ASSESSMENT OF SPACIOUSNESS IN BUILDINGS VIA COMPUTER SIMULATIONS: CASE STUDIES ON CLASSROOMS

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Submitted by **GÜLER ÖZYILDIRAN** in partial fulfillment of the requirements for the degree of **Doctor of Philosophy in Architecture Department, Middle East Technical University** by,

Prof. Dr. Gülbin Dural Ünver ______________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. T. Elvan Altan ______________________
Head of Department, **Architecture**

Prof. Dr. Vacit İmamoğlu ______________________
Supervisor, **Architecture Dept., METU**

Examining Committee Members:

Prof. Dr. Mualla Erkılıç ______________________
Architecture Dept., METU

Prof. Dr. Vacit İmamoğlu ______________________
Architecture Dept., METU

Prof. Dr. Gülay Hasdoğan ______________________
Industrial Design Dept., METU

Prof. Dr. Selahattin ÖNÜR ______________________
Industrial Design Dept., Karabük Univ.

Assist. Prof. Dr. Naz A. G. Z. Börekçi ______________________
Industrial Design Dept., METU

Date: 13th February 2015

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Güler Özyıldıran

Signature :

ABSTRACT

ASSESSMENT OF SPACIOUSNESS IN BUILDINGS VIA COMPUTER SIMULATIONS: CASE STUDIES ON CLASSROOMS

Özyıldıran, Güler
Ph.D., Department of Architecture
Supervisor: Prof. Dr. Vacit İmamoğlu

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The interaction between people and built environment has been examined in the field of architectural psychology since the 1960s. In this field, "spaciousness" has been one of the most significant concepts which have been frequently reported in the semantic differential scales, such as Spaciousness-Crampedness Scale (S-C-S) developed by İmamoğlu (1975) and used in several experimental studies via real rooms and scale models in 1970s and 1980s. However, there are still crucial architectural dimensions which have not been studied yet. The main aim of this thesis is to assess spaciousness factors in buildings via S-C-S, and within this framework, the second aim is to test the reliability of computer simulations as current research tools in architectural psychology research.

This thesis is composed of a preliminary study and two groups of experimental studies (each group consisting of four consecutive experiments). In literature survey, the last 45 years of architectural psychology was reviewed, and as a developing research tool, computer simulations were examined with their current and potential features. The first group of experiments was conducted through computer simulations to develop a procedure for the second group, which aimed to test the effects of permanent components of rooms on spaciousness. Ceiling height, types of ceiling and floor (flat and stepped), and plan geometry (rectangular and trapezoidal) were assumed to have an effect on spaciousness (appeal, planning, and space freedom). 350 participants, composed of both students and staff at METU, participated in the experiments. Sample spaces were selected from METU classrooms, and their detailed computer simulations and derivatives were used as stimuli. The results of the experiments indicated that higher ceiling made the room more spacious. The types of ceiling did not affect spaciousness in general. Flat ceiling indicated higher levels of space freedom compared to stepped ceiling. Classrooms with stepped floors were evaluated as better planned than those with flat floors. Plan geometry did not affect participants' evaluations of spaciousness significantly. Results of the experiments demonstrate that the effects of some components of rooms on spaciousness can be identified via computer simulations.

Keywords: spaciousness, spaciousness-crampedness scale (S-C-S), computer simulation, architectural psychology, classroom design.

ÖZ

BİNALARDA FERAHLIĞIN BİLGİSAYAR SİMULASYONLARIYLA İNCELENMESİ: DERSLİKLER ÖRNEĞİ

Özyıldıran, Güler
Doktora, Mimarlık Bölümü
Tez Yöneticisi: Prof. Dr. Vacit İmamoğlu

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İnsan ve yapılı çevre etkileşimi, mimarlık psikolojisi alanında 1960'lardan beri incelenmektedir. Bu alanda "ferahlık", anlamsal farklılık ölçeğinde sıklıkla kullanılan en önemli kavramlardandır. Bu ölçeklerden biri, 1975 yılında İmamoğlu tarafından geliştirilen Genel Uzam Değerlendirme (GUD) ölçeğidir, 1970'lerde ve 1980'lerde gerçek oda ve maketler üzerinde yapılan birçok çalışmada kullanılmıştır. Ancak ferahlıkla ilgili bazı mimari boyutlar henüz incelenmemiştir. Bu çalışmanın amacı, binalarda ferahlık faktörlerinin GUD ölçeği ile incelenmesi ve bu kapsamda, mimarlık psikolojisi alanında yeni yaygınlaşan bilgisayar simülasyonlarının güvenirliğinin test edilmesidir.

Bu çalışma, bir ön çalışma ve iki grup deneysel çalışmadan oluşmaktadır. Literatür taramasında, mimarlık psikolojisinin son 45 yılı ve gelişmekte olan araştırma aracı olarak bilgisayar simülasyonlarının mevcut ve potansiyel özellikleri incelenmiştir. Birinci grup deneyler, ikinci grup deneyler için en uygun yöntemi geliştirmek üzere yapılmıştır. İkinci grup deneylerde ise, odaların kalıcı öğelerinin ferahlık üzerine etkilerini test etmek amaçlanmıştır. Tavan yüksekliğinin, tavanın ve zeminin yüzey formlarının (düz ve kademeli) ve plan geometrisinin (dikdörtgen ve yamuk) ferahlık (çekicilik, planlama, özgürlük) üzerinde etkisi olduğu varsayılmıştır. Deneylere, ODTÜ öğrencileri ve personelinden toplam 350 kişi gönüllü olarak katılmıştır. Örnek mekanlar ODTÜ dersliklerinden seçilmiş, bu dersliklerin detaylı bilgisayar simülasyonları ve türevleri kullanılmıştır. Simülasyonlarla yapılan deneylerde, yüksek tavan mekanı daha ferah göstermiştir. Tavanın yüzey formlarının ise ferahlık üzerine genel bir etkisi olmamıştır. Düz tavan, kademeli tavana göre mekanı daha özgür göstermiştir. Basamaklı zemini olan sınıflar, düz zeminlilere göre daha iyi planlanmış olarak değerlendirilmiştir. Plan geometrisi ile ilgili değerlendirmelerde herhangi bir anlamlı etki tespit edilmemiştir. Deney sonuçları, mekanların bazı öğelerinin ferahlık üzerinde etkisinin bilgisayar simülasyonlarıyla tespit edilebildiğini göstermektedir.

Anahtar kelimeler: ferahlık, genel uzam değerlendirme ölçeği (GUD), bilgisayar simülasyonu, mimarlık psikolojisi, sınıf tasarımı.

To My Family

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LIST OF ABBREVIATIONS

ANOVA	: Analysis of Variance
AP	: Architectural Psychology
AR	: Augmented Reality
CAD	: Computer-aided design
CAVE	: Cave Automatic Virtual Environment,
	: Computer Assisted Virtual Environment,
	: Computer Augmented Virtual Environment
CI	: Confidence interval
df or ν	: Degree of freedom
DV	: Dependent variable
E&B	: Environment and Behavior (journal)
EDRA	: Environmental Design Research Association
F	: *F* distribution, Fisher's ratio
$F(\nu_1, \nu_2)$	: *F* with ν_1, and ν_2, degrees of freedom
GUD	: *Genel Uzam Değerlendirme* ölçeği (Turkish name of S-C-S)
HMD	: Head-Mounted Display
IAPC	: International Architectural Psychology Conference
IAPS	: International Association for People-Environment Studies
IV	: Independent variable
JEP	: Journal of Environmental Psychology
M	: Mean
MANOVA	: Multivariate ANOVA
MERA	: Man-Environment Relations Association
METU	: Middle East Technical University
N	: Total number of cases

ns	: Not statistically significant
PaPER	: People and Physical Environment Research
p or *Sig.*	: Probability; probability of a success in a binary trial
S-C-S	: Spaciousness-Crampedness Scale
SF	: Spaciousness Factor
SD	: Standard deviation
SPSS	: Statistical Package for the Social Sciences
VE	: Virtual Environment
VR	: Virtual Reality

CHAPTER 1

INTRODUCTION

1.1. THE CONCEPT OF SPACIOUSNESS

Physical environment influences people's perceptions and may enrich or worsen their lives. The concept of "spaciousness" expresses positive connotations of feelings of people in relation to physical environment. "How people perceive their environment" and "how to make a space more spacious" are some of the research questions to be answered for better understanding of the situation and to design better environments.

Etymologically, the word *spacious* was derived from the word *space*, which is an area or extent delimited or determined in some way. In Oxford English Dictionary (OED), the word *spacious* has various definitions. However, in the scope of this thesis, particularly the following definitions are significant:

1) of a room, dwelling, etc.: that has or provides ample space or room; large, roomy, commodious.
2) of a road, street, courtyard, etc.: wide, broad; large, open.
3) of an immaterial thing: great, ample; extensive, far-reaching.
4) characterized by largeness, breadth, or comprehensiveness of views or sympathies.

OED defines the word of *spaciousness* as "the state or quality of being *spacious*, wide, or commodious; extensiveness of area or dimensions; roominess" and "largeness or breadth of mind, views, etc."

In addition to dictionary definitions, spaciousness has a more comprehensive meaning in the architecture and psychology studies. Isenstadt (1997) defined *spaciousness* as “the sense of space”. He explained *spaciousness* by the distinction between actual space and perceived space. Figuratively, he used the term of “the ruler and the eye” to define this distinction:

> Where does this living room stop? By the ruler, just a few feet from you. By the eye, it reaches on out into the woods. (Thermopane window advertisement quoted by Isenstadt 1997, p.147).

In these two spatial modes, actual and perceived, one may see deep space where only shallow space existed. He emphasized that the subjective impression of space was independent of its objective existence. Hence, he considered *spaciousness* as a territory given to perception in phenomenological terms (Isenstadt S. M., 1997, p. 147).

Actual space can be tested during design period via two dimensional drawings and three dimensional models. Hence, it is possible for designers to make necessary interventions on designs immediately. After the design and construction period of a space, *perceived space* come into prominence when users interact with the built space. Some features of space might be amendable after post-occupancy evaluations, such as color, furniture arrangements and the like. However, this may not be possible for permanent components of space. For instance, a ceiling height of a space can be considered as appropriate when it is illustrated on a drawing paper; however, it might be perceived as too low or too high by users in the built space.

Beside the *actual space*, whether architects consider the *perceived space* sufficiently or not is a significant question. First of all, what bases architects should consider in designs have to be specified. An architectural design has three significant bases:

1) **identity of its architects**: aesthetic, artistic and ideological aspects of architecture (related with *actual space* and *perceived space*)

2) **scientific aspects of architecture**: materials, structural strength, disaster mitigation, acoustics, insulation and the like (related with *actual space*)
3) **users:** anthropometric dimensions, ergonomics, physiological needs, function (related with *actual space*), culture and perception (related with *perceived space*)

As grouped above, "user" is one of the three bases of architectural design; and space perception is only one of the dimensions related with users. While architects are considering several artistic and scientific aspects during their design processes, they might ignore how users perceive the space. However, since a space lives with its users, the interaction of user and space is an indispensable issue for successful designs.

Research studies related with people-environment interaction can be traced back to the 1960s, and these studies have formed an interdisciplinary research field called "environmental psychology". Within this field, studies related to people and built environment formed a research area called "architectural psychology". The first definitive constitution of architectural psychology was "1969 Architectural Psychology Conference" in Dalandhui organized by the University of Strathclyde and Royal Institute of British Architects (RIBA) in Europe (Philip, 1996, Pol, 2007, Mikellides, 2007). Since then, several empirical studies have been conducted to formulate the interaction between people and built environment.

Each empirical study in architectural psychology focuses on some parameters of a space. Although multiple parameters affect people-environment interaction in daily life, experiments are designed to emancipate effects of other parameters in order to obtain formulated research findings. In such studies, limited participants evaluate a sample space, such as a room, with an evaluation technique. How to present a sample space and how to develop an evaluation technique become two additional significant research questions within environmental psychology.

When it is difficult or impossible to use real spaces as stimuli, represented spaces are used for experiments. Perspective drawings, photographs, scale models and 1/1 mock-up models were commonly seen as stimuli in experiments in the literature in the early periods of environmental psychology. Representation technique and its reliability in such studies have been research questions on its own.

In empirical studies, people-environment interactions are evaluated either by behavior of people or their verbal statements. For behavioral evaluations, eye movements, walking direction, staying time, shopping habits are some of the examples to gather data. Verbal statements are gathered either by open-ended questions or rating scales. The choice of appropriate scale affects the success of research. Hence, construction of a rating scale has also been a significant research question. *Likert scale* which is a symmetric agree-disagree scale for a series of statements, and *semantic differential scale* which is a scale between two bipolar adjectives are examples of scale types.

A space dimension, *spaciousness* or *enclosedness* had been frequently reported in studies employing semantic differential technique in environmental psychology. It was expressed by adjectives such as spacious, roomy, open, airy, free space (Kashmar 1965, 1970; Canter 1969; Honikman 1970; Hersberger 1970, 1972; Acking and Küller 1972; Markus et a. 1972; Seaton and Collins 1972; Küller 1973). While architectural psychology was a newly developing research field, İmamoğlu studied "spaciousness of interiors" in his Ph.D. thesis at the University of Strathclyde, from 1972 to 1975. He studied spaciousness in terms of its meaning, measurement and relationship to some architectural variables. He developed a semantic differential scale called Spaciousness-Crampedness Scale (S-C-S) which was used in several empirical research studies via real rooms and scale models in Scotland (İmamoğlu, 1975, İmamoğlu, 1986). Later on, he verified the validity of his scale in Turkish culture and named it as *"Genel Uzam Değerlendirme (GUD) Ölçeği"*, to be used for carrying similar research studies in Turkey (İmamoğlu, 1979-b).

Before studying spaciousness, what has been changed in the comprehension of architectural psychology in the course of time should be surveyed. It has been 45 years since the first definitive constitution of "architectural psychology" in

Strathclyde. Instead of the specific name of *architectural psychology*, the field is called *environmental psychology* in a broader sense. In the last 45 years of the field, many graduate theses have been produced; many international conferences have been arranged; and thousands of articles have been published around the world. Related studies are still increasingly continuing in this interdisciplinary field. However, from the architects' point of view, the popularity of the field seems to decline among new trending subjects of architecture, such as, sustainability, energy considerations and computational architecture.

Since the constitution of the research field, architectural psychology has had two significant goals; to develop theories which guide research studies, and to carry out research studies which could be implemented in architectural practices. Some current publications criticize whether knowledge in architectural psychology have been put in practice in architectural designs as expected, or not (Keul, 1996, Philip, 1996). While "quality of life" and "well-being" are trending research keywords nowadays, it is surprising that knowledge of architectural psychology has not nourished design applications satisfactorily. There are two possible reasons for this problem. First, as mentioned before, architects have to consider several complex bases during their designs; hence, some might be ignored. Second, some research findings might not be intended and applicable for architectural designs. Contributions of other disciplines, such as psychology and cognitive sciences are quite valuable for increasing knowledge in architectural psychology. However, the decline in contributions of architects to this research field leads findings to be away from architectural design practice. For instance, several empirical research studies in the current field are generally based on schematic and unrealistic spaces which are incapable of contributing to architectural knowledge. Hence, to develop architectural psychology knowledge to be put into practice, there is a need for research studies which are designed by architects' point of view.

In addition to changes in the comprehension of architectural psychology, there has been a significant change in the use of research tools in the field over time. Instead of past representation tools, computer simulations are becoming widely used as representation tools for different experimental conditions. Presenting a wider variety of alternatives, and being more practical and economical than the past representation tools, computer simulations are becoming prevalent tools in the field. Besides its several advantages, computer simulations also bring several uncertainties to the people-environment studies. In the literature of architectural psychology, while there are several experimental research studies (Holmberg, Alkgren, Soderpalk, & Kuller, 1967; Inui & Miyata, 1973; İmamoğlu, 1975) which have confirmed validity of scale models as research tools, there is no satisfactory research on computer simulations yet. Having a wide range of apparatus and programs, computer simulations are still in question especially in space perception studies. As people-computer interaction has its own complexity, to use this tool as an interface to understand people-environment interaction becomes even more complex. Hence, it is essential to be cautious while designing experiments and interpreting results via computer simulations. Additionally, selection of a compatible evaluation scale to be used with computer simulations is also important. In the recent literature, computer simulations have been used only with simple scales, such as a single 10-point "spacious - not spacious" scale (Stamps & Krishnan, 2006; Matusiak & Sudbo, 2008; Stamps, 2009; Stamps, 2010; Stamps, 2011) ignoring the more sophisticated scales developed in the past (Vielhauer, 1965; Craik, 1968; Hershberger, 1969; Seaton & Collins, 1971; Hershberger, 1972; Canter D., 1973; İmamoğlu, 1975; İmamoğlu, 1986). Although these simple scales are easy to use and analyze, they may not lead to in-depth assessments. Thus, choosing compatible scales should be also questioned (Bechtel, 1973; Ostrander, 1974).

In the course of time, not only the research comprehension and tools, but also the people have changed. As Gifford (1997, p. 3) states, "today's problem involves different individuals in a different place and different time than did yesterday's problem"; therefore, the research literature often cannot provide a firm answer to a specific current problem in environmental psychology. Due to differences among individuals, cultures, eras, and settings, different results might be obtained in such studies. This paradox is one of the possible reasons why environmental psychology does not have a large number of established principles yet. Hence, how to benefit from the literature of environmental psychology is in question. Gifford (1997, pp. 3-4) also explains how past results in environmental psychology direct future studies. His explanations can be listed as follows:

1. Results may be repetitive and prove certain findings and principles correct.
2. Results may be unique for a specific group of people.
3. Results may “demonstrate that a certain idea or method is a blind alley” in which “no one should venture in that direction again”.
4. Results may lead to new questions by producing unexpected outcomes. Hence, future studies might be more sophisticated.

In summary, although 45 years passed, architectural psychology does not have a large number of established principles to put in architectural practices yet. In this interdisciplinary field, there is a need for research studies which are designed through architects’ point of view. In order for architectural psychology to contribute to architectural design practice, permanent components of rooms should be assessed firstly. *Spaciousness* is one of the significant concepts expressing the interaction of people and environment. Although this interaction is subjective, the architectural psychology discipline attempts to assess this interaction in objective ways. For this purpose, several evaluation scales and several representation tools have been developed since the beginning of this research field. S-C-S has been one of the developed scales for spaciousness in the literature since 1975, and computer simulations have been used as representation tools in the field for the last two decades and developing every other day. In the recent literature of spaciousness studies, computer simulations have been used only with simple scales, such as, a 10-point “spacious - not spacious” scale. However, in order to assess spaciousness in-depth, more sophisticated scales, such as S-C-S, are needed. S-C-S was used with conventional representation tools in the past studies of 1970s and 1980s, but it has not been used with current tools, i.e. computer simulations, yet. The use of S-C-S and computer simulation together should be considered in order to assess the effects of different permanent components of space on space evaluations.

1.2.AIM AND SCOPE OF THE THESIS

This study emphasizes the critical role of spaciousness perception in relation between "space" and "user" which should be considered in designs. The main aim of this study is to assess spaciousness factors in buildings. This subject has been examined by various researchers in the field of architectural psychology since the 1960s; nevertheless, there are still crucial architectural dimensions which have not been studied yet, and the current study approaches the subject from today's conditions. Spaciousness-Crampedness Scale (S-C-S), which is one of the semantic differential scales in the literature, was used as an evaluation tool for the current study. S-C-S was developed by İmamoğlu (1975) and used in several experimental studies via real rooms and scale models in 1970s and 1980s. In the current study, S-C-S was used with computer simulations as the prevalent representation tools in the field of architectural psychology. However, although computer simulations have many advantages over the conventional representation tools, they have still some uncertainties for space perception studies. Hence, the aim of the current study is also to test reliability of computer simulations as current research tools, and in return, to develop a more adequate procedure for the use of computer simulations in architectural psychology research.

This thesis is composed of a literature survey and experimental studies in which sample spaces are examined via S-C-S. Sample spaces were selected from rooms, since "room" is a unit of a building, which has well-defined space with its own walls, floor, and ceiling. The study focused on the three main permanent components of rooms, which are ceiling, floor and walls. Some related architectural parameters, which were assumed to be effective on spaciousness, were determined to be tested by the S-C-S. These variables are ceiling heights, ceiling type (stepped and flat), floor type (stepped and flat), and plan geometries (rectangular and trapezoid).

In the experiments of the current thesis, sample spaces were represented by computer simulations. Computer simulations vary in terms of their presentation techniques: conventional basic displays (flat screens and projections on flat boards), advanced immersive displays, such as VR Dome (Virtual Reality Dome), CAVE (Computer Augmented Virtual Environment), and HMD (Head-Mounted Display), and mobile medium with AR (Augmented Reality). In the current study, simulations were presented on laptop screens (flat screen) due to its practical and economic advantages, instead of the advanced techniques which need laboratory settings and a high research budget. There are also several computer simulation programs for different purposes, such as architectural design, game industry, defense industry, and training in driving and medicine. In the recent literature, there are several examples of architectural psychology studies which tried to adapt these programs, such as game programs, to their experiment settings. However, they do not produce simulations of spaces as realistic as architectural programs in terms of perspective rules, light and shadow, and the like. Hence, for this thesis, computer programs were selected from some professional architectural programs which have real-time rendering and virtual walking facilities.

A space simulation on a laptop screen only represents people’s monocular vision in a frame, whereas advanced immersive techniques try to make people perceive simulations as if they were in the simulation. However, the immersive technologies have been still developing, and they have some uncertainties in space perception such as perspective distortions and some side effects such as cybersickness. Hence, their usages have not been common in architectural psychology studies, yet. For these reasons, simulations on laptop screens are preferred in this thesis. In fact, people’s perception of space is not only related with sense of sight, but also senses of hearing, smell and touch. Instead of a representation, only a real-room can have all these aspects. Even 1/1 mock up models are unnatural environments for people. However, as mentioned before, the use of real-rooms as stimuli is very limited and it is not possible to use them in every experimental condition which needs different alternatives of a space or needs to eliminate effects of some parameters. There may be more comprehensive representation alternatives in the future, but within the present tools, the most appropriate ones are computer simulations. Recognizing these facts, this study is directed to assess spaciousness of interiors via S-C-S and computer simulations with architectural programs on laptop screens which are common, economical and easy to use.

In order to have realistic simulation models, cases were selected from real rooms, and their computer models were constructed as detailed as possible. In the literature, sample rooms have been mostly selected from offices, classrooms, meeting rooms, hospital rooms and living rooms of houses. Classrooms were preferred for this study because they have simple forms which are easy to manipulate for different experiment conditions, including ceiling and floor types. These rooms were selected from several faculties of Middle East Technical University. When their realistic computer models were completed, several alternative models were derived for various conditions of each experiment.

1.3.METHODOLOGY AND STRUCTURE OF THE THESIS

As mentioned above, this study approaches the concept of spaciousness in an experimental research design via computer simulations. The starting point of this study was the Ph.D. thesis of İmamoğlu (1975) and Spaciousness-Crampedness Scale (S-C-S) he developed. Hence, at the preparatory period of the study, first, the thesis of İmamoğlu and its references were reviewed. In order to have a more comprehensive insight about the study, the field of architectural psychology was briefly surveyed from its first constitution in the 1960s to today. Since computer simulations are becoming widespread research tools in the field, applicability of computer simulations were also questioned for the current study. Thus, in addition to the literature of architectural psychology, related literature of visual perception, cognitive science and computer technologies were also reviewed in the scope of this thesis.

The literature survey indicated that there was a need for further research which will assess the main components of rooms affecting spaciousness perception of people. Following a preliminary study with open-ended questionnaires in Middle East Technical University (METU), the meaning of spaciousness and related parameters were tried to be defined. Within the parameters determined through the preliminary study, four main variables, which were related to the permanent physical components of rooms, were selected to be tested in the following experiments.

In order to select the most suitable rooms that would be adaptable for the focused parameters of experiments, various classrooms in the different faculties of METU were examined, photographed, sketched, measured and modeled. First, the classroom called R46 was selected from the Faculty of Architecture to test the representativeness and reliability of computer simulations as a research tool. Second, B06 in the building of Social Sciences, which was a typical classroom at METU, was selected due to its simplistic form and minimal ceiling height which could be adaptable for manipulating ceiling height in experimental settings. Third, G103 classroom in G block of the Mechanical Engineering Department, which has a stepped floor with stepped ceiling, was selected for experiments on ceiling type and floor type. Finally, for testing different plan geometries (rectangular and trapezoid), MM319 room in the Central Engineering Building, which has a trapezoid plan, was selected.

Several architectural programs were examined to select the most appropriate computer simulation technique. Among those, SketchUp, Lumion, Rhinoceros programs, which have real-time rendering and virtual walking facilities, were selected to be utilized for the experiments. Models of selected real rooms were first modeled in SketchUp in detail. Some small modifications were made to have room dimensions with fractions rounded up. For instance, a plan dimension of 7.85m x 7.16m was rounded up to 8.00m x 7.00m. Based on these models, alternative models were derived for related independent variables of the experiments. In the alternative models, dimensions were kept as realistic as possible to be applicable in real life.

All the participants were students or staff members from various faculties of METU, mostly from the Faculty of Architecture. The participants, who voluntarily joined the experiments, were asked to evaluate the stimuli in the experiments they took part in. Since Turkish was the native language for all the participants employed, Turkish version of S-C-S was used. The original scale (İmamoğlu, 1975) includes two dimensions: *spaciousness* and *crampedness.* However, in the scope of the current study, only the *spaciousness* dimension was used. This dimension is composed of three *spaciousness factors* (SF); *appeal*, *planning*, and *space freedom*. These three SFs are used as dependent variables in all of the analyses.

This thesis is composed of five chapters and nine appendices. In the first chapter, the concept of spaciousness is introduced with its meaning and its role in architectural design. Its place in people-environment studies is stated after a brief statement about architectural psychology. Within this field, the significance of sample space, its representation and evaluation technique are emphasized. The S-C-S is explained and then the state of the computer simulation, which is a new widespread representation tool in the field, is presented. Following this brief introduction, the aim, scope, methodology and structure of the thesis are defined.

The second chapter is allocated to literature review. Firstly, the field of architectural psychology is briefly reviewed. Secondly, representation techniques and evaluation techniques in the literature are briefly introduced. Thirdly, related past research findings are presented. The field is rich in terms of published research studies such as conference proceedings and journal papers and several Ph.D. theses. Due to the large number of published documents, only a limited portion of the relevant literature is mentioned. Fifth, computer simulations are explained with their current and potential features in more detail. Finally, the literature is reevaluated in order to select the research tools and cases for the current study.

In the third and the fourth chapters, the preliminary study and experiments are presented in two groups. The first group (Chapter-3) is composed of a preliminary study and four experiments as preparations for the second group of experiments. The second group (Chapter-4) is composed of four main experiments which aimed to assess the effects of permanent components of rooms on spaciousness evaluations.

In the third chapter, the results of the preliminary study, which examined the meaning of spaciousness and the related factors through open-ended questionnaires, are given. Then, early experiments are presented. Experiment-1 compared the real room and its computer models in order to test the representativeness of simulations and to choose the most appropriate program (SketchUp, Lumion, and Rhinoceros). Experiment-2 compared S-C-S evaluations of a real room and its computer simulation to test the validity of the simulations. Experiment-3 is a trial for spaciousness assessment of different ceiling heights (3m, 4m and 5m) of a sample room, in which each participant evaluated only one of the models via a virtual walk in SketchUp program. After observing some weak points, this procedure was improved in Experiment-4 with some changes in modeling and presentation techniques. Lumion video animations were used instead of virtual walks in SketchUp models. With this animation technique, series of models (two types of ceiling height and two types of window size) were tested and their pairwise comparisons were analyzed. Following inferences about strengths and weaknesses of the tested representation methods, a procedure for further experiments was determined.

The fourth chapter is allocated the second group of experiments composed of four main experiments. Stimuli of these experiments were presented as Lumion video animations. Unlike the previous group of experiments, in this one, each participant evaluated all of the models in an experiment. Multivariate analysis of variance (MANOVA) was performed to assess the effects of independent variables on spaciousness evaluations, while dependent variables were the three spaciousness factors (appeal, planning, and space freedom). Experiment-5 examined different ceiling heights (3m, 4m and 5m) with this comparison method. Experiment-6 tested two independent variables which are ceiling type (stepped and flat) and ceiling height. Experiment-7 focused on two different floor types (stepped and flat) of the same classroom. Experiment-8 assessed different plan geometries (rectangular and trapezoid).

The fifth chapter is the conclusion chapter which reviews the thesis, and focuses on implications and possible future extensions. Additional information about the experimental studies in the current thesis is given in the appendices, including questionnaire forms, summary tables of the open-ended questionnaire, a survey on classroom design guides of ten universities, the selection of cases in METU campus, measured sketches and 3D models of selected cases, modeling and animation procedures, detailed descriptions of methods of analysis, and summary tables of all experiments. Three extra experiments, which are the byproducts of the main experiments, are also added to appendices.

CHAPTER 2

LITERATURE REVIEW

For a better understanding of the past studies assessing spaciousness in buildings, a wider review of people-environment interaction studies in the field of architectural psychology is needed. Since the constitution of the research field in the 1960s, many conferences and many journals have contributed to the literature (see Figure 1).

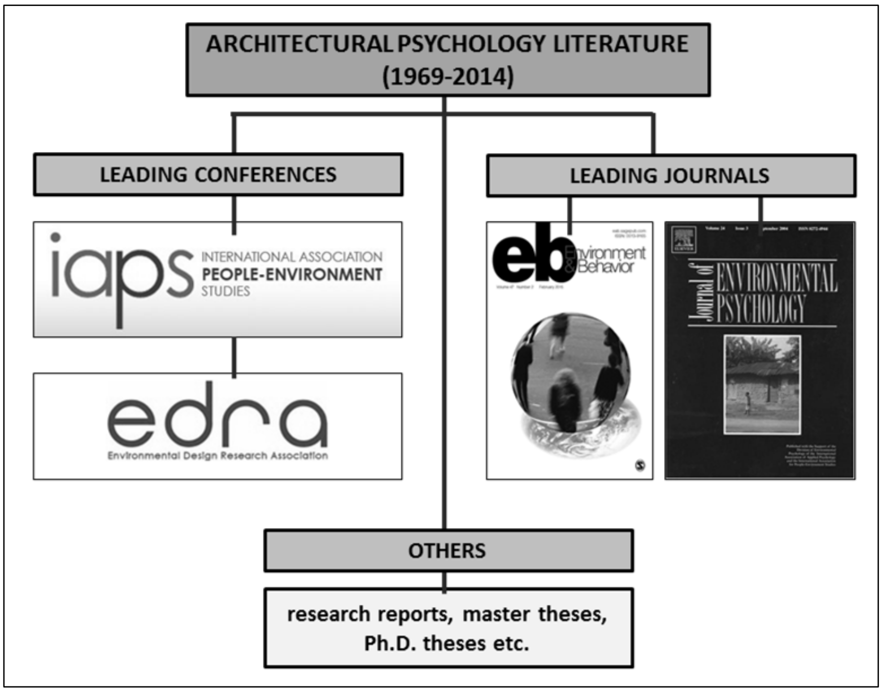


Figure 1 Main sources of the thesis: architectural psychology literature 1969-2014 (Özyıldıran, 2014).

The first conference was the *Architectural Psychology* conference, which was organized by the University of Strathclyde and Royal Institute of British Architects

(RIBA) in 1969 in Dalandhui in UK. Six serial conferences were organized with the name of *Architectural Psychology* (AP) between 1969 and 1976, and as a continuation of these, another conference called *International Architectural Psychology Conference* (IAPC) was held in 1979 in Belgium with the theme of "Conflicting Experiences of Space". In 1981, based on these series of conferences from 1969 onwards, *International Association for People-Environment Studies* (IAPS) was formed. The next conference was organized with the name of "IAPS 7" in 1982 in Spain. Since then, IAPS conferences have been held regularly as biennial conferences with specific themes in various countries in Europe, with two exceptions; one in Israel (IAPS 9) and the other in Egypt (IAPS 19).

Parallel to the studies of IAPS in Europe, *The Environmental Design Research Association* (EDRA) has organized conferences annually in USA since 1969. After its constitution in 1968, the goal of EDRA was "to advance and disseminate environmental design research toward improving understanding of the interrelationships between people, their built and natural surroundings" and its main aim was "to facilitate the creation of environments that are responsive to human needs" (EDRA, 2012). Both IAPS and EDRA have made significant contributions to the environmental psychology literature with their interdisciplinary conference proceedings, and some of these are accessible all around the world from their online databases.

In addition to IAPS in Europe and EDRA in North America, two organizations with similar goals were founded at the other side of the world in the 1980s. *People and Physical Environment Research* (PaPER) was established in Australia and New Zealand in 1980, while *Man-Environment Relations Association* (MERA) was founded in Japan in 1982. Nevertheless, PaPER does not have a database accessible online, and MERA does not have English webpages, except a short introduction. Hence, neither of them could be included in the literature review for the current study.

In addition to conference proceedings, journals have also been significant media for sharing research findings in the field. *Environment and Behavior* (E&B) and

Journal of Environmental Psychology (JEP) have been pioneering journals in the field. E&B published its first issue in 1969 which was also the beginning year of AP and EDRA conferences, and JEP was first published in 1981. In addition to these journals, *Building and Environment*, which was formerly known as "*Building Science*" between 1965 and 1975, have contributed to the field with its research papers and review articles related to building science and human interaction with the built environment since 1976. Moreover, "*Architectural Science Review*", which presents papers on a wide range of topics in architecture, "*Design Issues*", which examine design history, theory, and criticism, and some other journals were also reviewed in the scope of the current study.

The field of architectural psychology has also disseminated as research reports, master theses, and Ph.D. theses since the 1960s. Some of them were also included in the literature review of the current thesis. Especially the thesis called "Spaciousness of interiors: Its meaning, measurement and relationship to some architectural variables", which was prepared by İmamoğlu (1975) with the supervision of Thomas A. Markus in the University of Strathclyde, became the starting point for the current study.

Within all these past studies of people-environment interaction, there are three types of references for *spaciousness*:

1) studies which held the concept of *spaciousness* as a primary research subject,
2) studies which include the concept of *spaciousness* as a part of other research subjects,
3) studies which focus on similar subjects with the above stated items, but do not mention the concept of *spaciousness*.

For the scope of the current thesis, all related past works tried to be obtained, especially from online databases of the two leading conferences "IAPS and EDRA (1969-2014)" and the two leading journals "E&B (1969-2014) and JEP (1981-2014)". In addition to the literature of this interdisciplinary field of architectural psychology, which includes architecture, psychology and other space related disciplines, a survey in computer sciences and cognitive sciences was also needed in order to get knowledge of computer simulations as potential research tools of the current study. In total, almost a thousand related documents were obtained and tried to be surveyed to develop the current thesis within five years.

The architectural psychology literature has been extended substantially due to its interdisciplinary nature and worldwide concern since the 1960s. With today's internet facilities, it is possible to access most of these documents around the world, and even some of the old ones are also accessible as scanned documents. Nevertheless, since this facility was not possible in the past, researchers referred only to a limited reference group whose studies they were aware of. Hence, it seems that not all the related publications refer to each other, and they do not benefit from all the previous studies in terms of their implications and flaws. As a result, the literature of architectural psychology is not complementary and well-organized. Since it is too wide to review all in the scope of this chapter, the most related documents for the spaciousness assessments were selected to review from the beginning and recent periods.

This Chapter starts with a brief introduction of various sources of the literature review. Section 2.1 of this chapter briefly reviews the field of architectural psychology, in order to clarify the background of spaciousness studies. After giving an insight about the field, a review about evaluation techniques and representations of sample spaces, which are the two significant research components of such studies, are presented in Section 2.2 and Section 2.3 respectively. In Section 2.2, after a short introduction about various scales in the field, the *Spaciousness-Crampedness Scale* (S-C-S) is introduced in more detail, including its construction stages in Glasgow (İmamoğlu, 1975), and its verification in Turkish in Turkey (İmamoğlu, 1979-b). In Section 2.3, various representation tools and techniques to represent sample spaces are presented by referring to the literature. In Section 2.4, some research findings on spaciousness in architectural psychology literature are mentioned. As newly developing research tools, computer simulations are examined with their current and potential features in detail in Section 2.5. Finally, in Section 2.6, the literature is reevaluated in order to select the research tools and cases for the present study.

2.1. ARCHITECTURAL PSYCHOLOGY AND THE CONCEPT OF SPACIOUSNESS

2.1.1. Architectural psychology from the 1960s onwards

Research studies related with people-environment interaction have formed the *environmental psychology* as a recognized field since the 1960s. The *environment* refers both to the built and to the natural environment. Within this field, the studies related with people - built environment interaction have gained a more specific name as *architectural psychology* with the "1969 Architectural Psychology" (AP) conference in Dalandhui in UK.

It was thought-provoking why, in the 1960s, the research field occurred and spread rapidly in Europe and America. As Pol (2007, p. 5) stated, the intense activity of urban reconstructions during the post-war period in Europe led to "an architectural opening in social sciences". İmamoğlu (1975, p. 2) pointed out that "with advancing technology and population growth", modern people had been forced to concentrate on their relationship with the built environment.

> One of the most striking features of our time is the progressive concentration of a large human population in compact cities. It is mainly like rapid urbanization that has caused an incredible growth in scale and complexity of buildings. Paralleling to this phenomenon is a desire and attempt to continually improve standards of physical and social well-being, whilst pressing general economic constraints have demanded more economical and functional building designs; functional, not only in terms of primary human needs like heating, lighting, noise control, but also in terms of social well-being and psychological satisfaction (İmamoğlu, 1975, p. 2).

Then, a further question comes into mind about the aim of architectural psychology in the 1960s and 1970s. The answer was given by Canter, who is a psychologist and was the editor of the first AP conference. He presented his paper titled "The place of architectural psychology: a consideration of some findings" in the second conferences of both IAPS in Europe and EDRA in America in 1970, and questioningly explained it as follows (Canter D. V., 1970-b):

> What then is the place of architectural psychology? If collecting data on the specific architectural requirements of building users is going to lead to unimaginative architecture and is based on a doubtful psychological premise, what is the contribution to be made?
> The answer is not simple and is not likely to be readily accepted by the present generation of architects. It can be briefly stated by saying that the contribution of psychology should be to study the processes of interaction between buildings and their users with the aim of making architects understand more clearly the psychological impact of the built environment. This will influence their designs by changing their attitudes towards architecture. This approach is unlikely to produce any design solutions, but architects themselves are the experts in the production of design solutions and assistance at that level from psychologists or sociologists is neither necessary nor desirable (p. 3)

In his both papers, Canter also mentioned two considerations from the first AP conference. In his own words, “before entering into the dangerous waters of theory building, two warnings from the Dalandhui conference should be born in mind” (Canter, 1970-b, p3, 1970-c, p.23). First, by referring to Stringer (1969), Canter emphasized that “our explanation of how people interact with their physical environment should also contribute to an understanding of how buildings are designed”. Second, by referring to his own old saying (Canter D. V., 1969-b), he reminded that “the subjective experience of a building and the objective observation of others using it must both be taken into account if we are to gain anything like a complete picture of the process of building/user interaction”.

The research field was commonly named as *architectural psychology* in the literature during the periods of the AP conferences between 1969 and 1979. However, instead of this specific name, it seems that the name of *environmental psychology* has been preferred since the 1980s. *Architectural psychology* is an interdisciplinary field, which is mainly contributed by works of architects and psychologists, while the field of *environmental psychology* acts as a significant branch of psychology which is mostly sustained by psychologists with interdisciplinary contributions. It might be inferred that architects have been probably directed to other popular research subjects than architectural psychology since 1980s, and the field has been sustained under the more inclusive field of *environmental psychology*. Hence, in order to assess the field from today's perspective, a review on *environmental psychology* is also needed.

Gifford (1997) explained the principles of *environmental psychology* which make it special in psychology discipline:

- It is ultimately capable of improving the built environment and the stewardship of natural resources.
- It is carried out in everyday settings (or close simulations of them).
- It considers the person and setting to be a holistic entity.
- It recognizes that individuals actively cope with and shape settings, rather than passively absorb environmental forces (p. 4).

In order to analyze past, present and future of empirical research in environmental psychology, Giuliani and Scopelliti (2009) reviewed the two leading journals in the field, namely *Environment and Behavior* (E&B) and the *Journal of Environmental Psychology* (JEP), from their first issues to those until 2005. As a result, they identified four leading subjects in environmental psychology, which can be listed as follows:

1) residential environment, whether home, domestic surroundings or neighborhood, which was addressed from different points of view: people's satisfaction and preferences for their residential environment, as well as sources of stress/discomfort; affective evaluations, attachment and the connection between place experience and the definition of personal identity,
2) environmental cognition, preference and affective evaluation, mainly pursued through an experimental approach in the laboratory setting, and by using simulations of the environment,
3) actual behavior in the environment (whether natural or built, indoor or outdoor), in which observation is the key method to understand how people use the environment, or react to it,
4) nature and global environment, which were taken into consideration by emphasizing ecological problems (Giuliani & Scopelliti, 2009, pp. 384-385).

In the latest Annual Review of Psychology, Gifford (2014) emphasized the significance of the premise of *environmental psychology*:

> Wherever you go, there you are – and it matters. This is the fundamental premise of environmental psychology: We are always embedded in a place. In fact, we are always nested within layers of place, from a room, to a building, to a street, to a community, to a region, to a nation, and to the world. If, instead, we happen to be in a vehicle, an urban

> park, on the water, or in a wilderness, we are still somewhere. Person-place influences are both mutual and crucial. We shape not only buildings but also the land, the waters, the air, and other life forms – and they shape us (p. 543).

2.1.2. Expectations for architectural practice

As mentioned before, Canter (1970-b; 1970-c) stated that architectural psychology would influence the designs of architects "by changing their attitudes towards architecture". However, nowadays, there are some articles criticizing whether the field has contributed to architectural practice or not. For instance, Mikellides (2007) questioned whether the knowledge of architectural psychology influenced the practice of architects. By looking at the real world architecture, he claimed that "a considerable amount of this research has gone unnoticed". Philip (1996) also mentioned the practical failure of *architectural psychology*:

> The potential failure in the dialogue between the social and behavioural science and architecture was summarized by James (1971) long ago. A breakdown in communication was evident then, as it is still. The level of understanding between applied sciences and architecture may not always be high but in terms of building processes, science was able to offer advice which could be incorporated directly into the architect's decision making; choices of material, structure and construction were assisted by a range of building sciences. In the late 1960s and 1970s, it would seem that architects had similar hopes for the potential of architectural psychology (and sociology, sometimes) to assist in areas which were really architecture, rather than mere building (p. 280).

Philip (1996, p. 281) tried to define the problem area by a study, in which (*psychologically naive*) students of architecture reviewed 45 papers in recent volumes of E&B and JEP in 1991. As a result, he conveyed that students considered almost all the papers as "very difficult to read". He also pointed out "specialized language" and "statistical manipulation of data" as the major problem areas.

In an optimistic way, Gifford (1997) confirmed the challenge in turning the environmental psychology knowledge into practice:

> Around the world, the face of environmental psychology changes with national and regional concerns, but it retains a fundamental commitment to understanding and improving human-environment relations. Environmental psychology is at the forefront of a general movement to make psychology more relevant to everyday life. But it is still challenged to find more

> ways to turn knowledge into practice, to devise methods that are better able to accomplish its goals, to reach greater consensus on what constitutes its central core, and to develop more comprehensive theories reflecting and embodying that core. However, the field is vigorous and will meet these challenges (p. 15).

In addition to these, Giuliani & Scopelliti (2009) looked at the effects of the research field on architectural practice from a different stand point:

> Although the collaboration between architects and psychologists has not fully satisfied all the initial promises, environmental psychology continues to be a reference point for many architects and planners, not only as regards the integration in design of an increased attention to users need, but also for concepts like place identity and attachment (p. 386).

2.1.3. The concept of "spaciousness" in architectural research

In Section 2.1.1, how the studies of people-environment interaction began in the 1960s was discussed. Within these studies, *spaciousness* is one of the significant concepts. Since the concept is also the main subject of the current study, now in Section 2.1.3, how the studies about spaciousness began is discussed more specifically.

İmamoğlu (1975, p. 8) indicated that *spaciousness* was a "widely used term in everyday life and architecture to describe and evaluate spaces". As mentioned before, Isenstadt (1997, p. 115) defined *spaciousness* as "the sense of space". With its comprehensive contents, the concept of *spaciousness* has drawn attention of some of the researchers who are interested in environmental perception. In the literature, this concept was handled at theoretical level in architectural history and at empirical level in environmental psychology.

Isenstadt (1997; 2006) is one of the researchers, who approached the concept of *spaciousness* in the field of architectural history and theory. He handled this concept within his Ph.D. thesis titled "Little Visual Empire: Private vistas and modern American house" in Architecture, Art and Environment Studies at the Massachusetts Institute of Technology (Isenstadt S. M., 1997). As understood from his thesis title, he discussed the concept of *spaciousness* while referring to American houses of mid-twentieth century. However, some of his discussions might provide an insight about general understanding of spaciousness:

> Spaciousness, despite small dimensions, was at the time widely praised as a particularly modern contribution to the design of modest houses. To this end, key formal attributes of modern house design, including smooth surfaces, the extension of wall and ceiling planes, minimized details, as well as glass walls and siting, are revisited for their ability to reproduce the optical experience of distance (Isenstadt S. M., 1997, p. 3).

In his thesis, Isenstadt (1997) focused on economic limitation of the middle class that could only afford small houses but need *spacious* environments. By studying the modern American houses, he emphasized that spatial perception could be visually enhanced free from its small dimensions. He explained that houses by the 1950's were often said to be smaller in size but roomier in perception than they used to be. He also stated that "the creation of interior spaciousness was usually considered an invention of the modern movement in architecture and associated with its other innovations" (Isenstadt S. M., 1997, pp. 115-116).

The thesis of Isenstadt (1997) might be interpreted for a general understanding of the concept of *spaciousness*; however, some add-ons are required. First, Isenstadt (1997) pointed out the phenomenon of *small house* as a result of economic limitations. For *small spaces* in general, several reasons could be listed:

1) economic limitations,
2) geographical limitations,
3) high population density,
4) architectural preferences.

Second, Isenstadt (1997) mentioned difference between *actual space* and *perceived space* only in a positive way. However, with a failure in design, *perceived space* might also be worse than *actual space.* Third, he only mentioned size related factors of spaciousness, such as *dimensions, distance,* and *depth*. Nevertheless, if spaciousness is *the sense of space*, there are several factors affecting people's perceptions of spaciousness.

2.2. EVALUATION TECHNIQUES IN ENVIRONMENTAL PSYCHOLOGY AND DEVELOPMENT OF SPACIOUSNESS-CRAMPEDNESS SCALE (S-C-S)

2.2.1. Evaluation techniques in environmental psychology

The research field of environmental psychology aims to assess the subjective phenomenon of people-environment interaction in objective ways. Hence, how to measure this interaction has been a significant question.

Gifford (1997) stated environmental psychology as "a multiple paradigm field" and he explained this as follows:

> This means that different researchers may employ not only different methods but also entirely different techniques based on different philosophies of science. Research methods vary not just in their procedures but also in the very beliefs and values of the investigators who use them (p. 11).

Parallel to this, there are also several ways of measuring techniques. Basically, these measurements can be grouped in two categories; 1) observations of people's behaviors, and 2) people's verbal statements. The significance of these methods was also emphasized by Craik (1968).

> The kinds of descriptive judgments and other behavioral reactions requested of observers of environmental displays and the format provided for guiding and assisting them in making their responses are of central importance, for they are the signs by which the nature of the observer's comprehensions is made known to us (pp. 32-34).

Craik (1968) also tried to categorize and define all kinds of measurement. In brief, labels of his categorizations are listed below:

1) Free descriptions
2) Adjective checklists

3) Activity and mood checklists
4) Q-sort descriptions
5) Ratings
6) Thematic potential analysis
7) Symbolic equivalents
8) Multisensory equivalents, emphatic interpretations
9) Social stereotypic cues
10) Beliefs about human consequences
11) Viewing time
12) "Motational" systems (pp. 32-34).

Most of the above mentioned items are related to people's verbal statements about their environments. Among these, Craik (1968, pp. 32-34) defined *ratings* as "standard and flexible technique for obtaining observer judgments". He also defined *the semantic differential* as "a sensitive form of the rating scale". One of the recent definitions of the scale is made by Franz (2005) as follows:

> In a semantic differential, dimensions of environmental qualities are presented by pairs of oppositional adjectives and a rating scale (usually seven discrete steps) in order to allow a differentiation between two extremes (p. 50).

In the literature of environmental psychology, there are several *semantic differential* scales constructed for specific purposes. One such kind of scales for spaciousness is *Spaciousness-Crampedness Scale* (S-C-S) constructed by İmamoğlu (1975).

In the Ph.D. studies of İmamoğlu (1975), first, he used *a single seven-point "spacious-cramped" scale* for his first group of experiments. However, after several experiments, he felt the need for a more sophisticated scale in order to make assessments of spaciousness in more detail, and he constructed S-C-S. İmamoğlu (1986) explained the significance of scales in environmental psychology and S-C-S as follows:

> The advantages of scales in environmental psychology were spelled out by a number of authors: Kashmar (1970) constructed a semantic scale for description of interiors, Canter and Wools (1970) for appraisal of interiors, Küller (1972), on the other hand, developed a scale applicable to both interiors and exteriors. These scales, no matter how little usage they had in architecture, shed some light on our understanding and evaluation of interiors and motivated further studies. The present study stemmed from the same common ground with the hope that development of a spaciousness scale would not only clarify the meaning of spaciousness, hence space – but also provide a descriptive tool to evaluate interiors (p. 129).

After constructing S-C-S, İmamoğlu (1975) completed his second group of experiments in his Ph.D. study with this scale. The Turkish version of the scale was also prepared by him, when he returned to Turkey (İmamoğlu, 1979-b). Both the original English version and the Turkish version of the scale were used in many other research studies in Scotland and Turkey. The construction stages and the contents of S-C-S will be explained below.

2.2.2. Construction of Spaciousness-Crampedness Scale (S-C-S) by İmamoğlu (1975)

İmamoğlu (1975) constructed his Spaciousness-Crampedness Scale (S-C-S) in five stages as part of his Ph.D. studies at the University of Strathclyde in Glasgow. In Stage-1, İmamoğlu gathered adjective pairs which are used to describe spaciousness of a room. He scanned all available sources to collect related adjectives, and he obtained a pool of 151 adjective pairs. For the assessment of internal consistency of the ratings, he repeated 10 of the adjective pairs in the list. Hence the total list was made up of 161 adjective pairs. A total of 135 participants (94 males and 41 females), who were composed of undergraduate and graduate architecture and psychology students from the University of Strathclyde and some Glaswegian office workers, rated these adjectives on *an 11-point (extremely inappropriate - extremely appropriate) scale* to describe the spaciousness of a room. Participants were also free to use question marks to label any unclear pairs. Subjects' agreement and clarity of meanings of the adjective pairs were obtained by using means, standard deviations and the number of question marks for each adjective pair. By using these criteria, the most appropriate 31 adjective pairs were selected to be used for the following stages of the study.

In Stage-2, İmamoğlu selected 36 slides of interiors (offices, living rooms, exhibition halls and the like) from a large pool of colored slides. Half of these slides represented "not spacious" or "cramped" interiors, whereas the other half represented "spacious" interiors. Twenty five office workers (18 male and seven female) and 88 undergraduate students (31 male and four female) evaluated each slide by *a* *four-point (very spacious, spacious, not spacious, not spacious at all) scale*. When the mean ratings for each slide were calculated for students and office workers separately, it was revealed that the ratings of the two participant groups were extremely similar. Based on the ratings of both subject groups, İmamoğlu selected five slides which had the most spacious ratings and other five slides which had the least spacious ratings to be used for the third stage of the study.

In Stage-3, İmamoğlu aimed to obtain ratings of selected slides with the final list of adjective pairs. After a pilot study, the selected 10 slides were presented to 66 undergraduate architecture students (58 males and eight females) and 21 office workers (10 males and 11 females). They were asked to evaluate these 10 slides by using 31 adjective pairs selected in Stage-1. This time, a seven-point scale was employed. With this scale, each participant evaluated each of the 10 slides. Their evaluations were transformed into numerical scores of 1 to 7. While "1" was signifying the undesirable end of the scale such as small, cluttered and the like; "7" was denoting the desirable one such as large, uncluttered and so on. İmamoğlu, first, calculated the mean scores for each of the 31 adjective pairs for each of the 10 interior slides. These mean values made up the bases for two correlation matrices for the five most and the five least spacious interiors. He applied *the Mc Quitty's Elementary Linkage Analysis* to each group of interiors to form meaningful clusters of adjective pairs.

In Stage-4, İmamoğlu carried out factor analysis of the data as a further analysis of Stage-3. He subjected the two correlation analyses in the previous stage to two separate principal component analyses and rotated to orthogonal, simple structure by the *varimax method*. Within these solutions, three factors in *spacious* interiors, and five factors in *not spacious* interiors were the most meaning ones.

In spaciousness case, three factors accounted for 47.7% of the total variance. Factor-1 comprised of 47.7% of the common variance, whereas Factor II was 27% and Factor III was 27%. He named these factors as *"appeal", "planning"* and *"space freedom"* respectively.

Spaciousness Factor I – Appeal: The first spaciousness factor was associated with "attraction, charm or appeal" of the interiors. İmamoğlu (1975) explained this factor as carrying pleasantness and perhaps a homeliness character; "how much at home one might have felt in the interior" or "how appealing, attractive or charming" the room seems to the individual. Variables concerned with the size and the function of interiors were excluded from Factor-I. With its high loadings and evaluative character, Imamoğlu stated this factor to be parallel to Kashmar's (1965) "aesthetic appeal", Canter's (1969-a) and Küller's (1972) "pleasantness", Hersberger's (1969; 1972) "space-evaluation", or Collin's "aesthetic evaluation" factors (Seaton & Collins, 1971).

Spaciousness Factor II – Planning: Factor-II was associated with the planning aspect of the interiors. It was primarily concerned with the organization and fitness of the room to its function, its scale, balance and coordination.

Spaciousness Factor III – Space Freedom: Factor III comprised the feeling of "roominess" along with the physical size or "largeness" of the interior, as well as, the crowding and clutteredness of spaces. Basically, it was composed of two aspects; size (roomy, large) and clutteredness. Hence, İmamoğlu named this factor as "*space freedom*".

In addition to construction of the three *spaciousness factors*, İmamoğlu conducted a similar method over the evaluations of *not spacious* interiors to figure out *crampedness factors*. Among all the analyses, the five-factor solution was thought to be the most meaningful one, which was accounted for 58.4% of the total variance. Factor-I comprised of 30.8% of the common variance, whereas Factor II was 20.7%, Factor III was 18.7%, Factor IV was 17.8, and Factor V was 12%. The last factor; however, was not taken into consideration in the interpretation of the factors and in the scale construction since it had very low variance.

Crampedness Factor I – Planning: The first crampedness factor was associated with planning and organizational dimensions of the interiors. Due to its correspondence to the spaciousness Factor II, it was also named "*planning*" factor.

Crampedness Factor II – Physical Size: In the varimax rotated factor loadings of the crampedness scale, the highly loaded first three items (small-large, tiny-huge, and narrow-wide) were quite distinct from the rest of the variables. Hence, this factor was labelled as "*physical size*".

Crampedness Factor III – Clutteredness: Factor III involved both a judgment of fullness, emptiness with regards to people and items in a room along with a perceived adequacy of size of interiors. Due to the items relating to crowding and cluttering, İmamoğlu called this factor as the "*clutteredness*" factor.

Crampedness Factor IV – Appeal: This factor indicated the feeling of "coziness", "comfort", and "liveableness" of an interior: how attractive, charming or appealing the room seems to the individual. Similar to the first factor of spaciousness, İmamoğlu labelled this factor as the "*appeal*" factor.

To sum up the factor analyses in Stage-4, in order to consider a room as spacious, "first, the room must be appealing, then well planned, and finally must have space freedom". On the other hand, in order to consider a room as cramped, "it must be poorly planned, it must fail to satisfy the functional requirements, it must be too small for that particular function (physical size factor); in addition to these, the number of people or the number of items in the space must seem excessive (clutteredness factor); and finally it must look unappealing" (İmamoğlu, 1975).

> On the bases of the results obtained, one can speculate that every interior must at least score low on Crampedness scale (not cramped); the failure of this condition means the failure of proper functioning of the space. On the other hand, high values on the spaciousness scale means that the particular interior not only fits functional and physical requirements, but also gives some emotional satisfaction or comfort to the occupants (İmamoğlu, 1986).

Stage-5 was the last stage of the scale construction for the selection of the final adjective pairs for *Spaciousness-Crampedness Scale* (S-C-S). For each of the spaciousness and crampedness factors, the most discriminative and representative adjective pairs were selected to constitute the final S-C-S. The aim was to have "the maximum reliability using the minimum number of items". For this purpose, alpha reliability coefficient was used together with factor analysis. In addition to exploring the dimensionality of spaciousness-crampedness domain, “it was possible to decide on the number of items required in order to measure each dimension or factor at an appropriate level of reliability” (İmamoğlu, 1986, p. 132). In this analysis, alpha reliability values for Spaciousness Factors I, II and III were .89 (n=4), .86 (n=5), and .79 (n=8), respectively, and for Crampedness Factors I, II, III and IV, they were .86 (n=4), 88 (n=3), .83 (n=5), and .86 (n=3), respectively. In the end, İmamoğlu obtained 19 adjective pairs which have formed the final version of the S-C-S. Within this, spaciousness scale is composed of 17 items, whereas crampedness one comprises 15 items. Both scales share 13 items.

Table 1 Adjective pairs of Spaciousness-Crampedness Scale. Tabulated from İmamoğlu (1975)

	SPACIOUSNESS FACTOR-1 : APPEAL	
S.1.1	uncomfortable	comfortable
S.1.2	repelling	inviting
S.1.3	disturbing	restful
S.1.4	unlivable	livable

	SPACIOUSNESS FACTOR-2 : PLANNING	
S.2.1	poorly organized	well organized
S.2.2	poorly balanced	well balanced
S.2.3	poorly planned	well planned
S.2.4	poorly scaled	well scaled
S.2.5	uncoordinated	coordinated

	SPACIOUSNESS FACTOR-3 : SPACE FREEDOM	
S.3.1	cramped	roomy
S.3.2	small	large
S.3.3	restricted space	free space
S.3.4	tiny	huge
S.3.5	crowded	uncrowded
S.3.6	closed	open
S.3.7	narrow	wide

	CRAMPEDNESS FACTOR-1 : PLANNING	
C.1.1	poorly planned	well planned
C.1.2	poorly balanced	well balanced
C.1.3	poorly organized	well organized
C.1.4	uncoordinated	coordinated

	CRAMPEDNESS FACTOR-2 : PHYSICAL SPACE	
C.2.1	tiny	huge
C.2.2	small	large
C.2.3	narrow	wide

	CRAMPEDNESS FACTOR-3 : CLUTTEREDNESS	
C.3.1	crowded	uncrowded
C.3.2	cluttered	uncluttered
C.3.3	cramped	roomy
C.3.4	inadequate size	adequate size
C.3.5	full	empty

	CRAMPEDNESS FACTOR-4 : APPEAL	
C.4.1	uncomfortable	comfortable
C.4.2	disturbing	restful
C.4.3	unlivable	livable

2.2.3. Verification of Spaciousness-Crampedness Scale (S-C-S) in Turkish by İmamoğlu (1979)

In order to use Spaciousness-Crampedness Scale (S-C-S) in Turkish culture, its translation and validity in Turkish was needed. Since the scale is semantic based, İmamoğlu (1979-b) tried to make the most accurate translation by a research study.

First, he sought for the assessments of a group of Turkish referees composed of four architects and four psychologists. They were selected from faculty members of METU and Hacettepe University, which had at least one graduate or post-graduate degree from an Anglophone country. After obtaining their individual translations, İmamoğlu prepared the S-C-S in Turkish. Second, a sample classroom was selected from the Faculty of Architecture at METU, where an English medium education system is used. A total of 52 freshmen, junior and graduate students of the faculty participated in the study. Half of them took the Turkish form and the other half took the English form of S-C-S and evaluated the classroom. Statistical analyses indicated that the results from both the English and the Turkish forms were very similar. Hence, the validity of the scale in Turkish culture was verified, and it was named as "*Genel Uzam Değerlendirme (GUD) ölçeği*" in Turkish (İmamoğlu, 1979-b).

2.3. RESEARCH TOOLS TO REPRESENT SAMPLE SPACES

In environmental psychology research, the interaction between people and built environment has been tried to be tested by experiments through sample spaces. Hence, how to select a sample space and how to present it to participants have been the questions to be answered at the beginning of each study. This subject was also mentioned by Craik (1973) in the first annual review of environmental psychology:

> Environmental settings can be presented to observers either directly (e.g. via a standard tour, a long-term residence) or indirectly by means of simulation techniques (e.g. films, photographs, models, videotapes, computer graphics). The complex task of appraising the degree to which each mode of simulation approximates response to direct presentations is currently under way. The effects of relative complexity upon environmental perception and evaluation continue to interest psychologists and designers (pp. 404-405).

As Craik (1973) defined, either sample spaces are presented directly or their representations are used. Since it is not possible to present real spaces in every type of study, various representation techniques have been developed and used in experiments. Both the use of real spaces and other representation techniques have some strengths and weaknesses, which will be briefly introduced in the following subsections.

2.3.1. Real spaces (real rooms)

People perceive their environment with the combination of their four senses which are visual, haptic, audial and olfactory. In addition, physiological, psychological, and cultural aspects of people have significant roles in the interpretation of these senses, and then, the real perception occurs. Hence, *real space* is the most natural way to observe the interaction of people and environment.

Although all other representation techniques aimed to reach the realistic dimension of real spaces; they have more or less missed some realistic aspects within their artificial settings. By knowing this fact, the reasons of using representations instead of real spaces come into question. Some basic reasons can be listed as follows:

1) Some studies may be for future environmental scenarios; hence, there may not be a real space, yet (e.g., design research before construction).
2) In some studies, related real space may be dangerous to study in; hence its representation may be preferred as a stimulus (e.g., defense industry and disaster research).
3) Some real spaces may be inaccessible or hard to reach for participants.
4) For the comparison studies, the mobility of participants from one space to another may cause some aspects of the previous space to be forgotten, which might affect the accuracy of results negatively.
5) In order to focus on some factors in the environment, a researcher may want to eliminate the effects of some other factors; however, this may not be possible in real environment.
6) In some studies, a researcher may need to compare the derivatives of a space, systematically.

