LIGHTING AESTHETIC EVALUATION

USING SCALE MODELS

by

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TABLE OF CONTENTS

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LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The science and art of lighting depends upon the ability of the eye to function with reasonable efficiency in a wide range of conditions. The eye is able to make use of very high and low levels of light, but there are certain optimum conditions in which it works best, and one aim of the lighting research is to find out exactly what are these optimum conditions. The aim of good lighting is to provide them.

The eye as an organ of sight and the brain as an organ of interpretation operate together in the determination of visual performance of an individual. The measurement of visual performance requires a detailed analysis both of the process of sight and of the geometric and photometric characteristics of the visual field. More is known of the characteristics of the eye as an optical instrument than of the characteristics of the brain as an interpretive mechanism. Consequently much of the analysis which goes into the determination of visual performance is concerned with the optics of the situation rather than with its interpretation.

The quantity and quality of lighting depends on the following four requirements; visual performance, comfort, pleasantness, economy. Measurable relationships have been found between quantity of illumination and performance of a task. But different tasks need different levels of illumination for maximum performance. Visual performance may be measured in an entirely objective manner. Performance may be defined meaningfully in terms of such variables as speed and accuracy. It is straight-forward to measure the speed and accuracy of visual performance as a function of quantity of illumination. Such measurements could presumably be made for every visual task of practical interest. It is quite important that lighting installations must satisfy the criterion of visual comfort. Visual comfort occurs when there are no overly high luminances or contrasts within the worker's visual field. Visual comfort is usually evaluated subjectively. Economy, requires that the standards of lighting should not be more than required so that lighting costs are kept to the minimum and energy is not wasted. Taking for granted that all the requirements for a good lighting environment, like visual performance, comfort and economy, are met, the modern interior lighting designer is much concerned about the aesthetics of the lighted space.

General Lighting Aesthetics

The basic purpose of lighting is nominally considered to be that of enabling people to see, however, its function is actually much broader in scope. Lighting is a dominant factor in environmental design. It affects the usefulness and enjoyment of a building interior and is often an inseparable part of the architectural concept.

Thus the art and science of modern interior lighting is broad in scope and involves many factors. Some of these relate to light and vision and the visual response of the eye under varying light and environmental conditions. Others relate to the production, control, and distribution of light. Still others relate to the enclosure itself, or building structure, including size, shape, color, and related decorative considerations.

The problem for the lighting engineer and architect today is no longer that which faced the lighting designer some years ago, when the provision of enough light for seeing was the main issue. Now "enough light" is taken for granted, and it is "what to do with it" that is of prime importance. The increase of illumination levels has produced its own problems, both from the point of view of physical comfort and emotional well-being. It is important that the psychological values of the artificially lit environment are understood so that light may be employed usefully to achieve the character most appropriate to the use of the building. That is to say considerable attention has to be paid to the quality in addition to the quantity of lighting.

Quality of lighting is a term used to describe all the factors in a lighting installation not directly concerned with quantity of illumination. Certainly it is obvious that if a given room is alternately lighted with a bare bulb and with a luminous ceiling, both giving the same average quantity of illumination, there is a vast difference in the two lighting systems. This difference is in the quality of the lighting, a term which describes the luminous ratios, diffusion, uniformity, and chromaticity of the lighting.

The term aesthetics of a lighting environment is concerned with its quality rather than the quantity of illumination. Aesthetics of a lighted space is a complex phenomenon to explain as it is a combined effect of various things that describe the quality of lighting. Its measurement is highly subjective.

Quite a few attempts have been made to measure the meaning, in different situations. The development of the semantic differential as a general method of measuring meaning by Osgood (1957), has proved to be a successful approach. A few studies have been attempted by some researchers, to make use of the semantic differential techniques to measure meaning of different real lighting environments. Due to high cost and lack of flexibility involved in using real environments, simulations rather than the real environments were tried successfully by a few researchers in lighting studies. So, in recent years, a few studies were attempted using scale models and slides in lighting research.

The main object of the present study is to find out people's subjective reactions to a space, in particular the aesthetic pleasantness of certain lighting variations using a scale model for different situations under particular lighting conditions. Aesthetic pleasantness is multi-dimensional. The semantic differential technique can be used to measure meaning multidimensionally.

Semantic Differential Technique

Canter (1968), has stated that " ... words are of interest because they are frequently predictions of actions. To say one hates a place is often a precursor to his/her leaving it. Another way of expressing this is that words take less force to trigger off than actions and thus are more sensitive indicators of the situation ... They give insight into what is going on inside people." The semantic differential and other semantic scaling devices appear to offer possibilities in measuring people's reactions quantitatively in an environment, because they correspond to the verbal mode by which the people express their thoughts, feelings, attitudes etc.

The semantic differential technique, as a general method of measuring meaning, consists of using sets of pairs of words that represent the meaning of a particular concept expressed on linear scales. Each pair of words that are opposite in meaning to each other correspond to a linear scale and represent the extreme ends of the scale as shown in Figure 1. The scale is conveniently divided into a few segments that will be assigned numerical values in ascending or descending order. This facilitates measuring the subjective responses quantitatively.

The semantic differential can be employed, a) to discover relationships between the form of the physical environment and those who occupy it, and b) to provide a basis for understanding the WHY of the relationship. Then one should account for those attributes of the physical environment which "moves him", which causes his heart to palpitate, his head to spin, his spirits to set sail or conversely to make him calm, sulky, hateful or fearful. Also one should account for those attributes which affect how one acts; where he goes, how directly, at what speed, to whom he speaks, etc.

One should seek on one hand a set of semantic scales which represent all meaningful aspects of the physical environment. On the other, a set of semantic scales which describe potential human responses to the attributes of the physical environment described by the first set, are needed. Hershberger (1972), says that considering together the above two sets of scales, the architect can discover what he needs to know about how a specific group of users will respond to his buildings; if the users will "like" his buildings, if they will consider it comfortable and pleasant, if they will behave appropriately -- with reverence, indifference, or whatever.

Specifically, then, one should characterize the set(s) of semantic scales used to describe the physical environment and the responses to it.

unpleasant 1 2 3 4 5 6 7 pleasant

The 1 to 7 scale is defined as:

1. Very unpleasant
2. Moderately unpleasant
3. Slightly unpleasant
4. Neutral
5. Slightly pleasant
6. Moderately pleasant
7. Very Pleasant

Figure 1. A semantic scale

First the limitations of the semantic differential and similar adjectival descriptions should be recognized. The adjectives should not be too specific. The variations in the environment are infinite -- and hence impossible to describe completely.

The semantic differential technique is a generalized technique in the measurement of meaning. So, there are no standard concepts and no standard scales. Rather, the concepts and scales used in a particular study depend upon the purposes of the research. The semantic differential yields quantitative data which are verifiable, in the sense that other investigators can apply the same sets of scales to equivalent subjects and essentially obtain the same results.

The development of semantic differential involves, a) the use of factor analysis to determine the number and nature of factors entering into semantic description and judgment, and (b) the selection of a set of specific scales corresponding to these factors which can be standardized as a measure of meaning.

The purpose of the factor analysis is to isolate a limited number of general dimensions of meaning having a maximal differentiating power, to try to bring some order out of semantic chaos. The nature and number of factors obtained in any analysis is limited by the sources of variability in the original data. In other words the effectiveness of a factor analysis can be assessed by the proportion of the total variance of the data that is accounted for by the factors extracted.

Substantial research in the use of semantic differential techniques for the measurement of meaning in the architectural environments, has been accomplished by Vielhauer (1965), Canter (1968), Craik (1968), Collins (1969), Brittell (1969), and Hershberger (1972). Most of these studies were reviewed by Collins and Seaton (1972). As a result of the above studies, five dimensions of architectural meaning emerged, namely, 1) aesthetic evaluation, 2) physical organization, 3) space or size, 4) friendliness, and 5) potency.

Subjective Reactions to Lighting and their Measurement

Gibson,(1971) argues a theory of visual perception based on the idea that light can convey information, and that the brain constructs the phenominal world from this information. Gibson suggests that this idea "depends on a new conception of light in terms of an array at a point of observation --- light considered not merely as a stimulus but also as a structure." This suggests that as the designer changes lighting modes, he changes the composition and relative strength of visual signals and cues; and this alters some impressions of meaning for the typical room occupant or user.

A recent study (Flynn, Spencer, Martyniuk and Hendrick, 1973), reports findings concerning the effect of environmental lighting as a medium that affects user impressions and behavior. They suggest that light can be a vehicle that facilitates the selective process and alters the information content of the visual field. The researchers made use of a room at General Electric's Lighting Institute at Nela Park near Cleveland, Ohio, that has a number of alternative lighting arrangements. Judgments on semantic differential rating scales were obtained for each of six different lighting arrangements (1) low intensity overhead down-lighting, 2) peripheral lighting (all walls), 3) low setting overhead diffuse lighting, 4) combination: overhead downlighting (1) + end walls, 5) high setting overhead diffuse lighting, and 6) combination: overhead downlighting (1) + peripheral (2) + overhead diffuse (3)) in a medium sized conference room. Ratings were analyzed from 12 groups with a total of 96 subjects in groups of eight. All the subjects were adults and their age and educational backgrounds were mixed.

For each group, initial ratings of the room were obtained for the lighting arrangement that was in effect when the subjects first entered the room. Each of the six lighting arrangements was in effect for two of the 12 groups as they first entered. Subjects were asked to judge the room with respect to all of its characteristics. Thus any significant differences in the ratings between the groups was taken as the differential effect of lighting variations on the overall impressions of the physical space.

The principal factors to emerge from Flynn's study were called "evaluative", "perceptual clarity" and "spaciousness". The best (high evaluation) lighting system was a combination of down-lights plus diffuse overhead plus peripheral (wall) lighting. This verifies that light should come from more than one direction. The peripheral clarity factor was largely dependent upon the amount of illumination. Spaciousness resulted from peripheral rather than overhead lighting.

A few more researchers, Rodman (1970), Howard, Mlynarski, and Sauer (1972), Lemons and Macleod (1972), and Lemons and Cole (1977), tried to find the subjective reactions to different lighting environments in different living spaces. But all of these studies were made in simulated rather than the real environments. The researchers claim that the simulated environments can be successfully used in place of real environment to measure the subjective reactions.

Scale Model Techniques

There are many advantages in studying simulated rather than real environments. The architect may represent his architecture by drawings, models, or slides of models, and measure people's responses to them before the buildings are actually constructed. It seems reasonable to assume that many architectural disasters could have been avoided if the reactions of their occupants or observers had been accurately measured beforehand.

The disadvantage in using simulations is that subjects may not respond to them as they would to the actual environments. Although the pattern of behavior elicited by simulation is interesting in its own right, it may tell little about the subjects responses when confronted with the actual building, room, or landscape.

Given advantages of using simulations, it becomes increasingly important that one can have objective data comparing responses to environments represented in various ways, so that both the architect and the researcher may make rational decisions about this method of stimulus presentation.

