CUSTOMER RESPONSES TO PRODUCE AT POINT OF SALE IN LIGHTING SIMULATIONS

by

BARNALI NANDY

B. Arch., University of Pune, India, 2000

A THESIS

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF ARCHITECTURE

Department of Architecture
College of Architecture, Planning and Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2003

Approved by:

O. John Selfridge

Major Professor
O. John Selfridge

ABSTRACT

The study focuses on relationships between lighting simulated using computer graphics and subject responses with the intent of determining aspects of lighting that would affect the consumers while shopping for produce.

The research design included presentation of computer simulations of lighting in a retail space to the subjects. The simulations were modeled based on the typical environment of a produce section in a food market and were made to vary in their "quality" of lighting for the study. The quality of lighting depended on single or combination of factors such as illuminance, color of the lamp source, distribution of light and luminance ratios. The computer models were executed using Autodesk Viz 4. The subjects rated the simulations on six five-point rating scales as well as a direct question. These scales were based on the categories of impressions namely, perceptual clarity, behavioral impression and overall preference.

The analysis of the responses showed that higher illuminance levels, higher luminance ratios and higher color temperature independently helped improving the visual clarity of the scene. However, low illuminance levels were more conducive to a "relaxing" environment. Accent lighting was preferred over an interior with no accent lighting. Such information tell the lighting designers of retail spaces that using accent lighting for focusing on the merchandise will help in attracting the customers, as long as the illuminance levels are not too high to make the customers feel uneasy in the environment. Selecting lamps with good color properties can make a difference in the appearance of the merchandise. The findings of the research also suggested that more

evaluation was needed to measure perceptual clarity, mainly with respect to the effects of the source color. The computer generated models prepared in Autodesk Viz 4 were found to be not as effective in representing the combined effects of color temperature and illuminance or evoking the impression of relaxing vs. tense.

This and similar research can help improve lighting design in the produce departments of food markets from the people's end and will also have the potential to be transferred to other retail environments, theaters and museums where the effects of lighting are also crucial.

TABLE OF CONTENTS

Page

LIST OF FIGURES…………………………………………………………………………iii

LIST OF TABLES…………………………………………………………………………..v

ACKNOWLEDGEMENTS………………………………………………………………vi

DEDICATION……………………………………………………………………………vii

CHAPTERS

I. Introduction……………………………………………………………………………..1

II. Literature review………………………………………………………………………..4
  Background……………………………………………………………………………4
  Factors in visual acuity…………………………………………………………………6
  Characteristics of light………………………………………………………………...8
  Lighting affecting impressions…………………………………………………………12
  Computer graphics as a research tool……………………………………………………15
  Light sources……………………………………………………………………………...17
  Case study – Semantic differential scale…………………………………………………18
  Purpose of this study..19

III. Methodology……………………………………………………………………………21

  Research hypotheses……………………………………………………………………21
  Research design…………………………………………………………………………..23
    Creating the "scales"…………………………………………………………………..23
    Creating the "CGMs"……………………………………………………………………...24
    Pilot study……………………………………………………………………………..31
    Actual experiment……………………………………………………………………..33

IV. Results and discussion…………………………………………………………………...35

V. Summary and conclusion…………………………………………………………………45
  Conclusion………………………………………………………………………………...45
  Limitations………………………………………………………………………………...47
    Method…………………………………………………………………………………...47
    Population……………………………………………………………………………..48

Recommendations..49
Future research..49

REFERENCES..51

APPENDICES..55
A. Consent form..55
B. Response form (shown for Pair 1 only)..56
C. Photometric data of lamps..57
D. Calculations for illuminances and luminance ratios..59
E. JPEG formats of the Pairs..61
F. Results of T-test for comparison of means between "pairs" on all six scales as well as the direct question of preference..63
G. Correlation between the scales and the categories of impression..70
H. Participants' responses..71

