed team members.

Theme 6 was named **Status**. Five participants from the experienced group who were concerned about the issue of status in their design were particularly focused on power seats. They either deliberately accommodated status in their design or eliminated status from their configuration. For example, one participant [P38] created a design that he believed eliminated power seats in the room. In his opinion, there was no seat where a person would have an advantage relative to the displays, other people, or team members. Similarly, Participant 31 made the following statement "You will notice there is no actual head of the tables so there isn't anyone that is in charge per se." Conversely, participant [P48] felt that team leaders should be given the power seats.

Theme 7 was named **Available Workspace**. Nine of the ten participants made statements about workspace size when they considered the type of work surfaces and computers they envisioned in their rooms. Their main concern was providing space for activities besides computer use, such as taking notes or managing supporting documents. Participant 36 was concerned about workspace flexibility. In his design, he envisioned each team member having access to a self-contained workspace that completely supported the tasks anticipated in the room.

Theme 8 was named **Lighting**. Eleven participants indicated that lighting had to be flexible in their design. In their designs, different areas in the rooms could have different amounts of lighting, type of lighting, or color of lighting.

Theme 9 was named **Flexible Furniture**. Eighteen participants believed that in order to have control over the arrangement of furnishings in the room, the furniture would have to afford changes in configuration. These participants requested furniture that was flexible and easily arranged by team members.

Theme 10 was named **Team Collaboration.** Sixteen participants believed that the configuration of the space contributed to team interaction and, therefore, created a design to maximize team collaboration. Participants' concerns about collaboration were often coupled with issues of status or perceptions about distributed teams. In particular, team members were concerned with eliminating status to foster collaboration [P34] or the impact of size on collaboration [P1, P39].

Theme 11 was named **VTC needs**. There were two types of concerns. First, participants addressed the needs of VTC technology. For example, participants were concerned about the type of transmission the team would feed to a remote site. These technology related concerns include camera position [P47, P50], color of room and its impact on the image the team was generating, and effective lighting for VTC transmission [P43, P44], etc.

The second type of concerns was focused on the needs of people in the distributed meeting environment. Participants commented on issues such as a sense of presence [P38], type of laptops for VTC needs [P41], fostering collaboration, and microphone quality [P49]. Comments were also made about what their team would look like on cameras, group size [P4], the importance of being visible by cameras, and lastly, the need for colors and decorations that are not distracting [P19].

Theme 12 was named **Supporting Breakaways**. Participants also thought it was important to create smaller meeting spaces in the larger meeting room to accommodate the need for side conversations [P28] or where smaller groups could do parallel work [P34]. Three different approaches were taken to create the space for breakaway groups. Two participants created zones for smaller meetings [P11, P34]. One participant created a design where the tables in the main configuration were mobile and could be moved to support smaller groups [P31]. Another participant suggested the use of partitions such as portable walls or curtains to support breakaways.

Theme 13 was named **Unobtrusive Technology.** Both naïve and experienced users were concerned about the obtrusiveness of technology in their meeting room. Several participants stated that technology should not impede interaction in the room [P26, P4, P48, P49], and one participant clearly stated that the people in the room are more important than the technology [P38].

Other participants provided examples of how their choices of technology made their design less awkward. First, technology should be used for convenience. For example, participant [P4] chose wireless microphones because they would be easier to use as opposed to bending over to talk into a microphone. Or, Participant 7 felt that technology such as a whiteboard had to be conveniently located so participants would walk up and use it to express an idea.

Participants were also concerned that the technology required to support these meetings could also be a visual impediment. Several suggestions were made on how to minimize the impact of technology on visibility. These included the use of ceiling mounted microphones, laptops, and PCs with monitors recessed into the tabletop.

Theme 14 was named **Auditory Clarity**. Many participants were concerned with impediments to sound quality and clarity during large and/or distributed meetings. The areas of concern included sound detection (P44, P49), sound localization, and sound quality. These concerns were addressed by specifying or stating the importance of the types of speakers and microphones [P38], the quality of the speakers and microphones [P35] and the number of speakers [P42] and microphones. Some specific suggestions included the use of ceiling mounted microphones as a back-up system for desk microphones[P13] or using earphones to enhance the quality of the sound [P47].

A Chi-square test was conducted to determine whether an expert was more likely to use a particular design theme than a naïve user. The test was used to evaluate the differences between the frequencies of the design themes and to determine whether experience level is related to the use of a particular design theme. The significance of the results of this test is shown in the third column of Table 3.36 and is summarized in the following list:

Table 3. 36 - Summary of Design Themes in Distributed Meeting Room Design

	Naïve	Expert	p
1. Visibility of displays	23	17	0.04
2. Ability to see each other	10	13	0.40
3. Privacy	13	8	0.35
4. Accommodating participants	8	4	0.25
5. Multipurpose configuration	3	4	0.69
6. Status	0	5	0.02
7. Available workspace	5	6	0.74
8. Lighting	3	8	0.09
9. Flexible furniture	6	12	0.08
10. Team collaboration	5	12	0.04
11. VTC needs	5	12	0.04
12. Supporting breakaways	1	5	0.08
13. Unobtrusive technology	7	8	0.76
14. Auditory clarity	2	10	0.01

- Significantly more naïve users than experienced users stated Theme 1: Visibility of Displays
- Significantly more experienced users than naïve users stated Theme 6: Status
- Significantly more experienced users than naïve users stated Theme 10: Team Collaboration
- Significantly more experienced users than naïve users stated Theme 11: VTC needs
- Significantly more experienced users than naïve users stated Theme 14: Auditory clarity

Nonparametric correlational analyses were performed to determine whether there was a pattern in the relationship between design themes. Kendall's Tau-b was used to determine significant positive or negative patterns in the relationship between design themes.

A significant positive relationship (alpha < .05 unless otherwise indicated) was observed between the a number of design themes. For example, a significant number of the participants who stated multipurpose configuration (5) as a design theme also stated flexibility in Lighting (8) as a design theme. The significant relationship between design themes and the correlation coefficient is shown in Table 3.37:

Table 3. 37 - Significant Correlation between Design Themes

Design Themes	Kendall tau-b	Significance Level
Multipurpose Configuration and Lighting	.342	.017
Multipurpose Configuration and Flexible furniture	.298	.037
Status and Lighting	.306	.032
Status and Flexible Furniture	.306	.032
Status and Team Collaboration	.324	.023
Status and Auditory Clarity		.049
Status and Supporting Breakaways	.492	.001
Unobtrusive Technology and Accommodating Participants	.313	.027
Unobtrusive Technology and Lighting	.284	.046

3.4.11 EMS Heuristics

There was no predefined method for developing heuristics outlined in the literature. The examples of heuristics that were found in the literature (Neilsen & Molich, 1990; Kahn and Prail, 1994) provided little information on the development of the heuristics themselves.

The process used in this research was to transcribe post-experimental interviews of fifty participants and to identify design themes. Each participant had described his or her method of designing a distributed meeting room including the reasoning behind his or her choices for equipment location, table configuration, lighting, technology facilitation, etc. As described in Chapter 3, design themes emerged from the content analysis of these interviews. The occurrence of a theme was coded each time that it occurred in a particular interview. However, when the design theme data were summarized, a binary approach was used to counting the occurrence of a design theme in an interview. Therefore, in the summarized data, each design theme was only counted once per interview. The design characteristic data that originated from coding of the participants' interviews and designs were used in the heuristic process. Both the design themes and characteristics are shown in Table 3.38.

Table 3. 38 – Design Characteristics and Themes

Design Themes	Design Characteristics
1. Visibility of Displays	1. Display location
2. Privacy	2. Technology facilitation
3. Accommodating Participants	3. Lighting
4. Multi-purpose configuration	4. Mobility of furniture
5. Status	5. Zoning Supplemental Tasks
6. Available Workspace	6. Seating and Configuration (aisles, stadium and gallery seating)
7. Lighting	
8. Flexible Furniture	
9. Team Collaboration	
10. VTC Needs	
11. Supporting Breakaways	
12. Unobtrusive Technology	
13. Auditory Clarity	

In developing the heuristics, several options of how to integrate the data were considered. First, it appeared that a one-to-one mapping of design themes to heuristics was not a good approach. Some of the heuristics would be repetitive and redundant if this approach was taken. Second, it appeared from the examples of heuristics in the literature that the heuristics should have very little overlap or should be considered orthogonal in terms of the collection of design issues they addressed. Third, it appeared from the existing examples that the heuristic should be a broad statement that represented the intersection of ideas from a particular domain. Fourth, examples of heuristics in the literature were from a particular vantage point. For example, they can be user-centered (Neilsen, 1990) or focused on methodology development (Kahn and Prail, 1994). Fifth, in defining a vantage point, the scope and the language of the heuristics is also defined. Finally, the language of the heuristic text and the supporting statements for should be appropriate for the user of the heuristics. If there is a need for clarification then supporting statements should be provided. This approach was used in the heuristics created by Kahn and Prail (1994).

The vantage point used in this set of heuristics is the voice of the user in the design session. Users tended to group issues together in their interview discussion.

Those groupings were reflected in the heuristics. For example, all issues related to the visibility of displays were grouped together as one heuristic. One example of heuristic formation is as follows:

The heuristic *Minimize obstruction to vision* is a combination of both design themes and design characteristics. Ideas from design characteristics such as display location and lighting, and design themes such as visibility of displays and lighting were incorporated into the supporting text of this heuristic.

The following heuristics were developed to reflect the findings from the content analysis and the relationships revealed from the design themes and characteristics. The heuristics for EMS distributed room design are described in detail below. Each heuristic is presented with supporting text. The first ten heuristics represent the core heuristics developed to help both naïve and expert users with the room design process. The eleventh heuristic was an instructional heuristic designed for the evaluation process. This heuristic is presented here but is not recommended as a design heuristic.

<u>1. Design an adaptive environment</u>

Be prepared to adapt the meeting room to your needs and perceptions of what is important. Non-experienced and experienced team members identify different aspects of the room as important to control or to have the flexibility to rearrange. In particular, location of displays, location of microphones, and flexibility of the computers are key areas of concerns.

<u>2. Minimize obstruction to vision</u>

People using these rooms want to be able to see each other and displays. For example, some preferences include small computers (laptops), monitors recessed to varying degrees into the work surface, and obscure microphones (lapel, wireless, ceiling mounted. Lighting should be used to increase visibility.

<u>3. Maximize the ability to hear and speak</u>

Placement of microphones (and speakers) should support effortless conversation. Power participants of these facilities prefer obscure microphones (lapel, wireless, ceiling mounted). Less frequent users often prefer visible microphones (tabletop) as a visual confirmation that sound is being transferred to all meeting points.

4. Support the desired team structure

Meeting rooms need to be designed both to support hierarchical organizations and to deconstruct them. The placement of audio-visual support such as displays greatly affects the perception of whether the room is designed for a hierarchical team or a self-managed team.

5. Accommodate participants

Being able to accommodate different size groups all in the same facility is one of the tradeoffs of facility design. The team should determine how to support breakaway meetings, smaller groups, or individual work. Team members have different viewpoints on how meetings of different size groups can be accomplished. Some believe that the tables should be moved or removed to accommodate different team sizes. Others believe that the need for different size groups should be integrated into the design.

6. Task oriented design

Teams are involved in different activities. Support the core activities or objectives of the team with the room configuration.

7. Where possible centralize functions

The location of supporting peripheral devices is not as important as their accessibility in a logical centralized location in the room. Therefore, things that are used together should be located together. For example, many participants believe the room's utility is increased if there is a presentation station (i.e. overhead, document reader, and whiteboard in one location) or an administration station (fax, printer, computer, and stapler in one location).

8. Consider the mobility of all devices in the room

The mobility of the devices and equipment will influence how quickly and whether the room can be reconfigured.

9. Minimize the intrusiveness of technology

People using these rooms understand the purpose of computer and technology support which is to help them improve their meeting process or to overcome the distance between them and their remote team members

10. Let the desired group dynamics dictate the location of support staff

The location of the workstation for the technology facilitator should also be flexible. Some teams view the facilitation as an integral part of the team dynamics. In this case, the facilitator is usually placed with the team or in front of the room. Other teams view facilitation as a support function that is separate from the team's activity. In this case, the facilitator should be placed in the back of the room. Participants stated that both the location and proximity of the facilitator contribute to their interpretation of the role of technology support in the room.

11. Select the configuration that meets your group's needs

Possible examples,

- V shaped is a good design for small teams, and it can easily be reconfigured to support opposing teams, to eliminate power seats, or to support video teleconferencing.
- Conference Style includes circular, semi-circular, oval, and U shaped designs. It is a good design for collocated teams as it increases the ability to see the entire team.
- Auditorium or Theater style is a good design for presentations and video teleconferencing.

3.4.12 - Summary

There were differences in the preferences of naïve versus experienced users in a VEMS design. These differences were in the type of equipment that each group perceived should be flexible in a VEMS meeting room.

