To the Graduate Council:

I am submitting herewith a thesis written by Jennifer D. Webb entitled "A Comparison of Spatial Perception Using Two and Three-Dimensional Representations." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Interior Design.

Alton J. DeLong, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:

Associate Vice Chancellor
and Dean of the Graduate School

A COMPARISON OF SPATIAL PERCEPTION USING TWO- AND THREE-DIMENSIONAL REPRESENTATIONS

A Thesis
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ABSTRACT

This study examines the use of scale models as an alternative to two-dimensional drawings to communicate spatial relationships in an attempt to improve the level of understanding by laypeople. Doll-house type three-dimensional scale models involve tactile and kinesthetic sensory modalities through direct manipulation of the components and scale figures. The scale model may also allow the aspects of design programming that deal with implicit, out-of-awareness knowledge which is frequently unexplored to become more apparent. If laypeople can develop more accurate cognitive representations of three-dimensional relationships through the use of scale models, some of the communication problems between designers and users may be eliminated.

Subjects were given two basic tasks separated by a latency period to determine if scale models permit users to more accurately comprehend and evaluate spatial relationships than two-dimensional drawings relative to the full size environment. The media tested include two-dimensional drawings, two-dimensional drawings with figures, and scale models with figures. The drawing representations were scaled at 1/4" = 1' - 0" and the scale model representations were scaled at 1" = 1' - 0". The subjects were asked to arrange furniture in the drawing and the model environments based on familiar activities and were then asked to create the same relationships in the full size environment. The spacing in the drawing and scale model environments were compared to the spacing in the full size environment.

Results indicate that while all media tested have statistically significant correlations

between the measurements in the representational medium and the full size environment, the drawing without figure reflects a significant difference in the measurements. Additional analyses on the ratio values of the measurements suggest that the type of representation employed may result in specific spacing trends when compared to the full size environment. The spacing ratios in the scale model environments differ significantly from the drawing with and without the scale figure. Results show that the scale model allows people with no design training to define spatial relationships more accurately than drawings. Findings also suggest that drawings with figures may have a potential impact on the definition and comprehension of three dimensional relationships by creating a kinesthetic component to the drawing environment.

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CHAPTER 1

Introduction

There are inherent problems in the communication process between designers and clients. Many problems revolve around the clients' lack of skill in comprehending spatial relationships from two-dimensional drawings typically used by designers to communicate their designs. Evans (1980, p. 259) explains that the "real world settings differ from the stimulus arrays;" interaction, immersion within the environment and context are seldom addressed. This study examines the use of scale models as an alternative to two-dimensional drawings to communicate spatial relationships in an attempt to improve the level of understanding by laypeople.

The design professional must ask *What forms of spatial representation will most closely imitate the array of sensory information provided by the actual environment?* Doll-house type three-dimensional scale models involve the tactile and kinesthetic modalities through direct manipulation of the components and scale figures. If laypeople can develop more accurate cognitive representations of three-dimensional relationships through the use of scale models, some of the communication problems between designers and users may be eliminated. The scale model may also allow the aspects of design programming that deal with implicit, out-of-awareness knowledge which is frequently unexplored to become more apparent.

The experience of space involves many types of sensory information simultaneously. Not only is information gained visually, but movement and touch concurrently provide information about spatial relationships. The interaction of the senses has been of interest since the time of Aristotle and is of continuing interest to researchers in a variety of fields. For example, the development of the brain stem's vestibular system has been linked to motion stimulation; research has determined that without motion stimulation of the vestibular system, perceptual development may be delayed (Restak, 1979). The use of two-dimensional drawings to communicate spatial relationships does not take advantage of haptic or kinesthetic information except in the most abstract manner.

ProblemStatement

Spatial perception and the understanding of spatial relationships may vary depending upon the type of representational media implemented during the design process. This study will examine the perception of common spatial relationships through the use of different forms of representational media and the full size environment by individuals with no design training. The media tested include two-dimensional drawings, two-dimensional drawings with figures, and scale models with figures. The drawing representations were scaled at 1/4" = 1' - 0" and the scale model representations were scaled at 1" = 1' - 0". The subjects were asked to arrange furniture in the drawing and the model environments based on familiar activities and were then asked to create the same relationships in the full size environment. The spacing in the drawing and scale model environments were compared to the spacing in the full size environment.

Purpose and Significance of the Study

The purpose of the study is to determine if scale models permit users to more accurately comprehend and evaluate spatial relationships. Designers may be able to develop more appropriate and effective communication methods to gather information from and present information to clients if differences do exist between the forms of spatial representation tested. Designers and architects may realize an advanced problem solving capability if cognition and understanding of the design solution by laypeople can be strengthened.

Hypotheses

Two general hypotheses will be tested. First, differences will be found between spacing in the representational conditions as compared to their respective full size conditions. Second, differences will be found in the relative accuracy of the various types of representational media. Initial analysis of the data will determine the presence of order or group effects in order to further validate the research methodologies and to rule out a portion of the potential variation due to sampling error or test-retest learning.

CHAPTER 2

Literature Review

This chapter presents a review of theoretical and empirical literature related to this study. The chapter will first discuss some current design methodologies and the inherent strengths and weaknesses of each. The chapter continues with a discussion of the cognitive structure of the human mind, how information is received and encoded in the brain, and its relationship to understanding spatial relationships.

The common theme which runs through the literature is the importance of the amodal sensory processes of the human body and how the human body interacts with the spatial environment. Interior design and architecture are visually oriented both in methods of presentation as well as methods of information gathering. Other paradigms are rich in supporting evidence that the spatial environment is experienced through every sense. Not only must a design process be created which stimulates the user's entire perceptual system but the information needed to create a design solution must be elicited through every sense of the user as well to insure the optimal design solution.

Some Typical Programming and Presentation Techniques

Programming methodologies are either verbal or visual and seldom involve the interaction of the user. Data is collected through questionnaires, interviews and participant observation and then solutions are presented to the user in the form of two-dimensional drawings and type-written specifications.

Questionnaires. Questionnaires allow the professional designer the opportunity to detect patterns of use and similar needs of the sample group (Zeisel, 1990). Inherent weaknesses include difficulty in defining particular areas of concern or specific problems for individual respondents and the difficulty of not being able to reach each person within the facility. Open-ended questions may elicit some of the information, but can often become difficult to code and the responses may not always be interpreted consistently by the design team members. An additional issue is that questionnaires do not address the out-of-awareness knowledge that individuals possess but are unable to impart in verbal interaction. This out-of-awareness knowledge is not released through questions in a pencil-and-paper format; the information is unaccessed because it is unaccessable (Reber, 1993). The behaviors initiated by tacit knowledge may be parallel to an autonomic response which is more specifically a physical response to a particular stimuli where the individual's nervous system reacts in such a way that it is entirely unconscious on the part of the organism (Drickamer and Vessey, 1993). These autonomic acts are as simple as adjusting a shirt collar or crossing one's arms when the ambient temperature drops only one or two degrees. Behaviors elicited through interaction with the spatial environment may be just as unconscious as an autonomic response.

Interviews. Interview techniques may avoid some of the problems encountered in a non-interactive questionnaire such as one received through the mail; the interviewer may be able to probe for additional information and to ask for clarification on a topic by involving the respondent in a one-on-one discussion (Sommer and Sommer, 1991). The interview method has inherent weakness as well. Tacit knowledge may never be communicated to the designer adequately since tacit knowledge is not verbal knowledge and occurs out-of-awareness. Davis (1972) outlines other weaknesses associated with interviews in a case study; problems include response bias as a result of the presence of superiors or co-workers during the interview process, accurate and available information from the original instrument, statistical information being of limited use to architects and designers during the design process, and consistent and accurate definitions of terms.

Participant observation. This observation technique permits behavior patterns and types of interaction to be recorded by the design professional. Spradley (1980) discusses the shortcomings of recording and interpreting such behavior by an outsider. The design professional may not share the cultural knowledge of the group or individual under observation and therefore may introduce elements of outside bias into the data collection process.

Presentation of design solutions. After the programming information is gathered and a design solution completed, the designer returns to the client with drawings and specifications. A layperson may be incapable visualizing a three-dimensional space from a flat drawing or verbal description. Research has investigated the evaluation of hand-drawn sketch maps and actual cognition and has found that systematic distortion such as straightening curved lines or incorrectly drawing elements which have unusual constructions or placements (Evans, 1980). One might assume that if the general population experiences problems drawing a sketch map accurately, they may also have trouble interpreting sketch maps or floor plans drawn by others. The layperson is inhibited from participation in the evaluation of the design solution if they are unable to interpret

The information exchange has been effectively shut down.

Cognitive Structure

The human mind's structural and perceptual functioning provides a foundation for the study of spatial knowledge. Medin and Ross (1992) state that the ambiguity of the information received by the human organism has resulted in evolutionary constraints which allow the evaluation and comprehension of this information. Users must use sensory information in evaluating the appropriateness of the design solution. How the human mind receives, organizes, and retrieves this information is important in developing a design methodology which allows for an adequate evaluation of spatial relationships to occur.

Cognitive models. One cognitive representation theory states that people use mental imagery which provides a schematic, less detailed image of the actual information (Kosslyn, 1975; Shepard, 1975). This model is referred to as the analog model of organizing objects and spatial relationships. An alternate theory depicts information in the form of representational meanings stored in lists of labels. This structure allows for the search and comprehension of information required for spatial location and orientation (Kaplan, 1973; Neisser, 1976; Stea, 1969). This model is referred to as the propositional model. Evans (1980) presents a theory originally developed by Kosslyn and Pomerantz (1977) which combines the two systems mentioned above; information may be encoded propositionally yet can be handled and reorganized analogically.