LIST OF FIGURES

Figure		Page
2-1	The color temperature scale	10
2-2	Example of a semantic differential scale	14
3-1	Schematic flow of research methods.	23
3-2	A simple CGM in Autodesk Viz 4	24
3-3	Part of the Material Editor box showing the textures assigned	25
3-4	Plan showing the grid spacing	26
3-5	The photometric data entry box for a diffuse lamp source	28
3-6	The photometric data entry box for a spotlight	29
3-7	Radiosity panel	30
3-8	Collapsing the scale	32
4-1	The mean locations of the scenes in Pair 1	36
4-2	The mean locations of the scenes in Pair 5	37
4-3	The mean locations of the scenes in Pair 3	39
4-4	Comparative means of preference of scenes in Pair 3	39
4-5	The mean locations of the scenes in Pair 4	40
4-6	A negative correlation between relaxing / tense and preference	42
4-7	Performance of the scales	43
E-1	Pair 1 - Varying in luminance ratio	61

E-2 Pair 2 - Varying in luminance ratio and CCT..61

E-3 Pair 3 - Varying in luminance ratio..61

E-4 Pair 4 - Varying in CCT...62

E-5 Pair 5 - Varying in luminance ratio and CCT..62

LIST OF TABLES

Table Page

C-1 Photometric data of the luminaires for ambient lighting..............................57

C-2 Photometric data of the luminaires for accent lighting................................58

D-1 Calculations of illuminances and luminance ratios....................................60

ACKNOWLEDGEMENTS

I am grateful to my committee members, O.John Selfridge, Richard Hoag, John Lewis-Smith, and Alan Purvis for their guidance and time. I would especially like to thank Bryan Zimmer, alumni of Kansas State University, for the valuable information on lighting design in stores.

A grateful appreciation goes to Sailesh, Jamie and Professor Kevin Emery for their valuable help in the statistical analysis. I would also like to thank Don and Dereatha for helping me with the computer laboratory.

Last but not the least; I would like to thank my husband, Malay for inspiring me throughout my research, and my family and friends for their love and support.

DEDICATION

Dedicated to Baba, Ma, Dada and Malay

CHAPTER I

Introduction

Reacting to competition and changing consumer patterns, store owners started employing strategies that gave lighting designers a prime role in attracting shoppers and increasing sales. More than fifty percent of retail areas in all older stores used lighting as a major design consideration in their retrofitting and renovation (Harwood, 1988). This research focused on the section of retail stores concerned with selling produce. Shifting consumer patterns revealed a preference for fresh fruits and vegetables. Kaufman, Handy, McLaughlin, Park, and Green (2000) state that customers have more than doubled their purchase of fruits and vegetables in the last fifteen years, responding to increased evidence of the importance of fresh fruits and vegetables to better health and nutrition. Robert Gorski, (as cited in Barr, 2002) an experienced food market lighting designer, has predicted that the trends will shift to favor quality in products over discounters.

Sentry Foods -- Hilldale, Madison, Wisconsin, has used both lighting and front-end display of produce in its remerchandising. According to Gorski, (as cited in Barr, 2002), Sentry Foods used theatrical techniques in its lighting design to create excitement. Bryan Zimmer (personal communication, February 2001), the lighting designer and interior architect for the Baker's at Eagle Run, Omaha, Nebraska, also arranged the produce in the front of the store. Zimmer has used 75w metal halide lamps from Litelab Inc., mounted at approximately twelve feet from the floor and at four feet center-to-center distance wherever there was a display. The remaining circulation space was lit with the same lamps at twelve feet center-to-center distance. The ambient lighting was provided by 250w high-bay high intensity discharge (HID) lamps on twenty four feet centers.

More generally, produce departments have gained high priority due to increasing customer demands and the perishable nature of fresh produce. Fresh produce varies in color, surface texture, and shape and has a more multi-dimensional appearance than canned and boxed products. Hence produce selection is a multi-factorial process and is significantly dependent on the way it is lit. This research does not consider the tactile or the olfactory inputs, otherwise essential factors in the selection process, but focuses only on the visual cues due to lighting. The attempt here is to add to the ongoing research in subjective reactions to lighting as well as explore the application of a computer generated model in lighting studies.

With considerable developments of the integrated chip, computers have become very powerful and are capable of handling complex tasks. There are some extremely sophisticated modeling packages that produce realistic scenes (Roy, 2000). Such computer generated models (CGMs) could be a useful tool for studies involving lighting.