Naïve users assigned significantly higher importance to arranging the public displays than their experienced counterparts. Naïve users also tended to assign more importance to arranging computers then their experienced counterparts. Pairwise comparisons between the ranked equipment revealed groups of equipment which shared non-significant pairwise rankings. These groups were the 1) displays and computers; 2) cameras, microphones, seating, and workstations; and, 3) overheads, speakers, whiteboards, document readers, and privacy shields.

Experienced users assigned significantly higher importance to arranging the microphones than naïve users. Pairwise comparisons between the ranked equipment also revealed groups of equipment which shared non-significant rankings. These groups were 1) microphones and seating; 2) displays and cameras; 3) computers, whiteboards, workstations, and speakers, and 4) overheads, document readers, and privacy shields.

Two scales emerged from the 23 item questionnaire given to all participants. The first was a seventeen-item scale named Importance of Fixture Criteria. This scale contained items which rated the importance of the: 1) Position of the displays, whiteboards, cameras, lights, speaker, microphones and document reader, 2) Type of displays, tables, whiteboard, lights, seating, microphones, floors, and walls, and 3) Color of the walls and furniture.

The second scale consisted of two items and was named Ability to Reconfigure or Regroup the Environment. The items in the scale were individual privacy and supporting breakaway meetings for individuals or groups during a session.

Three items did not correlate with either of the two scales. These items represent important equipment needs in each individual's work domain: table configuration, position of the computer, and type of computer. Perhaps, additional items should be developed to create a separate scale to assess work area configuration.

The fifty designs generated by the participants were coded and classified into three groups. These groups were based on the shape of each design. Four designs were

V-shaped, twelve designs were Theater style, and 34 designs were Conference style. Theater style designs were divided into two subgroups: those with curved rear seating and those with straight rows in the rear seating. Conference style designs were also divided into three subgroups: boardroom, horseshoe, and circular (either semi or full).

Participants experienced with groupware, video-teleconferencing, and electronic communication such as chat, email and listservs were compared based on the classifications of their designs. The results showed that all participants, indiscriminate of experience level with other aspects of the VEMS technology, preferred a conference style design more often than the V-shape or Theater style designs.

Participants selected similar room décor preferences and workstation preferences. A number of color categories were used and selected for walls, tables, and carpeting in each room. The color categories were consistent throughout the room and indicated that participants made an attempt at color matching when making their selections.

In particular, participants focused on several key areas in the description of their design. The content from their interviews was coded into variables that represented four key areas: display location, lighting, mobility, seating and configuration. Furthermore, major themes emerged from participants' responses to the post-task interview questions. These themes addressed the rationale participants used when creating their designs. In total, fourteen design themes were identified. There was a significant positive relationship between the experience level and the following design themes: visibility of displays, status, team collaboration, VTC needs, and auditory clarity. There was also a significant positive correlation among the occurrences of several design themes.

A methodology was documented for creating heuristics from coded data. This methodology was applied to created ten design heuristics and one instructional heuristic. These heuristics were used and tested in Studies 2 and 3.

CHAPTER 4 - STUDY 2
PATICIPATORY SESSION

4.1-Introduction

The data from Study 1 were used to generate a set of heuristics for participatory design of the EMS meeting room. User preferences as well as interview themes were incorporated into a small number of concepts that both designers and users of a facility could refer to when planning the configuration of a distributed meeting space.

In this study, a 12 person distributed team applied a participatory ergonomic approach to the design of their meeting facilities. The design for this field study was a one-group pretest-posttest design (Martin, 2000) where the participants were asked to configure their meeting space and to provide feedback on their configuration and the remote sites' configuration. The participants were exposed to the heuristics for meeting room design and then asked to do the same task they were given in the pretest. The design of the field study is shown in Figure 4.1 using Cook and Campbell's notation for nontraditional research.

Figure 4. 1 - One Group-Pretest-Posttest Design

Kies' (1997) extensive Questionnaire for Communication Effectiveness was used

$$O_1 \;\; X \;\; O_2$$

to collect data about video-mediated experience. This instrument addressed issues of video and audio quality, the physical environment, and software communication tools. Twelve items were added to the questionnaire to address the usability of the heuristics (stated as guidelines in the questionnaire). Six items were also added to gather data on the team's opinions on participating in the design of their room.

4.2 - Participants

Ten students were solicited from the AEGIS Training Center at the Naval Surface Warfare Center, Dahlgren, VA (NSWC). There were no prerequisites for the level of experience the students had in video teleconference meetings. Students were not given monetary compensation for participation in the experimental session.

4.3 - Materials and Equipment

Two sites on the NSWC base were used to hold the experimental session. These sites were in separate buildings approximately three miles apart. Both sites were recently established meeting spaces for distributed teams. Site A (Building 1200) was designed to accommodate EMS functions such as GDSS, GSS, video and audio teleconferencing. Site A also had the support of a permanent facilitator and technographer. Site B (Building 1490) was designed to meet the video and audio teleconferencing needs of self-managed distributed teams using the room. The room has the required outlets for computer support but any computer equipment needed must be supplied by the team.

Site A was 36' x 24' with two large 115" (on the diagonal) rear projection displays. The room was equipped with two Canon VC-C3 cameras which were remotely controlled and two Audio Technica flat desktop microphones. The PictureTel 4500 (Ascend Multiband VSX) VTC system was in the rear control room along with a VCR Panasonic SVHS deck and 3 ISDN lines.

Site B was also connected to 3 ISDN lines through its Polycom View station 512 VTC system. The system was connected to a 32" Sony monitor and a standard Polycom microphone and camera. The size of the room at Site B was 30'x20'.

Audiovisual capabilities at the sites differed due to the type of microphones available. Site A had 2 flat tabletop microphones which were connected to the customized VTC system. Participants at Site A did not have direct access to the volume controls because only the technographer had access to the VTC system control panel. Site B was equipped with a single tabletop microphone unit which was connected to the portable VTC system. Participants at Site B had direct access to the volume controls and could mute, increase, or decrease volume as needed. The differences in capabilities were due to the constraints of the VTC systems at each site.

Each site had access to camera controls. At Site A, the cameras were in a fixed location mounted at almost ceiling level in the front and back of the room. At Site B the camera was part of the portable VTC system. Both cameras could be remotely controlled and participants could change camera angles and focal lengths at both locations.

The display units at each site differed. At Site A, the two displays were fixed wall-mounted displays. At Site B, the display was a television screen. Both display units were capable of picture-in-picture display, therefore, the participants could see the remote Site And their site simultaneously.

The videoconference was held by a direct connection to Site A's bridge. Both systems were connected by ISDN lines that allowed the systems to operate at 384 kbps. Each room was equipped with re-configurable furniture: 7 rectangular pieces, 2 semi-circular pieces, an electronic whiteboard, and a flip chart. Each table surface had connection points and could be bolted together at those points. Each room was also equipped with 5 Toshiba Pentium II 266 MHz laptops running Microsoft Office 2000 under Windows 98. The laptops were connected to the groupware via the Internet to the host Dual Pentium III 800 MHz Citrix® Server server in Building 1200. Citrix® Client software was used to remotely connect the laptops into Site A. GroupSystems® 2.0 Client Installation was used through that connection to establish a collaborative meeting. GroupSystems® software is a widely available commercial product for group collaboration.

4.4 - Procedure

The participants met in an office at Site A. Six were sent to Site B and the other six remained. The participants were divided so that three females and three males were at each site. Each participant was asked to complete an informed consent form outside of the meeting conference room. Once the consent form was completed, the facilitator at each Site Brought the participants into the conference room. Only five participants were requested for each Site But since six had volunteered we made the decision to allow all of them to participate.

The team entered the distributed meeting space and the experimenters welcomed the team members at both sites. They were given instructions about the experimental session (see Appendix B) and the task. Team members at both sites were asked if they had any questions.

In the first phase of the session, the participants were required to configure the meeting space for an EMS with their remote team members. In the instructions, they were told that they could move any of the furniture and equipment into their ideal configuration.

After a configuration was decided upon, each team was given a list of the design heuristics which were created from the results in Study 1. The team members were asked to review the design heuristics and to make any changes to the configuration of their design based on the information they read.

The team members were asked to give feedback about their design and the remote site's design before and after the heuristics. They provided their feedback on the forms shown in Figure 4.2.

In the second phase of the session, the teams were asked to participate in a distributed meeting in the rooms they had configured. The groupware was enabled on the computers and on the public displays so team members could review the agenda. The researcher provided a brief description of each agenda item and then the teams began their meeting.

Feedback about Design

Strengths:

Weaknesses:

Changes:

Feedback about Design

Strengths:

Weaknesses:

Changes:

Guidelines used:

1. Design an adaptive environment ___
2. Minimize obstruction to vision ____
3. Maximize the ability to hear and speak ___
4. Support the desired team structure ____
5. Where possible centralize functions ____
6. Accommodate participants ___
7. Create a task oriented design ___
8. Consider the mobility of all devices in the room ____
9. Minimize the intrusive ness of technology ____
10. Let desired group dynamics dictate the location of support staff. ____
11. Select the configuration that meets your groups needs ______

Figure 4. 2 a and 4.2 b- Forms for feedback on distributed team room configurations before and after heuristics

The goal of the meeting was to create a name for the room configuration process they had completed in Phase 1. The agenda was adapted from Neal's (1995) recommendations for evaluating team performance in computer supported meeting rooms. The agenda given to the team to help them meet their goal was as follows:

- Hold an electronic brainstorming session,
- Use the idea organizing tools to group names together and to weed out farfetched candidates, and
- Vote by rank or multiple selection for the final candidate.

Once the teams had completed the meeting agenda, each team member was asked to complete the post-experimental questionnaire (see Appendix B).

4.5 - Data Analysis Methods

The data collected in this study addressed the research goal of testing participatory ergonomic techniques as an approach to facility design and to improving user satisfaction with the distributed meeting environment. The primary focus of this study was to address the third research question in Chapter 1 and therefore, to study the impact of the ability to control aspects of the operating environment on users' reports of satisfaction with the distributed meeting process. Control of the environment was manipulated in two ways in this field study. First, participants were asked to use a participatory process to reconfigure their room and second, participants were asked to complete the configuration process twice: without heuristics and then with heuristics. The source of data and the variables used in this study are shown below in Table 4.1.

Table 4. 1 - Definitions and Sources of Research Variables for Study 2

Variable Type	Source of Data
Independent variables	
Participatory ergonomics with or without heuristics	
Control Variable	
Age	Pre-task Questionnaire
Gender	Pre-task Questionnaire
Level of Education	Pre-task Questionnaire
Experience with Videoconferencing	Pre-task Questionnaire
Dependent Variables	
Heuristics	
Design Issues	Feedback Forms
Preferred heuristics	Feedback Forms
Usability	Post-Task Questionnaire
Usefulness	Post-Task Questionnaire
Quality of Distributed Meeting	
Speaker's Perspective on video communication	Post-Task Questionnaire
Listener's Perspective on video communication	Post-Task Questionnaire
Transmission System	Post-Task Questionnaire
Quality of Participatory Ergonomics	
Ease of participation	Post-Task Questionnaire
Satisfaction with participation	Post-Task Questionnaire
Meeting Dynamics	Post-Task Questionnaire/Observation Sheet

Analysis of Research Question 3

The majority of the data collected in the field study was interval data and originated from a Likert-type rating scale. The sample size in this field study was small and the study is classified as a nonexperimental design both of these facts contribute to the type of analysis that can be performed with the data.

Demographic information was summarized from the data provided by the control variables i.e. mean age, distribution of education level, etc. Design issues were listed for each site. The number of design issues identified by participants were counted. The number of heuristics used by participants were also counted. Descriptive statistics such as the mean and standard deviation were calculated for each of the items in the post-task questionnaire. These data were reported for each site.

4.6 - Results

The design heuristics developed from Study 1 were tested in an applied setting with a 12-person distributed team. The heuristics were tested as a tool to facilitate participatory ergonomics in distributed meeting room design. The results of the session are summarized in this section.

4.6.1 - Demographics

Team members had never participated in a distributed meeting before, however, four members reported prior participation in a distributed learning environment. The distributed team consisted of six male and six female members ranging in age from 19 to 28 years old (X=22.5, s=3.21). Six of the team members were high school graduates, five reported having some college education, and one team member had completed an Associate's degree.

There was a standing group history between some of the team members. Team members reported knowing or working with at least one other member of the team. The details of the relationship between team members are shown in the Appendix.

4.6.2 - Pre-Treatment Configuration

Each team worked together to configure their room for the meeting. Support staff was available at both locations to help with furniture, computers, microphones, cameras, lighting, and other equipment and to answer basic questions about the room design and the meeting.

Design at Site A

The team at Site A configured the room in a V-shaped design (Figure 4.3). They decided to share computers and positioned the computers one between two people. They had two tabletop microphones which they placed at the center of each side of the V-shaped table. They placed the whiteboard and podium in the back of the room. The technographer was located at Site A and was positioned in the far-left corner of the room.