Categorization. Categorization is a method by which human beings are believed to organize information for use. A category's conceptual basis is founded on the "systematic organization of similarities which allows comprehensibility" (Glucksberg and Keysar, 1993, p. 27). Rosch (1977) constructs the foundation for basic-level categories from images or motor actions of the human body that may lend themselves to the interpretation of spatial and orientational concepts. Lakoff describes basic level categories in a manner which allows one to see the importance of the interaction of the human body and its environment:

> Perhaps the best way of thinking about basic-level categories is that they are 'human-sized.' They depend not on objects themselves independent of people, but on the way people interact with objects: the way they perceive them, image them, organize information about them, and behave toward them with their bodies. (1987, p. 51)

The human body is illustrated to have an important role in the way information is organized in the human mind. The term "interactional property," as formulated by Elenor Rosch, is based upon the combination of experience between the physical and cultural aspects of the environment and a human being's physical body and cognitive abilities (Lakoff, 1987, p.51).

The casual observer may conclude that spatial relationships must be difficult to store and to retrieve in the above-described models. Distances between objects in relation to the human body are not easily interpreted either into abstract labels or schematic pictures. Tacit knowledge, or non-verbal knowledge, may take a different form and may address the realms of spatial knowledge more fully. Edward Hall (1966) illustrates spatial knowledge through his carefully constructed proxemic zones. Though variation is noted within the descriptions of the various zones, Hall is careful to point out that cultural heritage and context as wells as distance receptors such as the eyes, ears, and nose play significant roles in our perception and use of space when interacting both with inanimate objects as well as other people. Hall uses intercultural proxemic patterns to illustrate "our own out-of-awareness patterns" that were recognized only "when Americans began interaction with foreigners who organize their senses differently so that . . . the American became aware of his own spatial envelope, which he had previously taken for granted" (1966, p. 128). Scale models may allow this spatial knowledge to be expressed behaviorally through interaction within a spatial environment.

Amodal sensory input. Aristotle used the term *sensus communis* to define "all of the qualities of sensation that are general . . . not particular to a single sense" (Marks, 1978, p. 4). Landau and Jackendoff (1993) describe spatial information as either "heteromodal" or "amodal". These terms are interpreted as representing several sources of sensory input. Visual, auditory, and haptic sensations combine to form spatial representation.

A further example is that of synesthesia, which is the experience and encoding of stimuli in a different sensory modality than that which it is normally experienced. Luria (1968) worked with a subject who exhibited an extraordinary long term memory; the informant was able to enhance the recall of verbal information by combining visual imagery and verbal encoding.

This duality of coding may enhance the overall cognition of sensory input; Allan Paivo has proposed this hypothesis based upon his observations with memory tests involving picture and picture name recall (1971). Pavio's research indicates that pictures, which are encoded both verbally and imaginal, are recalled better than words alone, which are encoded only verbally.

Redundancy of the senses may allow reference points to become internalized or to become tacit knowledge. De Long (1976b) discusses this premise and indicates this internalization may lead to a lack of awareness by the informant. Therefore, designers may elicit responses from clients which would not normally be accessed by allowing them to interact with a scale model.

The multi-sensory nature of the phenomena described above emphasizes the importance of the amodal nature of input and output in the cognitive process of the human mind. This premise is important in developing a theoretical foundation to support the use of scale models in the design process. Scale models offer a wider range of sensory information, particularly tactile-kinesthetic input. Scale models may take advantage of the multiple coding of information and allow the clients to experience a fuller and more accurate sensory representation of three-dimensional space than is supplied by the use of simple two-dimensional drawings and specifications.

Tactile-Kinesthetic Basis for Spatial Perception and Conceptual Development

The following sections will address the tactile-kinesthetic theory for spatial cognition and the effects of tactile sensation and movement on the layperson's ability to understand spatial relationships.

Human beings began to navigate through the environment long before a spoken language was developed. Lakoff defines the relationship between the physical environment and concept development by explaining that “it is incidental to the nature of meaningful concepts and reasons that human beings’ have the bodies they have and function in their environments the way they do” (1987, p. xiii). Lakoff and Johnson (1980) state that metaphorical orientations are not determined by the whim of the individual but have foundations constructed from physical and cultural experiences.

Sheets-Johnstone (1990) further addresses the relationship between the conceptualization process of the human mind and the evolutionary process of the human body through anthropological research. For example, tactile-kinesthetic articulatory gestures and physiognomy are considered to be the beginning of spoken communication within the human species. These physical gestures have been correlated to the intellectual development of spoken language in non-literate societies.

Human beings have a strong physical basis from which conceptual foundations are developed. Therefore, designers must learn to take advantage of the knowledge base human beings have acquired through interaction with the spatial environment in order to enhance the design process.

<u>Sensory substitution</u>. Bach-y-Rita (1972) has further explored the realm of spatial information acquired through tactile-kinesthetic interaction with three-dimensional objects. A sensory substitution system allows blind subjects to receive and encode spatial information through tactile stimulation. The sensory substitution system operates through a television camera which relays points of reflected light from objects to the skin surface of the subject. With practice, the subjects are able to use the camera to scan objects and scenes and recognize the items which are in the tactile vocabulary of the subject.

Recognition time can be reduced to just a few seconds with practice. A further discovery is that the system can be moved from one area of skin to another without having to relearn the vocabulary. The research indicates, however, that object recognition and depth perception requires the active movement of the camera by the subject. When the camera is controlled by a researcher, the subject is unable to identify objects which were in the active vocabulary when they were controlling the motion of the camera. Another point is the special feature detectors associated with vision are not required to encode spatial information; the substitution system acts as a relay between the visual system and the brain (Lindsay and Norman, 1972).

Movement. Additional research emphasizes the importance of motion on the development of spatial cognition and perceptual development. The vestibular system is located in the brain stem and proper development of this system is crucial to the fetus' earliest perceptual abilities (Restak, 1979). Vestibular stimulation has been proven to result in earlier vision and hearing development. Movement is required for these developmental processes and, ultimately, to aid in the evaluation of sensory information received by the brain.

Held and Hein (1963) discovered that motion and active exploration of the environment was paramount to the development of perceptual abilities in cats. Kittens were reared in total darkness; one kitten was allowed to explore the environment while the other kitten was moved through the space in a basket through a pulley system attached to the roaming kitten. Only the kitten who was allowed to explore developed normal perceptual abilities.

Landau, Spelke, and Gleitman (1984) investigated the spatial knowledge of a congenitally blind child in order to determine if the knowledge was gained only through visual sensory input or if a spatial system of knowledge was inherent within human beings and amodal in nature. The child was able to make inferential decisions based on specific path knowledge in a variety of tasks when allowed to actively explore the environment. The researchers determined the subject was not successful at navigating the space and locating landmarks in instances when the child was carried through the space by a researcher.

The use of scale models may allow the client to experience a tactile-kinesthetic relationship with the three-dimensional space prior to its construction. Scale models can provide kinesthetic information which is not received during a design process which implements only two-dimensional drawings and specifications.

Media Representations And Responses To Architecture

Many studies have been conducted in order to determine which media produces responses most similar to the actual environment. Frequently, these comparisons address the subjective responses to attributes and seldom examine the conceptualization of spatial relationships. The media (most frequently black and white or color film, black and white or color photographs, slides, holograms, and renderings) emphasize the visual components of the the spatial environment and do not address haptic or kinesthetic experiences.

Howard, Mlynarski, and Sauer (1972) compared the subjective responses between real environments, both exterior and interior viewpoints, to slides of the environments.

The research indicated that the responses to the slides, both black and white as well as color, were slightly less extreme than responses to the actual environment. The research did not address how well the media communicated spatial relationships.

Seaton and Collins (1972) investigated subjective responses to buildings as represented by the actual facility, color photographs, black and white photographs, and three-dimensional scale models. The buildings were scored consistently across presentation types and the actual facility. The factors included such items as "appealing" and "tidy" and again did not address spatial relationships.

Hershberger and Cass (1972) compared the evaluation of built environments with a variety of media ranging from colored slides (singly or in series), photographs (black and white and color), and video-tape. The research determined that various media result in a range of evaluations: photographs were more accurate in communicating spatial relationships while single or multiple colored slides were more accurate in attribute evaluation.

Canter, Benyon, and West (1973) have investigated whether or not the mode of presentation, a black and white slide or a hologram, influenced the perception of size or friendliness of an architectural structure. Their results indicate that while dimensions such as height and width were affected by the order of stimulus type and not the actual representation technique, qualities such as depth and friendliness were judged to be "more real" and less sparse when evaluating the hologram (Canter, Benyon, and West, 1973, p. 637).

In an effort to establish accurate responses on subjective response questionnaires, Danford and Willems (1975) compared the responses of subjects to a colored slide display and the real environment. The replies were consistent across all descriptors. The adequacy of various media representations of environments must be verified through comparison to an actual environment in order to obtain validity. While this research further establishes the range of subjective responses to presentation media, spatial relationships were not investigated.

Dalholm and Rydberg-Mitchell (1992) compared two-dimensional drawings, scale models, and full size environments in an effort to determine which tool enhanced communication between laypeople and architects. Their observations suggest that drawings communicate spatial organization but not relationships both when drawn by and presented to the layperson. Scale models and full size environments indicated volume and functions more clearly than drawings. The limitations of the full scale mockups were noted and the multimedia approach was recommended during the design process. The study did not attempt to measure the accuracy of the media but focused instead on qualitative analyses of observation.

The use of video computer imaging is becoming more common-place and requires careful evaluation in order to determine if it is as accurate in the representation of the built environment as purported. Sirikasem and Shebilske (1991) evaluated the responses of spatially naive subjects to manual renderings, computer generated renderings with single or multiple viewpoints and computer animation. Results indicated that while animation yields the highest subjective ratings by laypeople of all media tested, it also had the lowest accuracy for size and texture. This could be indicative of a lack of haptic-kinesthetic sensory input. These shortcomings were noted in comparisons of computer generated renderings with virtual environments. It is significant to observe the reliance required by a CAD-generated representation on "a single or even dominant sense" while virtual reality may appeal to the amodal sensory perceptual system of human beings (Ribarsky, Bolter, den Bosch, and van Teylingen, 1994, p. 10). Although virtual environments may provide a multi sensory interaction with spatial environments, other issues surrounding the use of virtual environments still render it far from capable of allowing the common man to sample an immersive experience. The still-crude and very expensive hardware required to experience such a world is still suffering from large lag times during generation of the scenes. Combined with learning curve required to operate such systems, use of virtual reality in an architect or designer's office is still ten years in the future (Mahoney, 1994).