As listed above, contrary to real spaces, representations as stimuli provide convenience for researchers in terms of accessibility, flexibility, and manageability.

One example of the use of real room as stimuli is the study of İmamoğlu (1973), titled “the effect of amount of furniture on the subjective evaluation of spaciousness and estimation of size” via two adjacent office rooms. One of the rooms was kept as standard, and the other one was manipulated as empty, furnished and over furnished for comparisons. Another example can be given from post-occupancy studies. For instance, İmamoğlu (1979-a) studied “assessment of living rooms by householders and architects” via real rooms. He surveyed 60 lower and upper socio economic status (SES) houses in Ankara, in which living rooms were evaluated by householders and architects using S-C-S.

2.3.2. Photographs

Presenting only a two-dimensional vision of the space and having only one angle of view are some disadvantages of photographs compared to real spaces as stimuli. However, using photograph is preferred for its following aspects:

1) no accessibility problem,
2) being portable and time saving,
3) being easy to keep in mind for users to compare one after another.

One example from recent literature is the study of Ozdemir (2010) on “the effect of window views’ openness and naturalness on the perception of rooms’ spaciousness and brightness” via real rooms and photographs. He selected 18 identically sized offices in a three-storey building, and took photographs of interiors and window views to use as stimuli. He gave five-point scales (1 = spacious / dim, 5 = confined / bright) to the users in the real rooms and he also asked the opinions of the experts via photographs.

2.3.3. Perspective drawings / Sketches

Perspective drawings were used as stimuli especially at the early periods of architectural psychology studies. For instance, Küller (1970) used this type of representation in his study on “perception of interior as function of its color”. He obtained 31 color slides from a perspective drawing (see Figure 2). He cut out the three wall surfaces, and placed the drawing on colored sheets. He systematically changed the colored sheets as regards to lightness, chromatic strength and hue. Hence, he manipulates the color of walls, while keeping ceiling, floor and interior elements as gray. He used a semantic scale composed of eight adjectives in a seven-point scale for the evaluations of the slides.

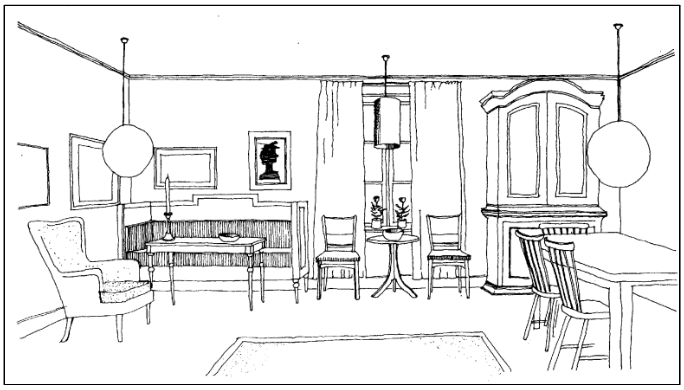


Figure 2 A perspective sketch of a room used as stimuli by Küller ((1970, p. 50).

The study of Garling (1973) on “structural analysis of environmental perception and cognition” was another example for the use of sketch drawings as stimuli. He obtained 24 perspective drawings made after photographs of urban and suburban views (see Figure 3). He compared semantic differential technique and multidimensional scaling based on similarity and preface rating on these drawings.

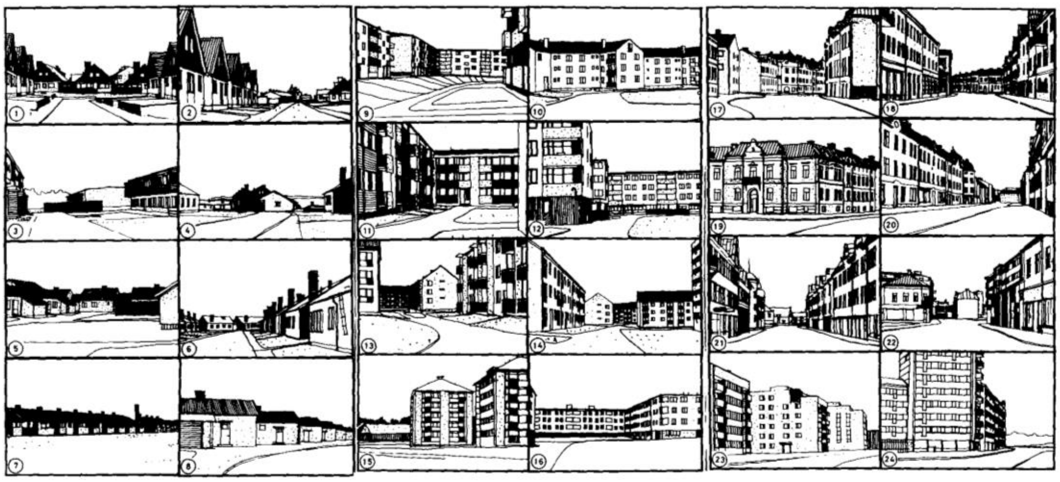


Figure 3 Perspective drawings used as experimental stimuli by Garling (1973, p. 171).

As seen in the both examples, perspective drawings were used as an alternative to photographs when some manipulations were needed. In fact, such kinds of representations lack of several perceptual cues such as color, shade and shadow. With today's computer facilities, it is easy to make manipulations on photographs and also make photo-realistic renders of models. Thus, sketch drawings are not preferred nowadays.

2.3.4. Full-scale (mock-up) models

Full scale models, which are also named as 1/1 mock-up models, have been used to test people-environment interaction in a realistic size. It is preferred especially, when tests with user function or anthropometric dimensions are required (Thiberg, 1966).

One of the recent perception studies via full-scale model is the study of Matusiak (2006) on "the impact of window form on the size impression of the room" (see Figure 4). She built three identical full-scale rooms adjacent to each other. The window walls were constructed out of opaque boxes (50 x 50 x 25cm) and translucent window elements (50 x 50 x 25cm). She obtained different window forms by changing places of the window elements in the wall without changing the total numbers. By this method, she asked people to evaluate the impression of the height, width and length, as well as the general impression of the room size.

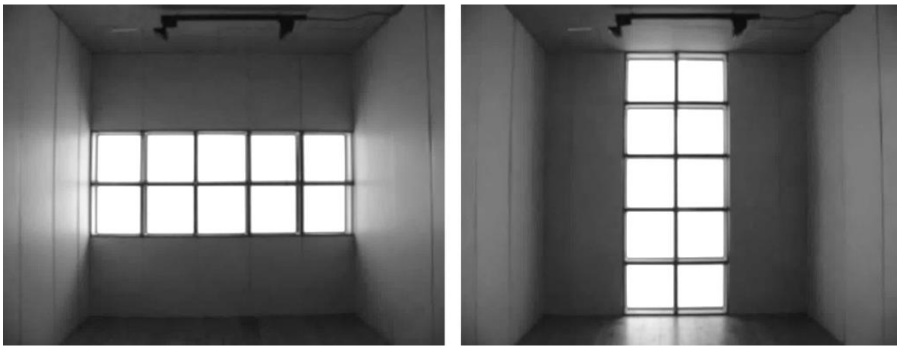


Figure 4 Vertical contra horizontal: one window at the middle of the window wall, daylight (Matusiak, 2006, p. 44)

For perception studies, full-scale models give participants opportunity to perceive the space with their four senses. Moreover, participants can experience the space while walking and looking around as they want. In this process, the participants' way of "seeing" is natural in terms of physiology and optics (Crary, 1990). However, there are also some disadvantages of full-scale models, which are listed below:

1) A laboratory setting is needed.
2) A high research budged is needed.
3) In order to save time and money, some full-scale models may not be built in detail. Thus, some researchers may prefer to build simplistic models, which only prioritize the research aims and eliminate the complexity of the environment. This may affect attitudes of participants in perception studies.
4) For the comparison studies, mobility of participants from one space to another may cause forgetting some aspects of the previous space, which might affect accuracy of results negatively (as also mentioned for real-spaces).

2.3.5. Scale models

Scale models are economical and practical alternatives of full-scale models as stimuli. Being reduced sized and impenetrable are their weaknesses, when compared to full-size models. However, they were commonly used tools in experimental studies in architecture, due to its several advantages over the other representation tools and the real space:

1) Constructions of scale models are more economical and practical than full-scale models.
2) Since scale models can be portable, they are not as depended on laboratory settings as full-scale models.
3) As they are small in size, they can be placed in any environment, for instance, in the real space represented by the scale model, in front of a real scene, under natural daylight and the like.

4) Quick mobility of participants from one model to another is possible. Hence, memory effect is eliminated.

For the effective use of scale models, several techniques were developed for model designs. Two of these are listed below:

1) To test different alternatives using one model, convertible models can be designed. Modular constructions and sliding walls are some of the techniques for this aim.
2) Instead of top views, observing the interiors of the models from a scaled person's eye level (horizon line) is significant to make space observations as realistic as possible. Having the observer look at the model from outside through an opening in one of the walls, or having the observer extend his head into the model are some procedures for this purpose.

Figure 5 illustrated two examples of scale models which were used for daylight studies (Hopkinson, 1963).

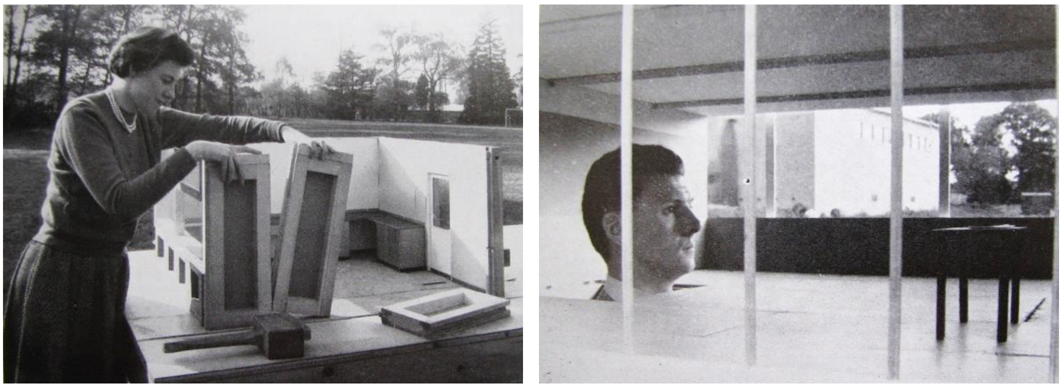


Figure 5 Examples of scale models as stimuli: Left: a unit-construction model for lighting studies. Right: a model room viewed through floor (Hopkinson, 1963).

Many researchers used scale models in several visual tasks. İmamoğlu (1975, pp. 73-98) checked the validity of 1/10 scale models with regards to spaciousness. As a part of his Ph.D. study, İmamoğlu selected a square planned meeting room. He constructed its 1/10 scale model (standard model) and also two adjustable models in

$\sqrt{2}$ and $\sqrt{3}$ plan proportions. Both the standard model and one of the adjustable models were placed in the real room. Participants were asked to compare spaciousness of the real room with its 1/10 scale model (standard model), and then they were asked to compare one of the rectangular models with the standard model.

> This procedure was thought to help the subjects to follow a smooth mental judgment; step by step starting with the consideration of the spaciousness of an actual room, continuing with the judgment of the 1/10 scale model of the same room and ending with the comparison of the same scale but two different shape models (1975, p. 88).
>
> The results of the present experiment verified that 1/10 detailed scale models can be used as a means to represent the interior spaces. More than 50% of subjects saw no difference between the spaciousness of the actual room and its model. About 30% assessed the model as being more spacious than the room. This may be due to the fact that during the experiment the models (both the standard and the comparison) that were placed on tables, occupied a certain volume (1975, p. 94).

After constructing Spaciousness-Crampedness Scale (S-C-S), İmamoğlu (1975) compared a square conference room with its 1/10 scale model and colored slides in another experiment. He asked 66 participants to evaluate the three conditions via S-C-S. His results indicated that "there were no difference between a real-room and its 1/10 scale models; however, the slide of the room was perceived as having significantly less space freedom and to be much less appealing and less well-planned, hence less spacious, as compared to the other conditions" (p. 172). Due to these findings, in his further research, he did not employ slides but he continued to use scale models as well as real rooms utilizing his scale.

2.3.6. Computer Simulations

For the last few decades, computer simulation has been becoming widely used representation tools in environmental psychology. It has been substituting the conventional representation techniques for its following properties:

1) It is practical and economical.
2) It presents a wider variety of alternatives.
3) Its technology is rapidly developing.

As mentioned in Chapter-1, computer simulations vary in terms of their apparatuses and programs. Moreover, they are used by many disciplines. Hence, related terminologies might be changed from reference to reference. Thus, before reviewing the related literature, it is necessary to define what *computer simulation* refers in the scope of the current thesis. In Oxford English Dictionary (OED, 2014), one of the definitions of *simulation* is "the technique of imitating the behavior of some situation or process (whether economic, military, mechanical, etc.) by means of a suitably analogous situation or apparatus, esp. for the purpose of study or personnel training". In addition, the verb *simulate* is defined as "to imitate the conditions or behavior of (a situation or process) by means of a model, esp. for the purpose of study or of training; spec. to produce a computer model of (a process)" in the same dictionary.

In fact, as Winsberg (2013) stated, computer simulations got involved in the research of other disciplines much earlier:

> Computer simulation was pioneered as a scientific tool in meteorology and nuclear physics in the period directly following World War II, and since then has become indispensable in a growing number of disciplines. The list of sciences that make extensive use of computer simulation has grown to include astrophysics, particle physics, materials science, engineering, fluid mechanics, climate science, evolutionary biology, ecology, economics, decision theory, medicine, sociology, epidemiology, and many others. There are even a few disciplines, such as chaos theory and complexity theory, whose very existence has emerged alongside the development of the computational models they study.

The literature survey indicated that computer simulation technologies were not immediately involved in environmental psychology studies. This delay might occur due to the fact that the technology of computer simulations might not be seen adequate until the technology reach a more satisfactory level to simulate realistic vision of environment. The following explanation of Brey (2008) might support this:

> It is not usually an aim in computer simulations, as it is in virtual reality, to do realistic visual modeling of the systems that they simulate. Some of these systems are abstract, and even for those systems that are concrete, the choice is often made not to design graphic representations of the system, but to rely solely on abstract models of it. When graphical representations of concrete systems are used, they usually represent only the features that are relevant to the aims of the simulation, and do not aspire to the realism and detail aspired to in virtual reality (p. 363).

In the current situation, there are many examples of research with computer simulations in environmental psychology. However, although the computer technology is developing further, new developments in computer technology is followed from behind in environmental psychology. This might be due to the concerns about whether the new developments present a realistic space or illusion. In Section 2.5, computer simulations will be assessed in more detail with its latest developments. Now in Section 2.3.6, how these tools are used in the field of environmental psychology will be briefly introduced.

> The benefits of using virtual environments (VEs) in psychology arise from the fact that movements in virtual space, and accompanying perceptual changes, are treated by the brain in much the same way as those in equivalent real space. The research benefits of using VEs, in areas of psychology such as spatial learning and cognition, include interface flexibility, the reproducibility of virtual experience, and the opportunity for on-line monitoring of performance (Foreman, 2009, p. 225).

As mentioned in Section 2.3.5, validity of scale models in environmental psychology were verified in several studies, one of which was the study of İmamoğlu (1975, pp. 73-98). Since all scale models have more or less similar properties in terms of optical and physiological aspects of visual space perception, these verifications might be generalized for the use of all kinds of scale models in environmental psychology. However, a general verification for computer simulations seems not possible due to their wide variety of apparatuses and programs which are rapidly developing. Hence, many researchers started their study by the verification of the computer simulation technique they intended to use. Some of these will be briefly mentioned below.

Matusiak and Sudbo (2008) conducted a study on “width and height” impact on size impression of spaces via both full-scale models and computer simulations. In their study, they designed a sample room in the form of a rectangular prism which has a translucent square window in one wall, and they produced two types of full-scale models of the sample which had the same volume but one in vertical and the other in horizontal position. They also built models with larger windows and obtained four different full-scale models of equal volume in total. They also built computer simulations of the four models in two different computer programs (ArchiCAD and

Radiance), and presented them to participants as “virtually generated pictures” on two different computer screens (see Figure 6).

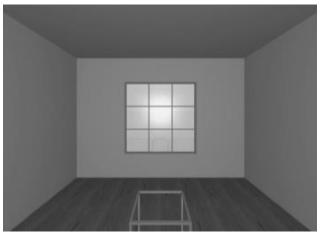
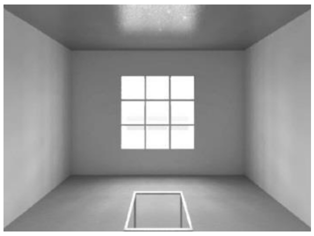
	Full-scale Model	ArchiCAD Model	Radiance Model
Model A (3,5 x 2,5 x 3,6)			
Model B (2,5 x 3,5 x 3,6)			

Figure 6 Six model examples tabulated from an experimental study on width and size impact on size impression via full-scale models and computer simulations (Matusiak & Sudbo, 2008).

All models were repeatedly evaluated by 24 students of architecture on a single five-point “small-large” scale. According to the results of the full-scale study, Matusiak and Sudbo (2008) stated that “width has stronger positive impact on the size impression than height”; however, “the student evaluations of the size impression were considerably different in full-scale than in both the Radiance and ArchiCAD simulations”:

> The study showed that the precise evaluation of the room SIZE based on virtually generated pictures alone is still difficult, even the use of the most advanced lighting simulation program, Radiance does not guarantee success. A possible reason for this may be the third dimension, depth of the room cannot be shown on the flat screen, but may be important in the full-scale evaluations (Matusiak & Sudbo, 2008, p. 171).

As mentioned before, due to the wide varieties of computer simulations, it is not possible to generalize such kind of results to all computer simulation techniques. However, this type of results might help to develop more advanced procedures for the future studies. The main weaknesses of the mentioned study might be 1) simplicity of the scale used and 2) lack of three dimensional qualities and complexity of the presented images.

Computer simulation can be illustrated to participants either as a two-dimensional image (render) or as an animation to experience *virtual walking* in the model which is also named as *virtual reality* (VR) or *virtual environment* (VE). Stamps (2007-a) named these two alternatives as "static and dynamic media", and he compared these two in one of his studies on spaciousness. He designed "a museum gallery" in an irregular convex hexagon plan form with 5m ceiling height in a CAD program called *Microstation*. From this standard model, he derived eight models: two floor areas ($77.5m^2$ and $155m^2$) x two lighting condition (bright and dim) x two occlusions (with or without partition walls). By recording three different viewing directions for each, he obtained 24 images (see Figure 7). He presented these images in a Power Point show to 26 undergraduate engineering students in a class. They evaluated the images in a single eight-point "spacious - not spacious" scale. In the second step of his study, he exported the CAD models to software called *OpenGL game engine* to obtained VR models. In this process, in order to have realistic lighting, he obtained renders of each wall in the *Microstation* and attached to the related surfaces in the game engine. The VR models were presented to eighteen participants in a laptop data collection program with a row of buttons and verbal labels for evaluations. In addition to answers of the scale, motions, viewing directions and time were also recorded.

As a result, Stamps (2007-a, p. 553) stated that "both methods generated the same conclusions: rooms with larger floor areas, no occlusions, or more light perceived as being more spacious than were rooms with smaller floor areas, occlusions, and less light, regardless of the simulation medium." Since static images represent only a limited area of view, how participants evaluated the static images and the dynamic model similarly is thought-provoking. One possible reason is that, by a simple rating scale, participants might evaluate the stimuli shallowly. In addition to statistical results, Stamps explained his observations on the usage of dynamic VR systems. He stated that preparation of VR models were both costly and time consuming than static images; however, VR models were more effective and participants spent more time and paid more attention to the models (Stamps, 2007-a).

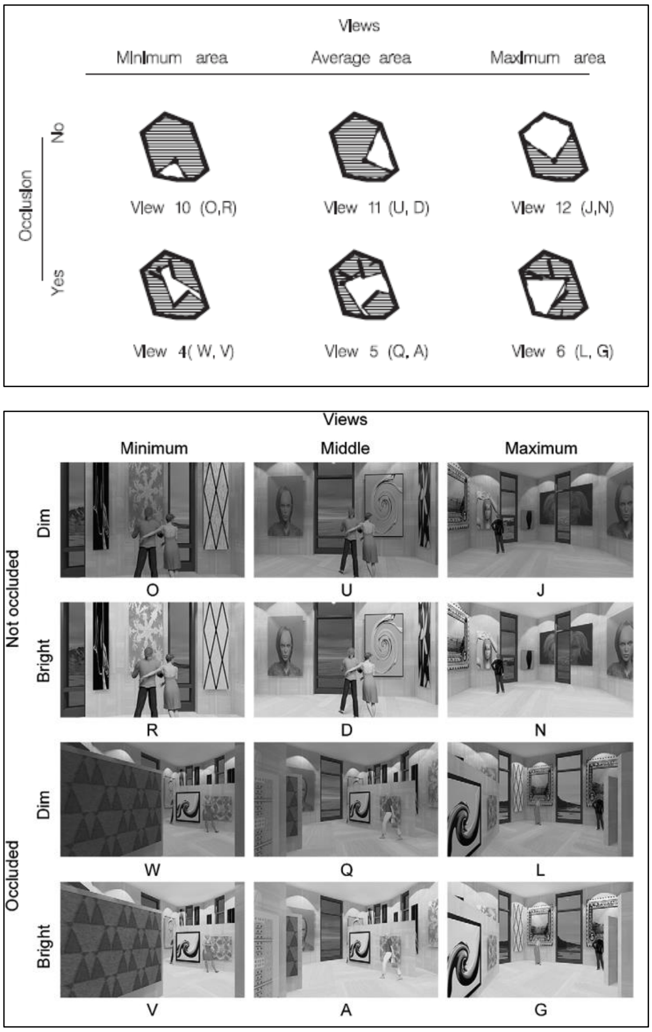


Figure 7 Plans and images of the 77.5m^2 museum gallery used as stimuli by Stamps (2007-a): two lighting condition x two occlusion x three viewing direction. The gray hatches in plans illustrated the invisible areas.

These examples can be multiplied. Since the beginning of the 2000s, several studies focusing on how virtual environments could be used in architectural and psychological research have been added to the literature. However, due to the diversity of computer simulations and the complexity of people-computer interaction, it is not possible to state a generalization about the validity of computer simulations in environmental psychology. The statement of Franz (2005) also supports this situation.

> Virtual reality offers promising qualities both for architectural simulation and perceptual experiments. Yet, since VR is a novel medium, the question has to be raised as to what degree experiences in VR can be transferred to reality. Validity criteria can be defined more generically for architectural simulation in general or more narrowly for the particular main goal of investigating affective responses to architectural properties. Unfortunately, the current state of knowledge represented in literature does not allow conclusive statements on the general validity of VR for architectural simulation. Although there are several studies comparing aspects related to architectural perception between VR and reality, the transferability of their findings cannot be taken for granted a priori. VR simulations consist of many design aspects that all contribute to a vast parameter space. Due to possible interactions and unknown mutual influences, all general predications based on current studies have to be seen as provisional (p. 78).

To sum up, computer simulations have been substituting the conventional representation tools in the environmental psychology. By learning the strengths and weaknesses of the past computer simulation techniques in the field and following the recent developments in the computer technologies, each study has to design its own research procedure and verify its validity.

2.4. SOME RESEARCH FINDINGS ON SPACIOUSNESS IN ARCHITECTURAL PSYCHOLOGY LITERATURE

In the previous sections of this Chapter, the concept of *spaciousness* was introduced in the research field of architectural psychology in a broad sense. The two significant components of architectural psychology research, which are the evaluation techniques and the presentation of sample spaces (real or represented), were introduced. After having an insight about the architectural psychology research, now in Section 2.4, the concept of spaciousness will be reviewed in detail through past research findings in the literature.

There are mainly three types of studies directly or indirectly related to *spaciousness*:

1) Studies concerned with exterior spaces:
    a) Urban spaces (streets, alleys, public squares, plazas).
    b) Natural environments (parks, gardens, landscape).
2) Studies concerned with building interiors:
    a) Rooms: building interiors which have its own walls, floors, and ceilings (offices, classrooms, meeting rooms, hospital rooms and living rooms).
    b) Building interiors with walls on either side which connects one room or place to another (corridors, waiting areas, lobbies, atriums).
3) Studies concerned with vehicle interiors:
    a) Vehicle interiors for short term usage (train, airplane).
    b) Vehicle interiors for long term usage (spacecraft).

There are several empirical studies for each of the above mentioned subjects in the literature. However, since the current thesis approaches the subject in the discipline of architecture, the literature on building interiors will be focused. In buildings, *rooms* are the manageable units with their well-defined surroundings. Hence, rooms have been the mostly selected sample spaces in experiments.

The parameters that have been evaluated in these empirical studies can be listed in five main groups as follows:

1) User profile of spaces:
    a) Biological properties of people (gender; age; disability etc.)
    b) Acquired properties of people (education; occupation etc.)
    c) Culture
    d) User and non-user
    e) Activities in the space (personal-intimate, social, and public)

2) Permanent components of interior spaces:
    a) Room size and dimensions (plan ratio; height; total volume etc.)
    b) Room boundaries (surface properties: smoothness, reflectiveness etc.)
    c) Window (orientation; position; size; shape; daylighting)
3) Temporary components of interior spaces:
    a) Order within the space (organized, disorganized, very disorganized)
    b) Furniture density (empty, furnished, over furnished)
    c) Color (hue, value, chroma)
4) Window views (locations of spaces):
    a) Urban and non-urban
    b) City center and suburb
    c) Street view and nature view
    d) Level in relation to the ground (ground floor, upper floors)
5) Lighting:
    a) Daylighting and artificial lighting
    b) Amount of lighting (low, medium, and high)
    c) Direction of lighting source (from ceiling, from corners etc.)
    d) Section of day (day, night; summer, winter)
    e) Solar control tools (curtains, solar screens, sunshades etc.)

Since the people-environment interaction is bilateral, diversity in both the people and the environment may affect this interaction. Hence, some studies focus on how a sample space is perceived by different groups of people, on the other hand, some other studies examine how different spaces are perceived by a sample group of people. Moreover, it is also possible to examine both of them in one study. Some of the studies, which focused on the user profile (the people), will be mentioned in Section 2.4.1.

As listed above, the environment parameters can be grouped in four: interior space components (permanent and temporary), exterior effects and lighting. Within those, the lighting parameters were related with both interior and exterior parameters.

However, due to its wide content and specialized discipline, the lighting was written as a different item in the list above and will not be taken into the scope of this thesis. For the current thesis, the most significant group of parameters are "the permanent components of interior spaces", which are directly related to architectural design. Hence, after introducing the user parameters, the literature review will focus on "the permanent components of interior spaces".

2.4.1. User profile of spaces

Participants and their characteristics have a significant role on assessing the interaction of people and the environment. This is emphasized in the latest edition of APA Style as follows:

> **Participant (subject) characteristics.** Appropriate identification of research participants is critical to the science and practice of psychology, particularly for generalizing the findings, making comparisons across replications, and using the evidence in research syntheses and secondary data analyses. If humans participated in the study, report the eligibility and exclusion criteria, including any restrictions based on demographic characteristics (APA, 2010, p. 29).
>
> Even when a characteristic is not used in analysis of the data, reporting it may give readers a more complete understanding of the sample results and the generalizability of results and may prove useful in meta-analytic studies that incorporate the article's results (APA, 2010, p. 30).

It is clear that the participants, which are chosen to represent the users of a sample space, is significant to be identified in every study in the field. Even a random selection of participants also leads to a specified group of characteristics, which was also described by Cooper (2011):

> Most Method sections begin with a description of who took part in the study and how they were recruited. Some people will always be more likely than others to participate in a study, often simply because some people are convenient to recruit. For example, your hypothetical perfume labeling study, like many studies in psychology, may have been conducted with undergraduates drawn from the subject pool of your psychology department who may have participated as part of a course's requirements. Such samples are restricted primarily to young adults going to college in a particular part of a country who have at least a curiosity about psychology. Studies drawing participants from communities that are near an institution of higher learning are also restricted in some ways, at least geographically. Even samples meant to be nationally representative can include based on, for example, language and accessibility (p. 24).

There are several examples of experimental studies, which compare space perceptions of different participant groups, such as different ages (young people vs. elderly people), genders (females vs. males), educations (students vs. staff), occupations (architects vs. non-architects) and the like. Since the results may vary from experiment to experiment according to the focused spaces and their presentation techniques, they will not be cited in the current thesis one by one. However, there are two significant questions, which should be mentioned before starting to design a new experimental study:

1) Do the desirable degrees of spaciousness differ for different activities?
2) Is there a difference between users' and nonusers' perceptions of spaciousness?

These were also questioned and examined in some experiments by İmamoğlu (1975). He grouped activities into three, namely *personal-intimate*, *social*, and *public*:

> … The 'personal-intimate' grouping referred to those activities which involved only themselves and/or someone with whom they had very close relationships; such as a lover, a mother, a very close friend, etc. With such people they would tolerate more physical contact and might engage in intimate, ego-involved activities. The 'social' grouping, on the other hand, would include the activities which usually involved more than two persons with whom they had more general, neutral topics. These relationships might involve friends in general, teachers, etc. Finally the 'public' grouping referred to those activities that they would engage in with people whom they either knew very little or did not know at all (pp. 57-58)

Then, he asked ten participants to classify a list of 35 activities into the above mentioned three groups. Within these classifications, five activities were selected for each group. In the following step, 32 architecture students evaluated the fifteen activities on a seven-point "spacious-confined" scale. According to the results, *personal-intimate activities* (studying alone, prying alone, etc.) required confined spaces, whereas *social activities* (studying with a group, dining with a group, etc.) require rather spacious environment. *Public activities* (waiting for a train, giving a public speech, etc.) require the most spacious environments (İmamoğlu, 1975, pp. 61-64).

After constructing the *Spaciousness-Crampedness Scale* (S-C-S), İmamoğlu (1975) reexamined the activity groups on spaciousness in an experiment via real rooms. First, he hypothesized that "one may expect the interiors allocated for *public activities* to be perceived as being the least spacious, while the rooms for *personal-intimate activities* the most; the interiors for *social activities*, on the other hand, can be expected to be perceived in between" (p. 232). He selected a private office room (15.35m^2), a postgraduate student's lounge (27.45m^2), and a staff-student common room (53.35m^2) in the same floor of a building as stimuli to represent each activity groups. Each room was evaluated via S-C-S by fifteen participants, and the results supported the hypothesis:

> A room of 53.35 sq.m. with 28 seats for public activity was evaluated as being the least spacious interior; that of 15.35 sq.m. with 6 seats for a personal-intimate activity was perceived as being the most. On the other hand, the room of 27.45 sq.m. with 26 seats allocated for social activities, although little more favourable, was rated similar to that of the room for public activity. In other words, in spite of the fact that, the common room was about twice as big as the post-graduate lounge, and 3.5 times as the private office room, it was evaluated the lowest in spaciousness scale (İmamoğlu, 1975, pp. 243-244).

In another experiment, İmamoğlu (1975) questioned whether spaciousness of a room was evaluated by its *users* and *non-users* similarly or not. He selected a postgraduate lounge as stimuli. The room was evaluated via S-C-S by 15 students, who had been using the room as their lounge for the last five months, and 15 non-user students. Results indicated that the users "evaluated it as being less well-planned and having less space freedom as compared to those who did not know the room" (p. 231).

> It seems that using and sharing a lounge of this size with 18-20 people is different than just "imagining" it to be used in that way. Among some social aspects there may be a number of other reasons; a) getting used to the interior, b) knowing their own needs and requirements, the type and nature of the activities in the particular section of time, and perhaps, c) attitude to the institution and the particular social group (İmamoğlu, 1975, p. 231).

These experiments indicated that spaciousness perception is more complicated than visual perception. It may be affected by functional needs, social aspects and experiences. However, as mentioned in Section 2.3, it is not possible to test every aspect together. Hence, being aware of these, experiments are generally designed by controlled parameters.

2.4.2. Permanent components of interior spaces

Because of being directly related to architectural design, the permanent components of interior spaces are significant parameters in the scope of the current thesis. As mentioned before, related literature can be grouped in three main subjects: 1) room size and dimensions, 2) room boundaries, and 3) windows. However, most of the studies examined more than one of these components together. Hence, instead of presenting past findings according to this classification, they will be presented in chronological order.

2.4.2.1. Studies in the 1960s and 1970s:

The 1960s and the 1970s were *the beginning period* in which the field of architectural psychology started to be shaped by various empirical studies.

Holmberg, Alkgren, Soderpalk and Kuller (1967) (cited in İmamoğlu, 1975) examined the effect of the *ratio between depth and width* on the *perception of volume* content of rectangular rooms. They carried out four experiments, one with 1/10 scale models, one with 1/5, and two with full-scale mock up rooms. For the full-scale experiments, six rooms were built in a laboratory. They were different from each other in terms of depth and width ratio (1.0, 1.5, 2.9, 2.5, 3.0 and 3.5), while their height (2.5m) and the floor area (25m^2) were kept constant. Furthermore, with these proportions, 1/10 and 1/5 scale models were built. Evaluations were made by the magnitude estimation method. While 100 point was referring to the volume of the square room, namely “the standard”, 60 participants were asked to give a point value to volumes of the each comparison rooms.

The result of Holmberg et al. (1967) showed that volume perceptions of rooms were affected by the plan proportions of the rooms; “the more oblong a room, the more spacious it looked”. When the subjects were stationary, the result showed a correspondence between full-scale and small-scale models regarding the proportion and volume estimation". However, when the participants were permitted to walk around the full-scale rooms, they were less affected by the proportions. Holmberg et al. (1967) stated that "the reason for this might be that the distance to the walls from the observer is critical for volume perception". They interpreted that "if the distance to the wall is a relevant factor in the perception of volume content, then one might predict that if stationary subjects perceive a room from a door in one of the long walls, they will perceive the room as smaller than if they view it from a door in one of the short walls".

Jeanpierre (1968) (cited in İmamoğlu, 1975) conducted three series of experiments which focused on 1) *distance perception*, 2) *ceiling height*, and 3) *room proportion* in mock-up rooms. In his first experiment, the mock-up room (7.00m long, 2.88m wide and 2.12m high) had a movable wall which could be commanded by an electronic device. He asked 36 participants to bring the opposite wall to a reference point (2.50m, 3.00m, 3.50m or 4.00m) which he randomly changed each time. The results indicated that "when the wall was closer than 4.00m to the subjects, there was a significant tendency to locate the panel further away". Jeanpierre confirmed the results by verbal estimations of participants in another study and stated that "There is an obvious sensitivity in man when his immediate environment diminishes" and "estimation of space within the dimensions of a house (room) is a complex phenomenon. It uses some elements of perception but it is something else, something beyond the perception" (p. 65).[1]

In the second experiment, Jeanpierre (1968) examined two room sizes: 1) 3.00m deep and 4.00m wide, 2) 5.00m deep and 6.00m wide. The ceiling height could be changed between 2.00m and 2.90m. He asked 100 subjects to adjust the ceiling height for 12 times (six sitting down and six standing up position) to choose the best ceiling-room relation. The results showed that there was no relationship between height of the participants and the ceiling adjustments. However, room size and the

[1] Translations from French were made by Mr. J.F. Allain, Department of Modern languages in University of Strathclyde.

position of participants were significant, since "adjusted ceiling heights in the large room were greater than those in the smaller room and adjustments made in the standing up position were higher than those for sitting down". (Mean adjustments in $12m^2$ room were 2.54m and 2.44m while in $30m^2$ room 2.71m and 2.65m, for standing up and sitting down positions, respectively).

In the final experiment, Jeanpierre (1968) tried to find *the most satisfactory proportion in an enclosed space*. He manipulated all three dimensions of his mock-up room; ceiling height (2.00m to 3.00m), side wall (1.50m to 4.00m) and the opposite wall (1.00m to 5.50m). Eight subjects made their evaluations on a five-point "greatly satisfied - not satisfied at all" scale, while they were able to move around the experimental room. The results showed that 2.50m ceiling height and square or square like rectangular rooms were considered as the most favorable ones. He also noted that "People react much more acutely to unpleasant space than a pleasant one" (Jeanpierre, p. 112). İmamoğlu (1975, p. 28) commended his study as follows:

> Though very comprehensive and valuable, Jeanpierre used only mock-up interiors in his research. As he himself mentioned; a) there were some shortcomings in his experimental technique of the last group of studies (irregularities in model room, cold surroundings, small number of subjects, etc.) and in general, b) it is necessary to verify his findings in real rooms with windows, furniture, etc.

Mercer (1971) (cited in İmamoğlu, 1975) focused on *measuring the extra space* which a *window* might imparts to a room. He selected three rooms with the same ceiling height. Two of them were identical in size, while the third room was 6.2 times the volume. Windows of the second and the third rooms were occluded. Fifty two participants (30 psychology and 22 architecture students) were asked to estimate six sizes in three rooms: two body dimensions (the size of their head and the width of shoulders); two imagined lengths of one foot and one foot six inches; and finally two real lengths of 32.2cm and 43.0cm. The results indicated that "the three of the six estimates (lengths around 25cm) were significantly bigger in the large room, as compared to the small one. Additionally, he compared the estimations in two small rooms (a room with a window and a windowless room). The results showed that "the two of the estimations were greater in the windowed room as compared to the windowless one". He explained the results as follows:

> By plotting mean estimation against room volume and fitting the estimates from the windowed room on the resulting graphs, the apparent or phenomenological volume (PV) of SW (small room with window) was found. The extra space (ES) due to the window is then given by: PV – real volume (RV) i.e., PV – RV = ES.
>
> It would appear that the PV and thus the ES varies with what the person is concerned about. When the subject is concerned with his own body size that is, with something related to himself, the effect of the window is greatest. When he is concerned with imagined length the window effect is not as marked, and when he is concerned with size for which there is a visible comparison the window has no effect at all. In other word, the window affects most the person's perception of himself – it makes him 'feel' bigger, as manifest in his increased body boundary (Mercer 1971 cited in İmamoğlu 1975, p.23).

Results of the estimations of 1ft imagined length indicated that there was a significant occupational effect. For all size estimations, architecture students were more precise than the psychology students.

İmamoğlu (1975) questioned the article of Mercer (1971) in terms of "the way he calculated the PV" and "relevance of estimations of lengths and body dimensions to the perception of interiors".

Dalkvist and Garling (1971) (cited in İmamoğlu, 1975) studied the visually perceived or sensed *restricted space* in terms of two variables; *wall or screen arrangements* and *lighting*. The number of screens (80cm x 80cm) was changed between 0 – 4 – 8 and 12, combined with four brightness levels (about 1, 10, 100 and 1000 lux) measured at the floor. They asked 11 subjects to evaluate how restricted the space appeared, by marking a position along a 10cm straight line, in which two ends defines as "completely restricted – not enclosed at all". The results showed that "apparent restricted space increased directly with number of screens". Conversely, the relationship between the apparent restriction of space and brightness level was more complex: Though there was an increase in the restrictedness of space by increases in brightness (from 1 to 10 and 10 to 100 lux), this tendency altered in the opposite way for the highest brightness level (1000 lux), and despite the number of screens, the space was evaluated to be less restricted. This study was commended by İmamoğlu (1975) as follows:

> Although they used few subjects and worked with small screens under laboratory conditions, Dalkvist and Garling's both findings are valuable for the present project. The results may imply that; i. the more solid surfaces you have around the space, the ore restricted it looks, and ii. Low brightness levels make the space look restricted; however, this later statement has a very limited implication for their experiment did not cover the usual brightness range (100 to 1000 lux) of architectural spaces in detail (p. 19).

Küller (1972) assumed that "rooms with light surfaces would seem larger and/or more spacious". He examined the relationship between *openness (spaciousness) of a room* and *lightness of its surfaces* via color slides of drawings. According to the results, there was a high positive correlation between these variables ($r = 0.76$, $p < .01$). He further checked his findings by repeating the experiment via three full-size rooms and confirmed the earlier results.

Another experiment of Küller (1972) focused on *room size*. He chose three rooms, which were $6m^2$, $12\ m^2$ and $24m^2$ in floor area, as stimuli. He asked each participant a) to evaluate one of the rooms via a semantic scale and b) to evaluate the length and width. The results of the semantic scale indicated that the rooms had been judged significantly different. He stated that "this shows the existence of an inner frame of reference with which the individual can compare volume of rooms in absolute ratings" (p. 101). Evaluations of the three rooms were also significantly different with regard to length and width. With reference to total curves, both of the evaluation methods (a and b) produced similar results. However, for the individuals in both semantic and length-width ratings, there were great error variances, which he explained as follows:

> Thus, it seems as if the way in which an individual makes use of the semantic scale is independent of the way in which he indicates length and width for one and the same room. The interpretation of this result is very intricate. The most far-reaching conclusion would be that individual variations in perceived size are independent of variations in perceived length and width. The most probable conclusion is, however, that both rating methods give a random, and between them independent, deviation from the perception (p. 101).

The study of Inui and Miyata (1973) (cited in İmamoğlu, 1975), which was titled "spaciousness in interiors", approached *spaciousness* from the *lighting* point of view. They designed and constructed three types of office models in 1/20, 1/10 and 1/5 scales; the widths of the interiors were variable, whereas heights (3.00m) and depths were (8.00m) fixed. One of the walls of each model had an adjustable window starting from a sill of 1.00m. The researchers obtained the various combinations of the models; 3 sky luminance (using an artificial sky) x 7 average horizontal illuminance on the working plane x 8 window width in eight steps. They obtained 474 combinations from the above variables, and asked 10 participants to give spaciousness value to each of them as compared to the standard (which was valued as 100 points of spaciousness).

According to the results of Inui and Miyata (1973), there was no difference between the results obtained from 1/20, 1/10 and 1/5 scale conditions. Interior illuminance, room size and window size affected the spaciousness of different sky luminance. However, the effect of room shape as a variable did not significantly affect the estimations of spaciousness. Inui and Miyata checked the results obtained from the scale model experiments with 43 real rooms and confirmed the earlier findings. İmamoğlu (1975) criticized the reliability of the experiment design in which only 10 participants evaluated hundreds of combinations. He also emphasized the cultural difference that "spaciousness may be quite a different construct in Japanese culture from the British or European cultures".

İmamoğlu (1975) conducted several experiments within the scope of his thesis. Four of them were related to permanent components of interior spaces. The first one examined the effect of *window size, room proportion* and *window position* on spaciousness evaluations of rooms (İmamoğlu, 1975, pp. 73-98). As stimuli, he used a square conference room, its 1/10 model (namely standard model), and two adjustable models, which have similar architectural character with the standard model. The size of each model could be changed by means of a handle, but proportion and ceiling height of each was kept constant. He obtained eight different conditions from the two models by manipulating the size and position of windows in wall panels: 2 room proportions (square root two by one and square root three by one) x 2 window size (three-bay and continuous) x 2 window position (window on short side and window on long side) (see Figure 8 and Figure 9).

For each experiment condition, he placed the standard model and one of the adjustable models side by side in front of the window of the real room, and left the adjustable model in equal area position with the standard model. There were fifteen participants in each of the six conditions of the experiment. İmamoğlu individually asked 120 participants to compare the spaciousness of the real room with its 1/10 model (standard model) and then to adjust the rectangular model to be equal in spaciousness to the standard one. When the participant left the room, the researcher measured and recorded the assessed size.

From the experiment mentioned above, İmamoğlu (1975) obtained several research results. Results indicated that, in all of the eight conditions, participants adjusted sizes of the comparison models very close to the size of the standard model. This means that either participants did “very careful and consistent judgments of spaciousness” or they “associated the spaciousness very closely with physical volume or floor area”.

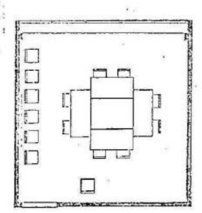
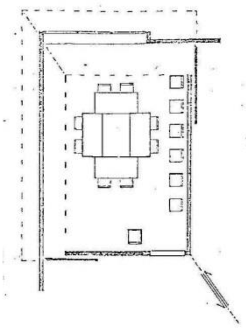
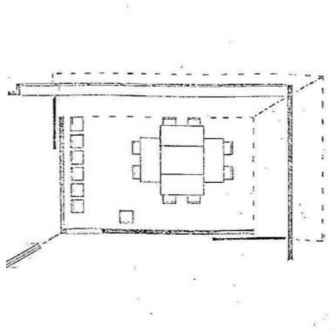
Standard Model	Adjustable Model-1	Adjustable Model-2
		

Figure 8 Plans of the 1/10 scale models used by İmamoğlu (1975). Standard model: 1/10 models of the existing square conference room. Adjustable Model-1: root-two plan proportion, window on short wall, three-bay window. Adjustable Model-2: root-three plan proportion, window on long wall, continuous window. (Tabulated by Özyıldıran 2014).

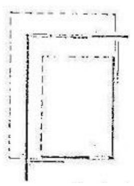
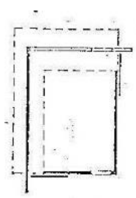
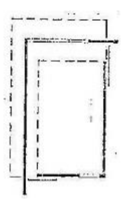
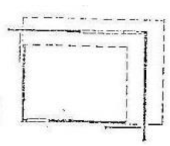
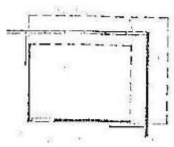
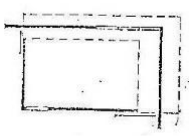
	Adjustable Model-1		**Adjustable Model-2**	
	plan proportion: $\sqrt{2}$ / 1		**plan proportion: $\sqrt{3}$ / 1**	
	three by window	**continous window**	**three by window**	**continous window**
window on the short side				
window on the long side				

Figure 9 Plans of eight experiment conditions from the two adjustable models of İmamoğlu (1975): 2 room proportions (square root two by one and square root three by one) x 2 window size (three-bay and continuous) x 2 window position (window on short side and window on long side). (Tabulated by Özyıldıran 2014).

After constructing the Spaciousness-Crampedness scale (S-C-S), İmamoğlu (1975, pp. 194-209) repeated the experiment mentioned above to examine the effect of *window size*, *room proportion* and *window position* on spaciousness evaluations of rooms via S-C-S. He again used the two adjustable models to obtain eight different conditions: 2 room proportions (square root two by one and square root three by one) x 2 window size (three-bay and continuous) x 2 window position (window on short side and window on long side). He invited 128 participants and divided them into groups of 16, who one by one evaluated one of the eight models via S-C-S by looking through the aperture. With the help of S-C-S, he obtained more detailed results in terms of the three spaciousness factors and the four crampedness factors. Results indicated that the evaluation of rooms in terms of spaciousness factors was related mainly to window position and window size. The results of this experiment (İmamoğlu, 1975, pp. 194-209) can be summarized as follows:

1) Window position (when window size was not taken into consideration):

    - Rooms having windows on the long sides were perceived as having high degree of space freedom without differing significantly in terms of appeal and planning factors. However, this effect differed for different window sizes.

2) Window position (for three-bay windows):

    - Rooms having 3-bay windows on the long sides, when compared to those having them on short, received higher evaluations on the space freedom factor but lower ones on the planning factor. The appeal factor did not change significantly.

3) Window position (for continuous windows):

    - Rooms having continuous windows on the long sides, when compared to those having them on the short, received a higher value on the space freedom factor but a lower one on the appeal factor. They did not differ on the planning factor.

4) Window size (when placed on the short side):

    - When positioned on the short side, rooms having continuous windows when compared to those having three-bay ones, received higher values on both the appeal and space freedom factors; the planning factor did not vary significantly.

5) Window size (when placed on the long side):

    - When located on the long side, interiors having continuous windows did not appear to vary significantly from those having 3-bay windows, although there was a slight tendency for the former to receive slightly higher evaluations on the space freedom factor.

İmamoğlu (1975, pp. 210-217) designed another experiment to explore the effect of *room proportion* and *window size* in more detail. He obtained nine different conditions from the three models by manipulating the size of windows: 3 room proportion (square root two by one, square root three by one and square) x 3 window size (two-bay, three-bay and continuous). All three models were equal in volume and had their windows on the short side. For the four conditions containing three-bay and continuous windows on the short wall of root-two and root-three models, the related data was used from the previous experiment. Sixteen participants evaluated each of the new five conditions. Spaciousness factor results of İmamoğlu (1975, pp. 210-217) can be summarized as follows:

1) Window size:
    - Rooms with continuous windows are perceived as being more spacious than those with smaller (two-bay and three-bay) windows.
2) Room proportion:
    - Root-two and root-three models did not differ significantly for the spaciousness evaluations.
    - A square interior was evaluated higher on space freedom than the root-two model.
    - A square interior was rated higher on both planning and space freedom factors than the root-three model.

2.4.2.2. Studies in the 1980s and 1990s:

In the period of the 1980s and the 1990s, most of the pioneer researchers of the field tended to deal with other research fields and the popularity of the field was decreased. Hence, there are relatively few examples to review in the literature from this period.

Oldham & Rotehford (1983) studied relationship between *employee reaction measures* (satisfaction, behavior during discretionary periods, and spatial markers) and *office characteristics* (openness, office density, workspace density, accessibility, and office darkness). They collected data from 114 employees of 19 offices. As a result, they stated that “each of the office characteristics related significantly to one or more of the employee reaction measures”.

Sadalla and Oxlex (1984) tested “the relationship between the *shape* and the *perceived size* of *rectangular* and *square* rooms”. They constructed three mock-up rooms, which had different plan ratios (1.00, 2.25, and 9.00) but of the same floor areas (144ft^2), and a square comparison room in smaller floor area (64ft^2). Fifty-six participants were asked to estimate the area of each room. Results indicated that “more rectangular rooms were consistently estimated as larger than less rectangular rooms of equal size”.

Sato and Inui (1994) examined *human behavior* in *windowless office spaces* in two experiments. The researchers observed behaviors of participants while they were performing some basic tasks and general office tasks given. As a result, they stated that “windowless office spaces have adverse effects on human behavior in comparison to windowed ones” and “these adverse effects can be compensated for by interior decoration or by considering task contents to be assigned in windowless office spaces”.

Kim (1997) assessed *subjective responses* to *daylight*, *sunlight*, and *view* in *college classrooms with windows* in his thesis. He examined psychological responses in two experiments, which compared 1) the windowless and windowed classrooms, and 2) different window configurations. He used slide pictures taken from different conditions of a 1/8 scale model as stimuli. He stated that “The windows in the classrooms provide positive emotion to the classroom environment and serve to increase academic satisfaction with the classrooms. However, there is no difference between classrooms without the windows and with the windows which do not provide view and natural light”. “The best window condition selected by participants in [his] study is eight small windows providing sunlight and a good view. The worst condition is two large windows providing daylight (no sunlight) and a poor view" (Kim, 1997, p. iv).

2.4.2.3. Studies between 2000-2014:

Since the 2000s, the research field has gained some new dimensions by computer simulations as new research tools. As mentioned in Section 2.3.6, although computer simulation technologies have been extensively used in several disciplines since 1960s, they involved in environmental psychology studies after 2000s. Besides this delay to reach a more satisfactory level to simulate realistic vision of environment, computer simulations have been becoming the mostly used representation technique in environmental psychology studies. Moreover, with the spread of internet, past and new findings became easily accessible. Both the practicality of simulations and easy access to the literature, interest on architectural psychology research has started to be increased again. However, due to the new dimensions and the stagnation in the previous two decades, new studies in the field did not benefit from the past experiences adequately.

Franz, Von der Heyde and Bülthoff (2005) studied quantitative relations between the *experience of architectural spaces* and *physical properties* via computer simulations. They used VR models of 16 vacant rectangular interiors as stimuli, which were presented as 360^{o} panoramic images on a spherical wide-angle projection system called *Elumens VisionStation* (VR Dome) (see Figure 10). Sixteen participants evaluated them on a semantic scale composed of eight adjective pairs, which were *pleasure*, *interestingness*, *beauty*, *normality*, *calm*, *spaciousness*, *brightness* and *openness*. Some of their findings can be summarized as follows: They stated that "spaciousness correlated with the actual room area, but the coefficient with overall window area was even higher." However, it is necessary to keep in mind that they presented *spacious* as an antonym of *narrow*. "Perceived *openness* and *brightness* were highly correlated to the relative *wall openness ratio* (wall area/window area), which is a direct correspondent to the physical brightness of the scenes." "The results of rated *calm* were widely oppositional to rated *openness*, it was negatively correlated with all factors influencing relations to the exterior as for instance *balustrade height* and *window sizes*." "The three affective rating dimensions beauty, pleasure, and interestingness, appeared highly interrelated." Franz et al. (2005) stated that "virtual reality simulations proved to be a powerful means for basic architectural research that allows for optimized empirical methods".

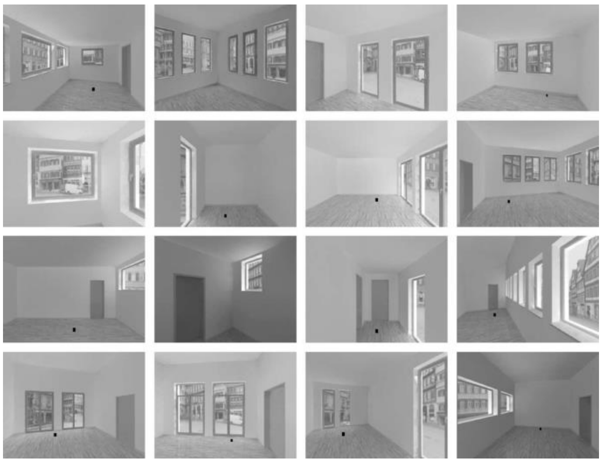


Figure 10 Screenshots of 16 models, which were presented as 360^o panoramic images on a spherical wide-angle projection system by Franz et al. (2005).

Matusiak (2006) studied the impact of *window form* on the *size impression* of the room. As stimuli, she constructed three adjacent full-scale models in equal sizes and obtained different window forms (see Section 2.3.4). Her study was composed of eight experiments, and in each one, two or three window conditions were evaluated by participants (sees Figure 11). She asked 21 participants to evaluate the impression of *height*, *width*, *length*, and the *general size* of each room. Her results indicated that window form affected the impression of room dimensions, although the total glazing areas were equal. She indicated that vertical windows make the room appear higher, whereas horizontal make it wider. She also pointed out the effects of window position: "Window adjacent to a sidewall contributes to higher luminance of this wall, it appears as being further away from the observer; the room appears as wider. The same principle is true for windows adjacent to the ceiling or floor. They contribute to increasing the impression of height" (Matusiak, 2006).

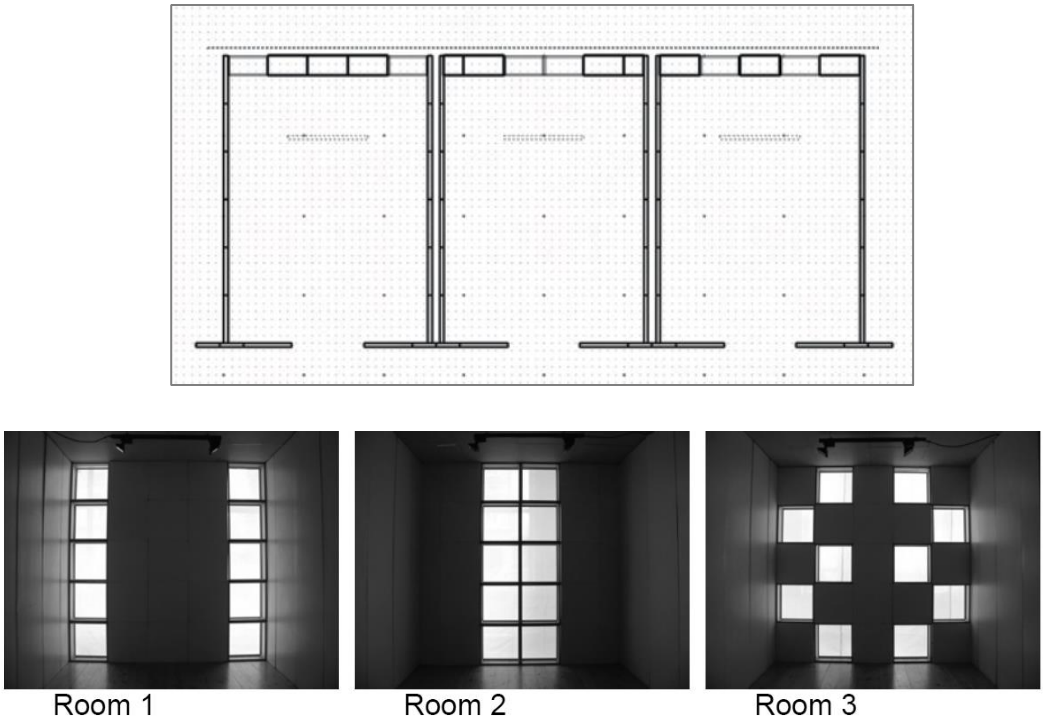


Figure 11 Full-scale models in one of the experiments of Matusiak (2006).

Matusiak and Sudbo (2008) examined the impact of *width* and *height* on impression of *room size* via full-scale models and computer simulations (see Section 2.3.4). The results from full-scale studies carried out with school children indicated that “width has a stronger positive impact on size impression than height” and “daylight has a positive influence on the size impression”. However, they also pointed out that “the precise evaluation of the room size based on virtually generated pictures alone is still difficult, even the use of the most advanced lighting simulation program, Radiance, does not guarantee success”.

Alkhresheh (2007) studied “enclosure as a function of *height-to-width ratio and scale*” in terms of its effects on “user's sense of *comfort and safety* in *urban street* space” in his PhD thesis. His study focused on outside environments, which is out of the scope of the current thesis. However, his method could be adapted to interior studies. He built 42 models with different degrees of enclosure, and integrated them as still images. Eighty three participants evaluated each of them by degrees of *comfort*, *safety*, and *perceived enclosure*. Since the perceived *enclosure* and *safety* might be different for exterior and interior spaces, results will not be mentioned here in detail.

The study of Yıldırım and Hidayetoğlu (2008) is one of the recent examples of real room studies. They studied “the effects of *curved areas* located in the *living rooms* of apartment housing on *functional* and *perception-behavioral* quality”. Their stimuli were living rooms with curvilinear forms, which were located differently (side, center and corner) as seen in Figure 12. They selected them from some apartment houses of upper middle socio-economic status in Çukurambar and Çiğdem districts in Ankara. With the help of a questionnaire, they tried to examine the use of the space, the use and perception of the curved space, and how it was decorated. Although the use of real rooms as stimuli is the most naturalistic and realistic way to assess the people-environment interaction, it is hard to obtain systematic varieties of a real space to compare focused variables by keeping other factors constant.

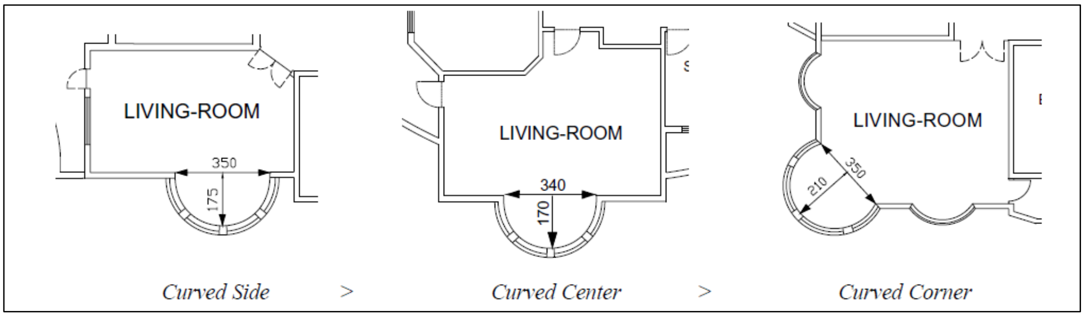


Figure 12 Plans of the main living rooms with differently located curvilinear forms, which were used as stimuli by Yıldırım and Hidayetoğlu (2008).

With their own words, results of the Yıldırım and Hidayetoğlu (2008) can be summarized as follows:

> It was observed that in cases where curvilinear formation occurred in the main corner of the main living room, the furniture could not be positioned in accordance with the space and therefore some users either placed flowers-vases in the curvilinear volume or left it empty. If curvilinearity was in the center of main living room, then the settlement in the space was more appropriate and attractive (p. 51).

Stamps and Krishnan (2006) studied *spaciousness* and *boundary roughness* in two experiments via computer simulations and an eight-point “spacious - not spacious” scale. In the first experiment, they designed a square planned room in 2.75m height and derived 16 models by changing room size (3x3m, 4x4m, 5x5m, 6x6m), lighting ($10cd/m^2$, $37cd/m^2$, $136cd/m^2$, and $500cd/m^2$) and roughness of walls. In order to measure roughness objectively, they systematically changed fractal dimension and fractal recursion depth as illustrated in Figure 13. Models were presented to 49 engineering students as static color simulations in a *PowerPoint show* in a class. According to their results, “fractal recursion depth had a larger effect on subjective impressions, replicating findings from the psychology literature, but the walls with greater recursion depths produced rooms that appeared larger, not smaller, than rooms produced with smaller recursion depths”, and rougher appeared larger while smoother was not more spacious.

Stamps and Krishnan (2006), acknowledged that the models in the first experiment were “intentionally designed to be unfamiliar” and “they necessarily look pretty strange”, which were “pretty hard to imagine how the relevant principles apply to actual design decisions”. Hence, to be applied in designs, they needed another experiment which had familiar environments. In this case, wall roughness conditions were produced by three variations of book cases; “empty book cases, partially filled book cases, and book cases with solid doors”. They obtained 12 models by changing room size (5x5m and 6x6m), lighting ($300cd/m^2$ and $600cd/m^2$) and roughness of walls (see Figure 14). They presented them to 16 participants as static images on a laptop computer.