The aesthetics of a lighted space is one of the main considerations of lighting design. The engineer may use all the technical material available to him and yet be unable to create an environment that is aesthetically pleasing. The interior designer may provide the correct combination of surface finishes and textures and elegant finishings, but produce an improperly illuminated environment. A marriage of these skills is therefore needed to create environments that are pleasing to the inhabitants.

A successful simulation device can be the means by which the full nature of the final solution is identified and accepted. From this solution an architect can draw the information necessary to put together the forms and shapes, and the lighting engineer can obtain information to construct a lighting system which will produce a particular kind of luminous environment. So, various researchers made attempts to arrive at a more sophisticated design and evaluation technique which should have meaning both to architects and lighting engineers.

Rodman (1970), proposed a technique which gives a good simulation of full-scale reality, yet maintains a wide freedom and facility for experimentation. In essence, it consists of the use of a special kind of variable model, the recording of model variaton "sketch studies" in slide form, and the comparison and evaluation of these studies are slides projected to scale which may approach full size. The researcher suggests that one of the most important uses of this technique may be that of a communication device, or middle ground for architects, lighting designers, and their clients and also it would reduce many of the stresses and costly misunderstandings and make the design a cooperative and creative joint effort.

Howard, Mlynarski, and Sauer, (1972), used slides as the simulation of real environments and collected data on people's responses to them. In this attempt, they claim that although the effective responses to the real and simulated environments are not the same, the differences are consistant enough to make several practical suggestions about the future use of slides as a method of simulating environments.

Lemons, and Macleod, (1972), suggest that basic environments can be created, varied and evaluated at low cost in scale models and also various illumination systems can be introduced into the environment. In this study the researchers used a scale model to arrive at the quality evaluation of a lighting system design prior to actually constructing the real environment. From the research, it was found that the quality of lighting within an environment is more dependent upon luminance ratios than quantity (horizontal footcandles). The luminance ratios are dependent upon the brightness of the luminaires, ceiling, walls and floor.

Lemons, and Macleod, (1975) tried to demonstrate the concept of the levels of equivalent sphere illumination (esi) for some tasks, in place of standard footcandle levels to specify the lighting system quality. Based on the previous success of model studies, scale models were used here to demonstrate esi concepts and thereby system performance differences. The researchers claim that models can help a complex subject become more readily understood.

Lemons, and Cole (1977), also used scale models to investigate the problem and potential solution to the lighting of open office systems.

Incandescent Vs Fluorescent Lighting

Kruithof (1941), confirmed experimentally the phenomenon that at low levels of illumination, most people prefer a "warm" light, whereas at high levels of illumination, a "cold" light is preferred. It is widely believed that this is because the people are used to high levels of illumination from the natural daylight, whereas in the interior of homes long experience with warm light from the fire or from incandescent lighting sources such as candle light or incandescent filament light, is related in their minds with low levels of illumination.

Historically, fluorescent home lighting has been used for the workshop. So, when someone thinks of fluorescent, he thinks of lighting that's commercial in appearance. For that reason, in homes, fluorescent lighting has been fairly accepted in utility areas such as kitchens, garages, laundry rooms, etc., whereas incandescent lighting has been well accepted in non-utility areas such as living rooms and dining rooms, in places intended for relaxation or social activity. The preference of incandescent lighting in non-utility areas is certainly related,so far as this country and others with similar cultures are concerned, to the long tradition which shows itself in the pleasure of dining by candle light or talking to friends by the light of an open fire.

Generally, in commercial spaces, like workshops, class rooms, merchandise handling places uniformly distributed fluorescent lighting is used. That is because of the fact that emphasis is given to the quantity and economy rather than the aesthetics of illumination in the spaces. But in other commercial spaces like restaurants, show rooms, where lighting aesthetics is of much concern, non-uniformly distributed incandescent lighting is used. So, it would seem that the use of a light source and the distribution of its light in a space mainly depends upon the activity (task) in that space.

PROBLEM

Research has been carried out in providing the proper illumination levels, light sources, uniformity of illumination and types of luminaires for different situations. Most of the research was done in real environments. The purpose of the present study is to carry out similar research using scale models on one particular aspect of the aesthetics of lighting, namely the differences between fluorescent and incandescent lighting.

Considering previous research work and experience in the field of lighting and its aesthetics, the following hypotheses were made for the low illumination level chosen for the present study:

1. In both "relaxation" and "commercial" situations (living room and waiting room), circular shaped, non-uniform ceiling luminaire pattern with an incandescent light source would be judged more pleasant.
2. Both tne rooms would be judged more clear under fluorescent light source with rectangular shaped uniform ceiling luminaire pattern.
3. Rectangular luminaire patterns under fluorescent light source for waiting room and circular luminaire patterns under incandescent light source for living room would be preferred significantly.

METHOD

In this study two scale models of a room, each 20" x 12" x 8" were made (see Figure 2) to the scale of one inch equals to one foot. One of the scale models was used under an incandescent lighting system (see Figure 3), and the other was used under fluorescent lighting system (see Figure 4) of equal average illumination (28 fc). Under each lighting system, subjects were asked to observe two ceiling light patterns (uniform and non-uniform), with two kinds of luminaire shapes (rectangular and circular). Subjective evaluations on lighting quality were made by the subjects on eleven semantic differential scales for each lighting condition. Nine semantic differential scales were taken from the Flynn's study and the other two "warm-cool" and "cloudy-sunny" were included to make the set of eleven semantic scales.

Tasks

Sixteen situations were chosen for this study. They consisted of four ceiling luminaire patterns (rectangular shaped uniform and non-uniform and circular shaped uniform and non-uniform), under two different light sources (fluorescentand incandescent), for two types of rooms (living room and waiting room). These are shown in Figure 5. Rectangular and circular shaped, uniform and non-uniform ceiling luminaire patterns were chosen because of their common usage for fluorescent and incandescent recessed lights respectively. Also the fluorescent and incandescent light sources were selected for this study, because they were the most commonly used light sources. Till now lotsof studies were made in the area of lighting aesthetics

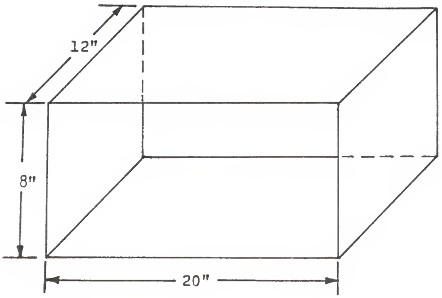
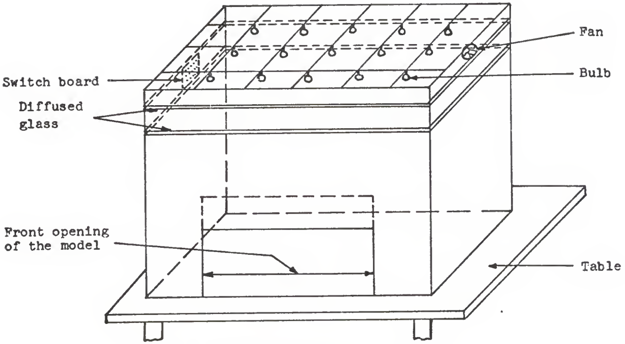
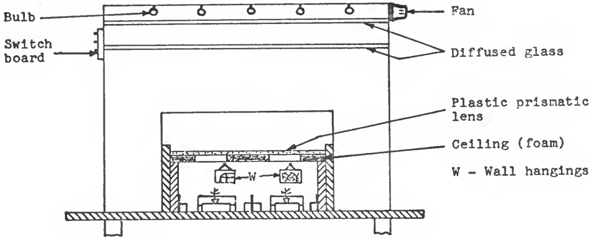


Figure 2. Overall dimensions of the scale model

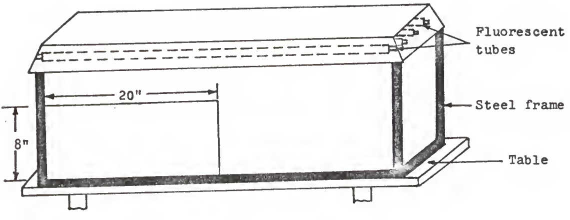


Incandescent lighting booth

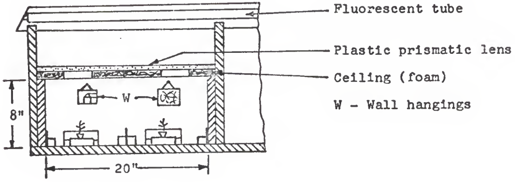


Cross sectional front view of incandescent
lighting booth with scale model

Figure 3. Scale model under incandescent light source



Fluorescent lighting booth



Cross sectional front view

Figure 4. Scale model under fluorescent light source

TYPE OF ROOM	TYPE OF SOURCE	TYPE OF LUMINAIRE PATTERN	
LIVING ROOM	FLUORESCENT	RECTANGULAR UNIFORM	1
		RECTANGULAR NONUNIFORM	2
		CIRCULAR UNIFORM	3
		CIRCULAR NONUNIFORM	4
	INCANDESCENT	RECTANGULAR UNIFORM	5
		RECTANGULAR NONUNIFORM	6
		CIRCULAR UNIFORM	7
		CIRCULAR NONUNIFORM	8
WAITING ROOM	FLUORESCENT	RECTANGULAR UNIFORM	9
		RECTANGULAR NONUNIFORM	10
		CIRCULAR UNIFORM	11
		CIRCULAR NONUNIFORM	12
	INCANDESCENT	RECTANGULAR UNIFORM	13
		RECTANGULAR NONUNIFORM	14
		CIRCULAR UNIFORM	15
		CIRCULAR NONUNIFORM	16

Figure 5. Situations

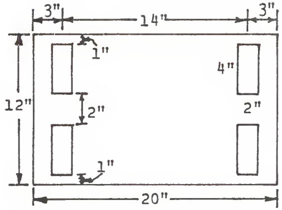
pertaining to public places like classrooms, conference rooms, waiting rooms, etc. But very little was done in finding the lighting aesthetics of private rooms like living rooms. So, in the present study, both the waiting room (public place) and the living room (private place) situations were chosen to find out the difference in the preferences of the two situations under different lighting conditions.

Each subject was shown four conditions (ceiling luminaire patterns, see Figure 6), for one of the two room types and one of the two types of light source. This reduced the possibility of effects of pre-conceptions about different room types and light sources by the subjects. Thus each subject judged the room with respect to the overall impression made by its physical space, only under different ceiling light arrangements. In this experiment, the situations are the independent variables, and the subjective responses (semantic differential scales) are the dependent variables.

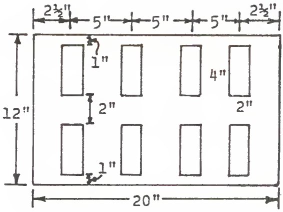
After the subject was shown each setting for a brief period of time, he (she) was asked to evaluate it in a booklet having the semantic scales (see Figure 7).