Use of Scale Models in Behavioral Research

Finally, uses of three-dimensional scale models in previous research will be discussed. Two aspects of scale models or scale figures used in behavioral research will be addressed independently. The first consideration is the use of scale models and their accuracy and reliability in research. The second aspect is the temporal experience of time and the potential impact on the design process.

Accuracy of scale models in behavioral research. Edwards (1973) investigated the consistency in the orientation measures of dolls (human figures created from paper maché at the 1:12 scale) as well as distance placements when compared to anthropological observations during intra-cultural research. No significant variation was found.

Research has been conducted to determine the accuracy of scale models to the full size environment for applications in behavioral research (De Long, 1976). In a replication of a study conducted by Robert Sommer (1969), De Long discovered that subjects consistently shifted seating positions during a discussion of "an impersonal topic" at the same distance in both full-size and scale model environments. Accuracy of scale model research was confirmed in a later study (De Long, 1977). The relative accuracy has been compared in scale model environments and full size spaces between people seated in chairs. Subjects reported changes in their relationships to others seated in chairs at varying distances and with different orientations. The average difference was 6.3 % in spacing between full size and scale model environments. De Long suggests this is not likely an "error" factor since a variation of approximately 5% was recorded for the same spacing in repeated trials in full size spaces. These findings are consistent with those of Smith (1980); a study was conducted in both scale model and full size environments to determine the validity of scale model research. Statistical analyses indicated no significant variation between the two types of environments in placement conditions. A more recent study by Liberto (1990) involved the use of scale models in the design and redesign of residential spaces. After designing a satisfactory residence the client was told the square footage had to be reduced by approximately one-half. When this was completed, the client was once more asked to reduce the space by approximately one-half. The reliability of scale models was supported by the correlation of spatial arrangement and organization in Liberto's research to the previously defined proxemic zones of Hall (1966).

Experiential space-time relativity. A separate and substantial issue arises from the use of scale models to define spatial relationships. Spatial scale has been shown to be related to temporal experience, information processing, behavioral timing, and attention span in a series of studies (De Long 1981, 1983, 1985; De Long, Greenberg, and Keaney, 1986; De Long, et al, 1994; and Brickey, 1994).

De Long (1981) reported an interaction between space and time in which the scale of space mediates one's experience of time. Spatial compression, as experienced by the individual through a scale model or other reduced environment, was reported to be related to a proportional compression of the perceived passage of time. The formula, $E = x\ (T)$, where E = experienced duration, T = elapsed clock time, and X is the reciprocal of spatial scale was proposed. Thus, five minutes of elapsed time (T) should result in the observer experiencing 60 minutes (E) in a 1/12th scale environment ($x = 12$). In other words, a minute as it is experienced by the individual is compressed to 1/12th of the normal minute on the clock (De Long, 1981).

In an attempt to identify connections between scale, the experience of time, and information processing, research was conducted with subjects playing video games on a large (23") monitor and a small (7") monitor. Two independent samples confirm a 12 - 15% improvement in subjects who played games on the small monitor. Additionally, subjects reported the games on the smaller screens were of longer duration although the games were actually shorter in duration (De Long, 1983).

De Long, Greenberg, and Keaney (1986) examined the behavioral timing in lizards to determine if the effects of spatial scale on temporal experience occur on a basic level. Two novel environments with surface patterns that varied in visual and tactile scale were created; the small scale environment had sandpaper patches exactly 1/2 the size of the patches in the large scale environment. The latency period -- the length of time from the introduction to the novel environment to exploratory behavior -- was measured. The animal's latency period was twice as long in the large scale environment as that in a small-scale environment. Dividing the length of the latency period in the large environment by the latency period in the small environment resulted in a ratio of 1.91; the hypothesized value was 2.0 (De Long, Greenberg, and Keaney, 1986, p. 340).

In a subsequent study, De Long, et al. (1994) applied the same logic to the play behavior of children, reasoning that if reduced spatial scale compresses temporal experience (relative to the clock) placing children in smaller environments should speed up their experience of time. If the hypothesis is true, then the compressed spatial scale should result in the children entering complex forms of play more quickly and having a longer attention span. Children studied under conditions of the normal environment and a scale-reduced environment were found to enter complex forms of play faster and exhibit evidence of increased attention spans, engaging in play segments longer under the scale-reduced condition.

Further research addressed the effects of different surface pattern scales on the attention span of children (Brickey, 1994). Similar to the earlier lizard study, the scale of the surface pattern was manipulated. Evidence of increased attention span, defined as play segment length, was found under the smaller pattern scale condition.

These studies are suggestive of several things. First. there appears to be a strong relationship in behavior and spacing between scale models and full size environments.

Second, the experiential space-time relativity studies suggest an alteration in temporal experience, behavioral timing, and information processing as well as an alteration in attention span. Third, De Long has reported that scale model environments facilitate a "remembering" of behavior that is often out-of-awareness because of the enriched spatial contexts the models provide.

By reducing the scale of the environment through the use of scale models, subjects may experience an improved level of information processing and by experiencing a condensed perception of time may actually become immersed in the environment and the task more quickly and more effectively.

CHAPTER 3

Methodology

Subjects were given two basic tasks separated by a latency period to determine if scale models permit users to more accurately comprehend and evaluate spatial relationships than two-dimensional drawings relative to the full size environment. This chapter describes the procedures used in the study. The following sections include the sample selection, pilot study, materials developed for the representational environments and the full size environment, and data collection procedures for the experiment. The final section will outline the methods of analyses.

Sample

The study population consisted of a convenience sample of acquaintances and students of the primary researcher. The age range was 18 to 39 and the median range was 25.2 years. There were a total of three groups with 12 to 14 subjects per group; the demographic information of each group is summarized in Table 1. Groups were stratified on the basis of gender and age with the age categories defined as 18 to 22 years of age (college student), 23 to 29 years of age (young professional), and 30 to 39 (professional). The stratification was determined to equalize the effects of maturation and life experiences between groups. Subjects were excluded on the basis of past or present education or employment in the fields of mechanical drafting, architecture, interior design or engineering as it may be assumed that skills taught in these fields may affect the ability to

Table 1. Demographic Information as Stratified by Age and Gender

Group	Mean Age	Female	Male
I	24.8	6	6
II	23.6	7	5
III	26.2	8	6

interpret two dimensional drawings. Subjects were limited to Caucasians of North American origin due to potential cultural differences in the conceptualization and use of three dimensional space (Hall, 1966).

Subjects completed a questionnaire which included name, gender, date of birth, country of origin and any past or present education or experience in the fields outlined above during Phase One of the experiments.

Pilot Study

A pilot study was conducted to identify areas which required clarification prior to the beginning of data collection. The study population (n = 9) consisted of a convenience sample of the researcher's acquaintances. The activities described below were presented to the subjects. Following the experiment, the researcher gathered input on the wording, amount of detail, gender identification of the "friends" in the activities, and ways in which to facilitate interaction with the two and three dimensional apparatus. The procedures were adapted following the pilot study in order to reduce ambiguity and to improve contextual understanding by the subjects.

Materials

Two dimensional drawing, furniture components and scale figures. The floor plan of the space was drawn on a sheet of 20" x 30" white Bristol board in black ink. The scale used was 1/4" = 1'0". Standard drafting conventions for doors, windows, stairs and walls were used. No written or bar scale was included on the drawing. The presentation was designed to most closely emulate the actual format of presentation floor plans in the field during facilitated presentations with clients. The generalizability of the results demand replication of the actual design process, including the scale and materials of the presentation materials, as closely as possible (Plate 1).

The floor plan furniture components and were drawn on light-weight chipboard in a neutral color (Plate 2). These components were trimmed to their outer edge so that the