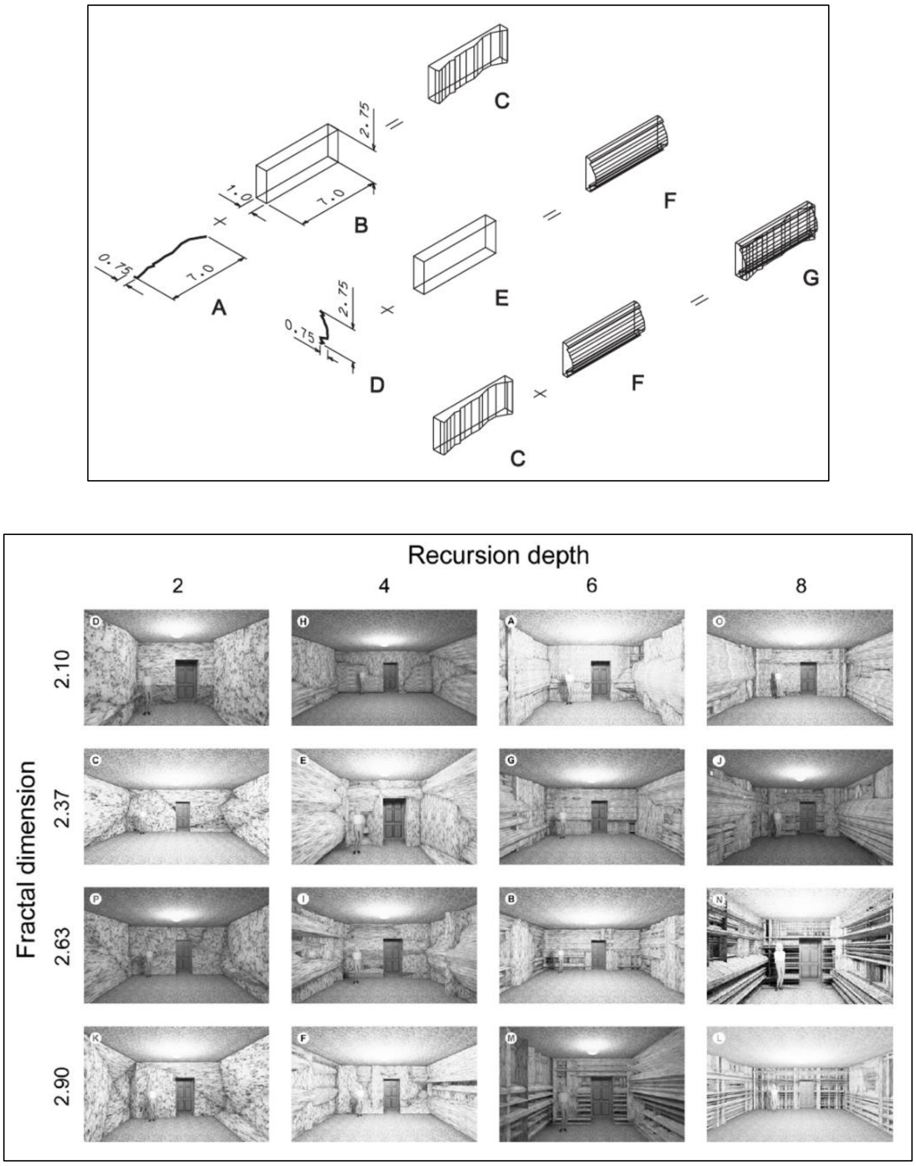


Figure 13 Experiment 1 of Stamps & Krishnan (2006): fractal grottos.[2]

[2] Stamps and Krishnan (2006) defined fractal dimension as "how flat or kinky a surface is", and fractal recursion as "depth indicates the smallest grain size in the surface". They obtained walls with known fractal dimensions as following steps: "Step A: Use the math given in Hastings and Sugihara (1995) to create a line with known values of fractal dimension and recursion depth. Import that line into a computer-aided drafting program (Microstation). Step B: Create a blank slab for the wall. The slab used in the figure measured 7m × 1m × 2.75m high. Think of it as a piece of clay. Step C: Use the line to slice the wall in a vertical direction. Think hot wire and plasticine. Steps D, E, F: Repeat steps A, B, and C, but this time slice the slab in the vertical direction. Move both Slabs C and F to the same location. The result is a surface (G) with the intended properties."

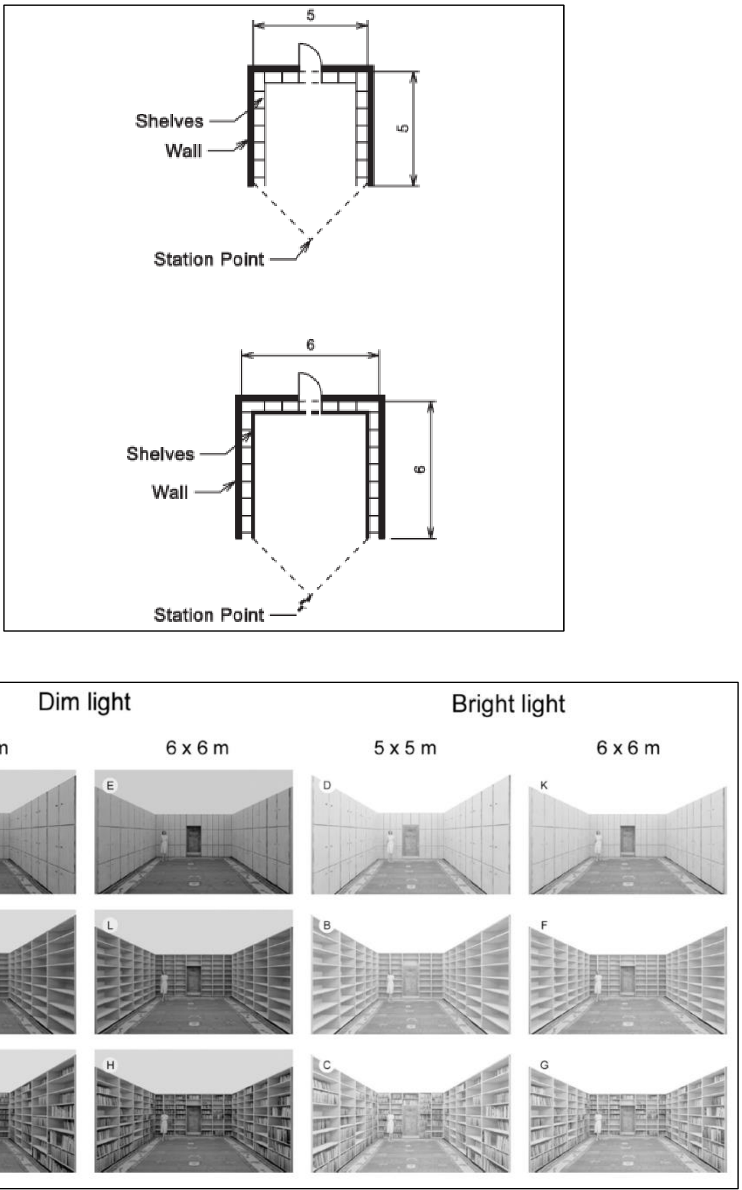


Figure 14 Experiment 2 of Stamps & Krishnan (2006): wall systems and spaciousness.

Results in both experiments of Stamps and Krishnan (2006) consistently indicated that “smoothing the boundaries did not make rooms appear more spacious”. However, they stated that “if spaciousness is a design criterion, then open shelves will increase apparent size without increasing the total size of the room”. Floor area was shown up as “a very strong predictor of impression of spaciousness”. For the effects of lighting, they obtained mixed results in two experiments; hence they will not be mentioned in detail.

Stamps (2009) studied *spaciousness* and *shapes of streets* in two simulation techniques (dynamic virtual reality models and static color images) on a laptop computer. Since it focused on outside environments, the study will not be mentioned in the scope of this thesis in more detail. However, it can be mentioned that "both simulation techniques generated same conclusions" and "even if the actual size of a space is fixed, it is possible to increase perceived spaciousness by modifying the shape of the space."

Stamps (2010) conducted four experiments which examined *spaciousness* and *enclosure* in 1) rooms (conservatories), 2) random hulls, 3) sticks, and 4) Danish megaliths. Since the third and the forth experiments were unrealistic environments, only the first two experiment will be mentioned here. In the first experiment, he designed computer models of octagonal rooms with domed roofs as stimuli. He divided each wall in four bays, which were 1m wide and filled by either glass or solid bookshelves. Above each bay, he also divided the roof with arches, which were filled by glass or wood sheathing. He changed the degree of permeability by covering one or more bays per wall and roof. He obtained 12 stimuli by two areas (77.25m^2 and 309m^2), two lighting conditions (day and night), and three levels of visual permeability (25%, 50%, and 75%) (see Figure 15). Models were evaluated in two sessions; first, 17 participants rated an eight-point "open - enclosed" scale, and second, 29 participants rated an eight-point "spacious - not spacious" scale. According to the results, Stamps (2010) stated that "perceived enclosure and spaciousness were strongly related to each other, but enclosure was more dependent on the permeability of boundaries than on horizontal area, whereas spaciousness was more dependent on horizontal area than on boundary permeability".

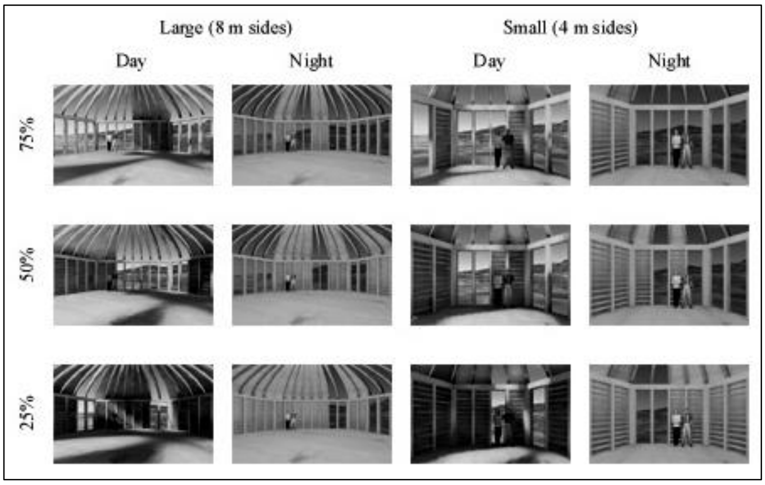


Figure 15 Experiment 1 of Stamps (2010): octagonal rooms.

In order to support the findings of the experiment mentioned above, Stamps (2010) designed the second experiment under different conditions. Stimuli were composed of models of four randomly generated convex hulls. There were four horizontal areas (16.00m^2, 33.29 m^2, 96.22m^2, and 144m^2), four levels of boundary permeability (0%, 33%, 66%, and 100%), and four levels of light (150, 300, 450 and 600 lux at floor level) (see Figure 16). Eighteen participants rated images of models on laptop computer by an eight-point "open - enclosed" scale. Results of the experiment indicated that "perceived enclosure was mainly a function of visual permeability of the boundary. The more visual permeability of the boundary, the less enclosed the space feels. Horizontal area, which indicates locomotive permeability within the boundary, also had an effect on perceived enclosure, with more area resulting in a feeling of less enclosure".

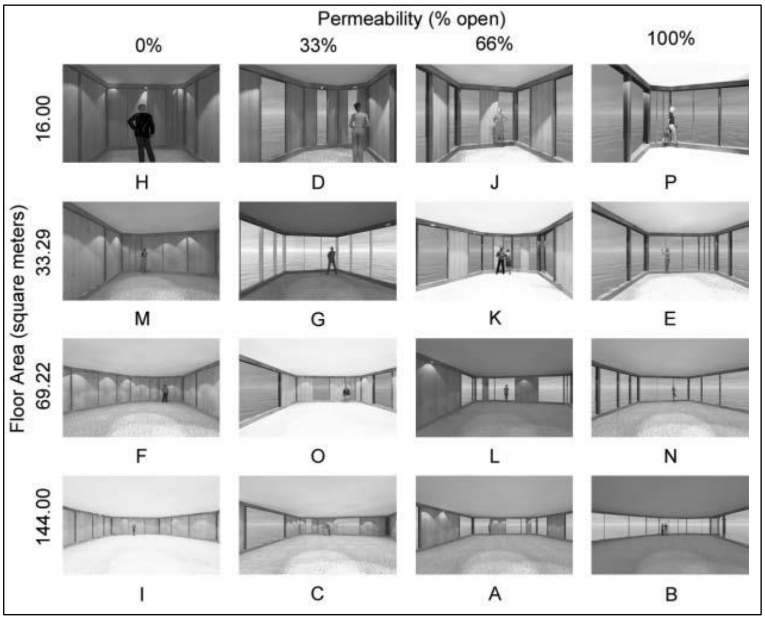


Figure 16 Experiment 2 of Stamps (2010): convex hulls.

Stamps (2011) studied effects of *area*, *height*, *elongation* (plan ratio) and *color* on *spaciousness* through three experiments. The first experiment will not be covered in this literature review, since it was about streets. However, in the second and the third experiments, he used computer models of rooms as stimuli. First, he used computer models of "very simple, plain, convex spaces with a wood floor, gray walls with vertical joints 1.22m on center, and a white ceiling". He obtained 18 rooms by using three areas ($12m^2$, $16m^2$ and $20m^2$), three plan ratios (1:1, 1:2, and 1:9, which he also labelled as a square, a rectangle and a corridor), and two ceiling heights (2.44m and 3.66m). Models were presented to 24 participants on a laptop computer to be rated by an eight-point "spacious - not spacious" scale. Results indicated that "long, narrow spaces were perceived as being much less spacious than square or rectangular spaces of the same area." Stamps did not detect any difference in spaciousness between the square and rectangular rooms.

In the third experiment, Stamps (2011) repeated the same procedure but in more realistic dimensions to contribute housing designs. He made 16 room models by using four horizontal area ($49m^2$, $38.9m^2$, $30.9m^2$, and $24.5m^2$), four plan ratio (1:1, 1:1.26, 1:1.57, and 1:2), four ceiling height (2.5m, 3.15m, 3.96m and 5.0m) and four color (blue, green, yellow and pink), while all volumes were constant (see Figure 17). Seventeen participants evaluated models on a laptop computer by an eight-point “spacious - not spacious” scale. Results indicated that the “horizontal area had the strongest effect on perceived spaciousness” and “larger horizontal area leading to an increase in perceived spaciousness”. “The rooms with lower ceilings being judged as more spacious than the rooms with higher ceilings”. “No detectable difference between these levels of elongation” and also “no detectable differences were found for effects of color on impressions of spaciousness”.

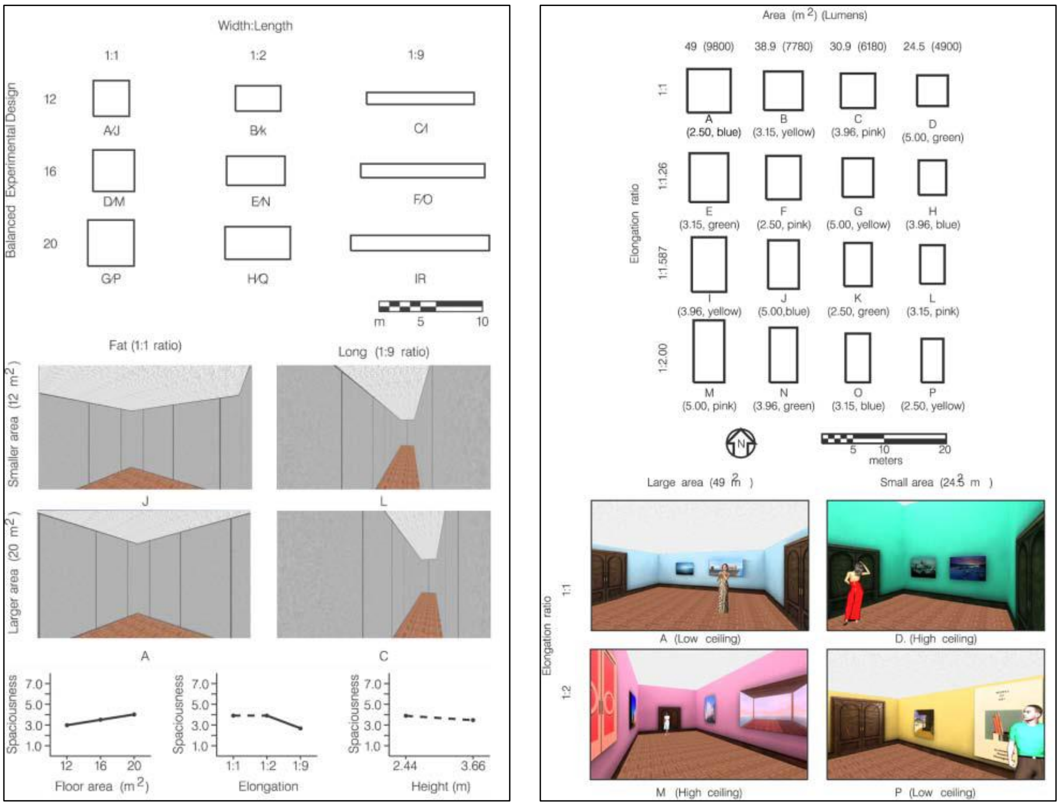


Figure 17 Plans and images from experiment 2 and 3 of Stamps (2011).

2.5. RESEARCH TECHNIQUES WITH COMPUTER SIMULATIONS

The use of *computer simulations* in environmental psychology was briefly introduced in Section 2.3.6, and several examples were seen through the research findings in Section 2.4.2.3. However, as mentioned before, although the computer technology is developing further, new developments in this technology are followed from behind in environmental psychology discipline. A strong possible reason for this delay is the concerns about whether the new developments present a realistic space or illusion. In the current section, computer simulations will be assessed in more detail with its latest developments in various disciplines and expectations in environmental psychology discipline.

Before introducing new technologies, it was needed to remind that the related *terminologies* might change from reference to reference due to the following reasons:

1) computer simulations vary in terms of their apparatuses (hardware),
2) computer simulations vary in terms of their programs (software),
3) computer simulations are used by various disciplines, which might develop their own terminology.

Hence, different classifications and different labels might be seen in computer simulation and virtual reality (VR) literature. As said by Sherman and Craig (2003, p. 37), “the terminology of VR is still young and evolving rapidly, and many words and phrases are used inconsistently even by the VR community (most notably by those trying to market the technology)”. In the current study, this classification is made from the environmental psychology point of view, and related terminologies are tried to be selected from the most common names for each.

In this section, first, *visual perception* in *virtual environments* will be briefly introduced in order to understand what makes a computer simulation successful. Then, latest developments of computer simulations will be introduced by classifications of hardware and software. In addition to current features, finally, the potential features of the computer simulation technologies for environmental psychology field will be mentioned.

2.5.1. Visual perception in virtual environment

Visual perception in virtual environments has two significant dimensions; *visual depth cues* and *properties of visual displays* which are summarized and tabulated from Sherman and Craig (2003, pp. 116-140) as follows.

Table 2 Dimensions in visual perception in virtual environments. Summarized and tabulated from Sherman and Craig (2003, pp. 116-140).

VISUAL DEPTH CUES	PROPERTIES OF VISUAL DISPLAYS	
	Visual Presentation Properties	**Logistic properties**
1) Monoscopic image depth cues • Interposition • Shade and shadow • Size • Liner perspective • Surface texture gradient • Height in the visual field • Atmospheric effects • Brightness 2) Stereoscopic image depth cue (stereopsis) 3) Motion depth cues 4) Physical depth cues • Accommodation • Convergence	• Color • Spatial resolution • Contrast • Brightness • Opacity • Masking • Number of display channels • Focal distance • Field of view • Field of regard • Head position information • Graphics latency tolerance • Temporal resolution (frame rate)	• User mobility • Interface with tracking methods • Environment requirements • Associability with other sense displays • Portability • Throughput • Encumbrance • Safety • Cost

2.5.1.1. Visual depth cues

Sherman and Craig (2003, pp. 118-121) defined *visual depth cues* as host of distance indicators in which people perceive information regarding the relative distance of objects. They classified varieties of visual depth cues as follows; monoscopic image, stereoscopic image, motion and physical depth:

2.5.1.1.1. **Monoscopic image depth cues**

In a single static view of a scene, such as in photographs and paintings, *monographic image depth cues* support visual perception. Sherman and Craig (2003, pp. 118-121) classified and defined them as follows; *interposition, shading, size, liner perspective, surface texture gradient, height in the visual field, atmospheric effects,* and *brightness* (see Figure 18).

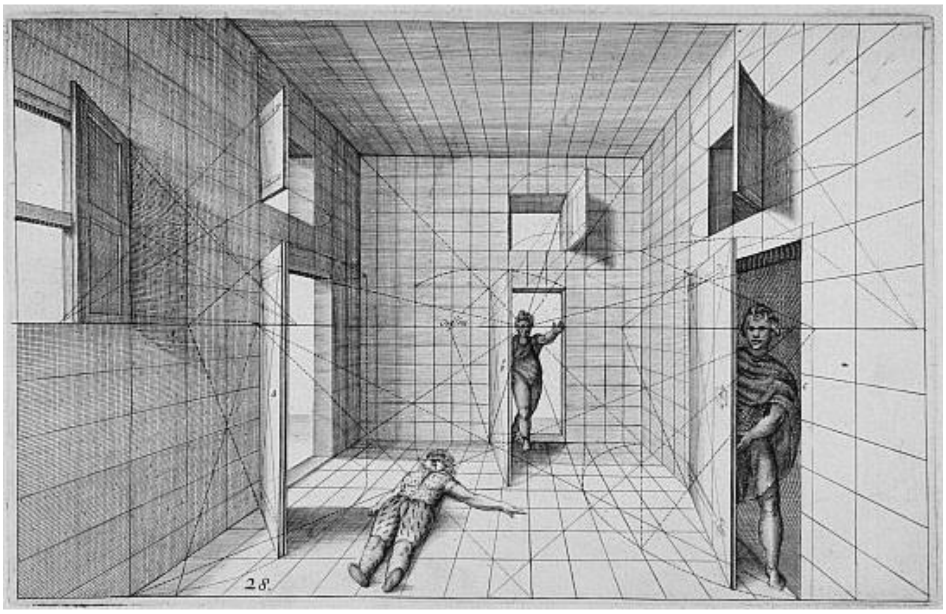


Figure 18 An example of monoscopic images with several depth cues: A perspective print by Hans Vredeman de Vries, 1604 (Retrieved in July 16, 2014, from: http://www.swaen.com/antique-map-of.php?id=13680).

Interposition cues obtained when one object masks another, which indicates that it is closer than the other. *Shading cues* give information about the shapes, while *shadows* show positional relationship between two objects. Comparisons of *sizes* of objects to other same type of objects (such as human figures) help to decide the relative distance between them, and the larger one means the closer. Moreover, this comparison helps to estimate the distance of the object from the observer. In *linear perspective,* parallel lines meet at a single vanishing point. Since our retinas cannot distinguish details of a texture at a distance, *surface texture gradient* indicates the distance between the object and the observer. Since the horizon is higher in the visual field than the ground near the feet of the observer, the further object appears higher in the view. Hence, *height in the visual field* is one of the significant depth cues. Due to *atmospheric effects*, such as haze and fog, the visually less distinct objects are considered as the more distant objects. *Brightness* is one of the moderate depth cues, and the brighter objects are perceived as being closer (Sherman & Craig, 2003).

2.5.1.1.2. **Stereoscopic image depth cues (stereopsis)**

Retina in each eye receives slightly different images (binocular disparity) due to *parallax*, which is "the apparent displacement of objects viewed from different locations". The *stereoscopic image depth cue* comes from this parallax and particularly effective for objects within about 5m (Sherman & Craig, 2003).

Figure 19 Stereoscopic photograph of a classroom and adjoining interior spaces in Mills Hall by Eadweard Muybridge, 1873 (Retrieved in July 16, 2014, from: http://content.cdlib.org/ark:/13030/kt3199r91h/).

2.5.1.1.3. **Motion depth cues**

Motion depth cues depend on the *parallax* produced due to the change of relative position between the head of the observer and the object being observed. Due to the fact that the objects nearer to the eye are perceived to move more quickly than more distant objects, the depths of the objects can be distinguished. Sherman and Craig (2003) defined two basic ways for the change in the view; “the viewer moves or the object moves”. When the bodies of observers move, they obtain feedback about how far they moved; hence, they can have more precise determination about the distance. However, as Sherman and Craig (2003) stated, parallax from *object movement* or *non-self propelled movement*, such as riding in a car, is not as informative about the rate of relative movement as *observer-originated movement*. Observers’ judgments become less precise, when they cannot determine the rate of relative movement between themselves and the object.

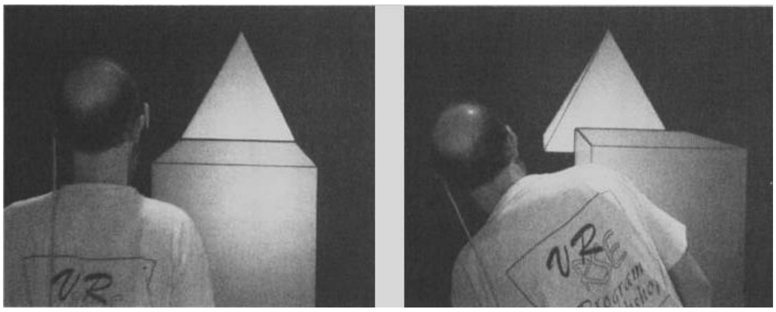


Figure 20 The perception of depth of objects (and the 3D nature of the world) can be enhanced by the relative motion between the observer and the world (Sherman & Craig, 2003, p. 120).

2.5.1.1.4. **Physical depth cues**

The fourth depth cue in the classification of Sherman and Craig (2003) is named as *physical depth cue*, which is related to the muscles movements of the eye to bring an object into clear view. For this type of depth cues, the eye makes two significant adjustments called *accommodation* and *convergence,* which are defined by Sherman and Craig (2003) as follows:

1) The eyes make focusing adjustments by changing the shape of eye lens, which is called *accommodation.* Distance information is provided for objects within 2m or 3m by the amount of this muscular change.
2) The eye muscles move to bring an object into the same location on the retina of the each eye, which is called *convergence*. By these muscle movements of *convergence,* information about the distance of objects in view is provided.

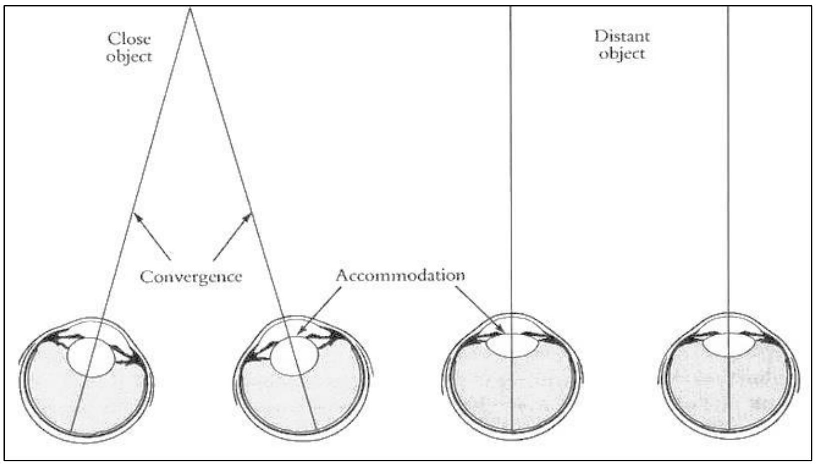


Figure 21 David Humel's graphic explanation for accommodation and converge of eye when an observer looks at a close and a distant object. (Retrieved in July 16, 2014, from: http://hubel.med.harvard.edu/book/b54.htm).

2.5.1.2. Properties of visual displays

Based on the classifications of Sherman and Craig (2003), "properties of visual displays" were summarized in Table 2 (on page 74). In this section, three of these properties will be mentioned in more detail. These are "focal distance", "field of view (FOV)" and "field of regard (FOR)", which are significant properties to understand the classification of the computer simulation technologies.

2.5.1.2.1. **Focal distance**

Focal distance is the distance of an image from the observer's eyes (Sherman & Craig, 2003). The *accommodation* of the eyes helps the observer to identify this distance. However, in 2D images and in computer simulations, "all images in a scene are seen on the same focal plane regardless of their virtual distance" from the observer (Sherman & Craig, 2003). Figure 22 explains how an image is seen on the same *focal distance*. This may cause an incompatibility of *accommodation* with other depth perception cues, such as *interposition, shadow* and the like, and may cause confusions in visual perception. While this is not a problem for visual perception of real rooms, full-scale mock-up models and scale models, it is one of the challenging subjects for the computer simulation displays.

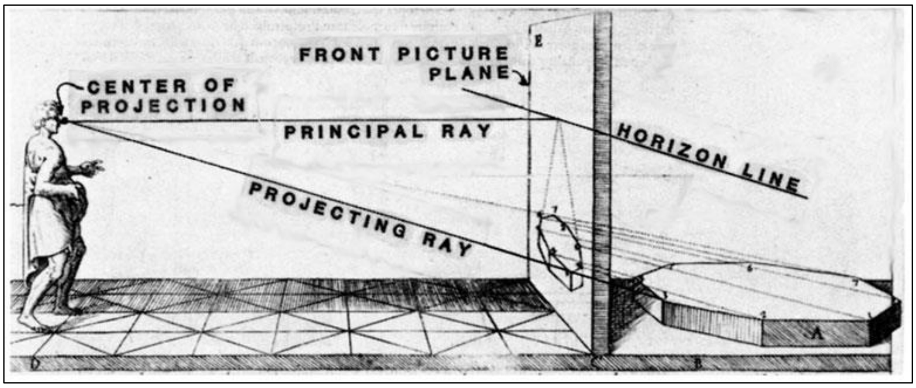


Figure 22 Perspective projection on a picture plane (focal plane): representation of Alberti's window by G. B. Vignola, 1611 (modified version was retrieved from Kubovy, 2003).

2.5.1.2.2. **Field of view (FOV)**

Field of view (FOV) is defined by Oxford English Dictionary (OED) as "the entire area that a person or animal is able to see when their eyes are fixed in one position". Figure 23 illustrates FOV of human in vertical and horizontal positions. According to this figure, FOV of human is in the limits of 120^o, while the optimum FOV is within 60^o in horizontal position and 55^o in vertical position. Within these limits, the optimum FOV can be narrowed by the *accommodation* and *convergence* adjustments of eyes.

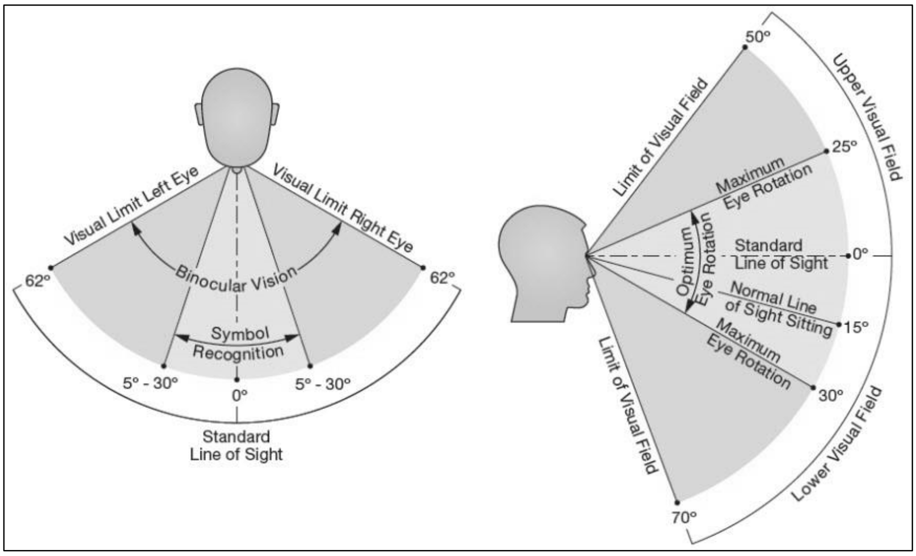
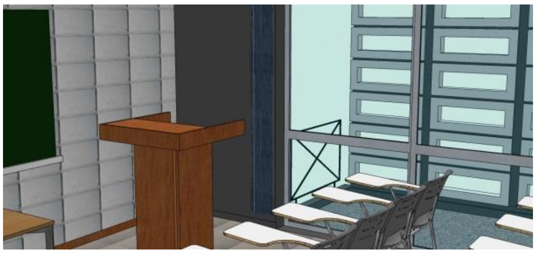
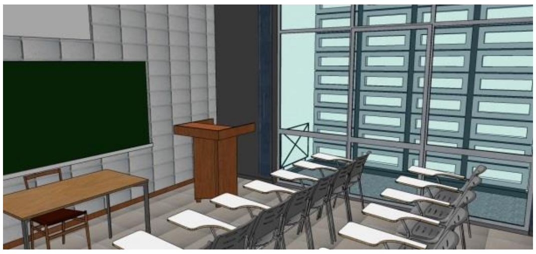


Figure 23 Graphic description for field of view (Extron, n.d.)

For computer simulation displays, the definition of FOV is slightly different. Sherman & Craig (2003, pp. 128-129) defined FOV as “a measure of angular width of a user’s vision that is covered by the display at any time given”. The FOV degree of computer simulations can be changed to any value. Table 3 illustrates some examples of different FOV degrees on a SketchUp model of a classroom (R46 in Faculty of Architecture). Although the images were taken from the same position in the model, different results were obtained by changing the degree of FOV. The examples of 20^o and 35^o were too narrow to identify the interior, since most of the images were cut off by the edge of the computer screen. On the other hand, 70^o and 100^o presented distorted images which may cause confusions about the geometry and dimensions of the interior. The optimum solution was obtained in 50^o, which presented two walls, floor and ceiling in the same scene with minimum distortions. However, these optimum FOV degrees may change for different models, different programs and different displays. Hence, FOV is a significant concept to be considered while designing and presenting computer simulations.

Table 3 Screenshots from a SketchUp model of classroom R46 by different field of views (FOV).

Field of view	Screenshots from a classroom model	Visual quality
20^o		The field of view is so small that it is hard to identify any elements and the room.
35^o		Athough some objects (such as, table, chairs and the like.) can be identified, it is hard to have general idea about the room. Taking floor and ceiling together in one picture is impossibe.
50^o		Two walls can be seen together with floor and ceiling. Hence, image can give general cues about the room.
70^o		Three walls of the room can be seen. However, the rectangular prism form of the room is distorted. Rectangular walls are seen as if they are trapezoidal. Floor and ceiling are seen as sloped.
100^o		The perspective is so distorted that neither the geometries nor the distances can be identified clearly.

2.5.1.2.3. **Field of regard (FOR)**

Field of regard (FOR) is defined by Sherman and Craig (2003, p. 129) as "the amount of space surrounding the user that is filled with the virtual world or, in other words, how much the viewer is enveloped by the visuals". When a computer simulation completely surrounds the observer, 100% FOR is obtained. The FOR is free from the FOV. For instance, a very narrow FOV can be used in the surrounded display. Moreover, a very wide screen may present a very wide FOV but may have a very limited FOR unless the screen surrounds the observer (Sherman & Craig, 2003). Wide FOR helps the observers to isolate themselves from the real environment and concentrate on the virtual environment.

2.5.2. Classification of computer simulations in terms of apparatuses

2.5.2.1. Conventional basic type of Virtual Reality displays: Flat screens and projections on flat boards

The simplest forms of VR visual display techniques are presentations on *flat screens* and *projections on flat boards* (see Figure 24). For presentations on screens, Sherman and Craig (2003) used the terms of *monitor-based VR*, or *fishtank VR*. However, *fishtank VR* differs from generic presentations on monitor, since a VR system tracks the head of the observer, and the rendered scene changes in response to movement of the head. Another display technique is projections on boards, namely *projection VR*, which enable a larger area of presentation. Both *monitor-based VR* and *projection VR* present two-dimensional (2-D) view of simulations but they have three significant advantages:

1) they are economical and practical,
2) they can be portable,
3) they enable controlled presentations, since 2-D vision has known parameters.

Figure 24 An example of VR display on a flat screen: an experiment setup of Van der Spek and Houtkamp (2008, p. 20).

2.5.2.2. Advanced immersive type of Virtual Reality displays: Virtual Reality DOMEs and Curved Screens, Head-Mounted Displays (HMDs), and Cave Automatic Virtual Environments (CAVEs)

2.5.2.2.1. **Virtual Reality DOMEs and Curved Screens**

Virtual Reality DOMEs and *curved screens* are more immersive ways of presentation than *flat screens*. Figure 25 illustrates two examples of *VR DOMEs*: The first has a diameter of 1.5m for a single immersive viewing, and the second has a diameter of 3m for mid-size workgroups, small audiences, or larger single user applications. Large and curved screens cover *the field of view* of the observers, who are looking at one direction, and this wider view of curved screens makes them more advantageous than flat screens. However, as it is seen in Figure 25, images in sight views have some distortions due to the curved surfaces, which might cause misjudgments for *visual depth cues*. They are mostly used in driving simulations, flying simulations, games and the like, in which the perceptions of sight views are not as significant as the central view. For architectural research, the study of Franz et al. (2005) can be given as an example of this type of simulations (see Figure 10 on page 63).

Figure 25 Examples of VR domes. Left: the VisionStation of 1.5m in diameter, designed for single-user immersive viewing. (Retrieved in 2011, from: http://www.vrealities.com/visionstation.html) Right: the VisionDome3, of 3m in diameter, for mid-size workgroups, small audiences, or larger single-user applications. (Retrieved in 2011, from http://www.vrealities.com/visiondome3.html).

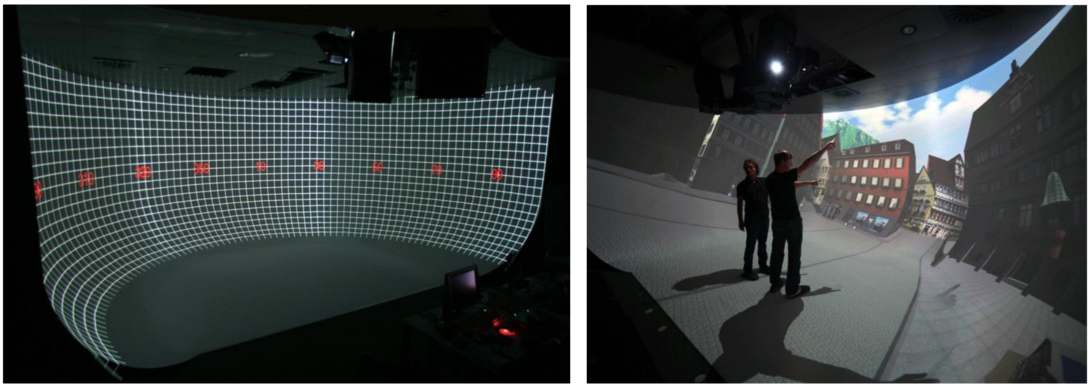


Figure 26 An example of a wide-area hemispherical projection system: “PanoLab” of the Max-Planck Institute for Biological Cybernetics (Retrieved in July 16, 2014, from: http://www.domeprojection.com/?p=527).

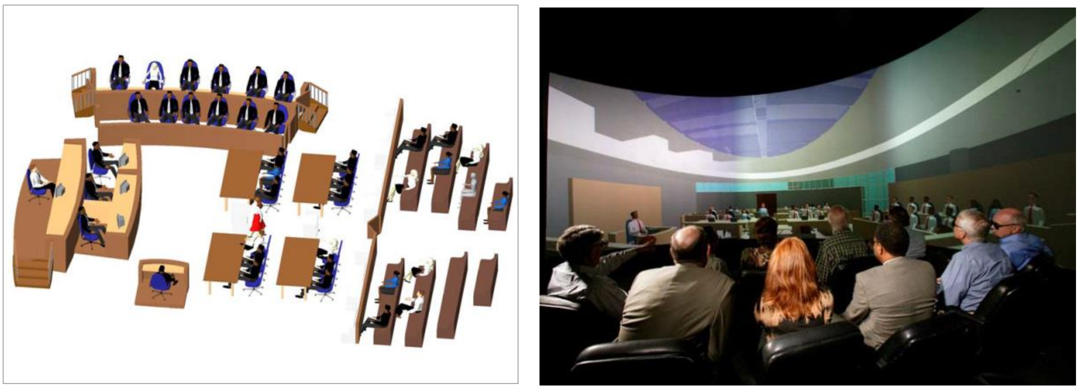


Figure 27 An example of curved front projection screens used in a conceptual design review session of a courtroom with judges (Majumdar, Fischer, & Schwegler, 2006).

Figure 26 illustrates a wide-area hemispherical projection system, in which observers can stand. Distortions of buildings on curved projections can be clearly seen in this figure. To use these technologies to present stimuli in architectural psychology studies, further developments are needed to prevent misjudgments in depth perception. However, the current technology can be used in some design studies. For instance, Majumdar, Fischer and Schwegler (2006) used a curved front projection screen with a polarization-preserving screen illuminated with three pairs of projectors (see Figure 27). In their study, judges, attorneys and other participants were able to virtually seat themselves in various positions in the courtroom and could navigate through the spaces. In this way, they could evaluate the courtroom design based on various criteria; visual sightlines from the judge's bench to the witness box and other key locations, layout of the courtroom, access to key positions in the room, dimensions and positioning of furniture. It also enabled real-time modifications to design the courtroom on feedbacks. Additionally, it enabled to focus the collective attention of the participants on one issue at a time.

To sum up, wide and immersive display is the main advantage of *VR DOMEs* and *curved screens*; however, there are questions about perspective distortions on curved displays. Additionally, these technologies are expensive and need a permanent place (a laboratory setting) to be kept and used.

2.5.2.2.2. **Head-Mounted Displays (HMDs)**

All techniques mentioned above limit the position of observers. Although the view on the screen can change as if the observer moves, observers have to find and keep the proper positions to have their field of view coincide with the screen. *Head-Mounted Display (HMD)* is an alternative way of immersive presentations, which enables free head movements and abstraction from the real environment. It is a wearable technology and contains stereoscopic displays which cover each eye. To simulate the correct view, the location and orientation of the observer are provided by a head-tracking device (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992, p. 67).

The first HMD was developed in 1968 by Ivan Sutherland (1968) at Harvard University (see Figure 28). "The display uses miniature *cathode ray tubes (CTR)*, similar to a television picture tube, with optics to present separate images to each eye and an interface to mechanical and ultrasonic trackers" and "the display provided stereoscopic visual images, mechanical or ultrasonic tracking, and a demonstration of the potential of virtual reality" (Sherman & Craig, 2003, pp. 26-27). As in the case of other computer technologies, HMD has been developing further. Some current examples of HMDs, which were designed for different purposes, can be seen in Figure 29. Their usage varies from aerospace and defense industry to game industry. Hence, their complexity and designs change according to their purposes.

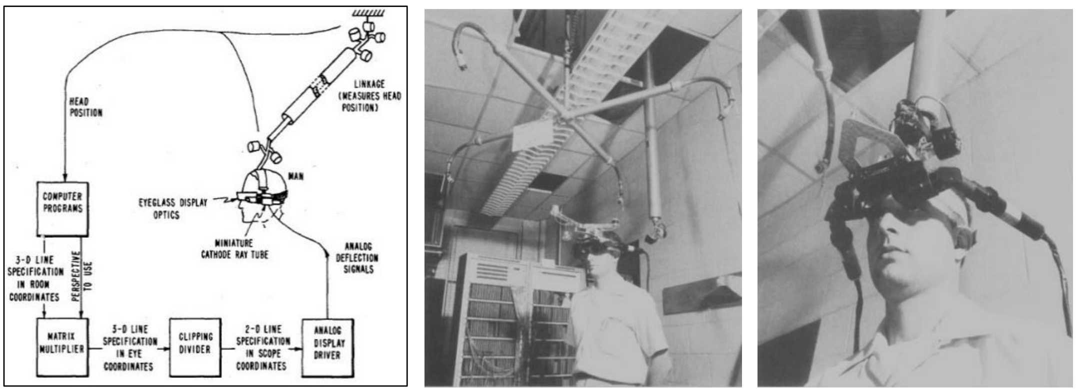


Figure 28 The earliest version of HMD by Ivan Sutherland at Harvard University (Sutherland , 1968, p. 760; Sherman & Craig, 2003, p. 27).

Figure 29 Examples of HMDs for different purposes: Left: HMD photo by NASA (Retrieved in July 16, 2014, from: http://www.virtualreality.net.au/). Middle: A stereoscopic HMD (Retrieved in July 16, 2014, from: http://www.vrealities.com/head-mounted-displays). Right: Google glass (Retrieved in July 16, 2014, from: http://www.google.com/glass/help/).

Within the HMDs illustrated above, *Google glass* is the newest development, which became officially available to the general public on May 15, 2014. It is slimmer and smaller than the previous HMDs and designed for limited daily use, such as taking photographs and video talks. Since it is very new, it is not mentioned in the literature yet, but has potentials for future research.

As this technology is wearable, the literature reported some *aftereffects* for its users. Blade and Padgett (2002, p. 17) defined *aftereffects* as “any effect of VE (virtual environment) exposure that is observed after a participant has returned to the physical world” for the users. One of them was defined by Cruz-Neire et al. (1992) as follows:

> The HMD is light, compact and easy enough to move quickly. Hence, the viewer can alter position and orientation much faster than present day tracking equipment. The result is a distracting lag: when the user turns, the environment turns with the user and then moves back to the correct orientation. Users of such systems are forced to move quite slowly and smoothly to avoid this problem. (p. 67).

2.5.2.2.3. **Cave Automatic Virtual Environments (CAVEs)**

As an alternative to *head-mounted displays (HMD)*, Cruz-Neira, Sandin, DeFanti, Kenyon and Hart (1992) introduced *CAVE* technology at the SIGGRAPH’92 computer graphics conference in Chicago. It is a cube display-screen faces surrounding an observer, which is graphically illustrated in Figure 30. There are various examples for the use of this technology in the literature; however, although the abbreviation of *CAVE* is commonly used for them, its full name differs from reference to reference. Cruz-Neira et al. (1992) introduced it with the name of “Cave Automatic Virtual Environment”, which also referred to “Plato’s allegory of the cave”. Additionally, “Computer Augmented Virtual Environments” and “Computer Assisted Virtual Environments” are other common names.

Cruz-Neira et al. (1992, p. 67) defined the *CAVE* as similar to surround systems such as early *flight simulators* and *OMNIMAX theaters*; however, its recent instance is coupled with a *head-tracking device*. “As the viewer moves within the bounds of the

CAVE, the correct perspective and stereo projections of the environment appear on the display screens". They mentioned that the users of the CAVE experience the same "viewer location and head rotation measurement delays" similar to the users of the HMD; however, the effect is less noticeable, as rotations only need a small change to the stereo projections (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992, p. 67).

One of the examples of CAVE usage is the study of Wahlström et al. (2010) which assessed four patient rooms and a bathroom modeled by the CAVE and the actual hospital wards (see Figure 31). Eleven nurses and 11 patients (end-users) participated in their study. According to their findings, some advantages of the CAVE are listed below:

1) Behaviors and comments of the participants indicated that they felt as if they were in a real hospital room.
2) The use of CAVE-based virtual modeling might be more cost-effective than the use of physical full-scale mock-ups.
3) Digital virtual model can be stored more easily than the physical mock-up.

Wahlström et al. (2010, p. 208) explained some disadvantages of the current CAVE technology as follows:

> 1) **Perceiving size:** End-users were not always certain about sizes and distances in the modeled rooms.
>
> 2) **Lack of touch:** On the actual hospital wards, end-users seemed to evaluate the rooms on the basis of touch. Especially in toilets, being able to brace oneself against correctly situated grab bars was important.
>
> 3) **Perception of light:** Due to the limited dynamic range and relatively low brightness of the projectors and screens testing whether or not the lights produce sufficient luminance levels without causing unpleasant glare would be impossible.

Figure 32 illustrates other examples of CAVE from studies of Dunston, Arns, and McGlothlin (2007) and LaViola (2009), in which participant could interpret the designs of the sample rooms.

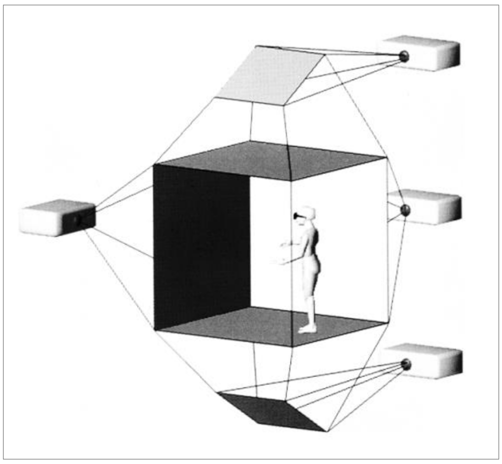


Figure 30 Graphic illustration of CAVE presented in 1992 by Cruz et al. (Cruz-Neira, Sandin, DeFanti, Kenyon, & Hart, 1992, p. 66)

Figure 31 Examples of CAVE. Left: outside view of a CAVE. Right: Patient interview in a CAVE. (Wahlström, et al., 2010)

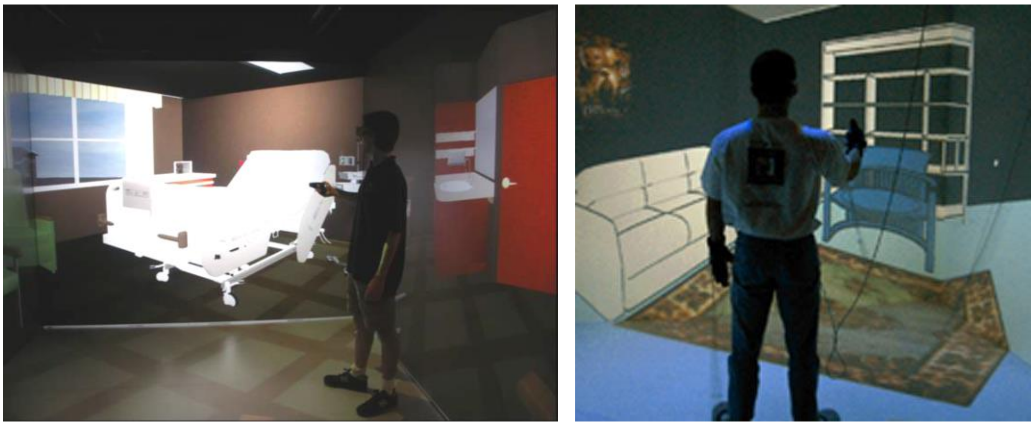


Figure 32 Examples of observer interventions in CAVE. Left: an observer in a patient room display in a CAVE (Dunston, Arns, & McGlothlin, 2007) . Right: a user in the process of creating a conceptual model of his living room (LaViola, 2009).

Dunston et al. (2007) assessed patient rooms via CAVE models of actual rooms in a hospital (see Figure 32 – left side). Some healthcare personnel participated in the study and they were asked to perform a variety of actions; they walked in the room, and checked clearances, sound levels, sightlines, functionality, and general appearance. Since almost all the virtual furnishing in the model was portable, participants could grab pieces of equipment and furniture, and they rearranged them. While they were walking, they could also carry the virtual items with them to check the adequate space for each. As a result, Dunston et al. (2007, p. 9) stated that the use of this technique for patient-centered design is “a reasonable and cost-effective means to advance the state-of-the-science in form and function for hospital design, construction, and operation”.

LaViola (2009) formed a system called “room designer” with *TAN-Cube*, which has similar principles of CAVE systems. It was a four-sided VR display which has a multimodal interface consisting of hand gestures and speech input (see Figure 32 – right side). In this study, they presented “room designer” as an application prototype, which allows users to settle simple architectural spaces with furniture and interior decorations. They acknowledged that the system was still in its infancy, and needed further developments to have more realistic applications.

2.5.2.3. Mobile medium and Augmented Reality (AR)

In addition to the *conventional basic displays* and the *advanced immersive displays* of *Virtual Reality* (VR) which were mentioned above, there are two significant concepts called *mobile medium* and *Augmented Reality* (AR) which can be classified as the third type of computer simulations.

The *mobile medium* consists of laptop computers, smartphones, tablet PCs and the like. The first laptop (the Grid Compass 1100) was released in 1982 and the first smart phone (the IBM Simon Personal Communicator) was introduced in 1992. As it is clearly seen in Figure 33, the first examples of *mobile medium* were lack of visual qualities (with a resolution of 320x240 pixels and 160x293 pixels, respectively) to be used for space perception studies. However, they have been developed and diffused rapidly since the end of 1990s. Ahonen (2012) stated that *mobile* was invented as a mass media in 1998. Hence, instead of the dates of early examples, the starting time of *mobile medium* can be considered as 1998. When compared to advanced systems, which cover in laboratory settings and require large budgets, these small types of mediums, which can be easily carried in hands and pockets and affordable for ordinary people, should not be underestimated. Ahonen (2012) expressed the rapid development of mobile technology with a stunning example. By emphasizing that NASA launched into space in 1969 with the help of computers, Ahonen (2012) claimed that “the mobile device in our pocket has more computing power than all of NASA’s computers in 1969”.

Figure 33 The first examples of mobile devices. Left: The first laptop (the Grid Compass 1100), 1982 (Retrieved in October 11, 2014, from: http://history-computer.com/ModernComputer/Personal/images/Grid1101.jpg). Right: the first smartphone (the IBM Simon Personal Communicator), 1992. (Retrieved in October 11, 2014, from: http://www.smart421.com/wp-content/uploads/2013/06/ibm-simon-personal-communicator.jpg).

As mentioned before, the *conventional basic displays* and the *advanced immersive displays* have been used to present Virtual Reality (VR). In addition to VR, *mobile medium* enables *Augmented Reality* (AR) which presents a digital interface to the real world. *Augmented Reality* (AR) was first termed by Boeing researchers Caudell and Mizell (1992) in 1992 at IEEE Conference. They defined that: “combined with head position sensing and a real world registration system, this technology allows a computer-produced diagram to be superimposed and stabilized on a specific position on a real-world object.” Some of their graphic illustrations are seen in Figure 34.

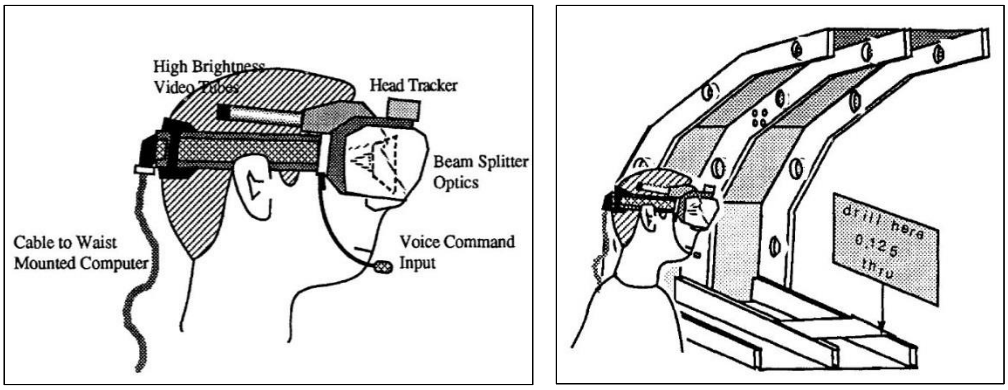


Figure 34 The earliest introduction of Augmented Reality (AR): Graphic illustrations of heads-up, see-through, head-mounted display (HUDset) presented by Caudell and Mizell (1992, pp. 660, 663).

In fact, when compared to the technology of today, these examples in 1990s were in their infancy. Ahonen (2012) stated that *Augmented Reality* (AR) started in 2009 and reached five million users in 2011. He also clarified the questions about what would be the next mass media after *mobile* (the seventh mass media). His answer (2012) was that *Augmented Reality* (AR) became *the eight mass media*. AR can be prepared by *mobile apps* (computer programs designed to run on mobile medium). For the last five years, various *apps* have been designed to have visual and audial AR for various purposes. For the scope of the current study, some of the existing AR types were selected from Abbund (2013), enhanced and listed as follows:

- Examining virtual furniture to check its scale and its harmony in a real room.
- Examining virtual wall color, texture and materials (ceramic tile and the like) to check its harmony in a real room.
- Examining virtual shutters to check its appropriateness on a real window.
- Exploring hidden systems (mechanical, structural systems) of buildings behind existing walls.
- Exploring past and future of buildings.

- Obtaining 3D view of 2D maps, plans, and other images on published documents or on flat screens.
- Obtaining motion view or rotated view of static images on published documents or on flat screens.

Two examples of AR applications for architecture are illustrated in Figure 35. Both of them superimpose virtual images on real environments by *mobile apps*. Left figure illustrates how the ruined Coliseum could be seen as its past condition via AR. While the camera of the mobile is directly taking the perspective, sky, walking people and other elements from the real environment, it superimposes a computer model of the undestroyed Coliseum over its ruined parts. Right image illustrates how AR enriches looking a published plan as if looking at a 3D model and enables to turn around it.

Figure 35 Some examples of AR applications for architecture. Left: exploring the past of ruins of the Coliseum in Rome via Adriane AR. (Retrieved in October 13, 2014, from: http://www.myariadne.com/features/augmented-reality/). Right: obtaining 3D view of 2D plans on a published document via ViewAR Architecture. (Retrieved in October 13, 2014, from: https://itunes.apple.com/us/app/viewar-augmented-reality/id629689579?mt=8).

Next figures illustrate the use of AR for interiors. Figure 36 explains the application of AR catalog of IKEA (a home furnishing company) while costumers were placing the selected 3D representations of the products in their own rooms. Figure 37 illustrates the real room after the real furniture was bought and placed (IKEA, 2013; Löwenborg-Frick, 2013). By comparing these two figures, it can be inferred that the AR catalog mostly succeeds to represent the real situation.

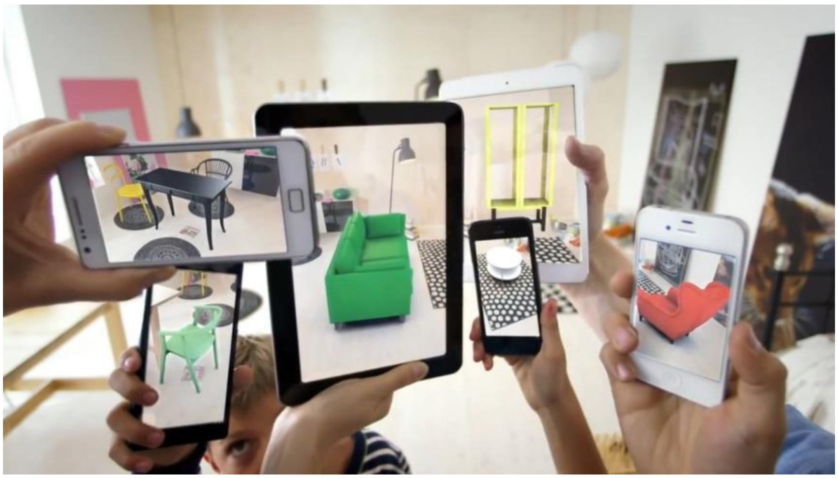


Figure 36 Superimposing virtual furniture in an empty real room by IKEA augmented reality catalog (Abbund, 2013, p. 2; IKEA, 2013).

Figure 37 The real room after the real furniture was placed (IKEA, 2013).

Figure 38 Superimposing virtual shutters on real windows by Crane Augmented Reality shutter demo (Crane 3D Media, 2012)

Within these examples, Figure 38 illustrates the most relevant example for assessing permanent components of rooms. It is an AR shutter demo which superimposes various virtual shutters on real windows. These AR examples can be multiplied; there are various *mobile apps* for doors, cabinets, and the like.

As seen from all these examples, existing *mobile* AR technology can superimpose a virtual element on a real scene. Addition to its portable, practical and affordable properties; presenting “the combination of real and virtual” gain great advantages for this type of representation as follows:

1. This solves most of the problems about perspective distortions, which might be problematic in *advanced immersive VR displays.* Since it overlaps real perspective setting, most of the visual depth cues are presented to an observer as they should be.
2. Contrary to VR, since the represented part of the vision is minimized, artificiality of the vision is also minimized.
3. Since it is not wearable or immersive, it does not cause the aftereffects.
4. Since *mobile* AR is presented in the real environment; audial, haptic and olfactory senses about the real environment are also included in the perception.

Although *mobile* AR has not been included in the environmental psychology literature yet, it has a great potential as a representation tool for the future experimental studies. However, there are two significant questions about *mobile* AR to be answered before determining to use it as a research tool in the scope of the current thesis:

1. Can AR be used to change the general form and dimensions of the real environment/interior successfully? Is it capable of presenting this type of variations of the existing environment?
2. As Sherman and Craig (2003, pp. 129-132) stated “in displays with a less than complete *field of regard* (FOR), stereopsis can be lost when a nearby object is only partially in the display”. Do the edges of the small mobile screen decrease the quality of the visual representation?

2.5.3. Evaluations of the current computer simulation technology and expectations for future computer simulations

2.5.3.1. Evaluations of the current computer simulation technology for environmental psychology research

In Section 2.3.6 and 2.4, many examples of the use of computer simulations in environmental psychology research were mentioned. Based on these examples, it was emphasized that the use of computer simulations in environmental psychology has lagged behind the state-of-the-art technology in their period. In Section 2.5.2, the current technology of computer simulations was classified and assessed in more detail by referring to the starting time of each one. When this is compared with the applied examples in environmental psychology literature, it is clearly seen that the new developments in computer simulation technology were not used right after their inventions. In this section, the reasons for the delay of the use of current technology in environmental psychology research, its weaknesses and its potentials for future research will be discussed. In addition, possible features of computer technology, which are expected for the near future, will be mentioned.

First of all, it is important to remind that the terminology and classification of computer simulations differ from reference to reference, mainly due to its interdisciplinary nature. The classification in Section 2.5.2 was made from the environmental psychology research point of view. However, it was difficult to classify this technology in clear cut groups. There were two exceptions for laptops and some HMDs, which can be identified in more than one group. Laptop medium can be identified both in conventional basic type of VR displays (flat screens) and mobile medium. In addition, some HMDs can be used both for VR presentations and AR presentations, and some of them, especially the ones like googleglass, can be identified as mobile medium. By having knowledge of these exceptions, the classification in the current thesis was made to identify the current computer simulation technology for environmental psychology research.

Within this classification, the *conventional basic VR displays* (flat screens and projections on flat boards) are the most commonly used type of computer simulations in environmental psychology literature. The main weakness of this type of displays is that they present only *monoscopic visions*, limited *field of regard* (FOR) and *field of view* (FOV). However, visual perception of monoscopic images has known parameters which have been experimented since the renaissance period, such as Brunelleschi's mirror, Alberti's window. Hence, this type of simulation display has been the mostly preferred representation tool in environmental psychology literature.