Experimental Design

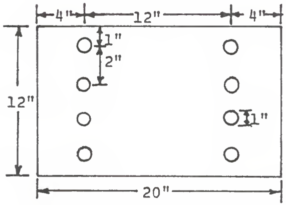
For this experiment, sixty students from different disciplines of science and engineering of Kansas State University, Manhattan, Kansas, participated as subjects. They were both males and females of different ages (mostly between 20 and 30 years) and educational backgrounds. The experimenter contacted the subjects personally, explained the study and requested their participation. The recruitment of the subjects in this study was made purely on voluntary basis.



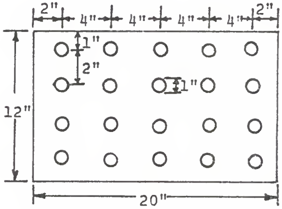
1. Rectangular nonuniform



2. Rectangular uniform



3. Circular nonuniform



4. Circular uniform

Figure 6. Ceiling luminaire patterns

FOR EXPERIMENTER USE ONLY:

TYPE OF ROOM: LR/WR

TYPE OF SOURCE: F/I

LUMINAIRE PATTERN: 1/2/3/4

GRADING SHEET

NAME: ______________________, AGE: ______yrs, SEX: M/F

				AVERAGE				
Unpleasant	1	2	3	4	5	6	7	Pleasant
Warm	1	2	3	4	5	6	7	Cool
Vague	1	2	3	4	5	6	7	Distinct
Short	1	2	3	4	5	6	7	Long
Cloudy	1	2	3	4	5	6	7	Sunny
Small	1	2	3	4	5	6	7	Large
Tense	1	2	3	4	5	6	7	Relaxed
Cramped	1	2	3	4	5	6	7	Spacious
Hazy	1	2	3	4	5	6	7	Clear
Monotonous	1	2	3	4	5	6	7	Interesting
Dim	1	2	3	4	5	6	7	Bright

DATE: ______________ ______________________________
(SIGNATURE)

REMARKS:

Figure 7 . Grading sheet

For one of the two room types and one of the two types of light source, the four ceiling luminaire patterns were assigned at random, to each subject. The room type and light source were also assigned randomly to the subject. Furniture arrangements (see Figure 8), wall hangings (see Figures 3 and 4), and the average foot candle level (28 fc), in the scale models were kept unchanged throughout the experiment. The 28 fc level chosen for this study was a constraint of the experimental setup. But it is well within the range of foot candle levels normally used in typical living and waiting room situations. The foot candle level was maintained the same in all sixteen lighting conditions.

Before the starting of the experiment, each subject was given an informed consent and instruction sheet (Living room or waiting room). The informed consent and instruction sheets were prepared as shown in Figure 9 and Figure 10. When the subject was ready for the experiment, his/her signature was taken on an informed consent statement form as shown in Figure 11. The subject was then given a booklet consisting of four sheets, each having eleven semantic scales as shown in Figure 7 . Then the subject was shown the lighting conditions briefly one after the other. After the subject was exposed to each condition for a brief period of time, he/she was asked to evaluate it in the booklet. Each subject spent approximately fifteen minutes in this experiment.

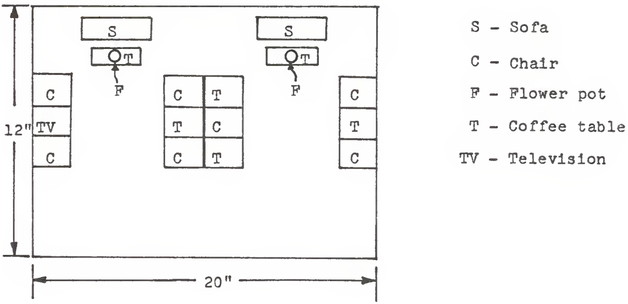


Figure 8. Furniture layout in the model

INFORMED CONSENT AND INSTRUCTIONS

LIVING ROOM

This experiment is designed to study "THE LIGHTING AESTHETICS USING SCALE MODELS".

Your task will be very simple. You will be asked to sit down in front of a scale model of a LIVING ROOM, lit by a particular kind of lighting. You will be shown this condition briefly. Then you will judge the lighting in a booklet. Altogether you will be exposed to four light settings and make judgments in each case. For example, if you feel that a particular light setting is very pleasant, very friendly and is average in beauty, circle the number close to your judgment on the sheet, as shown below

				average				
unpleasant	1	2	3	4	5	6	(7)	pleasant
unfriendly	1	2	3	4	5	6	(7)	friendly
ugly	1	2	3	(4)	5	6	7	beautiful

There will be no risk in this experiment. However, you are free to stop your participation at any time. Naturally, I would prefer that you continue until the end so that I can get all the data. If you have any questions, now or later, feel free to ask.

Now, if you are ready for the experiment, please sign the informed consent statement form given by the experimenter.

If you have any comments about the procedure and experiment, please feel free to write them at the end of the experiment in the space provided in the booklet.

Thanks for your cooperation.

Figure 9. Instructions

INFORMED CONSENT AND INSTURCTIONS

WAITING ROOM

This experiment is designed to study "THE LIGHTING AESTHETICS USING SCALE MODELS".

Your task will be very simple. You will be asked to sit down in front of a scale model of a WAITING ROOM, lit by a particular kind of lighting. You will be shown this condition briefly. Then you will judge the lighting in a booklet. Altogether you will be exposed to four light settings and make judgments in each case. For example, if you feel that a particular light setting is very pleasant, very friendly and is average in beauty, circle the number close to your judgment on the sheet, as shown below

				average				
unpleasant	1	2	3	4	5	6	(7)	pleasant
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ugly	1	2	3	(4)	5	6	7	beautiful

There will be no risk in this experiment. However, you are free to stop your participation at any time. Naturally, I would prefer that you continue until the end so that I can get all the data. If you have any questions, now or later, feel free to ask.

Now, if you are ready for the experiment, please sign the informed consent statement form given by the experimenter.

If you have any comments about the procedure and experiment, please feel free to write them at the end of the experiment in the space provided in the booklet.

Thanks for your cooperation.

Figure 10. Instructions

INFORMED CONSENT STATEMENT

Having read the informed consent, I hereby freely agree to be a subject in the research entitled "THE LIGHTING AESTHETIC STUDY USING SCALE MODELS".

S. NO.	SIGNATURE	AGE (yrs)	SEX: (M/F)	DATE

Figure 11. Informed consent form

RESULTS

The data obtained in this experiment was collected in four sets. The first two sets were collected for a living room situation, under fluorescent and incandescent light sources. The third and fourth sets were collected for a waiting room situation, under fluorescent and incandescent light sources. The ratings of the 60 subjects and the corresponding four significant factors, for each living environment condition are shown in Appendix I . The correlations among the eleven semantic scales for all 240 observations are shown in Table 1.

The subjective ratings were factor analyzed using the statistical analysis system computer program (User's guide to SAS 76, North Carolina, SAS Institute Inc., 1976) to find areas of relationships in the use of semantic scales. This factor analysis resulted in identification of four factors or "categories of impression". The factor pattern of these factors are shown in Table 2. The factors and the highest factor loadings (above 0.56), are shown in Table 3.

In the next part of the analysis, tests were made for homogeneity within covariance matrices of the factors. This is shown in Table 4. From this analysis it was found that there was heterogenity within the covariance matrices. Therefore multivariate analysis of variance could not be done for the factors. Thus only, univariate analyses of variance were done by considering each factor separately.

These analyses of variance were conducted to find the significant differences among the room types, and the light sources and their interactions.

TABLE 1

Correlation Matrix

NUMBER OF OBSERVATIONS= 240

CORRELATION MATRIX

	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11
R1	1.00000	-0.05879	0.23362	0.15810	0.21490	0.08939	0.48341	0.23387	0.17556	0.41559	0.17317
R2	-0.05879	1.00000	-0.00188	0.00167	-0.14999	-0.01304	-0.09023	-0.04131	-0.03393	-0.19346	-0.08104
R3	0.23362	-0.00188	1.00000	0.17640	0.54052	0.33371	-0.02769	0.16099	0.55943	0.20550	0.56734
R4	0.15810	0.00167	0.17640	1.00000	0.16023	0.54242	0.02154	0.27213	0.22151	0.00664	0.19393
R5	0.21490	-0.14999	0.54052	0.16023	1.00000	0.33538	-0.13333	0.20248	0.69147	0.13273	0.78475
R6	0.08939	-0.01304	0.33371	0.54242	0.33538	1.00000	-0.03658	0.40821	0.46569	0.00410	0.40665
R7	0.48341	-0.09023	-0.02769	0.02154	-0.13333	-0.03658	1.00000	0.36069	-0.07232	0.48961	-0.11363
R8	0.23387	-0.04131	0.16099	0.27213	0.20248	0.40821	0.36069	1.00000	0.36673	0.30701	0.24382
R9	0.17556	-0.03393	0.55943	0.22151	0.69147	0.46569	-0.07232	0.36673	1.00000	0.14644	0.73165
R10	0.41559	-0.19346	0.20550	0.00664	0.13273	0.00410	0.48961	0.30701	0.14644	1.00000	0.19550
R11	0.17317	-0.08104	0.56734	0.19393	0.78475	0.40665	-0.11363	0.24382	0.73165	0.19550	1.00000

TABLE 2

Factor Pattern

FACTOR PATTERN

	FACTOR1	FACTOR2	FACTOR3	FACTOR4
R1	0.39907	0.61505	-0.08507	0.22378
R2	-0.12834	-0.19273	0.29599	0.90764
R3	0.70724	-0.13402	-0.21597	0.21780
R4	0.42813	-0.02094	0.69679	-0.16068
R5	0.79475	-0.25756	-0.31930	-0.03498
R6	0.63546	-0.15707	0.56485	-0.14144
R7	0.09981	0.86871	0.05760	0.08773
R8	0.52093	0.38745	0.38345	-0.04342
R9	0.83731	-0.21733	-0.10028	0.06754
R10	0.34952	0.68650	-0.26427	-0.00976
R11	0.83278	-0.25030	-0.24975	0.02443

TABLE 3

Factors and the Factor Loadings

			Loadings
Factor 1 - CLARITY			
Hazy	---------------------	Clear	0.84
Dim	---------------------	Bright	0.83
Cloudy	---------------------	Sunny	0.79
Vague	---------------------	Distinct	0.71
Factor 2 - EVALUATION			
Tense	---------------------	Relaxed	0.87
Uninteresting	---------------------	Interesting	0.69
Unpleasant	---------------------	Pleasant	0.62
Factor 3 - SPACIOUSNESS			
Short	---------------------	Long	0.70
Small	---------------------	Large	0.56
Factor 4 - COLOR			
Warm	---------------------	Cool	0.90

TABLE 4

Chi-Square Test

DISCRIMINANT ANALYSIS TEST OF HOMOGENEITY OF WITHIN COVARIANCE MATRICES

NOTATION:

K = NUMBER OF GROUPS

P = NUMBER OF VARIABLES

N = TOTAL NUMBER OF OBSERVATIONS

N(I) = NUMBER OF OBSERVATIONS IN THE I'TH GROUP

$$V = \frac{\prod |\text{WITHIN SS MATRIX(I)}|^{N(I)/2}}{|\text{POOLED SS MATRIX}|^{N/2}}$$

$$RHO = 1.0 - \left[\text{SUM} \frac{1}{N(I)-1} - \frac{1}{N-K} \right] \frac{2P^2 + 3P - 1}{6(P+1)(K-1)}$$

$$DF = .5(K-1)P(P+1)$$

UNDER NULL HYPOTHESIS: $-2\ RHO\ LN \left[\frac{N^{PN/2}\ V}{\prod N(I)^{PN(I)/2}} \right]$ IS DISTRIBUTED APPROXIMATELY AS CHI-SQUARE(DF)

TEST CHI-SQUARE VALUE = 51.66837364 WITH 30 DF PROB > CHI-SQ = 0.0083

THE CHI-SQUARE VALUE IS SIGNIFICANT AT THE 0.0500 LEVEL

The results of these analyses are shown in Tables 5, 6, 7 and 8. Duncan's multiple range test was also conducted for the above analyses and the results are shown in Tables 9, 10, 11 and 12 for room types and Tables 13, 14, 15 and 16 for source types, respectively. Another analysis of variance was carried out for each factor, to find the significant differences among the ceiling luminaire patterns, and the interactions between the luminaire patterns, the room types and the light source types. The results of these analyses are shown in Table 17, 18, 19 and 20. Then the Duncan's multiple range test was conducted for the above analyses and the results of these tests are shown in Tables 21, 22, 23, and 24. A two tail $\underline{t}$ test was carried out for the shapes and distribution of the luminaire patterns, for all the four factors separately and the results are shown in Tables 25, 26, 27 and 28.

All statistical tests were made at 0.05 significant level. A guide to the various symbols in the analyses is given in Appendix II.

TABLE 5

Clarity Factor: Analysis of Variance for Room and Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: F1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	8.66419307	2.88806436	0.51	0.6804	0.026631	99999.9999
ERROR	56	316.67988548	5.65499795		STD DEV		F1 MEAN
CORRECTED TOTAL	59	325.34407855			2.37802396		0.00000000

SOURCE	DF	ANOVA SS	F VALUE	PR > F
R	1	3.70505249	0.66	0.4217
S	1	1.10105941	0.19	0.6607
R*S	1	3.85808117	0.68	0.4123

TABLE 6

Evaluation Factor: Analysis of Variance for Room and Source Types

STATISTICAL ANALYSIS SYSTEM

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: F2

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	16.47908470	5.49302823	1.49	0.2261	0.073902	99999.9999
ERROR	56	206.50523822	3.68759354		STD DEV		F2 MEAN
CORRECTED TOTAL	59	222.98432292			1.92031079		0.00000000

SOURCE	DF	ANOVA SS	F VALUE	PR > F
R	1	1.74437659	0.47	0.4944
S	1	3.64859072	0.99	0.3242
R*S	1	11.08611739	3.01	0.0884

TABLE 7

Spaciousness Factor: Analysis of Variance for Room and Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: F3

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	5.02952764	1.67650921	0.34	0.8009	0.017727	99999.9999
ERROR	56	278.68990750	4.97660549		STD DEV		F3 MEAN
CORRECTED TOTAL	59	283.71943514			2.23083067		0.00000000

SOURCE	DF	ANOVA SS	F VALUE	PR > F
R	1	0.47752339	0.10	0.7579
S	1	0.00617932	0.00	0.9720
R*S	1	4.54582493	0.91	0.3433

TABLE 8

Color Factor: Analysis of Variance for Room and Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DEPENDENT VARIABLE: F4

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	3	11.88646343	3.96215448	0.84	0.4822	0.042874	99999.9999
ERROR	56	265.35588694	4.73849798		STD DEV		F4 MEAN
CORRECTED TOTAL	59	277.24235037			2.17680913		0.00000000

SOURCE	DF	ANOVA SS	F VALUE	PR > F
R	1	0.00457289	0.00	0.9753
S	1	10.19588286	2.15	0.1480
R*S	1	1.68600768	0.36	0.5532

TABLE 9

Clarity Factor: Duncan's Test for Room Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F1

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=5.655

GROUPING	MEAN	N	R
A	0.248497	30	L
A			
A	-0.248497	30	W

TABLE 10

Evaluation Factor: Duncan's Test for Room Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F2

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=3.68759

GROUPING	MEAN	N	R
A	0.170508	30	L
A			
A	-0.170508	30	W

TABLE 11

Spaciousness Factor: Duncan's Test for Room Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F3

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=4.97661

GROUPING	MEAN	N	R
A	0.089212	30	W
A			
A	-0.089212	30	L

TABLE 12

Color Factor: Duncan's Test for Room Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F4

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=4.7385

GROUPING	MEAN	N	R
A	0.008730	30	W
A			
A	-0.008730	30	L

TABLE 13

Clarity Factor: Duncan's Test for Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F1

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=5.655

GROUPING	MEAN	N	S
A	0.135466	30	I
A			
A	-0.135466	30	F

TABLE 14

Evaluation Factor: Duncan's Test for Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F2

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=3.68759

GROUPING	MEAN	N	S
A	0.246597	30	I
A			
A	-0.246597	30	F

TABLE 15

Spaciousness Factor: Duncan's Test for Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F3

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=56 MS=4.97661

GROUPING	MEAN	N	S
A	0.010148	30	F
A			
A	-0.010148	30	I

TABLE 16

Color Factor: Duncan's Test for Source Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

ANALYSIS OF VARIANCE PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE F4

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=56   MS=4.7385

GROUPING	MEAN	N	S
A	0.412227	30	F
A			
A	-0.412227	30	I

TABLE 17

Clarity Factor: Analysis of Variance for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: FACTOR1

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	68	119.10141299	1.75149137	2.50	0.0001	0.498332	99999.9999
ERROR	171	119.89875957	0.70116234		STD DEV		FACTOR1 MEAN
CORRECTED TOTAL	239	239.00017256			0.83735437		0.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
ID	59	81.33601964	1.97	0.0004				
P	3	35.57479895	16.91	0.0001	3	35.57479895	16.91	0.0001
P*R	3	1.89276901	0.90	0.4446	3	1.89276901	0.90	0.4446
P*S	3	0.29782539	0.14	0.9314	3	0.29782539	0.14	0.9314

TABLE 18

Evaluation Factor: Analysis of Variance for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: FACTOR2

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	68	70.18808083	1.03217766	1.05	0.4016	0.293674	99999.9999
ERROR	171	168.81209343	0.98720522		STD DEV		FACTOR2 MEAN
CORRECTED TOTAL	239	239.00017426			0.99358202		0.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
ID	59	55.74608073	0.96	0.5673				
P	3	11.70186142	3.95	0.0094	3	11.70186142	3.95	0.0094
P*R	3	1.65244902	0.56	0.6476	3	1.65244902	0.56	0.6476
P*S	3	1.08768966	0.37	0.7796	3	1.08768966	0.37	0.7796

TABLE 19

Spaciousness Factor: Analysis of Variance for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEOURE

OEPENOENT VARIABLE: FACTOR3

SOURCE	OF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	68	91.93244573	1.35194773	1.57	0.0102	0.384654	99999.9999
ERROR	171	147.06773074	0.86004521		STO OEV		FACTOR3 MEAN
CORRECTEO TOTAL	239	239.00017647			0.92738622		0.00000000

SOURCE	OF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
ID	59	70.92985879	1.40	0.0505				
P	3	13.45375752	5.21	0.0020	3	13.45375752	5.21	0.0020
P*R	3	1.16809194	0.45	0.7195	3	1.16809194	0.45	0.7195
P*S	3	6.38073748	2.47	0.0623	3	6.38073748	2.47	0.0623

TABLE 20

Color Factor: Analysis of Variance for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: FACTOR4

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	68	85.59075145	1.25868752	1.40	0.0415	0.358120	99999.9999
ERROR	171	153.40946480	0.89713137		STD DEV		FACTOR4 MEAN
CORRECTED TOTAL	239	239.00021625			0.94717019		0.00000000

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE IV SS	F VALUE	PR > F
ID	59	69.31058759	1.31	0.0932				
P	3	14.72654019	5.47	0.0014	3	14.72654019	5.47	0.0014
P*R	3	0.48093650	0.18	0.9085	3	0.48093650	0.18	0.9085
P*S	3	1.07268716	0.40	0.7575	3	1.07268716	0.40	0.7575

TABLE 21

Clarity Factor: Duncan's Test for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE FACTOR1

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=171 MS=0.701162

GROUPING		MEAN	N	P
	A	0.592527	60	4
	B	0.050881	60	3
	B			
C	B	-0.194722	60	2
C				
C		-0.448686	60	1

TABLE 22

Evaluation Factor: Duncan's Test for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE FACTOR2

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=171   MS=0.987205

GROUPING	MEAN	N	P
A	0.144468	60	3
A			
A	0.128160	60	1
A			
A	0.109219	60	2
B	-0.381846	60	4

TABLE 23

Spaciousness Factor: Duncan's Test for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE FACTOR3

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05   DF=171   MS=0.860045

GROUPING		MEAN	N	P
	A	0.327190	60	1
	A			
B	A	0.104405	60	2
B				
B	C	-0.134745	60	3
	C			
	C	-0.296850	60	4

TABLE 24

Color Factor: Duncan's Test for Luminaire Pattern Types

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

GENERAL LINEAR MODELS PROCEDURE

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE FACTOR4

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

ALPHA LEVEL=.05 DF=171 MS=0.897131

GROUPING	MEAN	N	P
A	0.378475	60	2
B	0.018591	60	1
B			
B	-0.091242	60	4
B			
B	-0.305824	60	3

TABLE 25

Clarity Factor: Two Tail *t* Test for Shape and Distribution of Luminaire Patterns

Patterns	Mean	N	$t_{calculated}$	t_{table}
Circular	0.321704	120	5.95*	1.66
Rectangular	-0.321704	120		
Uniform	0.198903	120	3.68*	1.66
Non-uniform	-0.198903	120		

Mean Square = 0.701162

* Significant at 0.05 level

TABLE 26

Evaluation Factor: Two Tail *t* Test for Shape and Distribution of Luminaire Patterns

Patterns	Mean	N	$t_{calculated}$	t_{table}
Circular	-0.118689	120	-1.85*	1.66
Rectangular	0.118689	120		
Uniform	-0.136314	120	-2.13*	1.66
Non-uniform	0.136314	120		

Mean Square = 0.987205

* Significant at 0.05 level

TABLE 27

Spaciousness Factor: Two Tail *t* Test for Shape and Distribution of Luminaire Patterns

Pattern	Mean	N	$t_{calculated}$	t_{table}
Circular	-0.215798	120	-3.61*	1.66
Rectangular	0.215798	120		
Uniform	-0.096223	120	-1.61	1.66
Non-uniform	0.096223	120		

Mean Square = 0.860045

* Significant at 0.05 level

TABLE 28

Color Factor: Two Tail _t_ Test for Shape and Distribution of Luminaire Patterns

Patterns	Mean	N	$t_{calculated}$	t_{table}
Circular	-0.198533	120	-3.25^*	1.66
Rectangular	0.198533	120		
Uniform	0.143617	120	2.35^*	1.66
Non-uniform	-0.143617	120		

Mean Square = 0.897131

* Significant at 0.05 level

DISCUSSION

Factors

As a result of the factor analysis of the raw data, four factors emerged. These factors are:

Clarity. Under a particular lighting condition, if people rank it high, as clear, bright, sunny and distinct, means that high clarity is achieved. In this clarity factor, four semantic scales "hazy-clear", "dim-bright", "vague-distinct", and "cloudy-sunny" have substantial loadings. Out of the four semantic scales, the first three were taken from Flynn's study to measure perceptual clarity. So, the present analysis verifies the Flynn's study results.