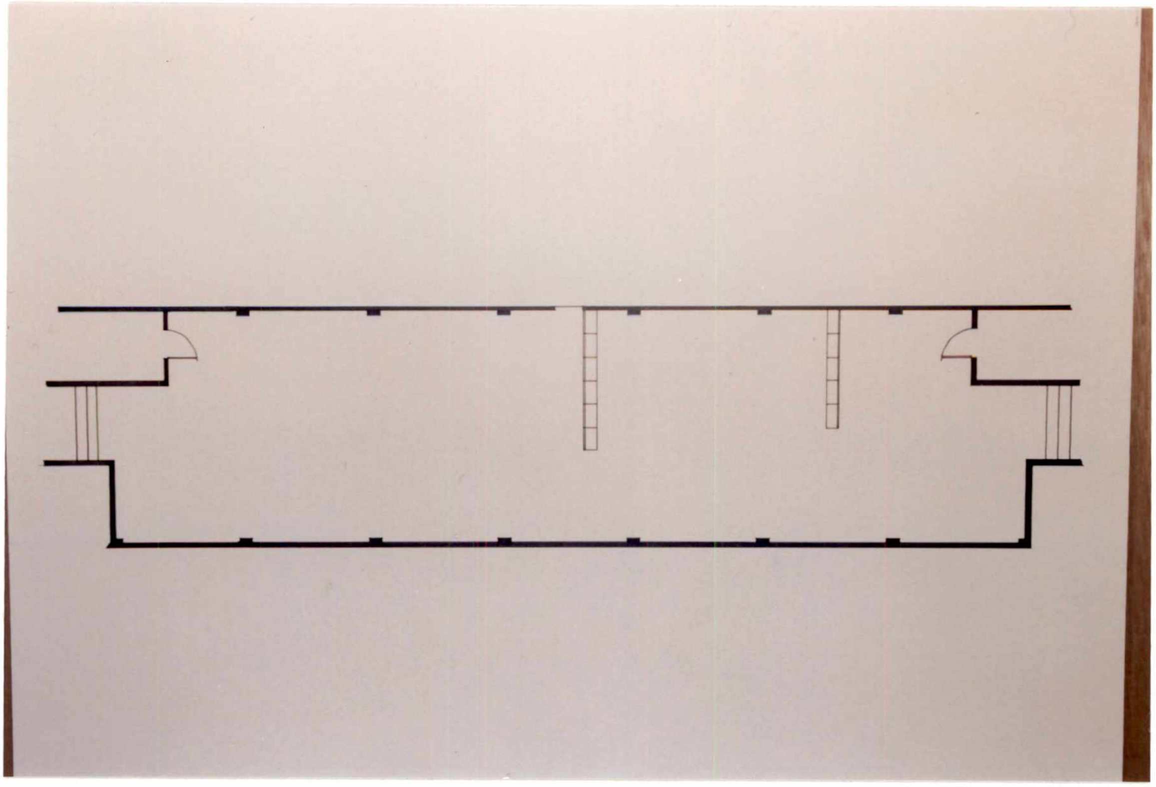


Plate 1. Photograph of Two Dimensional Drawing

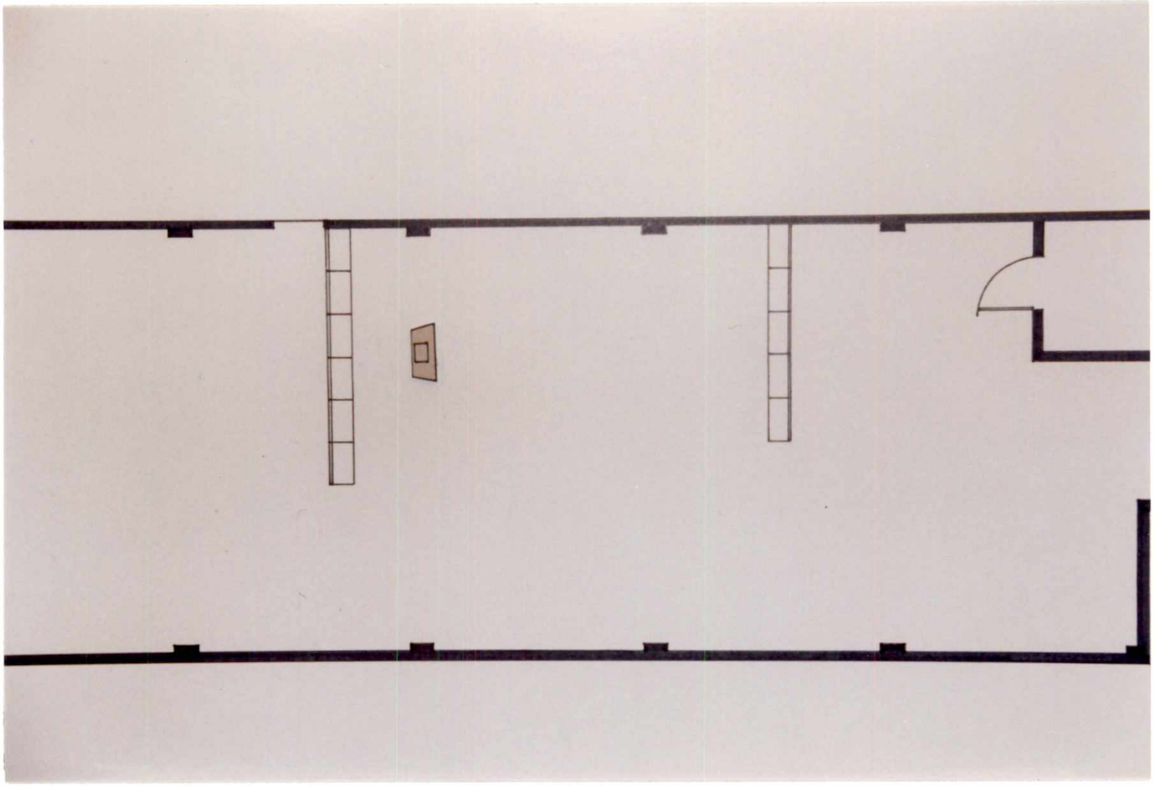


Plate 2. Photograph of Two Dimensional Drawing with Two Dimensional Furniture Components.

subjects were able to position the components on the plan. The outlines and detail were drawn in black ink. Attention was given to replicating the contours of the actual furniture components. The plan views of the human figures were based upon information provided in Human Dimensions (1976).

Three dimensional scale model, furniture components, and scale figures. The base of the model was constructed of 1/2" Styrofoam with the walls and partitions constructed of corrugated cardboard. The furniture items were constructed of neutral chipboard (the same material from which the two dimensional components were constructed) and unstained basswood (Plate 3). Attention was given to replicating the contours and actual volume of the upholstered furniture components. Scale figures were constructed of the

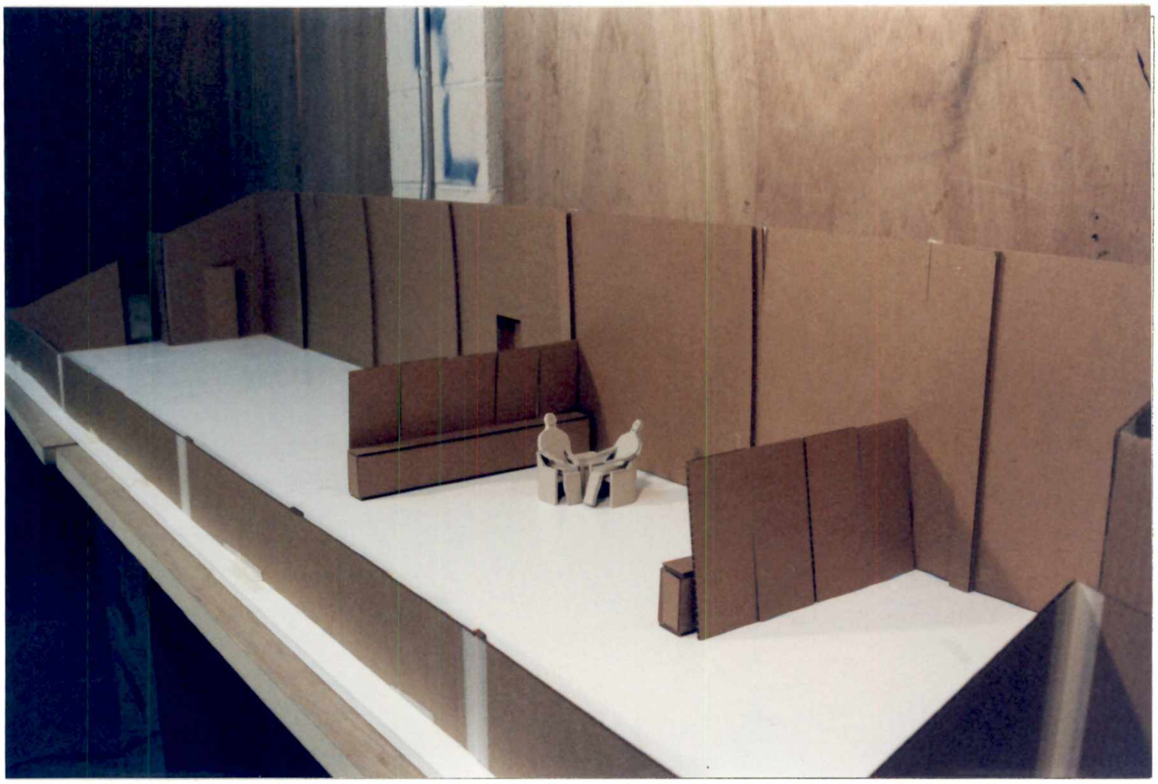


Plate 3. Photograph of Three Dimensional Scale Model with
Scale Figures and Furniture Components.

same chipboard and sizes were based upon data included in Human Dimensions (1976). The figures were flexible at the upper arm, hip and knee areas which allowed them to be placed in a sitting position. Two figures of each gender were provided to fulfill the requirements of the scenarios.The scale of the model was 1" = 1' - 0". Accuracy of spatial relationships in behavioral research has been compared between scale models and the full size environment at this scale (De Long, 1976, 1977).

Full Scale Environment

The study was conducted in a space within Stokely Athletic Center on the University of Tennessee Knoxville campus (Plate 4). The space was approximately 25' 0"

Plate 4. Photograph of Full Size Environment Arranged for Data Collection

x 84' 0" with a sloped roof (the peak was located at 14' 0" on one side of the space and dropped to approximately 5' 0" on the other side). The floor was an uncovered concrete slab and the walls were of exposed concrete block. One window was located in the center of one wall and measured 9" x 9". The actual research space did not include the area with the window; therefore outdoor conditions could be determined to have minimal impact on the study .

The experiment occupied only one-half of the available space. The front portion of the area was used to conduct the scale model and drawing portions of the experiment and the adjacent area was used for the full size environment. Because the entire experiment was conducted in a single space, the lighting, acoustical, and thermal levels were consistent between all phases and activities. Metal file cabinets and unfinished doors were used as dividers between the two research areas and the remainder of the space. This allowed the researcher to prevent the subjects from viewing the full size environment prior to exposure and to maintain consistent exposure between subjects. The dividers also allowed the portion of the area, including a small window, not used for the experiment to be screened from view. This area was used for storage of the furniture components used in the full size activities when not in use.

Experimental Procedure

Different conditions were developed in order to determine if there were differences in the ability of the layperson to understand spatial relationships in the full size environment based upon the media representation employed.

Three groups participated in a two-phase experiment. The phases were separated by a three to four week latency period. There was a change in the setting and the task in order to prevent test-retest sensitization. The order of the conditions was altered between groups in order to determine if a learning effect was present. Each subject encountered the scale model condition and one of the drawing conditions.