Immersive VR displays (VR DOMEs and curved screens, HMDs, and CAVEs) are more advanced ways of computer simulations; nevertheless, their usage in the environmental psychology literature has not become common yet. For instance, Franz et al. (2005) used a VR Dome as a reliable stimulus; however, Majumdar et al. (2006) used curved screens, Wahlström et al. (2010), Dunston et al. (2007) and LaViola (2009) used CAVEs to test only the validity of these display systems and they concluded with future expectations for these systems. Hence, it can be interpreted from the literature that these immersive systems are still being approached cautiously in environmental psychology research, yet. The main reason for these concerns is about whether the new developments present a realistic space or illusion. These *immersive displays* surround the observer and also some of them are wearable. Thus, they are more advantageous than *basic VR displays* in terms of FOR, and the observer can be isolated from the real environment in order to concentrate on VR. However, the basic problem is about how VR is projected on curved screens or surfaces of cubes. As it was seen in the previous figures (Figure 25, Figure 26, Figure 31 and Figure 32), there were perspective distortions on the curved surfaces and on the edges of the cube surfaces. Although the effects of these distortions on visual perception have been reduced by head-tracking features, the problem has not been completely solved, yet. Moreover, due to their immersive properties, there may occur some additional problems called *cybersickness* and *aftereffects*. Blade and Padgett (2002) defined *cybersickness* as “sensations of nausea, oculomotor disturbances, disorientation, and other adverse effects associated with VE exposure”.

Their definition of *aftereffects* was “any effect of VE exposure that is observed after a participant has returned to the physical world.” Welch (2002, p. 620) explained the disadvantages of computer simulations in more detail as presented in the table below.

Table 4 Sensory/perceptual, behavioral and physical complaints affecting VE users (Welch, 2002, p. 620).

Sensory/perceptual problems reported by VE users:	• Momentary reduction in binocular acuity (e.g., Mon-Williams, Rushton, & Wann, 1993 cited in Welch, 2002) • Misperception of depth (e.g., Roscoe, 1993 cited in Welch, 2002) • Changes in dark accommodative focus (e.g. Fowlkes, Kennedy, Hettinger, & Harm, 1993 cited in Welch, 2002) • Potentially dangerous “delayed flashbacks” (e.g., illusory experiences of climbing, turning, and inversion) that may not surface until several hours after user has left an airplane simulator or similar VE (e.g., Kennedy, Fowlkes, & Lilienthal, 1993 cited in Welch, 2002)
Disruptive behavioral effects of VEs:	• Disturbed perceptual–motor (e.g., hand–eye) coordination (e.g., Biocca & Rolland, 1998 cited in Welch, 2002) • Locomotory and postural instability (e.g., DiZio & Lackner, 1997 cited in Welch, 2002) • Degraded task performance (e.g., Fowlkes et al., 1993 cited in Welch, 2002)
Physical complaints reported by VE users:	• Eye strain, or “asthenopia” (e.g., Mon-Williams et al., 1993 cited in Welch, 2002), which may be symptomatic of underlying distress of or conflict between oculomotor subsystems (e.g., Ebenholtz, 1992 cited in Welch, 2002) • Headaches (e.g., Mon-Williams et al., 1995 cited in Welch, 2002) • Cardiovascular, respiratory, or biochemical changes (e.g., Calvert & Tan, 1994 cited in Welch, 2002) • Motion-sickness symptoms (e.g., pallor, sweating, fatigue, and drowsiness, although rarely vomiting; e.g., Gower et al., 1987 cited in Welch, 2002)

As mentioned above, the current technology of *advanced immersive VR displays* has several disadvantages. However, since the technology is rapidly developing, the above mentioned problems might be solved in the near future. When they will be developed further, these *immersive VR displays* may present the most realistic and reliable representations of spaces. Then, they may be the most preferred representation tools for environmental psychology research.

When compared with the *advanced immersive VR displays*, *Augmented Reality* (AR) in *the mobile medium* is small, hand-held, portable and inexpensive. However, its representation is unexpectedly successful. Since AR is superimposed on the real scene, the perspective is not distorted. Moreover, since AR does not surround the observer, it does not cause the *cybersickness* and *aftereffects*, which were mentioned for *immersive VR displays*. However, *mobile ARs* require two significant developments in order for them to be a research tool for the scope of the current thesis. The first one is about how the general form and dimensions of the real environment/interior can be changed by AR successfully. The second one is about the edges of the small mobile screen which decrease the quality of the visual representation. When developments are promoted for these two subjects, *mobile AR* may be the leading representation tool in environmental psychology research, as in the case of *immersive VR displays.* Moreover, *mobile AR* may be the most preferred one because of its practical, portable and economical properties. However, for the present conditions, *conventional basic VR displays* seems to be the most appropriate and reliable representation tool for the scope of this thesis.

2.5.3.2. Expectations for future computer simulations

The computer simulation technologies mentioned above are all based on visual perception. People observe and evaluate the space, first and foremost, through visual senses. However, as stated before, people perceive their environment with the combination of their four senses, which are *visual*, *haptic*, *audial* and *olfactory*. For instance, the quality of air circulation of a space is hard to understand with *visual* senses alone, the supports of other senses are needed for different aspects: *Audial* senses can hear the voice of breeze, *haptic* senses can feel the temperature and moisture, *olfactory* senses can smell fresh air, dampness and the like. As a result, all these sense-data can affect the general perception of the space. Hence, in addition to the advancements of existing visual simulation technology, further computer developments should be based on how simulations can be experienced by all four senses as in real life. This was also declared by IBM (2012), which is a multinational technology and consulting corporation. IBM annually unveils five predictions about how technology innovations will change within the next years. In December 2012, IBM displayed the seventh annual “IBM 5 in 5” as follows (Armonk, 2012):

> **Touch:** you will be able to touch through your phone.
> **Sight:** A pixel will be worth a thousand words.
> **Hearing:** Computers will hear what matters.
> **Taste:** Digital taste buds will help you to eat smarter.
> **Smell:** Computers will have a sense of smell.

These five items indicate the expectations for the incorporation of all senses into the computer technology. *Visual* simulations, which were mentioned in section 2.5.2 in detail, and a*udial* simulations are possible with the current technology. Within the five expectations, the newly proposed features of computer technology are *taste*, *smell* and *touch*. The *taste* and *smell* features mentioned by IBM do not seem directly related with the people’s perception of space; however, “touching through computer systems” may be a beneficial feature to enrich research tools of environmental psychology.

Wahlström et al. (2010, p. 208) also considered “not being able to touch” as a limitation for space representations via computer simulations. In their study, they compared how participants evaluated a real hospital room and its CAVE model, and they observed that, in the real rooms, participants evaluated environments on the basis of “being able to touch or hold features and to brace against things”. Their suggestion for a further developed method was to complement the VR evaluation session with an evaluation session in which physical objects were used. However, this is not a comprehensive solution for all kinds of environmental psychology research; *haptic* representations should be included in the computer simulation technique.

In order to understand the kinds of haptic simulations needed for environmental psychology research, what kind of haptic experiences are gained when a person evaluate a real space should be taken into consideration. Basic haptic experiences in a space can be listed as follows; walking in the space, climbing up and going down its stairs/slopes, touching the barriers and limits of the space, holding the railings, opening the doors, feeling the textures of the ground and the like. Although haptic simulations have not been included in environmental psychology literature yet, various tools to develop haptic simulations (especially for the game industry) have been invented and unveiled in computer sciences literature. These inventions are based on two main haptic subjects; 1) how to move and walk in a virtual reality (VR) model and 2) how to touch VR objects.

Simulations with head-mounted displays (HMDs) and simulations with mobile medium give observers the chance to freely walk around. However, since the virtual environment they see and the real environment they walk in are different, the motion may be disturbed by an unseen obstacle and some accidents may occur. Figure 39 illustrates two examples of products which were designed to solve such kind of problems and let observers move free from the real environment. The first example is *Virtusphere* (see Figure 39 – left side) which is composed of a 10-foot hollow sphere on a special platform. A user looking a VR through HMD can walk and run inside the sphere, which can be rotated in any direction according to the user's steps. The data of the user's movements are collected and sent to the computer and replicated in VR simultaneously (Virtusphere, 2013). The second example is *Virtuix Omni* (see Figure 39 – right side) which has similar purposes with *Virtusphere* but does not have an enclosed form. The *Virtuix Omni* consists of a concave platform, which enables walking and running motion, and a robust support ring and unattached support harness, which provide safety and versatility of movements. There are also specially designed Omni shoes for extended gameplay on *Virtuix Omni*. A user can "walk, run, jump, and turn swiftly and smoothly in 360 degrees without restraints" (Virtuix Omni, 2013). In order to supply "natural gait", its platform was designed with low-friction curved base and radial grooves (Kelion, 2013). Although

Virtusphere and *Virtuix Omni* were designed for the game industry, they and similar other products can be used in environmental psychology research. Hence, while participants are observing a VR, they can physically move and experience the model as if they are really walking in it. However, in addition to walking on a flat ground, features for climbing up and going down stairs/slopes are needed to be developed in these simulation systems.

The second dimension of haptic simulations is “touching to VR objects”. It has two main concerns; 1) transferring the real hand motions into VR models and 2) getting haptic feedback from the touched VR object. The former has been solved by wearable gloves with electronic sensors, which are called *DataGloves*. (They are also named as *CyberGloves* and *Wired gloves* in different references). An example called *CyberTouch,* which was released in 1995 by Virtual Technologies Inc. (HITLab; VTI, 1999), was illustrated in Figure 40 (left side). As it is clearly seen in the figure, hands with DataGloves are represented in the computer model in the same position. Left hand is opening the door while right hand is pushing the buttons on the wall in the VR model. This type of transfer has been achieved; however, how to get haptic feedback from the touched VR object has still been a challenge for computer technologies. As Newton stated in the law of action-reaction, “for every action there is an equal and opposite reaction” (Smith, 2008; Williams, n.d.). Hence, when a real object is touched, the hand gets an opposite reaction force from the object, and the hand motion is limited according to the shape, hardness and elasticity of the touched object. In order to provide force feedback from computer simulations, “wearable mechanical exoskeleton systems”, such as *Dexmo F2* (Figure 40 – right side), have been developed. When the hand representation in VR model hits a digital object, “the small actuators actuate, brake the joint and lock the exoskeleton” (Dexmo, 2014). It aims to “stimulate sensation of actually holding something that isn’t really there” (NDTV, 2014). However, this system only controls the skeleton movements on the hands; it does not give a tactile sense on the skin. Some other products, such as *TeslaTouch* (Figure 41), try to enhance tactile feedback based on the electrovibration technology.

Figure 39 Left: Virtusphere (Virtusphere, 2013). Right: Virtuix Omni (Kelion, 2013).

Figure 40 Left: CyberTouch (Konno, 2010) . Right: Dexmo F2 (Dexmo, 2014).

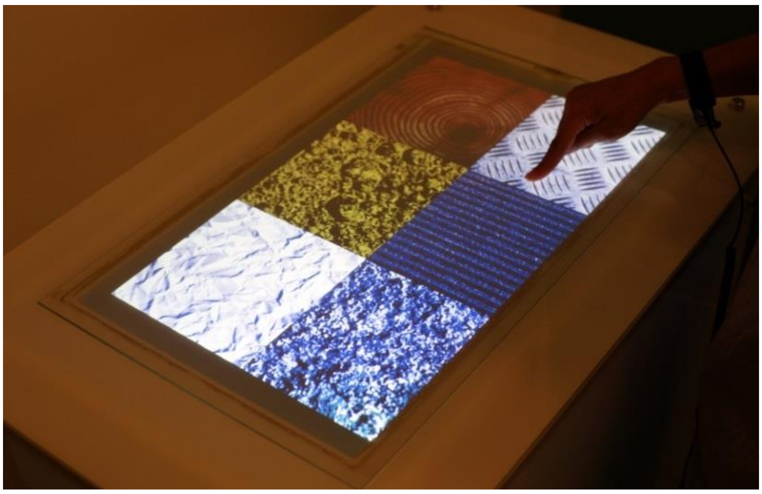


Figure 41 TeslaTouch: A tactile texture display (Bau, Poupyrev, & Harrison, 2010).

As illustrated in Figure 41, the designers of *TeslaTouch* claimed that the feeling of textures and materials, such as rough like sandpaper, smooth like glass, or bumpy like corduroy, could be experienced by sliding fingers over their images (Bau, Poupyrev, & Harrison, 2010).

To sum up, computer simulations have been substituting the conventional representation tools in environmental psychology. The superiorities of computer simulations over the other representation tools are not only their economic and practical properties, but also their wide range of presentation alternatives (Section 2.5.2). However, since the ways of seeing in real scene and on computer interface have some differences (Section 2.5.1), it is essential to be cautious to prevent misjudgments, while producing visual representations via computer simulations. In order to present more realistic representations, immersive VR displays and mobile AR displays have been developing. Although they have various advantages (Section 2.5.2), they also have some weaknesses (Section 2.5.3.1), which need to be improved further. In addition to visual simulations, future developments in computer sciences may also enhance the haptic simulation tools. Existing haptic tools have not become practical enough to be used for environmental psychology research, yet. However, with future developments, participants may not only observe the simulated environments, but also walk in and touch them as in the case of real space evaluations.

2.6. EVALUATION OF THE LITERATURE AND SELECTION OF RESEARCH TOOLS AND CASES FOR THE CURRENT STUDY

In the beginning part of Chapter-2, studies within the last 45 years on people-environment interaction, especially on the spaciousness assessments, were reviewed. After surveying almost a thousand studies, it was seen that each experimental study in architectural psychology (and more broadly environmental psychology) examines one or more *parameters* of people-environment interaction (Section 2.4), through sample spaces and sample participant groups. Before starting the experimental phase of the current study, two significant decisions were needed to be made in the light of the literature survey; 1) choosing the parameters to examine in the scope of the study and 2) determining the appropriate methodology. The former was determined with a preliminary study, which will be mentioned in Section 3.1. The latter will be discussed in the following subsections, in which the literature is briefly reevaluated in order to shape the experimental settings of the current thesis.

2.6.1. Selection of evaluation technique

In Section 2.2, evaluation techniques in environmental psychology were briefly introduced and categorized into two; 1) observations of people's behaviors and 2) verbal statements of people. Since the current study does not aim post-occupancy evaluations, the former option was eliminated and the latter was concentrated on. Hence, semantic differential scale, which is one of the common evaluation techniques based on verbal statements of people, was analyzed in more detail.

To remind briefly, various sematic differential scales were constructed for specific purposes in architectural psychology in the 1960s and 1970s, such as the scales of Vielahauer (1965), Kashmar (1970), Canter and Wools (1970), Küller (1972), İmamoğlu (1975) and the like. These scales were sophisticated scales which were produced following series of experimental studies and validity verifications. However, in the 1980s and 1990s, which were less active periods of architectural psychology, productions of such kind of scales were declined in parallel with the decline in the popularity of architectural psychology. Since 2000s, the field has gained its currency again by the inclusion of computer simulations as new research tools in the field. As the production of computer models is more economical and practical than other techniques, obtaining several alternatives of a sample space is easier than the conventional methods. Hence, there is a new tendency to ask tens of derivatives of a sample model to one participant at a time. In the recent literature, on one hand, the number of compared models is increased; on the other hand, the evaluation technique is selected from the simplest ones (such as a single eight-point "spacious – not spacious" scale). This type of approach has two weak points: 1) It might be confusing for a participant to consecutively evaluate tens of models at a time, and this might cause misleading results. 2) It is not possible to make in-depth analyses through the simple scale, whose evaluation is completed in just around 10 seconds. Although various sophisticated evaluation scales were developed and published in the 1960s and the 1970s, the reason why recent studies use simple scales instead of the developed ones is questionable. Possible reasons are listed below:

1) Related old literature might be difficult to access for recent researchers:
   a) Due to the interdisciplinary nature and worldwide concern, architectural psychology literature has been extended so greatly that it might be hard to obtain and review all related items.
   b) Due to accessibility difficulties in the past, not all the related publications referred to each other. Hence, it is not possible to say that the literature is complementary from the 1960s till today.
   c) Since most of the detailed application information about the developed scales is archived as unpublished hardcopies, they can be accessible only for small groups of people.
   d) Due to the less active period between the 1980s and the 1990s, there might be a disconnection between the recent literature and the past.
2) Simple scales might be considered more convenient for studies with computer simulations:
   a) Since evaluating tens of models at a time is difficult for a participant at a time, simple scales might be preferred not to cause mental burden on the participants.
   b) Since computer simulations can be presented quickly, also a fast evaluation technique might be preferred to gain more time.

Simple evaluation scales might be practical for both the participant and the researcher. Nevertheless, instead of evaluating “many spaces via simple scale”, evaluating “feasible number of spaces via sophisticated scale” might lead to more reliable results in architectural psychology. For instance, compared to a single-item seven-point “spacious – not spacious” scale, a sophisticated scale composed of several seven-point items about various dimensions of spaciousness has two main advantages:

1) Participants are directed to evaluate the subject more comprehensively by questioning more items.
2) Researchers can obtain more data about the various dimensions of the subject.

For these reasons, a sophisticated scale was preferred to be used in the experiments of the current thesis. However, since the construction of an evaluation scale requires a comprehensive research on its own, instead of designing a new evaluation scale, one of the developed and verified scales in the literature was preferred to be used in the scope of the current study. In this regard, spaciousness-crampedness scale (S-C-S) constructed by İmamoğlu (1975) was selected (see Section 2.2.2 and 2.2.3 for more detail).

There was an additional reason for this selection. Although the written format of the current thesis is in English, its experimental studies were conducted in Turkish as the participants native language was Turkish. Hence, S-C-S was an appropriate scale for the bilingual dimensions of the current study. S-C-S was constructed in English (1975), adapted to Turkish with the name of *Genel Uzam Değerlendirme* (GUD) and verified in both cultures (İmamoğlu, 1979-b). However, its validity for the current target groups and compatibility with computer simulations needed further verification. The validity will be examined in the preliminary study, and the compatibility will be examined in the first groups of experiments in Chapter-3.

2.6.2. Selection of representation technique

As mentioned in Section 2.3, computer simulations have become the prevalent representation tools in architectural psychology and have been substituting the conventional representation techniques for the last few decades. Hence, as the contemporary research tools, computer simulations were selected to be used in the space representations in the experiments of the current thesis.

S-C-S was used with scale models and real rooms in the 1970s and 1980s. On the other hand, the current study aimed to use S-C-S with computer simulations. Thus, features of scale models and computer simulations need to be compared in this regard. The advantages of computer simulations compared to scale models can be summarized as follows:

1) Both the production and the evaluation of computer simulations are more practical than scale models.
2) Scale models present only limited viewpoints (such as a view through a small hole in one of the walls); on the other hand, computer simulations can be observed from various viewpoints.
3) Interior tour is not possible in scale models, whereas it is possible in computer simulations by virtual walking feature.

In addition to the advantages mentioned above, computer simulations have some weaknesses when compared to scale models. Although some studies in the literature supported that the way people perceive scale models are similar with the way people perceive real environments, there is not a general verification for computer simulations yet due to their wide range of varieties. For this reason, in Section 2.5.1, the visual perception of real environments was briefly introduced with the four types of visual depth cues (*monoscopic, stereoscopic, motion* and *physical*) by referring to Sherman and Craig (2003). Although the conventional representation types (scale models and full-scale models) benefit from all these depth cues naturally, computer simulations can only benefit from the *monoscopic* and *motion depth cues*. Today's simulation technology has not been able to give *physical depth cues* yet. Moreover, although there are efforts to represent *stereoscopic image depth cues* in simulations, whether it is realistic view or an illusion effect is questionable. Hence *monoscopic image depth cues* and *motion depth cues* are needed to be used effectively for realistic representations. Due to some aftereffects mentioned in Section 2.5, such as cybersickness, the *motion depth cues* should be used carefully in computer simulations.

After the evaluations of different types of computer simulation displays mentioned in Section 2.5.3, VR presentation on a laptop screen, which is a type of basic flat screen VR displays, was selected as the representation tool of the current thesis. For the simulation program, various architectural modeling programs (such as ArchiCAD, AutoCAD, Revit Architecture, 3ds Max, and the like) and rendering programs (such as Artlantis, V-Ray, QuickTime VR, and the like) were examined. After surveying many examples on the internet and trying many sample models, the most applicable ones, namely Lumion, SketchUp and Rhinoceros, were selected primarily for the scope of the current thesis. The final selection among the three programs, their validity tests and the development of application procedures were made after a series of experiments which will be mentioned in Chapter-3.

2.6.3. Selection of sample spaces

As mentioned with the examples in Section 2.3 and 2.4, although experimental studies aim to test the effects of the focused parameters on buildings as a whole, the experiment area has to be narrowed down to “a sample space”, which is in controllable small size. A sample space can be either a room, which has its own walls, floor and ceiling, or a space which connects one room/place to another (corridors, waiting areas, lobbies, atriums). For the current thesis, sample spaces were selected from rooms, since they have well-defined spaces with surrounding walls, floors, and ceilings.

Some experimental studies in the literature (Section 2.3 and 2.4), especially the recent ones with computer simulations and full-scale models, examined sample spaces in very simplified forms (like an empty prism) isolated from most of the exterior and interior elements (such as window view, interior furniture), and ignored some realistic details (such as window frames, curtains, lamps and the like). These simplifications make samples aligned from real spaces, and weaken the visual depth cues, which might lead to misperceptions. Moreover, in a simplified model like an empty prism, detailing only the elements related to the research subject (such as windows) is likely to awake and force the participants to judge the spaces in the direction of the research hypothesis. However, in this type of method, some unnoticed and ineffective variables might be evaluated as if they were one of the significant ones affecting the space perception of people. Since, in real situations, people perceive and evaluate environments with their components and surroundings, studies with more realistic sample models are needed to contribute to architectural design research. Hence, in the current thesis, all sample spaces were selected from real rooms and modeled in detail. After their realistic computer models were completed, several alternative models were derived for various conditions of each experiment.

In the literature, sample rooms have been mostly selected from offices, classrooms, hospital rooms and house living rooms. The forms of hospital rooms and houses are restricted with their functions and related furniture; on the other hand, classrooms have simple forms which are easy to manipulate for different experimental conditions, including ceiling and floor types. The users of classrooms have to spend at least a course/meeting hour in limited positions; and they might not have chance to select their sitting place and/or intervene in any components of the actual classroom. Hence, the perceived space becomes crucial for classroom designs. For these reasons, classrooms were considered as the most appropriate cases for the experiments in the current thesis. In this regard, sample spaces were selected from various classrooms (lecture classrooms and seminar rooms) with the capacity of 15 to 90 students at Middle East Technical University.

2.6.3.1. A survey on classroom design guides: cases of ten universities among the top 100 list of Times Higher Education

In order to give insight into university classroom designs and their terminologies, some of the “classroom design guides” of the top 100 universities in the World (Times Higher Education, 2014) were searched via the internet by using the English and Turkish keywords. And eventually, classroom designs guides of ten universities among a hundred were accessed as follows; Cornell University (1994), The University of North Carolina at Chapel Hill (1997; 2003), University of Washington (2002; 2008), Emory University (2008), Stanford University (2009), University of

California Berkeley (2007; 2010), University of Toronto (2012), McGill University (2013; 2014), Yale University (2014), Princeton University (2014). Most of these guides were published in recent years, and thus, most of them were obtained after the experimental phases of the current thesis were completed. However, a brief information about these guides might be beneficial to understand the experiments carried out in the current thesis (for further information, see Appendix C).

The reason why these universities need a “classroom design guide” is thought-provoking. The answer is also written in these guides. Stanford University (2009, p. 2) indicated that “space is a precious and finite resource at most academic institutions”, and as University of California Berkeley (2007, p. 3) pointed out, “high quality classrooms are necessary for effective instruction and to attract and retain top-notch faculty and students”. The expectations for “classroom designs” were defined by The University of North Carolina at Chapel Hill (UNC, 1997) as follows:

> Classrooms should support a student’s ability to see all visual material, to hear without noise or distortion, and to be physically comfortable. Classrooms should support the instructor’s ability to present material and communicate with students in an effective manner, and classrooms should be able to be easily cleaned and maintained. This is an effort to identify the specific characteristics that combine to create good classrooms (p. 2).

The guides listed above were prepared based on reviews of existing guides of other institutions, surveys on a wide range of university spaces, and advices of university staff, designers and education experts. They are based on “actual space”, and they do not consider “perceived space”. However, the knowledge they produced might be beneficial to interpret some experiment results of the current thesis in terms of comparing “actual space” and “perceived space”. Hence, in Appendix C, the classroom design guides will be briefly assessed under six subsections: 1) classroom size and capacity, 2) classroom plan proportions, 3) classroom floor and ceiling types, 4) classroom ceiling heights, 5) classroom plan geometries and walls, 6) seating arrangements in classrooms.

2.6.3.2. A survey on METU campus and preliminary selection of sample classrooms

In order to select the most appropriate cases for each experiment, various classrooms in different faculties of METU were assessed and photographed, sketched, measured and modeled (for further information, see Appendix D).

Figure 42 Photographs of some of the surveyed classrooms at METU (Özyıldıran 2011-2013).

CHAPTER 3

PRELIMINARY STUDY AND THE FIRST GROUP OF EXPERIMENTAL STUDIES

3.1. PRELIMINARY STUDY: THE CONCEPT OF SPACIOUNESS

This thesis is composed of a series of experiments to assess the spaciousness of rooms/classrooms. Before conducting the experiments, a preliminary study was required to understand how the target group perceived spaciousness semantically, whether S-C-S was a valid evaluation scale for the current study, and which variables would be examined in the following experiments.

With a similar purpose, İmamoğlu (1975) started his Ph.D. study by using an open-ended questionnaire, a card-sorting method to see the rank order of characteristics of spaciousness of a room, and surveys of English and Scottish newspapers in Glasgow. In his open-ended questionnaires, each participant was given a sheet of A4 size paper with a printed sentence at the top: "*My concept of a spacious room is:* " and requested to write down their opinions. He counted the frequencies of the mentioned characteristics in the responses of participants and derived the following basic variables:

1) Activity in the room,
2) Shape, dimensions and size of the room,
3) Materials used,
4) Furniture used,
5) Light – natural, artificial – and view,
6) Colors,
7) Other sensory stimuli – sound level, smell,
8) General atmosphere of the room (İmamoğlu, 1975).

Since all experiments of the current study were conducted in Turkey, it was necessary to reexamine the concept of *spaciousness* due to both language and cultural differences between Scotland and Turkey. For this purpose, the main questions to be answered were whether *spaciousness* carries a similar meaning with its Turkish translation "*ferahlık*", and how it was evaluated in Turkey.

As mentioned in Section 2.2.3, İmamoğlu adapted S-C-S to Turkish culture as GUD in 1979, and verified both scales by experiments comparing S-C-S and GUD for the same room. In his adaptation process, İmamoğlu aimed to find the most appropriate translations of the 19 adjective pairs, which formed the S-C-S. However, "*ferahlık*" in Turkish has more comprehensive meaning than spaciousness has in English. Hence, its dictionary definition was the first question to be answered in this preliminary study. According to the Turkish Dictionary (TDK, 2006), *ferah* has psychological meanings such as "inner calm, peace of mind, and the absence of distress," from Arabic origin, and physical meanings such as "1) large, roomy, ample" and "2) airy, luminous" from Persian origin.[3] When the three spaciousness factors of S-C-S are assessed in this context, it is seen that "appeal factor" has psychological evaluations, "space freedom factor" has physical evaluations and "planning factor" has both. This indicates that S-C-S also covers both dimensions of "*ferahlık*" in Turkish.

Since S-C-S and its Turkish version (GUD) were developed and verified in 1970s, the second question of the current preliminary study was raised about the perceptual changes in the course of time. At this point, it is necessary to remind the statement of Gifford (1997, p. 3) that "today's problem involves different individuals in a different place and different time than did yesterday's problem". Individuals from different eras, cultures and settings might perceive a space differently, which was emphasized by Gifford as a paradox of environmental psychology. Hence, although

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[3] Definition of *ferah* in the Turkish Dictionary (TDK, 2006):

ferah *(Ar.) : Kalp, gönül, iç vb.nin sıkıntısız, tasasız olma durumu.*

ferah *(Far.) : 1) Bol, geniş. 2) Havadar, aydınlık, iç açıcı (yer).*

S-C-S was verified in 1970s in both cultures, an additional study was needed in order to verify its appropriateness for the current target group of people.

One purpose of this study is to test the validity of S-C-S in Turkish culture in the present by taking the answers of the following two questions into consideration:

1) How do the participant groups (staff and students of METU) define the concept of spaciousness?
2) Are they conscious about the variables affecting spaciousness?

In the light of the answers, another purpose is to determine the variables to be tested in the experiments following this preliminary study.

3.1.1. Participants

Three groups of people voluntarily participated in this experiment. The first group was 11 METU staff members living in Eryaman (a suburb in Ankara). The second group was 10 staff members from METU Faculty of Architecture. The third group was 19 first-year architecture students from METU Faculty of Architecture.

3.1.2. Stimuli and procedure

In order to understand how people consider and describe the concept of *spaciousness*, two open-ended questions were used in Turkish. The English translations of the two questions were "*What is spaciousness*?" and "*Which factors make a room spacious*?"

The first group of participants responded to the questions while commuting between METU campus and Eryaman in a METU school bus. Each participant's individual responses were written on a netbook simultaneously by the researcher, while the second group responded to the questionnaire in their office rooms when they were alone. The open-ended questionnaire was given to the third group in a printed form in their studio, and they were asked to write down their answers on the given paper.

3.1.3. Results and discussion

When the study was completed, certain word groups were elicited from the open-ended responses. A total of 110 different word groups were obtained from the answers to both questions. Each word group was written in a row of an excel table, and the number of people who mentioned that word group was counted and tabulated (see Appendix-B).

Results of the first question indicated that “comfort (*rahatlık* in both physical and psychological sense)” and “tranquility (*huzur*)” were the most frequently stated concepts to define the concept of “spaciousness”[4]. They were uttered by 19 and 11 participants respectively. The third and the fourth most repeated (6 times) word groups were “airy (*havadar*)” and “luminous and/or sunny (*aydınlık, güneşli*)” (see Figure 43). There were also 25 other word groups which were used to define spaciousness; however, since their frequencies were less than four, they will not be mentioned here in detail (see Appendix-B for details). Only two of the participants had difficulty to define the word spaciousness and left the question unanswered.

In the second question, 80 different word groups were phrased as factors which make a room spacious. Some of these word groups had very close meanings such as “wideness” and “optimum wideness”. Since their emphases were slightly different, they were counted and tabulated as different word groups in Appendix-B. However, for the ease of analysis, similar word groups were combined under ten main subjects. Figure 44 illustrates these subjects with the total numbers of people who used the word groups.

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[4] “*Rahatlık*” which was the frequently mentioned Turkish word in the open-ended questionnaire has two meanings: one is physical such as “comfort, ease” and another is psychological such as “inner calm, peace of mind”. Since which meaning was emphasized by the participant was not possible to determine, it was evaluated as a combination of both.

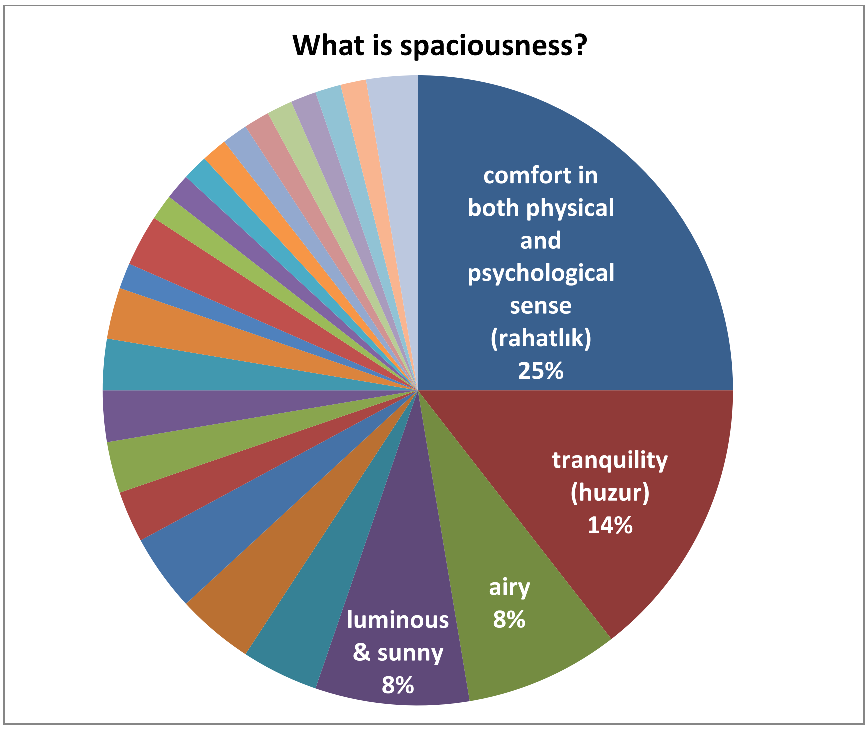


Figure 43 Summary graphic for the answers of the second question in the preliminary study (Özyıldıran, 2011).

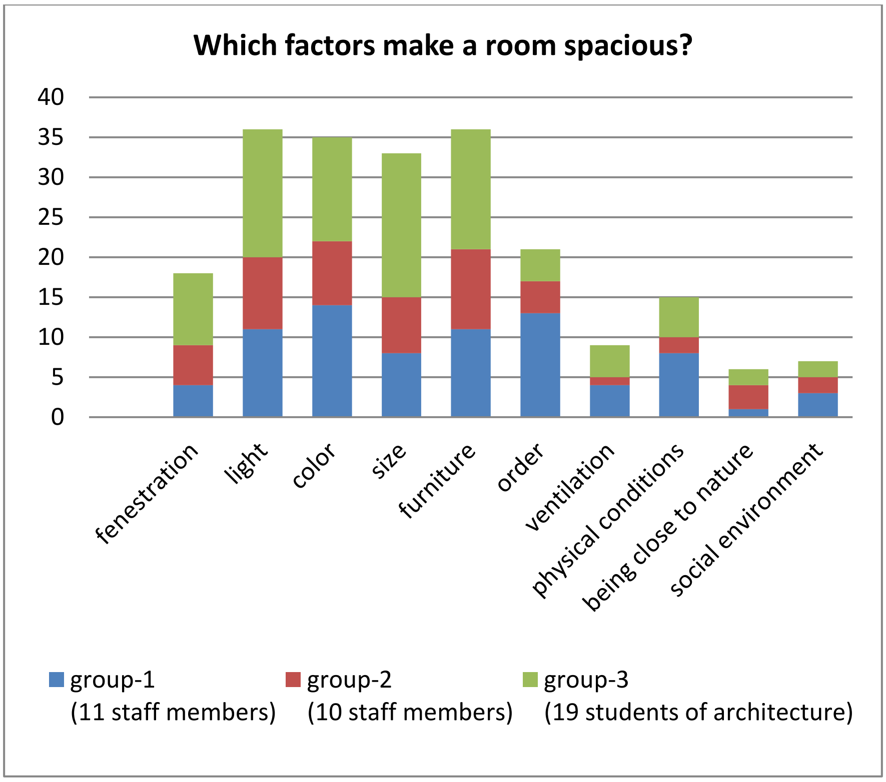


Figure 44 Summary graphic for the answers of the second question in the preliminary study (Özyıldıran, 2011).

As to the responses given to the second question, the majority of the participants stated that "light", "color", "size" and "furniture" were the properties affecting the spaciousness of a room. Following these, "order", "fenestration", "physical conditions (temperature, acoustics, strength and the like)" and "ventilation" were also mentioned. In addition to these, a small proportion of the participants expressed that "being close to nature" and "social environment" could also affect the spaciousness of a room.

It was understood that the participants defined spaciousness mostly in psychological sense (*rahatlık* and *huzur)*; however, they were conscious about which physical variables might affect spaciousness of a space. When the results of the current study are compared with the results of the preliminary study of İmamoğlu (1975), which were from different times and different culture, the following differences were detected:

1) None of the participants of the current study mentioned variables related to "activity in the room", whereas this was stated in the study of İmamoğlu (1975).
2) Variables related to "fenestration" were mentioned by 45% of the current participants; however, it was not listed in the study of İmamoğlu (1975).
3) Variables related to "being close to nature" and "social environment" were mentioned by six and seven participants respectively; however, these two concepts were not listed in the study of İmamoğlu (1975).

These differences might have emerged due to the dictionary definitions given on page 1 and 114. Although "spaciousness" and "*ferahlık*" were the most appropriate translations from English to Turkish, "spaciousness" is mostly attributed to size oriented meaning, whereas "*ferahlık*" refers to psychological as well as the physical senses. However, the items listed above are not directly related with the 19 adjective pairs, which compose S-C-S. Except these items, the variables obtained in the current preliminary study were mainly similar with the variables obtained by İmamoğlu's

(1975) preliminary study. As a result, it can be interpreted that S-C-S could be used in experimental studies following the current preliminary study.

The final phase of the current preliminary study is to determine variables which were examined in the following experiments. For this purpose, ten items illustrated in Figure 44 were used as a reference. Since studying all of them would be too extensive for the scope of a thesis, the most appropriate variables were selected for the current study based on the following criteria:

1) contributing to the architectural design knowledge
2) examining unknown interactions between people and built environment

Hence, the selected variables should be related to the permanent components of buildings and the subject should have unknowns to be searched by architects. During the final phase, subjects about "color" and "furniture" were eliminated since they are temporary components of buildings and they can be changed by users easily. "Light" was excluded from the scope of the current thesis due to its very specialized research field. As "fenestration" has been one of the most studied subjects of architectural psychology since 1970s, it was also eliminated. "Ventilation" and "physical conditions (temperature, acoustics, strength and the like)" are related with actual space instead of perceived space, and they are the subjects of building physics. Subjects related to "being close to nature" and "social environment" were mentioned by small proportion of the participants in the questionnaire, and these subjects were mostly studied by landscape architects and psychologists/sociologists respectively. Among the ten subjects, "size" and "order" were the most appropriate subjects for the scope of the current thesis.

After narrowing down the research subjects to "size" and "order", a closer examination of related answers of the open-ended questionnaire was needed. Figure 45 illustrates the direct translations of the word groups mentioned by the participants (For the original answers, see Appendix-B). In these answers, it is seen that some participants mentioned the variables by emphasizing the maximum dimensions such as "high ceiling"; some pointed out ideal dimensions such as "optimum height" and “appropriate size”; and some mentioned the variables in a neutral way such as “ceiling height”. When all the answers in Figure 45 are neutralized, the first group has seven main variables; size, width, ceiling height, ceiling type, proportions of space, story level and empty/unused area. The second group has mainly the variables related with interior arrangements, which are produced by permanent components of architecture and temporary components of interior design.

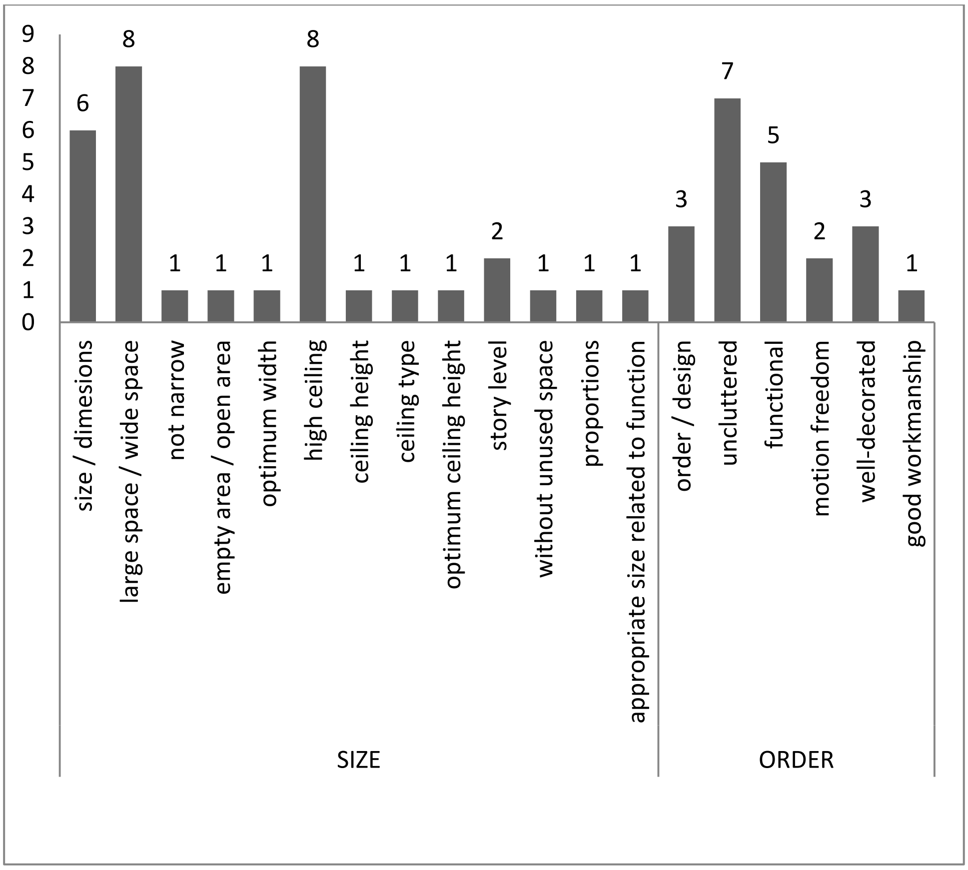
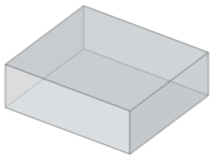
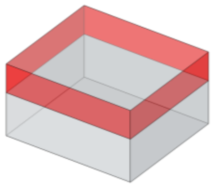
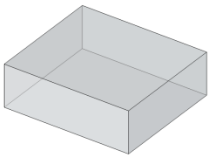
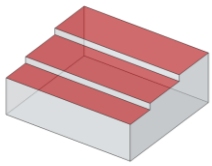
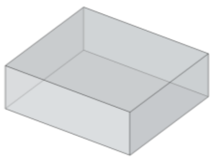
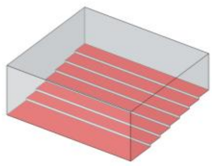
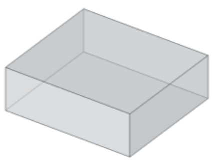
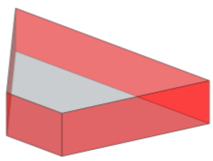


Figure 45 Detailed graphic of the answers related to “size” and “order” in the second question in the preliminary study (Özyıldıran, 2011).

In the light of the literature review and the results mentioned above, some variables were selected in order to be tested in the following experiments in the current thesis. The selected variables are four main permanent components of classrooms, which are ceiling height, ceiling and floor type (stepped and flat), and plan geometries (rectangular and trapezoidal). These variables are graphically illustrated in Table 5.

Table 5 Four variables of classroom design.

Ceiling height	 low ceiling	 high ceiling
Ceiling type	 flat ceiling	 stepped ceiling
Floor type	 flat floor	 stepped floor
Plan geometry	 rectangular plan	 trapezoidal plan

In this preliminary study, the appropriateness of S-C-S was verified for the current thesis, and the variables of experiments were determined. Following this preliminary study, the first group of experiments (Chapter-3) was conducted to develop an appropriate experimental procedure via S-C-S and computer simulation. With the developed procedure, the second group of experiments (Chapter-4) was conducted to examine the four variables mentioned above (see Table 5).

Here in Chapter-3, following this preliminary study, the first group of experiments consisting of four consecutive experiments will be mentioned: 1) representativeness of computer simulations, 2) computer simulation vs. real room, 3) computer simulations as virtual walking: cases of ceiling heights, 4) computer simulations as video animations: cases of ceiling heights.

3.2. EXPERIMENT-1: ASSESSING THE REPRESENTATIVENESS OF COMPUTER SIMULATIONS FOR SPACE PERCEPTION

3.2.1. Introduction

The aim of the first experiment was to determine the research tool for the following series of experiments. Based on the literature review (Section 2.6), computer simulations were considered as the most appropriate representation tool for the experiments in the current thesis. Since there is a wide range of presentation types for computer simulations, there was not a general verification for the validity of computer simulations as representation tools in the literature of architectural psychology. Hence, as the first stage of the experiment series, Experiment-1 was designed to select the appropriate apparatus and programs, and to test their representativeness.

In the preparation phase of Experiment-1, a survey was made in METU campus to learn classroom alternatives and to select appropriate samples for each experiment in the current thesis (for further information, see Section 2.6.3 and Appendix D). In order to model the real rooms, three available programs were selected within various architectural programs (Section 2.6.2).

This experiment entailed two steps: First, each participant individually evaluated the real room via S-C-S. Second, they compared the real room with the three computer simulations by giving 1 to 10 points for each case.

3.2.2. Participants

Participants were selected from *non-architect staff members* for the following reasons:

1) As this was the first stage of experiment series, participants' first impressions (without any prejudgment) on real space and its simulations was needed in order to obtain objective comparisons.
2) *Non-architect staff members* were not familiar with the selected computer programs and 3D computer models.
3) *Non-architect staff members* did not use the actual classroom before.

Participants were 25 non-architect staff members from various faculties of METU (one research assistant from the Faculty of Education; four research assistants from the Department of Mathematics; two janitors, two computer experts, six secretaries and ten technicians from the Faculty of Architecture). There were 14 males and 11 females. The mean age for the group was 38.8 with a range of 24 and 57 years.[5]

3.2.3. Stimuli

The stimuli of the current experiment were a real classroom and its computer simulations. As mentioned before, experimenting via real rooms has some difficulties. For the current experiment, the main challenges of a real sample room were 1) being accessible for the participants (in terms of distance and time) and 2)

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[5] There were three additional participants whose ratings were not included in the statistical analyses: They participated in the trial study of Experiment-1. After the trial of the procedure, they commended on experiment settings (sitting position, laptop position and lighting), computer models (need for a reference for horizon line outside the windows and color correction on window frames), and the readability and clarity of the evaluation form (font sizes, colored rows), and then, the procedure was reorganized. Since it was a pilot evaluation, their questionnaire ratings were not included in the statistical analysis.

having an appropriate design for the research question. Thus, classroom called R46 in the Faculty of Architecture was selected as the sample room, due to the following reasons:

1) For the researcher, classrooms in the Faculty of Architecture would be easy to access and follow their spare times in order to schedule appointments.[6]
2) R46 is one of the middle sized classrooms with a capacity of 30 students which is typical for the faculty building.
3) Since R46 is a rectangular-planned classroom with particular characteristics (various textures, materials, fenestration and the like), it was thought that participants might compare the real room and its simulations more comprehensively.

3.2.3.1. **Classroom R46 (real room):**

The classroom R46 has 3.56m ceiling height and 5.80m x 6.36m floor dimensions (see Figure 46 and Figure 47). South and north walls of the classroom are constructed out of white concrete blocks of 20cm x 39cm, with 2cm joints. West and east walls are exposed reinforced concrete. Entrance door (with a window at its top) is on the east wall and there are three slit windows between the room and the corridor at 2.25m level, which were glazed with translucent glass. There is a green board and a projection screen on the south wall, in front of which there is a lectern, a table and a chair for the instructor. Thirty student tablet-arm chairs within the room are placed in the order of three rows facing the green board. There is a floor to ceiling window (3.48m x 3.56m) on the west side which opens to a balcony (3.97m x 1.30m in plan) by a glass door. The balcony has solar shadings made of 86cm x 32 cm x 5cm white

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[6] Each participant would be individually invited to the real classroom when the classroom was empty. However, since almost all classrooms in METU campus have intensive course programs, they might be left empty only in a limited time period per week. Due to the limited time per week, the experiment would take a long time (around a month), and a close follow-up for the classroom program, which might be changeable for each day, was required in order to effectively use its empty times.

concrete hollow blocks. During the experiment, navy blue color curtains were kept in an open position on both sides of the window. The floor is paved with 45cm x 45cm beige ceramic tiles and ceiling is covered with a special rough, white plaster (for further information, see Appendix E.1.1 and E.1.2).

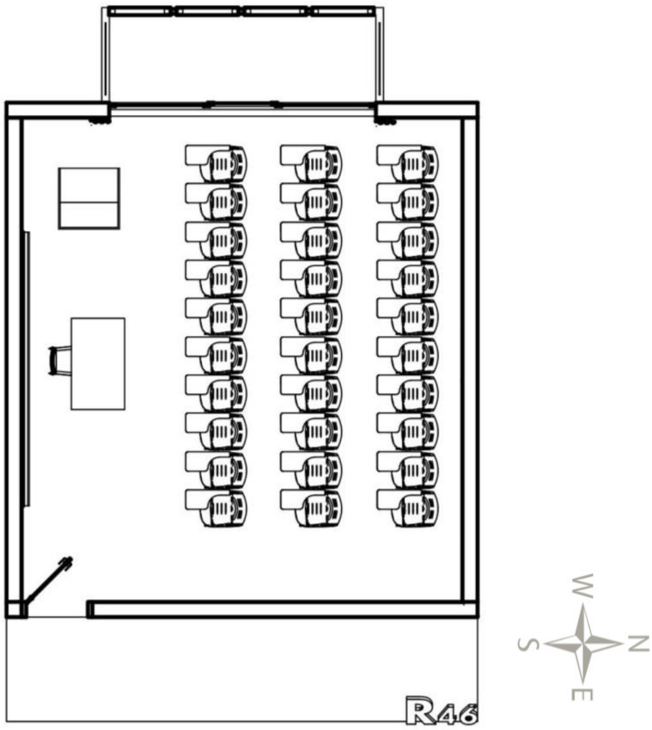


Figure 46 Plan of classroom R46 (Scale: 1/100).

Figure 47 Photographs of classroom R46 (2012).

3.2.3.2. **Computer simulations of R46:**

R46 was documented with photographs and detailed measured drawings (see Appendix E.1.1). Three computer programs were selected from several 3D computer modeling programs; “Google SketchUp 8”, “Lumion free sp2.b8” and “Rhinoceros 4.0 evaluation” (Section 2.6.2). These three programs had real-time rendering, virtual walking facilities and also they were freely available programs.

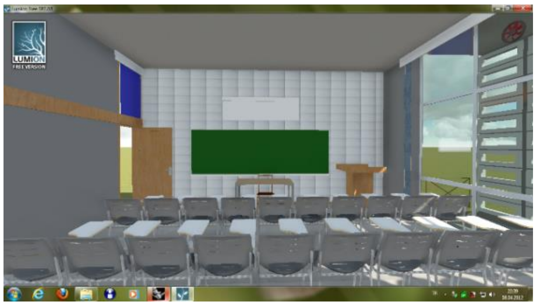
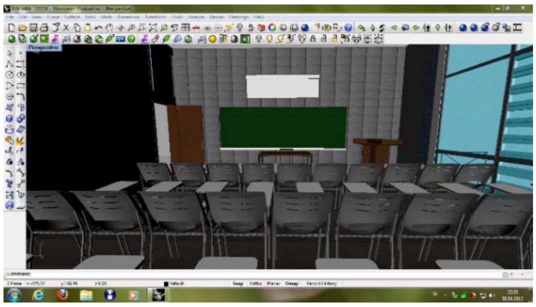
 Photograph of R46.	 SketchUp model of R46
 Photograph of R46.	 Lumion model of R46
 Photograph of R46.	 Rhinoceros model of R46

Figure 48 Photographs of classroom R46 and screenshots of computer models of Experiment-1.

R46 was modeled first in “Google SketchUp 8”, since SketchUp models could also be opened by the other two programs.[7] The room was modeled as detailed as possible and material textures were assigned to related surfaces from the material library of the program. For some specific materials, such as concrete blocks of the wall and ceramics covering the floor, close-up photographs were taken, and perspective distortions of the photographs were corrected in Photoshop program. They were scaled and assigned to related surfaces of the model. Furniture of the classroom was also modeled one by one according to the real situation[8].

After finishing the SketchUp model, it was exported to Lumion as well as to Rhinoceros programs. After these processes, dimensions of the model and the assigned surface patterns from scaled photographs were also protected in all programs. However, in order to have similar representation properties, each program needed some modifications, such as focal distance (see Table 3 on page 81), sun light, reflectivity and transparency of windows.[9, 10] These modifications were made and models were saved in all three programs in the same virtual view point .

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[7] Lumion program can open a SketchUp (*.skp) model if it is exported in collada (*.dae) file format. Rhinoceros 5.0 can import the SketchUp 8 model, but older versions of it cannot import it without much loss. Thus, Rhinoceros 5.0 was used to save the SketchUp model (*.skp) as a Rhinoceros model (*.3dm).

[8] It was difficult to model the existing gray chairs in SketchUp due to its curved surfaces which require NURBS (Non-uniform rational basis spline) feature. Hence, a similar chair was downloaded from “Google 3D Warehouse” and manipulated to make it as existing chairs. Similar procedures were followed for door handles, air fan on the window, and curtains. Except these four items, all other details were modeled by Özyıldıran.

[9] Transparency of glass was checked in both Lumion and Rhinoceros programs. In Lumion, lighting option was selected as “natural”, sun direction as “north west”, altitude of sun and cloudiness options were left in the middle of the diagram. In rhinoceros, view option was turned as “rendered”, and ceiling of the room was hidden to prevent the shadow of the ceiling and to have more light in the room.

[10] For Rhinoceros, camera of the monitor arranged to be able to turn around the center of the room. All models of R46, SketchUp, Lumion and Rhinoceros were saved in the same monitor position looking at the green board from the eye level of a person standing in the middle of the opposite wall. Viewing angles also become similar by changing camera lens options; Lumion left as default (20mm), while SketchUp was changed to 50mm and Rhinoceros was changed to 20mm.

A laptop with 1366x768 resolution 15.6” Toshiba TruBrite screen was selected to present the models.[11] The Turkish version of S-C-S (see Appendix A.2) was used for the evaluations.

3.2.4. Procedure

Step-1: Each participant was individually invited to the classroom. The door was closed and curtains were kept open as in the model. First, the participant was seated on the chair which was in the center of the front row, where all the corners of the room could be observed from similar distance. A printed S-C-S form was given and the participant was asked to evaluate the room by using the form. Two types of forms were employed; half of the participants evaluated the room by a list of seven-point 19 adjective pairs in a random order (as illustrated in Appendix A.2).; the other half used a list arranged in the reverse order. First, the use of a seven-point scale was explained to each participant, and then they evaluated the room by using S-C-S. The Step-1was thought to help the participants to follow a smooth mental evaluation of the actual room, and then continue with the Step-2.

Step-2: After finishing the first step, each participant was invited in front of the laptop to observe the room seen on the screen (see Figure 49). Each participant was asked to give a point between 1 to 10 for each of the three computer models according to its representation level of the room. The order of presentation for each of the three computer models was changed for each participant. First, how to use the mouse to control the virtual walking in each program was explained to the participants, and then they evaluated models by giving 1 to 10 scores for each (for the form, see Appendix A.1.)

[11] The computer used in this experiment was a silver colored Toshiba Satellite L755-14G laptop with a black screen frame.

Figure 49 Photographs of setting in Experiment1, Step-2, (2012).

3.2.1. Results and discussion

Descriptive statistics indicated that SketchUp model got the highest score (*M* = 7.84, *SD* = 1.72), and the Lumion was the second highest one (*M* = 7.56, *SD* = 2.20). On the other hand, Rhinoceros model was perceived as the least representing program (*M* = 7.12, *SD* = 1.79) (see Figure 48).

Additionally, from the researcher’s observations, basic visual differences among representations of SketchUp, Lumion and Rhinoceros models can be expressed as follows:

1- SketchUp presents lines on all edges of the model (like a cartoon drawing). The program has an option to hide the black edge lines, but they were preferred to be presented in case these lines support the perception of the geometries.
2- Lumion had more realistic textures, light and surface reflections on real-time renderings; however, it might have exaggerated perspective distortions more during virtual walking in the model than the other two programs.
3- Rhinoceros had less perspective distortions during motions; however, it had some disadvantages concerning its light and shadow quality during real-time rendering views.

According to the results of the 10-point scale, SketchUp model was chosen as the representation tool for the following experiments. However, a further study was also needed to test the validity of the selected tool. Hence the following experiment was designed and conducted.

3.3. EXPERIMENT-2: COMPARING SPACIOUSNESS EVALUATIONS OF A REAL ROOM AND ITS COMPUTER SIMULATION

3.3.1. Introduction

The aim of Experiment-2 was to test the validity of the computer simulation technique, which was developed in Experiment-1, as a representation technique. Therefore, Experiment-2 was designed to compare the S-C-S scores of the real room and its computer simulation. It was expected that there would be no difference between the spaciousness evaluations of the real room and its simulation. In addition, the question whether gender differences affected the spaciousness evaluations was needed to be clarified in order to determine the participant compositions of the following experiments.

The current experiment was composed of two parts: 1) the evaluation of the real room and 2) the evaluation of its computer simulation. Each condition was evaluated by a different group of participants.

3.3.2. Participants

In order to have participants' objective evaluations for each of the two experiment case, a different participant group's evaluation was needed for each case. On the other hand, in order to have equal conditions in both cases, similar participant compositions (in terms education and age ranges) was needed in each group. Hence, all participants were randomly selected from undergraduate students of the Faculty of Architecture. A total of 60 students, with 30 in each group, voluntarily participated in the experiment. There were equal number of males and females in each group.

Group-1: The first group was composed of 30 students from the Faculty of Architecture. There were 15 males and 15 females. The mean age for this group was 20.57 with a range of 19 and 23 years.

Group-2: Similarly, the second group was composed of 30 students from the Faculty of Architecture. There were 15 males and 15 females. The mean age for this group was 21.23 with a range of 19 and 24.

3.3.3. Stimuli

The classroom R46 used in the first experiment was again used as the "real room" condition (see Section 3.2.3.1). Its computer model by "SketchUp 8" program (see Section 3.2.3.2) was selected as "computer simulation" condition due to its highest score from the Experiment-1. A laptop with 1366x768 resolution 15.6" Toshiba TruBrite screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

3.3.4. Procedure

Step-1: Participants in Group-1 were individually invited to the classroom R46. The door was closed and curtains were kept open. First, the participant was seated in the chair which was in the center of the front row, where all the corners of the room could be observed from similar focal distance. A printed S-C-S form was given and the participant was asked to evaluate the room by using this form. First, the use of a seven-point scale was explained to each participant, and then they evaluated the room by using S-C-S.

Step-2: Participants in Group-2 were individually invited to a cubicle located in the second-year architecture studio in the Faculty of Architecture building (see Figure 50). They were seated in front of the laptop, and were asked to evaluate the simulation of the room as seen on the screen. They were not informed about the model and its name. First, the experimenter gave a printed S-C-S form to the participant and explained how to use the seven-point scale. Second, the experimenter showed the interior by a quick tour in the model. The tour started from the door, and the camera view was directed by the mouse commands of the experimenter. Instead of random movements, the virtual camera moved at 1.67m level above the ground of the model, as if it was the eye level (horizon line) of a walking person. After all the details of the interior of the model were presented, the tour ended. Third, the virtual camera was fixed in front of the door in the model, and participants were asked to turn the virtual camera by moving the mouse with right click if they desired. Participants evaluated the model via S-C-S, while they were rotating the camera.

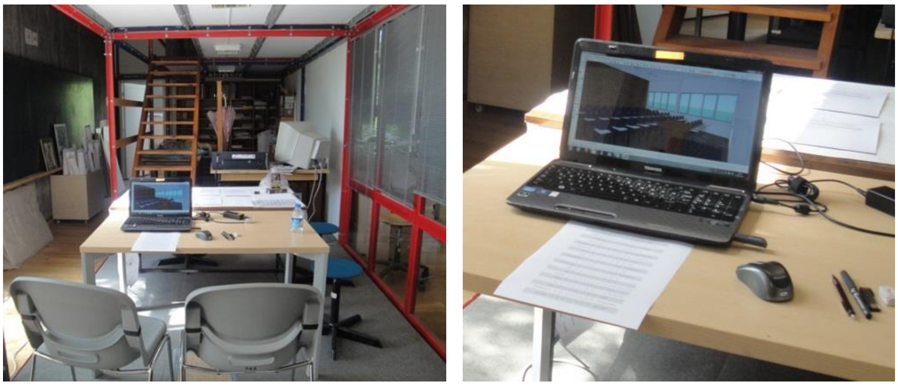


Figure 50 Photographs of the cubicle and the set up used in Experiment 2, 3 and 4 (2012).

The reasons for deciding this procedure are listed below:

1) Instead of the participant, the experimenter directed the virtual tour, because
    a) the tour experience should be similar for each participant.
    b) some details of the model might be missed when participants directed the camera (e.g. ceiling might not be seen).
    c) the tour might be slow and disturbing when a participant was not able to use the mouse correctly (e.g. the model might be turned upside-down).
2) Participants were allowed to rotate the virtual camera to every direction from a fix point, because

a) rotating the camera is more manageable and easy than touring for participants.

b) participants might forget some features of the model and need to look and remember again.

c) motion gives additional depth cues for 3D perception (Section 2.5.1).

3.3.5. Results

Photograph of R46.

SketchUp model of R46.

Figure 51 Photographs of classroom R46 and screenshots of computer model of Experiment-2.

A two-way multivariate analysis of variance was performed to investigate the effects of presentation technique and gender differences on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variables were presentation technique (real room and computer simulation) and gender (female and male).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between real room and computer simulation on the combined dependent variables, F (3, 54) = 1.14, p = .342; Wilks' Lambda = 0.94; partial eta squared = .06. There was no statistically significant difference between female and male on the combined dependent variables, F (3, 54)

= 0.87, p = .462; Wilks' Lambda = 0.95; partial eta squared = .05. There was no statistically significant difference between real room – computer simulation and female – male on the combined dependent variables, F (3, 54) = 0.85, p = .474; Wilks' Lambda = 0.96; partial eta squared = .05. When the results for the dependent variables were considered separately, no statistically significant difference was found.

3.4. EXPERIMENT-3: SPACIOUSNESS EVALUATIONS VIA VIRTUAL WALKING IN SKETHCUP MODELS: CASES OF DIFFERENT CEILING HEIGHTS

3.4.1. Introduction

With the results of Experiment-2, the validity of the simulation technique was verified to be used in the following experiments. Hence, the tested procedure of Experiment-2 would be used in Experiment-3 in order to examine one of the variables mentioned in Table 5 (on page 121). The aim of Experiment-3 was to evaluate ceiling height differences via S-C-S and the computer simulations.