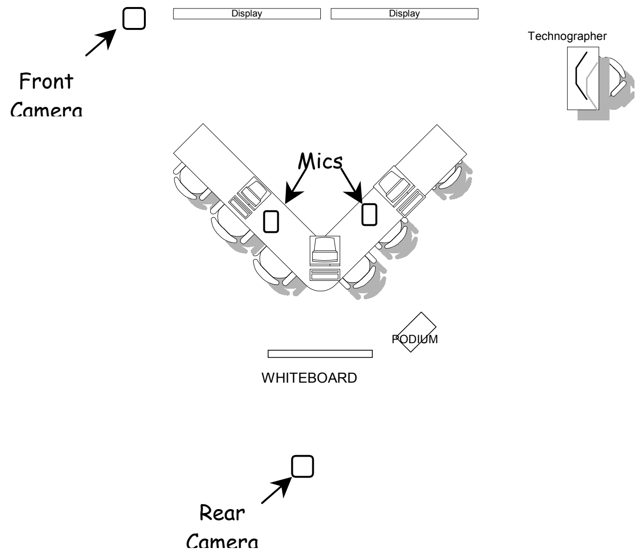


Figure 4. 3 - Pre-Treatment Design for Site A

<u>Design at Site B</u>

The team at Site B also configured the room in a V-shaped design (Figure 4.4). They decided to use all five of the computers available to them, and they gave the sixth person the camera remote control. Their system was a portable system where the television monitor and camera were one mobile unit. The team placed the unit in the center of the room. The team also had two tabletop microphones which they placed at the center of each leg of the V-shaped table.

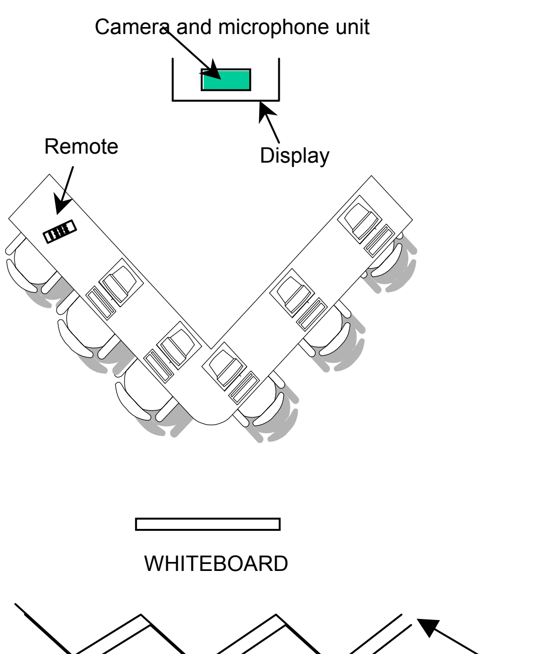


Figure 4. 4 - Pre-Treatment Design for Site B

During the room configuration both sites tested camera angles and sound quality and were very critical of the camera feed they were sending to their remote team members.

4.6.3 - Design Issues Identified by Nonexperts

Participants were asked to evaluate their own design and their remote team members' design. The evaluations were written reports and the participants were candid but tended to be more scrutinizing of their remote team members' design then their own. The types of problems identified by the teams ranged from environmental issues, such as lighting, to design issues, such as use of the available space and location of the whiteboard. Team members were also concerned about the use of computers in their meeting and each site had a different interpretation about the impact and the use of computers in their design. The list of design issues and recommended changes in Table 4.2.

Table 4. 2 - Design Issues Noted by Non-experts

Design Issues	Design Changes
Site A	
Remote team members are looking down instead of at team members. At Site A Camera mounted almost at ceiling height on front and rear walls of Site A.	
Appearance and location of wires. Adds to clutter. Creates trip and electrical hazards .	Table skirting used at Site A to reduce appearance of clutter.
Available work surface for computers and papers.	At Site A computers were removed to increase the available work surface and reduce clutter.
Amount of meeting room space used by tables. Looks cramped.	Change table configuration. Get a wider camera angle.
Difficult to see people at the ends of the table at Site A due to width of camera angle .	Change table configuration to a U shaped design.
Lack of communication and flexibility due to the number of computers used in the design at Site A.	Remote team members at Site B believed the number of computers at Site A to be a weakness and recommended more computers be added to increase communication.
Lack of access to written media at Site A when whiteboard was removed.	
Site B	
Color contrast in Site B makes it hard to distinguish objects and people in the room.	Team members at Site B decided to increase the lighting in their room to improve contrast.
Poor lighting.	
Used all of the computers, therefore, less table room (available workspace) and more wires. Wires create a trip hazard.	
Cramped, feels crowded, unorganized, clutter creates a messy background.	
Difficulty seeing whiteboard (could be contrast or location) at Site B.	
General	
Difficult to understand when everyone is talking.	

4.6.4 - Design Strengths Identified by Nonexperts

The team members completed written reports about strengths at both sites pre- and post-treatment. Many of the strengths directly countered the issues documented in the previous section. For example team members at Site A, identified the following design strengths:

1. Having more available work space was a strength when computers were shared,
2. The appropriate color contrast in the meeting room helped viewing on the display
3. A v-shaped open configuration made it easy to communicate with remote team,
4. It was important to be able to see and look at people when they were talking.

Team members at Site B identified another set of design strengths:

1. Being able to see everyone during the meeting
2. Being able to have a group discussion, and
3. Being able to interact with local and remote team members.

4.6.5 - Post Treatment Configuration

After the reviewing the heuristics, both teams made modifications to their design. At Site A, the team requested table skirting to cover the wires and cables. The team also removed all of the laptops except for one, which they gave to the team leader. They also moved the whiteboard and podium off to left of the room and decided that they would use either piece of equipment as needed for their upcoming meeting.

At Site B, the team debated about hiding the microphones. They also decided that their room needed more light and therefore increased the lighting using the dimmer switch in their room. The final configurations for each Site A are shown in Figure 4.5.

Team members reported the following design issues at Site A repeatedly: (1) the camera angle caused you to feel you are looking down at them and (2) the number of computers used in their design. One new design issue emerged due to the post-treatment reconfiguration. Remote team members could no longer see the whiteboard and felt that removing visual access to written media diminished the teams' ability to communicate.

Similarly, team members reported the following persistent design issues at Site B: (1) the appearance of clutter and, (2) laptop computers reduced the ability to see team members. There were no new issues that emerged because of the post-treatment reconfiguration.

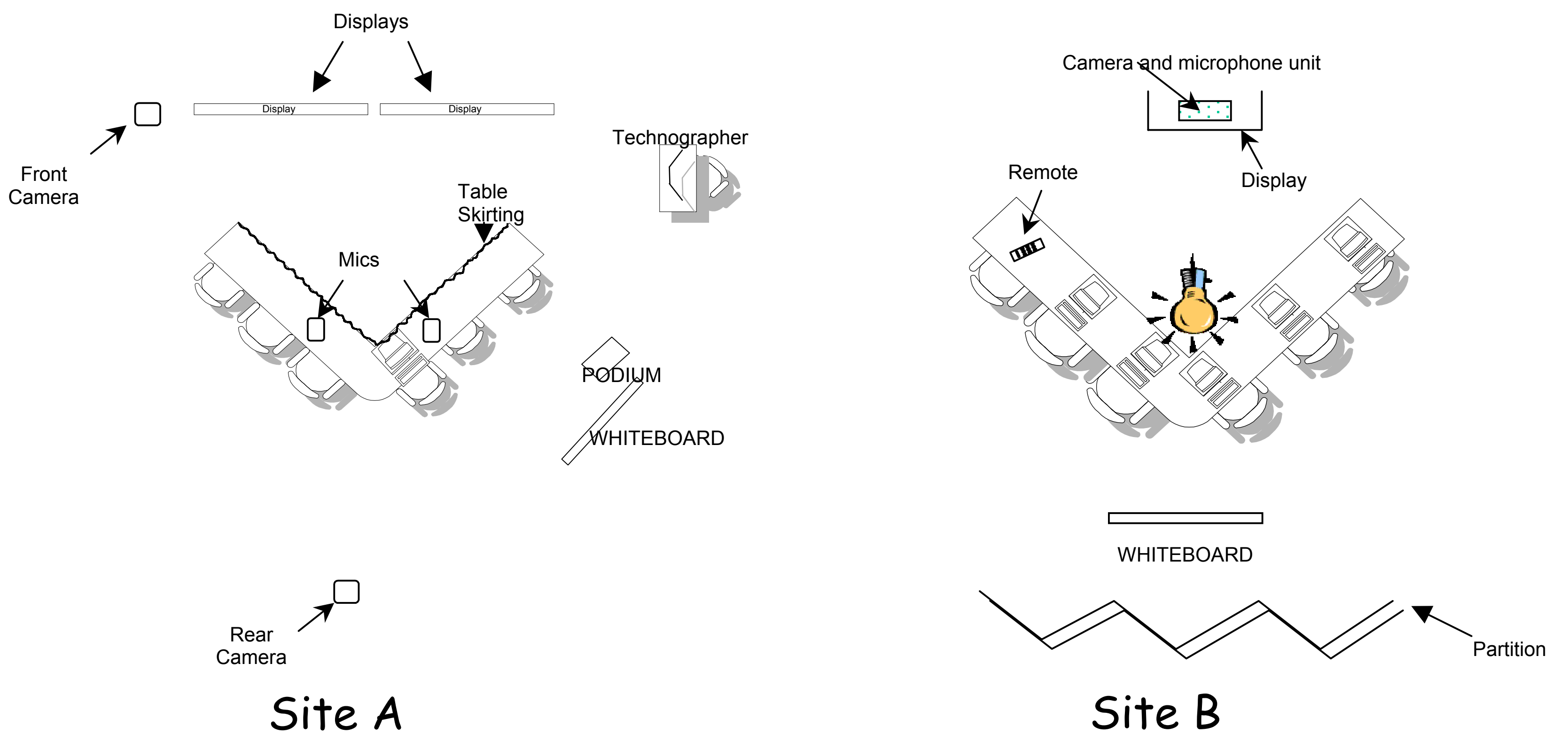


Figure 4. 5 - Final Room Configurations

4.6.6 -Feedback on Distributed Team Meeting

After the teams reconfigured the rooms with the aid of the heuristics, they participated in a distributed meeting. The goal of their meeting was to generate and select a name for the room configuration process that they had experienced. The meeting had a brief agenda that included brainstorming and selection (as detailed in Chapter 3). The meeting portion of the experimental session took about 20 minutes to complete.

There were a number of critical incidents during the meeting that impacted the quality of the meeting. The technical support staff was unable to connect three of the laptop computers at Site B to the network. This was due to an oversight during testing. The laptops were configured to work with the network but had not been assigned IP addresses. This was discovered with troubleshooting but it delayed the start of the meeting and caused several of the team members to grow impatient with the technology. Second, one team member at Site A dominated the discussion. Many of the remote team members were hesitant about participating in any discussion with this team member. The team at Site B often muted their sound output and held a private discussion before sharing their thoughts with the remote team. Third, the dominating team member decided to bypass the agenda while the support staff and researchers were addressing the technical difficulties. It was then difficult to engage the team once again with the process outlined in the agenda. However, they were able complete the agenda, once the technology issues were addressed.

Kies (1997) extensive questionnaire for communication effectiveness was used to collect subjective data from the team on their distributed meeting experience. This data has been summarized for both sites and is presented in Table 4.31. No statistical tests were conducted on the data because of the small number of non-experts that participated in this portion of this study. However, the data, does provide some insight on the perceptions of customized video teleconferencing systems (Site A) versus portable video teleconferencing systems (Site B).

The questionnaire contains four sections. In the first and second sections, participants are as asked their opinions on their experience as a speaker and listener respectively. In the third section, participants are asked their opinions on the transmission system (i.e. audio and video). In the fourth section, participants are asked their opinions about the physical environment.

Although statistical testing is not appropriate for the questionnaire data collected, it is possible to examine themes in the data (Kies, 1997). Two processes are important in the analysis of different groups. First, conducting a comparison of the responses between the team at Site A (customized VTC) and the team at Site B (portable VTC). Second, is to examine the consistency of the responses at a particular site. This informal approach is analogous to the within group and between group comparisons often conducted in the team research.