Evaluation. Here, if people rank a lighting condition, high for evaluation, it means that the particular lighting condition is preferred. Three semantic scales, "tense-related", "uninteresting-interesting" and "unpleasant-pleasant", have high loadings in this factor. All these semantic scales were picked up from Flynn's study, under evaluation factor. This clearly verifies the Flynn's study results.

Spaciousness. If a lighting conditions gets a high spacious effect, this means that people rank that particular lighting condition, high, as long and large. Two semantic scales, "short-long" and "small-large", have high loadings in this factor. The above two scales were also taken from Flynn's study. Originally, a third semantic scale, "cramped-spacious" was also taken for the present investigation from Flynn's study to measure spaciousness. However, this third scale did not have a high enough loading to be included under any one of the four factors in this study. The reason could be that the subjects did not understand the relevance of the terms "cramped" and "spacious" in the present study and so, did not react to it properly.

Color. If people rank a lighting condition as warm, it means that the lighting condition is preferred for its warm color. But, if a lighting condition is ranked high for its cool effect, then it means that the lighting condition is preferred for its cool, daylight color. Only one semantic scale "warm-cool", in this factor, had a substantial loading. Another semantic scale "cloudy-sunny", was also expected to be present in this factor. But people reacted to the above scale primarily under the clarity factor. This is a slight deviation from the expected factor results.

The identification of the above factors, as a result of the factor analysis, very closely verifies the factors emerged in the Flynn's study. Flynn used an actual conference room in his investigation and in the present study, a scale model of a living and waiting rooms was used. This clearly suggests that the factors do not depend on the environment (type of room, whether it is a real one or simulated), but do have some broader meaning.

Room Effects

Analysis of variance was carried out for each factor, to find the significant differences within room types and their interaction with light sources types. The analysis showed that there was no overall effect of room types and their interactions with light source types on the subjective responses. This is contradictory to the hypothesis that there is an effect of room type. It could be that even though the subjects were informed about the room type before the experiment, (living room or waiting room), they did not consider it in their evaluation. Further, the miniature scale model may not have brought this to the attention of the subjects as a full-scale environment might. It could also be, due to the fact that each subject was told of only one situation (living room or waiting room), and so the subject's preconceptions about room types had little effect.

Lighting Effects

The analysis of variance for all the four factors, showed that there was no overall effect of source types and their interaction with room types. This is also contradictory to the hypothesis that there is an effect of source type. It could be that in this experiment, since the subjects were not told about the presence of different light sources and since the subjects were exposed to only one type of light source, they did not consider their presence in the evaluations. Further, both the light sources could be appropriate in both the living room and waiting room situations. Another possible reason might be that both the light sources were preferred equally for the recessed (only) fixtures used in this study.

Pattern Effects

The analysis showed that there was an overall effect of luminaire patterns. The pattern number, its description and the number of luminaires for all the four luminaire patterns are shown below.

Pattern No.	Description	No. of Luminaires
1	Rectangular non-uniform	4
2	Rectangular uniform	8
3	Circular non-uniform	8
4	Circular uniform	20

Duncan's test revealed the following information for all the four factors.

The circular-uniform luminaire pattern has the highest mean and rectangular non-uniform pattern has the lowest, for the clarity factor. It could be due to the presence of higher number of luminaires (20), in the case of circular-uniform luminaire pattern and lower number of luminaires (4), in the case of rectangular non-uniform luminaire pattern (It might be that a lighted space looks brighter, when large number of luminaires are used). A two tail _t_ test also showed that the circular uniform luminaire pattern was preferred to achieve higher clarity. This is contrary to the second hypothesis that rectangular uniform pattern would be preferred for clarity (not considering room and light source effects).

The circular-uniform luminaire pattern has the lowest mean compared with the other three luminaire patterns for the evaluation factor. This is in agreement with a common negative aesthetic reaction of people to a large number of regular arrays of luminaire fixtures of a given room. The circular non-uniform luminaire pattern has the highest mean of all the patterns. This is in agreement with the first hypothesis that circular non-uniform luminaire pattern would be judged more pleasant (not considering room and light source effects). A two tail _t_ test showed that there was a difference in the preferences for rectangular and circular luminaire patterns. This verifies the third hypothesis (not considering the room and light source effects).

The rectangular non-uniform luminaire pattern has the highest mean and the circular uniform luminaire pattern has the lowest mean for the spaciousness factor. This suggests that the former pattern gives more spacious feeling to a given room and the latter pattern gives the least. A two tail t test reveals that rectangular luminaire patterns are preferred over circular luminaire paterns for the spaciousness factor. But it also suggests that uniform and non-uniform luminaire patterns are equally preferred.

The rectangular uniform luminaire pattern was preferred to give cool environment and circular non-uniform luminaire pattern was preferred to give warm environment, to a given room situation. A two tail t test also revealed the same results.

Implications

The analysis of the data showed that there were no overall effects of room type and light source types on the subjective reactions. The reasons were explained previously. But the analysis also showed that luminaire patterns affected the subjective responses differently. It could be that people might have preferred some luminaire patterns differently over the others in different conditions. Further, it could also be that change of luminaire patterns during the experiment might have brought the attention of the subjects towards the ceiling and thus caused them to react differently. So, future research in this area, using scale models can be conducted to obtain completely unbiased subjective responses by exposing each subject to only one luminaire pattern under a particular light source for a particular room situation. It could help getting responses to only the physical effects of a situation rather than the general beliefs about these.

The analysis suggests that circular uniform luminaire patterns should be used to achieve higher clarity. But, for pleasantness circular non-uniform luminaire patterns are preferred. To achieve spaciousness, rectangular non-uniform luminaire patterns should be considered. Lastly, to achieve cool environment, rectangular uniform luminaire patterns and for warm and candle light environment circular non-uniform luminaire patterns should be used. These results could be of help to the interior designers and lighting engineers who try to design and incorporate lighting environments, which suit the individual tastes. All in all, by observing the results obtained in this study, it is obvious that quite a few interior lighting design decisions can be made at lower costs using scale models rather than real full-scale environments.

CONCLUSIONS

1. Four factors which emerged as a result of the factor analysis, closely verify the Flynn's study results. The factors are clarity, evaluation, spaciousness and color.

2. There was no overall effect of room and source types on the subjective reactions.

3. The circular uniform luminaire pattern produced highest clarity. The circular non-uniform luminaire pattern was the most preferred. To achieve spaciousness, the rectangular non-uniform luminaire pattern was superior. The rectangular uniform luminaire pattern was best to achieve a cool environment and the circular non-uniform luminaire pattern was best to achieve a warm environment.

4. Further research can be done as a continuation of the present study, with a greater number of subjects, to obtain completely independent subjective responses, by exposing each subject to only one luminaire pattern under a particular light source for a particular room situation.