Ceiling height is one of the significant design components of classrooms which has been frequently reported in "classroom design guides" of universities (for further information, see Appendix C.1.4). Since the volume of the *actual space* increases by the increase in the ceiling height, it was assumed that different ceiling heights might affect spaciousness evaluations of a room. Especially, the space freedom factor (SF3), which is composed of adjective pairs such as "small-large", "tiny-huge", "narrow-wide" and "close-open", was expected to be affected by the changes in ceiling height.

This experiment entailed three parts in which three different ceiling heights (3m, 4m and 5m) of a sample room were tested via virtual walking in SketchUp models. Each condition was evaluated by a different group of participants.

3.4.2. Participants

A total of 60 participants, 20 in each group, voluntarily participated in the experiment. Each group evaluated only one of the three conditions of the experiment and did not see the other two. Participants were 33 students and 27 staff members from various faculties of METU. In the sampling procedure, it was attempted to have similar participant composition in each group. Eventually, each group was composed of five male, six female students, four female and five male staff members.

Group-A: The mean age was 31.35 with a range of 20 and 50 years.
Group-B: The mean age was 27.90 with a range of 19 and 48 years.
Group-C: The mean age was 28.35 with a range of 20 and 50 years.

3.4.3. Stimuli

A classroom named as B06 in the Social Sciences Building of METU was chosen for this experiment. There were three main reasons for this selection:

1) It was a typical example of middle sized classrooms in METU.
2) It had a rectangular-plan with simple components which could be easily manipulated for different variables in an experiment.
3) It was one of the classrooms which had the lowest ceiling height in METU.

After making the realistic model of the existing classroom in SketchUp program, its three computer models were derived for three conditions of the experiment based on the realistic model. Only the computer models were used as stimuli in the current experiment.

3.4.3.1. **The classroom B06 (real room):**

The selected classroom B06 has 2.97m ceiling height and 7.85m x 7.16m floor dimensions (see Figure 52 and Figure 53). The north wall of the room is constructed out of exposed red brick while other three walls are covered by a white plaster. The entrance to the room is in the west wall which has a white framed blue painted door and a small window over it. There is a white board along the south wall and a projection screen over it. In front of the south wall there is a lectern and a chair for instructor. Sixty blue tablet-arm chairs within the room are placed in the order of five rows facing the white board. Window sills are 1m above the floor level on the east wall. The windows are divided into two parts by a column in the middle of the wall. Floor is covered with 20cm x 20cm gray-black mosaic tiles and ceiling is covered with white plaster (for further information, see Appendix E.1.3 and E.1.4).

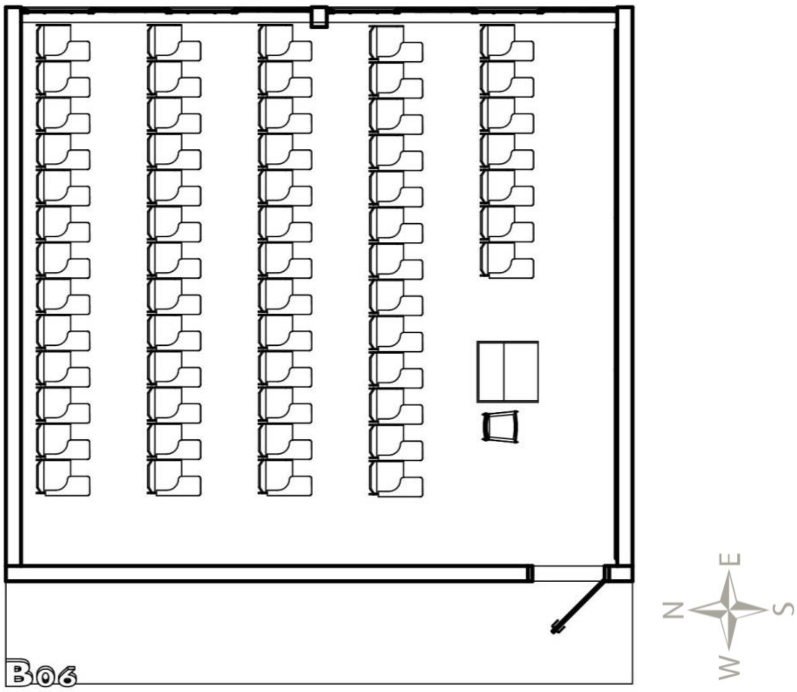


Figure 52 Plan of classroom B06 (Scale: 1/100).

Figure 53 Photographs of classroom B06 (2012).

3.4.3.2. **Computer simulations of B06:**

The classroom, B06, was documented with photographs and detailed measured drawings (see Appendix E.1.3). Its computer model was made in SketchUp program as the way mentioned in Experiment-1. Three alternatives of the room were prepared as stimuli of this experiment. In all three conditions, all room components, window sizes and positions were kept constant. Only the ceiling heights were manipulated systematically:

Model 3-A: 3.00m ceiling height
Model 3-B: 4.00m ceiling height
Model 3-C: 5.00m ceiling height
All models had 8.00m x 7.00m dimensions in plan.

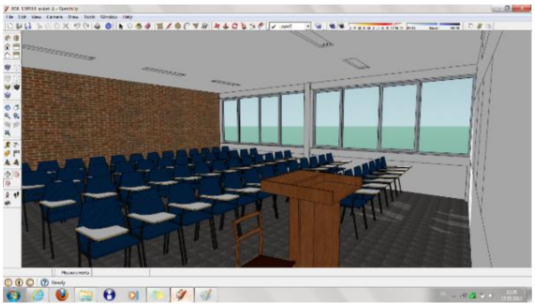
A laptop with 1366x768 resolution 15.6” Toshiba TruBrite screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

3.4.4. Procedure

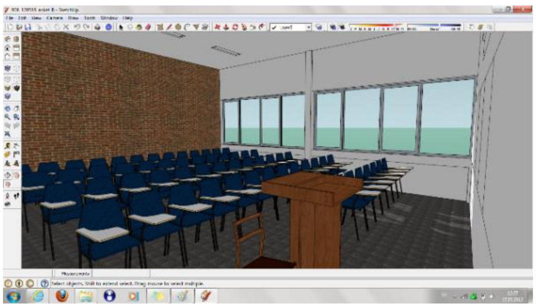
Participants were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were randomly assigned to one of the three computer models. Similar procedure was conducted as in Experiment-2 Step-2. Participants were seated in front of the laptop, and were asked to evaluate the simulation of the room as seen on the screen. First, the experimenter gave a printed S-C-S form to the participant and explained how to use the seven-point scale. Second, the experimenter showed the interior by a quick tour in the model. The tour started from the door, and the camera view was directed by the mouse commands of the experimenter. Instead of random movements, the virtual camera moved at 1.67m level above the ground of the model, as if it were the eye level (horizon line) of a walking person. After all the details of the interior of the model were shown, the tour ended. Third, the virtual camera was fixed in front of the door in the model, and participants were asked to turn the virtual camera by moving the mouse with right click if they desired. Participants evaluated the model via S-C-S, while they were rotating the camera.

Some participants asked some questions about the metric sizes of the room, and the number of chairs in the model. No information was given about numeric values, and they were reminded that the study was about how they perceive the interior.

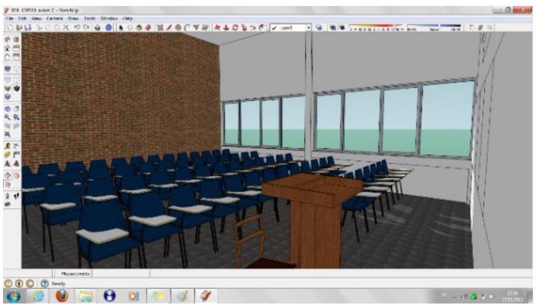
3.4.5. Results



Model 3-A



Model 3-B



Model 3-C

Figure 54 Screenshots of computer models of Experiment-3.

A one-way multivariate analysis of variance was performed to investigate the effects of ceiling height on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 and space freedom. The independent variable was ceiling height (3m, 4m and 5m).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between 3m, 4m and 5m ceiling heights on the combined dependent variables, F (6, 110) = 1.56, p = .167; Wilks' Lambda = 0.85; partial eta squared = .08. When the results for the dependent variables were considered separately, no statistically significant difference was found.

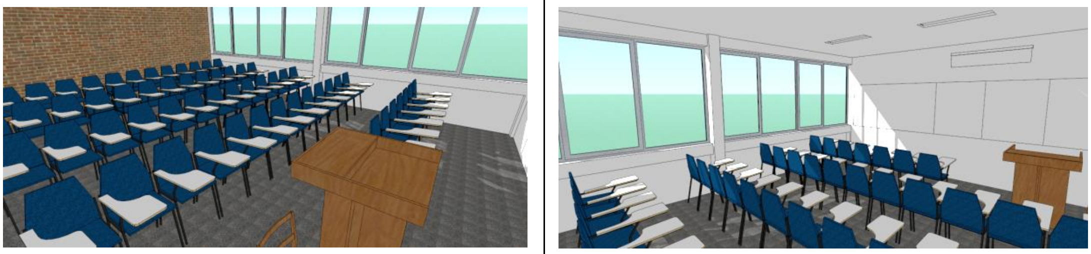
3.4.6. Discussion

The statistical analyses indicated that there was no significant difference between the three different ceiling heights in spaciousness evaluations. This was an unexpected result for the study. As hypothesized before, at least space freedom factor, which is mainly related to size perceptions, was expected to be different for different ceiling heights.

Since the current experiment was the first experience to use the computer simulation procedure to compare classroom design variables, it was thought that there was a need for further developments of the simulation technique. Possible weaknesses of the used simulation technique for the space perception are listed as follows:

1) Virtual walking might not be sufficient enough to experience the whole room.
    a) Due to random motion in the model, ceiling height might be unnoticed (see Figure 55-a).
    b) Walking in the center of the model might present only a limited area of view, which might also lead to misperception of the size (see Figure 55-b).

c) The ability of computer use and mouse control might differ from participant to participant. Some participants might not catch the viewpoints as they wished.

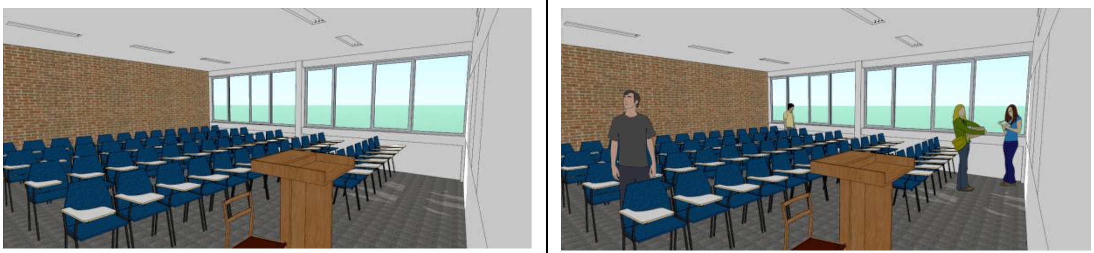


(a) (b)

Figure 55 Screenshots from B06 model during random virtual walking: a) There is no cue about ceiling height; b) There is no cue about room width and length.

2) Some additional visual cues might be needed to support depth perception (as mentioned in Section 2.5.1).

   a) To perceive the height and the depth in the model correctly, some well-known sized references such as human figures might be needed (see Figure 56).



(a) (b)

Figure 56 Screenshots from B06 model: a) the empty room, b) the room with scaled human figures.

b) A more realistic outside view, such as several trees and plants placed in close and long distances, might also improve the depth perception of the interior.

c) A more realistic light, shade and shadow might support the depth perception.

d) More realistic textures such as a reflecting board, a shining glass and a switched-on lamp might enrich the space perception.

3) The number of existing seats in the classroom B06 exceeded the optimal classroom capacity when compared with the "classroom design guides" of several universities (see Appendix C.1.1 and C.1.6). For instance, according to Stanford University (2009, p. 28), the maximum seating capacity is 43 for a $56m^2$ classroom with movable tablet arm chairs. However, there were 60 seats in B06 and in the models of Experiment-3. The exceeding seats might dominantly draw attention and negatively affect the general spaciousness evaluations of the models, such as "restricted space - free space" "crowded-uncrowded" (To clarify this, a further analysis was conducted, see Appendix G.2).

4) Not only the ceiling but also the window height might need to be raised to perceive the space realistically.

By addressing the above mentioned possibilities, the following experiment was designed.

3.5. EXPERIMENT-4: SPACIOUSNESS EVALUATIONS VIA VIDEO ANIMATIONS OF LUMION MODELS: CASES OF DIFFERENT CEILING HEIGHTS

3.5.1. Introduction

As mentioned in Section 3.4.6, some questions were revealed about the computer simulation technique used in Experiment-3, which might also have affected the experiment results. Hence, Experiment-4 aimed to reexamine the hypothesis proposed in Experiment-3 by developing the used computer simulation technique. To remind briefly, it was assumed that different ceiling heights might affect spaciousness evaluations, especially the space freedom factor of a room.

In the light of the discussion in Experiment-3, the following modifications were made:

1) Instead of virtual walking in the models, video animations were recorded. Hence, models were presented with all their details and each participant experienced the models from similar viewpoints.
2) Instead of SketchUp program, Lumion program was preferred since it presents real-time photorealistic renders. Hence, additional features of Lumion program, which are animated human figures, outside scene, realistic material textures, lighting, and shade and shadow, were used to enrich the *monoscopic view* with *depth cues*.
3) The number of chairs were decreased from 60 to 40, which is in the limits of the acceptable numbers for such classrooms according to "classroom design standards" (Stanford University, 2009, p. 28)
4) To clarify the questions whether high ceiling requires high windows, an alternative model with high window was added. On the other hand, one of the previous models, which had the medium ceiling height (4m), was eliminated in the current experiment.

Experiment-4 was composed of three parts: 1) 3m ceiling height with the standard window (h = 1.70m), 2) 5m ceiling height with the standard window (h = 1.70m), 3) 5m ceiling height with a larger window (h = 3.70m). Each condition was evaluated by a different group of participants.[12]

[12] Model A and C in Experiment-3 were used again in Experiment-4. Hence, the models were coded similarly (A and C) in Experiment-4. Model B was eliminated in the current experiment, and an additional model was included. However, in order to prevent confusions, the code of "B" was not used, and the new model was coded as "D". Since each participant group evaluated only one of the

3.5.2. Participants

A total of 45 participants, with 15 in each group, voluntarily participated in the experiment. Participants were a mixture of undergraduate students and staff members from METU. Each participant assigned to one of the groups randomly. Each participant was unaware of the other conditions of the experiment.

Group-A: The first group was composed of 12 undergraduate students from the Faculty of Architecture and three staff members from METU. There were four males and 11 females. The mean age for this group was 22.53 with a range of 20 and 33 years.

Group-C: The second group was composed of 13 undergraduate students and two staff members from the Faculty of Architecture. There were two males and 13 females. The mean age for this group was 20.53 with a range of 20 and 26 years.

Group-D: The third group was composed of ten undergraduate students from the Faculty of Architecture and five staff members from METU. There were seven males and eight females. The mean age for this group was 23.60 with a range of 19 and 35 years.

3.5.3. Stimuli

The models of Experiment-3, which were derived from classroom B06 (see Section 3.4.3), were again used in Experiment-4 with the following changes:

1) Since the ceiling height did not affect spaciousness evaluations in Experiment-3, only the two models which had the lowest and the highest ceiling heights were selected to be reexamined in Experiment-4.
2) An additional model was built in which the ceiling height was raised together with the window.

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models, participant groups were also named according to the model they evaluated for the ease of reading.

3) The existing chairs of the classroom were exceeding the capacity; hence, they were decreased from 60 to 40 in order to obtain optimum level and to eliminate their possible negative effect on the general judgments of the models. The lectern of instructor was also removed to the corner of the classroom.
4) Instead of SketchUp program, Lumion program was used to have more developed simulation options.

Models were recorded as video animations for further information, see Appendix F.1). A total of three video animations were used as stimuli of the experiment:

Model 4-A: 3.00m ceiling height, 1.70m window height (similar to Model 3-A).
Model 4-C: 5.00m ceiling height, 1.70m window height (similar to Model 3-C).
Model 4-D: 5.00m ceiling height, 3.70m window height.
All models had 8.00m x 7.00m dimensions in plan.

In parallel to the discussions in Experiment-3, following changes were made in Lumion program to develop computer simulations:

1) Instead of free virtual walking in the model, a standard video animation was presented:
    a) For the tour of animation, a regular circular route was followed, in which none of the corners of the model was left unseen.
    b) During the tour, all virtual camera positions were arranged to have widest area of view, in which the floor, the ceiling and two or three walls were seen together.
    c) Each video animation was standardized and presented equal to participants without depending on the participant's ability of computer use and mouse control. Hence, all observers could observe the model from the same angles, in the same order, and for the same duration.
2) Some additional visual cues were added to support depth perception:

a) Four dynamic human figures added to the three sides of the room in order to give scale references for the observers.
b) With the material properties of the Lumion program, more realistic textures were assigned to some surfaces such as a reflecting board, a shining glass and lamplight to enrich the space perception.
c) More realistic outside view obtained by placing several trees and plants placed in close and long distances, in case, they might also improve the depth perception of interior.

To record animation, eight virtual cameras were placed in the model, four of which were in the corners of the room, and four in the middle of each wall (see Figure 57). Each camera angle was in the position of the eyes of a standing person looking at the center of the classroom. By these camera views, a video animation of 360^o virtual tour was recorded. The program recorded videos by taking different renders between each camera positions. In order to prevent possible cybersickness of participants, the animation did not turn continuously; it stopped occasionally when the screen caught a parallel view of each wall.

The video animation started from the camera in front of the door, toured the classroom by following a counterclockwise circle, and ended with the same camera. Hence, it was possible to watch the video repeatedly without any disconnection (see Figure 57).

A laptop with 1366x768 resolution 15.6” Toshiba TruBrite screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

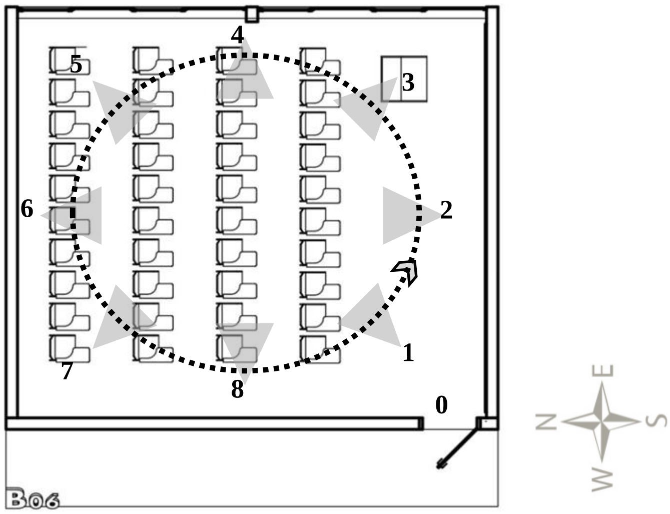


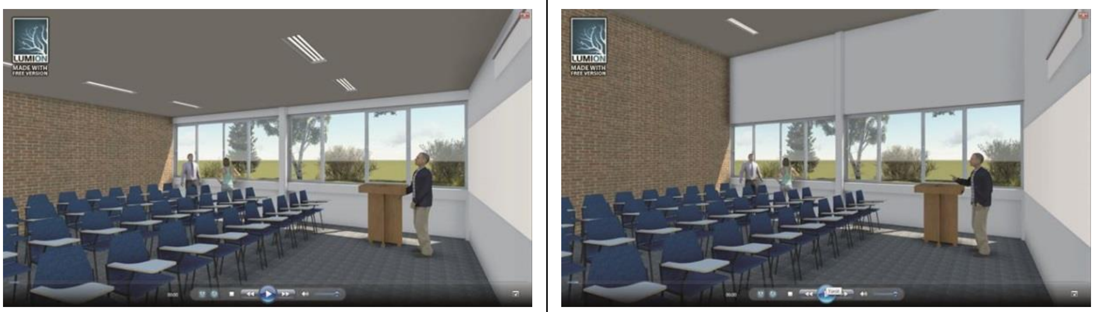
Figure 57 Plan of Model 4-A with virtual camera positions.

3.5.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were randomly assigned to one of the three computer models. They were asked to evaluate the simulation of the room as seen on the laptop screen, with S-C-S. After a brief explanation about the use of a seven-point scale, animation video of the model was played. Each video started from the door, toured 360^o counterclockwise in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation.

3.5.5. Results

3.5.5.1. **Analysis-1: Is there any difference between spaciousness evaluations of rooms with different ceiling heights?**



Model 4-A | Model 4-C

Figure 58 Screenshots of computer models of Experiment-4 Analysis-1.

A one-way multivariate analysis of variance was performed to investigate the effects of ceiling height on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was ceiling height (3m and 4m).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between 3m and 5m ceiling heights on the combined dependent variables, F (3, 26) = 0.38, p = .767; Wilks' Lambda = 0.96; partial eta squared = .04. When the results for the dependent variables were considered separately, no statistically significant difference was found.

3.5.5.2. **Analysis-2: Is there any difference between spaciousness evaluations of rooms with equal ceiling heights with different window sizes?**

	
Model 4-C	Model 4-D

Figure 59 Screenshots of computer models of Experiment-4 Analysis-2.

A one-way multivariate analysis of variance was performed to investigate the effects of window size on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was window height (1.70m and 3.70m).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between 1.70m and 3.70m window heights on the combined dependent variables, F (3, 26) = 1.68, p = .195; Wilks' Lambda = 0.84; partial eta squared = .16. When the results for the dependent variables were considered separately, no statistically significant difference was found.

3.5.5.3. **Analysis-3: Is there any difference between spaciousness evaluations of two rooms: one with a 3m the other with a 5m ceiling heights both having windows up to their ceilings?**

	
Model 4-A	Model 4-D

Figure 60 Screenshots of computer models of Experiment-4 Analysis-3.

A one-way multivariate analysis of variance was performed to investigate the effects of ceiling height on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was ceiling height (3m and 5m).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between 3m and 5m ceiling height on the combined dependent variables, F (3, 26) = 1.39, p = .269; Wilks' Lambda = 0.86; partial eta squared = .14. When the results for the dependent variables were considered separately, no statistically significant difference was found.

3.5.6. Discussion

Contrary to *virtual walking* in models, the researcher observed that the *video animations* let all participants to observe the models from the same viewpoints, same angles, same order, and same duration. Moreover, since the entire camera positions were preset by the researcher, there was no detail left unseen in the model. In addition to the motion control, the computer simulation technique was developed by adding some visual cues to support depth perception.

The statistical analyses indicated that neither the ceiling height nor the window size affected the spaciousness evaluations. This was again an unexpected result for the study. At least the third spaciousness factor (space freedom), which was related to size perceptions, were expected to differ for the different ceiling heights.

A further revision was needed to develop the simulation technique for further experiments. In the experiments of İmamoğlu (1975), each participant evaluated only one of the models by S-C-S (see Figure 9 on page 58). However, the scale models were presented in the room which the models were derived from. Hence, the real room had a role as a comparison model for the participants. Moreover, in the recent examples in the literature (Franz, 2005; Matusiak, 2006; Matusiak & Sudbo, 2008; Stamps & Krishnan, 2006; Stamps, 2007-a; Stamps, 2009; Stamps, 2010; Stamps, 2011), each participant evaluated every model consecutively. In this respect, the following modifications were needed in the experiment procedures of the current study:

1) Each participant should evaluate every model in the experiment consecutively (see Table 6).
2) There is a need for a standard model to be used as an anchor to compare different experiment conditions (see Table 7).

Table 6 Graphic illustrations of two experimental procedures about participants' assignments.

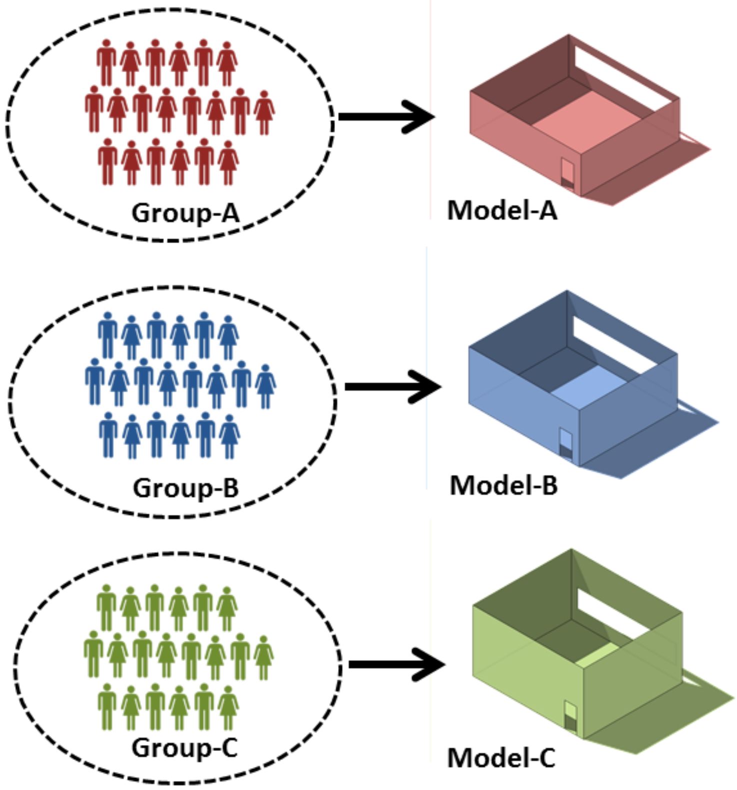
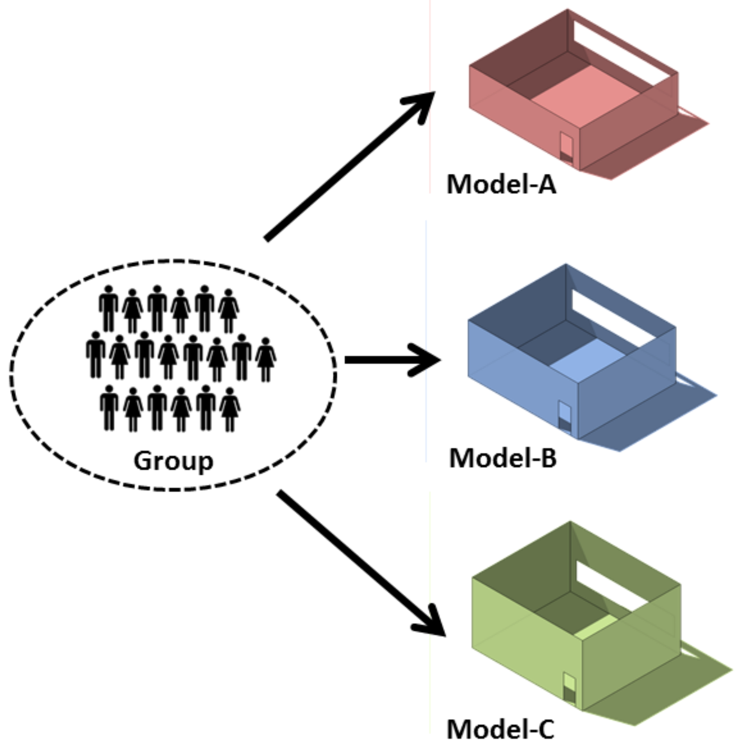
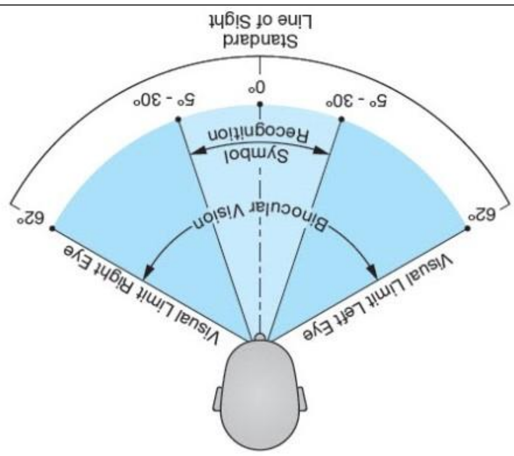
Participants' assignments in the first group of experimental studies: Each participant evaluates only one of the models in the experiment.	
Participants' assignments in the second group of experimental studies: Each participant evaluates every model in the experiment consecutively.	

Table 7 Graphic illustrations of two experimental procedures about computer presentations.

Computer presentations in the first group of experimental studies: One of the models is presented on a laptop computer with 1366x768 resolution 15.6” screen.	
Computer presentations in the second group of experimental studies: Two of the models are simultaneously presented on two identical netbooks with 1024x600 resolution 10.1” screen.	 **Model-A** **Model-B**
Field of view: The graphic description by Extron (Environmental Considerations and Human Factors for Videowall Design, n.d.)	

In the light of the developed methods in the first group of experimental studies and the two additional modifications mentioned above (see Table 6 and Table 7), the second group of experimental studies (Chapter-4) were designed in order to examine the four variables of classroom design (see Table 5 on page 121).

CHAPTER 4

THE SECOND GROUP OF EXPERIMENTAL STUDIES

Gifford (1997, p. 11) defined environmental psychology as “a multiple paradigm field” in which “different researchers may employ not only different methods but also entirely different techniques based on different philosophies of science”. This was also clearly seen in the examples in Section 2.3 and 2.4 in Chapter-2. In a similar manner, a method development was needed based on the selected *representation tool* and the *evaluation scale* for the current study. Hence, in the first group of experimental studies in Chapter-3, a method was developed in order to assess spaciousness of a room via computer simulations and spaciousness-crampedness scale (S-C-S).

In the preliminary study in Section 3.1, the variables which would be assessed in the current experimental studies were selected. The selected variables were the four main permanent components of classrooms, ceiling height, ceiling type, floor type (stepped and flat), and plan geometries (rectangular and trapezoidal) (see Table 5 on page 121). In this regard, the second group of experimental studies was conducted to examine the effects of the four variables on spaciousness and the three spaciousness factors (appeal, planning and space freedom).

4.1. EXPERIMENT-5: EFFECTS OF CEILING HEIGHT ON SPACIOUSNESS EVALUATIONS

4.1.1. Introduction

Experiment-5 aimed to assess the effects of ceiling height on spaciousness evaluations. Although Experiment-3 and 4 (in Section 3.4 and 3.5) tested the ceiling height, their main aim was to test and develop the research method. Hence, in the current experiment, the effects of ceiling height were reexamined with the developed method.

Ceiling height is one of the significant design components of rooms, which is formed in the architectural design period and stays as it is after construction. Due to its significance for classroom designs, ceiling height has been frequently reported in "classroom design guides" of universities (for further information, see Appendix C.1.4). However, the guides focused on *actual space*, instead of *perceived space*. For instance, they aim to support students "to see all visual materials, to hear without noise or distortion" and the like (UNC, 1997, p. 2), which can be tested mechanically without human factor. Nevertheless, not only *actual space* but also *perceived space* needs to be considered for a successful design and user satisfaction.

Although ceiling height is a significant component of rooms, it was not reported adequately in the literature of architectural psychology. Studies of Jeanpierre (1968) and Stamps (2011) about ceiling height should be noted at this point (in Section 2.4). Jeanpierre (1968) (cited in İmamoğlu, 1975) conducted an experiment on *ceiling height* using two full-scale models which have 3.00m x 4.00m and 5.00m x 6.00m dimensions in plan, and asked 100 participants to adjust the ideal ceiling height between 2.00m and 2.90m for each room. He concluded that "adjusted ceiling heights in the large room were greater than those in the smaller room". (Mean adjustments in 12m^2 room were 2.540m and 2.473m while in 30m^2 room 2.709m and 2.646m, for standing up and sitting down positions, respectively).

Stamps (2011) examined ceiling height to contribute to housing designs in one of his experiments. He used four models which have almost similar volumes but different floor areas (49m^2, 38.9m^2, 30.9m^2, and 24.5m^2) and different ceiling heights (2.5m, 3.15m, 3.96m and 5.0m). He asked 17 participants to evaluate the models via a laptop computer and an eight-point “spacious - not spacious” scale. According to his results, “horizontal area had the strongest effect on perceived spaciousness” and “larger horizontal area leading to an increase in perceived spaciousness”. He further stated that “the rooms with lower ceilings [were] being judged as more spacious than the rooms with higher ceilings”.

In the current experiment, it was assumed that different ceiling heights might affect spaciousness evaluations of a room. As mentioned in Section 3.4.1, especially the space freedom factor (SF3) was expected to be affected by the changes in ceiling height since the volume of the *actual space* increases.

This experiment entailed three conditions, in which three different ceiling heights (3m, 4m and 5m) of a sample room was tested via video animations. Each condition was evaluated by every participant.

4.1.2. Participants

A total of 20 participants voluntarily participated in the experiment. Each participant evaluated all of the three conditions of the experiment consecutively (see Table 6 on page 151). Participants were randomly selected from undergraduate students of the Faculty of Architecture. There were six males and 14 females. The overall mean age was 20.90 with a range of 19 and 25 years.

4.1.3. Stimuli

The classroom B06 in Social Science building was chosen as the case of this experiment (see Section 3.4.3). The Model-A and Model C in Experiment-4 (see Section 3.5.3) was again used in Experiment-5. In addition to those models, Model B was also derived by changing ceiling heights. Models were recorded as video animations as mentioned in Experiment-4. A total of three video animations were used as stimuli.

Model 5-A: 3.00m ceiling height (same with Model 4-A).
Model 5-B: 4.00m ceiling height
Model 5-C: 5.00m ceiling height (same with Model 4-C).
All models had a 1.70m window height, and 8.00m x 7.00m floor dimensions.

Two identical netbooks with 1024x600 resolution 10.1” screen was used to present the models (see Table 7 on page 152). The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

4.1.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture design studio of METU Faculty of Architecture building (see Figure 50 on page 132). They were informed that they would watch a total of three video animations on two netbook screens, and they were asked to evaluate them with S-C-S consecutively. After a brief explanation about the use of a seven-point scale, animation videos of the models were played. Each video started from the door, toured 360^o counterclockwise in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation. First, Model A was displayed on the left screen and Model B on the right screen simultaneously. Later, Model C was displayed on the right screen, while the model B was again displayed on the left screen simultaneously. All participants were asked to concentrate and evaluate Model A first. Half of the participants evaluated models in the order of A, B and C, the other half of the participants used the order of A, C and B.

4.1.5. Results

 Model 5-A	 Model 5-B
 Model 5-A	 Model 5-C

Figure 61 Screenshots of computer models of Experiment-5.

A one-way multivariate analysis of variance was performed to investigate the effects of ceiling height on the spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was ceiling height (3m, 4m and 5m).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was a statistically significant difference between ceiling heights on the combined dependent variables, F (6, 110) = 3.76, p = .002; Wilks' Lambda = 0.69; partial eta squared = 0.17. When the results for the dependent variables were considered separately, the only difference to reach statistical significance was "space freedom" factor, F (2, 57) = 7.57, p = .001, partial eta squared = .21.

Pairwise comparisons (Bonferroni) showed that neither the difference between the 4m and 3m ceiling heights (mean difference = 0.49, p = .356) nor the 4m and 5m ceiling heights was significant (mean difference = 0.70, p = .078), whereas the difference between the 3m and 5m ceiling heights was significant (mean difference = 1.18, p = .001, CI(95%) 0.43-1.94). An inspection of the mean scores indicated that the 5m ceiling height had higher levels of space freedom (M = 4.62, SD = 1.19) than the 3m ceiling height (M = 3.44, SD = 0.80).

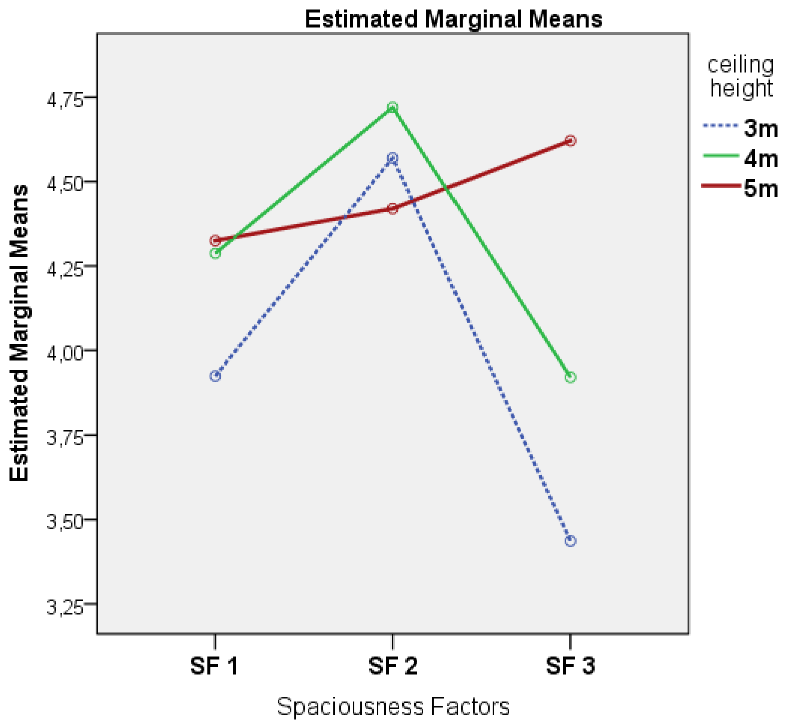


Figure 62 Mean scores of spaciousness evaluations for different ceiling heights in Experiment-5.

4.1.6. Discussion

Results indicated that ceiling height significantly affected the general evaluations of spaciousness. When each spaciousness factor was analyzed separately, there was a significant difference in space freedom factors of rooms between 3m and 5m ceiling heights. However, neither the difference in 3m and 4m ceiling heights nor the difference between 4m and 5m ceiling heights did not affect the spaciousness evaluations significantly. This means that in a room with floor dimensions of 8m x 7m, ceiling height difference of 1m is not noticeable whereas a rise of 2m in ceiling height significantly affected the evaluations of spaciousness in a positive way. When appeal and planning factors were analyzed separately, there were no differences among 3m, 4m and 5m ceiling heights.

The results of the current experiment indicated that “higher ceiling made the room more spacious”. This finding was different from Stamps’ (2011). This contradiction might be due to the lack of depth cues in his simplified computer models (such as the absence of furniture, light, shade and shadow and the like) which might lead to a misperception of space.

In order to compare the results with actual space standards, related items of “classroom design guides” need to be mentioned here. For a room with the capacity of 40 stations, University of Toronto (2012-a, p. 10) defined minimum clear ceiling height 9’6 (2.90m) when screen housing is not inset. Emory University (2008, p. 15) defined minimum ceiling height for classrooms as 10’ (3.05m). The University of North Carolina at Chapel Hill (UNC, 1997, p. 6) defined ideal ceiling height as 12’ (3,66m) for classrooms with 20-49 stations and flat floor. Similarly, Yale University (2014, p. 5) defined minimum clear ceiling height as 12’ (3.66m) for classrooms with the capacity of 20-49 and flat floors. In brief, when actual space is considered within the framework of guidelines specified by these universities mensioned above, ceiling height of a classroom (with a capacity of 40 stations and flat floor) should not be less than 2.74m – 3.66m; on the other hand, when perceived space is considered according to the results of the current experiment, 5m ceiling height was seen as more spacious than the one with 3m ceiling height.

4.2. EXPERIMENT-6: EFFECTS OF CEILING TYPE AND CEILING HEIGHT ON SPACIOUSNESS EVALUATIONS

4.2.1. Introduction

Experiment-6 aimed to assess the effects of ceiling type and ceiling height on spaciousness evaluations. Ceiling type is mostly reported in the studies of acoustics and structural engineering. For instance, "Classroom design guides" of Universities mension ceiling type in terms of acoustic quality of classrooms, and visibility of instructor and the presentation boards (UNC, 1997; University of Toronto, 2012-a; Yale University, 2014). However, ceiling type was not reported in the literature of architectural psychology before.

In the current experiment, it was expected that different ceiling types (flat and stepped) might affect spaciousness evaluations of a room. It was assumed that flat ceiling might be evaluated more positively.

This experiment entailed four conditions, in which two ceiling types (flat and stepped) and two ceiling heights of a sample room was tested via video animations. Each condition was evaluated by every participant.

4.2.2. Participants

A total of 24 participants voluntarily participated in the experiment. Each participant evaluated all of the four conditions of the experiment consecutively. Half of the participants were undergraduate students of architecture and the other half were staff members of METU. There were seven males and 17 females. The overall mean age was 28.42 years with a range of 20 and 49 years.

4.2.3. Stimuli

One of the stepped-floor classrooms from METU campus was considered as the case for this experiment. The classroom called G103 was selected from the G building of the Department of Mechanical Engineering, which was mainly composed of stepped-floor classrooms. There were two main reasons for this selection: 1) it is one of the typical small classrooms which are repeated with different ceiling types in the building. 2) it has a simpler design compared to the other buildings, which are mainly composed of stepped-floor classrooms in the campus. Hence, its design could be easily manipulated for different experimental conditions.

After making the realistic model of the existing classroom in SketchUp program, its four models were derived for four conditions of the experiment based on this model. Models were recorded as video animations as mentioned in Experiment-4. A total of four video animations were used as stimuli for the current experiment.

4.2.3.1. **The existing classroom G103:**

The selected classroom, G103, has a stepped floor and stepped ceiling (see Appendix E.1.5 and E.1.6). There are six steps in the floor (each level difference being 15cm). There are three steps in the ceiling (each level difference being 30cm). Both the floor and the ceiling have a 90cm level difference from the east wall to the west. Hence, the ceiling height is 2.50m on both sides. Floor dimensions in the plan are 9.71m x 8.97m. East wall of the room is made of exposed red brick, while the other three walls are covered with white plaster. The entrance to the room is in the north wall which has a brown painted double door and a small window over it. There is a white board and a projection screen on the east wall. In front of this wall, there is a 147cm wide marble platform which is elevated 13cm above the ground level. A locked cabin, a marble table and a stool for an instructor are located over this platform. 91 fixed seats within the room were arranged in the order of seven rows facing the white board. On the north wall, beside the main door which opens to a corridor, there is a second door opening to a courtyard and windows looking to this direction. The floor is covered with 45cm x 45cm beige mosaic tiles and the edges of steps are covered with brown marbles in stripe form. The ceiling is covered with white plaster and has a total of 30 spot lights arranged in five rows of six.

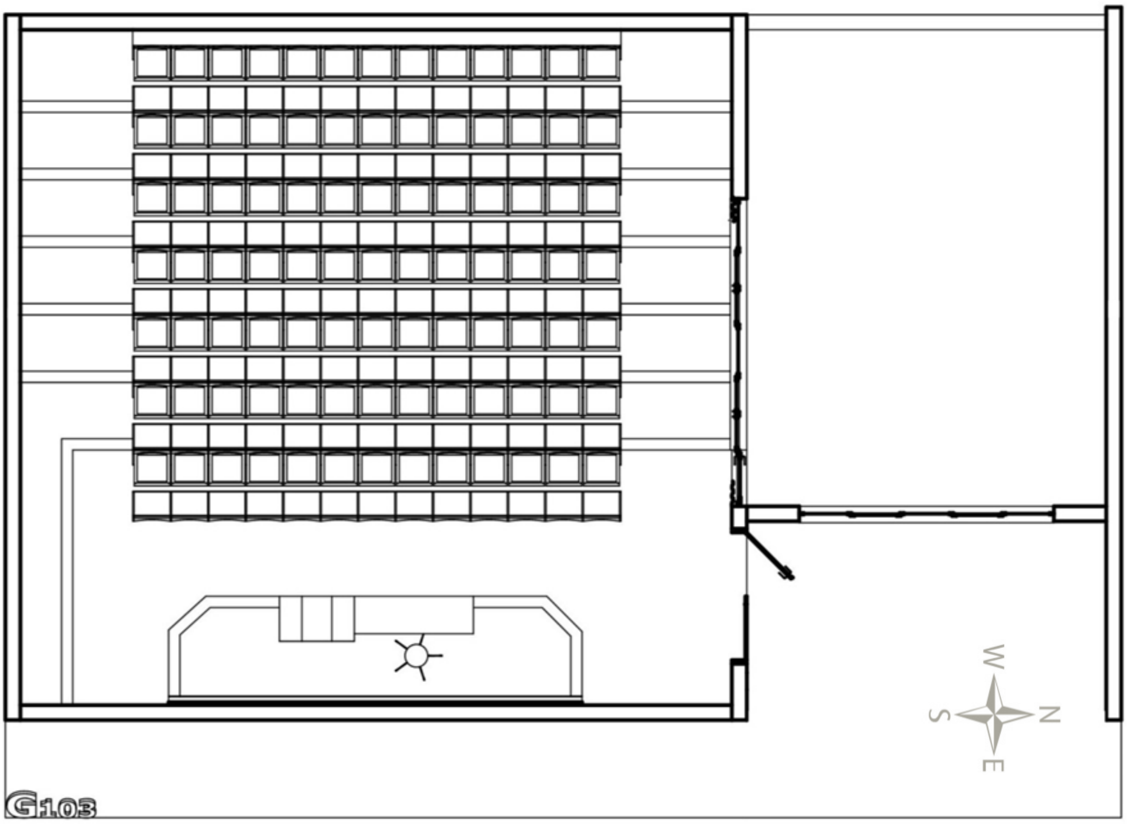


Figure 63 Plan of classroom G103 (Scale: 1/100).

Figure 64 Photographs of classroom G103 (2013).

4.2.3.2. **Computer simulations of G103:**

G103 was documented with photographs and detailed measured drawings. Its 3D model was made in SketchUp program as mentioned in Experiment-1. Four alternatives of the model were made as stimuli for this experiment. In all four conditions, all room components, window size and position were kept constant; only the ceiling types (stepped and flat) and ceiling heights (1m difference) were changed systematically:

Model 6-A: stepped ceiling (3.00m height in the rear wall, 3.00m in the front wall)
Model 6-B: stepped ceiling (4.00m height in the rear wall, 4.00m in the front wall)
Model 6-C: flat ceiling (3.00m height in the rear wall, 3.90 in the front wall)
Model 6-D: flat ceiling (4.00m height in the rear wall, 4.90 in the front wall)
All models had stepped floors with 9.50m x 9.00m plan dimensions and 15cm level differences between each step.

 Model 6-A (h: 3m)	 Model 6-C (h_{rear}: 3m – h_{front}: 3.90m)
 Model 6-B (h: 4m)	 Model 6-D (h_{rear}: 4m – h_{front}: 4.90m)

Figure 65 Sections of computer models of Experiment-6.

As mentioned in Experiment-4, eight virtual cameras were placed in each model: four of them were in the corners of the room and four of them in the middle of each wall to record animation. Each camera position was arranged at the eye level in a way where a standing person looking at the center of the classroom. By these camera views, a video animation of 360^o virtual tour was recorded. The video tours started from the camera in front of the door and ended with the same camera in 30 seconds. Hence, it was possible to watch the video repeatedly without any disconnection.

Two identical netbooks with 1024x600 resolution 10.1” screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

4.2.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were informed that they would watch a total of four video animations on two netbook screens, and they were asked to evaluate them with S-C-S consecutively. After a brief explanation about the use of a seven-point scale, animation videos of the models were played. Each video started from the door, toured 360^o clockwise in the room at the eye level of a standing person. The video tour took 30 seconds, and it continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation. The model on the left screen was presented until the evaluations of all models were completed. The other three models were presented consecutively on the right screen. Models were presented in a different order to each participant.[13]

[13] For four models {A, B, C, D}, there are 24 possible presentation order. $P_4 = 4! = 24$.
By changing the order systematically, such as (A, B, C, D), (A, B, D, C), (A, D, C, B), and the like, models were presented to each of the 24 participants in a different order.

4.2.5. Results

A three-way multivariate analysis of variance was performed to investigate the effects of ceiling type and ceiling height on spaciousness evaluations of rooms. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variables were ceiling type (stepped ceiling and flat ceiling), ceiling height differences (3m and 4m h_{rear}).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

 Model 6-A	 Model 6-C
 Model 6-B	 Model 6-D

Figure 66 Screenshots of computer models of Experiment-6.

4.2.5.1. **Effect of ceiling type:**

There was no statistically significant difference between stepped ceiling and flat ceiling on the combined dependent variables, F (3, 90) = 2.09, p = .107; Wilks' Lambda = 0.94; partial eta squared = .07.

When the results for the dependent variables were considered separately, the only difference to reach statistical significance was "space freedom" factor, F (1, 92) = 4.63, p = .034; partial eta squared = .05. An inspection of the mean scores indicated that flat ceiling had higher levels of space freedom (M = 4.30, SD = 1.15) than stepped ceiling (M = 3.83, SD = 1.10). (See Figure 67).

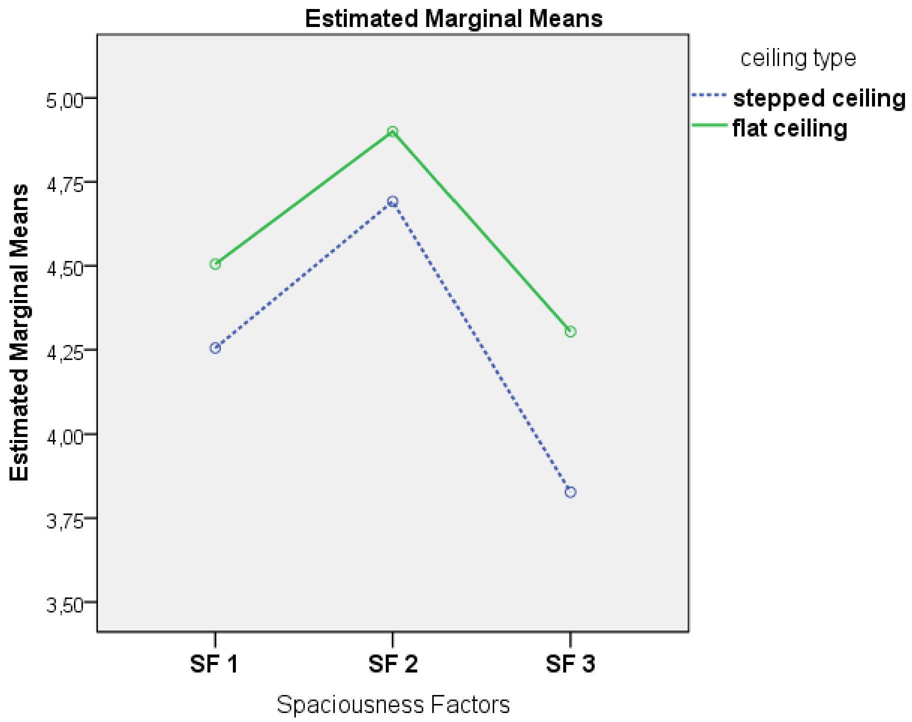


Figure 67 Mean scores of spaciousness evaluations for different ceiling types in Experiment-6.

4.2.5.2. **Effect of ceiling height:**

There was a statistically significant difference between 3m and 4m ceiling heights on the combined dependent variables, *F* (3, 90) = 3.48, *p* = .019; Wilks' Lambda = 0.90; partial eta squared = .10.

When the results for the dependent variables were considered separately, the only difference to reach statistical significant difference was "space freedom" factor, *F* (1, 92) = 9.22, *p* = .003, partial eta squared = .09. An inspection of the mean scores indicated that 4m ceiling height had higher levels of space freedom (*M* = 4.40, *SD* = 1.06) than 3m ceiling height (*M* = 3.73, *SD* = 1.14). (See Figure 68).

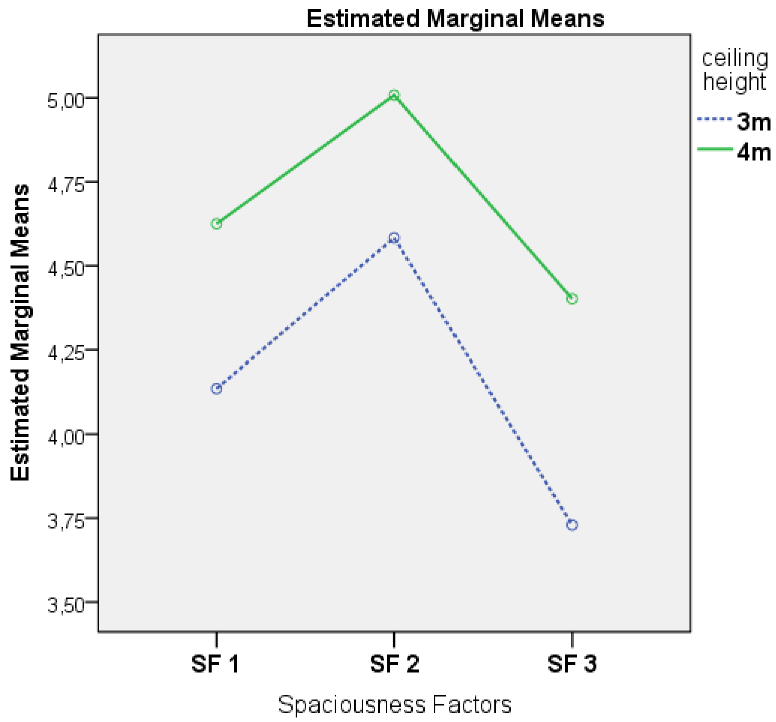


Figure 68 Mean scores of spaciousness evaluations for different ceiling heights in Experiment-6.

4.2.6. Discussion

Results indicated that *ceiling type* did not affect the overall evaluations of spaciousness. However, when each spaciousness factor was analyzed separately, the rooms with flat ceiling were evaluated as having more *space freedom* than the room with stepped ceiling.

It was revealed that *ceiling height* significantly affected the spaciousness evaluations in general. When each spaciousness factor was analyzed separately, only the *space freedom* factor reached significance level between the rooms with different ceiling heights. This finding is a verification of Experiment-5.

Before interpreting this finding, items related to ceiling form in "classroom design guides", which considered acoustic quality of classrooms, and visibility of instructor and the presentation boards, need to be explained here. The University of North Carolina at Chapel Hill (UNC, 1997) stated that "the ceiling in lecture halls should be tilted at an angle from the ceiling to the front wall" in order to "enhance the instructor's voice projection". Moreover, it was emphasized that "rooms with low ceilings may seem cramped or have poor sight lines for projected images if the floor is sloped or tiered" (UNC, 1997, p. 5). As University of Washington (2008, pp. 03-04) explained, "the depth and slope of rooms have a direct and critical impact on the required floor to ceiling height of rooms". By considering the accommodation of the appropriately sized projection screen, "farther away the last row of seats is from the front wall of the room, the higher the ceiling must be" (2008, pp. 03-04). Other guides pointed out the minimum ceiling height at front row and rear wall when the floor and/or ceiling are stepped. For instance, University of Toronto (2012-d) defined minimum ceiling height of stepped-floor classrooms as 9' (2.74m) at front wall and 8' (2.44m) at rear wall. Emory University (2008, p. 15) stated that "in large, sloped or tiered classrooms, the ceiling height is directly related to the distance to the last row of seats". For small lecture halls, Emory University (2008, p. 15) defined minimum ceiling height as 15' (4.57m) at the front wall and 9' (2.74m) at the rear wall. For a room with the capacity of 80, University of Toronto (2012-a, p. 10) defined the minimum clear ceiling height as (front of room) 11’6 (3.51m) when screen housing is not inset. Princeton University (2014, p. 2.3/5) explained the reason why a minimum ceiling height of 10’6 (3.20m) is required for instructional rooms as follows: “this will allow inclusion of indirect lighting in the space, with proper throw for the fixture and clearance from the floor”.

In the current experiment, the case was a stepped-floor classroom which has 9.00m x 9.50m plan dimensions, and 91 fixed seats arranged in the order of seven rows. According to the actual standards of stepped-floor classrooms mentioned above, ceiling height at front wall should be higher than the rear wall. In the current samples in Experiment-6, ceiling heights in stepped-ceilings are the same at front and rear walls; on the other hand, flat-ceiling produces a higher ceiling at front wall. For this reason, participants might have evaluated the models with flat-ceiling more positively than stepped-ceiling in terms of space-freedom.

4.3. EXPERIMENT-7: EFFECTS OF FLOOR TYPE ON SPACIOUSNESS EVALUATIONS

4.3.1. Introduction

Experiment-7 aimed to assess the effects of floor type on spaciousness evaluations. Floor type is one of the significant design components of classrooms, which has been frequently reported in “classroom design guides” of universities (for further information, see Appendix C.1.3). However, it was not reported in the literature of architectural psychology.

In the current experiment, it was assumed that different floor types (flat and stepped) might affect spaciousness evaluations of a room. Especially, the planning factor (SF2) was expected to be affected by the changes in the floor type since it was frequently emphasized in “classroom design guides”.

This experiment entailed two conditions, in which two floor types (flat and stepped) of a sample room was tested via video animations. Each condition was evaluated by every participant.

4.3.2. Participants

A total of 20 participants voluntarily participated in the experiment. Each participant evaluated both conditions of the experiment consecutively. All participants were undergraduate students from the Department of Architecture. There were seven males and 13 females. The mean age was 21.35 with a range of 20 and 22 years.

4.3.3. Stimuli

The classroom G103 in the G building of the Department of Mechanical Engineering was chosen as the case of this experiment (see Section 4.2.3). The model-D in Experiment-6 was again used in Experiment-7. In model-D, there were six steps on the floor. Each step was 15cm in height; hence, the total level difference on the floor was 90cm. In addition to that model, one more model was derived by flattening the floor. In order to have the same volume in the two models, ceiling heights were slightly manipulated. Models were recorded as video animations as mentioned in Experiment-5. A total of two video animations were used as stimuli for the experiment:

Model 7-D: stepped floor (4.00m height in the rear wall, 4.90 in the front wall)
Model 7-G: flat floor (4.50m height in the rear wall, 4.50 in the front wall)
Both models had flat ceilings with 9.50m x 9.00m plan dimensions.

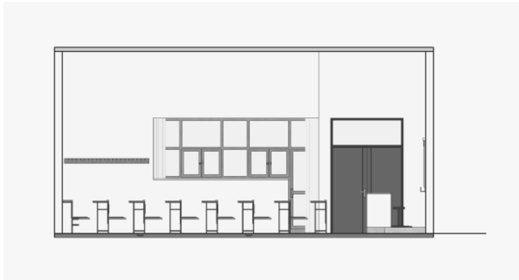
 Model 7-D (h_{rear}: 4m – h_{front}: 4.90m)	 Model 7-G (h: 4.50m)

Figure 69 Sections of computer models of Experiment-7.

Two identical netbooks with 1024x600 resolution 10.1” screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

4.3.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture design studio of METU Faculty of Architecture building. They were informed that they would watch a total of two video animations on two netbook screens, and they were asked to evaluate them with S-C-S consecutively. After a brief explanation about the use of a seven-point scale, animation videos of the models were played. Each video started from the door, toured 360^o clockwise in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during evaluations. The model on the left screen was presented until evaluations of both models were completed. The other model was presented on the right screen simultaneously. Half of the participants evaluated the models in reverse order in contrast the other half of the participants.

4.3.5. Results

Model 7-D | Model 7-G

Figure 70 Screenshots of computer models of Experiment-7

A one-way multivariate analysis of variance was performed to investigate the effects of floor type on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was floor type (stepped floor and flat floor).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was a statistically significant difference between flat floor and stepped floor on the combined dependent variables, F (3, 36) = 3.25, p = .033; Wilks' Lambda = 0.79; partial eta squared = .21. When the results for the dependent variables were considered separately, the only difference to reach statistical significance was "planning" factor, F (1, 38) = 6.71, p = .014, partial eta squared = .15. An inspection of the mean scores indicated that, stepped floor had higher levels of planning (M = 4.83, SD = 1.13) than flat floor (M = 3.99, SD = 0.91).

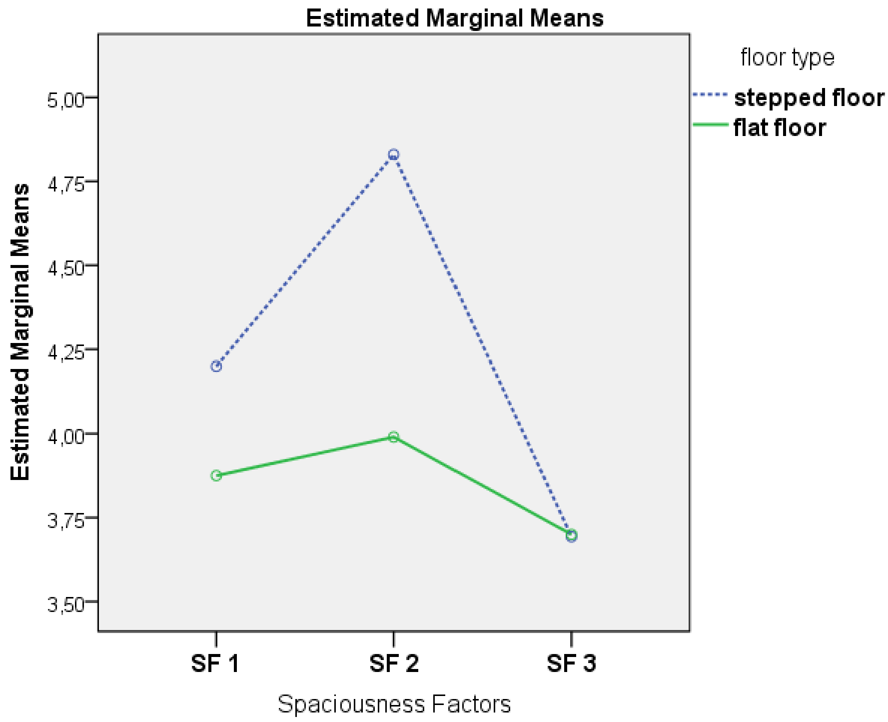


Figure 71 Mean scores of spaciousness evaluations for different floor types in Experiment-7.

4.3.6. Discussion

The classroom used in Experiment-6 was used again in Experiment-7 in order to examine the effects of floor form (stepped and flat) on spaciousness evaluations. The experiment had two conditions both of which had flat ceilings and the same volumes. Results indicated that floor types significantly affected general evaluations of spaciousness.

When each spaciousness factor was analyzed separately, the *planning* factor was significantly affected. The results of the experiment indicated that “classrooms with stepped floors were evaluated as better planned than those with flat floors”.