Table 4. 3 - Summary of Participant Responses to Speaker Perspective Communication Effectiveness Questionnaire

Item	Site A Mean SD	Site B Mean SD
1. I felt as if my message was well understood by the remote group.	5.2 (1.2)	4.8 (1.0)
2. I was able to keep the remote group's attention.	3.5 (1.4)	3.8 (1.5)
3. I knew if the remote group was paying attention.	5.0 (2.4)	4.7 (1.8)
4. I was not distracted by computer arrangement when talking.	6.0 (0.6)	6.3 (0.5)
5. I thought arrangement was just as effective as face-to-face communication.	4.5 (1.9)	2.5 (1.9)
6. I was able to make eye contact with the remote group.	4.3 (2.3)	2.2 (0.8)
7. I was able to see the remote group's facial expressions.	5.0 (1.4)	2.3 (1.5)
8. I was able to see the remote group's hand gestures.	5.5 (1.0)	4.7 (1.4)
9. I was able to see the remote group's body movements.	6.0 (0.9)	4.7 (1.0)
10. I did not feel awkwardly interrupted by the remote group.	4.7 (1.9)	3.7 (1.8)
11. I felt that transitions between who was speaking were smooth.	4.8 (1.6)	2.8 (1.3)

Overall, members at both sites felt that their message was well understood and that they knew when the remote group was paying attention (Table 4.3). Both sites felt that they were unable to keep the attention of their remote team members. Neither group felt that they were distracted by the computer arrangement while they were talking.

Team members at each site held differing perceptions of six items. Team members at Site B tended to moderately disagree ($x=2.2$, $s = 0.8$) that the arrangement was as effective as face to face. Although there was less internal agreement between the participants' responses at Site A, overall they tended to be indifferent to the arrangement ($x=4.5$, $s = 2.3$)

The responses also differed for the four items relating to the understanding of facial cues and gestures. Team members at Site A tended to give much higher and more positive responses than team members at Site B. At Site A, participants were indifferent towards their ability to make eye contact, however, at Site B, participants moderately disagreed that they were able to make eye contact. Similarly, participants at Site A tended to mildly to moderately agree that they could see the remote group's facial expressions, hand gestures, and body movements. However, participants at Site B tended to moderately disagree to mildly agree about the same items.

There were also differences between members' responses at each site on the issue of turn taking in the conversation. Team members at Site A felt less awkwardly ($x=4.7$, $s=1.9$) about interrupting the remote group than those at Site B ($x=4.7$, $s=3.7$). Similarly, team members at Site A tended to mildly agree that the transitions between who was speaking were smooth ones. However, team members at Site B tended to mildly disagree that the transition between speakers was smooth.

Differences could depend on the technology and the group dynamic. The differences in response may be due in part to the differences in VTC systems used at the two sites. At one site, one of the group members was very dominant and did not allow others to participate without comments in the meeting.

Table 4. 4 - Listener's Perspective

1.	I was able to understand remote group's message.	4.8 (1.5)	4.0 (1.5)
2.	I did not have to strain too much to understand the remote group's message.	5.7 (1.5)	4.0 (1.7)
3.	I paid attention to the remote group.	6.2 (0.8)	4.3 (2.0)
4.	I was not distracted by the computer arrangement when listening.	6.2 (0.8)	5.2 (1.7)
5.	I thought this arrangement was just as effective as face-to-face Communication	4.3 (2.0)	2.2 (1.6)
6.	I was able to make eye contact with the remote group.	4.7 (2.0)	2.2 (1.2)
7.	I was able see the remote group's facial expressions.	4.8 (1.9)	2.8 (1.5)
8.	I was able to see the remote group's gestures.	5.3 (1.4)	3.8 (1.8)
9.	I was able to see the remote group's body movements.	5.5 (1.4)	4.8 (1.2)
10.	I was able to interrupt the remote group easily.	4.0 (1.5)	4.3 (1.9)
11.	I felt that transitions between who was speaking were smooth.	5.0 (1.4)	3.2 (1.3)

Team members were also asked to provide their responses from a listener's perspective in their distributed meeting as shown in Table 4.36. The responses paralleled team members' responses from the speaker's perspective. In general, the participants at Site A held more positive perceptions about their experience than the participants at Site B. However, the responses may have reflected issues within group dynamics between the two sites.

The mute button was used several times during the session by Site B in order to have uninterrupted discussions before sharing information with their remote team members. This may have been reflected in Site A's indifferent response to the item "I was able to interrupt the remote group easily". The less favorable responses given in Site B may have been a reflection of the difficulty members of that group expressed during interaction with the dominant team member at Site A.

Table 4. 5 - Transmission System

Item	Site A Mean (Std Dev)	Site B Mean (Std Dev)
1. The video quality was acceptable.	4.8 (1.0)	5.2 (1.2)
2. The video was clear enough.	5.2 (0.8)	4.7 (1.4)
3. The size of the video was adequate.	5.5 (1.4)	4.2 (1.5)
4. The video was just as good as a live lecture in the same room.	4.8 (1.5)	2.2 (1.2)
5. The audio quality was acceptable.	5.5 (0.5)	4.0 (1.5)
6. The audio was clear enough.	5.5 (0.5)	4.0 (1.5)
7. The audio was just as good as being in the same room.	4.5 (1.8)	2.2 (1.5)

Members at both sites were asked their perceptions of the Transmission System (Table 4.5). Overall both sites tended to mildly agree that the video quality was acceptable and the video was clear enough in their meeting rooms. The team members at Site A tended to moderately agree that the size of the video was adequate and that the video was as good as a live lecture in the same room. Team members at Site B responded indifferently to the size of the video and moderately disagreed with the comparison. The differences in responses to the two latter items may have reflected the differences of the VTC systems at the two sites: Site A was a customized system with a wall mounted display and Site B was a portable system with a television display.

The remaining items referred to the quality of the audio during the distributed meeting. The team members at Site A moderately agreed that the audio quality was both acceptable and clear enough and mildly agreed that the audio quality was the same as being in the same room. The team members at Site B responded indifferently to the audio quality and clarity at their site. However, at Site B the team members moderately disagreed that the audio was just as good as being in the same room.

Table 4. 6 - Participation

Item	Site A Mean Std dev	Site B Mean Std. dev
1. It was easy to participate in the design of our room.	6.2 (0.8)	5.8 (0.4)
2. Participating in the design of the room increased my commitment level to the success of our meeting.	5.8 (0.8)	4.0 (2.1)
3. Our team selected the best design for our needs.	6.5 (0.8)	5.3 (2.3)
4. I would be highly committed to this process if our group met again.	5.8 (2.4)	3.7 (2.3)
5. I would be highly committed to using this design if our group met again.	6.5 (0.5)	5.3 (1.8)

Team members were asked to respond to questions on the impact of participation in the design of their meeting space, on their commitment to the meeting, to the design selected, and to the process (Table 4.6). Overall team members reported that it was easy to participate in the design of their room. The team at Site A tended to moderately agree that participation in the design process increased their commitment level to the success of the meeting, whereas the team at Site B was indifferent to the relationship inferred by the item.

Team members at Site A also reported higher ratings than those at Site B on the last two items about commitment to the process and commitment to the design used. At Site A, team members tended to moderately agree that they would be committed to the process and also tended to strongly agree that they would be committed to the design if their group met again. Team members at Site B tended to be indifferent about their commitment to the process, however, they responded more favorably by mildly agreeing that they would be committed to their design.

4.7 - Summary

The purpose of this study was to examine the impact of control over the work environment on satisfaction with distributed meetings. The participatory ergonomics approach was used to present users with a method of intervening with their work system design. The heuristics were used successfully to provide users with both guidance and instruction in the interventions process.

A set of design heuristics was created from the design themes articulated by the participants. These ten heuristics are focused on the design process repeatedly mentioned by naïve and expert users. An eleventh heuristic was added as an instructional guideline. This heuristic was added as an example for the non-experts in Study 2 but was most used by the expert evaluators in Study 3.

Non-experts reported on their experiences in the distributed environment. Overall, the reports on listener quality, speaker quality, and transmission quality varied by site. The reports on the impact of participation in the design process also varied by site. In most instances, Site A reported more favorably to items than Site B.

CHAPTER 5 - STUDY 3
EXPERT EVALUTATION

5.1 - Introduction

Experts were asked to evaluate a meeting room design shown to them in pictures in a one-group pretest-posttest design. The design created by the team at Site A was selected for expert evaluation. Site A was selected for two reasons. The first was availability of the sites at the time of the evaluation and organizational constraints in terms of access to the facilities. The second was that the team at Site A made more changes to their design during the participatory session than the team at Site B. Therefore, Site A's design appeared to be more challenging.

Expert evaluation sessions were held in Site A in order for the expert to become familiar with the site he or she was evaluating.

5.2 - Participants

Six experts were asked to volunteer one hour of their time to participate in an evaluation of a meeting room design. Each expert had previous experience in the design of a computer-supported meeting room for distributed teams.

5.3 Materials and Equipment

The participants used a Toshiba Pentium laptop to view a PowerPoint presentation of the room configuration they were asked to evaluate. The participants were also given paper questionnaires and feedback forms to record their opinions about the heuristics and the designs.

5.4 - Procedure

At the beginning of the session, each expert was welcomed and seated at a work area equipped with a laptop in the front of the room. The researcher read a set of instructions (see Appendix C) and asked each expert to complete a short demographic questionnaire.

Upon completion of the questionnaire, each expert was asked to use the feedback form shown in Figure 4.2a to evaluate the pre-treatment design generated by the distributed team at Site A. Two pictures of the pre-treatment design and a schematic diagram of the layout of the room design were available for the expert to review in a slide presentation on the laptop. The researcher reviewed each of the three slides with the expert and answered any questions before the evaluation.

When the initial evaluation was completed, each expert was given the heuristics and asked to read and to review them. They were asked to evaluate the team's design again and to apply the heuristics they had read.

Finally, they were asked to complete the Questionnaire for Usability of Heuristics that is shown in Appendix B.

5.5 - Data Analysis Methods

The focus in this Study was to collect data from experts on the usefulness and usability of the heuristics that emerged from Study 1. The design of the study was very similar to Study 2 except that experts were asked to evaluate Site A's design rather than participate in a design session. The variables used to collect data and their sources are shown in Table 5.1.

Table 5. 1 - Definitions and Sources of Research Variables for Study 3

Variable Type	Source of Data
Independent Variables	
With or without EMS heuristics	
Control Variables	
Age	Pre-task Questionnaire
Gender	Pre-task Questionnaire
Level of Education	Pre-task Questionnaire
Experience with Videoconferencing	Pre-task Questionnaire
Dependent Variables	
Heuristics	
Design Issues	Feedback Forms
Preferred heuristics	Feedback Forms
Usability	Post-Task Questionnaire
Usefulness	Post-Task Questionnaire

Analysis of Research Question 4

Similar to Study 2, a nonexperimental research design with an extremely small sample size. The majority of the data that were collected were interval data from Likert-type rating scale. Descriptive statistics such as the mean and standard deviation were calculated for each item on the post-task questionnaire. Design Issues and data on preferred heuristics collected on the feedback form were listed and counted for further interpretation. The data collected from the control variables were reduced to provide a summary of the participants' demographic characteristics.

5.6 - Results

5.6.1 - Design Issues Identified by Experts

Each expert evaluated the design and was asked to identify design issues according to their expertise. Fourteen design issues were identified. In Table 5.2, the first column lists the design issues and the second column indicates the number of experts who identified the issues.

Table 5. 2 - Design Issues Identified by Experts

Design Issues	Number of Experts
1. Each participant should have a laptop computer.	2
2. Location of whiteboards.	2
3. Not satisfactory for a large number (above 10) participants.	3
4. Number of microphones could have been increased.	2
5. Placement of microphones might have resulted with the people at the ends speaking more towards the center.	1
6. Place a microphone at the podium.	2
7. Location of podium.	2
8. Picture in Picture.	1
9. Distractions (Floor cables, legs).	1
10. Determine if there is sufficient lighting. Although appears okay.	1
11. Limited workspace on table.	1
12. Add secure phones in case microphones don't work.	1
13. Need capability to mute microphones for private discussion.	1
14. Add place cards in front of seats to identify team members.	1

Although the number of experts used in the study is relatively small, the chart shown in Figure 5.1 indicates that the number of unique design issues identified by the experts began to plateau at about five experts.