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APPENDIX - I

SUBJECTIVE RATINGS

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

OBS	IO	R	S	P	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	GROUP	FACTOR1	FACTOR2	FACTOR3	FACTOR4
1	1	L	F	3	5	4	6	6	6	7	2	3	6	4	6	1	1.1478	-1.5902	0.3106	-0.2062
2	1	L	F	1	7	2	3	4	2	6	4	2	5	4	3	1	-0.6144	0.3251	-0.0186	-1.1228
3	1	L	F	2	7	4	6	6	5	6	2	2	6	4	6	1	0.9372	-1.1196	-0.1761	0.3106
4	1	L	F	4	6	2	7	6	6	6	3	3	7	6	6	1	1.5840	-0.5240	-0.7923	-0.9699
5	2	L	F	4	7	6	6	7	4	5	7	5	4	4	4	1	0.4856	1.0482	1.5010	1.6888
6	2	L	F	3	7	2	6	3	5	3	6	3	4	3	5	1	-0.0538	0.5043	-2.0422	-0.1598
7	2	L	F	1	7	7	6	6	7	5	4	6	7	6	6	1	1.7347	0.1078	0.2261	2.3543
8	2	L	F	2	7	1	7	2	7	7	4	7	7	7	7	1	2.2460	0.6655	-1.3804	-1.1201
9	3	L	F	4	4	4	7	4	5	6	4	5	7	5	7	1	1.3628	-0.7846	-0.6105	0.2871
10	3	L	F	2	5	5	6	4	5	5	4	5	4	4	5	1	0.3072	-0.3512	-0.1718	0.8992
11	3	L	F	3	5	3	5	4	4	4	5	4	6	6	5	1	0.2974	0.4446	-1.1017	-0.2569
12	3	L	F	1	6	5	3	4	4	4	5	3	5	3	4	1	-0.5549	-0.0483	-0.2269	0.8895
13	4	L	F	2	6	2	4	4	2	5	7	4	3	5	3	1	-0.6763	1.6237	0.0501	-1.0115
14	4	L	F	4	6	3	6	5	6	3	5	6	6	7	5	1	1.0214	1.0380	-1.2042	-0.0570
15	4	L	F	3	3	6	6	3	4	5	4	3	6	5	5	1	0.0532	-0.9896	-0.8385	1.5063
16	4	L	F	1	3	6	6	3	3	6	3	4	4	5	5	1	-0.1698	-0.9675	-0.0725	1.2314
17	5	L	F	3	6	3	2	4	7	7	5	6	7	4	6	1	1.1704	0.0440	0.2496	-0.9576
18	5	L	F	4	7	4	7	2	5	2	4	6	6	7	6	1	0.8059	0.9528	-2.7992	1.4152
19	5	L	F	2	7	6	2	3	3	3	6	4	3	5	4	1	-1.0557	1.3614	-0.5330	1.7421
20	5	L	F	1	4	4	2	6	2	4	2	5	2	4	2	1	-1.4792	-0.1993	1.5745	-0.9085
21	6	L	F	1	4	3	2	3	1	4	3	4	3	3	2	1	-1.8674	-0.1896	0.2277	-1.0004
22	6	L	F	2	5	5	5	4	4	5	5	5	4	3	4	1	-0.1727	-0.0852	0.3904	0.8104
23	6	L	F	4	3	6	6	3	5	6	2	5	6	2	5	1	0.3008	-2.1281	0.1116	1.2084
24	6	L	F	3	7	1	7	4	6	5	6	5	5	5	6	1	1.2577	0.9039	-1.4199	-1.0462
25	7	L	F	2	5	2	4	6	5	7	3	7	6	5	5	1	1.1220	-0.1060	1.2420	-1.9005
26	7	L	F	1	6	3	5	5	3	7	5	7	3	5	4	1	0.3695	1.0605	1.4591	-0.7779
27	7	L	F	3	6	3	5	5	4	4	6	6	5	6	6	1	0.7008	1.2237	-0.3670	-0.2483
28	7	L	F	4	4	2	3	6	7	6	5	7	7	6	7	1	1.6085	0.1656	0.3815	-1.9743
29	8	L	F	2	6	6	4	4	3	6	5	6	5	4	4	1	0.0677	0.4528	1.1204	1.3928
30	8	L	F	4	5	3	6	5	4	6	4	6	6	3	6	1	0.9494	-0.5319	0.5306	-0.5404
31	8	L	F	1	5	6	4	4	4	4	5	5	4	4	4	1	-0.4058	0.1925	0.1941	1.4086
32	8	L	F	3	4	3	4	4	5	3	3	4	5	4	5	1	-0.2417	-0.7299	-1.1550	-0.6508
33	9	L	F	2	3	7	7	5	4	7	2	6	7	1	7	1	1.1040	-2.5817	1.5018	1.7230
34	9	L	F	1	3	6	6	6	4	7	2	6	6	3	6	1	0.9032	-1.8433	1.7864	0.7035
35	9	L	F	4	5	4	6	6	7	6	3	6	6	4	6	1	1.4766	-0.9023	0.4824	-0.1535
36	9	L	F	3	3	3	6	6	4	6	3	6	6	3	4	1	0.5446	-1.1202	1.2748	-1.1130
37	10	L	F	1	3	2	3	4	2	5	6	6	3	6	3	1	-0.8088	1.2017	0.5660	-1.8242
38	10	L	F	4	5	6	6	6	5	5	3	5	5	3	5	1	0.5385	-1.0294	0.8727	1.2835
39	10	L	F	2	6	3	6	4	3	5	6	6	3	6	5	1	0.2807	1.4370	-0.1840	-0.1588
40	10	L	F	3	2	6	2	2	2	3	2	2	2	2	2	1	-2.6405	-1.6018	-0.3677	0.7930
41	11	L	F	2	5	4	6	7	6	7	3	6	6	5	6	1	1.6332	-0.6550	1.2462	-0.3819
42	11	L	F	3	7	5	6	6	4	6	5	7	6	5	5	1	1.2530	0.7767	1.2561	0.9757
43	11	L	F	4	7	5	7	5	6	6	4	5	6	4	5	1	1.2833	-0.2289	0.1098	1.2335
44	11	L	F	1	7	7	5	6	4	6	5	6	6	7	6	1	1.2504	0.9331	1.0729	2.1546
45	12	L	F	4	5	3	5	3	3	5	6	5	3	4	3	1	-0.5810	0.8207	-0.1125	-0.3507
46	12	L	F	1	3	6	2	2	1	2	3	2	1	2	1	1	-3.1234	-0.7795	-0.3879	1.0984
47	12	L	F	2	3	5	2	3	1	2	4	3	2	3	2	1	-2.5093	-0.2184	-0.2068	0.3998
48	12	L	F	3	4	3	5	5	3	5	6	6	5	6	4	1	0.2196	0.9490	0.4738	-0.7221
49	13	L	F	1	6	4	5	6	3	4	3	3	5	2	3	1	-0.4638	-0.7310	0.5774	0.1907
50	13	L	F	4	5	3	5	4	2	5	2	2	3	3	6	1	-0.6001	-1.1652	-0.5392	-0.5387
51	13	L	F	3	3	5	3	5	2	4	4	1	2	3	3	1	-1.8262	-0.8565	0.4732	0.1304
52	13	L	F	2	5	6	5	3	1	4	6	5	6	4	3	1	-0.6043	0.6232	0.1744	1.9017
53	14	L	F	1	2	5	3	4	2	3	4	4	3	3	4	1	-1.5173	-0.7578	0.2207	0.1673
54	14	L	F	3	3	2	3	3	3	4	3	4	5	5	4	1	-0.7613	-0.4159	-0.9322	-1.5977

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

OBS	ID	R	S	P	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	GROUP	FACTOR1	FACTOR2	FACTOR3	FACTOR4
55	14	L	F	2	4	6	4	4	3	4	2	4	3	4	3	1	-1.0929	-0.7965	0.2807	1.0489
56	14	L	F	4	3	3	5	3	4	4	4	3	4	5	4	1	-0.6111	-0.4440	-1.2909	-0.6046
57	15	L	F	4	1	4	7	6	7	7	1	4	7	2	7	1	1.3575	-3.4317	0.5093	-0.7796
58	15	L	F	1	4	3	4	4	3	4	4	5	3	4	4	1	-0.7233	0.0309	-0.0506	-0.8025
59	15	L	F	3	5	3	4	4	3	3	6	6	4	5	3	1	-0.5759	1.2870	-0.2224	-0.4071
60	15	L	F	2	7	6	4	4	3	3	7	7	5	6	3	1	-0.1443	2.1409	0.1987	1.9618
61	16	L	I	2	7	3	4	3	2	3	6	2	4	5	2	2	-1.2101	1.3683	-1.2904	0.2066
62	16	L	I	3	6	2	6	2	7	2	3	3	4	6	5	2	0.0518	0.0282	-3.5384	-0.3324
63	16	L	I	1	6	4	6	4	3	3	5	2	2	4	4	2	-0.8869	0.3325	-1.1051	0.7396
64	16	L	I	4	6	3	5	4	3	3	4	2	3	3	4	2	-0.9302	-0.1457	-1.0877	-0.0771
65	17	L	I	2	6	5	4	6	3	7	6	7	5	3	4	2	0.4691	0.6326	2.5020	0.3999
66	17	L	I	1	6	6	5	5	5	6	5	5	6	6	5	2	0.9110	0.4036	0.4547	1.4589
67	17	L	I	3	7	2	4	5	5	4	6	5	3	5	4	2	0.0174	1.4352	-0.3192	-0.9965
68	17	L	I	4	4	5	7	5	6	5	5	4	6	6	7	2	1.2591	-0.4276	-0.7892	0.9364
69	18	L	I	2	6	4	3	5	2	5	7	6	3	4	3	2	-0.6298	1.5744	1.4481	-0.0570
70	18	L	I	1	5	3	4	5	4	6	4	6	4	4	4	2	0.1172	0.1196	0.9878	-0.9944
71	18	L	I	3	3	3	4	3	6	4	3	4	5	4	5	2	-0.1443	-1.0989	-1.3418	-0.8303
72	18	L	I	4	4	3	5	6	5	6	3	7	6	2	6	2	0.9784	-1.1878	1.2762	-1.1121
73	19	L	I	2	4	1	3	4	1	4	7	7	4	7	4	2	-0.4776	2.1485	0.1023	-2.0818
74	19	L	I	3	4	6	4	5	7	7	5	6	7	5	7	2	1.5230	-0.5828	0.7317	0.8476
75	19	L	I	4	7	1	7	6	7	7	7	7	7	7	6	2	2.5134	1.5743	-0.0022	-1.4337
76	19	L	I	1	4	1	3	4	1	4	6	6	4	6	4	2	-0.6639	1.4868	0.0008	-2.1015
77	20	L	I	1	4	6	3	4	2	3	3	5	5	2	3	2	-1.2067	-0.7966	0.6248	1.1585
78	20	L	I	4	6	3	5	4	5	4	5	4	6	5	5	2	0.4520	0.3615	-1.1660	-0.0986
79	20	L	I	2	4	4	3	4	3	4	4	5	3	4	3	2	-1.0432	0.0981	0.3512	-0.3282
80	20	L	I	3	5	3	3	4	3	4	3	4	4	4	4	2	-0.7464	-0.1861	-0.2711	-0.7683
81	21	L	I	3	5	2	5	4	4	6	6	5	4	5	4	2	0.1850	0.8125	0.0115	-1.2120
82	21	L	I	1	5	3	4	2	3	3	5	5	4	5	3	2	-0.8824	0.8776	-1.2915	-0.1722
83	21	L	I	2	4	3	5	5	4	5	3	5	4	5	5	2	0.1385	-0.3782	0.0846	-0.9115
84	21	L	I	4	6	3	6	7	6	6	3	6	6	2	6	2	1.4088	-0.9985	1.1177	-0.7250
85	22	L	I	1	6	3	2	4	3	6	7	7	4	6	3	2	-0.1761	2.0942	1.0596	-0.8731
86	22	L	I	4	7	2	5	3	5	6	4	6	6	3	4	2	0.6386	0.1605	-0.3300	-0.7990
87	22	L	I	2	3	5	4	2	4	3	2	2	2	1	4	2	-1.7337	-1.9686	-1.2316	0.6315
88	22	L	I	3	7	2	3	6	6	5	6	6	3	6	5	2	0.5704	1.6215	0.3366	-1.4450
89	23	L	I	4	6	3	4	2	6	4	3	4	6	4	6	2	0.3216	-0.5481	-2.0837	-0.1132
90	23	L	I	3	6	4	4	3	3	4	6	5	4	6	5	2	-0.1983	1.3214	-0.8036	0.4959
91	23	L	I	2	5	4	3	5	3	5	4	5	4	5	4	2	-0.3561	0.3380	0.7342	-0.3413
92	23	L	I	1	4	4	3	4	3	5	3	6	5	6	4	2	-0.2275	0.1304	0.3611	-0.4363
93	24	L	I	1	3	4	2	4	1	6	2	1	1	2	1	2	-2.4671	-1.3333	1.2235	-0.9463
94	24	L	I	3	5	2	5	4	5	6	6	6	6	5	6	2	1.0465	0.5520	-0.2920	-1.1394
95	24	L	I	4	6	2	6	5	6	6	6	7	6	6	6	2	1.6658	1.0246	-0.1196	-0.9930
96	24	L	I	2	5	4	5	3	5	5	4	5	4	4	4	2	-0.0563	-0.1404	-0.4974	0.2014
97	25	L	I	3	6	1	4	6	5	6	7	6	4	4	4	2	0.5325	1.2545	0.9768	-2.0998
98	25	L	I	1	5	4	6	6	5	6	3	4	4	2	4	2	0.2442	-1.1723	1.0006	-0.1574
99	25	L	I	4	6	5	5	4	5	5	3	4	5	4	5	2	0.2842	-0.5682	-0.3923	0.9334
100	25	L	I	2	5	3	4	5	4	5	6	5	5	5	5	2	0.2900	0.6863	0.1867	-0.6740
101	26	L	I	3	6	5	6	5	5	6	3	4	7	3	5	2	0.8924	-1.0681	0.2743	0.9489
102	26	L	I	1	5	4	4	5	4	4	5	5	2	4	3	2	-0.7280	0.5524	0.5294	-0.1352
103	26	L	I	4	6	6	3	4	3	4	7	3	4	3	3	2	-0.9915	0.6959	0.3178	1.6176
104	26	L	I	2	6	5	6	3	4	3	5	5	5	5	6	2	0.2824	0.4570	-1.4370	1.5695
105	27	L	I	2	4	2	5	4	3	4	3	4	5	2	3	2	-0.6626	-0.9064	-0.2595	-1.2314
106	27	L	I	4	5	3	4	4	4	4	3	4	5	4	5	2	-0.1605	-0.4757	-0.7195	-0.5673
107	27	L	I	1	3	4	3	4	3	4	3	4	4	4	3	2	-1.0935	-0.6353	0.1116	-0.4826
108	27	L	I	3	5	5	4	4	5	4	4	5	5	4	5	2	0.0486	-0.2666	-0.3222	0.7394