Since there is not a space perception study on floor form in architectural psychology literature, only “the classroom design guides” could be referred in order to interpret the findings of the current study. In general, design guides suggest stepped-floor as better designs for the classrooms with capacity of 91 seats as in the case of the current experiment. The University of North Carolina at Chapel Hill (UNC, 1997, p. 5) stated that “classrooms with flat floors provide greater flexibility when classroom activities involve collaborative learning projects or small group discussion”; however, for the general purpose classrooms with more than 60 seats, “classrooms with sloped or tiered floors may provide better sight lines for students”. They explained stepped-floor designs further as “the seats should be fixed and there should be an entrance at the lower end of the slope (i.e., the instructor area) to provide access for equipment carts and people who use wheelchairs.” University of Toronto (2012-a, p. 9) defined floor form based on the number of seating rows as: “any classroom with more than 7 rows must be tiered/sloped”.

When the stepped-floor classroom in Experiment-7 is evaluated by the design standards mentioned above, it is seen that the classroom met the required standards. Hence, it can be interpreted that the highest score in the planning factor of spaciousness evaluations matched up with the actual room standards for the stepped-floor classroom.

4.4. EXPERIMENT-8: EFFECTS OF PLAN GEOMETRY ON SPACIOUSNESS EVALUATIONS

4.4.1. Introduction

The final experiment aimed to assess the effects of plan geometry of rooms on spaciousness evaluations. Since rectangular plan form is common in room designs, in the current experiment, it was assumed that different plan geometries (rectangle and trapezoid) might affect spaciousness evaluations of a room. It was expected that the room in rectangular plan, which have all walls in perpendicular order, might be evaluated more positively than the room in trapezoidal plan.

In the literature, there are studies which examined the effects of plan proportions on spaciousness via scale models (İmamoğlu, 1975) and via computer simulations

(Stamps, 2011). As a floor form study, Hidayetoğlu et al. (2010) studied the location of the curvilinear forms. However, to the knowledge of the author, the effects of plan geometry (rectangular and trapezoidal) on perceived space were not much examined in the field of architectural psychology. In this respect, the classroom design standards about plan geometry come into question. In general, the guides suggested trapezoidal form in large lecture halls and auditoriums in terms of acoustical purposes and visibility of presentation boards (UNC, 1997, p. 18); on the other hand, rectangular forms were suggested for small and medium size classrooms. For instance, University of Washington (2008, p. 3) stated that “seminar/breakout rooms are generally recognized to be either rectangular or almost square with little distinction of a ‘front’ side of the room.” Emory University (2008, p. 18) pointed out the proportions of the plan geometry as: “avoid creating seminar and conference rooms with long narrow tables that make it difficult for everyone to see each other” and added “rooms which are almost square or have a shape based on viewing angles are best.” Similarly, University of Toronto (2012-d) emphasized the plan proportion while defining the plan geometry as follows: “Rooms that ‘tend to square’ offer combined benefits of the narrow-deep and wide-shallow rooms, while minimizing the negative effects of each.” It is seen that square form was frequently mentioned by the design standards, which indicates the role of plan geometry for ideal classroom designs.

This experiment entailed two conditions, in which two plan geometries (rectangle and trapezoid) of a sample room was tested via video animations. Each condition was evaluated by every participant.

4.4.2. Participants

This study employed 20 volunteered participants composed of second-year architecture students.[14] Each participant evaluated both of the two conditions of the

[14] There were three additional participants whose ratings were not included in the statistical analyses. They were the first three participants of Experiment-8, and the video animation was modified after their evaluations. Hence, their questionnaire ratings were evaluated as a trial study.

experiment consecutively. There were 13 males and seven females. The mean age was 21.21 with a range of 19 and 26 years.

4.4.3. Stimuli

A room called MM319 was selected as the case room for this experiment. This room was used by the Graduate School of Natural and Applied Sciences in the Central Engineering building named MM at METU. The room was selected due to its trapezoidal plan geometry.

After making a realistic model of the existing room (MM319) in SketchUp program, two models were derived for the two conditions of the experiment (trapezoidal plan and rectangular plan). Models were recorded as video animations as mentioned in Experiment-5. A total of two video animations were used as stimuli of the experiment.

4.4.3.1. **The existing room MM319:**

The selected room, MM319, has a trapezoidal plan (9.25m in depth and 19.78m in maximum width between walls) (see Figure 73). Its ceiling height is 2.64m. Entrance of the room is on the south wall which has a glazed timber double door and a small translucent window over it. There are two reinforced concrete structural frames passing through south to north direction in the center of the room. Windows of the room are along the north wall and they are divided into three parts by the columns of the concrete structure. Eight rectangular tables and six arch shaped tables are arranged together to have an ellipsoid shaped table unit in the center of the room. Twenty two chairs are placed around. (Two chairs are positioned for each table). On the east and west walls, there are two timber cabinets with glazed fronts. There is a portable white board in one of the corners of the room. The floor is covered with timber parquet; walls and ceiling are plastered and painted in white (see Figure 73).

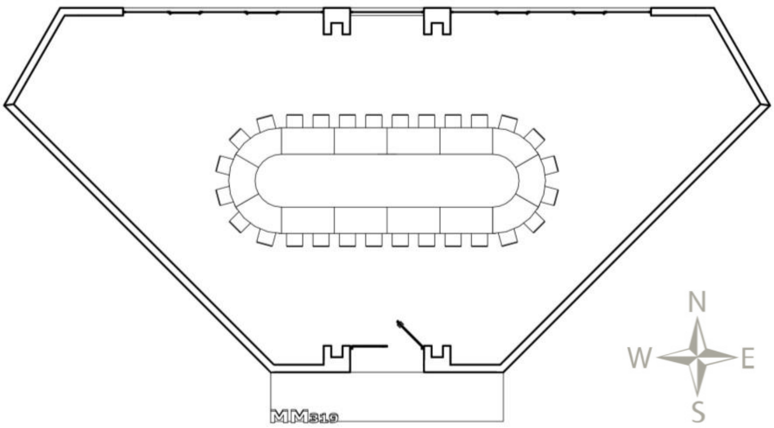


Figure 72 Plan of room MM319 (Scale: 1/200).

Figure 73 Photographs of room MM319 (2013).

4.4.3.2. **Computer simulations of MM319:**

MM319 was documented with photographs and detailed measured drawings (see Appendix E.1.7 and E.1.8). Its 3D model was made in SketchUp program as mentioned in Experiment-1. Two alternatives of the room were built as stimuli for this experiment. In both conditions, all room components and window size and position were kept constant; only the plan geometry was changed. In order to have the same volume in the two models, ceiling heights and total plan areas were kept constant. Window sizes were determined according to the rectangular-planned model, because its window wall was narrower than the trapezoid planned model. Hence, both models had the same size of windows (two 5.32m x 1.90m windows on the two sides and a 1.96m x 1.20m window in the middle of the north wall). The portable white board and existing wooden cabinets were eliminated from the computer models.

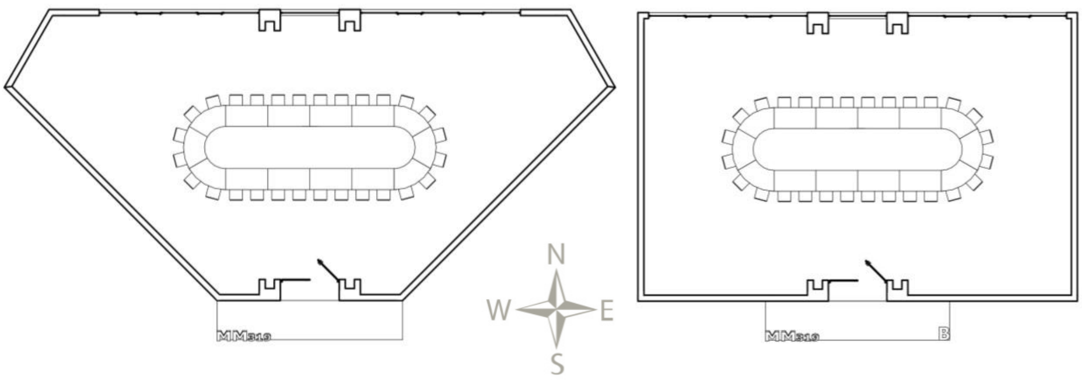


Figure 74 Plans of models in Experiment-8.

Model 8-A: trapezoidal floor plan (9.25m in depth and 19.78m in maximum width)
Model 8-B: rectangular floor plan (9.25m in depth and 14.31m in width)
Both models had a 3.50m ceiling height, and a $132m^2$ floor area with a 9.25m perpendicular dimension in the short side of the plan.

Two identical netbooks with 1024x600 resolution 10.1” screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

4.4.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were informed that they would watch a total of two video animations on two netbook screens, and asked to evaluate them with S-C-S consecutively. After a brief explanation about the use of a seven-point scale, animation videos of the models were played. Each video started from the door, toured 360^o clockwise in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation. The model on the left screen was presented until evaluations of the two models were completed. The other model was presented on the right screen simultaneously. Half of the participants evaluated the models in reverse order than the other half.

4.4.5. Results

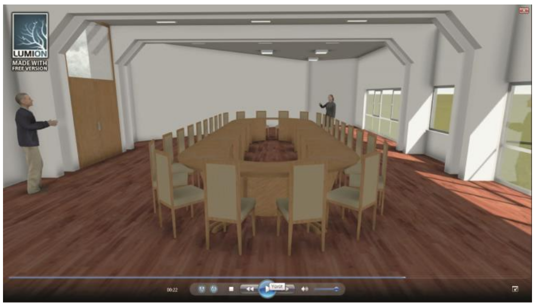
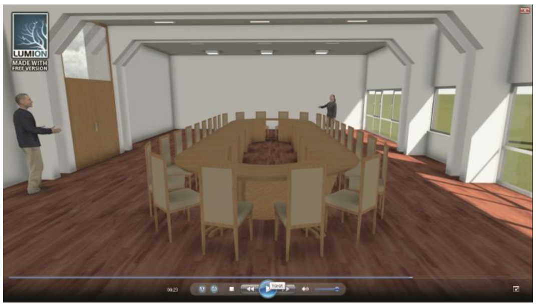
	
Model 8-A	Model 8-B

Figure 75 Screenshots of computer models of Experiment-8.

A one-way multivariate analysis of variance was performed to investigate the effects of plan geometry on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was plan geometry (rectanglar plan and trapezoidal plan).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between rectangular plan and trapezoidal plan on the combined dependent variables, F (3, 36) = 0.55, p = .650; Wilks’ Lambda = 0.96; partial eta squared = .04. When the results for the dependent variables were considered separately, no statistically significant difference was found.

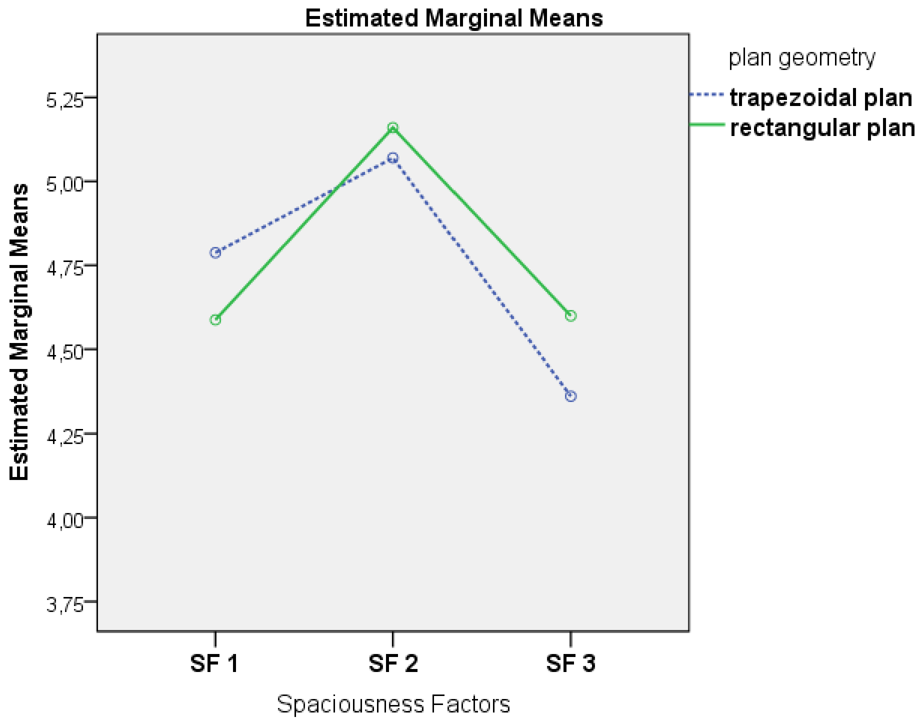


Figure 76 Mean scores of spaciousness evaluations for different plan forms in Experiment-8.

4.4.6. Discussion

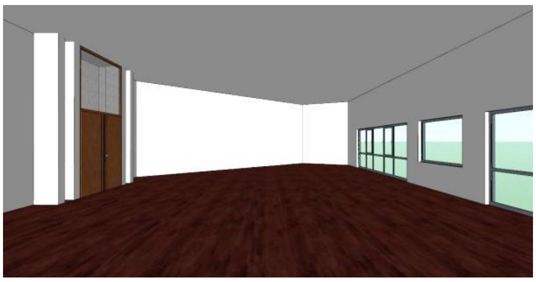
Contrary to expectations, results indicated that there was no significant difference between spaciousness evaluations of rooms with a rectangular and a trapezoidal plan. Although the difference is clearly seen in plans (Figure 74), as seen in photographs of the real room (Figure 73) and in the images of the computer simulations (Figure 75), it might be hard to identify the trapezoidal geometry from the rectangular one by the *monoscopic image depth cues*. Only the *motion depth cues* of the video animation might help to identify the geometry. There are two possible reasons for such visual difficulties.

1) In real environments, rectangular forms in horizontal surfaces are naturally seen as trapezoidal forms due to the perspective rules; nevertheless, it is perceived as rectangular by the brain. However, when the similar perspective

distortions happened in computer simulations, it is hard to identify whether a form is trapezoidal or rectangular. In Section 2.5.1.1, such weaknesses of computer simulations were discussed through *focal distance* (see Figure 22 on page 79) and *field of view* (see Table 3 on page 81). This situation can be observed in the current model as illustrated in Figure 77. For instance, the surface of the table in the front might be identified as rectangular or trapezoidal. In fact, it is rectangular. Similar confusions over plan geometry might arise while the participants were evaluating the models of the current experiment.

Figure 77 Identifying rectangular or trapezoidal table by monoscopic depth cues: a screenshot from the SketchUp model of room MM319

Model of MM319 with details.



Simplified model of MM319.

Figure 78 SketchUp models of room MM319: Left: models with details. Right: simplified model.

2) In the case of most examples from the recent literature, models could be built by omitting the details (such as furniture, beams and the like). Hence, it would be easier to define the geometry of the space as illustrated in the examples in Figure 78. In the left figure, as in the current situation, ground edges and ceiling edges are mostly masked by other elements such as furniture, beams and the like. On the other hand, in the right one, the geometry of the room can be clearly identified due to its simple prismatic form.

As illustrated above, the simplified models might help participants to perceive the main geometries in the computer simulations; however, this might have misled the participants and thus, affected the results of the experiment (for further information, see Section 2.6.3). As mentioned before, since, in real situations, people perceive and evaluate environments with all the surrounding elements, studies with more realistic sample models are needed to contribute to architectural design research. Instead of simplifying the computer simulation, the two conditions of the experiment might be reevaluated via full-scale models in the future to support or modify the results of the current experiment.

Since a special situation was observed concerning the perception of plan geometry in computer simulations and 2D, a reexamination of the current hypothesis via real-rooms or full-scale models in the future might be worthwhile.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1. REVIEW OF THE THESIS

The starting point of this thesis was to assess spaciousness concept in buildings. It was seen that spaciousness has comprehensive meanings beyond its dictionary definitions. It is a concept which carries almost all positive connotations related to space perception. However, as Isenstadt (1997) points out, *perceived space* might be different than *actual space*. This paradox, on the other hand, might turn into a benefit if the designer of the space is conscious about the factors which make the space spacious.

Since *perceived space* is a subjective subject, first and foremost, an extensive literature review was required in order to understand how it was handled by researchers in objective ways. In this respect, the literature between 1960s and the present day on architectural psychology, which focused on the interaction between people and built environment, was surveyed. It was seen that each experimental study examined this interaction through the following dimensions:

1) *one or more parameters* of people-environment interaction
2) *sample space* (mostly one or more rooms of a specific type of buildings, such as houses, hospitals, offices and education buildings)
3) sample participant groups (random participants from a specific group of people)

4) evaluation technique (observation of people’s behavior and/or verbal statements of people)

According to the literature, the four dimensions listed above can briefly be explained by their limitations as follows: First, although spaciousness of a space has been affected by the combination of various parameters related to people and environment; all other parameters (except the selected ones) need to be fixed and ignored due to the nature of experimental studies, which need clear cut theorems. Second, similarly, although the experiments aim to test the effects of the focused parameters on buildings as a whole, the area has to be narrowed down to a controllable small size such as a room. Moreover, since using a real space is not possible in most studies, represented sample spaces are preferred instead. Hence, results are based on narrowed down and artificialized spaces. Third, as Gifford (1997) emphasizes, the perceptions of space might change based on people’s characteristics; therefore, each experimental study in the literature might have unique results which are hard to prove by the replication of the study with participants with different characteristics. For this reason, the sampling procedure and demographic features of participants are significant to interpret results. Fourth, an appropriate evaluation technique is as significant as the dimensions mentioned above. Both the behaviors and verbal statements of people might reveal people’s perceptions about space. Since behavior observations require a constructed sample space, the current study focused on the verbal evaluations. Among the verbal evaluation techniques, *semantic differential scales* have been one of the mostly used techniques since the beginning of architectural psychology research in the 1960s. In this respect, the content of the semantic scale, its appropriateness to the three dimensions mentioned above and its validity have significant roles in the success of the experimental research.

In the light of the four dimensions discussed so far, experiments of the current thesis were designed. Various parameters were obtained from the literature review. Sample spaces were selected from various classrooms (lecture classrooms and seminar rooms) with the capacity of 15 to 90 students at METU, and participants were selected from students and staff at METU. For the evaluation technique, Spaciousness-Crampedness Scale (S-C-S) developed by İmamoğlu (1975) was chosen as one of the sophisticated semantic differential scales in the literature. As in the case of other studies in the literature, represented spaces were used instead of the real ones. Contrary to conventional type of representations (scale models, full-scale models and the like), computer simulations were preferred as the contemporary representation tools. Although the computer simulation technology traced back to 1950s and was used in various disciplines, it has been used as a representation tool in architectural psychology since the 2000s. Moreover, S-C-S was used and verified via scale models and real rooms, but it was not used via computer simulations before. Hence, the use of computer simulations as the representation tool in architectural psychology emerged as the second aim of the current thesis while conducting the literature review.

In line with the second aim of the current thesis, literature review was extended to the field of computer simulation. In order to understand space perception through computer simulation, first, visual perception was reviewed through four visual depth cues (*monoscopic image*, *stereoscopic image*, *motion* and *physical depth cues*) explained by Sherman and Craig (2003). Based on these explanations, the ways of perceiving real space, conventional representations (scale models and full-scale models) and the computer simulations were compared. Although conventional representations benefit from the four visual depth cues, current computer simulation technology lacks of *physical depth cues* and the reliability of its *stereoscopic image depth cues* are questionable. Hence, computer simulations should present *monoscopic image* and *motion depth cues* more effectively in order to be perceived realistically. Second, the properties of visual displays mentioned by Sherman and Craig (2003) were investigated. *Focal distance*, *field of view* (FOV) and *field of regard* (FOR) are the three concepts which differs computer simulations from the real environment, scale models and full-scale models. The misuse of these properties might lead to misperception about the presented computer simulation. Hence, computer simulations should be designed cautiously by considering the above mentioned properties.

Although computer simulation technology has recently been utilized in the field of architectural psychology as a representation tool, it has become the prevalent representation tool in the field by substituting the conventional representation tools. Its main advantages can be summarized as follows: production of computer simulations and evaluations are practical and economical; photo realistic representations can be obtained; it presents various viewpoints; and it enables interior tour by virtual walking facilities. In addition to the basic type of flat displays, advance immersive displays (Curved Screens, VR DOMEs, HMDs and CAVEs) have been developing. They have been mentioned in the literature as potential representation tools of architectural psychology and tested in various experimental studies; however, they have not been used in the field of architectural psychology as a generally accepted representation tool yet. Moreover, mobile medium with augmented reality (AR) has been developing rapidly since 2008, but it has not been mentioned in architectural psychology literature yet. Following further developments which might prevent possible misperceptions about space representations, the advanced immersive displays and mobile AR might substitute all other representation tools in the field. However, for the current thesis, computer simulations on laptop screen (a flat display) were preferred, due to presenting more reliable representations among the current technology.

Following the comprehensive literature review about the methodology, this thesis involves a preliminary study and two groups of experiments.

5.1.1. Method development in order to assess spaciousness via computer simulation and spaciousness-crampedness scale: review of the preliminary study and the first group of experimental studies

In the light of the literature review, computer simulations and spaciousness-crampedness scale (S-C-S) were selected as research tools of the current study. Sample spaces were METU classrooms, and participants were students and staff at METU. However, based on the selected research tools and the participant characteristics, development of a method was needed in the first group of experimental studies.

In the preliminary study, two open-ended questions were asked to 40 participants in order to understand their semantic perception of spaciousness and factors affecting the spaciousness. Since the results of the current preliminary study were similar with the results of İmamoğlu's (1975) preliminary study, S-C-S was considered as an appropriate evaluation scale for the current study. With regard to the results of the open-ended questionnaire, the variables which would be examined following the current study were determined: ceiling height, ceiling type (flat and stepped), floor type (flat and stepped), and plan geometry (rectangular and trapezoidal).

By taking the preliminary study into consideration, Experiment-1 and Experiment-2 were conducted in order to test the validity of computer simulations for spaciousness assessments. In Experiment-1, a classroom (R46) was modeled in three different programs (SketchUp, Lumion, and Rhinoceros), and the representativeness of each computer simulation was compared with the real room via a 10-point scale. Results indicated that SketchUp model got the highest score (M = 7.84, SD = 1.72) with the Lumion being the second highest one (M = 7.56, SD = 2.20). However, a further experiment was also needed to test the validity of the representation method for spaciousness assessments. In this respect, Experiment-2, in which two different participant groups evaluated the real classroom and its computer simulation via S-C-S, was conducted. Results indicated that there was no significant difference between the spaciousness evaluations of the real room and its computer simulation.

The change between the real room and its simulation did not significantly affect any of the three spaciousness factors (SF1 appeal, SF2 planning, SF space freedom). Additionally, genders of the participants were also considered in the analysis. Since the spaciousness evaluations of female and male participants did not differ significantly, it was interpreted that gender variable could be ignored in the following experiments, and random selection could be acceptable.

In Experiment-3 and Experiment-4, the research tools mentioned above were tried on spaciousness evaluations of different ceiling heights in order to develop the most appropriate procedure for the second group of experimental studies. First, in Experiment-3, a computer model of a classroom (B06) was made, and its three different computer models were derived by changing the ceiling height (3m, 4m and 5m). Each computer simulation was presented via virtual walking in SketchUp program to a different group of participants. It was expected that different ceiling heights might affect spaciousness evaluations of a room, as the volume of the *actual space* increases with the raise in the ceiling height. Mainly, the space freedom factor (SF3), which is composed of seven adjective pairs four of which being “small-large”, “tiny-huge”, “narrow-wide” and close-open”, was assumed to be affected by the changes in the ceiling height. However, the statistical analyses indicated that difference in the ceiling height did not affect any of the spaciousness factors. Hence, possible weaknesses of the representation technique were discussed to develop the procedure. In brief, following four modifications were proposed for the procedure:

1) A video animation for each model might be better than virtual walking in order to illustrate models from similar viewpoints and with all their details to each participant.
2) Some additional visual cues might be needed to support depth perception in the models (some well-known sized references such as human figure, a more realistic outside view such as several trees and plants placed in close and long distances, a more realistic light, and shade and shadow, more realistic textures such as a reflecting board, a shining glass and a switched-on lamp)

With the developed procedure, the hypothesis proposed in Experiment-3 was reexamined in Experiment-4. However, one of the previous models, which has the medium ceiling height (4m), was eliminated in the current experiment. Additionally, an alternative model with high windows was added in order to clarify the questions whether high ceiling requires high windows. The results indicated that there was no significant difference between the spaciousness factors of the two different ceiling heights and two window sizes. Hence, the experiment procedure was compared with the examples in the literature, and it was realized that two additional modifications were needed in the experiment procedures of the current study:

3) Each participant should evaluate every model in the experiment consecutively, rather than evaluating only one of them.
4) There is a need for a standard model to be used as an anchor to compare different experiment conditions.

5.1.2. Effects of permanent components of rooms on spaciousness evaluations: review of the second group of experimental studies

Regarding the methods in the first group of experimental studies, the second group of experimental studies was designed in order to examine the four variables of classroom design, which are ceiling height, ceiling type, floor type (stepped and flat), and plan geometries (rectangular and trapezoidal).

In this framework, Experiment-5 aimed to reexamine the effects of ceiling height with the developed method. The results indicated that the difference in ceiling height significantly affected the overall evaluations of spaciousness. When each spaciousness factor was analyzed separately, the space freedom factor in 3m and 5m ceiling heights were significantly different. However, the *appeal* and *planning factors* did not differ significantly among 3m, 4m and 5m ceiling heights.

Experiment-6 and Experiment-7 aimed to assess the effects of ceiling type and floor type (stepped and flat) on spaciousness evaluations, respectively. For this purpose, a classroom (G103) with stepped-floor and stepped-ceiling was selected as the sample room, and its computer model and derivations were prepared as stimuli. Experiment-6 assessed the effects of ceiling type and ceiling height on spaciousness evaluations. The experiment had four conditions: two ceiling types (flat and stepped) and two ceiling heights. It was assumed that different ceiling types (flat and stepped) might affect spaciousness evaluations of a room, and that the flat ceiling might be evaluated more positively. In general, the *ceiling type* did not affect the overall spaciousness evaluations; however, the flat ceiling was evaluated higher in *space freedom* factor when compared to stepped ceiling.

In Experiment-7, which aimed to assess the effects of floor type on spaciousness evaluations, it was expected that different floor types (flat and stepped) might affect spaciousness evaluations of a room. Especially the planning factor (SF2) was assumed to be affected by the changes in the floor type since it was frequently emphasized in “classroom design guides”. The experiment possessed two conditions: flat and stepped floor. As expected, the two floor types significantly affected the evaluations of spaciousness of the classroom. When each spaciousness factor was analyzed separately, the stepped-floor got higher levels of planning scores than flat-floor; however, other spaciousness factors did not differ significantly.

The final experiment, Experiment-8, aimed to assess the effects of plan geometry (rectangular and trapezoidal) on spaciousness evaluations. It was assumed that the room in rectangular plan, which has all walls in a perpendicular order, might be evaluated more positively than the room with a trapezoidal plan. Contrary to expectations, the results indicated that spaciousness evaluations of rooms with a rectangular and a trapezoidal plan did not differ significantly. However, a special situation was observed concerning the perception of plan geometry in computer simulations and 2D images, which is that it might be hard to identify the trapezoidal geometry from the rectangular one by the *monoscopic image depth cues*.

5.2. IMPLICATIONS AND POSSIBLE FUTURE EXTENSIONS

The process, the limitations and the findings of this thesis are briefly reviewed in Section 5.1. In this section, the current study will be compared with the literature and discussed, and possible future extensions will be mentioned.

İmamoğlu (1975) constructed the spaciousness-crampedness scale (S-C-S) and examined the effects of various components of rooms via S-C-S using scale models or real rooms. Three of these components were related to permanent components of rooms: room proportion (1, √2, and √3), window size (three-bay and continuous), and window position (on short and long walls). He found that all these three dimensions affected spaciousness evaluations significantly. He indicated that square rooms were seen as more spacious than oblong ones (√3), and rooms with larger (continuous) windows were perceived as more spacious than those with smaller (2-3-bay) ones (1975). In the current study, S-C-S was used to assess other permanent components of rooms which were not studied before. Hence, ceiling height, ceiling type (flat and stepped), floor type (flat and stepped), and plan geometry (rectangular and trapezoidal) were examined using S-C-S. However, since forty years passed, this thesis is not a direct continuation of the study of İmamoğlu (1975); a comprehensive literature review and method developments were required to include the technology of the contemporary conditions. In this sense, instead of scale models, computer simulations were selected as representation tools. Hence, the current thesis is the first attempt to use S-C-S together with computer simulations.

The use of computer simulations in the current thesis differs from other examples in the literature in terms of three aspects: 1) the complexity of the evaluation scale used with computer simulations, 2) the number of models presented to each participant at a time and 3) the realistic details of the computer simulations. At this point, the use of computer models and the evaluation scales used with them in the literature need to be noted. Franz et al. (2005) asked each participant to evaluate 16 models on a seven-step Likert-like scale which was composed of pleasure, interestingness, beauty, normality, calm, brightness, openness, and spaciousness. (They asked spaciousness as a ‘narrow – spacious’ adjective pair in German). Stamps and Krishnan (2006) presented 16 models in one experiment and 12 models in the other experiment, while Stamps (2007-a) asked each participant to evaluate 24 models. In the studies of Stamps and Krishnan (2006) and Stamps (2007-a), a single eight-point “spacious – not spacious scale” was used. Stamps (2010) presented 12 models in the first experiment and 16 models in the second, and used a single eight-point “open – closed” scale. These examples indicate that in the studies with computer simulations, tens of models were presented to each participant, on the other hand, participants were asked to evaluate each model via a simple evaluation scale. In the current study, as in the method of İmamoğlu (1975), each participant evaluated two, three or four models using S-C-S, which is a seven-point semantic scale composed of 19 adjective pairs, and results were analyzed through three spaciousness factors. Hence, the current study is one of the first attempts to use one of the sophisticated evaluation scales of the 1970s together with today’s computer simulations.

Computer simulations enable researchers to make detailed representations, which can be more realistic compared to conventional representation methods. However, the computer simulation examples in the architectural psychology literature were simplified models like an empty prism, and only limited details were added. To remind briefly, Franz et al. (2005) used panoramic images of empty rectangular rooms with various type of windows and door. Stamps and Krishnan (2006) used an empty rectangular room and added a human figure, a carpet and wall textures or bookshelves. Stamps (2007-a) added some human figures and 2D framed art prints hung on walls in a gallery as a stimulus. Stamps (2010), in one experiment, added two human figures in empty octagonal rooms, the walls of which were each divided into four bays and filled with either glass or solid bookshelves. In his second , he added one or two human figures in empty rooms. Stamps (2011), in another experiment, used various empty rooms with a range of different plan proportions (1:1, 1:2 and 1:9 which is a very exaggerated proportion) with no details, and in the second experiment, he used plan ratios between 1:1 and 1:2, a human figure, two double doors and 2D art prints hung on walls in order to make them more realistic. In all these examples, empty rooms were presented to participants as stimuli. However, simplified models might reveal the aim of the study to the participants, which might influence the results. In reality, people perceive space with all components of the environment. For instance, İmamoğlu (1973) indicated that furniture density and (1976) room organization affect evaluations of spaciousness. Hence, in order to obtain realistic computer simulations in the current thesis, real classrooms were selected as cases and their detailed models were made and derived for each condition of each experiment.

The table below summarizes the results of the experimental studies of the thesis:

Table 8 Summary of results.

- **Higher ceiling** made the room more spacious.
- **The types of ceiling** did not affect spaciousness in general.
  Flat ceiling indicated higher levels of space freedom compared to stepped one.
- **Classrooms with stepped floors** were evaluated as better planned than those with flat floors.
- **Plan geometry** did not affect participants' evaluations of spaciousness significantly.
- Results of the experiments demonstrate that the effects of some components of rooms on spaciousness can be identified via **computer simulations.**

5.2.1. Future expectations

In the final section of the current thesis, some suggestions for future research will be offered.

Classroom design guides might not only consider the actual space (visibility of presentation board, acoustics of the classroom and the like) but also the perceived space (spaciousness). In this respect, the effects of ceiling height on spaciousness might be tested for classrooms in different sizes and different plan proportions. The effects of other parameters of classsroom design, such as classroom size and capacity, seating arrangements and the like, on spaciousness might be examined using S-C-S and computer simulations with the procedure developed in the current study.

This study is not only limited to classrooms and education buildings, it might be extended to other type of buildings, such as houses, offices and the like. Moreover, this study is not only limited to rooms, it might be extended to other closed, semi-open and open spaces, such as entrance halls, atriums, courtyards and the like.

In architectural psychology research, it is essential to be cautious while designing an experiment via computer simulations and interpretting its results, since there are still various unknowns for people-computer interaction, which has been researched by cognitive sciences and computer sciences for years. However, the experimental results of the current study indicated that the effects of some components of rooms on spaciousness can be identified via computer simulations and S-C-S.

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APPENDIX A

QUESTIONNAIRE FORMS

A.1. QUESTIONNAIRE FORM USED IN EXPERIMENT-1 STEP-2

Lütfen, bulunduğunuz odayı ekranda gösterilenler ile karşılaştırıp, 1 ile 10 arasında bir puan veriniz:

1 : hiç benzemiyor
10: çok iyi temsil ediyor, aynısı

1.	
2.	
3.	

Figure 79 Questionnaire form used in Experiment-1, Step-2 (in Turkish).

A.2. S-C-S QUESTIONNAIRE FORMS USED IN EXPERIMENTS

YAŞ / CİNSİYET : ....

MESLEK : ....

BÖLÜM / SINIF : ....

Bu çalışma, insanların iç mekanları nasıl algılayıp değerlendirdiklerini anlamak amacıyla yapılmaktadır. İçinde bulunduğunuz odayı ilişikteki liste yardımıyla değerlendirmeniz istenmektedir. Liste 19 çift karşıt anlamlı kelimeden oluşmaktadır; karşıt anlamlı kelimeler arasında 7 kutucuk bulunmaktadır. Kelimelere en yakın kutucuklar <u>çok</u>, onun yanındakiler de sırasıyla <u>oldukça</u> ve <u>biraz</u> anlamına; en ortadaki kutucuk <u>tarafsız (yansız)</u> anlamına gelmektedir:

	çok	oldukça	biraz	yansız	biraz	oldukça	çok	
KELİME 1	☐	☐	☐	☐	☐	☐	☐	KELİME 2

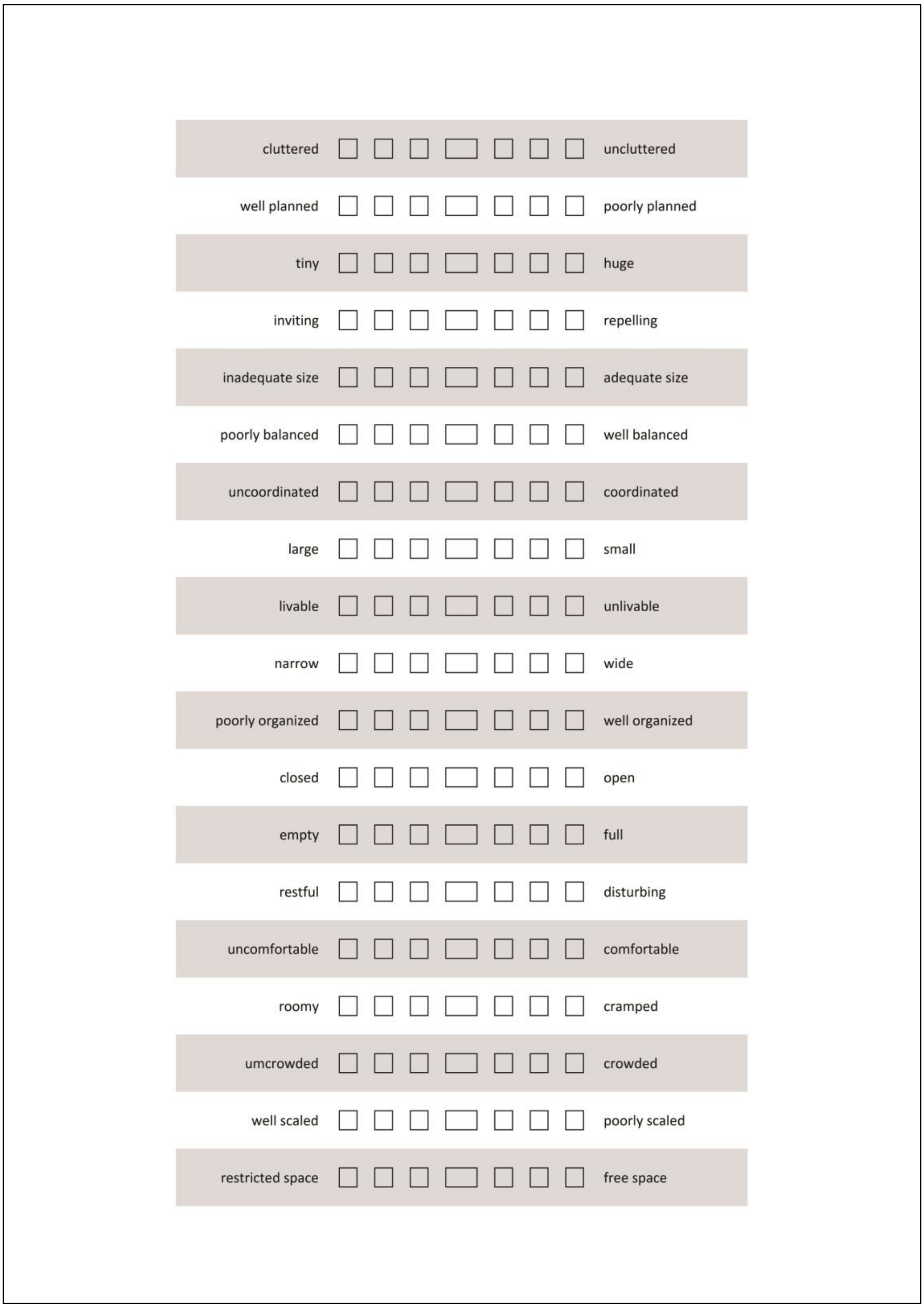
Her karşıt kelime çiftinde, yalnız bir kutucuğu işaretleyiniz.
Hiçbir satırı işaretlemeden geçmeyiniz.
Bu çalışmada doğru veya yanlış cevap yoktur. Önemli olan şu andaki izleniminizi bize iletmenizdir.

Yardımınız için teşekkür ederiz.

Figure 80 Front page of S-C-S questionnaire form used in experiments (in Turkish).

karışık, sıkış tepiş	☐ ☐ ☐ ☐ ☐ ☐ ☐	düzenli
iyi planlanmış	☐ ☐ ☐ ☐ ☐ ☐ ☐	kötü planlanmış
ufacık	☐ ☐ ☐ ☐ ☐ ☐ ☐	kocaman
davet edici	☐ ☐ ☐ ☐ ☐ ☐ ☐	itici
büyüklüğü yetersiz	☐ ☐ ☐ ☐ ☐ ☐ ☐	büyüklüğü yeterli
kötü dengelenmiş	☐ ☐ ☐ ☐ ☐ ☐ ☐	iyi dengelenmiş
uyumsuz	☐ ☐ ☐ ☐ ☐ ☐ ☐	uyumlu
büyük	☐ ☐ ☐ ☐ ☐ ☐ ☐	küçük
içinde yaşanabilir	☐ ☐ ☐ ☐ ☐ ☐ ☐	içinde yaşanamaz
dar	☐ ☐ ☐ ☐ ☐ ☐ ☐	geniş
kötü düzenlenmiş	☐ ☐ ☐ ☐ ☐ ☐ ☐	iyi düzenlenmiş
kapalı	☐ ☐ ☐ ☐ ☐ ☐ ☐	açık
boş	☐ ☐ ☐ ☐ ☐ ☐ ☐	dolu
dinlendirici	☐ ☐ ☐ ☐ ☐ ☐ ☐	tedirgin edici, taciz edic
rahatsız	☐ ☐ ☐ ☐ ☐ ☐ ☐	rahat
ferah	☐ ☐ ☐ ☐ ☐ ☐ ☐	tıkış tıkış, sıkıntı verici
tenha	☐ ☐ ☐ ☐ ☐ ☐ ☐	kalabalık
iyi ölçülendirilmiş	☐ ☐ ☐ ☐ ☐ ☐ ☐	kötü ölçülendirilmiş
kısıtlı mekan	☐ ☐ ☐ ☐ ☐ ☐ ☐	özgür mekan

Figure 81 Main page of S-C-S questionnaire form used in experiments (in Turkish).



cluttered	☐	☐	☐	☐	☐	☐	☐	uncluttered
well planned	☐	☐	☐	☐	☐	☐	☐	poorly planned
tiny	☐	☐	☐	☐	☐	☐	☐	huge
inviting	☐	☐	☐	☐	☐	☐	☐	repelling
inadequate size	☐	☐	☐	☐	☐	☐	☐	adequate size
poorly balanced	☐	☐	☐	☐	☐	☐	☐	well balanced
uncoordinated	☐	☐	☐	☐	☐	☐	☐	coordinated
large	☐	☐	☐	☐	☐	☐	☐	small
livable	☐	☐	☐	☐	☐	☐	☐	unlivable
narrow	☐	☐	☐	☐	☐	☐	☐	wide
poorly organized	☐	☐	☐	☐	☐	☐	☐	well organized
closed	☐	☐	☐	☐	☐	☐	☐	open
empty	☐	☐	☐	☐	☐	☐	☐	full
restful	☐	☐	☐	☐	☐	☐	☐	disturbing
uncomfortable	☐	☐	☐	☐	☐	☐	☐	comfortable
roomy	☐	☐	☐	☐	☐	☐	☐	cramped
umcrowded	☐	☐	☐	☐	☐	☐	☐	crowded
well scaled	☐	☐	☐	☐	☐	☐	☐	poorly scaled
restricted space	☐	☐	☐	☐	☐	☐	☐	free space

Figure 82 Main page of S-C-S questionnaire form in English.

APPENDIX B

SUMMARY TABLES OF THE PRELIMINARY STUDY

B.1. ANSWERS OF OPEN-ENDED QUESTIONNAIRE IN THE PRELIMINARY STUDY

The preliminary study, which was mentioned in Section 3.1, is graphically summarized in Figure 83. The answers of the open-ended questionnaire are illustrated in the following pages.

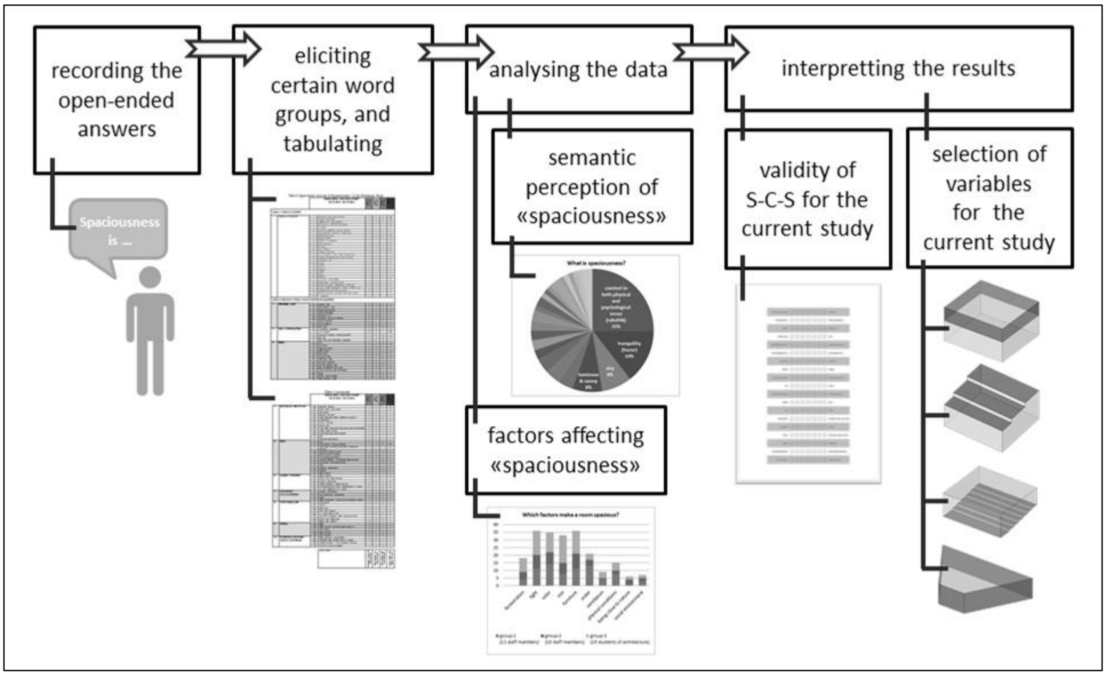


Figure 83 The procedure of the preliminary study.

Table 9 Answers of the open-ended questionnaire in the Preliminary Study

		ÖNÇALIŞMA: AÇIK UÇLU ANKET 19.12.2011 - 23.12.2011		GRUP-1 (11 kişi)	GRUP-2 (10 kişi)	GRUP-3 (19 kişi)	TOPLAM CEVAP (40 kişi)
SORU-1: FERAHLIK NEDİR?							
	FERAHLIK NEDİR?	1	RAHATLIK /İÇİNİN RAHAT OLMASI	5	6	8	**19**
		2	HUZUR / İÇ HUZURU	3	3	5	**11**
		3	NEFES ALINAN / BOL OKSİJENLİ	1	2	1	**4**
		4	SIKILMAMAK / SIKINTININ OLMAMASI	2	0	1	**3**
		5	HAVADAR	1	1	0	**2**
		6	SIKINTININ ARDINDAN YAŞANAN DUYGU	0	0	1	**1**
		7	RAHATSIZLIKTAN ARINMAK / KURTULMAK	0	0	1	**1**
		8	BOĞUCU OLMAYAN	1	0	2	**3**
		9	SAĞLIKLI ORTAM	2	0	0	**2**
		10	KENDİNİ İYİ HİSSETMEK	0	1	1	**2**
		11	BASIK OLMAYAN	0	0	2	**2**
		12	GÜNEŞLİ	0	0	2	**2**
		13	IŞIK / AYDINLIK	0	1	2	**3**
		14	KARANLIK OLMAYAN	0	0	1	**1**
		15	ALIŞIK OLDUĞUN YAŞAM TARZINI BULABİLMEK	0	0	1	**1**
		16	FİZİKSEL VE GÖRSEL OLARAK İÇİNİN AÇILMASI	0	0	1	**1**
		17	PSİKOLOJİK ALGI	1	0	1	**2**
		18	MUTLU	0	0	1	**1**
		19	ENERJİK	0	0	1	**1**
		20	HOŞLUK	0	1	0	**1**
		21	TAZELİK	0	0	1	**1**
		22	ORAN	0	0	1	**1**
		23	DÜZENLİ	0	0	1	**1**
		24	ÇALIŞMAYA MOTİVE EDEN	1	1	0	**2**
		25	DARALMADAN RAHATSIZ OLMAK	0	0	1	**1**
		26	ENGEL OLMAKSIZIN İSTEDİKLERİNİ YAPABİLMEK	0	0	1	**1**
		27	RAHAT HAREKET EDİLEBİLEN / YETERLİ HAREKET ALANI	0	1	1	**2**
		28	GEREKSİZ EŞYALARIN BULUNMAMASI	0	0	1	**1**
		29	SOMUT OLAYLARIN YOL AÇTIĞI SOYUT BİR KAVRAM	0	0	1	**1**
		30	*… (CEVAPSIZ)*	*0*	*1*	*1*	**2**
SORU-2: BİR ODAYI FERAH YAPAN FAKTÖRLER NELERDİR?							
1	**PENCERE / CAM**	31	pencere / cam	0	0	2	**2**
		32	geniş pencere / cam	2	2	3	**7**
		33	boydan boya pencere	2	0	0	**2**
		34	pencere büyüklüğü	0	0	2	**2**
		35	pencerenin yeri	0	0	1	**1**
		36	pencerenin önü açık / manzaralı	0	1	0	**1**
		37	gökyüzü görülmeli	0	1	0	**1**
		38	açıklık - kapalılık	0	0	1	**1**
		39	geniş kapılı	0	1	0	**1**
2	**IŞIK / AYDINLATMA**	40	ışıklandırma / aydınlatma	2	2	7	**11**
		41	ışıklı / aydınlık	6	6	4	**16**
		42	çok aydınlık olmamalı, çok da loş olmamalı	1	0	0	**1**
		43	gün ışığı	1	1	5	**7**
		44	orta ışıklar yerine köşelerden ışıklandırma	1	0	0	**1**
3	**RENK**	45	renk	0	2	6	**8**
		46	açık renkler	3	0	3	**6**
		47	soğuk açık renkler	0	0	1	**1**
		48	pastel renkler	2	1	0	**3**
		49	duvar rengi	0	0	1	**1**
		50	açık duvar rengi	2	1	0	**3**
		51	mobilyaların rengi	0	1	0	**1**
		52	açık renkli mobilyalar	1	0	0	**1**
		53	halı rengi, pencere rengi	1	0	0	**1**
		54	oda ve içindekilerin renk uyumu	1	0	1	**2**
		55	aydınlık durumuna göre renklendirme	0	0	1	**1**
		56	beyaz	2	2	0	**4**
		57	fosforlu renkler olmamalı	1	0	0	**1**
		58	deseni olmayan / sade	1	1	0	**2**

Table 9 (continued)

		ÖNÇALIŞMA: AÇIK UÇLU ANKET 19.12.2011 - 23.12.2011		GRUP-1 (11 kişi)	GRUP-2 (10 kişi)	GRUP-3 (19 kişi)	**TOPLAM CEVAP (40 kişi)**
4	**BÜYÜKLÜK / BOYUTLAR**	59	büyüklük / boyutlar	1	1	4	**6**
		60	büyük mekan / geniş mekan	3	3	2	**8**
		61	dar olmayan	0	0	1	**1**
		62	boş alan / açık alan	0	0	1	**1**
		63	yeteri kadar geniş mekan / ortalama bir genişlik	1	0	0	**1**
		64	yüksek tavan	1	3	4	**8**
		65	tavanın yüksekliği	0	0	1	**1**
		66	tavanın şekli	0	0	1	**1**
		67	yeteri kadar yüksek tavan (çok yüksek ya da çok alçak değil)	0	0	1	**1**
		68	yerden yüksek / üst kat	1	0	1	**2**
		69	kullanılmayan boş alanlar olmamalı	1	0	0	**1**
		70	oran	0	0	1	**1**
		71	fonksiyona göre boyutlar	0	0	1	**1**
5	**EŞYA**	72	eşya	0	1	1	**2**
		73	az eşya olmalı / fazla eşya olmamalı	4	4	5	**13**
		74	yeteri kadar eşya (fazla eşya olmamalı ama boş da olmamalı)	2	0	1	**3**
		75	fazla büyük olmayan eşyalar	1	0	0	**1**
		76	gereksiz eşyaların olmaması	0	0	4	**4**
		77	sıkışık olmayan eşya düzeni	0	0	1	**1**
		78	eşyaların portatifliği / istenildiğinde değiştirilebilmesi	1	1	0	**2**
		79	yeni eşyalar / eski olmayan eşyalar	0	1	0	**1**
		80	sade	3	2	1	**6**
		81	görülmeyi engellemeyen	0	0	1	**1**
		82	ergonomi	0	1	0	**1**
		83	doluluk boşluk	0	0	1	**1**
6	**DÜZEN / TASARIM**	84	düzen /tasarım	2	0	1	**3**
		85	düzenli eşya / dağınık olmayan	3	2	2	**7**
		86	kullanışlı / fonksiyonel	4	0	1	**5**
		87	hareket edilebilen / hareket alanı açık	0	2	0	**2**
		88	zevke göre döşenmiş olması / dekorasyonunun iyi olması	3	0	0	**3**
		89	iyi işçilik / badanasının vb. iyi olması	1	0	0	**1**
7	**HAVADAR / HAVALANDIRMA**	90	havadar / havalandırma	2	1	3	**6**
		91	hava sirkülasyonu / havalandırma	1	0	0	**1**
		92	rüzgar	0	0	1	**1**
		93	doğal havalandırma / klima vb suni havalandırma olmayan	1	0	0	**1**
8	**FİZİKİ KOŞULLAR**	94	fiziki koşullar	0	0	0	**0**
		95	temizlik	1	2	0	**3**
		96	temiz hava	0	0	1	**1**
		97	temiz koku / kokusuz	2	0	1	**3**
		98	ısı / uygun sıcaklık / iklim	3	0	0	**3**
		99	ses yalıtımı / gürültüsüz ortam / seçici ses yalıtımı	1	0	1	**2**
		100	güvenli yapı / sağlam yapı	1	0	0	**1**
		101	odanın yönü / konumu	0	0	2	**2**
9	**DOĞAL**	102	doğal	0	0	1	**1**
		103	doğal malzeme kullanılması (gerçek ahşap vb)	0	2	0	**2**
		104	canlı çiçekler	0	0	1	**1**
		105	doğa manzarası	0	1	0	**1**
		106	deniz manzarası	1	0	0	**1**
10	**DİĞER KULLANICILAR / SOSYAL FAKTÖRLER**	107	diğer kullanıcılar / sosyal faktörler	0	0	1	**1**
		108	mekandaki diğer insanlarla arasının iyi olması	1	0	0	**1**
		109	kalabalık olmaması / kişisel mesafelerin korunması	1	2	1	**4**
		110	kişinin bir sıkıntısının olmaması	1	0	0	**1**

katılan gruplar:	Eryamanda ikamet eden ODTÜ personeli	ODTÜ Mimarlık Fak. idari personeli	ODTÜ Mimarlık Böl. 1.sınıf öğrencileri	İfadeyi telaffuz eden toplam kişi sayısı

APPENDIX C

A SURVEY ON CLASSROOM DESIGN GUIDES

C.1. CASES OF TEN UNIVERSITIES AMONG THE TOP 100 LIST OF TIMES HIGHER EDUCATION

Table 10 Classroom design guides of ten universities (ordered by year)

	University	Year	Document Name
1	Cornell University	1994	Space Planning Guidelines: Cornell University Ithaca Campus
2	The University of North Carolina at Chapel Hill (UNC)	1997	Chancellor's Classroom Improvement Initiative Classroom Standards (draft)
		2003	Classroom Utilization and Mix Analysis
3	University of Washington	2002	General Assignment Classrooms: Facility Design Information
		2008	General Assignment Classrooms: Design Guide
4	Emory University	2008	Emory College Classroom Design Guide
5	Stanford University	2009	Stanford University Space and Furniture Planning Guidelines
6	University of California Berkeley	2007	Teaching and Learning in a Great Place: Managing the Classroom Resource
		2010	The Case for Active Learning Classrooms (Final Report)
7	University of Toronto	2012	Design Criteria for Classrooms
8	McGill University	2013	McGill University Classroom Guidelines and Standards: Prepared for the teaching and learning spaces working group (TLSWG)
		2014	Building Design Standards, Special Building Areas: Classrooms
9	Yale University	2014	Guidelines for Yale Learning Spaces
10	Princeton University	2014	Princeton University Facilities Department Design Standards Manual

As mentioned in Section 2.6.3, “classroom design guides” were surveyed in order to have insight into university classroom designs and their terminologies. The design guides were selected from the top 100 universities in the World (Times Higher Education, 2014). They were searched via internet by using the English and Turkish keywords, and classroom designs guides of ten universities, which are listed in Table 10, were accessed.

These guides can be categorized according to their contents as follows:

1) Guides compiling and comparing other classroom design guides (Cornell University, 1994)
2) Guides briefly introducing general principles of classroom design (Emory University, 2008; Washington University, 2008; McGill University, 2013; 2014; Yale University, 2014)
3) Guides defining ideal classroom designs in detail (UNC, 1997; University of California Berkeley, 2007; Stanford University, 2009; University of Toronto, 2012-a; Princeton University, 2014)
4) Guides analyzing the existing classrooms (UNC, 2003)

Since the eight of the ten universities listed above are from the USA, a short description for their common terminology is needed. Nearly all universities across the USA use a standard reference document called “Postsecondary Education Facilities Inventory and Classification Manual (FICM)”, published by the U.S. Department of Educational Research and Improvement (NCES, 2006). In FICM, the term “classroom” contains “not only general purpose classrooms, but also lecture halls, recitation rooms, seminar rooms, and other spaces used primarily for scheduled nonlaboratory instruction” (NCES, 2006). Similarly, the current thesis also uses the term “classroom” with this comprehensive meaning. The use of FICM was described as follows:

> The FICM is a tool that can help institutions initiate, conduct, report, and maintain an institutional space inventory that can provide answers to such basic questions as how much space is available, what kind of space is it, to whom is it assigned, and how efficiently is it being used and maintained. This information permits institutions to assess the adequacy of their current space and allows them to begin planning for future space needs (NCES, 2006).

FICM includes “space use codes” and “physical measurement standards”, such as “Net Assignable Area (Net Assignable Square Feet—NASF)”, which were referred by design guides of various universities.[15]

C.1.1. Classroom size and capacity

Classroom design guides define classroom size according to the total number of students (Cornell University, 1994; Emory University, 2008; Stanford University, 2009; University of Toronto, 2012-a). They define “assignable square feet per seat (ASF/S)” values either to determine the size of a new classroom design based on the required number of seats or to determine the number of seats which comfortably fit into an existing classroom. Table 11 illustrates ASF/S values in the guide of Cornell University, which compiles the related guides of the State University of New York (SUNY), Western Interstate Commission for Higher Education (WICHE), California Postsecondary Education Commission, and Massachusetts Institute of Technology (MIT).

One of the latest definitions of classroom size is written in design guide of Princeton University (2014) as follows:

> As a rule of thumb, if an instructional space is to have fixed seating it will require 15 square feet of space per student (not including space required for A/V or other specialized equipment). If a classroom is to be provided with moveable seating the minimum area allowance per student rises to between 20 and 25 square feet for typical instructional space and between 25 and 30 square feet for seminar or preceptorial use. (In preliminary design it may prove useful to establish target standards of 25 to 30 square feet per student in typical classrooms and to aim as high as 50 square feet per student in media-rich facilities.) (p. 2.3/5).

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[15] It is necessary to remind that the guides mentioned above use “imperial units”, whereas “Metric systems of units” were preferred in the current thesis. For the ease of reading in both cultures, the following definitions might be beneficial:

- 1 in (inch) = 2,54cm (centimeter).
- 1 ft (singular foot, plural feet) = 12 in (inch) = 0,3048 m (meter).
- 1 ft^2 (singular square foot, plural square feet) = 0.09290304 m^2 (square meters).

- 3 feet 5 inches is sometimes denoted as 3′−5″.
- 3 ft^2 sometimes denoted as 3 sq ft.

Table 11 Classroom / Classroom Service: Planning Guidelines Assignable Square Feet per Seat (Station) ASF/S* (Cornell University, 1994, p. 8).

Room Type	Number of Seats (Stations)	Cornell Guidelines ASF per seat	SUNY**** ASF per seat	WICHE ASF per seat	California ASF per seat	MIT***** ASF per seat
Seminar** Class and Lecture*** Rooms	5-9	22-26	20	20-30	15	24 w/tables
	10-19	18-22	20	20-30	15	24 w/tables
	20-29	17-18	16	16-20	15	17 w/tablet arms
	30-39	16-17	16	15-18	15	17 w/tablet arms
	40-49	15-16	16	14-16	15	17 w/tablet arms
	50-59	14-15	16	14-16	15	17 w/tablet arms
	60-99	13-14	16	13-15	15	13-14; theater
	100-149	12-13	13	11-14	15	12-13; theater
	150-299	10-12	12	10-14	15	11-12; theater
	300-500	10-12	12	9-12	15	11; theater

* Service, aisle and instructional spaces are included in the ASF per seat guidelines.
** Seminar guidelines can also be used to size conference rooms located within office complexes.
*** ASF/S guidelines for classroom and lecture hall seating assume use of folding table arm writing surfaces. Guidelines for small seminar rooms assume seating at tables. For Large lecture halls with stationary (i.e. continuous) work surfaces, the ASF/S should be increased accordingly.
****SUNY standards apply to the statutory colleges.
*****MIT utilizes three sets of ASF/S guidelines for seating (for rooms 5 to 19 seats), tablet arm chairs (for rooms from 20 to 59 seats) and theater seating (for rooms from 60 to 500 seats) are shown.

In addition to the classroom capacity, the shape of room, the types of furnishings and other special design features may affect the required space per student. University of Toronto (2012-a, p. 15) defined typical minimum classroom space allocation per station as follows: 1.5m^2 for tablet arms; 1.7m^2 for lecture style, fixed or loose; 2.4m^2 for seminar or horseshoe (case), workshop (group tables). Emory University (2008, p. 18) and Stanford University (2009, p. 28) define classroom sizes in more detailed tables.

C.1.2. Classroom plan proportions

As mentioned by Emory University (2008, p. 18), the plan proportion of a classroom affects “seating capacity, sight lines and ability for student and instructor to interact with one another”. Hence, many of the classroom design guides that were examined define the length to width ratio of ideal classroom design.

For classrooms and seminar rooms, the guides defined the ideal ratios between 1:1 and 1:1.5. The University of North Carolina at Chapel Hill (UNC, 1997, p. 5) and University of Washington (2008, p. 3) defined ideal classroom ratio as 1:1.5 ; on the other hand, University of Toronto (2012-d) defined the ideal ratio as 1:1 and maximum ratio as 1:1.5 .

Wide-shallow classrooms and narrow-deep classrooms have some advantages and disadvantages. In wide-shallow classrooms, instructors see more of the student body (University of Toronto, 2012-d); on the other hand, students at the sides may have difficulties to see the screen and to hear the instructor (Emory University, 2008, p. 18; University of Toronto, 2012-d). Moreover, it may be difficult for instructors to make eye contact with students and writing on boards (Emory University, 2008, p. 18).

Narrow-deep classroom are preferred by A/V (Audio Visual) professionals since all students can be “within a viewing cone of the projected image” (University of Toronto, 2012-d). Hence, UNC (1997, p. 5) suggested to design the instructor area along the narrow wall of the classroom. However, in deep classrooms, students in the last rows may have difficulties “to communicate, hear and see the front of the room”, and “instructor spaces may be too narrow for screens and boards” (Emory University, 2008, p. 18). University of Toronto (2012-a, p. 8) stated that “narrow-deep rooms should be avoided.”

Square classrooms combine benefits of the narrow-deep and wide-shallow rooms, and minimize the negative effects mentioned above (University of Toronto, 2012-d; Emory University, 2008, p. 18).