<u>Scale model lounge followed by full size lounge</u>. The subject was asked to listen to a familiar scenario about having a discussion with a friend a lounge setting. The subject was then asked to place lounge chairs in a comfortable relationship in the scale model environment based on the scenario (Plate 5). The subject was then introduced to the full

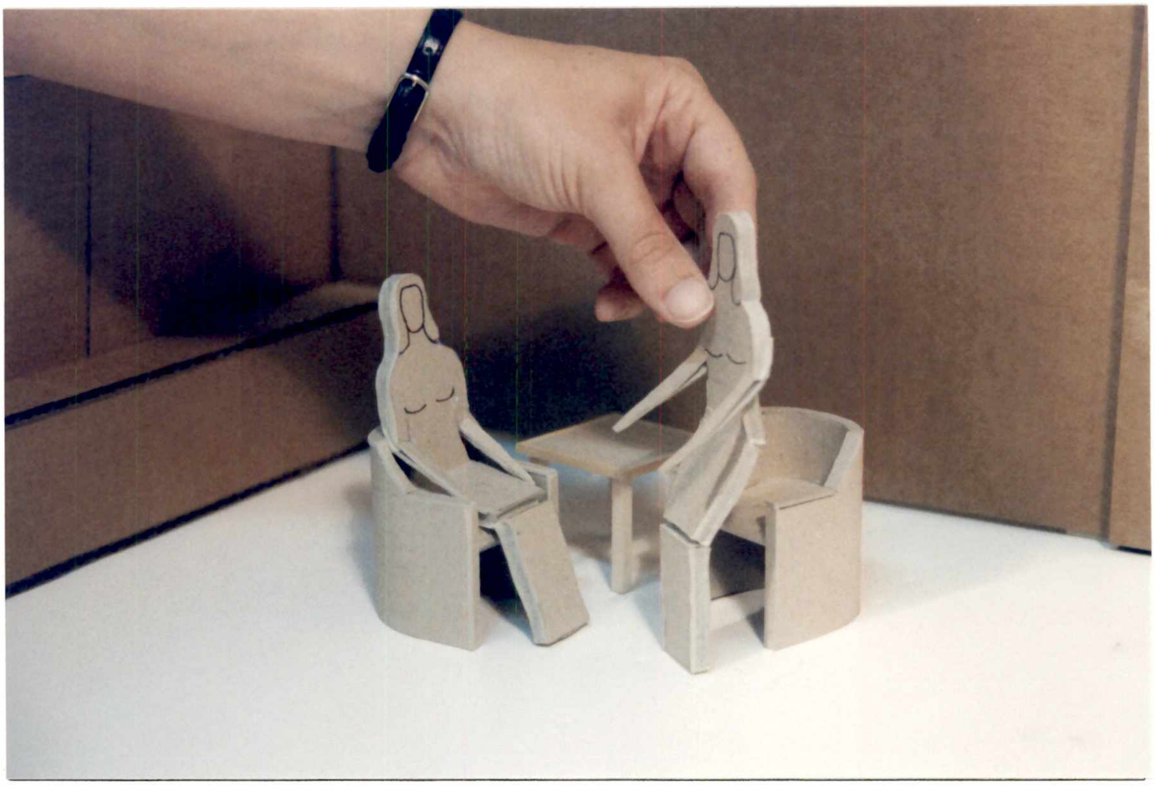


Plate 5. Photograph of Subject Defining the Spatial Relationship in the Scale Model Environment.

size environment and asked to create the same relationship using the full size components (Plate 6). Several questions about the perceived sizes of the different environments were asked by the researcher.

The materials used in this condition included the scale model of the full size environment, scale model and full size furniture components including two lounge chairs, one corner table, two scale figures of the appropriate gender, the script for the Lounge Scenario (Appendix A) and the questionnaire (Appendix D).

2D drawing class room without scale figure followed by full size class room. The subject was asked to listen to a familiar scenario about sitting in a class room with about 50

Plate 6. Photograph of a Spatial Relationship as Defined
In the Full Size Environment.

other students. The subject was then asked to imagine him or herself in the front row of the class room and to place a desk at a comfortable distance from the instructor's podium using the drawing (Plate 7). The subject was then exposed to the full size environment and was asked to create the same relationship using the full size desk and podium (Plate 8). Several questions about the perceived sizes of the different environments were asked by the researcher.

The materials used in this condition included the floor plan drawing of the full size environment, two-dimensional and full size furniture components including the instructor's podium and class room desk, the script for the Class Room Scenario

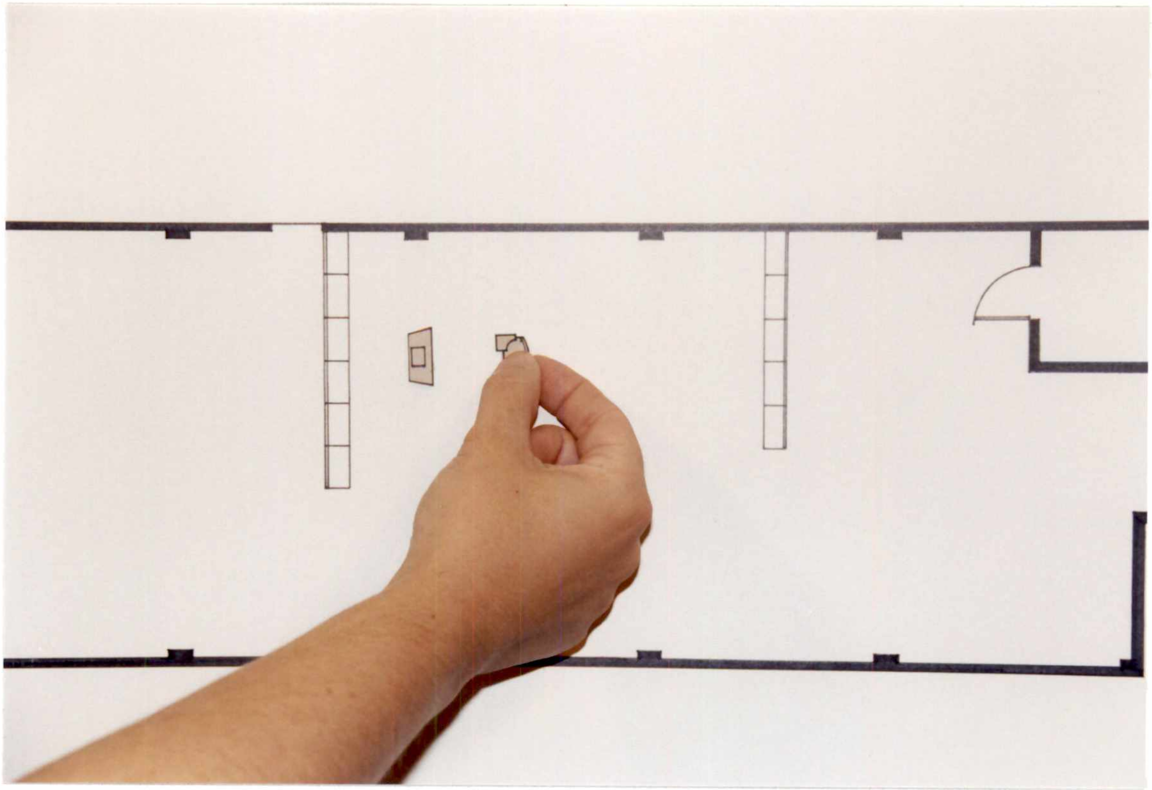


Plate 7. Photograph of Subject Placing Desk at a Comfortable Distance from the Podium in the Drawing Environment.

Plate 8. Photograph of Subject Placing Desk in the Full Size Environment.

(Appendix B), and the questionnaire (Appendix D).

2D drawing class room with scale figure followed by full size class room. This condition was identical to the 2D Drawing Class Room condition with the only exception being the use of plan view scale figures in the drawing environment (Plate 9). Additional materials included the scale figures and the script for the Class Room Scenario with Figure (Appendix C).

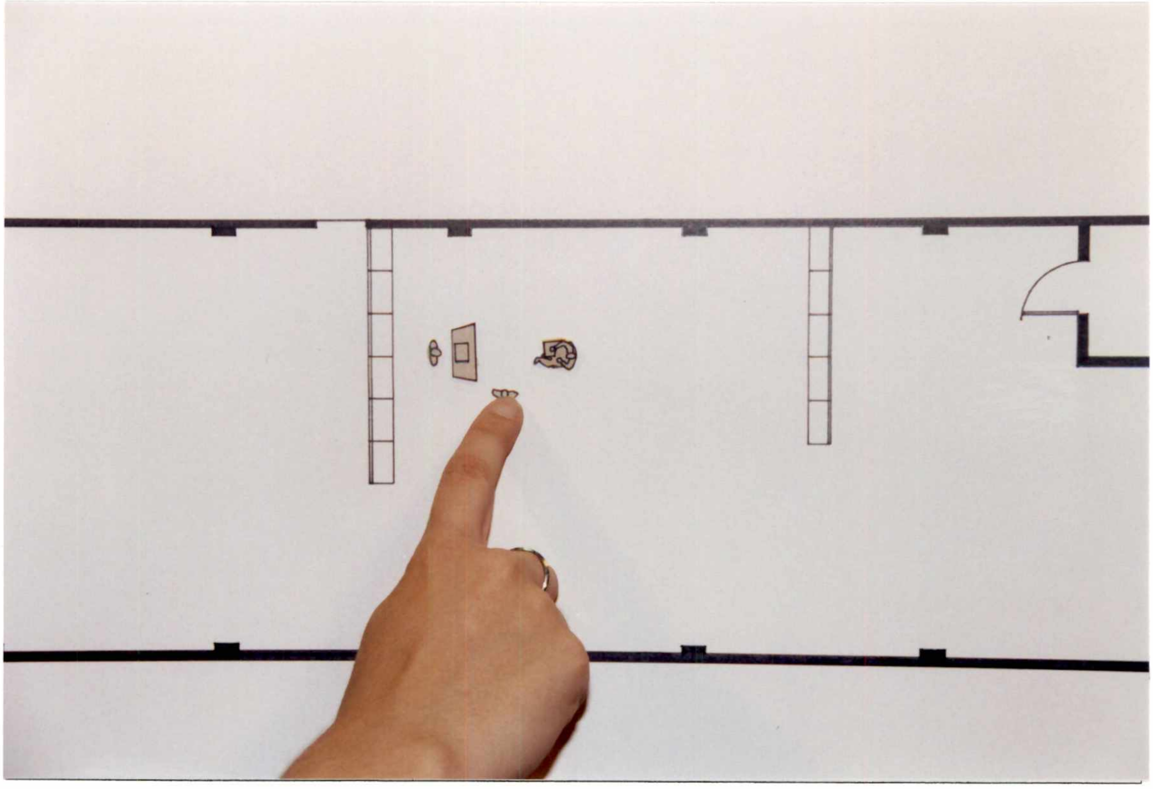
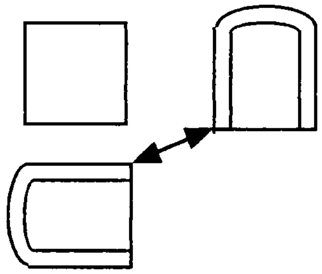


Plate 9. Photograph of Subject Placing Desk at a Comfortable Distance from the Podium in the Drawing Environment Using Scale Figure.