The purpose of this research is to determine what aspects of lighting design affect selection of produce in CGMs. Numerous scenes were created in Autodesk Viz 4, each portraying a stack of oranges under different lighting conditions. The lighting parameters of two scenes, taken at a time, were manipulated to form a "pair"; each differing in either one or more parameters. Five such "pairs" were used in the pilot study. The main objective of the pilot study was to see if different "pairs" evoked variable responses to the selected lighting environments. It was also important to see if the rating scales were understood by the viewers. The actual research was modified with the findings of the pilot study. The data from the research was analyzed to find relationships between the selected lighting parameters and the responses.

Results of this research would have the potential to form lighting design guides for retail settings that keep the customer's perception of space in mind. It could also be transferred to environments like museums and theaters where also, lighting is crucial. Finally it would encourage designers to explore software programs like Autodesk Viz 4, to assist them in visualizing and testing their designs before construction and occupancy.

CHAPTER II

Literature review

Background

Lighting design existed in a dichotomy until the Arab oil embargo of 1973 (Stein & Reynolds, 2000). They explained the dichotomy as architectural lighting indulging on the one hand in ornate lighting and form-giving shadows, and on the other, as utilitarian lighting seeing spaces in terms of illuminance levels and cavity ratios. The energy consciousness that followed the Arab oil embargo drove architects and lighting designers to search into satisfying actual vision needs within a framework of minimal energy use.

Lighting in retail areas has always been an important consideration. When shopping for food shifted indoors to "market houses" in the first part of the nineteenth century in the United States of America, retailers immediately realized the fundamental design principles of product exposure. They felt the need for better artificial lighting to enable people to sense the variety of goods. Food departments grew to be a major feature of supermarkets in the 1960s and 70s with concepts of theatrical lighting and other new techniques being introduced (Mayo, 1993). Mania (2001) reports that many lighting designs, especially in the commercial context, intentionally or unintentionally functioned more actively as shifting selectively human visual experiences such as focusing attention, guiding circulation, and generally affecting impressions of a room or situation. Mania (2001) restates Flynn's observation that many lighting systems have been designed to merely function as a "permissive" way, enabling performance or participation in a visual activity without attempting to evoke user impressions. Mania reports further that human responses to lighting indicate an effort towards assessing lighting designs from an impression point of view rather than a task point of view.

The ability of lighting to influence user impression has earned it a "manipulative" role. In retail lighting however, it is difficult to rule out deception entirely from design strategies because customers have to be attracted else the stores would not survive the competition. Some comments from experts in the field help us realize the awareness of the effects of lighting in the design community. Pegler (1990, p.7), emphasizing the theatrical model of lighting, says, "Today shopping is theatre; there are lights for ambience, lights for attention and lights for appraisal." Another forthright opinion comes from Jay (1978). He says that perhaps we should call this contemporary lighting strategy an "artifice" rather than "art" since this, more accurately, describes what display lighting technique is designed to achieve. It is not, as in working environments, simply to show us what is there, but to manipulate our perceptions in a controlled way. "For selling, it is the objects for sale which must be emphasized, in restaurants the tables and perhaps the bar, in the theater the actors and settings, in discotheques the dance floor and other special displays" (Jay, 1978, p. 99).

As a part of the post Arab oil embargo to establish energy conscious codes in lighting design, the Illumination Engineering Society of North America (IESNA) set out qualitative considerations in the codes in addition to quantitative ones. Loe and Rowlands (1996) stated the difficulty in balancing objective [quantitative] parameters with the subjective [qualitative] ones that affect human mood and sentiment. They state that the lack of experimental evidence in support of the subjective goals to be reason for this imbalance.

The above trends in lighting practice suggest the need for more research in the subjective reactions to lighting. Whether art or artifice, lighting evokes impressions in humans and Boyce (1981) adds that it is the subtlety of the various impressions that can be evoked and the practicality of doing so that makes lighting such an important means of manipulation. It is thus important to understand more clearly which parameters in lighting evoke what impressions to be able to balance the art and science in lighting design.