C.1.3. Classroom floor and ceiling types

In classrooms with loose seating, flat floors provide flexibility for different classroom activities (UNC, 1997, p. 5). On the other hand, in classrooms with fixed seating, sloped or tiered floors optimize sight lines (Yale University, 2014, pp. 5-6). In design guides, the ideal floor type is determined by classroom capacity, number of seating rows, and plan dimensions. For instance, the University of North Carolina at Chapel Hill (UNC, 1997, p. 5) stated that "classrooms with sloped or tiered floors may provide better sight lines for students, especially in larger General Purpose Classrooms (60+ seats). University of Toronto (2012-a, p. 9) emphasized that "any classroom with more than 7 rows must be tiered/sloped". The floor type should also be compatible with ceiling height, "rooms with low ceilings may seem cramped or have poor sight lines for projected images if the floor is sloped or tiered" (UNC, 1997, p. 5). Ceiling type is mostly mentioned for acoustic concerns in the classroom design guides.

C.1.4. Classroom ceiling heights

Ceiling height is one of the significant concepts in classroom design guides. The guides suggest ideal or minimum ceiling heights according to the classroom capacity, the distance to the last row, and the size of the projected image or board. As in the case of classroom capacity, the guides presented detailed tables defining ideal ceiling heights for various conditions. Table 12 and Table 13 illustrate the examples from The University of North Carolina at Chapel Hill (UNC, 1997). These tables indicate suggested minimum ceiling heights for classrooms depending on the room capacity, and for lecture halls depending on the distance to last row (UNC, 1997, p. 18). Simplified version of the same table can be seen in the design guide of Yale University (2014, p. 5).

Table 12 Suggested minimum ceiling heights for Classrooms, depending upon the room capacity (UNC, 1997, p. 6)

Room capacity	Distance to last row	Flat floor	Sloped or Tiered Floor	
		Ceiling height	Ceiling height in front	Ceiling height in rear
Less than 20	NA	9’	Not recommended	
20-49 stations	NA	12’	Not recommended	
50-75 stations	NA	12’	12’	10’
Greater than 75	50’ to last row	Not recommended	17’	10’

Table 13 Suggested minimum ceiling heights for Lecture Halls, depending upon the distance to last row (UNC, 1997, p. 18)

Distance to last row	Ceiling height in front	Ceiling height in rear
50’ to last row	17’	10’
75’ to last row	22’	10’
100’ to last row	28’	10’

University of Washington (2008, p. 4) defined required ceiling height depend on the depth and slope of rooms. When the distance between the front wall and last row increased, ceiling height should also be increased in order to accommodate the appropriate projection screen. University of Toronto (2012-d) also emphasized that the minimum ceiling height for classrooms depend on the projected image size: “The projected image must be min. 4’6 from the floor, and an 8’ wide image is 6’ tall (10‘6 total).”

C.1.5. Classroom plan geometries and walls

The University of North Carolina at Chapel Hill (UNC, 1997, p. 18) suggested a modified fan shape plans for Lecture Halls in order to provide good sight lines and acoustics. Both the UNC and Emory University (2008, p. 14) discussed plan geometry in terms of acoustic concerns. They emphasized that side walls should not be parallel, should be angled from the instructor's area, and should have rough or textured surfaces.

C.1.6. Seating arrangements in classrooms

Emory University (2008, p. 7) emphasized that "the conventional method of designing the room first then filling it- usually leads to an inefficient layout, poor sightlines and reduced seating capacity" and their suggestion was to develop classrooms from the "inside out". Different than the design guides of other universities, Emory University (2008) directed the design process in this way:

- Determine the general location, size and orientation of screens, whiteboards, and seating space.
- Ensure the instructor area meets the minimum dimensions required.
- Draw viewing angles from each screen and ensure that all students seating falls within the viewing area.
- Determine the width and depth base on the proposed seating space guidelines
- Determine the location and size of aisles
- THEN decide where the walls should be located (p. 7).

The above mentioned directions for the design process are questionable; however, this indicates the significance attributed to the seating arrangements in classroom designs.

Most universities defined the positions of seating based on the visibility of projection screen or board within the optimum viewing angles of the students. Both UNC (1997, p. 5) and University of Washington (2008, p. 3) defined "the 45 degree center axis of classrooms" in which student seating should be arranged in order for adequate viewing of projection screen or board. University of Washington (2008, p. 3) also stated that center aisles should be avoided in order to provide maximum seating area with the optimum viewing angle. University of Toronto (2012-a, p. 8) defined axes at 30 degrees from the left and right edges of the projected image. These lines produce a "viewing cone" in which 100% of the student seating should be arranged. For vertical direction, University of Toronto suggested that the top of the projected image should not exceed the 40 degrees of the students' eyes (2012-a, p. 8). Yale

University (2014, pp. 5-6) defined this are with 45 degrees of the central horizontal axis and 35 degrees vertical.

Some universities defined the type of seating based on the capacity and activity of the classroom. For instance, Yale University (2014, p. 9) stated that classrooms under the capacity of 50 students should have “movable seats and tables unless there are special design requirements.”

Depending on the type of seating, the required space might be changed. For instance, University of Toronto (2012-a, p. 16) defined minimum gap between furniture (rows) as follows; 30” for loose desks, fixed continuous loose seating, and fixed continuous radius-arm seating; 18” for fixed tablet arm (tablet/seat retracted).

These examples can be multiplied; however, these examples are sufficient to give an insight about different criteria of classroom designs for the scope of this thesis. For further information, the guides listed in Table 10 can be accessed via internet.

APPENDIX D

SELECTION OF CASES

D.1. SELECTION OF CASES IN METU CAMPUS

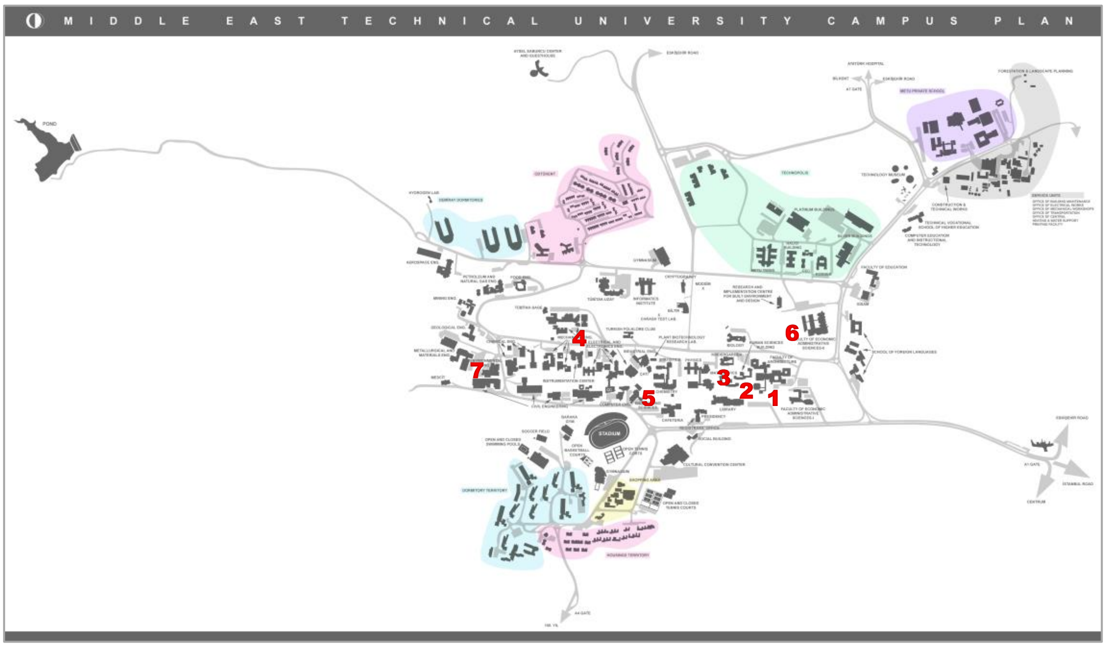


Figure 84 METU campus map, 2009.
(Source: http://odtuwebtest2.metu.edu.tr/sites/default/files/metu-map2009-ing.gif).

The red numbers in Figure 84 refer to the surveyed buildings as follows:
1) Faculty of Architecture, 2) Social Sciences Building (Human Sciences Building), 3) Department of Mathematics, 4) Department of Mechanical Engineering – G Block, 5) Central Engineering Building (Engineering Sciences), 6) Faculty of Economic and Administrative Sciences – B Block, 7) Department of Environmental Engineering.

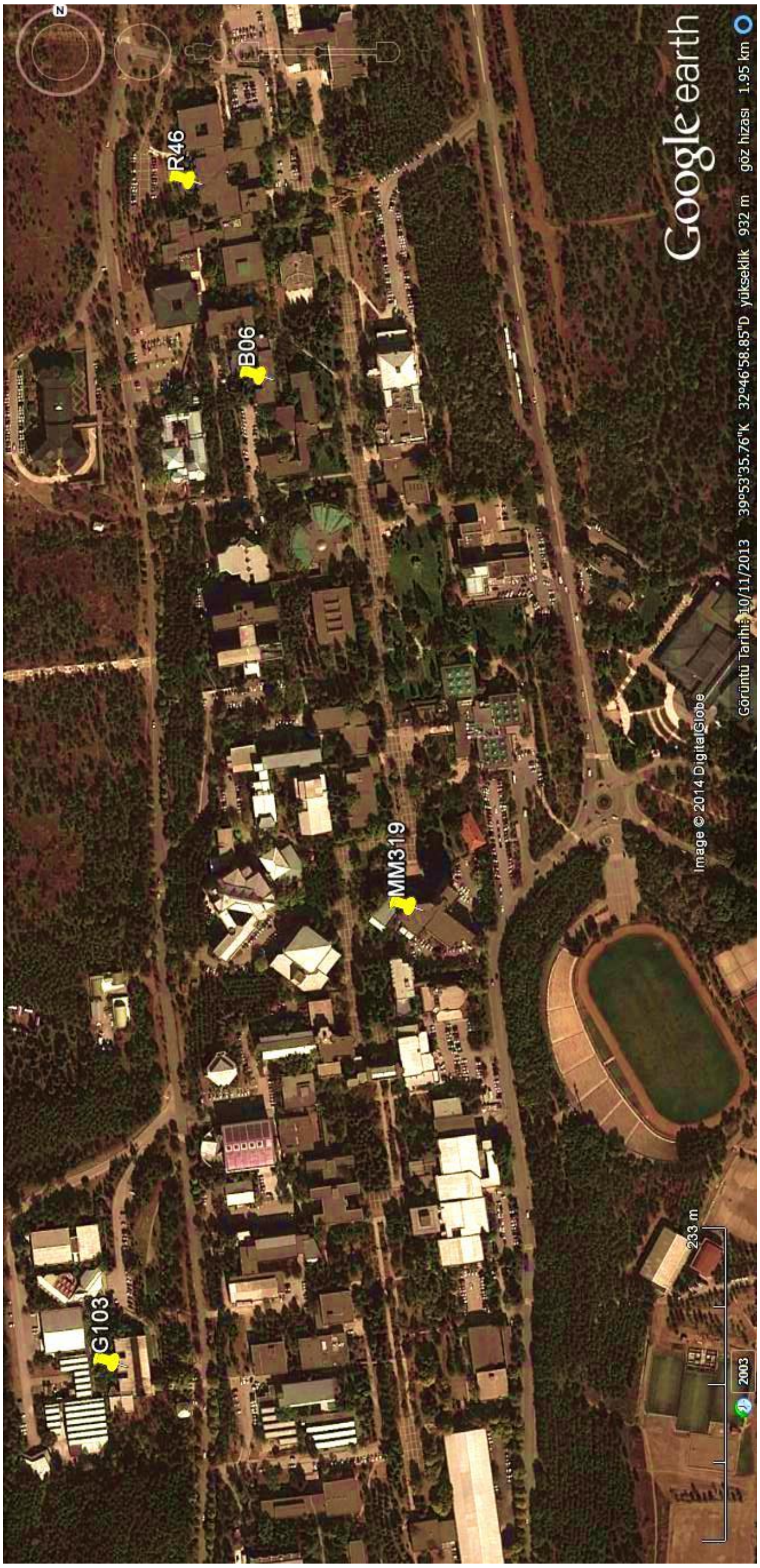


Figure 85 Locations of selected classrooms in METU campus (Googleearth, 2014).

Table 14 Summary information about surveyed classrooms at METU.

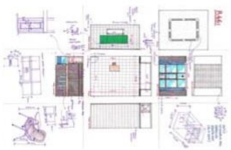
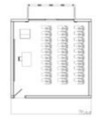
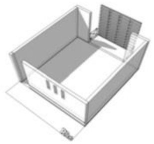
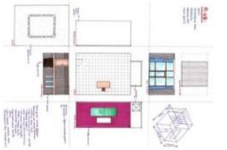
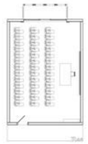
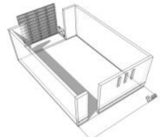
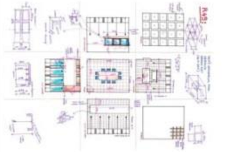
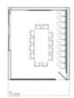
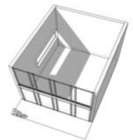
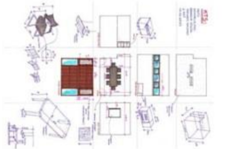
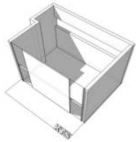
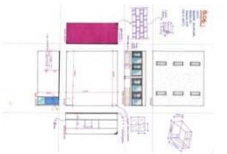
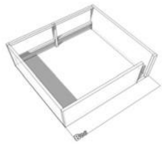
	Name	Photographs	Measured Sketches	Plans	SkecthUp Model (Simplified)	SkecthUp Model (Detailed)	Descriptions
1	**R46**						**Place:** Faculty of Architecture **Function:** Classroom **Capacity:** 30 **Width & Length:** 5.8mX6.4m **Height:** 3.6m
2	**R48**						**Place:** Faculty of Architecture **Function:** Classroom **Capacity:** 39 **Width & Length:** 5.8mX8.4m **Height:** 3.6m
3	**R49**	 					**Place:** Faculty of Architecture **Function:** Seminer Room **Capacity:** 12 (+18) **Width & Length:** 4.6mX5.7m **Height:** 4.9m
4	**KTS**	 					**Place:** Faculty of Architecture **Function:** Seminer/Meeting Room **Capacity:** 8 (+7) **Width & Length:** 4.1x5.7m **Height:** 4.5m
5	**B06**						**Place:** Social Sciences Building **Function:** Classroom **Capacity:** 59 **Width & Length:** 7.2mX7.9m **Height:** 3.0m

Table 14 (continued)

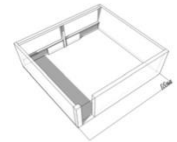
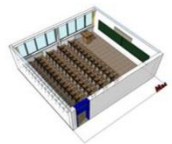
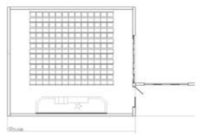
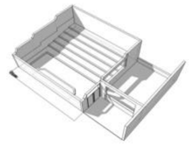
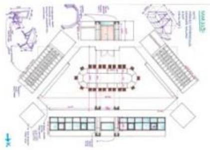
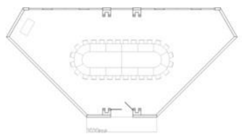
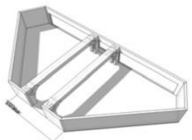
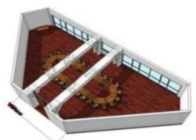
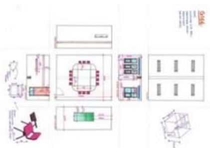
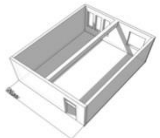
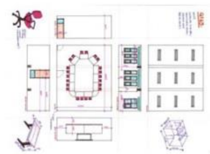
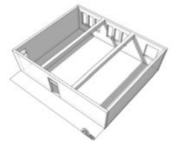
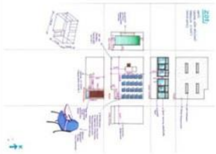
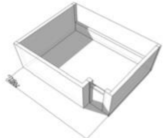
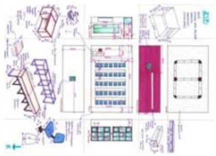
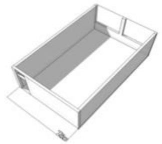
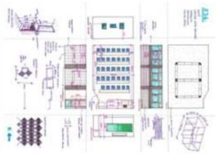
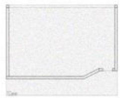
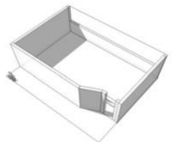
	Name	Photographs	Measured Sketches	Plans	SkecthUp Model (Simplified)	SkecthUp Model (Detailed)	Descriptions
6	**M04**						**Place:** Dep. of Mathematics **Function:** Classroom **Capacity:** 65 **Width & Length:** 7.2mX7.9m **Height:** 3.0m
7	**G103**						**Place:** Dep. of Mechanical Eng. **Function:** Tiered Classroom **Capacity:** 91 **Width & Length:** 9.0mX9.7m **Height:** 2.5-2.5m stepped-floor & stepped ceiling
8	**MM319**						**Place:** Central Engineering Building **Function:** Seminer/Meeting Room **Capacity:** 28 (+4) **Width & Length:** 9.3mX19.8m **Height:** 2.6m
9	**G166**						**Place:** Faculty of Economic and Administrative Sciences **Function:** Seminer Room **Capacity:** 14 (+4) **Width & Length:** 6.2mX7.8m **Height:** 3.2m
10	**G169**						**Place:** Faculty of Economic and Administrative Sciences **Function:** Seminer Room **Capacity:** 22 (+2) **Width & Length:** 7.8mX9.3m **Height:** 3.2m

Table 14 (continued)

	Name	Photographs	Measured Sketches	Plans	SkecthUp Model (Simplified)	SkecthUp Model (Detailed)	Descriptions
11	**Z01**						**Place:** Department of Environmental Engineering **Function:** Classroom **Capacity:** 20 **Width & Length:** 4.5mX5.8m **Height:** 2.4m
12	**Z17**						**Place:** Department of Environmental Engineering **Function:** Classroom **Capacity:** 35 **Width & Length:** 5.7mX9.4m **Height:** 3.0m
13	**Z36**						**Place:** Department of Environmental Engineering **Function:** Classroom **Capacity:** 34 **Width & Length:** 5.6mX8.7m **Height:** 3.0m

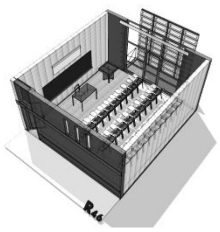
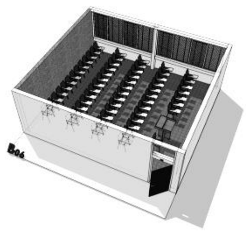
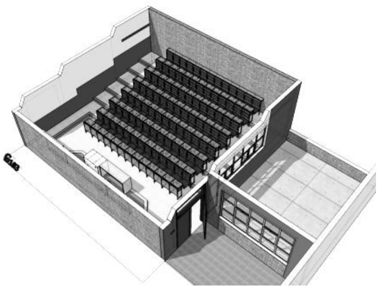
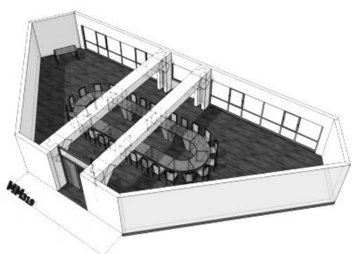
APPENDIX E

ADDITIONAL MATERIALS ABOUT SELECTED CASES

E.1. SKETCHES AND 3D MODELS OF SELECTED CASES

Among the 13 classrooms mentioned in Appendix D, four cases were selected and used in the experiments in the current thesis. The four classrooms are briefly introduced in Table 15, and their sketches and models are illustrated in the following pages.

Table 15 The classrooms used in the experiments in the current thesis.

 **R46** used in Experiment-1 and Experiment-2 (additionally, in Experiment-9)	 **B06** used in Experiment-3, Experinet-4, Experiment-5 (additionally, in Experiment-10 and 11)
 **G103** used in Experiment-6 and Experiment-7	 **MM319** used in Experiment-8

E.1.1. Sketches of R46

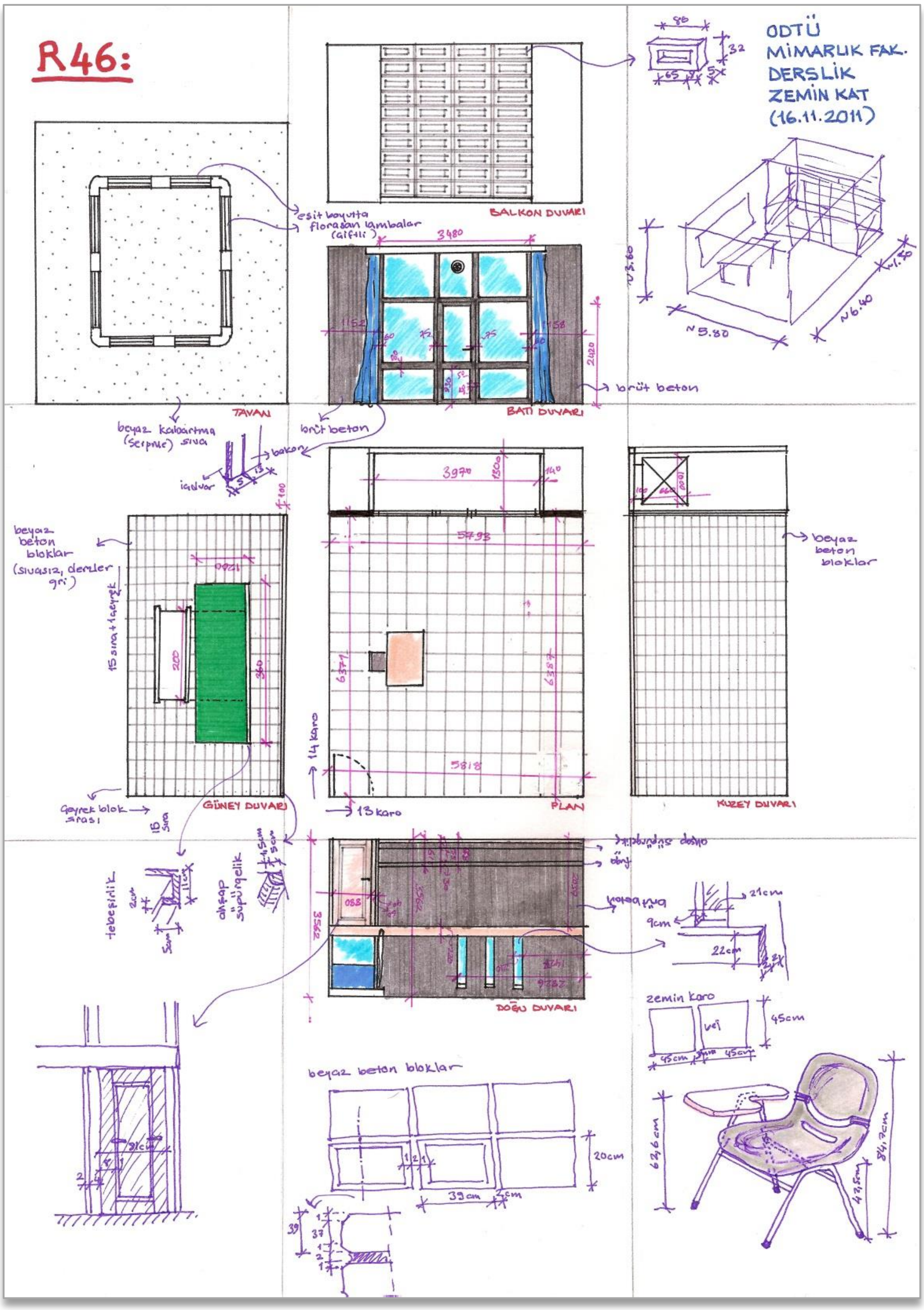


Figure 86 Sketches of classroom R46, by Özyıldıran, 2011.

E.1.2. Model of R46

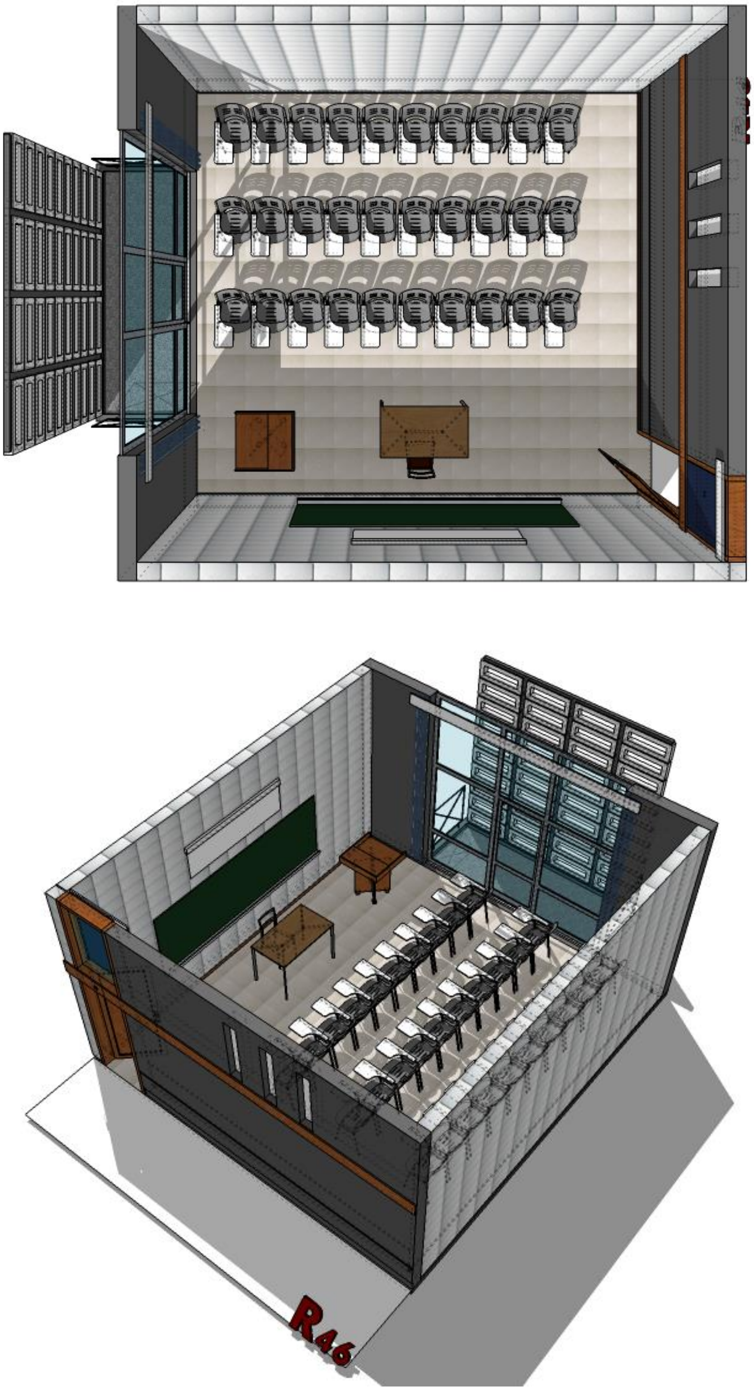


Figure 87 SketchUp model of classroom R46.

E.1.3. Sketches of B06

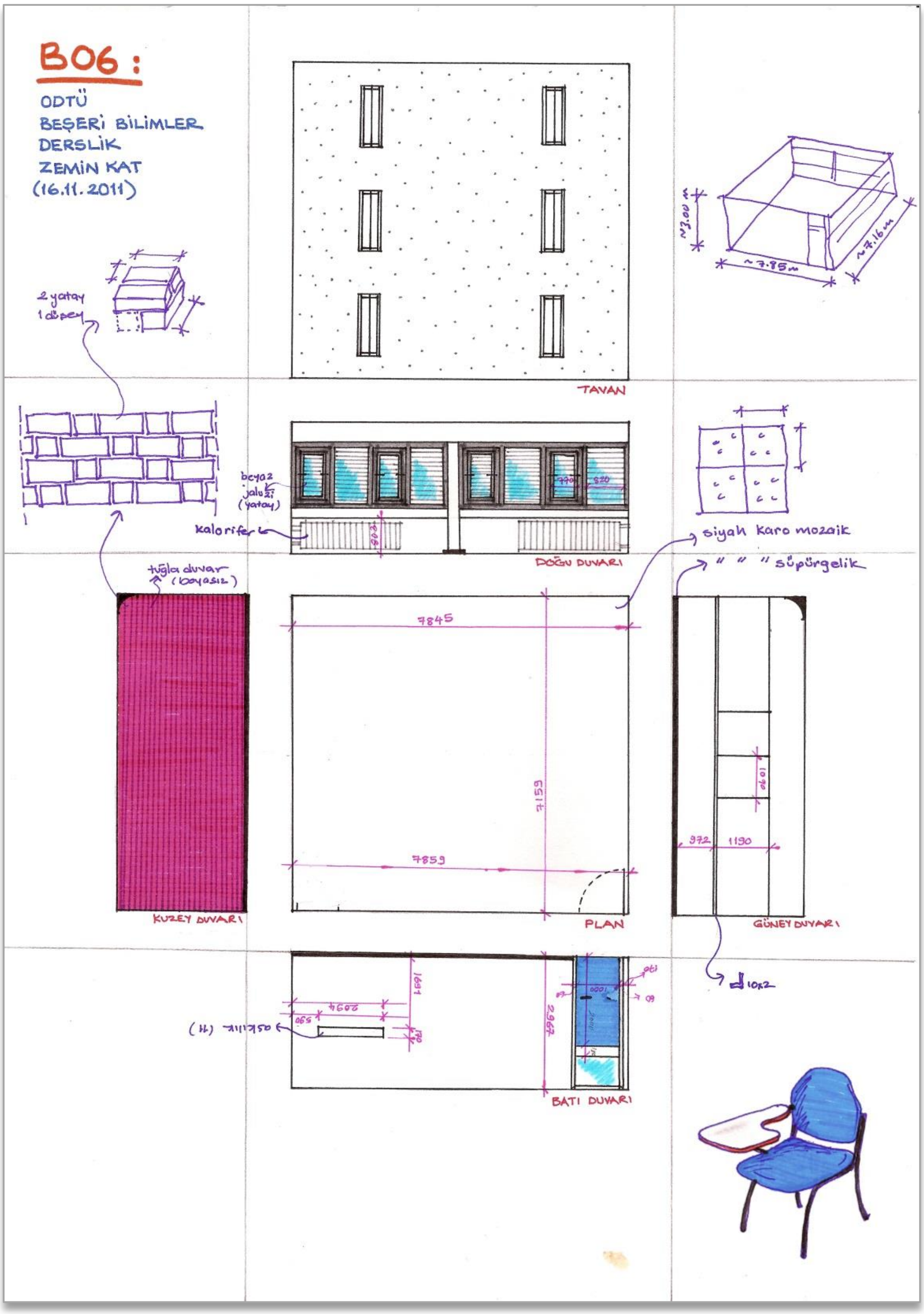


Figure 88 Sketches of classroom B06, by Özyıldıran, 2011.

E.1.4. Model of B06

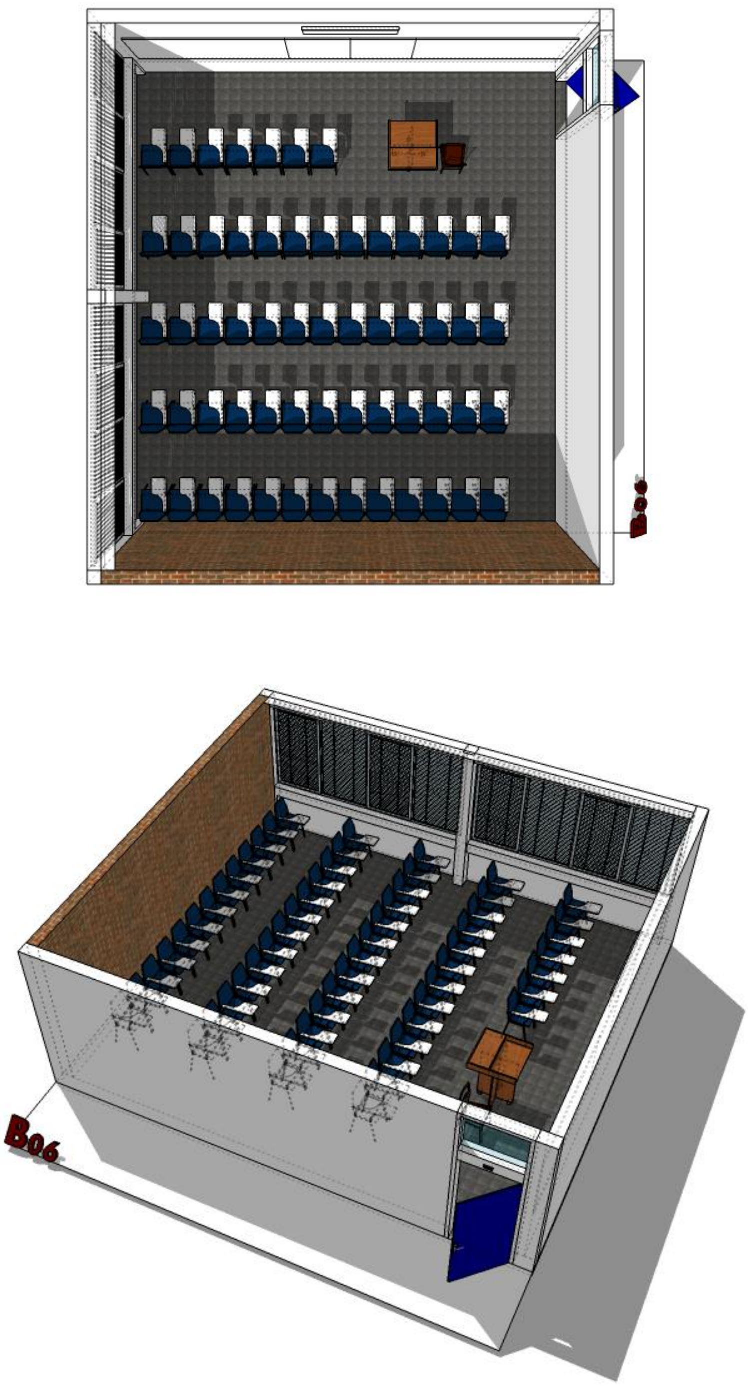


Figure 89 SketchUp model of classroom B06.

E.1.5. Sketches of G103

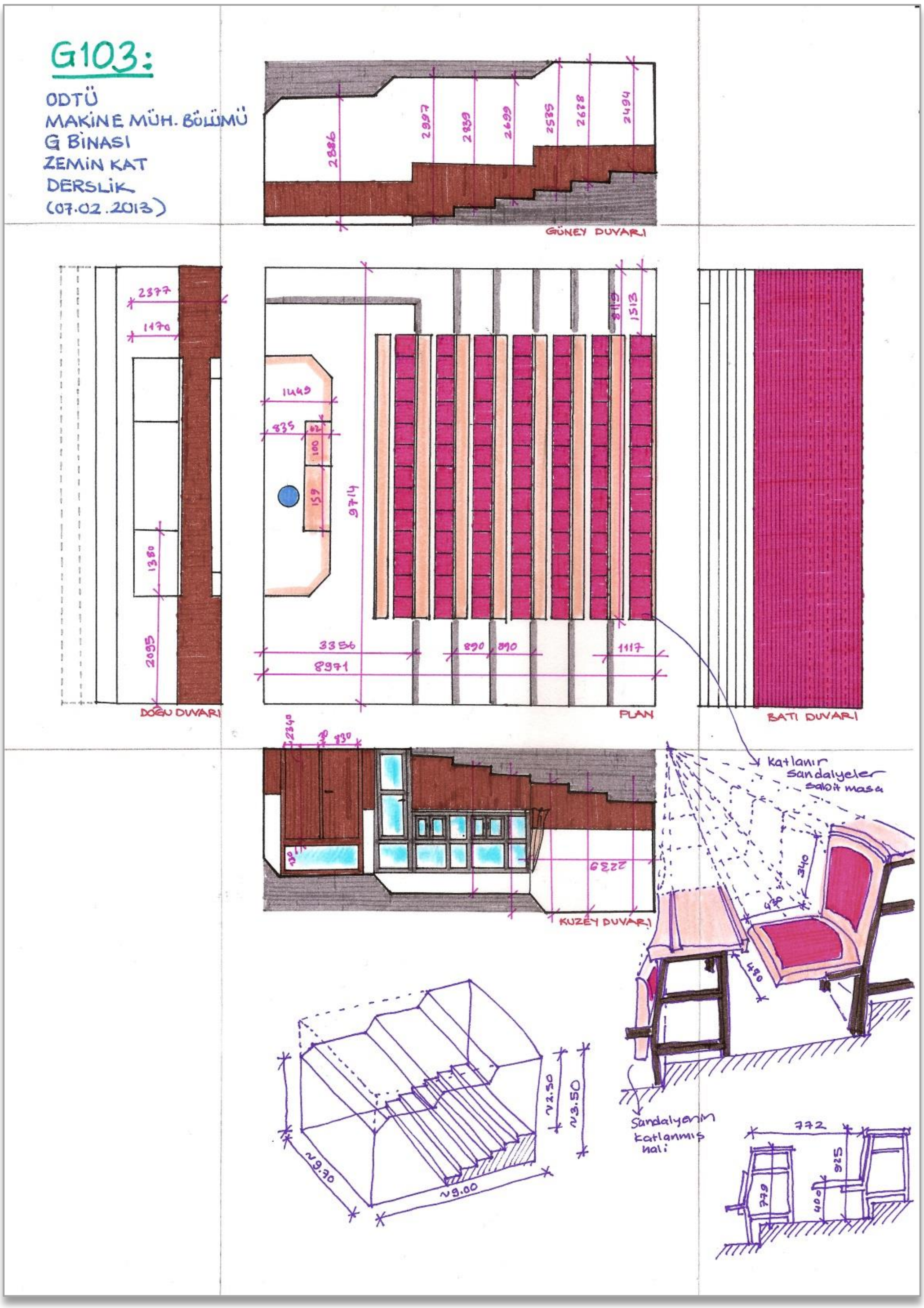


Figure 90 Sketches of classroom G103, by Özyıldıran, 2013.

E.1.6. Model of G103

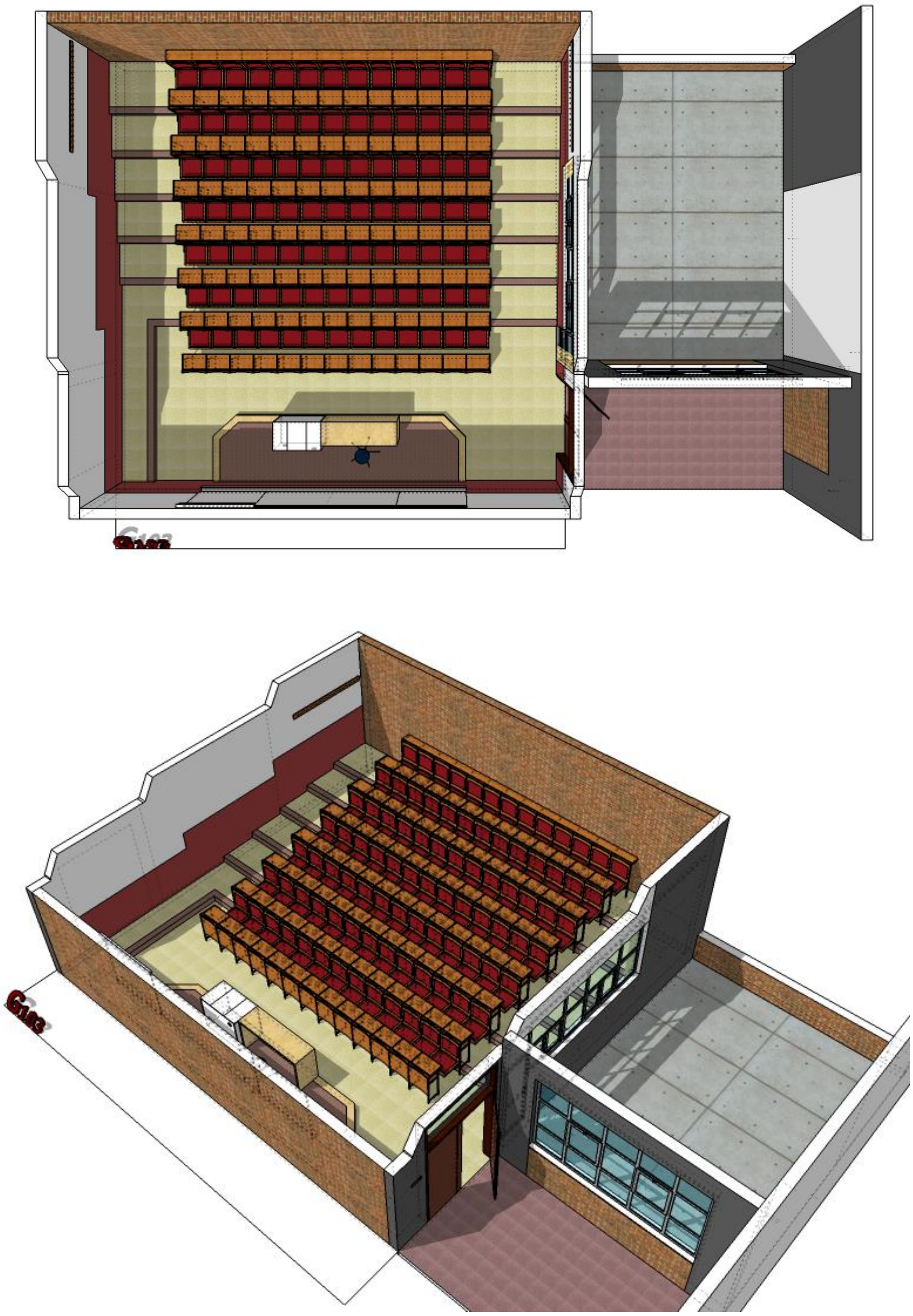


Figure 91 SketchUp model of classroom G103.

E.1.7. Sketches of MM319

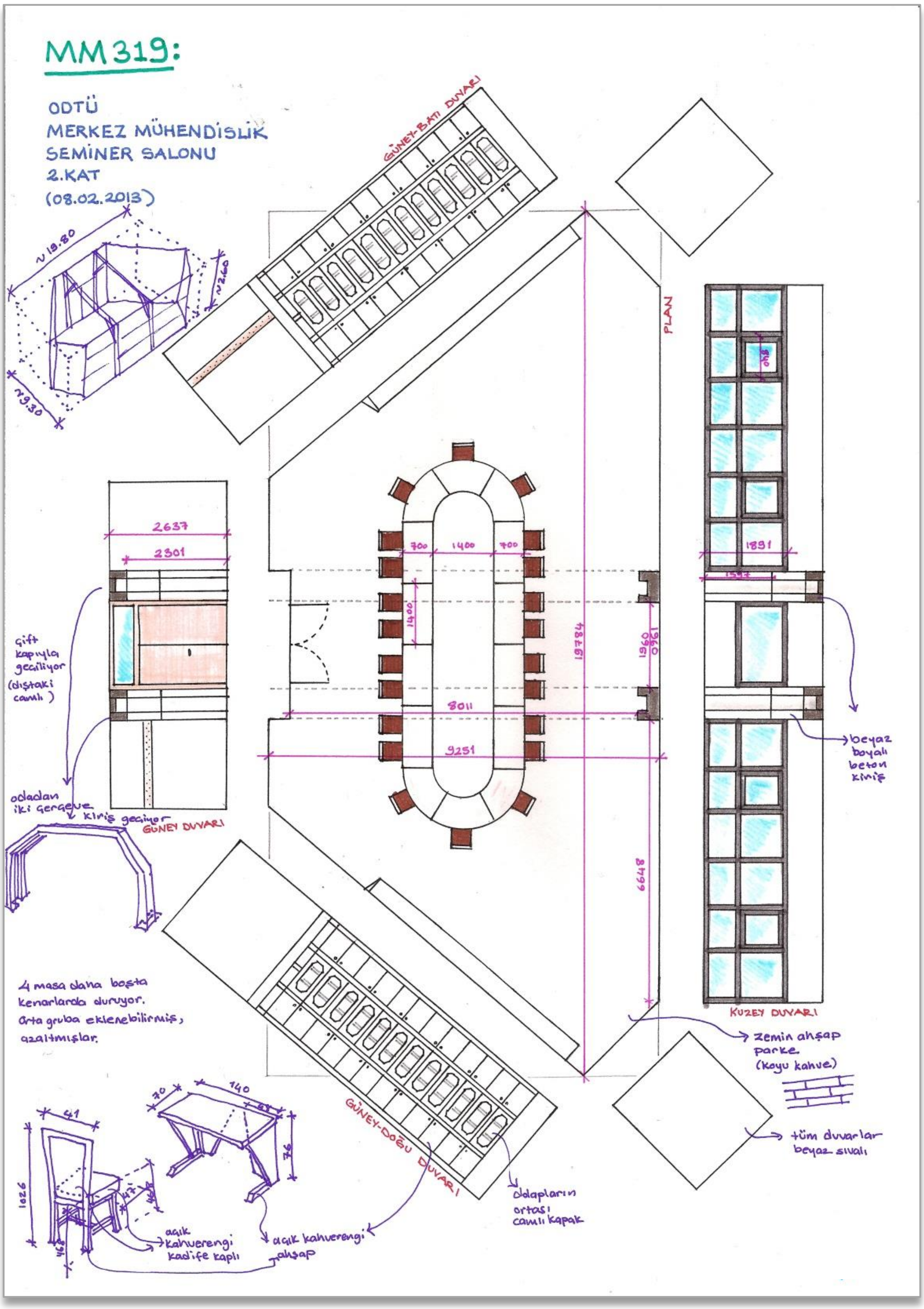


Figure 92 Sketches of room MM319, by Özyıldıran, 2013.

E.1.8. Model of MM319

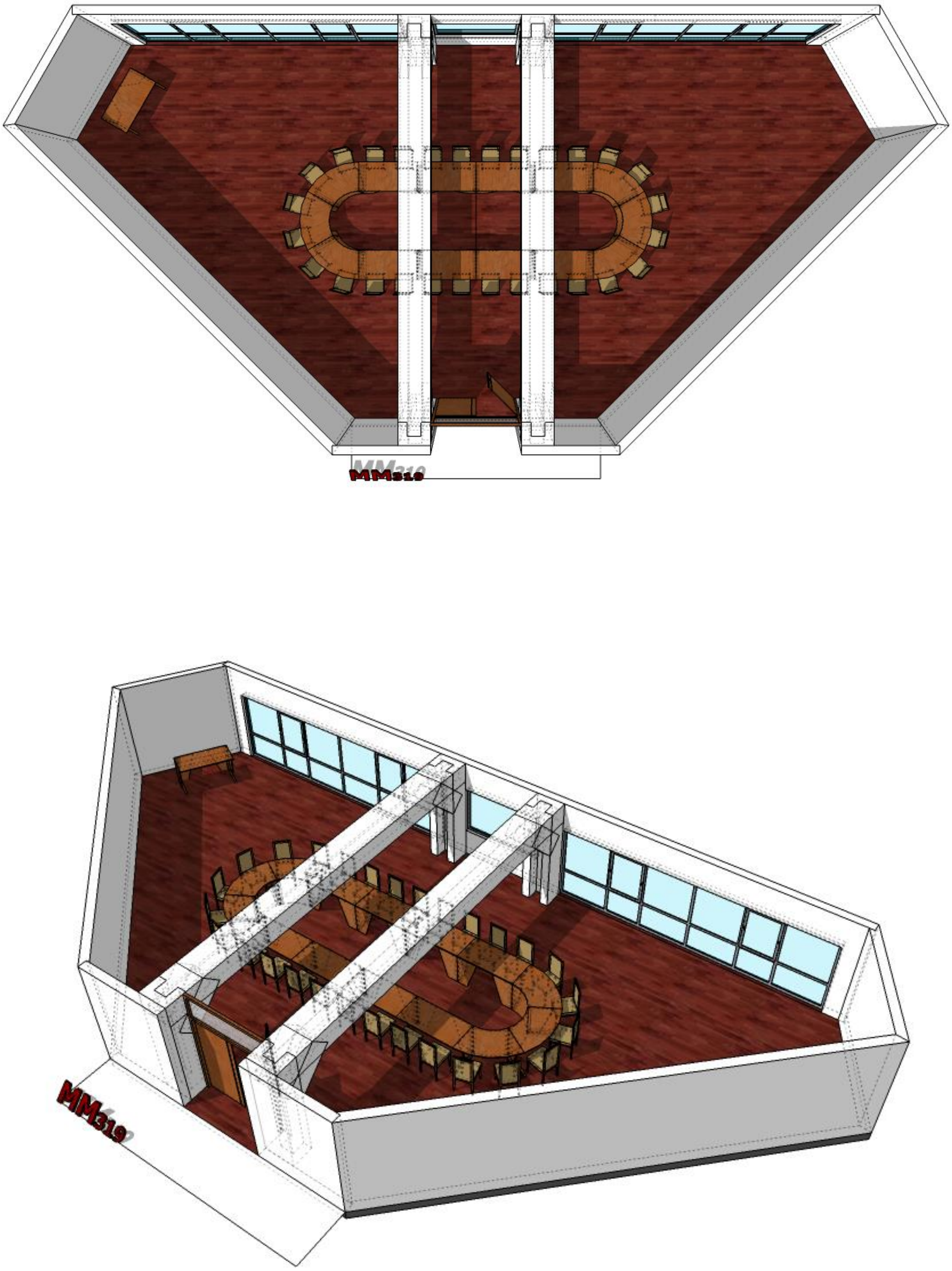


Figure 93 SketchUp model of room MM319.

APPENDIX F

MODELING AND ANIMATION PROCEDURES

F.1. MODELING AND ANIMATION PROCEDURES

F.1.1. Modeling and animation procedures: cases of chairs

Figure 94 Real room and its computer simulation. Left: a photograph of classroom B06 (2011). Right: screenshot from the computer simulation called Model-A in Experiment-5.

Table 16 Modeling and animation procedures: cases of chairs in classroom B06.

 sketch	 3D modeling in SketchUp	 assigning textures in SketchUp	 render & animation in Lumion

F.1.2. Modeling and animation procedures: cases of classrooms

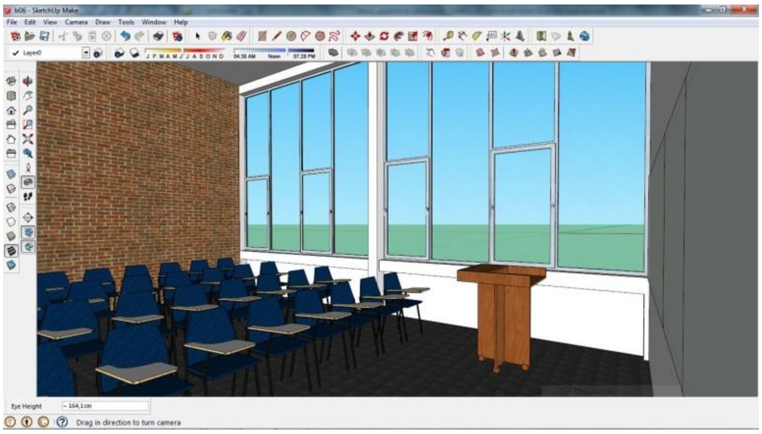


Figure 95 Step-1: modeling in SketchUp Program, Experiment-4 Model-D.

Figure 96 Step-2: modifications in Lumion Program, Experiment-4 Model-D.

Figure 97 Step-3: recording video animations, Experiment-4 Model-D.

F.2. TABLES OF SCREENSHOTS FROM ALL MODELS

Table 17 Screenshots of models of experiments.

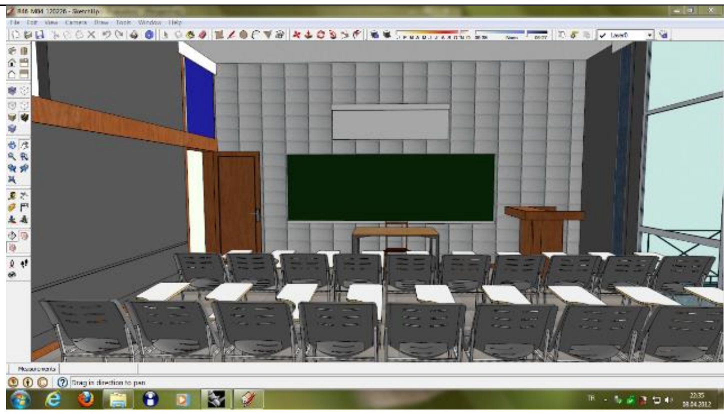
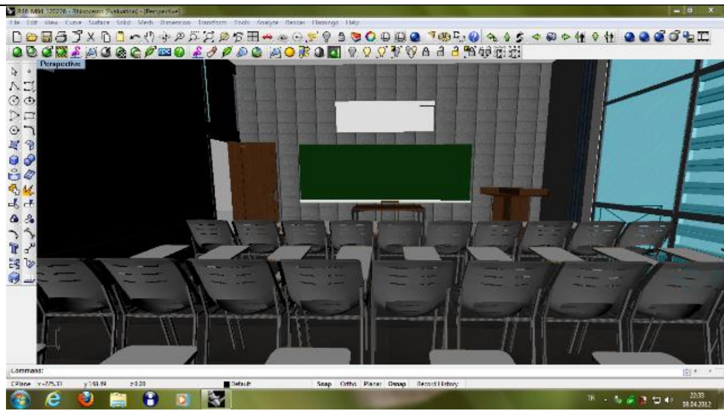
Classroom R46	
SketchUp Model (Model 1-B)	
Lumion Model (Model 1-C)	
Rhinoceros Model (Model 1-D)	

Table 17(continued)

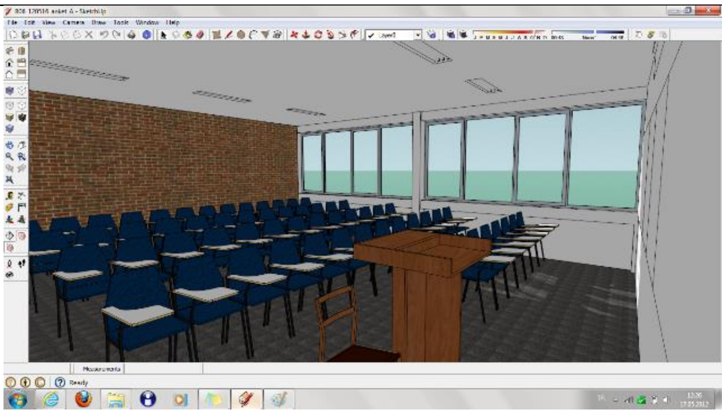
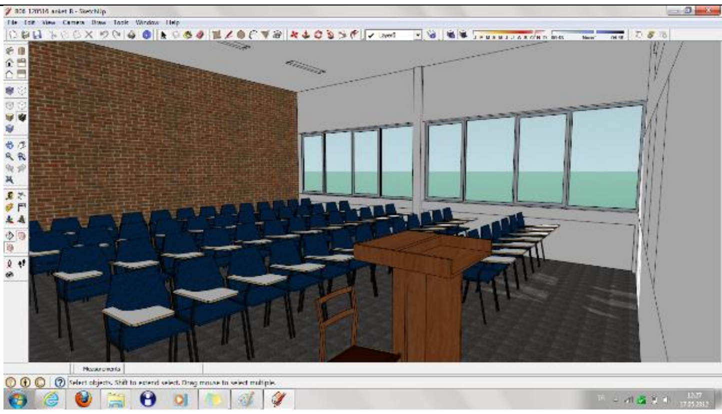
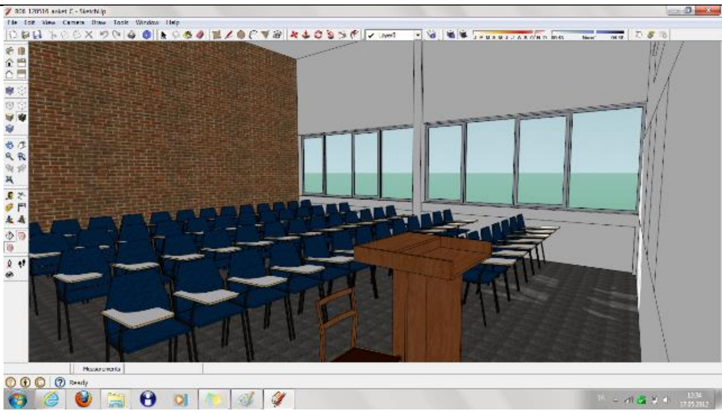
Classroom B06	
Model 3-A	
Model 3-B	
Model 3-C	

Table 17 (continued)

Model 4-A Model 5-A	
Model 5-B	
Model 4-C Model 5-C	
Model 4-D	

Table 17 (continued)

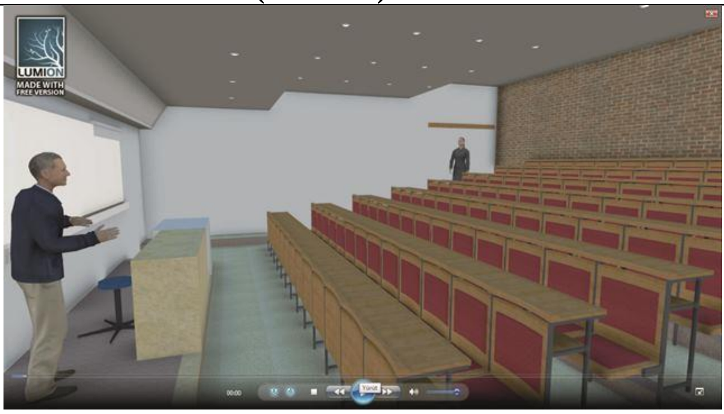
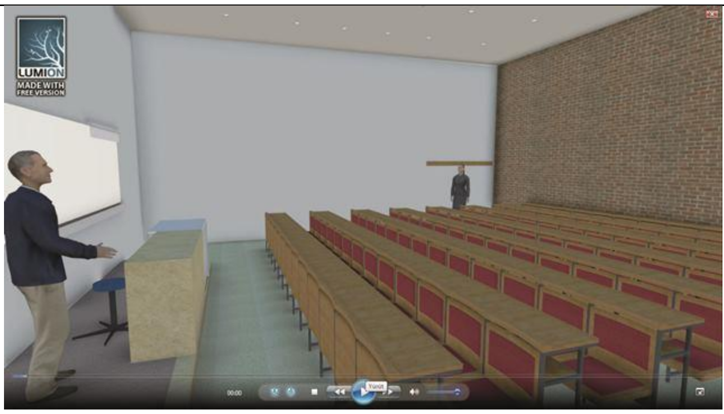
Model 6-A	
Model 6-B	
Model 6-C	
Model 6-D Model 7-D	

Table 17 (continued)

Model 6-D Model 7-D	
Model 7-F	
Model 8-A	
Model 8-B	

APPENDIX G

ADDITIONAL EXPERIMENTS

G.1. EXPERIMENT-9: COMPARING LAYPERSONS AND STUDENTS OF ARCHITECTURE ON SPACIOUSNESS EVALUATIONS

G.1.1. Introduction

Experiment-9 aimed to assess the effects of education on spaciousness evaluations. The question whether there was a significant difference between nonarchitect participants and architecture students in the spaciousness evaluations was questioned in this experiment. Related data were obtained from the data of Experiment-1 Step-1 and Experiment-2 Step-1. Results of this experiment would affect participant sampling procedure for experiments following Experiment-2.

G.1.2. Participants

Two groups of people voluntarily participated in this experiment. The first group was 25 non-architects and the second group was 30 undergraduate students from the Faculty of Architecture. Each condition of the experiment was conducted in different times. Each group was different in terms of their education and age ranges. As total numbers of participants were not equal in each group, test of normality and test of equality variance for each variable were examined in order to prevent possible violations of the analysis.

Group-1: The first group was composed of 25 non-architect staff members from various faculties of METU (one research assistant from the Faculty of Education; four research assistants from the Department of Mathematics; two janitors, two computer experts, six secretaries and ten technicians from the Faculty of Architecture). There were 14 males and 11 females. The mean age was 38.8 with a range of 24 and 57 years.

Group-2: The second group was composed of 20 first-year students, three second-year students, five third-year students, one fourth-year student from the Department of Architecture, and one second-year student from the Department of City and Regional Planning. There were 15 males and 15 females. The mean age for this group was 20.57 with a range of 19 and 23 years.

G.1.3. Stimuli

The classroom "R46" employed in Experiment-1 was again employed (see Section 3.2.3 on page 123). The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

G.1.4. Procedure

Each participant from the first group was individually invited to the classroom R46. As mentioned in Experiment-1 step-1, the participant sat in the center of the front seats to be able to see all the corners of the room. Participants were asked to evaluate the room by using the given S-C-S form. Two types of forms were employed; half of the participants evaluated the room by a list of seven-point19 adjective pairs in a random order; the other half used a list arrange in reverse order. First, the use of a seven-point adjective pairs was explained to each participant, and then they evaluated the room by using S-C-S.

One week later, the second group of participants was individually invited to the classroom to go through the same procedure.

G.1.5. Results

Photograph of R46.

Figure 98 Photograph of classroom 46.

A one-way multivariate analysis of variance was performed to investigate the effects of education on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was education (laypersons and students of architecture).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between layperson and student of architecture on the combined dependent variables, $F\ (3, 51) = 0.39$, $p = .760$; Wilks' Lambda = 0.98; partial eta squared = .02. When the results for the dependent variables were considered separately, no statistically significant difference was found.

G.2. EXPERIMENT-10: EFFECTS OF SEATING DENSITY ON SPACIOUSNESS EVALUATIONS

G.2.1. Introduction

Seating capacity (or the number of stations) is one of the significant design components of classrooms, which has been frequently reported in “classroom design guides” of universities (for further information, see Appendix C.1.1). Most of the universities assessed in the Appendix C, consider seating capacity in order to determine the size of the classroom. On the other hand, they determine the number of seats depending on the existing classroom size. According to the study of İmamoğlu (1973), the furniture of density of a room affects its spaciousness evaluations.

Since the current thesis focused on the permanent components of classrooms, the seating variable was not included in the scope of the experiments. When none of the expectations reached a significance level in Experiment-4, a question whether crowded chairs affected S-C-S scores dominantly or not was revealed. In previous experiments, it was observed that some participants focused on the number of chairs in the classroom and stated their opinions about crowdedness loudly. Hence, to clear up doubts about chair density, the current experiment was conducted before the second group of experimental studies.