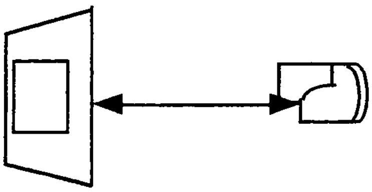
Condition sequence. The order of the conditions was altered in order to determine if a test-retest learning effect was present. Following is an illustration of the sequence of the conditions for each of the three groups in the experiment. The two conditions are identified as A (Phase I) and B (Phase II):

	Condition A	Condition B
Group I	SM Lounge ▷ FS Lounge	2D Class ▷ FS Class
Group II	2D Class ▷ FS Class	SM Lounge ▷ FS Lounge
Group III	2D Class w/ Figure ▷ FS Class	SM Lounge ▷ FS Lounge

Measurements. In the lounge setting, the distance between the lounge chairs were measured from the two most adjacent front corners of the chairs in the scale model and



the full size environment. The scale model environment was measured using an architect's scale at 1/4" = 1' - 0" and the full size environment was measured using a



25' - 0' tape measure at full scale. In the class room setting, the distance was measured from the front center point of the instructor's podium to the front center point of the seat on the student desk (Figure 2). The two dimensional environment was measured using an architect's scale at 1/4" = 1' - 0" and the full size environment was measured using a 25' - 0' tape measure at full scale.

Data Analysis

Analysis was completed using Statview on a Macintosh IIci. The two-sample t-test and the paired-sample t-test were used to compare the means between groups concurrently with Fisher's R - Z transformation to determine the strength of the relationships between the measurements in the representational environments relative to the measurements in the full size environment. Qualitative analysis of the subjects' responses to the questionnaires was used to determine if subjective responses to the environment reflected the qualitative trends.

CHAPTER 4

Results

The original population for the experiment was comprised of three groups consisting of 42 individuals. Four subjects were dropped from the study population; a plot of the data indicated they fell outside of the normal distribution. A review of the notes recorded during the data collection process indicated these individuals changed orientation between the representative environment and the full size environment or exhibited other unusual behavior. The resulting sample size was 38; a total of 81 percent of the study population completed both phases of the experiment

It will be recalled that each subject encountered two conditions in reversed order: scale model followed by full size and drawing followed by full size and the order of presentation is illustrated below. The two conditions are identified as A (Phase I) and B (Phase II).

	Condition A	Condition B
Group I	SM Lounge ⊳ FS Lounge	2D Class ⊳ FS Class
Group II	2D Class ⊳ FS Class	SM Lounge ⊳ FS Lounge
Group III	2D Class w/ Figure ⊳ FS Class	SM Lounge ⊳ FS Lounge

The two primary hypotheses for the present study, as stated earlier, are as follows:

H1: Differences will be found between spacing in the representational conditions as compared to their respective full size conditions.

H2: Differences will be found in the accuracy of the various types of representational media relative to the full size environment.

Testing for Group and Order Effects

Initial analysis was conducted to determine if the order of presentation (drawings preceding models or models preceding drawings) exhibited any effects on the second phase of the experiment. Unpaired t-Tests were performed on the actual measurements in inches to determine if spacing differed for the scale model and drawing conditions based on first (A) and second (B) exposures. Results indicate no statistically significant differences based on order, as shown in Table 2.

Table 2. Results of Unpaired t-Tests for Order of Exposure
(Actual Spacing Measurements in Inches)

Environment	Order	Mean Diff.	DF	T-Value	P-Value
Scale Model Lounge	A - B	1.425	32	0.313	0.7566
Full Size Lounge	A - B	-4.167	31	-0.834	0.4108
Drawing Class Room (No Figure)	A - B	-3.683	20	-0.484	0.6335
Full Size Class Room	A - B	-2.200	20	-0.233	0.8179

The second test was to determine if the three sample groups exhibited any differences across similar conditions. Unpaired t-Tests were performed for the various conditions across groups based on spacing measurements in inches. No statistically significant group effects were discovered as can be seen in Table 3.

The lack of order or group effects indicate the data for the various conditions can be combined for further analysis. This was done for the remainder of the analysis.

Table 3. Results of Unpaired t-Tests for Group Effects
(Actual Spacing Measurements in Inches)

Environment	Groups	Mean	DF	t-Value	P-Value
Scale Model Lounge	G1/G2	5.200	20	0.933	0.3619
	G1/G3	-0.3182	21	-0.619	0.5424
	G2/G3	-8.382	19	-1.466	0.1590
Full Size Lounge	G1/G2	0.627	19	0.118	0.9073
	G1/G3	-6.182	20	-1.092	0.2879
	G2/G3	-6.182	19	-1.002	0.3291
Drawing Class Room (No figure)	G1/G2	5.639	19	0.721	0.4794
Full Size Class Room	G1/G2	3.778	19	0.384	0.7055

Testing for Variation between Representational Media and the Full Size Environment

Paired t-Tests were performed to determine if differences existed between spacing in the representational conditions as compared to their respective full size conditions. Spacing is defined as the distance between the furniture components measured as described in Chapter 3.

Analysis indicates there is no statistically significant difference between scale model spacing and full size spacing or between the drawing condition with a scale figure and its full size counterpart. There is a statistically significant difference between spacing in the drawing condition with no figure and it's full size counterpart, however. The results are summarized in Table 4. These results also reflect the trend that subjects tend to increase the spacing in the full size environment after completing the same task in the drawing conditions. Further analysis of the ratios of relative accuracy which is described below provide additional information on this trend.

Table 4. Results of Paired t-Tests for Spacing between Representational Environments and the Full Size Environment (Actual Spacing Measurements in Inches)

	Condition	Mean Diff	DF	t-Value	P-Value
Lounge	Scale Model - Full Size	1.879	32	1.272	0.2127
Class Room	Drawing w/ Figure - Full Size	-8.500	13	-1.908	0.0787
Class Room	Drawing w/o Figure - Full Size	-17.409	21	-5.476	0.0001

Testing for Relative Accuracy between Types of Representational Media

Paired t-Tests were performed to determine if there were differences in the accuracy of the various types of representational media relative to the full size environment. A ratio was used for this analysis and was calculated as follows:

Measurement in the 2D or 3D Environment ÷ Measurement in the Full Size Environment

Dividing the model and drawing measurements by the full size measurement yields a ratio indicating the degree to which spacing behavior and perception is accurate as compared to the full scale environment. The ratio will be 1.0 if the spacing is identical under both conditions. A ratio of less than one indicates an underestimation of spacing (the furniture components will be placed closer together in the drawing or model environment than in the full size environment) where as a ratio greater than one indicates an overestimation of spacing (the furniture components will be placed further apart in the drawing or model environment than in the full size environment).

Mean ratio values are 1.11 for the scale model to full size condition, 0.87 for the drawing with figure to full size condition, and 0.80 for the drawing without figure to full size condition.

Paired t-Tests were performed to determine if there were significant differences between the ratios of the different media tested. The results of the paired t-Test between the scale model/full size ratio and the drawing without figure/full size ratio are significantly different [$T(17) = 2.695$, $p \leq 0.0153$]. The paired t-Test between the scale model/full size ratio and the drawing with figure/full size ratio are also significantly different [$T(10) = 2.483$, $p \leq 0.0324$]. There is no significant difference between the drawing with figure/full size ratio and the drawing without figure/full size ratio [$T(34) = -0.795$, $p < 0.4324$].

The results indicate the relationships in spacing are stronger between the scale model and full size environment than between the drawing and full size environment, with and without the use of a scale figure. Systematic differences are further illustrated when the Fisher's R to Z transformation is considered (Table 5). All correlations between spacing under scale conditions and their respective full size conditions are significant as shown below; the correlations indicate that measurements between the representational media and the full size environment are consistent with one another in the amount of variation and relative accuracy. There is no significant correlation for the different conditions across subjects, however; this suggests that you could not use drawings and extrapolate what would happen if you used models or vice versa. In other words, the responses from one type of media can not be used to predict what the subject will do when interacting with another type of media.

Table 5. Fisher's R to Z Transformation Based on Measurements (in Inches) in Scale and Full Size Conditions

	Correlation	Count	Z-Value	P-Value
Scale Model - Full Size	0.793	33	5.907	0.0001
Drawing w/ Figure - Full Size	0.599	14	2.292	0.0219
Drawing w/o Figure - Full Size	0.726	22	4.011	0.0001

Follow Up Questions

A series of questions were asked upon the completion of each phase of the experiment. These were intended to discover if the scale representations of space seemed to differ from the full size space. In particular, the intent was to find out if the full size space seemed larger or smaller than the scale representation of the space if differences were perceived to exist.