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

OBS	ID	R	S	P	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	GROUP	FACTOR1	FACTOR2	FACTOR3	FACTOR4
109	28	L	I	1	5	3	6	3	6	4	6	6	5	4	6	2	0.7144	0.3237	-1.2978	-0.0329
110	28	L	I	4	6	4	3	5	4	3	6	5	4	5	4	2	-0.3720	1.1840	-0.0739	0.1549
111	28	L	I	2	5	6	4	3	5	3	3	4	5	6	5	2	-0.1947	-0.2191	-1.4240	1.5947
112	28	L	I	3	6	6	3	6	3	6	3	6	4	5	3	2	-0.1659	0.3094	2.0559	0.7831
113	29	L	I	3	5	3	7	4	6	6	7	7	6	6	5	2	1.4646	1.0550	-0.2891	-0.1386
114	29	L	I	1	3	5	4	2	3	4	5	4	3	4	3	2	-1.2831	-0.0909	-0.5731	0.6615
115	29	L	I	4	6	2	7	6	7	6	6	7	7	6	7	2	2.3444	0.7267	-0.1522	-0.9278
116	29	L	I	2	5	6	4	3	3	3	6	3	4	3	3	2	-1.1823	0.1985	-0.5262	1.7885
117	30	L	I	1	6	3	4	4	2	4	6	6	4	6	3	2	-0.4293	1.7768	0.0770	-0.3305
118	30	L	I	3	5	5	5	4	6	6	4	6	6	5	6	2	1.0744	-0.3028	-0.0331	0.6744
119	30	L	I	4	3	5	6	6	3	6	3	4	5	6	6	2	0.5089	-0.8491	0.7028	0.2447
120	30	L	I	2	4	5	5	4	4	5	3	5	5	5	6	2	0.3072	-0.6650	-0.2001	0.5859
121	31	W	F	3	6	3	4	4	4	5	4	3	4	4	3	3	-0.4951	0.0877	-0.3065	-0.4965
122	31	W	F	1	4	6	3	4	2	4	6	6	2	3	3	3	-1.3093	0.5932	1.2671	1.0431
123	31	W	F	2	4	4	3	3	2	4	5	5	2	4	4	3	-1.2516	0.4596	0.0363	-0.1451
124	31	W	F	4	5	5	6	4	5	4	4	3	6	4	6	3	0.4292	-0.8044	-1.1534	1.1875
125	32	W	F	4	6	3	3	5	6	5	3	5	6	3	6	3	0.6352	-0.6813	-0.0426	-0.8041
126	32	W	F	3	4	4	3	7	3	5	7	5	3	6	3	3	-0.4451	1.3382	1.7439	-0.6709
127	32	W	F	2	4	5	2	4	3	3	2	2	2	2	2	3	-2.1279	-1.1643	0.0593	0.2058
128	32	W	F	1	5	4	5	5	5	5	4	3	4	4	3	3	-0.2342	-0.3521	0.0457	-0.0129
129	33	W	F	1	5	3	5	4	2	4	6	2	5	6	4	3	-0.4759	0.7711	-1.0077	-0.1519
130	33	W	F	2	4	3	6	5	5	5	5	5	5	4	5	3	0.5376	-0.2463	-0.0413	-0.6033
131	33	W	F	4	3	3	5	3	6	6	3	6	6	2	6	3	0.6515	-1.6194	-0.2836	-0.8845
132	33	W	F	3	5	3	6	4	5	4	5	4	6	6	6	3	0.7299	0.2281	-1.4995	-0.1025
133	34	W	F	2	5	4	5	6	3	4	3	6	6	3	2	3	-0.1755	-0.2932	1.1966	-0.0581
134	34	W	F	3	5	3	5	5	5	4	3	4	5	3	4	3	-0.0148	-0.7626	-0.3059	-0.5714
135	34	W	F	1	3	4	4	5	2	3	5	4	3	3	3	3	-1.3185	-0.1406	0.4741	-0.2392
136	34	W	F	4	5	3	6	5	6	5	2	4	5	4	6	3	0.7579	-1.1770	-0.6657	-0.5788
137	35	W	F	1	6	5	5	4	6	4	6	6	6	4	6	3	0.8561	0.3892	-0.5533	1.2001
138	35	W	F	3	7	4	6	4	6	4	7	7	7	5	6	3	1.4412	1.2314	-0.8231	0.9489
139	35	W	F	2	5	4	5	4	4	5	6	5	5	5	5	3	0.3109	0.5790	-0.1395	0.2680
140	35	W	F	4	7	3	5	4	6	4	7	7	7	7	4	3	1.1440	1.9918	-0.8751	0.0893
141	36	W	F	2	6	5	3	6	2	4	6	6	4	4	2	3	-0.7188	1.2884	1.7383	0.5474
142	36	W	F	4	6	2	2	5	6	3	3	3	4	6	6	3	-0.0670	0.1289	-1.4718	-1.4374
143	36	W	F	3	4	1	5	3	5	2	3	3	5	6	5	3	-0.2555	-0.2425	-2.8121	-1.5310
144	36	W	F	1	6	6	2	3	3	2	4	3	3	5	4	3	-1.4130	0.4777	-1.0825	1.5959
145	37	W	F	1	6	4	4	5	5	6	7	7	5	5	4	3	0.6880	1.3633	1.0503	-0.0075
146	37	W	F	2	4	3	5	4	5	4	4	4	4	3	5	3	-0.1688	-0.7169	-0.7240	-0.5851
147	37	W	F	4	4	3	5	5	5	5	5	5	6	5	5	3	0.6182	-0.0358	-0.1117	-0.7234
148	37	W	F	3	5	4	4	4	4	4	5	5	4	5	4	3	-0.2914	0.5633	-0.2535	0.0989
149	38	W	F	2	6	6	5	5	5	6	2	6	7	2	4	3	0.6957	-1.2398	1.2021	1.3065
150	38	W	F	1	4	6	5	5	4	5	3	4	4	2	4	3	-0.3914	-1.3421	0.8307	1.0783
151	38	W	F	3	4	5	5	5	3	5	3	4	5	4	4	3	-0.2199	-0.7947	0.5540	0.4823
152	38	W	F	4	5	5	6	5	6	4	3	5	5	4	5	3	0.5371	-0.7378	-0.3190	0.8468
153	39	W	F	2	4	5	3	3	2	4	5	5	2	5	3	3	-1.3679	0.7143	0.1859	0.4822
154	39	W	F	4	6	3	6	5	5	5	5	5	6	6	6	3	1.1442	0.5332	-0.5909	-0.2048
155	39	W	F	1	5	4	3	3	3	2	6	3	3	6	2	3	-1.5217	1.3101	-1.2815	0.3549
156	39	W	F	3	3	3	3	5	3	5	3	4	2	4	3	3	-1.1474	-0.4913	0.8051	-1.4711
157	40	W	F	2	4	6	5	6	3	5	3	6	6	2	3	3	-0.0797	-1.0465	1.8952	0.9312
158	40	W	F	4	4	5	6	5	3	5	3	6	5	2	5	3	0.1511	-1.1190	0.9984	0.6085
159	40	W	F	1	4	5	5	4	3	6	4	6	5	4	4	3	0.0472	-0.2810	0.9171	0.4939
160	40	W	F	3	4	5	4	5	3	6	5	6	5	3	4	3	-0.0457	-0.1917	1.6135	0.2691
161	41	W	F	2	2	5	2	3	1	2	1	2	1	1	1	3	-3.1898	-1.7602	0.0000	0.0311
162	41	W	F	1	2	3	2	6	4	4	3	4	3	1	3	3	-1.3165	-1.4856	1.2592	-1.7781