This experiment entailed two conditions, in which two seating densities (40 and 20 chairs) of a sample room was tested via video animations. Each condition was evaluated by a different group of participants.

G.2.2. Participants

A total of 30 participants, with 15 in each group, voluntarily participated in the experiment. Participants were a mixture of undergraduate students and staff members from METU. Each participant assigned to each group randomly. Each participant was unaware of the other parts of the experiment.

Group-D: The first group was composed ten undergraduate students from the Faculty of Architecture and five staff members from METU. There were seven males and eight females. The mean age for this group was 23.60 with a range of 19 and 35 years.

Group-F: The fourth group was composed of 14 undergraduate students and a staff member from the Faculty of Architecture. There were four males and 11 females. The mean age for this group was 20.50 with a range of 19 and 25 years.

G.2.3. Stimuli

The classroom, B06, in Social Science building was chosen as the case of this experiment (see experiment-3). The Model-D in experiment-4 was again used in this experiment. In addition to that model, a new model was also derived by reducing the number of chairs. Models were recorded as video animations as mentioned in Experiment-4. A total of two video animations were used as stimuli of the experiment:

Model 4-D: 40 chairs.
Model 4-F: 20 chairs.
All models had a 5.00m ceiling height, and 8.00m x 7.00m floor dimensions.

A laptop with 1366x768 resolution 15.6” Toshiba TruBrite screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

G.2.4. Procedure

Participants were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were randomly assigned to one of the two computer models. They were asked to evaluate the simulation of the room as seen on the laptop screen, with S-C-S. After a brief explanation about the use of a seven-point scale, animation video of the model was played. Each video started from the door, toured 360^o counterclockwise in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation.

G.2.5. Results

	
Model 4-F	Model 4-D

Figure 99 Screenshot of models of Experiment-10.

A one-way multivariate analysis of variance was performed to investigate the effects of seating density of a classroom on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was the number of chairs (20 chairs and 40 chairs).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between 20 chairs and 40 chairs on the combined dependent variables, F (3, 26) = 0.03, p = .992; Wilks' Lambda = 0.996; partial eta squared = .004. When the results for the dependent variables were considered separately, no statistically significant difference was found.

G.3. EXPERIMENT-11: EFFECTS OF THE SURROUNDING SPACE OF COMPUTER ON SPACIOUSNESS EVALUATIONS VIA COMPUTER SIMULATION

G.3.1. Introduction

Literature survey indicated that in the experiments with scale models, it was attempted to present models to all participants within the same environment (permanent room, the same lighting etc.). Regarding this, computer simulations of Experiment-2 and Experiment-3 were presented to participants in the same place (in the cubicle illustrated in Figure 50). However, it was in question whether the simulation on a laptop screen should be presented in a constant room, as in the case of scale models. A participant looking at the screen might isolate oneself from the outside environment. If so, being free from a place might have practical advantages to conduct experiments (no need to reserve a specific place, no need to make an appointment with each participant, and the like). The aim of this experiment was to test whether simulations could be presented in different places without affecting the results. This experiment entailed two parts and was conducted before Experiment-4.

G.3.2. Participants

A total of 30 participants, with 15 in each group, voluntarily participated in the experiment. Participants were a mixture of undergraduate students and staff members from METU. Each participant assigned to each group randomly. The first group of participants was invited one by one to a standard place (classroom R49) in which they experienced the same environment around the computer screen. The second group was reached alone in their own offices.

Group-1: The first group was composed of ten undergraduate students from Faculty of Architecture and five staff members from various departments of METU. There were seven males and eight females. The mean age for this group was 23.60 years with a range of 19 and 35 years.

Group-2: The second group was composed of 15 staff members, 13 of which were research assistants from various departments of METU. There were six males and nine females. The mean age for this group was 30.73 years with a range of 24 and 46 years.

G.3.3. Stimuli

Model 4-D: 5.00m ceiling height, 3.70m window height (see Section 3.5.3).

A laptop with 1366x768 resolution 15.6” Toshiba TruBrite screen was used to present the models. The Turkish version of S-C-S (Appendix A.2) was used for the evaluations.

G.3.4. Procedure

Participants in Group-1 were individually invited to the cubicle located in the second-year architecture studio of METU Faculty of Architecture building. They were asked to evaluate the simulation of the room as seen on the laptop screen, with S-C-S. After a brief explanation about the use of a seven-point scale, animation video of the model was played. Each video started from the door, toured 360^{o} in the room at the eye level of a standing person. The tour took 30 seconds, and the video continued repeatedly until it was stopped by the participant manually. Each individual was free to pause the video or play it continuously during the evaluation.

The second group of participants watched the video animations and responded the questionnaire in their office rooms when they were alone. The same model was shown to the participants in the same laptop; locations of the participants were different.

G.3.5. Results

Model 4-D

Figure 100 Screenshot of model of Experiment-11 (same with Model 4-D in Experiment-4)

A one-way multivariate analysis of variance was performed to investigate the effects of surroundings of a laptop presentation on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning and SF3 space freedom. The independent variable was presentation place (a standard place and different places).

Preliminary assumption testing was conducted to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.

There was no statistically significant difference between presentations in a standard place and presentations in different places on the combined dependent variables, F (3, 26) = 0.02, p = .995; Wilks' Lambda = 0.997; partial eta squared = .003. When the results for the dependent variables were considered separately, no statistically significant difference was found.

APPENDIX H

DETAILED DESCRIPTIONS OF METHODS OF ANALYSIS

Analyses of experiments in the current thesis were based on two significant stages: 1) compiling data tables and calculating mean scores for each spaciousness factors (SF) in Excel program, 2) making statistical analysis in SPSS program. In Appendix H, the method of analysis will be explained with the examples from Experment-5.

H.1. STAGE-1: DATA TABLES IN EXCEL

The first stage of S-C-S analyses is compiling data from questionnaire forms and calculating mean values for spaciousness factors (SF) and crampedness factors (CF). For each experiment in the current thesis, this stage was conducted in Excel program in six steps as listed below and illustrated in the following tables:

1) coding the data from a questionnaire form to an excel table (see Figure 101).
2) coding the data from all questionnaire forms to an excel table (see Table 18).
3) grouping adjective pairs into two: “negative → positive” and “positive → negative” (see Table 19).
4) converting all adjective pairs in “negative → positive” order (1 = the undesirable end; 7 = desirable one (see Table 20).
5) grouping adjective pairs under the related Spaciousness Factors (SF) and Crampedness Factors (CF), and calculating mean values (see Table 21).
6) forming a summary table of SF and CF mean values in vertical order (preparing a “codebook” for SPSS analyses) (see Table 22).

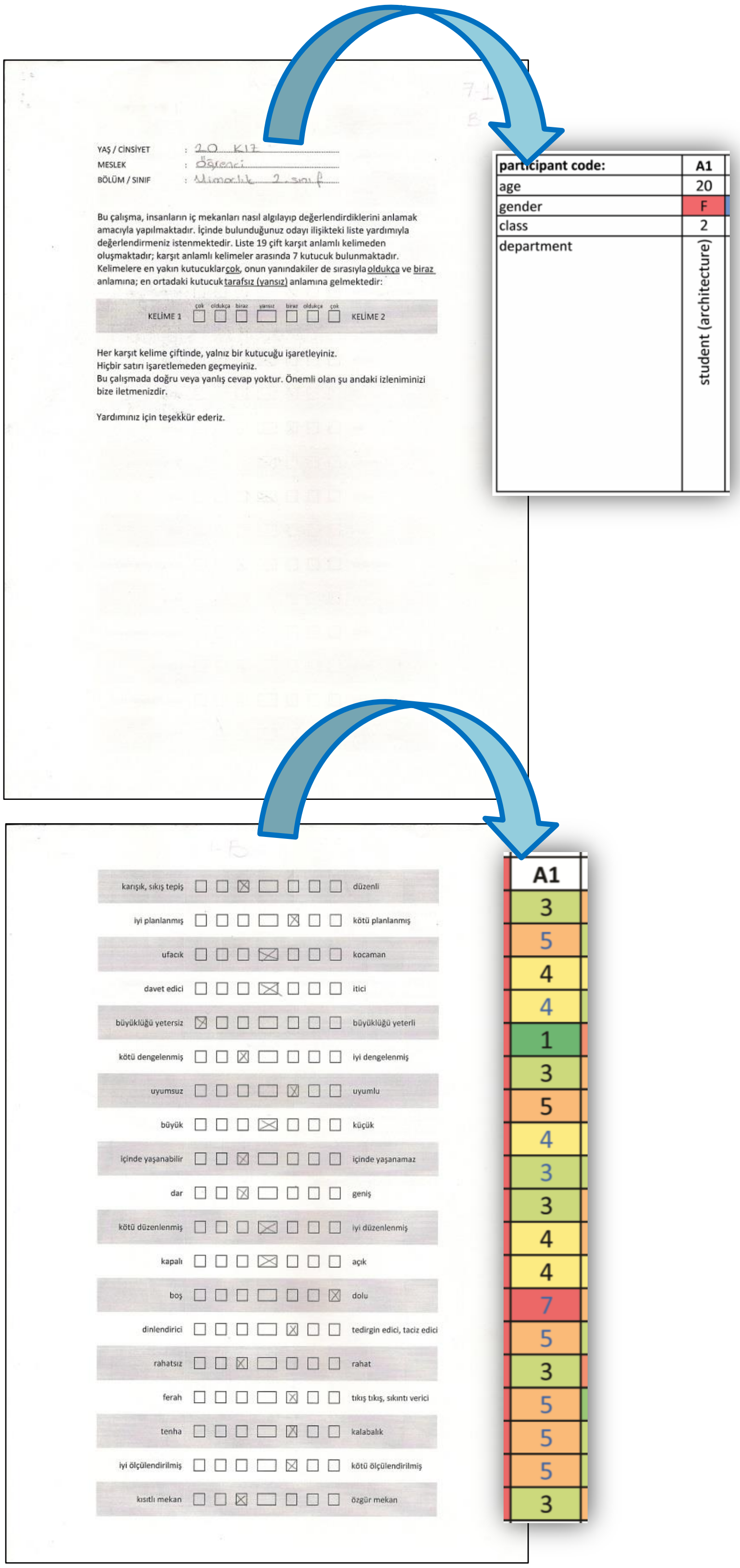


Figure 101 S-C-S analysis in Excel, step-1: coding the data from a questionnaire form to an excel table.

Table 18 S-C-S analysis in Excel, step-2: coding all data from questionnaire forms to an excel table.

	MODEL-5-A-B-C: SCS - (compared) 15-22.11.2012 - LMN (B06) A - h:3m, B - h:4m, C - h:5m	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	
1 point	7 point	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean
cluttered	uncluttered	3	5	6	2	4	7	6	5	6	5	7	3	3	7	5	6	5	4	2	7	4,9
well planned	poorly planned	5	3	2	3	4	2	2	2	4	3	2	4	5	3	5	2	1	3	4	2	3,1
tiny	huge	4	4	5	2	3	5	2	4	3	4	5	3	4	2	3	2	4	4	3	4	3,5
inviting	repelling	4	3	4	5	4	5	4	3	7	4	4	6	7	5	4	4	4	4	5	2	4,4
inadequate size	adequate size	1	6	6	2	5	6	1	6	5	4	6	2	4	2	1	3	6	4	2	6	3,9
poorly balanced	well balanced	3	5	5	3	4	6	7	6	2	4	4	5	3	4	2	5	5	5	5	6	4,5
uncoordinated	coordinated	5	5	6	4	5	6	5	6	1	4	5	3	4	4	4	2	3	5	6	7	4,5
large	small	4	4	4	6	5	2	5	3	5	4	4	6	4	5	4	6	4	4	5	4	4,4
livable	unlivable	3	3	4	3	2	2	2	2	7	3	1	5	6	6	4	2	5	3	2	1	3,3
narrow	wide	3	5	3	3	4	6	2	5	4	4	4	4	4	6	2	2	3	4	3	4	3,8
poorly organized	well organized	4	5	6	4	4	6	6	5	3	5	5	5	4	4	2	6	4	5	5	7	4,8
closed	open	4	4	5	6	6	2	6	6	3	6	5	2	1	5	5	3	3	4	4	6	4,3
empty	full	7	5	4	4	6	7	7	6	6	6	6	6	7	4	4	6	7	6	7	5	5,8
restful	disturbing	5	3	5	4	4	6	4	3	5	4	4	7	6	6	4	5	5	5	3	3	4,6
uncomfortable	comfortable	3	6	5	4	5	6	3	5	4	4	6	1	1	3	3	3	3	4	4	6	4,0
roomy	cramped	5	2	5	3	3	7	6	2	5	3	3	6	7	5	4	6	6	5	5	3	4,6
uncrowded	crowded	5	3	5	6	4	7	7	4	5	5	6	6	7	6	5	7	6	5	5	5	5,5
well scaled	poorly scaled	5	3	3	5	4	2	6	2	2	3	4	5	7	5	5	3	4	3	3	2	3,8
restricted space	free space	3	5	2	3	3	2	3	4	2	4	3	2	1	2	4	1	2	4	3	5	2,9
	presentation order:	a-b-c	a-b-c	a-b-c	a-b-c	a-c-b	a-b-c	a-b-c	a-b-c	a-b-c	a-c-b	a-b-c	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-b-c	a-b-c	

Table 19 S-C-S analysis in Excel, step-3: grouping adjective pairs into two: "negative - positive" and "positive - negative".

	MODEL-5-A-B-C: SCS - (compared) 15-22.11.2012 - LMN (B06) A - h:3m, B - h:4m, C - h:5m	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	
1 point	7 point	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean
cluttered	uncluttered	3	5	6	2	4	7	6	5	6	5	7	3	3	7	5	6	5	4	2	7	4,9
tiny	huge	4	4	5	2	3	5	2	4	3	4	5	3	4	2	3	2	4	4	3	4	3,5
inadequate size	adequate size	1	6	6	2	5	6	1	6	5	4	6	2	4	2	1	3	6	4	2	6	3,9
poorly balanced	well balanced	3	5	5	3	4	6	7	6	2	4	4	5	3	4	2	5	5	5	5	6	4,5
uncoordinated	coordinated	5	5	6	4	5	6	5	6	1	4	5	3	4	4	4	2	3	5	6	7	4,5
narrow	wide	3	5	3	3	4	6	2	5	4	4	4	4	4	6	2	2	3	4	3	4	3,8
poorly organized	well organized	4	5	6	4	4	6	6	5	3	5	5	5	4	4	2	6	4	5	5	7	4,8
closed	open	4	4	5	6	6	2	6	6	3	6	5	2	1	5	5	3	3	4	4	6	4,3
uncomfortable	comfortable	3	6	5	4	5	6	3	5	4	4	6	1	1	3	3	3	3	4	4	6	4,0
restricted space	free space	3	5	2	3	3	2	3	4	2	4	3	2	1	2	4	1	2	4	3	5	2,9
well planned	poorly planned	5	3	2	3	4	2	2	2	4	3	2	4	5	3	5	2	1	3	4	2	3,1
inviting	repelling	4	3	4	5	4	5	4	3	7	4	4	6	7	5	4	4	4	4	5	2	4,4
large	small	4	4	4	6	5	2	5	3	5	4	4	6	4	5	4	6	4	4	5	4	4,4
livable	unlivable	3	3	4	3	2	2	2	2	7	3	1	5	6	6	4	2	5	3	2	1	3,3
empty	full	7	5	4	4	6	7	7	6	6	6	6	6	7	4	4	6	7	6	7	5	5,8
restful	disturbing	5	3	5	4	4	6	4	3	5	4	4	7	6	6	4	5	5	5	3	3	4,6
roomy	cramped	5	2	5	3	3	7	6	2	5	3	3	6	7	5	4	6	6	5	5	3	4,6
uncrowded	crowded	5	3	5	6	4	7	7	4	5	5	6	6	7	6	5	7	6	5	5	5	5,5
well scaled	poorly scaled	5	3	3	5	4	2	6	2	2	3	4	5	7	5	5	3	4	3	3	2	3,8

Table 20 S-C-S analysis in Excel, step-4: converting all adjective pairs into "negative – positive" order.

	MODEL-5-A-B-C: SCS - (compared) 15-22.11.2012 - LMN (B06) A - h:3m, B - h:4m, C - h:5m	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	
1 point	7 point	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean
cluttered	uncluttered	3	5	6	2	4	7	6	5	6	5	7	3	3	7	5	6	5	4	2	7	4,9
tiny	huge	4	4	5	2	3	5	2	4	3	4	5	3	4	2	3	2	4	4	3	4	3,5
inadequate size	adequate size	1	6	6	2	5	6	1	6	5	4	6	2	4	2	1	3	6	4	2	6	3,9
poorly balanced	well balanced	3	5	5	3	4	6	7	6	2	4	4	5	3	4	2	5	5	5	5	6	4,5
uncoordinated	coordinated	5	5	6	4	5	6	5	6	1	4	5	3	4	4	4	2	3	5	6	7	4,5
narrow	wide	3	5	3	3	4	6	2	5	4	4	4	4	4	6	2	2	3	4	3	4	3,8
poorly organized	well organized	4	5	6	4	4	6	6	5	3	5	5	5	4	4	2	6	4	5	5	7	4,8
closed	open	4	4	5	6	6	2	6	6	3	6	5	2	1	5	5	3	3	4	4	6	4,3
uncomfortable	comfortable	3	6	5	4	5	6	3	5	4	4	6	1	1	3	3	3	3	4	4	6	4,0
restricted space	free space	3	5	2	3	3	2	3	4	2	4	3	2	1	2	4	1	2	4	3	5	2,9
poorly planned	well planned	3	5	6	5	4	6	6	6	4	5	6	4	3	5	3	6	7	5	4	6	5,0
repelling	inviting	4	5	4	3	4	3	4	5	1	4	4	2	1	3	4	4	4	4	3	6	3,6
small	large	4	4	4	2	3	6	3	5	3	4	4	2	4	3	4	2	4	4	3	4	3,6
unlivable	livable	5	5	4	5	6	6	6	6	1	5	7	3	2	2	4	6	3	5	6	7	4,7
full	empty	1	3	4	4	2	1	1	2	2	2	2	2	1	4	4	2	1	2	1	3	2,2
disturbing	restful	3	5	3	4	4	2	4	5	3	4	4	1	2	2	4	3	3	3	5	5	3,5
cramped	roomy	3	6	3	5	5	1	2	6	3	5	5	2	1	3	4	2	2	3	3	5	3,5
crowded	uncrowded	3	5	3	2	4	1	1	4	3	3	2	2	1	2	3	1	2	3	3	3	2,6
poorly scaled	well scaled	3	5	5	3	4	6	2	6	6	5	4	3	1	3	3	5	4	5	5	6	4,2

Table 21 S-C-S analysis in Excel, step-5: grouping adjective pairs under the related Spaciousness Factors (SF) and Crampedness Factors (CF), and calculating mean values.

	MODEL-5-A-B-C: SCS - (compared) 15-22.11.2012 - LMN (B06) A - h:3m, B - h:4m, C - h:5m	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	15.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	19.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	22.11.2012	
1 point	7 point	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean

	SPACIOUSNESS FACTOR-1	(APPEAL)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
S.1.1	uncomfortable	comfortable	3	6	5	4	5	6	3	5	4	4	6	1	1	3	3	3	3	4	4	6		S.F.1: (appeal)
S.1.2	repelling	inviting	4	5	4	3	4	3	4	5	1	4	4	2	1	3	4	4	4	4	3	6		
S.1.3	disturbing	restful	3	5	3	4	4	2	4	5	3	4	4	1	2	2	4	3	3	3	5	5		
S.1.4	unlivable	livable	5	5	4	5	6	6	6	6	1	5	7	3	2	2	4	6	3	5	6	7		
			3,75	5,25	4,00	4,00	4,75	4,25	4,25	5,25	2,25	4,25	5,25	1,75	1,50	2,50	3,75	4,00	3,25	4,00	4,50	6,00	3,93	3,925

	SPACIOUSNESS FACTOR-2	(PLANNING)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
S.2.1	poorly organized	well organized	4	5	6	4	4	6	6	5	3	5	5	5	4	4	2	6	4	5	5	7		S.F.2: (planning)
S.2.2	poorly balanced	well balanced	3	5	5	3	4	6	7	6	2	4	4	5	3	4	2	5	5	5	5	6		
S.2.3	poorly planned	well planned	3	5	6	5	4	6	6	6	4	5	6	4	3	5	3	6	7	5	4	6		
S.2.4	poorly scaled	well scaled	3	5	5	3	4	6	2	6	6	5	4	3	1	3	3	5	4	5	5	6		
S.2.5	uncoordinated	coordinated	5	5	6	4	5	6	5	6	1	4	5	3	4	4	4	2	3	5	6	7		
			3,60	5,00	5,60	3,80	4,20	6,00	5,20	5,80	3,20	4,60	4,80	4,00	3,00	4,00	2,80	4,80	4,60	5,00	5,00	6,40	4,57	4,57

	SPACIOUSNESS FACTOR-3	(SPACE FREEDOM)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
S.3.1	cramped	roomy	3	6	3	5	5	1	2	6	3	5	5	2	1	3	4	2	2	3	3	5		S.F.3: (space freedom)
S.3.2	small	large	4	4	4	2	3	6	3	5	3	4	4	2	4	3	4	2	4	4	3	4		
S.3.3	restricted space	free space	3	5	2	3	3	2	3	4	2	4	3	2	1	2	4	1	2	4	3	5		
S.3.4	tiny	huge	4	4	5	2	3	5	2	4	3	4	5	3	4	2	3	2	4	4	3	4		
S.3.5	crowded	tenha	3	5	3	2	4	1	1	4	3	3	2	2	1	2	3	1	2	3	3	3		
S.3.6	closed	open	4	4	5	6	6	2	6	6	3	6	5	2	1	5	5	3	3	4	4	6		
S.3.7	narrow	wide	3	5	3	3	4	6	2	5	4	4	4	4	4	6	2	2	3	4	3	4		
			3,43	4,71	3,57	3,29	4,00	3,29	2,71	4,86	3,00	4,29	4,00	2,43	2,29	3,29	3,57	1,86	2,86	3,71	3,14	4,43	3,44	3,435714286

	CRAMPEDNESS FACTOR-1	(PLANNING)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
C.1.1	poorly planned	well planned	3	5	6	5	4	6	6	6	4	5	6	4	3	5	3	6	7	5	4	6		C.F.1: (planning)
C.1.2	poorly balanced	well balanced	3	5	5	3	4	6	7	6	2	4	4	5	3	4	2	5	5	5	5	6		
C.1.3	poorly organized	well organized	4	5	6	4	4	6	6	5	3	5	5	5	4	4	2	6	4	5	5	7		
C.1.4	uncoordinated	coordinated	5	5	6	4	5	6	5	6	1	4	5	3	4	4	4	2	3	5	6	7		
			3,75	5,00	5,75	4,00	4,25	6,00	6,00	5,75	2,50	4,50	5,00	4,25	3,50	4,25	2,75	4,75	4,75	5,00	5,00	6,50	4,66	3,3375

	CRAMPEDNESS FACTOR-2	(PHYSICAL SPACE)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
C.2.1	tiny	huge	4	4	5	2	3	5	2	4	3	4	5	3	4	2	3	2	4	4	3	4		C.F.2: (physical space)
C.2.2	small	large	4	4	4	2	3	6	3	5	3	4	4	2	4	3	4	2	4	4	3	4		
C.2.3	narrow	wide	3	5	3	3	4	6	2	5	4	4	4	4	4	6	2	2	3	4	3	4		
			3,67	4,33	4,00	2,33	3,33	5,67	2,33	4,67	3,33	4,00	4,33	3,00	4,00	3,67	3,00	2,00	3,67	4,00	3,00	4,00	3,62	4,383333333

	CRAMPEDNESS FACTOR-3	(CLUTTEREDNESS)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
C.3.1	crowded	tenha	3	5	3	2	4	1	1	4	3	3	2	2	1	2	3	1	2	3	3	3		C.F.3: (clutteredness)
C.3.2	cluttered	cluttered	3	5	6	2	4	7	6	5	6	5	7	3	3	7	5	6	5	4	2	7		
C.3.3	cramped	roomy	3	6	3	5	5	1	2	6	3	5	5	2	1	3	4	2	2	3	3	5		
C.3.4	inadequate size	adequate size	1	6	6	2	5	6	1	6	5	4	6	2	4	2	1	3	6	4	2	6		
C.3.5	full	empty	1	3	4	4	2	1	1	2	2	2	2	2	1	4	4	2	1	2	1	3		
			2,20	5,00	4,40	3,00	4,00	3,20	2,20	4,60	3,80	3,80	4,40	2,20	2,00	3,60	3,40	2,80	3,20	3,20	2,20	4,80	3,40	4,6

	CRAMPEDNESS FACTOR-4	(APPEAL)	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	mean	S-C-Scale
C.4.1	uncomfortable	comfortable	3	6	5	4	5	6	3	5	4	4	6	1	1	3	3	3	3	4	4	6		C.F.4: (appeal)
C.4.2	disturbing	restful	3	5	3	4	4	2	4	5	3	4	4	1	2	2	4	3	3	3	5	5		
C.4.3	unlivable	livable	5	5	4	5	6	6	6	6	1	5	7	3	2	2	4	6	3	5	6	7		
			3,67	5,33	4,00	4,33	5,00	4,67	4,33	5,33	2,67	4,33	5,67	1,67	1,67	2,33	3,67	4,00	3,00	4,00	5,00	6,00	4,03	3,966666667

presentation order	a-b-c	a-b-c	a-b-c	a-b-c	a-c-b	a-b-c	a-b-c	a-b-c	a-b-c	a-c-b	a-b-c	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-c-b	a-b-c	a-b-c

participant code:	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20
age	20	24	21	21	20	25	21	21	21	21	19	20	20	20	20	21	20	20	22	21
gender	F	M	F	F	F	M	F	M	F	M	F	M	F	F	F	F	F	F	M	F
class	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
department	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)	student (architecture)

Table 22 S-C-S analysis in Excel, step-6: forming a summary table of SF and CF mean values in vertical order (preparing a "codebook" for SPSS analyses)

MODEL-5-A: SCS - (compared) 15-22.11.2012 - LMN (B06) A - h:3m, B - h:4m, C - h:5m	MODEL-5 participant code:	MODEL-5 participant no:	APPEAL	PLANNING	SPACE FREEDOM	PLANNING	PHYSICAL SPACE	CLUTTERED NESS	APPEAL		1:female 2:male				
			SF1	SF2	SF3	CF1	CF2	CF3	CF4	height	gender	gender	age	class	department
15.11.2012	5-A1	5101	3,75	3,60	3,43	3,75	3,67	2,20	3,67	3,00	1	F	20	2	student (architecture)
15.11.2012	5-A2	5102	5,25	5,00	4,71	5,00	4,33	5,00	5,33	3,00	2	M	24	2	student (architecture)
15.11.2012	5-A3	5103	4,00	5,60	3,57	5,75	4,00	4,40	4,00	3,00	1	F	21	2	student (architecture)
15.11.2012	5-A4	5104	4,00	3,80	3,29	4,00	2,33	3,00	4,33	3,00	1	F	21	2	student (architecture)
15.11.2012	5-A5	5105	4,75	4,20	4,00	4,25	3,33	4,00	5,00	3,00	1	F	20	2	student (architecture)
15.11.2012	5-A6	5106	4,25	6,00	3,29	6,00	5,67	3,20	4,67	3,00	2	M	25	2	student (architecture)
15.11.2012	5-A7	5107	4,25	5,20	2,71	6,00	2,33	2,20	4,33	3,00	1	F	21	2	student (architecture)
15.11.2012	5-A8	5108	5,25	5,80	4,86	5,75	4,67	4,60	5,33	3,00	2	M	21	2	student (architecture)
15.11.2012	5-A9	5109	2,25	3,20	3,00	2,50	3,33	3,80	2,67	3,00	1	F	21	2	student (architecture)
19.11.2012	5-A10	5110	4,25	4,60	4,29	4,50	4,00	3,80	4,33	3,00	2	M	21	2	student (architecture)
19.11.2012	5-A11	5111	5,25	4,80	4,00	5,00	4,33	4,40	5,67	3,00	1	F	19	2	student (architecture)
19.11.2012	5-A12	5112	1,75	4,00	2,43	4,25	3,00	2,20	1,67	3,00	2	M	20	2	student (architecture)
19.11.2012	5-A13	5113	1,50	3,00	2,29	3,50	4,00	2,00	1,67	3,00	1	F	20	2	student (architecture)
19.11.2012	5-A14	5114	2,50	4,00	3,29	4,25	3,67	3,60	2,33	3,00	1	F	20	2	student (architecture)
19.11.2012	5-A15	5115	3,75	2,80	3,57	2,75	3,00	3,40	3,67	3,00	1	F	20	2	student (architecture)
22.11.2012	5-A16	5116	4,00	4,80	1,86	4,75	2,00	2,80	4,00	3,00	1	F	21	2	student (architecture)
22.11.2012	5-A17	5117	3,25	4,60	2,86	4,75	3,67	3,20	3,00	3,00	1	F	20	2	student (architecture)
22.11.2012	5-A18	5118	4,00	5,00	3,71	5,00	4,00	3,20	4,00	3,00	1	F	20	2	student (architecture)
22.11.2012	5-A19	5119	4,50	5,00	3,14	5,00	3,00	2,20	5,00	3,00	2	M	22	2	student (architecture)
22.11.2012	5-A20	5120	6,00	6,40	4,43	6,50	4,00	4,80	6,00	3,00	1	F	21	2	student (architecture)
	mean	mean	3,93	4,57	3,44	4,66	3,62	3,40	4,03						
	S-C-S	S-C-S	3,925	4,57	3,4357	3,3375	4,3833	4,6	3,9667						

H.2. STAGE-2: STATISTICAL ANALYSIS IN SPSS

After tabulating all data from the questionnaire forms as mentioned in Section H.1, the second stage is to make statistical analyses. Since Spaciousness Crampedness Scale (S-C-S), which was constructed by İmamoğlu (1975), was used in all experimental studies in the scope of the current thesis, it was expected to follow a similar method of statistical analysis to the examples of S-C-S in the literature. However, since the 1970s, there have been changes not only in the representation techniques but also in the methods of statistical analysis. Moreover, in the recent examples of architectural psychology studies, various methods of statistical analysis are carried out for similar research questions. Hence, before performing statistical analyses, a survey on statistical analyses was needed to find out the most appropriate method for the current thesis. In the current section, after a brief introduction about statistical analyses, the method of analysis used in the current thesis will be briefly introduced.

H.2.1. Dependent and independent variables

In this thesis, spaciousness of classrooms was assessed through variables, which are graphically illustrated in Figure 102. As Dancey and Reidy (2011, p. 2) pointed out "variables are the main focus of research in science" and these variables can be measured and recorded and "vary from one situation or person to another".

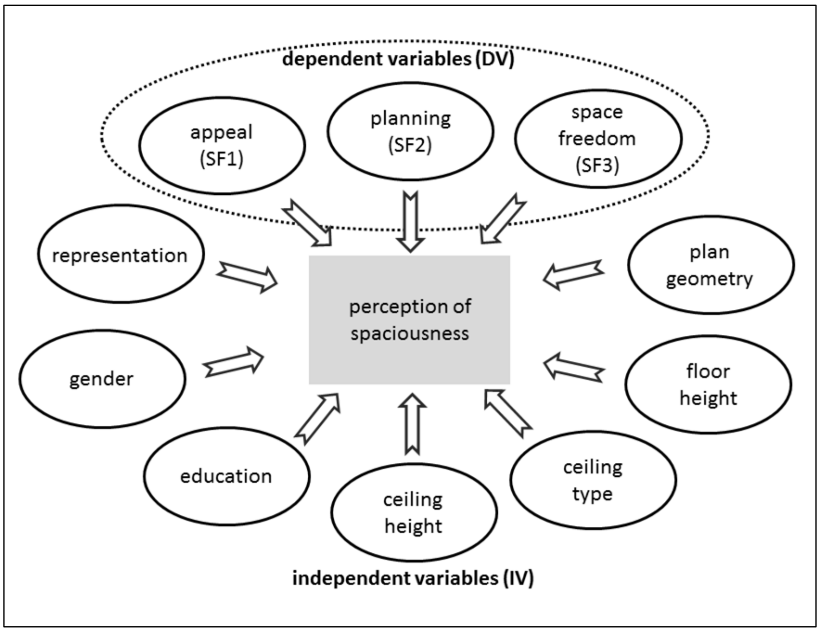


Figure 102 Dependent and independent variables examined in the experimental studies in the current thesis.

In the scope of the current thesis, three spaciousness factors (SF), namely *appeal, planning* and *space freedom* are the dependent variables while other factors are independent variables (Figure 102). In an experiment, independent variable is "a variable that stands alone and is not changed by the other variables" (NCES, n.d.). For instance, in Figure 102, participant's education is an independent variable which is not changed by other factors such as ceiling height. On the other hand, dependent variable is the variable that depends on other factors. Tabachnick and Fidell (2013, p.

2) noted that “IV and DV are defined within a research context; a DV in one research setting may be an IV in another”. Within this context, each spaciousness factors is a dependent variable because it could change depending on several factors such as ceiling height, education. When a research aims “to look for some kind of relationship between variables”, it aims “to see if the independent variables cause some kind of change in the dependent variables” (NCES, n.d.).

H.2.2. Null hypothesis, Significance Level and Type I & Type II errors

“Null hypothesis (H_0)” is a significant concept for testing research hypotheses. As Dancey and Reidy (2011, p. 138) explained, “the null hypothesis always states that there is no effect [relationship or difference] in the underlying population”. For instance, if a study aims to compare two groups of people, in which a difference is expected, the null hypothesis states that “there is no difference between them” (Dancey & Reidy, 2011, pp. 137-138). In this respect, null hypothesis of each experiment in the current thesis can be generalized as follows: “there is no difference between the variables”.

If a statistical analysis reaches *a significance level*, the null hypothesis is rejected, and the research hypothesis is supported. Taylor (n.d.-a) defined *the level of significance* (*alpha*) as a probability associated to the confidence level of a test. Taylor (n.d.-b) noted that “there is not a universal value of alpha that should be used for all statistical tests”, and he explained the most commonly used alpha values, 0.10, 0.05 and 0.01 as follows:

> For results with a 90% level of confidence, the value of alpha is 1 - 0.90 = 0.10.
>
> For results with a 95% level of confidence, the value of alpha is 1 - 0.95 = 0.05.
>
> For results with a 99% level of confidence, the value of alpha is 1 - 0.99 = 0.01.

The other value of a test of significance is *p-value* which is a corresponding probability. “This value is the probability that the observed statistic occurred by chance alone” (Taylor, n.d.-a). If *p-value* obtained from an analysis does not exceed the alpha value, *a significance level* is reached and the null hypothesis is rejected. In this regard, Dancey and Reidy (2011) have the following question and answer:

> "… how do we decide that the probability we calculate in null hypothesis testing is small enough for us to reject the null hypothesis? This is an excellent question and one that does not have a definitive answer. (p. 140).

Dancey and Reidy (2011, p. 140) explained that "most psychologists and indeed most reputable psychology journals use a probability of 5% is small enough to be a useful cut-off point" and *significance level* is conventionally set at 0.05. However, as Pallant (2011, p. 207) pointed out, "there is always the possibility of reaching the wrong conclusion". The two types of error are defined by Everitt and Skrondal (2010) as follows:

> **Type I error:** The error that results when the null hypothesis is falsely rejected.
>
> **Type II error:** The error that results when the null hypothesis is falsely accepted (p. 439).

Pallant (2011, p. 207) stated that there is an inverse relationship between these two errors, when researchers "try to control for a Type I error, they actually increase the likelihood that they will commit a Type II error". In this sense, *the power of a test* indicates whether the test correctly rejects the null hypothesis when it is false. Pallant (2011, p. 207) noted that statistical tests vary according to their power, and she explained by an example: "parametric tests such as t-tests, analyses of variance etc. are potentially more powerful than non-parametric tests, if the assumptions are met". Moreover, she (2011) pointed other factors that can influence the power of a test in a given situation as follows:

- **sample size** [the number of participants to be included in the study]
- **effect size** (the strength of the difference between groups, or the influence of the independent variable)
- **alpha level** set by the researcher (e.g. .05/.01) (p. 207).

Stevens (2009, pp. 4-5) emphasized that *the power of a test* is "directly dependent on the alpha level" and "heavily dependent on sample size". For the studies with small sample size, he suggested to set alpha level at a more liberal value (.10 or .15) in order to prevent Type II error:

> When sample size is large (say, 100 or more subjects per group), power is not an issue. It is an issue when one is conducting a study where the group sizes will be small ($n \leq 20$), or when one is evaluating a completed study that had small group size, then, it is imperative to be very sensitive to the possibility of poor power (or equivalently, a type II error). Thus, in studies with small group size, it can make sense to test at a more liberal level (.10 or .15) to improve power (p. 5).

In the current thesis, sample size in each experiment was ranged from 15 to 30 in the first group of experiments and 20 in the second group of experiments (with an exception in Experiment-6, which had 24). In this regard, Stevens' (2009, pp. 4-5) suggestion about the alpha value will be discussed in the following section.

There are various effect size statistics. As Pallant (2011, p. 210) pointed out, the most common ones to compare groups are Cohen's d (Cohen, 1988) and partial eta squared. Table 23 briefly explained how to interpret the effect size values as "small, medium and large". Publication Manual of the American Psychological Association (APA, 2010, p. 32) recommends that researchers include effect size in the results section for the reader to appreciate the magnitude or importance of a study's findings. Hence, in the current thesis, eta squared values were indicated together with p-values in the results of each experiment.

Table 23 Effect size (Pallant, 2011, p. 210)

Size	Eta squared (% of variance explained)	Cohen's d (standard deviation units)
Small	.01 or 1%	.2
Medium	.06 or 6%	.5
Large	.138 or 13.8%	.8

H.2.3. Selecting the appropriate method of analysis

The selection of appropriate statistical technique was based on the dependent variables (DVs) and independent variables (IVs). In this context, T-test compares one DV and one IV with two conditions. Analysis of variance (ANOVA) has one DV, and one or more IV (each with two or more conditions). Multivariate analysis of variance (MANOVA), on the other hand, has two or more DVs with one or more IVs (Dancey & Reidy, 2011, p. 494).

In the current thesis, each experiment has three spaciousness factors as DVs (SF: appeal, planning and space freedom) and one or more IVs (each with two or three conditions). When the analysis of S-C-S was surveyed in the literature, it was seen that "repeated measures analysis of variance (mixed between-within subjects analysis of variance)" was carried out in 1970s and 1980s. In this type of analysis, each spaciousness factors (appealing, planning, space freedom) were calculated as dependent variables which are evaluated by each participant repeatedly. It gives overall results whether there are significant differences among the various conditions, for instance the overall effect of ceiling height (3m, 4m and 5m) on overall spaciousness evaluations (*appealing, planning,* and *space freedom*). However, when the difference between specific conditions (such as the effects of 3m and 5m ceiling heights on *space freedom* factor) is needed to be analyzed, repeated measures ANOVA requires additional statistical analyses. In this respect, Dancey and Reidy (2011) suggested using T-tests for each condition separately; on the other hand, Pallant (2011) suggested using one-way ANOVA with post-hoc analyses, in which each dependent variable is analyzed separately. In this sense, conducting series of analyses separately has two disadvantages: 1) It is not practical for the researcher. For instance, when the effects of three ceiling heights on three SFs wanted to be analyzed in detail, addition to repeated measures ANOVA, three different one-way ANOVAs, or nine different T-tests are needed to be conducted. 2) The risk of Type I error is increased. Pallant (2011, p. 283) explained that "the more analyses you run the more likely you are to find a significant result, even if in reality there are no differences between your groups".

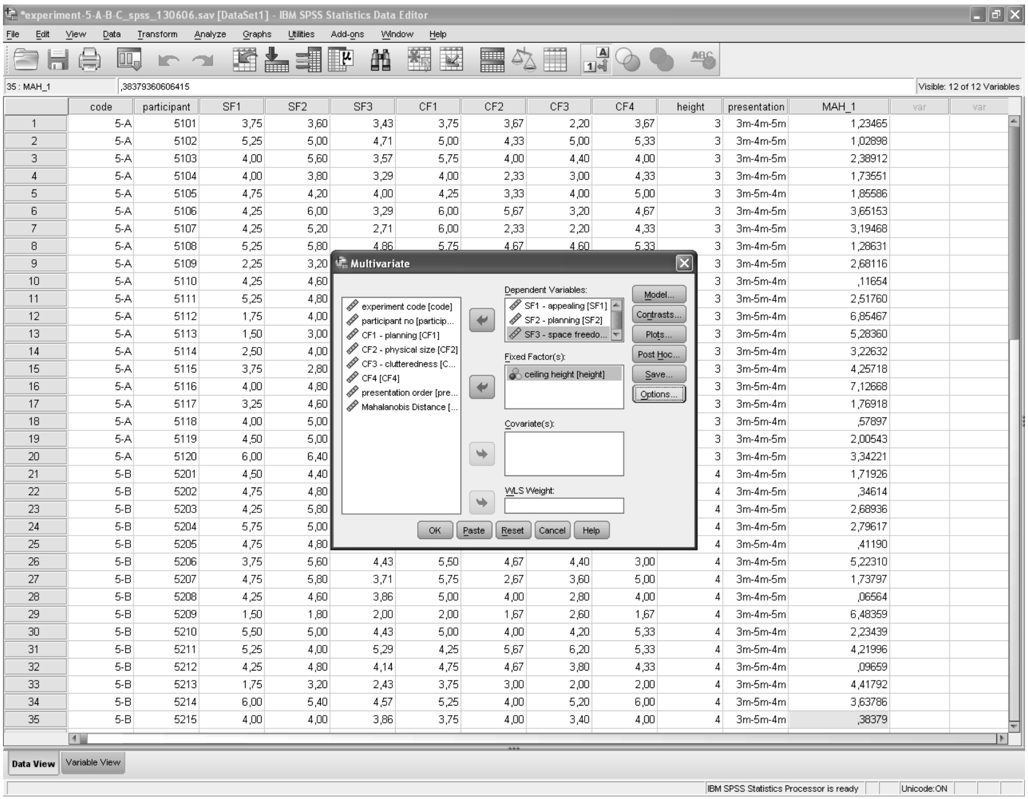
In the literature, multivariate analysis of variance (MANOVA) was also conducted to analyze evaluation scales similar to S-C-S. When compared to repeated measures ANOVA, the advantages of using MANOVA can be listed as follows: 1) A single analysis is adequate, instead of a series of analysis (Tabachnick & Fidell, 2013, pp. 1-2). 2) It 'controls' or adjusts for the increased risk of a Type 1 error (Pallant, 2011, p. 283),

Tabachnick and Fidell (2013) explained MANOVA as follows:

> Multivariate statistics are increasingly popular techniques used for analyzing complicated data sets. They provide analysis when there are many independent variables (IVs) and/or many dependent variables (DVs), all correlated with one another to varying degrees. Because of the difficulty of addressing complicated research questions with univariate analyses and because of the availability of canned software for performing multivariate analyses, multivariate statistics have become widely used (p. 1)
>
> Multivariate statistical methods are an extension of univariate and bivariate statistics. Multivariate statistics are the *complete* or general case, whereas univariate and bivariate statistics are special cases of the multivariate model (pp. 1-2).

In the light of Pallant (2011, pp. 283-296), for each experiment of the current thesis, a one-way or two-way multivariate analysis of variance was performed to investigate the effects of the independent variables on spaciousness evaluations. Three dependent variables were used: SF1 appeal, SF2 planning, SF space freedom (see Figure 103).

Pallant (2011) suggested setting a higher confidence level in MANOVA (Bonferroni adjustment: dividing the original alpha level of .05 by the number of DVs) to reduce the chance of a Type 1 error. On the other hand, Stevens (2009, pp. 4-5) suggested to set alpha level at a more liberal value (.10 or .15) in order to prevent Type II error in small sample size. Hence, by considering both, the alpha level set .05 in all experiments. MANOVA is a much more complex set of procedures; hence, it has a number of assumptions that must be met. In this sense, preliminary assumption testing (2011, pp. 283-296) was conducted for each experiment to check for normality, multivariate outliners and homogeneity of variance-covariance matrices, with no serious violations noted.



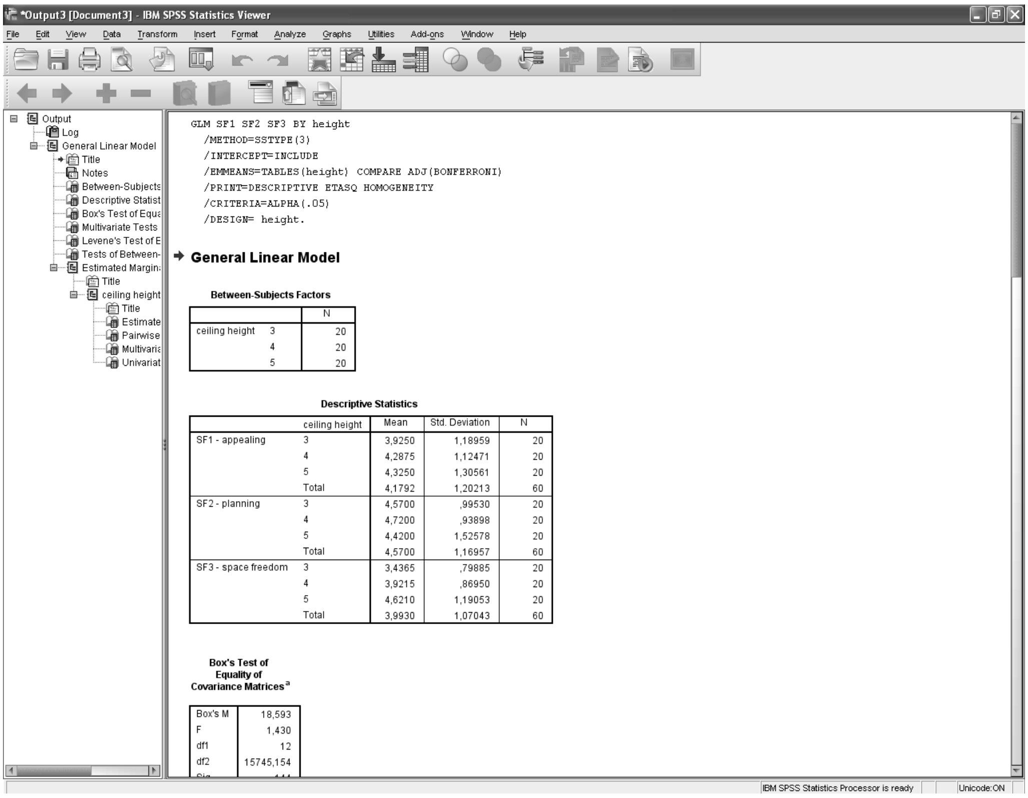


Figure 103 Copying the summary data from excel to SPSS and conducting MANOVA analysis.

APPENDIX I

SUMMARY TABLES OF ALL EXPERIMENTS

Graphic summary of the preliminary study and experimental studies in the current thesis is illustrated in Figure 104. Summary information of all experiments (model images, plans, stimuli, mean values of each SF, and participants) are illustrated in Table 24.

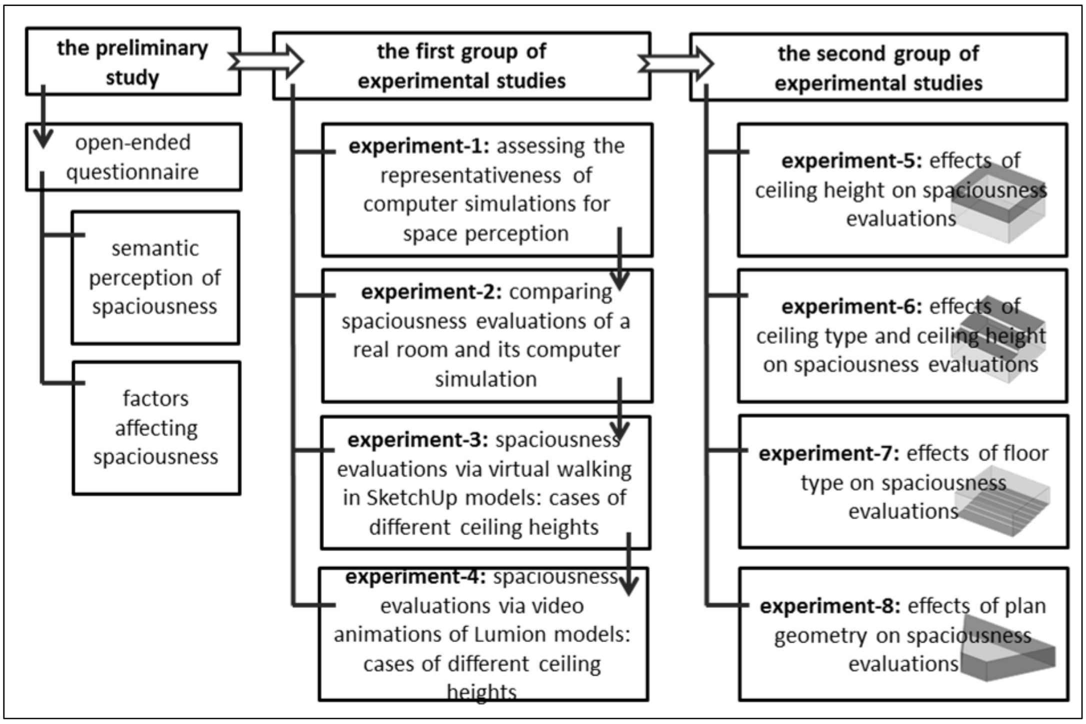


Figure 104 Graphic summary of the preliminary study and experimental studies in the current thesis.

Table 24 Summary information of all experiments: model images, plans, mean values of each SF, stimuli and participants.

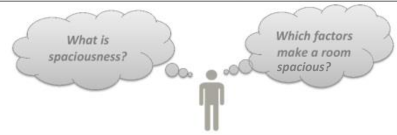
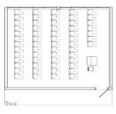
	MODEL NO & DATE	IMAGES	PLANS	STIMULI	SF-1: APPEAL (7)	SF-2: PLANNING (7)	SF-3: SPACE FREEDOM (7)	PARTICIPANTS
PRE. STUDY	PRELIMINARY STUDY (19-23.12.2011)			open-ended questions: What is spaciousness? Which factors make a room spacious?	Meaning: comfort (*rahatlık*) 19, tranquility (*huzur*) 11, ... Factors: light 36, furniture 36, color 35, size 33, order 21, fenestration 18, physical conditions 15, social environment 7, being close to nature 6.			N = 11 METU staff living in Eryaman N = 10 staff of METU Faculty of Architecture N = 19 first-year architecture students of METU
EXP. 1	MODEL-1-A (22.03.2012-20.04.2012)			R46 real room	M = 4.54 SD = 0.87	M = 4.76 SD = 0.87	M = 3.79 SD = 0.93	N = 25 nonarchitect staff members (who were unfamiliar with 3D computer models and did not use actual classroom R46 before)
	MODEL-1-B (22.03.2012-20.04.2012)			R46 computer model: google sketchup 8	(a 10-point scale) M = 7.84 SD = 1.72			
	MODEL-1-C (22.03.2012-20.04.2012)			R46 computer model: lumion free sp3.b8	(a 10-point scale) M = 7.56 SD = 2.20			
EXP. 9	MODEL-1-D (22.03.2012-20.04.2012)			R46 computer model: rhinoceros evaluation 4.0	(a 10-point scale) M = 7,12 SD = 1.79			
EXP. 2	MODEL-2-A (27.04.2012)			R46 real room	M = 4.28 SD = 1.05	M = 4.67 SD = 0.83	M = 3.73 SD = 0.77	N = 30 undergraduate students of the Faculty of Architecture (15male + 15female)
	MODEL-2-B (30.04.2012)			R46 computer model: google sketchup 8	M = 4.22 SD = 0.86	M = 4.93 SD = 0.93	M = 3.52 SD = 0.68	N = 30 undergraduate students of the Faculty of Architecture (15male + 15female)
EXP. 3	MODEL-3-A (17-18.05.2012)			B06 plan: 8mx7m ceiling height: 3m window height: 1.7m number of chairs: (program: skp)	M = 4.13 SD = 1.38	M = 4.60 SD = 1.39	M = 3.91 SD = 1.16	N = 20 students and staff members of METU
	MODEL-3-B (17-22.05.2012)			B06 plan: 8mx7m ceiling height: 4m window height: 1.7m number of chairs: 60 (program: skp)	M = 3.60 SD = 1.49	M = 4.40 SD = 1.30	M = 3.21 SD = 1.10	N = 20 students and staff members of METU
	MODEL-3-C (17-21.05.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 1.7m number of chairs: 60 (program: skp)	M = 3.71 SD = 1.31	M = 4.13 SD = 1.09	M = 3.15 SD = 0.95	N = 20 students and staff members of METU

Table 24 (continued)

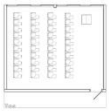
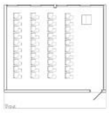
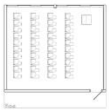
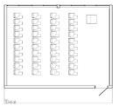
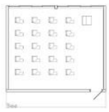
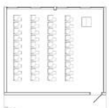
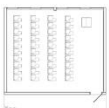
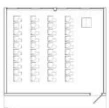
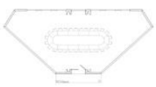
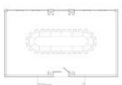
	MODEL NO & DATE	IMAGES	PLANS	STIMULI	SF-1: APPEAL (7)	SF-2: PLANNING (7)	SF-3: SPACE FREEDOM (7)	PARTICIPANTS
	MODEL-4-A (18.07.2012)			B06 plan: 8mx7m ceiling height: 3m window height: 1.7m number of chairs: 40 (program: lumion)	M = 4.42 SD = 0.73	M = 4.77 SD = 0.81	M = 3.71 SD = 0.84	N = 15 staff members of METU
EXP. 4	MODEL-4-C (18-19.07.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 1.7m number of chairs: 40 (program:lumion)	M = 4.60 SD = 0.93	M = 4.71 SD = 1.00	M = 3.90 SD = 0.88	N = 15 staff members of METU
EXP. 10	MODEL-4-D-s (11-18.07.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 3.7m number of chairs: 40 (program: lumion) *(laptop was presented in a standard place)*	M = 4.60 SD = 1.39	M = 5.11 SD = 0.98	M = 4.30 SD = 0.98	N = 15 staff members of METU
EXP. 11	MODEL-4-D-d (11-13.07.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 3.7m number of chairs: 40 (program: lumion) *(laptop was presented in different offices)*	M = 4.67 SD = 1.67	M = 5.12 SD = 1.23	M = 4.38 SD = 1.22	N = 15 staff members of METU
	MODEL-4-F (19-20.07.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 3.7m number of chairs: 20 (program:lumion)	M = 4.67 SD = 0.98	M = 5.20 SD = 0.77	M = 4.33 SD = 0.88	N = 15 staff members of METU
	MODEL-5-A (15-22.11.2012)			B06 plan: 8mx7m ceiling height: 3m window height: 1.7m number of chairs: 40 (program: lumion)	M = 3.93 SD = 1.19	M = 4.57 SD = 1.00	M = 3.44 SD = 0.80	
EXP. 5	MODEL-5-B (15-22.11.2012)			B06 plan: 8mx7m ceiling height: 4m window height: 1.7m number of chairs: 40 (program:lumion)	M = 4.29 SD = 1.12	M = 4.72 SD = 0.94	M = 3.92 SD = 0.87	N = 20 second-year architecture students of METU
	MODEL-5-C (15-22.11.2012)			B06 plan: 8mx7m ceiling height: 5m window height: 1.7m number of chairs: 40 (program:lumion)	M = 4.33 SD = 1.30	M = 4.42 SD = 1.53	M = 4.62 SD = 1.19	

Table 24 (continued)

	MODEL NO & DATE	IMAGES	PLANS	STIMULI	SF-1: APPEAL (7)	SF-2: PLANNING (7)	SF-3: SPACE FREEDOM (7)	PARTICIPANTS
EXP. 6	MODEL-6-A (30.04.2013-07.05.2013)			G103 plan: 9mx9,5m ceiling type: stepped floor type: stepped ceiling height: 3m-3m (program:lumion)	*M* = 3.92 *SD* = 1.52	*M* = 4.36 *SD* = 1.42	*M* = 3.42 *SD* = 1.08	*N* = 24 (12 architecture students and 12 staff members of METU)
	MODEL-6-B (30.04.2013-07.05.2013)			G103 plan: 9mx9,5m ceiling type: stepped floor type: stepped ceiling height: 4m-4m (program:lumion)	*M* = 4.59 *SD* = 1.15	*M* = 5.03 *SD* = 0.88	*M* = 4.23 *SD* = 1.00	
	MODEL-6-C (30.04.2013-07.05.2013)			G103 plan: 9mx9,5m ceiling type: flat floor type: stepped ceiling height: 3m-3,90m (program:lumion)	*M* = 4.35 *SD* = 1.44	*M* = 4.81 *SD* = 1.20	*M* = 4.04 *SD* = 1.14	
	MODEL-6-D (30.04.2013-07.05.2013)			G103 plan: 9mx9,5m ceiling type: flat floor type: stepped ceiling height: 4m-4,90m (program:lumion)	*M* = 4.66 *SD* = 1.39	*M* = 4.99 *SD* = 1.08	*M* = 4.57 *SD* = 1.12	
EXP. 7	MODEL-7-D (27-31.05.2013)			G103 plan: 9mx9,5m ceiling type: flat floor type: stepped ceiling height: 4m-4.90m (program:lumion)	*M* = 4.20 *SD* = 1.08	*M* = 4.83 *SD* = 1.13	*M* = 3.69 *SD* = 0.74	*N* = 20 architecture students of METU
	MODEL-7-G (27-31.05.2013)			G103 plan: 9mx9,5m ceiling type: flat floor type: flat ceiling height: 4.50m (program:lumion)	*M* = 3.88 *SD* = 0.84	*M* = 3.99 *SD* = 0.91	*M* = 3.70 *SD* = 0.87	
EXP. 8	MODEL-8-A (25.07.2013)			MM319 plan geometry: trapezoid (45o) plan area: 132.37m2 ceiling heighti: 3.50m (program:lumion)	*M* = 4.79 *SD* = 1.22	*M* = 5.07 *SD* = 0.99	*M* = 4.36 *SD* = 1.15	*N* = 20 architecture students of METU
	MODEL-8-B (25.07.2013)			MM319 plan geometry: rectangle plan area: 132.37m2 ceiling heighti: 3.50m (program:lumion)	*M* = 4.59 *SD* = 1.12	*M* = 5.16 *SD* = 0.97	*M* = 4.60 *SD* = 1.06	

Note for Table 24:

Abbreviations:
SF = Spaciousness Factor; EXP. = Experiment
M = Mean; SD = Standard deviation, N = Total number of participants.

Participants:
A total of 350 people participated in the experiments. Since the evaluations of six participants were pilot studies, only the evaluations of 344 participants were included in the statistical analyses mentioned above.

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name : Özyıldıran, Güler
Nationality : Turkish (TC)
Date and Place of Birth: 1982, Kütahya
Place of Registry: Burdur
e-mail : gulerozyildiran@hotmail.com

EDUCATION

Degree	Institution	Years
Ph.D.	METU Department of Architecture	2008-2015
M.Arch.	METU Department of Architecture	2005-2007
Eng. Prep.	METU Department of Basic English	2004-2005
B.Arch.	SDU Department of Architecture	2000-2004
High School	Burdur Anatolian High School	1993-2000

MASTER THESIS

ÖZYILDIRAN, G. (2007). "The Effects of Turkish Disaster Regulations on Architectural Design". Ankara: METU M.Arch. thesis. (Supervisor: Prof. Dr. Vacit İMAMOĞLU).

LANGUAGES

Turkish (mother tongue), English (advanced), German (beginner)

HOBBIES

Painting, Drawing Cartoon, Photography, Writing

AWARDS

Year	Award
2007	METU; Graduate Courses Performance Award (First-highest-ranking CGPA among students who completed master courses in two semesters in M.Arch. program).
2004	SDU; Second-highest-ranking Graduation in Department of Architecture.
1991-1998	Various awards in the field of painting, and literature from elementary and secondary education periods.

SCHOLARSHIP

2004-2015	Master & Doctoral Research Scholarship (Faculty Development Program) by the State Planning Organization.

WORK EXPERIENCE

Year	**Institution**	**Enrollment**
2005-2015	METU Department of Architecture	Research Assistant

EXPERIENCES AS A TEACHING ASSISTANT AT METU

ASSISTED DESIGN STUDIOS

Course Code and Name	**Term**
• Arch101 Basic Design	2007, 2008 falls
• Arch102 Introduction to Architectural Design	2008 spring
• Arch201 Architectural Design I	2011, 2012, 2013 falls
• Arch202 Architectural Design II	2012, 2013, 2014 springs
• Arch301 Architectural Design III	2009 fall
• Arch302 Architectural Design IV	2010 spring

ASSISTED COURSES

Course Code and Name	**Term**
• Arch103 Graphic Communication I	2011 fall
• Arch104 Graphic Communication II	2010 spring
• Arch121 Introduction to Architecture I	2010 fall
• Arch122 Introduction to Architecture II	2011 spring
• Arch203 Digital Media in Architecture I	2012 fall
• Arch204 Digital Media in Architecture II	2013 spring
• Arch231 Statics and Strength of Materials I	2009 fall
• Arch331 Structural Design in Architecture I	2014 fall
• Arch351 What Gets Building Made	2008 fall
• Arch489 Lighting in Architecture	2010 spring
• BS 531 Studies on Architectural Structures	2006 fall

ASSISTED SUMMER PRACTICES

- Arch190 Summer Practice in Building Construction and Surveying:
  - 2012, 2013 summers, Building Surveying Studio, METU, Department of Architecture.
  - 2010, 2011 summers, “Masonry Workshop”, Gazi University, Department of Construction Education.
  - 2008, 2010, 2011 summers, “Wood Workshop”, Gazi University, Department of Construction Education.
  - 2006 summer, Construction of a “Guardhouse” in the entrance of Eymir Lake in METU Campus.
  - 2005 summer, Construction of “Hisarköy Village Clinic” in Yahşihan in Kırıkkale.
  - 2005 summer, Topographic Surveying in METU Campus.