Chi-square analyses were performed to determine if any order or group (sample) effects were evident. The responses to the question "Was the space the same or different?" was analyzed across groups and order. There were no statistically significant differences based on the type of representational media or the order of the conditions; this indicates there was no consistency in whether or not the subjects felt the full size space was the same or different based upon the group or sequence of conditions.

Groups II and III were then combined for further analysis since these were the groups that first experienced the drawing representations of the space. This was done in order to determine if the actual differences in spacing were in concert with how the subjects' reported their perceptions when they did feel the space was different; for instance, were smaller distances (than in full size) in drawings versus slightly larger distances (than in full size) in scale models consistent with the responses to the questions. The reversal of scale model and drawing conditions allow a more strict statistical analysis. If full size environments are perceived to be larger relative to scale models and smaller relative to drawings then the follow up questions should exhibit a particular pattern; namely, there should be a reversal in cell frequencies between conditions A and B between group I and the combined groups II and III since the presentation order of models and drawings is reversed between them.

The chi-square analysis indicates there is a significant difference in the response patterns for scale model and drawing conditions ($p = 0.0035$) when subjects report a perceived difference in the full size environment relative to the representational media. Response counts for the two conditions are summarized in Tables 6 and 7.

Table 6. Response Counts for Condition A

In what way are the spaces different?		
	Group I Scale Model	Group II and III Drawing
Bigger	4	2
Smaller	1	14

Table 7. Response Counts for Condition B

In what way are the spaces different?		
	Group I Drawing	Group II and III Scale Model
Bigger	1	6
Smaller	5	4

The reversal of response is clear between conditions and phases. The subjects consistently respond that the full size space seems bigger than the scale model, regardless of which phase the model condition was experienced. The same consistency is also observed in the drawing conditions; the full size space seems smaller than the drawing regardless of the phase the drawing condition was experienced.

CHAPTER 5

Conclusions

There are important issues in the research findings. The first issue is the strength of the relationship between spacing in the scale model to the full size environment. The results indicate that scale models allow laypeople to understand and evaluate spatial relationships more accurately than two dimensional drawings. Additionally, the difference in the subjective responses to the two types of representations and the full size environment will be considered along with the spacing relationships in order to develop a line of reasoning for the trends. The third issue addresses the potential of scale figures used in conjunction with drawings to improve the spatial cognition of laypeople during the design process by more accurately communicating spatial relationships and enhancing orientation. Finally, the validity of scale model research and its impact on the design process is discussed.

Spacing Relationships Between Representational Media

From the findings that the scale model representation allows subjects to create more accurate relationships when compared to the two dimensional drawing representation, it is logical to assume that the use of the scale models may allow clients to define more accurate spatial relationships during the design process. In observing the subjects' levels of interaction with the different types of representation, the scale model environment appeared to facilitate a higher level of involvement when compared to the drawing environments. This generally meant that the subjects tested a larger number of possible solutions prior to reaching one which was satisfactory. By allowing more accurate relationships to be created and by allowing more relationships to be tested, the final solution may result in a higher level of acceptance and satisfaction by the client.

While the differences in the subjective perceptions about the different sizes of the environments may appear to be of little practical use to individuals in the design profession, there may be significant issues at stake. The review of some of the typical design methodologies reflected the inherent difficulties in the exchange of information between the design professional and the client. The client's perception of the design solution may be affected by the type of representational media implemented during the design process; a better understanding of those perceptions may allow the presentation to be tailored to more accurately communicate spatial relationships.

The reason(s) for the precise reversal of subjective responses to the perceived sizes of the space is not known. Following are several hypotheses have been created but require further testing to determine the potential validity of each:

1. The response that the full size space "feels smaller" than the drawing may be due to the consistent underestimation of spacing (the furniture components placed closer together in the drawing than in the full size environment), i.e. the fact that the furniture is placed further apart in full size makes the full size space feel smaller by comparison with the drawing.

2. The opposite would then hold true for the scale model and the consistent overestimation of spacing (the furniture components placed further apart in the scale

model than the full size environment), i.e. the fact that the furniture is placed closer together in full size makes the full size space feel larger by comparison with the scale model.

3. The amount of enclosure experienced by viewing the model as compared to the lack of enclosure when viewing the drawing may also account for the differences. Research with varying amounts of enclosure may provide additional insight.

4. The darker value of the "walls" in the scale model may create the appearance of a larger space as compared to the actual finishes of the experimental site.

5. Past research indicates that the more information one has concerning his or her environment, the smaller the environment feels (Ornstein, 1969; De Long, 1983); this may result in the trends in the subjective responses.

The accuracy of the representational media has a potentially large impact on the resulting design solution. The compression of scale may allow an enhanced level of information processing which facilitates a higher level of understanding of the spatial relationships and the behavioral implications in a reduced time frame. This enhanced information processing may also improve the relative accuracy of the relationships as defined by ratio between the scale model and the full size measurements and the strength of the correlation between the measurements. Improved understanding of the spatial relationships and the ability to experiment with possible solutions could result in fewer change orders after an environment is constructed.

Use of Scale Figures in Representational Media

The use of figures in drawings is generally limited to scale figures in perspective drawings or sections. The use of scale figures in the scale model is the normal mode of interaction. The findings resulting from the implementation of plan view figures may provide a foundation for future research. The human figure, in even a two-dimensional format, allows the space to be experienced in a kinesthetic manner and may provide information about spatial relationships which would not be gained through the use of other types of representation. The figure allows the scale of the two different environments (representational and full size) to be filtered out and permits the individual to interpret spatial relationships relative to their body.

The results indicate there is no significant difference between the actual measurements in the plan view with the figure and the full size environment. This shows that the use of the scale figure in the floor plan allowed the subjects to create more accurate relationships than the floor plan alone. It was further observed that subjects using the scale figure become more involved with the plan than those subjects who do not use a scale figure; this is again indicative of an increased level of experimenting with potential solutions. The individuals who did not use scale figures were also observed to orient the student desk incorrectly (either sideways or backwards) 63% of the time. An additional 28% of the subjects not using the scale figure questioned the researcher about orientation. The subjects using a scale figure oriented the desk correctly 100% of the time.

The human body as a reference point has been discussed in terms of cognition, intellectual evolutionary development, and tacit knowledge. The impact of movement on spatial cognition has been illustrated to be required for normal perceptual development. The use of the scale figure allows the individual to develop a reference point which may be moved about in the spatial environment regardless of the representational media implemented. The scale figure allows a scale relative to the human body to be developed so that items can be properly arranged in the spatial environment.

The Impact of Scale Models on the Design Process

De Long (1976, 1977, 1978), Smith (1980), and Liberto (1990) have demonstrated the reliability of scale models in behavioral research. The perception of the passage of time has been demonstrated to be altered by spatial compression and variation of pattern scale (De Long 1981, 1983, 1985; De Long, Greenberg, and Keaney, 1986; De Long, et al. 1994; Brickey, 1994). This study attempts to place the scale model into the more common design process.

Previous research leads one to the conclusion that subjects may become more alert and experience a higher level of information processing when interacting with scale models. Individuals becoming more quickly involved in the task is illustrated by the effects of pattern scale on latency periods as well as the play behavior of children. The increased attention span and improved scores on simple games in a reduced scale environment indicates the scale model may allow spatial relationships to become more accurately defined through improved concentration. The compression of the temporal experience may also allow the relationships appropriate to the context to be enacted in a reduced amount of time.

De Long (1978) discusses the effects of context on behavior which results in the subject expressing an appropriate relationship. The subject is able to express an appropriate relationship when the context is provided. When the context is inconsistent or "overstructured" the subject is unable to reconcile the behavior with the relationship (De Long, 1978, p. 360). The scale model allows the context to be more fully interpreted by the subject by allowing the tacit knowledge to be released or communicated through interaction with the environment. These behaviors are illustrated through the observation of subjects interacting with the model and subsequently with the full size environment. The subjects will act out the scenario using the scale figure, such as leaning over the back of the chair to greet their friend prior to being seated, which is then duplicated in the full size environment. The "acting out" of behaviors is releasing the subject's knowledge in a non-verbal, out-of-awareness manner which is not available in a design process where the information is being elicited only in verbal formats.

These premises may be combined to illustrate the resulting impact and enhancement on the design process. Following are possibilities which may be realized through a modified design process:

1. The amount of time spent in the design process may be reduced by decreasing the lag time between the presentation of the solution and subsequent corrections by the designer and by allowing immediate evaluation to occur by the actual user.

2. By experiencing an enhanced ability to define and evaluate spatial relationships through the use of scale models, laypeople may be able to help the designer create solutions which are more appropriate to their needs.

3. By allowing more appropriate solutions to be developed, there may be a reduction in change orders and subsequent down-time after occupancy for designed facilities.

4. By allowing tacit knowledge to be expressed, previously unexplored behavioral issues may identified and resolved prior to occupancy, enhancing employee satisfaction and productivity.

5. A more comprehensive understanding of the behaviors and relationships by the design professional may result by allowing the context in which the subject is being asked to express a particular relationship to be quickly and easily altered by the designer (De Long, 1978).

Future research will be required to verify these premises. The accuracy of spatial relationships expressed through two dimensional drawings with and without the use of figures must be further tested. The drawing scale must also be manipulated to determine if there is a relationship between scale and accuracy. The scale of the drawing is assumed to be irrelevant to the level of accuracy. This premise is developed on the basis that it is the amount of information relayed through the representational media that has the largest impact on accuracy and not the size of the representation.

The review of literature and the analysis of the results indicate that scale models possess qualities which may enhance the spatial cognition of laypeople and allow tacit knowledge to be more accurately communicated during the design process. To date, scale models are the only type of media commonly available to designers which offer this array of sensory information.

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APPENDICES

APPENDIX A

To be used with the Scale Model.
Lounge Area with Friend

Subject will be greeted upon arrival and invited to have a seat at the table where the forms can be filled out. The full scale environment will not be visible from this area.