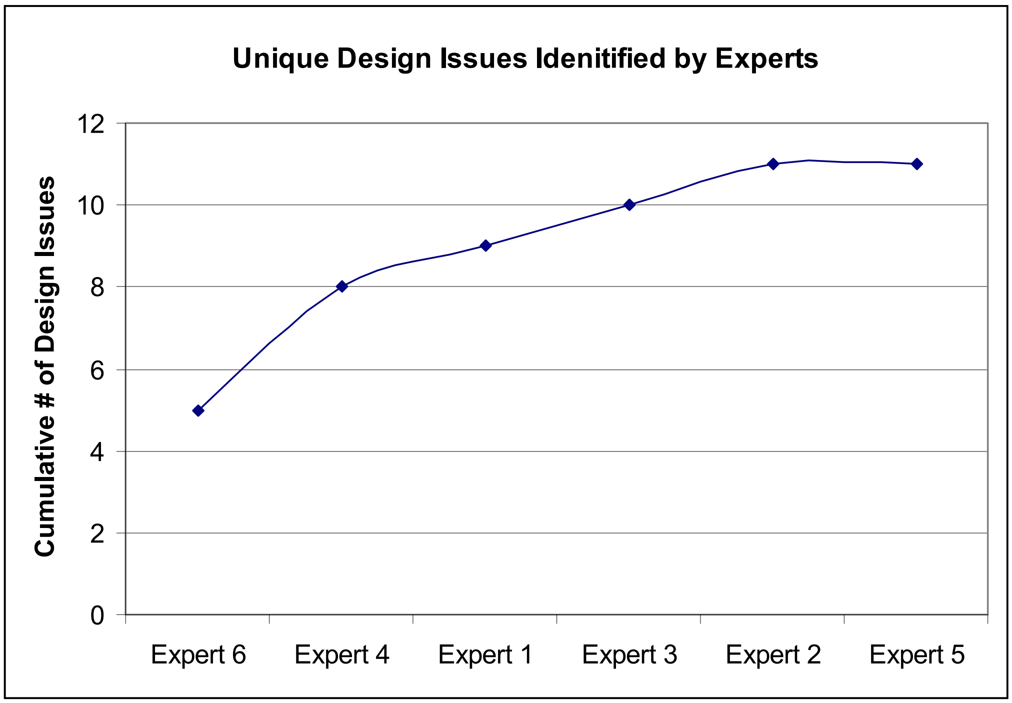


Figure 5. 1 - Unique Design Issues Identified by Experts

5.6.2 - Design Strengths Identified by Experts

The experts completed written reports about design strengths at Site A. The entire list of strengths reported pre- and post-treatment is provided in Table 5.3. Each item in the list was reported by an evaluation. Repetition in the list data shows the convergence of issues detected by the experts.

Table 5. 3 - Design Strengths Reported by Experts

Pre-treatment	Post-treatment
• Good configuration for small # of participants	• Layout matched participants
• Good set up for a small meeting	• Good design for a small group of relatively equal peers (3,4)
• Good arrangement for small group.	• This groups did a good job of configuration the room to meet their needs (11)
• Visual Contact with people in room (side and front view – no rear)	• V-shape was right for this meeting
• V-shaped table and seating provides good visibility for all	• The design seemed to work (11)
• Equal view, equal sitting	• Support staff in front (stationary save time and $)
• Position of participants allow good interchange of information	• Small group utility designated on feedback
• Participants had a good view of screen and each other	• Good visibility for participants
• Picture in Picture allowed remote participants to see local participants and what they were viewing	• Portable equipment
• Interpersonal interchanges due to good sight lines to each other	• Room can be rearranged
• Configuration was compact enough to fit into camera feed of view	• Participants can readily see each other, technographer, and most displays
• All can readily see displays and technographer	• Minimal obstruction for all (2)
• Technographer close to action and in view	• All participants had a clear view of the screen (2)
• Two screens – 1 VTC other for presentation	• (Assumed) minimal intrusiveness; technographer available too. (9)
	• The laptops might be helpful or necessary are not intrusive (9)
	• Accommodate participants (6)
	• Good for quick rearranging for opposing teams (6)
	• Use of 2 table microphones good for "non-power" participants.

EMS Heuristic Usability from Naïve Users and Expert Evaluators

Naïve users and expert evaluators were given Section G of the post-task questionnaire in Appendix B and asked to evaluate the heuristics they used in their experimental session. These Likert-type questions were used to gather data on the perceptions of the usability of the EMS heuristics. The items in the questionnaire reflected different components of usability. Three of the components of usability (easy to use, easy to remember, easy to learn) are commonly used in human-computer interaction (Neilsen, 1993). In addition, the ability to generalize the heuristics, and the thoroughness of the heuristics in terms of addressing design concerns were also considered components of usability. The responses to the items are shown in Table 5.4.

Table 5. 4 - Summary of Responses to Usability Items from Naïve Users and Expert Evaluators

	Site A	Site B	Expert
1. The guidelines are easy to understand.	5.3 (0.5)	4.8 (1.6)	6.5 (0.5)
2. The supporting text is easy to understand.	5.3 (0.5)	4.7 (1.5)	6.2 (0.4)
3. It is possible to apply the guidelines before reading the supporting text.	5.7 (0.5)	5.2 (0.8)	4.8 (1.0)
4. The supporting text for each guideline is useful.	5.2 (0.4)	4.7 (1.5)	6.2 (0.4)
5. The guidelines are easy to remember.	4.8 (1.0)	5.0 (2.0)	5.3 (0.8)
6. It was not difficult to decide which guideline to apply to the design. (R)	3.3 (1.8)	3.5 (1.4)	4.2 (1.2)
7. It was not difficult to make a decision about the strengths and weaknesses of this design. (R)	3.3 (1.5)	2.7 (1.5)	4.7 (1.4)
8. The guidelines helped me to determine the strengths and weaknesses of each design.	4.5 (1.2)	5.0 (1.1)	5.2 (1.2)
9. These guidelines can help any team make a decision on the best meeting room.	5.2 (0.8)	3.7 (1.6)	6.2 (0.8)
10. I would use these guidelines to help design a meeting room.	5.3 (0.8)	3.8 (2.3)	6.3 (0.5)
11. I believe guidelines were necessary to determine the best room for my team's needs. (R)	3.5 (1.4)	2.8 (1.8)	4.8 (0.8)
12. I was able to use the guidelines to address all of my concerns about each design.	4.8 (1.3)	3.3 (1.9)	5.3 (1.2)

Nonparametric statistics were used to compare the responses of the questionnaire data. However, because the data set was very small (12 naïve users and 6 expert evaluators) and the design of the study was nonexperimental, statistical analyses of the data was quite limited.

Mean scores for each item were compared between the three groups (non-experts at Site A on the customized system, non-experts at Site B on the portable system, and Experts) to identify any patterns in the responses from the three groups' experiences when they used the EMS heuristics.

"The guidelines are easy to understand." Both experts and naïve users tended to agree that the guidelines were easy to understand. Non-experts at Site B (roll about system) tended to mildly agree and the response from that group had the largest variance. Non-experts at Site A tended to moderately agree and expert users tended to strongly agree. The variation in responses from the last two groups was relatively small.

"The supporting text is easy to understand." Both experts and non-experts tend to agree that the support text given with each guideline was understandable. The responses were similar to those given about their ability to understand the guidelines. Non-experts at Site B tended to mildly agree, non-experts at Site A tended to moderately agree, and Experts tended to strongly agree. The variance in the response at Site B was relatively large in comparison to the variance of the responses from the other two groups.

"It is possible to apply guidelines before reading the supporting text." Again both experts and non-experts tended to agree about their ability to apply the guidelines without the supporting text. Non-experts tended to moderately agree on this item and experts tended to agree on this item.

"The supporting text for each guidelines is useful." The responses to this item corresponded with the responses to the previous questions about whether the supporting text is necessary in order to use the guidelines. Experts tended to strongly agree that the supporting text was necessary. Non-experts moderately agreed at Site A and mildly agreed at Site B that the supporting text was useful.

"The guidelines are easy to remember." Both experts and non-experts tended to agree that guidelines were easy to remember. Experts had the least variance in their responses and tended to moderately agree. Both groups of non-experts tended to mildly agree. The group at Site B had a large amount of variation (see table) in their responses to this item.

"It was not difficult to decide which guideline to apply to the design (R)". This item was negatively worded in the questionnaire. Experts tended to respond indifferently to this item. However, non-experts tended to disagree with this item. The variation in responses to this item was relatively large and consistent for all three groups.

"It was not difficult to make a decision about the strengths and weaknesses of each design (R)". Experts' responses tended to mildly agree with this item. However, non-experts tended to mildly disagree with this item. The variation in responses was also relatively large for this item.

"The guidelines helped me to determine the strengths and weaknesses of each design." Both experts and non-experts tended to mildly agree with this item. However, the variance for this item was relatively large.

"The guidelines can help any team make a decision on the best meeting room." The experts tended to strongly agree with this item. However, the non-expert responses to this item were not at all consistent. Non-experts at Site A tended to mildly agree with this item, however, their counterparts at Site B tended to mildly disagree with this item.

"I would use these guidelines to help design a meeting room." Again, the experts tended to strongly agree with this time. However, the responses from the two non-expert groups differed. The users at Site A tended to mildly agree with this item and the non-experts at Site B tended to respond indifferently to this item.

"I believe guidelines were necessary to determine the best room." The responses to this item ranged from mildly agree to indifferent to mildly disagree from the experts, non-experts at Site A, and non-experts at Site B respectively.

"I was able to use the guidelines to address all of my concerns about each design." The responses to this item were similar to those of the previous items. Experts tended to mildly agree, at Site A non-experts also tended to mildly agree, and non-experts at Site B tended to mildly disagree.

Finally, expert and non-experts opinions of the usability of the guidelines may have been impacted by the guidelines that they used in their evaluation of the design. A summary of the design heuristics that expert and non-expert users reported that they used is shown in Table 5.5.

Table 5. 5 - Design Heuristics Used by Naïve Users and Experts

	Site A	Site B	Expert
1. Design an adaptive environment.	6	5	2
2. Minimize obstruction to vision.	6	5	6
3. Maximize the ability to hear and speak.	4	5	6
4. Support desired team structure.	5	4	2
5. Accommodate participants.	4	4	4
6. Where possible centralize functions.	3	5	2
7. Utilize task-oriented design.	3	3	2
8. Consider mobility of all devices.	3	4	3
9. Minimize the intrusiveness of technology.	5	1	3
10. Desired location of support staff.	3	1	3
11. Optimize configuration for group needs.	0	1	4

5.7 - Summary

The objective of the study was to understand the usability and utility of the heuristics for expert evaluators. Expert evaluators in this study shared characteristics equivalent to those of experienced groupware facilitators, distributed meeting room facility designers, or distributed software consultants who oversee site installations. From the static images and layouts that experts were provided, expert users identified fourteen design issues overall. The number of unique issues identified by experts tapered off by the fifth expert.

Both experts and non-experts reported on the usability and usefulness of the guidelines. Overall the experts responded more favorably to the items on usability than the non-experts. In general, all participants agreed that the heuristics were easy to understand, but they scored them less conclusively in terms of their usefulness. Most participants did not believe they were necessary to determine the best design for their team's room. However, despite the lower rating on that item, participants did report that they utilized the heuristics and found them helpful in determining the strengths and weaknesses of a design.

CHAPTER 6 - DISCUSSION

The focus of this dissertation was to investigate the user requirements in the distributed meeting environment and to create heuristics (Section 3.4.11) that would allow users, designers, and experts to ameliorate their ability to engage in the facility design and distributed meeting process. The research hypotheses examined the relationship between user requirements and level of experience, user requirements and participatory approaches to facility design, and the ability of experts to apply user centered heuristics to facility design. This chapter will provide information about the relationships and observations made in each study in connection with the research questions.

In order to characterize the relationship among distributed meeting participants and the variables used to measure outcomes in their environment, an input/output model approach was applied.

6.1 - Group Member Attributes (Study 1)

The first research goal in the study was to *Identify user needs and preferences of the configuration and equipment in the VEMS meeting room environment*. Research Questions 1 and 2 address the two subjective data collection methods used to explore this goal and to examine the different needs of naïve versus experienced users.

Research Question 1: The focus of the first research question was to identify what equipment users believed was important in a distributed meeting room. The question asked: *What requirements do users identify as important (or necessary) in a virtually collocated room?* Users were asked to rank order a list of potentially flexible equipment in a distributed meeting environment. In addition, users were asked to rate the importance of position, type, and configuration of equipment in these meeting rooms. The consistency of requirements identified by users led to the first research hypothesis:

Research Hypothesis 1a: *There is a consistent subset of requirements (equipment, facility attributes, etc.) that users will identify.*

This hypothesis was supported by strongly significant Kendall coefficient of concordance of W at $\alpha<.01$ for both groups, which measures the within group consistency of the order in a ranked list. Both naïve users and expert users showed common patterns among their eleven choices of equipment which could be flexible in the a distributed meeting room. The common patterns indicated that users of equivalent experience level share a common belief about equipment flexibility in their meeting rooms.

The second hypothesis examined the differences between the requirements for each user group:

Research Hypothesis 1b: The *requirements will differ based on the users' level of experience in a distributed meeting environment.*

This hypothesis was supported by a significant result for two items on the rank ordered list. Experienced users assigned greater importance to arranging microphones, whereas naïve users assigned greater importance to arranging public displays. This corresponds to the results reported in the Chapter 3 which stated that user needs and preferences in this environment differ based on experience level. The key differences between naïve and expert users have been summarized in Table 6.1. This summary table provides a quick reference of the differences between the two groups based on their responses about what equipment was important in a distributed meeting room.

Table 6. 1 -Summary of key differences between Naïve and Experienced Users

Naïve Users

- Assign more importance to arranging public displays
- Tend to assign more importance to arranging computers
- Prefer obvious microphones (may facilitate turn-taking, environmental cue that a remote meeting is taking place).
- Identify least important items (or bottom three) as the whiteboard, document reader and privacy shields.