Factors in visual acuity

Loe and Rowlands (1996) state that light can be described as a communicator of information, transmitting images via the eye's optical elements through the photoreceptors of the retina then via the optic nerves to the brain for interpretation. Boyce (1981) explained this phenomenon as a perceptual characteristic of a visual system that has perceptual constancy. Boyce stated that through all the variations in the retinal image due to movement of the eyes and head and the spectral variations due to the time of the day, an object is still perceived as the same. Perceptual constancy includes brightness, color, shape and size constancies. Boyce (1981) further explains that brightness constancy was the most relevant to lighting studies. Color constancy as explained by Mania (2001) is responsible for humans perceiving white paper as white under a wide range of illumination. To understand brightness constancy, Stein and Reynolds (2000) have documented the concept of adaptation levels as well as the effect of adaptation levels on apparent brightness. The eye detects luminance over a range of one million to one, the lower levels being accomplished after an adaptation time. Dark adaptation takes place while going from light to dark and light adaptation takes place while going from dark to light. Dark adaptation usually takes a longer time. The eye adapts to the brightness levels of the overall scene and sees each object in the scene in the framework of that adaptation level. At low levels of adaptation, like indoors, the eye diminishes the differences between high brightnesses. As adaptation levels rise to daylight conditions, the diminishing effect is gone and smaller differences can be seen. Hence Stein and Reynolds (2000) conclude that visual acuity, the ability to distinguish between brightnesses, increases with increase in adaptation levels. They also conclude that at high adaptation levels, apparent brightness is lesser than actual brightness. For example, a piece of coal near a window appears darker than a piece of paper in shade. Similarly, at low adaptation levels, the reverse effect is seen: the apparent brightness becomes more than the actual brightness. These findings indicate that in places with low illumination, such as theaters and museums, a bright light source would (subjectively) appear brighter than it measures quantitatively. The lighting designers must take note of this and try to balance accent to ambient lighting ratios instead of using high illuminances to create contrasts in the spaces. Coming back to Boyce's explanation (1981) of brightness constancy, he noted that people perceived reflectance and illumination separately under normal lighting conditions. So even if the luminance, i.e. the product of reflectance and illumination, was the same, the piece of coal still appeared darker than the paper.

Brightness constancy is only observable over a range of illuminances and breaks down at extreme ranges (Boyce, 1981).

Characteristics of light

Appropriate lighting for any task must include a degree of luminance variation; it must consider luminance distributions, chromaticity, and the psychological effects of lighting in addition to the minimum level of illuminance (Loe & Rowlands, 1996; Stein & Reynolds, 2000). Following are descriptions of some terms important in the understanding of lighting design.

Illuminance -- the measurement of light falling onto an object or surface and expressed in lux or footcandles (IESNA Merchandise Lighting Committee, 2001). Illuminance recommendations by the IESNA (Rea, 2000) for the horizontal illuminance for produce, falls under category E, for which the recommended illuminance level is 500 lux. Horizontal illuminance means lighting intensity on horizontal surface like floors, top of produce display and so on (Steffy, 2000).

Luminance -- the perceived brightness of an illuminated object, dependent on the light falling onto it and the reflectance of the object itself. It is measured in candelas/meter^2 or candelas/foot^2 (IESNA Merchandise Lighting Committee, 2001). Chowdhary (1983) showed that increase in brightness of the luminaires had a positive influence on subject's evaluation of visual clarity.

Luminance ratio -- the relative luminances of any two areas in the visual field (IESNA Merchandise Lighting Committee, 2001). A study investigating lighting requirement for viewing paintings by Loe, Rowlands, and Watson in 1982 at Bartlett, Illinois, showed that optimum visibility occurred when the illuminance on the painting was approximately three times the general background illuminance (Loe & Rowlands, 1996). The IESNA Merchandise Lighting Committee (2001) suggested luminance ratios that are at least three, five or even ten times higher than the ambient levels for dramatic emphasis on focal points.

Patterns of Luminance -- patterns of light and shade in space result from the light distribution of the luminaries, as well as the objects that cast shadow (IESNA Merchandise Lighting Committee, 2001). It is the pattern of light that give ambience and subjective reactions of clarity / fuzziness, boredom / excitement, definition / shapelessness, sociability / isolation and so on. A ten to one luminance ratio is said to create areas of high brightness for points of interest and visual excitement (Stein & Reynolds, 2000).