Before we get started, I want to explain a little about what we are going to do. The material will be read in order to insure that each person receives the same amount of information about the exercise. Right now, I can not tell you exactly what we are studying because we do not want that knowledge to influence your responses. When the study is complete, we will send an outline of what we are hoping to discover in order to help you understand what you are doing today.

First, this is not a test and there are no right or wrong answers to what I am going to ask. The only thing that is important is the way that you feel and what makes you feel the most comfortable. You may make changes at any time; there is no time limit for the exercise. If you feel that I am rushing you, please let me know.

I am going to describe a situation. It is purely hypothetical and will require that you use your imagination. I will read the information about a setting and an activity; I can not answer any questions but if you wish, I will read the information for you again.

Remember, this is not a test and there are no right or wrong answers. You may have as much time as you would like and you may make changes at any time.

Take the subject to the model. Stand on the right side of the subject. Use pen as a pointer as you describe the model to the subject.

In front of you is a model of the space which we are currently in. The cardboard structures represent the walls and this is the stairway where you entered the space. This is the hypothetical area about which we are talking. This scale figure represents you and you may "walk" around the space to become comfortable with the model. *Demonstrate using the scale figure and allow several moments for the subject to become comfortable with the scale figure.)*
I would like for you to imagine that you are sitting in a lounge area. The lounge is fairly quiet - it is located just off of a busy corridor. There are several furniture arrangements where small groups of people can sit and talk and you are here with a friend. This friend is

fairly familiar and is of the same gender as yourself; you have maybe had lunch together several of times and feel at ease in chatting with him/her about a number of topics.

This is the chair in which your friend is seated. And this is your friend. *(Show the subject the 3D representation of the furniture pieces as you describe the activity.)*

This is a small table and this is the chair in which you will be sitting. Imagine that you are having a casual conversation with your friend. Place the table and the chair, the one you will be sitting in, at a comfortable distance while talking with your friend. Take your time and make changes whenever you want. You may use the scale figure to experiment with how you would feel most comfortable with the arrangement of the space.

Allow the subject to place the chair at on the plan and position it. Give the subject a few moments to look at what they have done.
Allow subjects to make adjustments if they wish to. Leave the apparatus set up just as the subject leaves it..

Great. Now, we are going to go around the divider here.

This part of the study is very similar to what you just did. Here, however, we are going to use real furniture instead of the model. Imagine that the setting is the same; you are in a quiet lounge area talking with a friend. This is the chair where your friend is sitting. Imagine that I am the friend that you have been talking with. I am going to sit where your friend would be. Now, place your chair and the table at what you consider to be a comfortable distance for conversation. You may walk around and sit in the chair. Take your time and make changes whenever you want.

Allow the subject time to position the chair and table and to move around if they wish.

Fill out the questionnaire. If it is the first visit, ask the subject to schedule the time for their second visit. If it is their final visit, give them the abstract on what the study is hoping to discover.

Thanks so much for your time. You have been a great help and we really appreciate it.

Measure the distances between the chairs in each setting. Use the nearest corners for consistent measurements. Record the level of involvement, any questions asked by the subject and any comments made during the activity.

APPENDIX B

To be used with the 2D Drawing without Scale Figure.
Classroom

Subject will be greeted upon arrival and invited to have a seat at the table where the 2D Apparatus will be set up. The full scale environment will not be visible from this area

Before we get started, I want to explain a little about what we are going to do. The material will be read in order to insure that each person receive the same amount of information about the exercise. Right now, I can not tell you exactly what we are studying because we do not want that knowledge to influence your responses. When the study is complete, we will send an outline of what we are hoping to discover in order to help you understand what you are doing today.

First, this is not a test and there are no right or wrong answers to what I am going to ask. The only thing that is important is the way that you feel and what makes you feel the most comfortable. You may make changes at any time; there is no time limit for the exercise. If you feel that I am rushing you, please let me know.

I am going to describe a situation. It is purely hypothetical and will require that you use your imagination. I will read the information about a setting and an activity; I can not answer any questions but if you wish, I will read the information for you again.

Remember, this is not a test and there are no right or wrong answers. You may have as much time as you would like and you may make changes at any time.

Take the subject to the 2D apparatus. Stand on the right side of the subject. Use pen as a pointer as you describe the drawing to the subject.

In front of you is a drawing of the space which we are currently in. The heavy black lines represent the walls and this is the stair way were you entered the space. This area *(point to and circle with finger)* is the hypothetical space which we are talking about.

I would like for you to imagine that you are sitting in a classroom. The class has about 50 students in it. You are sitting in the front row and the instructor's podium is directly in front of you. This is the podium. This is the desk at which you are sitting. *(Show the subject the 2D representations of the furniture pieces as you describe the activity.)*
Place the desk at a comfortable distance from the podium.

Allow the subject to place the chair in the drawing and position it. Give the subject a few moments to look at what they have done.
Allow subjects to make adjustments if they wish to. Leave the apparatus set up just as the subject leaves it. Measure after the subject has left.

Great. Now, we are going to go around the divider here.

This part of the study is very similar to what you just did. Here, however, we are going to use real furniture instead of the drawing. Imagine that the setting is the same; you are in a classroom with about 50 other students. You are sitting the front row of the class. Place your desk at a comfortable distance from the podium. You may walk around and sit in the desk. Take your time and make changes whenever you want.

Allow the subject time to position the desk and to move around if they wish.

Fill out the questionnaire. If it is the first visit, ask the subject to schedule the time for their second visit. If it is their final visit, give them the abstract on what the study is hoping to discover.

Thanks so much for your time. You have been a great help and we really appreciate it.

Measure the distances between the desk and the podium in each setting. Use the center of the desk seat and the center of the front of the podium for consistent measurements. Record the level of involvement , any questions asked by the subject and any comments made during the activity.

APPENDIX C

To be used with the 2D Drawing with Scale Figure.
Classroom

Subject will be greeted upon arrival and invited to have a seat at the table where the 2D Apparatus will be set up. The full scale environment will not be visible from this area

Before we get started, I want to explain a little about what we are going to do. The material will be read in order to insure that each person receive the same amount of information about the exercise. Right now, I can not tell you exactly what we are studying because we do not want that knowledge to influence your responses. When the study is complete, we will send an outline of what we are hoping to discover in order to help you understand what you are doing today.

First, this is not a test and there are no right or wrong answers to what I am going to ask. The only thing that is important is the way that you feel and what makes you feel the most comfortable. You may make changes at any time; there is no time limit for the exercise. If you feel that I am rushing you, please let me know.

I am going to describe a situation. It is purely hypothetical and will require that you use your imagination. I will read the information about a setting and an activity; I can not answer any questions but if you wish, I will read the information for you again.

Remember, this is not a test and there are no right or wrong answers. You may have as much time as you would like and you may make changes at any time.

Take the subject to the 2D apparatus. Stand on the right side of the subject. Use pen as a pointer as you describe the drawing to the subject.

In front of you is a drawing of the space which we are currently in. The heavy black lines represent the walls and this is the stair way were you entered the space. This area *(point to and circle with finger)* is the hypothetical space which we are talking about. This scale figure represents you and you may use the figure to "walk" around the space.
Demonstrate using the scale figure and allow several moments for the subject to become comfortable with the scale figure.
I would like for you to imagine that you are sitting in a classroom. The class has about 50 students in it. You are sitting in the front row and the instructor's podium is directly in front of you. *(Show the subject the 2D representations of the furniture pieces as you describe*

the activity.)

This is the podium. This is the desk at which you are sitting. This figure represents the instructor and this is the desk in which your are seated. You may use the scale figure to experiment with how you would feel most comfortable with the arrangement of the space.

Place the desk at a comfortable distance from the podium.

Allow the subject to place the chair at on the plan and position it. Give the subject a few moments to look at what they have done.
Allow subjects to make adjustments if they wish to. Leave the apparatus set up just as the subject leaves it..

Great. Now, we are going to go around the divider here.

This part of the study is very similar to what you just did. Here, however, we are going to use real furniture instead of the drawing. Imagine that the setting is the same; you are in a classroom with about 50 other students. You are sitting the front row of the class. Place your desk at a comfortable distance from the podium. You may walk around and sit in the desk. Take your time and make changes whenever you want.

Allow the subject time to position the desk and to move around if they wish.

Fill out the questionnaire. If it is the first visit, ask the subject to schedule the time for their second visit. If it is their final visit, give them the abstract on what the study is hoping to discover.

Thanks so much for your time. You have been a great help and we really appreciate it.

Measure the distances between the desk and the podium in each setting. Use the center of the desk seat and the center of the front of the podium for consistent measurements. Record the level of involvement , any questions asked by the subject and any comments made during the activity.

APPENDIX D

Questions for Groups I, II, and III

ID Code ______

Name ________

To be asked after Phase One and Two

1. Was the full scale environment the same or than you thought it would be after seeing the plan/model?

SAME DIFFERENT

2. In what way was it different? ____

____

____

____

3. Were there any surprises that you were not anticipating in different sizes of the environments?

YES NO

4. What were the surprises? ____

____

____

____

VITA

Jennifer Diane Webb was born in Knoxville, Tennessee. She received her high school education from West High School in Knoxville, Tennessee. She received her Bachelor of Science in Interior Design from the University of Tennessee, Knoxville in 1989.

In July 1988, she started as a student intern with McQuiddy Office Designers in Knoxville, Tennessee. In March 1989, she became a designer in the corporate and healthcare sectors with McQuiddy and completed a variety of projects in southeastern United States over the following five years.

In 1993, she entered the University of Tennessee, Knoxville to study Interior Design in their graduate program. As a Graduate Teaching Assistant, she has taught a variety of interior design courses and worked as a GTA in the School of Architecture as well. A variety of contract and freelance design contracts were completed during her graduate study, maintaining activity in the commercial interior design field.

Jennifer is a member of Kappa Omicron Nu National Honor Society, is NCIDQ certified and is a licensed interior designer in the State of Tennessee.