Experienced Users

- Assign more importance to arranging microphones.
- Prefer subtle microphones
- Identify least important items (or bottom three) as the whiteboard, document reader and privacy shields.

According to the findings there were significant differences in the importance rankings of naïve and experienced users. It can be inferred that level of experience may be an important consideration in distributed meeting situations where the users are required to interact with their physical environment. Although further empirical testing would be needed to determine a causal relationship between the level of experience factor and performance in this environment, the subjective rankings of the sample end user population suggest this relationship should be investigated further. In Chapter 1, an input/output model was used to operationally define the relationship among distributed meeting variables. This model has been revised to include all of the reported findings as shown in Figure 6.1.

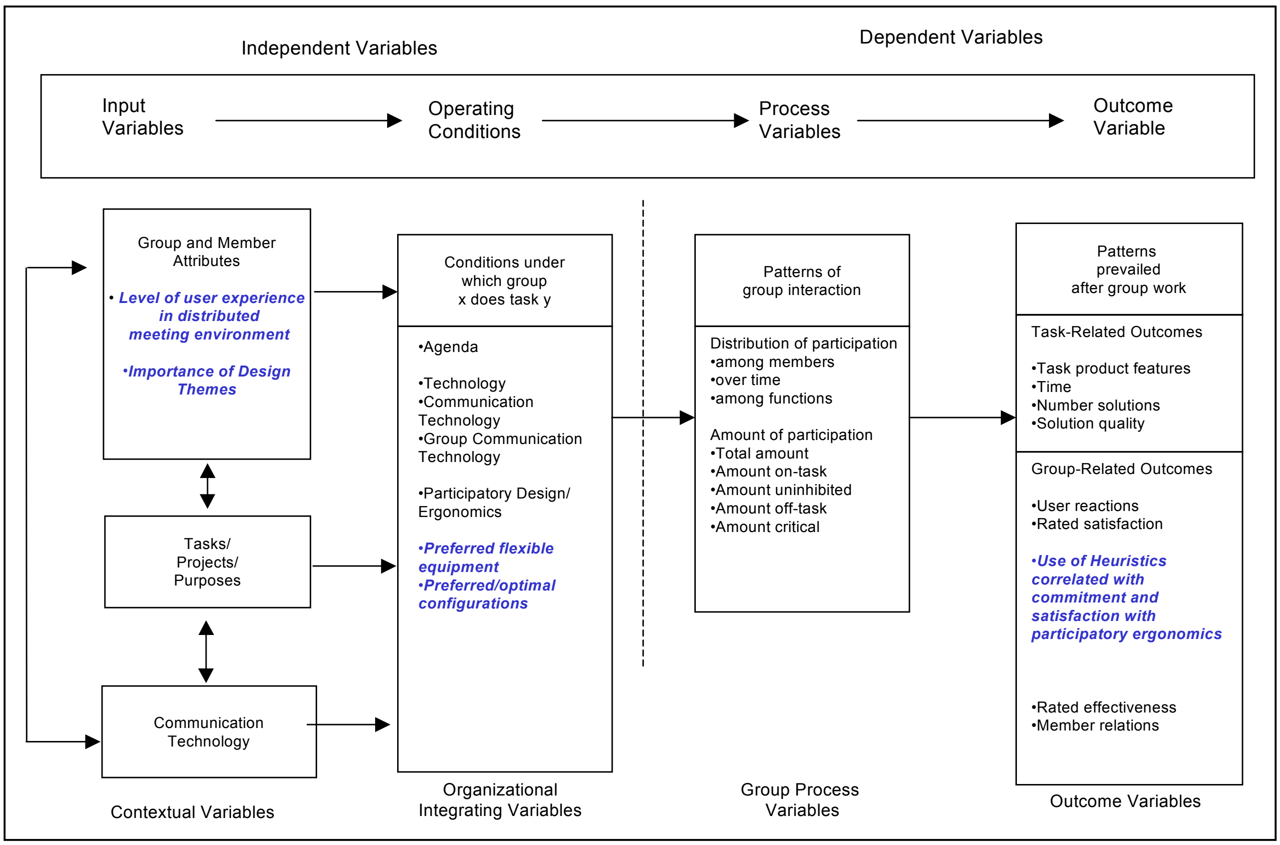


Figure 6. 1 - Revised Operational Research Model

There are several potential explanations why naïve and experienced users had different microphone preferences. Although this dissertation did not explicitly investigate the causal relationship explaining differences between users by experience level, the comments made by users during post-task interviews elucidated a number of possible reasons. One hypothesis is that the naïve user rated his/her concerns about audio issues based on perceived difficulty to accomplish turn-taking, whereas experienced users were more concerned about the quality and clarity of the audio once they are speaking.

The communication effectiveness survey provided another measure of naïve users' perceptions of audio channel quality as well as personal interaction in the distributed meeting domain. Team members from both sites responded negatively when asked to compare the distributed meeting setting to a face-to-face setting.

A more general attempt to understand the differences between user perceptions in the naïve and experienced groups was achieved by assigning categories to the Mean Importance Rankings from both groups as shown in Table 6.2.

Table 6. 2 -Naïve Users: Rankings for Equipment with Category

Equipment	Category
Display	Visual
Computer	Virtual Co-location
Camera	Virtual Co-location
Microphone	Audio (interactive)
Seating	Physical Co-location
Workstation	Individual Work Area
Overhead	Presentation
Speaker	Audio (passive)
Whiteboard	Presentation
Document Reader	Presentation
Privacy Shields	Individual Work Area

We can compare this table with Table 6.3. In this table, Mean Importance Rankings are assigned categories for the users in the experienced group.

Table 6. 3 - Experienced Users: Rankings for equipment with Category

Equipment	Function
1. Microphone	Audio (interactive)
2. Seating	Physical Co-location
3. Display	Visual
4. Camera	Virtual Co-location
5. Computer	Virtual Co-location
6. Whiteboard	Presentation
7. Workstation	Individual Work Area
8. Speaker	Audio (passive)
9. Overhead	Presentation
10. Document Reader	Presentation
11. Privacy Shields	Individual Work Area

The functional categorization of the list offers further insight into users' priorities. Naïve users were heavily biased towards meeting the needs of virtual co-location. Perhaps, they asked questions such as: *1. Can I see? 2. Can I communicate? 3. Can I be seen? 4. Can I be heard?* These potential questions are focused on their interaction with the remote site(s). The last question in this series is *5. Can I do all of the above locally* which is related to the physically co-located team members. However, expert users followed another model as shown in Table 6.3. *1. Can I be heard? 2. Can I do this locally? 3. Can I see? 4. Can I be seen? 5. Can I communicate*? (Please note that the numbers on the potential questions correspond to the numbers of the equipment ranking/categories shown in Table 6.2. and 6.3) The categorization approach illustrates that differences in preferences may also be related to the designer's mental model of the environment and that model may influence which functions are most important in the environment.

Rating questionnaire items on a Likert-type scale for importance comprised the second approach taken to gathering data on user requirements. These results also showed some agreement in the requirements of users. Inter-item correlation was used to uncover possible groupings of items (or scales) in the questionnaire. The results indicated that there might be six underlying factors in distributed meeting room design. Three were multi-item scales and three were single item scales. They are listed below:

- Type and position of fixtures
- Color of walls and furniture
- Ability to regroup (into smaller teams)

- Configuration of the tables (single item)
- Position of the computers (single item)
- Type of computers (single item)

There were no significant differences between naïve and expert users in comparing their scale scores. Therefore, the rating scale information supported research hypothesis 1a but did not support research hypothesis 1b.

The importance questionnaire findings are compelling because they provide more insight into the user's conceptual or mental model of design requirements in distributed meeting rooms. First, we can surmise that users do not separate position or location of equipment from type or style of equipment considered a fixture in the facility. This may indicate that there is a component of accommodation and adaptation in the users' models of the physical environment in a distributed facility. To some degree, users expect to utilize the equipment that is available. The high correlation between type and position may also indicate that users view type and position as integral characteristics of any piece of equipment. For example, the answer to the question, *Where will I position equipment?* may depend on the type or style of equipment.

The three single item scales Configuration of tables, Position of computers, and Type of computers are the only areas where position and type may be distinguished in the users model of facility design. From the importance questionnaire data, the following statements can be made:

First, users held beliefs about what configuration will work best for their situation. In their design sessions, users were able to create a relatively detailed design of the ideal meeting space. Their preferences for the configuration of the room were related to fourteen design themes that emerged from the user descriptions of their meeting rooms.

Second, users hold beliefs about the type of computer needed to best fulfill their design criteria. For example in the post-task interviews, many users believed laptop monitors are ideal for privacy. Other users felt that desktop machines had more computing power. Some users were more concerned about the ability to move the machine easily. Yet, another group of users was concerned with the amount of workspace the computer occupied.

Third, type and position of computer may be distinguishable characteristics because of the level anticipated interaction with the computer during the meeting and because users are able to envision the impact of the computer on success in the distributed meeting environment.

Table 6. 4 - Summary of Hypotheses Testing for Research Question 1

	Research Hypothesis	Method	
		Ranking	Rating
1a	There is a consistent subset of requirements (equipment, facility attributes, etc.) that users will identify.	Supported	Supported
1b	The requirements will differ based on the users' level of experience in a distributed meeting environment.	Supported	Unsupported

The summary of hypotheses testing for Research Question 1 is shown in Table 6.4. Users do share a consistent set of requirements for the design of distributed facilities. To a certain extent, these requirements varied based on the user's level of experience with the environment. These findings indicated that users may share a mental model for design requirements in a distributed meeting room, and this model may differ by experience level in the distributed meeting environment. The main characteristic of users' conceptual models is the prioritization of functions in a distributed meeting. Possible function areas include visual communication, auditory communication, virtual co-location, physical co-location, presentation, and individual workstation requirements.

Research Question 2: *What is the set of design rules users will engage to create their optimal design for a distributed meeting space?* Users were asked to discuss the following topics related to their design experience in the post-task interview: (1) justification of design choices, (2) greatest design challenge, (3) simplest design issue, and (4) design considerations for a smaller/larger group size. Later, the participants' responses were evaluated by content analysis.

The second research hypothesis explored the existence of a consistent set of design rules which emerged from the interview responses:

Research Hypothesis 2a*: There is a consistent set of rules users will engage to design a facility.*

Users had different approaches to resolving this design exercise and focused on specific themes to complete their design task. Consistency of design themes and relative importance among design themes was measured by the occurrence of a design theme in a participant's interview.

The most frequently recurring theme by far was ensuring that *Displays were* v*isible* by everyone in the room. The themes with the next highest frequency were the *Ability to see each other* and the issue of *Privacy*. Visual privacy dominated the discussion in the post-task interviews, however, participants also mentioned auditory privacy as an important concern.

Flexible configuration (i.e. a room where the furniture can be easily moved around), team collaboration, and considering VTC needs were the next most frequent group of recurring design themes. *Unobtrusive Technology*, *Accommodating Participants* (i.e. universal access and end user comfort), ensuring *Sufficient Available Workspace*, and *Flexible Lighting* were in the next group of themes. Design themes such as *Multipurpose configuration* (i.e. a room designed to accommodate many different activities and groups), *Supporting Status*, and *Supporting Breakaways* or smaller meetings were themes that occurred less frequently.

The post-task interviews made it clear that design themes vary in importance. Users were influenced by their perception of the ideal meeting space and accommodated themes they believed to be important in the design. Therefore, importance of design themes has been added to the operational model as a group/member attribute that influences user preferences of the physical environment. Overall, the recurrence of themes indicates a consistent rule structure that users will engage in during the design of a distributed meeting room.

The second research hypothesis focused on the differences between users and the rules they used while designing their rooms.

Research Hypothesis 2b: *The rules will differ based on the users' level of experience in a distributed meeting environment.*

The statistical comparison in Chapter 4 indicated that there were differences in the rules used by naïve users and those used by experienced users. The findings reported previously in Chapter 4 are summarized below in Table 6.5:

Table 6. 5 - Use of Design Themes by Experience Level

Design Theme	Preferred by
1. Auditory clarity 2. Status 3. Team collaboration 4. VTC needs	Used more often by experienced users ($\alpha < .05$).
5. Visibility of displays	Used more often by naïve users ($\alpha < .05$).
6. Supporting breakaways 7. Flexible furniture 8. Lighting	Tended to be used more often by experienced users ($\alpha < .10$).
9. Accommodating participants 10. Privacy 11. Ability to see each other 12. Multipurpose configuration 13. Available workspace 14. Unobtrusive technology	No differences in use based on experience level($\alpha > .10$).

The differences between user design rules matched those expressed as user requirements. In comparing the findings from Research Question 1, naïve users as a group assigned more importance to arranging the public displays. In examining the frequency of design themes, they also stated visibility of displays as a design theme more often than experienced users. Similarly, experienced users assigned more importance to arranging the microphones. In examining the frequency of design themes, more experienced users stated the need for auditory clarity than naïve users.