STATISTICAL ANALYSIS SYSTEM

OBS	ID	R	S	P	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	GROUP	FACTOR1	FACTOR2	FACTOR3	FACTOR4
163	41	W	F	4	6	2	6	4	6	4	5	4	6	5	5	3	0.7519	0.2994	-1.5899	-0.6128
164	41	W	F	3	5	3	5	4	4	3	5	4	5	4	5	3	-0.1223	0.1081	-1.1113	-0.1763
165	42	W	F	1	5	4	3	6	4	5	5	6	4	2	3	3	-0.3583	0.0540	1.7737	-0.4649
166	42	W	F	4	5	4	4	5	5	5	5	3	5	3	5	3	0.0478	-0.5011	0.0161	-0.0258
167	42	W	F	2	5	4	3	5	3	4	5	4	3	3	4	3	-0.8612	0.1457	0.5439	-0.1694
168	42	W	F	3	6	3	5	5	3	5	5	6	3	5	2	3	-0.3193	1.2162	0.8451	-0.5534
169	43	W	F	1	5	3	6	4	5	4	2	1	2	4	5	3	-0.5346	-1.1420	-1.6078	-0.3718
170	43	W	F	4	3	2	6	3	6	3	1	4	5	6	6	3	0.2729	-1.2517	-2.5208	-1.1628
171	43	W	F	3	6	6	5	7	4	6	7	4	7	5	6	3	1.1371	0.5025	1.2413	1.4408
172	43	W	F	2	7	7	6	7	2	6	7	5	3	7	4	3	0.3650	1.3622	1.9351	2.2050
173	44	W	F	1	5	4	5	4	5	4	6	7	6	6	5	3	0.7374	1.0032	-0.4419	0.3338
174	44	W	F	4	6	5	6	4	6	4	6	6	5	6	6	3	0.9715	0.8854	-0.8910	1.2997
175	44	W	F	3	3	3	4	5	4	4	2	3	3	3	2	3	-1.1977	-1.2075	0.1826	-1.2111
176	44	W	F	2	7	6	5	4	4	4	6	6	4	6	4	3	0.1495	1.5099	-0.0533	1.9297
177	45	W	F	4	5	5	4	3	3	3	2	5	4	5	5	3	-0.5779	-0.2949	-0.9083	0.8579
178	45	W	F	1	6	3	4	3	3	6	6	5	3	6	3	3	-0.3701	1.5125	0.0153	-0.4635
179	45	W	F	2	5	6	2	4	3	3	6	5	3	4	2	3	-1.4048	0.9636	0.5847	1.2029
180	45	W	F	3	1	2	6	3	6	3	4	5	6	6	6	3	0.4176	-0.7966	-2.1801	-1.3204
181	46	W	I	4	6	3	4	4	4	6	6	5	4	5	4	4	0.1050	1.0271	0.2350	-0.5462
182	46	W	I	2	6	4	3	4	3	4	4	4	3	3	3	4	-1.0462	0.1898	0.1809	0.0593
183	46	W	I	1	6	2	5	4	6	3	3	4	6	6	5	4	0.5076	0.0743	-1.9986	-0.7838
184	46	W	I	3	6	2	5	4	3	4	4	5	4	5	4	4	-0.1765	0.6811	-0.6064	-0.9061
185	47	W	I	3	6	2	7	7	5	6	4	6	5	7	4	4	1.3111	0.8125	0.6559	-1.2504
186	47	W	I	2	5	4	6	3	6	3	4	4	6	5	4	4	0.2167	-0.1985	-1.8763	0.6838
187	47	W	I	1	4	5	4	5	3	4	4	5	6	4	3	4	-0.3765	-0.2454	0.6547	0.4917
188	47	W	I	4	7	3	7	6	7	7	4	6	6	6	7	4	2.2460	0.1935	0.0720	-0.3476
189	48	W	I	4	2	4	4	4	5	6	4	6	6	3	4	4	0.1305	-1.1055	0.7565	-0.6577
190	48	W	I	3	5	3	4	4	3	4	6	5	3	4	3	4	-0.7621	0.9220	0.0373	-0.5273
191	48	W	I	1	5	4	4	4	3	5	4	4	5	4	4	4	-0.3258	-0.1514	0.0784	0.0349
192	48	W	I	2	5	4	5	5	5	6	3	5	6	2	6	4	0.7375	-1.2948	0.5493	-0.0912
193	49	W	I	4	2	2	1	2	7	6	1	7	7	1	7	4	0.3977	-2.4917	-0.3855	-2.3207
194	49	W	I	1	4	4	5	5	5	4	5	4	4	4	5	4	-0.0174	-0.2721	-0.2600	-0.0124
195	49	W	I	2	6	7	7	1	1	2	7	7	2	7	1	4	-1.2345	2.5732	-0.9463	3.2835
196	49	W	I	3	6	6	5	3	3	3	6	6	3	6	3	4	-0.6094	1.5872	-0.4210	1.9586
197	50	W	I	3	5	3	5	6	3	6	3	6	6	6	4	4	0.6307	0.1846	1.0376	-0.9223
198	50	W	I	1	3	4	4	6	3	4	3	5	3	5	4	4	-0.5976	-0.3371	0.8210	-0.6526
199	50	W	I	4	3	4	6	3	5	6	2	3	5	4	3	4	-0.1936	-1.5568	-0.5801	-0.1247
200	50	W	I	2	5	3	3	3	3	4	5	5	4	3	4	4	-0.7656	0.2978	-0.2850	-0.5452
201	51	W	I	1	5	3	7	6	2	5	4	5	3	2	2	4	-0.4870	-0.1736	1.3994	-0.5221
202	51	W	I	4	5	4	5	6	5	6	4	6	5	5	5	4	0.8367	-0.0103	0.9750	-0.2797
203	51	W	I	2	6	5	6	6	6	6	3	6	6	5	6	4	1.4629	-0.4186	0.6054	0.6880
204	51	W	I	3	5	3	5	3	3	4	5	3	3	5	3	4	-0.8755	0.5509	-1.0274	-0.2384
205	52	W	I	2	6	4	7	7	7	7	3	6	7	2	7	4	2.1059	-1.4173	1.1573	0.0139
206	52	W	I	1	5	6	4	5	5	6	5	5	5	5	5	4	0.4714	0.0551	0.8062	1.0853
207	52	W	I	4	3	6	7	5	7	7	1	4	7	4	7	4	1.5118	-2.6192	0.0359	0.9887
208	52	W	I	3	6	3	4	3	3	4	6	5	2	5	3	4	-0.8602	1.4732	-0.4625	-0.2762
209	53	W	I	3	5	2	3	4	1	5	5	4	3	2	2	4	-1.4231	0.3289	0.8479	-1.4374
210	53	W	I	1	4	4	4	4	3	4	4	5	4	3	3	4	-0.8169	-0.2588	0.3204	-0.1151
211	53	W	I	4	6	4	5	4	6	4	4	4	5	4	6	4	0.4852	-0.3222	-1.1336	0.4490
212	53	W	I	2	4	5	3	4	2	3	5	4	3	3	2	4	-1.6483	0.1690	0.4116	0.5400
213	54	W	I	3	4	4	6	3	4	6	5	3	6	5	3	4	0.0242	-0.2231	-0.5785	0.2885
214	54	W	I	1	5	5	6	5	6	6	6	5	6	5	5	4	1.0807	0.1569	0.2439	0.8362
215	54	W	I	4	4	4	4	3	3	4	3	3	3	3	2	4	-1.4444	-0.6575	-0.3617	-0.0424
216	54	W	I	2	6	3	6	6	6	6	6	4	6	6	6	4	1.4245	0.5259	-0.1755	-0.3804

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M

OBS	ID	R	S	P	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R11	GROUP	FACTOR1	FACTOR2	FACTOR3	FACTOR4
217	55	W	I	2	4	3	3	4	3	2	3	3	3	3	3	4	-1.5795	-0.5137	-0.7797	-0.7402
218	55	W	I	4	5	3	6	6	6	6	5	6	6	5	6	4	1.4650	0.0529	0.3991	-0.6713
219	55	W	I	1	3	4	3	6	3	6	4	4	3	4	3	4	-0.7722	-0.4168	1.6867	-0.9585
220	55	W	I	3	5	3	4	6	5	5	4	4	3	4	4	4	-0.1483	-0.1174	0.5519	-1.0163
221	56	W	I	2	5	7	6	2	7	5	4	4	7	3	7	4	0.9531	-1.4024	-1.4800	2.6314
222	56	W	I	4	3	4	5	6	3	5	3	5	3	2	2	4	-0.8340	-0.9801	1.7047	-0.6203
223	56	W	I	1	6	5	4	3	3	5	7	6	2	7	2	4	-0.6791	2.2604	0.2766	0.9087
224	56	W	I	3	5	5	5	4	3	5	3	3	3	4	3	4	-0.7971	-0.4602	0.1115	0.7093
225	57	W	I	3	5	4	6	7	5	6	6	4	6	2	6	4	1.0116	-0.6449	1.1406	0.0161
226	57	W	I	1	4	2	4	4	3	4	6	5	4	3	3	4	-0.7322	0.4468	0.0655	-1.3001
227	57	W	I	4	6	5	7	3	7	5	2	4	6	2	7	4	1.0613	-1.8223	-1.4106	1.3744
228	57	W	I	2	6	2	5	5	3	5	6	5	3	6	3	4	-0.1576	1.5770	0.2427	-1.1031
229	58	W	I	1	5	2	3	6	2	5	6	5	3	5	3	4	-0.6264	1.2767	1.2274	-1.6982
230	58	W	I	3	3	4	5	2	5	3	3	3	5	3	4	4	-0.7219	-1.3528	-1.8418	0.2696
231	58	W	I	4	3	3	5	2	5	3	3	4	5	2	3	4	-0.8167	-1.2932	-1.5226	-0.4246
232	58	W	I	2	6	2	6	4	6	4	5	4	6	5	6	4	0.9090	0.2126	-1.7197	-0.5955
233	59	W	I	2	5	5	6	4	4	6	6	6	7	6	4	4	0.8784	0.7186	0.2839	1.0023
234	59	W	I	3	4	3	5	6	2	6	3	6	6	5	4	4	0.3455	-0.2035	1.3739	-1.0670
235	59	W	I	4	7	6	7	6	7	6	6	6	6	5	7	4	2.0071	0.3869	0.3999	1.8447
236	59	W	I	1	5	6	3	6	3	6	4	6	3	5	4	4	-0.2270	0.3468	2.0536	0.6386
237	60	W	I	2	4	5	5	3	4	5	3	6	5	2	5	4	-0.0355	-1.1358	0.1312	0.6876
238	60	W	I	3	6	3	4	5	4	5	5	6	5	4	4	4	0.2355	0.6273	0.5848	-0.6014
239	60	W	I	1	4	4	3	5	3	5	4	5	3	3	3	4	-0.8801	-0.2075	1.2353	-0.5656
240	60	W	I	4	4	3	5	4	5	5	4	5	5	3	5	4	0.2235	-0.7107	-0.2332	-0.6844

APPENDIX II

DESCRIPTION OF SYMBOLS

Semantic Scales

R1 - "Unpleasant - Pleasant"
R2 - "Cool - Warm"
R3 - "Vague - Distinct"
R4 - "Short - Long"
R5 - "Cloudy - Sunny"
R6 - "Small - Large"
R7 - "Tense - Relaxed"
R8 - "Cramped - Spacious"
R9 - "Hazy - Clear"
R10 - "Monotonous - Interesting"
R11 - "Dim - Bright"

Factors

Factor 1 - CLARITY
Factor 2 - EVALUATION
Factor 3 - SPACIOUSNESS
Factor 4 - COLOR

General

R - Room type
S - Light source type
P - Luminaire pattern type
ID - Individuals
OBS - Observations
L - Living room
W - Waiting room
I - Incandescent light source
F - Fluorescent light source

P 1 - Rectangular Non-uniform luminaire pattern
2 - Rectangular Uniform luminaire pattern
3 - Circular Non-uniform luminaire pattern
4 - Circular uniform luminaire pattern

LIGHTING AESTHETIC EVALUATION

USING SCALE MODELS

by

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ABSTRACT

The main objective of this study was to find out subjective reactions to a space, in particular the aesthetic pleasantness of certain lighting variations using a scale model for different room types.

Two scale models of a room, each 20" x 12" x 8" were made to the scale of one inch equals to one foot. Sixteen lighting conditions (four ceiling luminaire patterns, under two light sources for two types of rooms) were considered in this experiment. Each subject was exposed to four ceiling luminaire patterns under one of the light sources for one of the room types. A total of 60 subjects evaluated the lighting conditions, each on a set of eleven semantic scales.

The data was factor analyzed and four factors, clarity, evaluation, spaciousness and color, emerged as a result of the analysis. Further analysis showed that there was no overall effect of room and source types on the subjective reactions. But, ceiling luminaire patterns did effect the subjective reactions significantly.

The circular uniform luminaire pattern was considered the best, to achieve clarity. But the circular non-uniform luminaire pattern was evaluated highest for pleasantness. The rectangular non-uniform luminaire pattern was chosen to achieve spaciousness. The rectangular uniform luminaire pattern was considered to achieve cool environment. But the circular non-uniform luminaire pattern was chosen to achieve warm environment.