It appears that experienced users tended to be more contextually aware in their use of design rules than naïve users. For example, more experienced users incorporated addressing VTC needs and issues related to team collaboration as design rules. In their interviews, they focused on how VTC needs could be met without interrupting the main purpose of the meetings. More experienced users also mentioned status or organizational hierarchy as a design issue in distributed meeting rooms. To some degree, this may be an artifact of their organizational environment because the Navy has a hierarchical organizational structure.

Differences between users' applications continue to provide more insight into the user's mental model for design of distributed meeting environments. The findings for each research hypothesis related to Research Question 2 are summarized in Table 6.6.

Table 6. 6 - Summary of Hypotheses Testing for Research Question 2

	Research Hypothesis	Status
2a	There is a consistent set of rules users will engage to design a facility.	Supported
2b	The rules will differ based on the users' level of experience in a distributed meeting environment.	Supported

6.2 - Operating Conditions And Group Related Outcomes (Study 2)

The second goal of this research was *to test participatory ergonomic techniques as an approach to facility design and improving user satisfaction.* The method to test the performance of participatory ergonomic techniques was a field study. Organizational constraints (i.e. Number of required participants, available resources, and technology requirements) prohibited the use of a true experiment. The research question related to this goal asked:

Research Question 3: *What impacts will the ability to control aspects of the operating environment have on users' reports of satisfaction with the distributed meeting process?* .

The research hypothesis associated with this question linked participatory ergonomic process to control over the physical environment. Likert-type rating scales were used to measure user satisfaction with the participatory process and user's satisfaction with the distributed meeting. The research hypothesis stated:

Research Hypothesis 3: *Users will report that having control of their environment increased their satisfaction with the distributed meeting process.*

This single test did reveal some of the difficulties with the participatory ergonomics approach. First, it is time consuming. About 1/3 of the 2-hour experimental session was spent on room configuration. This would significantly add to the meeting preparation time of a real-world team. Without performance measures, it is difficult to determine the cost-benefit tradeoffs of involving the team. A controlled experiment would be required to determine the relationship between participation, performance, and satisfaction for distributed teams.

Team ratings on participation varied and seemed to be related to their perceptions of VTC meeting at their site. The post-hoc analysis below in Table 6.7 revealed that two items directed towards participation in the design process were highly correlated to whether or not the team member believed that the distributed meeting was as "good as a live lecture." It appears from the significant correlation between items that although the users were not able to control the technical quality of the meeting, the technical quality still had an impact on their perception of the participatory process.

Table 6. 7 - Correlation between video quality and participation

	Good as a live lecture	Sig. (2-tailed)
Easy to participate	0.37	0.15
Participating increased my commitment to the success of the meeting	0.61*	0.01
I would be committed to this process if our group met again	0.60*	0.02
Kendall's tau_b: * = Correlation is significant at the .05 level (2-tailed).		

The fact that the technical quality was correlated to participation increases the validity of the current techno-centric approach to the evolution of distributed technology. It appears from members on this team that the technical quality impacts any social experience in the meeting rooms whether that experience is pre-meeting or the meeting itself. It is difficult to know, however, whether the relationships shown in Table 5.6 were confounded with the fact that the cameras remained on during the participatory ergonomic part of the session. In an experimental design, it would be recommended to manipulate this factor to determine whether it has any impact on user performance and satisfaction.

Furthermore, team members' responses to participation and commitment were strongly correlated to their evaluation of the heuristics they used in the participatory process. The following items were correlated:

- (P1) It was easy to participate in the design of our room and (G9) These guidelines can help any team make a decision on the best meeting room.
- (P2) Participating in the design of the room increased my commitment level to the success of our meeting and (G10) I would use these guidelines to help design a meeting room.
- (P3) Our team selected the best design for our needs and (G4) The supporting text for each guideline is useful.

- (P3) Our team selected the best design for our needs and (G10) I would use these guidelines to help design a meeting room.
- (P4) I would be highly committed to this process if our group met again and (G10) I would use these guidelines to help design a meeting room.
- (P5) I would be highly committed to using this design if our group met again and (G10) I would use these guidelines to help design a meeting room.

Table 6. 8 - Correlation between Participatory and Guideline Items

	P1	P2	P3	P4	P5
G1	0.369	0.263	0.581	0.101	0.286
G2	0.398	0.266	0.587	0.164	0.200
G3	0.000	0.279	0.456	0.343	0.303
G4	0.437	0.382	**0.720	0.360	0.483
G5	-0.049	0.182	0.151	0.061	-0.176
G6	-0.241	0.162	-0.249	0.144	-0.098
G7	0.000	0.095	-0.283	0.095	0.000
G8	0.174	0.061	0.370	-0.184	-0.156
G9	*0.571	0.275	0.500	0.353	0.383
G10	0.503	**0.703	*0.575	*0.505	**0.705
G11	-0.386	-0.243	-0.079	-0.075	0.041
G12	0.165	0.486	0.660	0.486	0.506

*= Significant correlation at the (α<.05); ** =significant correlation at the (α<.01)

The findings about the participatory ergonomic approach are few. In conclusion, there appears to be some correlation between technical quality and perceived satisfaction with the participatory approach. There also appears to be correlation between the participatory approach and the perception of guidelines. However, several more teams would need to be involved in the evaluation of participatory ergonomics in the distributed meeting environment before any statement could be supported on impact on task-related outcomes such as performance or impact on group-related outcomes such as satisfaction. Therefore, research hypothesis 3 was not supported.

Table 6. 9 - Summary of Hypotheses Testing for Research Question 3

Research Hypothesis	Status
Users will report that having control of their environment increased their satisfaction with the distributed meeting process.	Not Supported

6.3 - Evaluation of the Heuristics

The third research goal in this dissertation was "To provide ergonomic guidelines and heuristics for designers and technical support staff of video-enhanced distributed meeting facilities." Many technical and ergonomic guidelines for the design of VEMS facility exist in the body of literature in visual telephony, technology classrooms, computer-supported meeting rooms and group communication technology. A compilation of these guidelines was presented in Chapter 2. The body of literature was devoid of user-centered guidelines for these facilities. The focus of the technical and ergonomic guidelines was methods to produce the best quality meeting from a technical perspective i.e. guidelines to achieve the best transmission quality (Daly and Hansell, 1999). Neal's (1995) guidelines took into consideration user needs but her guidance is not supported by any empirical testing.

The heuristics developed in this study were user-centered. Although the goal was to provide guidelines that can be used by designers and technical staff, it appears from our evaluation session that these guidelines may also be usable by meeting participants as well. The research question was asked:

> Research Question 4: *How do non-expert and expert users report on the usefulness and the usability of the design heuristics developed to aid in the participatory process of distributed facility design*?

After evaluating a distributed meeting room design with and without heuristics, Likert-type rating scales were used to measure non-experts' and experts' satisfaction with the design heuristics. The research hypothesis stated:

> Research Hypothesis 4: *Both experts and non-experts will report that user-centered design heuristics are usable and useful in the distributed facility design process.*

From the responses to the subjective questionnaire, experts agreed that the heuristics were usable. Comments during the evaluation were mixed. Two evaluators were not convinced about the usefulness of guidelines in a facility designer's context. They believed that experts should have enough experience with the domain and therefore, would not need heuristics to aid in the assessment of a distributed room's design. On the other hand, one expert with minimal experience in distributed meeting room design believed that the heuristics were a good compilation of factors that must be considered to create a satisfactory distributed meeting room.

The metrics for usability of the heuristics were easy to use, easy to remember, easy to learn. The last three items about guidelines address the construct of usefulness or utility of the guidelines. The means of the items representing each of these a priori constructs are shown in Table 6.10.

Overall, experts responded favorably that the heuristics were easy to learn, easy to remember, easy to use, and useful. Non-experts responded favorably that the statistics were easy to use and easy to remember but tended to responded less favorably to the statement about ease of use of the heuristics and usefulness of the heuristics.

Table 6. 10 - Summary of Responses to A Priori Usability Constructs

	Non-experts	Experts
Easy to learn	5.1	5.9
(G1-G4)	(1.0)	(0.9)
Easy to remember	4.9	5.3
(G5)	(1.4)	(0.8)
Easy to use	4.2	5.0
(G6-G9)	(1.4)	(1.3)
Useful	4.5	5.5
(G10-G12)	(1.7)	(1.0)

Usefulness can also be quantified by evaluating how experts used the heuristics versus how novices used the heuristics. A Chi-square test was conducted to determine whether an expert was more likely to use a heuristic than a non-expert (Table 6.10). Of the design heuristics, the first heuristic design an adaptive environment was reported to be used significantly more by non-experts than experts. The last heuristic "optimize configuration for group needs" was used more by experts than non-experts. There were no other differences in the use of the heuristics.

Table 6. 11 - Summary of frequency of Heuristics and Chi-Squared Significance for Heuristics Test

Design Themes	Non expert	Expert	p
1. Design an adaptive environment.	11	2	0.05
2. Minimize obstruction to vision.	11	6	0.82
3. Maximize the ability to hear and speak.	9	6	0.44
4. Support desired team structure.	9	2	0.18
5. Accommodate participants.	8	4	0.29
6. Where possible centralize functions.	8	2	0.62
7. Utilize task-oriented design.	6	2	0.62
8. Consider mobility of all devices.	7	3	0.44
9. Minimize the intrusiveness of technology.	6	3	1.00
10. Desired location of support staff.	4	3	0.62
11. Optimize configuration for group needs.	1	4	0.05

Research Hypothesis 4 was partially supported. Although both experts and non-experts reported that the heuristics were usable, only experts reported favorably to the heuristics being useful. Non experts reported indifferently to the heuristics being useful (Table 6.12).

Table 6. 12 - Summary of Hypotheses Testing for Research Question 4

Research Hypothesis	Status
Both experts and non-experts will report that user-centered design heuristics are usable and useful in the distributed facility design process.	Partially Supported

6.4 - Summary

This chapter integrated the earlier results from each study with the research questions and hypotheses in Chapter 1. Some post-hoc analyses were also performed to further investigate relationships in the data.

Consistent requirements emerged for the design of distributed meeting rooms. These requirements differ based on level of experience with the meeting environment. It appears from this data that the design model for the naïve user will be more focused on meeting the technical goals of distributed communication whereas the goals of the experienced users are more focused on overall communication.

A consistent set of rules emerged in the form of design themes. However, it appears that the application of the design themes also differs based on experience level. The findings about rules usage support those on requirements. More experienced users cite the usage of rules that focus on overall communication and team collaboration than naïve users. More naïve users cite the need for visual communication (large public displays) than expert users. Experienced also tended to cite more esoteric concerns such as breakaways, flexible furniture and lighting more often that naïve user.

The participatory ergonomic approach to utilizing the heuristics during a meeting did not yield obvious results. The recommendation is to use an experimental design to investigate the impact of this method on user performance and satisfaction. The questionnaire data on participation indicated significant correlation with several of the guideline items and one of the technical items. This correlation between items from the self-report data provides further reason to investigate this factor with an experimental design.

Non-experts and experts alike reported the heuristics as usable. There were differences between the two groups in their reporting of the usefulness of the heuristics. Naïve users reported them to be less useful than expert users. This maybe because these heuristics were prescriptive in their approach but did not provide a step-by-step application of the heuristics to a particular room design. Instead, they required users to assimilate information and to apply the information to their design. This type of extraction of information for a set of guidelines may be more difficult for a non-expert because the lack experience in dealing with design issues related to the distributed meeting environment.

Overall, post-hoc analyses supported the notion that users do adhere to a consistent set of design rules and have a set a consistent of requirements for the distributed meeting room environment. The analyses also placed emphasis on the experience level factor and further established differences between naïve and experienced users and inexperienced and expert evaluators.

CHAPTER 7 - CONCLUSIONS

The purpose of this chapter is to summarize new knowledge gained from this research from a scientific perspective. This summary includes contributions to the body of knowledge about users' perspectives in the distributed meeting room environment. This chapter also serves the purpose of providing a summary of guidance to designers and facilitators of these meeting rooms who are examining methods to improve performance in the distributed meeting rooms that for which they are responsible.

7.1 - Summary of Findings

Level of experience is a distinguishing characteristic of users' preferences in the meeting environment. More experienced users assigned more importance to auditory clarity whereas naïve users assigned more importance to visual clarity. However, both groups shared a common set of design themes.

The findings from this dissertation research provided insight into the user's mental model of interaction in this environment. In Chapter 6, categorization was used to assert that the naïve users mental model is most concerned with the needs of virtual co-location whereas the experienced user mental model is more concerned with achieving immersion in the meeting experience despite the challenges of virtual co-location.

Furthermore, the findings showed that despite level of experience, the heuristics document in Section 3.4.11 which emerged from Study 1 are usable. Both non-experts and experts found the heuristics easy to understand. Non-experts reported that they were slightly more difficult to apply and therefore less useful to them.

The dissertation research did not fully prescribe how these heuristics can be used in a organizational meetings. The participatory approach was attempted. There were obvious issues with the amount of time required to complete this process. Most organizational teams will not take the necessary time for planning and/or room set up and are not likely to spend more than a few minutes on meeting preparation. It remains a question whether participation in design of the meeting space in the physical environment would have the same impact as pre-meeting participation in its design via the Internet (i.e. allowing team members to chat about their preferred design before a meeting or to review a proposed design and make modifications via email). Further research is required to determine the appropriate medium for participation.

Design strengths identified by participants in Study 1 were also identified by participants in Study 2. For example, themes and characteristics documented from the interviews in Study 1 were identified as design issues, strengths, and changes by participants in study 2. This observation adds validity to the methods used in Study 1 and 2. We can see convergence of the results in the field and laboratory settings.

The findings indicate that users have a shared mental model for conducting a distributed meeting. First, users' perceptions of this environment will be based on experience level. Naïve users will tend to focus on the technical goals of distributed communication. Experienced users will focus on the goals of overall communication. Naïve users will focus on the visual aspect of collocation and will focus to a lesser degree on physical collocation and aspects of a traditional meeting. Experienced users will focus on the overall communication at both meeting sites and have a heightened concern about audio quality during a meeting. Experienced users will also be more concerned about achieving the capabilities of a traditional meeting.

Neither naïve nor experienced users of these sites distinguished between position and type of equipment available in the room with the exception of three items: table configuration, position of the computer, and type of computer. Results in Study 1 indicate that users anticipated interaction with distributed technology may vary based on experience level. Users also have different views on the need for privacy, computing power, amount of available workspace and the ability to move machines. Visual privacy is a greater concern than auditory privacy. All of the specific issues mentioned here can be impacted by configuration, position of computer, and type of computer.

7.2 - User-centered Models for Distributed Meeting Room Design

The input-output model that has been used conceptually through this dissertation research also aids in making sense of the findings in Studies 1, 2, and 3. This input-output team communication model specified input variables, operating conditions, process variables and outcome variables. In Chapter 1, the input-output model (Figure 1.2) provided a concept around which to frame this research. In Chapter 2, the input-output model (Table 2.2) provided a context as it was compared and contrasted to previous models. In Chapters 6, the input-output model (Figure 6.1) was augmented with the findings extracted from each of the three studies. However, this model should not be considered the sole representation for the findings in this study.

There are a number of theoretical approaches which can be used to comprehend user data in the context of system (re)design. One additional approach which will be mentioned here is to understand user needs in the context of a specific activity. Activity theory is focused on the designing tools which support the activity and work practices of the user. It is a holistic approach to work design where the user, tools, work practices, division of labor, task, and task objectives are considered in the context their use (Bannon and Bodker, 1991).

To make sense of the data users provided on their preferences in this environment. Three high-level activities in the distributed meeting were considered. These are

- Participating in a co-located discussion
- Participating in a virtually co-located discussion
- Participating in a computer conference using groupware

From the activity-theoretical viewpoint, the objective of these activities is to successfully achieve the meeting goal (Figure 7.1). Participants in this environment interact with technology, equipment, and even configuration of their environment so that they may achieve the meeting objective. Techno-centric developments are most beneficial from the user's perspective if they enhance the available meeting technology and simultaneously enhance the meeting interaction. In fact, findings in Study 1 reinforce that users intend to focus on the meeting activity even in a technology supported environment. One of the design themes that emerged was to ensure technology is unobtrusive.

Another question emerges when we examine the distributed meeting environment from the activity level: *What does the consistent set of rules that emerged in VEMS design which were converted into the VEMS design heuristics represent in the activity model?* It may be possible to consider these rules, all or in part, as rules of practice which are often identified as part of the activity model. The utility of establishing these rules, all or in part, as the rules of practice for meeting room design is that these rules may aid users who are expected to participate in the design of their distributed meeting environment.

The discussion of models is important because this research provides empirical evidence that there is a consistent set of rules that users employ when constructing their ideal distributed meeting room environment. These rules include prioritizing the equipment that needs to be flexible in this environment, establishing design of criteria or themes, and consistent approaches to table configuration. The findings in Study 1 support the use of descriptive models to aid in understanding of the impact of physical environment design on user interaction with their meeting environment.

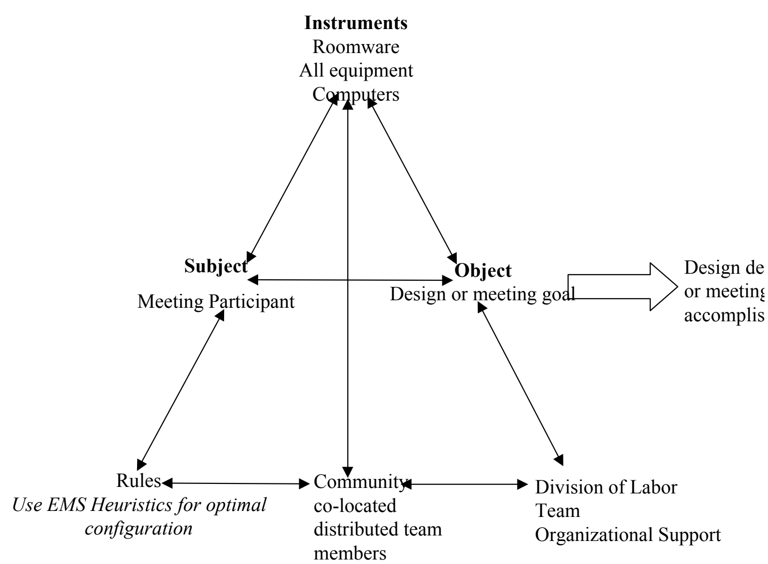


Figure 7. 1 - Participating in a VEMS (or virtually co-located, groupware supported meeting)

7.3 - Recommendations for Facility Designers

If designers need to gather data for requirements in their facility they should focus on the key areas of room layout extracted from the content analysis of 50 participant interviews and documented in Section 3.4.8. These are display location, technology facilitation, lighting, mobility, zoning of supplemental tasks, seating, and table configuration.

Designers should use the existing guidelines to aid with facility design, in particular, Daly and Hansell recommendations for color selection are quite useful. These guidelines were used in the color and equipment selection at Site A. Team members at both sites noted the contrast due to color selection.

Designers or facilitators should involve the participants in selecting the right configuration and variation for their team and the meeting space. Team members in both studies indicated strong opinions about the appropriate design for their team's needs.

If designers are considering a participatory approach to meeting room design:

- Due to the length of time they should consider addressing participatory ergonomics prior to the meeting.
- One alternative being explored at Navsea Dahlgren are to work with the major stakeholders prior to the meeting to determine the appropriate configuration as part of the meeting planning phase.
- Another alternative is to utilize the Internet as a meeting design environment where collaboration could occur in order to make room configuration decisions.

Designers should also be prepared for users to evolve and for their needs to change. The empirical evidence supports that naïve and experienced users indicates that requirements shift as users gain more experience in their environment.

Facilitators may also consider engaging in meeting pre-work with team members to level off the experience factor.

Designers need to be aware that the quality of the equipment impacts perceptions of meeting satisfaction, performance and perhaps level of participation. In Study 2, perceptions may have differed based on video teleconferencing systems. Team members who used the customized video teleconferencing systems (Site A) tended to rate their experiences more positively than team members who used the portable video teleconferencing systems (Site B).

Lastly, both designers and facilitators may consider using the heuristics because they can provide a common language of to discuss design issues among participants and between participants and designers. The heuristics provide designers with a framework which can be shared with the user and can help users to articulate concerns about the design of their distributed meeting room environment.

7.3 - The Future of Distributed Meeting Room Design

There will continue to be a need for distributed meetings especially with the advent of e-engineering as the new "competitive tool for boosting profits and increasing productivity" (Weinstein, 2001, p.15). Firms are taking advantage of software development talent from other countries because of the low labor costs. These distributed development teams have the potential to work around the clock because they can take advantage of time zone differences (Weinstein, 2001).

Their major dilemma is that e-engineering teams must meet to discuss timelines, issues, goals, and responsibilities. Conference calls have been one approach but they are difficult due to poor telephone connections. Email is currently the preferred medium for distributed meetings for these teams. But as video technology and compression algorithms become more sophisticated (Schaphorst, 1999), VEMS will be a solution for many of these teams.

The user-centered heuristics and knowledge gained about user requirements can be used to help improve these meeting rooms. Data collection on user preferences can be one of the most important contributions to the design of this system. Requirements gathering was accomplished in this dissertation by allowing users at opposite ends of the distributed meeting spectrum to voice their needs for the design of a distributed meeting room. Although the heuristics provide a good start toward the exploration of user-centered-design in this environment, it is necessary to continue research on how users' preferences in distributed meeting room can be incorporated into future of distributed meeting room design.

7.4 - New Methods of Participatory Ergonomics

The development of heuristics for use in a participatory ergonomic setting was one of the objectives of this research. The method for heuristic creation and application in the distributed work environment was previously unexplored. One of the by-products of this research is a method of heuristic creation that may be applied to other work situations.

Participatory ergonomics is a solution-based approach that incorporates many of the methods used in participatory design. Participatory design is normally used as a requirements gathering technique used in computer science to elicit user feedback during the development cycle. One of the emerging differences between participatory ergonomics and participatory design is the frequency of use during a given project or in a given work environment.

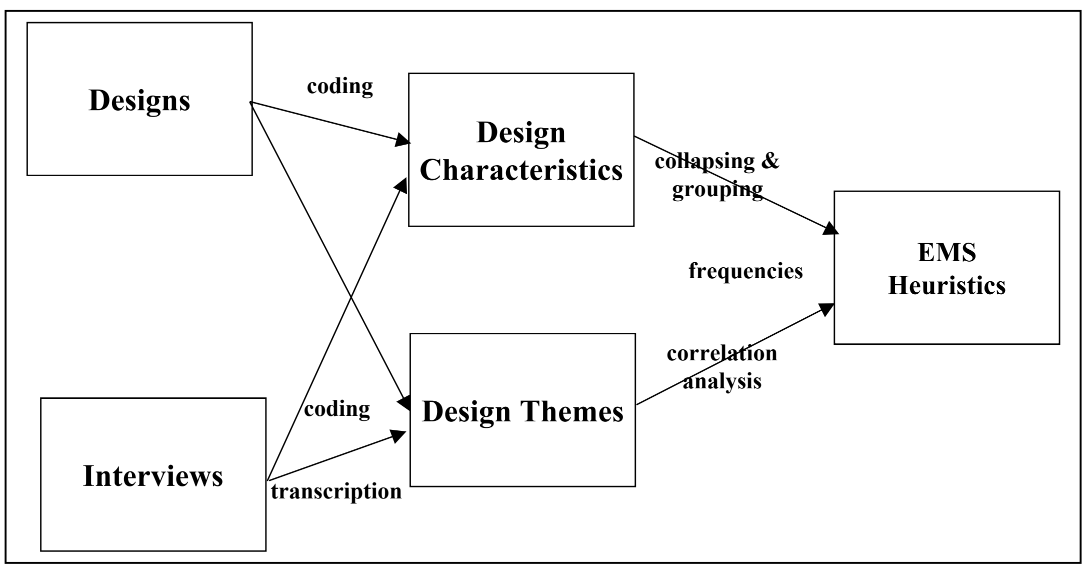


Figure 7. 2 - Method for Heuristic Development

This research established a methodology for converting design ideas articulated by a group of users into heuristics that can be applied in the actual work environment (Figure 7.2). Both the designs and transcribed interviews were coded. Design characteristics and design themes were extracted from the design exercise and interviews, respectively. Heuristics were generated based upon collapsing and grouping themes and characteristics in related topic areas. Finally, related topic areas were determined based on frequencies, correlation analyses, and the chunking of ideas articulated by participants during their design interviews. The method used to abstract design themes from a design exercise and convert these themes to heuristics was documented in detail in Section 3.4.9.

7.5 - Future Research Recommendations

To advance this line of research, these heuristics need to be tested on a larger population to be more definitive about their usability and usefulness. The findings from Study 2 and 3 are encouraging and provide some indication that with further experimental testing EMS heuristics can be to used to increase user satisfaction with the distributed meeting environment.

The usability of the heuristics should be independent of the expertise of the user. The usability of the heuristics should also be independent of the context in which the heuristics are used. The heuristics should be tested in a variety of contexts to determine how the user's situation impacts their perception of the usability of the heuristics.

Lastly, further exploration of two areas would aid in the understanding of the distributed meeting experience. First, the user's mental model of the distributed meeting room experience should be further explored and later articulated to help both meeting participants and the support staff of distributed meetings. Second, the rules of practice in a distributed meeting should be further defined and added to the activity theoretical model. If users and support staff understand their behavior and the activity level, further progress can be made in improving satisfaction in the distributed meeting environment.

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