Correlated color temperature -- the temperature of a black body whose chromaticity (color appearance) most nearly matches that of the light source. It is measured in degrees Kelvin. 2800K-3200K is considered "warm"; 4100K-4900K is considered "white" and above 5000K is considered "cool." This comes from heating a blackbody (think of a piece of coal) up to a certain temperature, as the coal gets hotter and hotter it changes from orange (i.e. 2300K) to yellow (3000K) to white (4700K) to blue (5000K). For the color temperature scale, see Figure 2-1. The IESNA Merchandise Lighting Committee

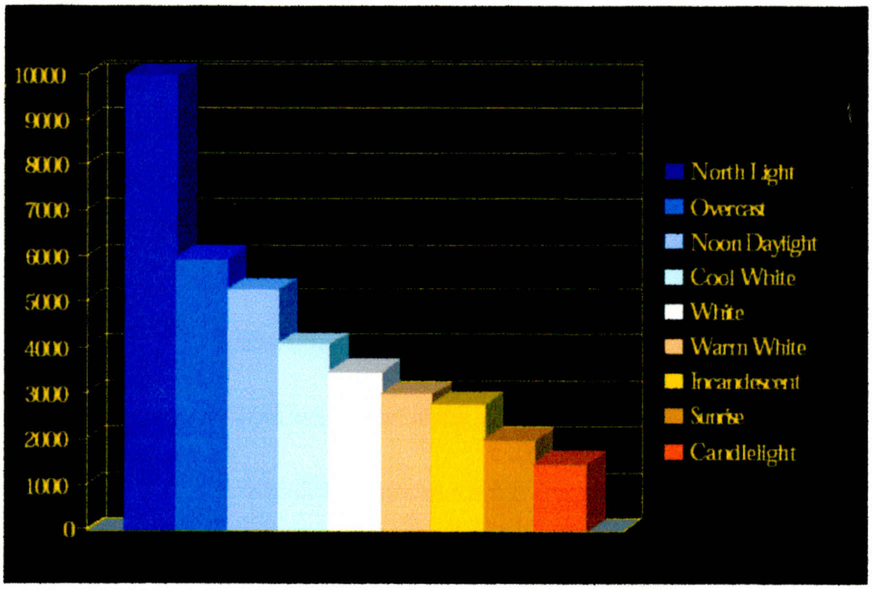


Figure 2-1. The color temperature scale

Note: From *Enhance your vision: Lighting in libraries* by Patricia Fitzgerald and Jeffrey Scherer, 2000/2001, http://institute21.stanford.edu/programs/workshop/facilities/scherer_tech.pdf

(2001) stated a relationship between illuminance levels and correlated color temperature (CCT) based on the experiments of Kruithof. In 1941, Kruithof (as cited in the IESNA Merchandise Lighting Committee, 2001) found that lamps with high color temperature at low illuminance made spaces appear cold and dim, while lamps with low color temperature and high illuminances made spaces appear artificial and overly colorful. What Kruithof essentially showed was that at low levels of illumination, most people prefer “warm” light and at high levels of illumination, they prefer “cool” light (Birren, 1969). Chowdhary (1983) explains this preference by saying that, when outdoors, people are accustomed to high levels of illumination from natural daylight, whereas in the interiors of their homes, they have been accustomed to warm light sources like candles, incandescent bulbs, etc. In 1975, Boyce (as cited in Gettu, 1983), showed that lamps with good color properties required low illumination to qualify for satisfactory visual clarity. Another result of the Bartlett study by Loe, Rowlands, and Watson in 1982, (in Loe & Rowlands, 1996), showed that once the illuminance on the paintings reached a level of approximately 200 lux (along with a good color rendering), the visual ability to see detail together with good color discrimination was satisfied. A source with a good color rendering could be any source with a CCT of 3000K or above (IESNA Merchandise Lighting Committee, 2001, p. 51). These studies show that there is an important relationship between color properties of a lamp and its illuminance. The IESNA Merchandise Lighting Committee (2001) suggests that more research is needed to clarify this relationship since many of studies have failed to show consistent findings even through many replications of these studies.

Ambient lighting -- the provision for a general diffuse layer of uniform illumination throughout the store. Ambient levels can range from low (150-300 lux) to high (500-1000 lux). Luminaries should have broad distribution patterns and should be symmetrically arranged (IESNA Merchandise Lighting Committee, 2001).

Accent lighting -- an emphasis on the shape, texture, finish and color of the product. Point sources are ideal for accent lighting as they can be controlled and directed. Beam angles vary from three degrees for spot lighting to sixty degrees for flood lighting. Luminaires are described according to their beam spread, focusing or aiming ability, and degree of cutoff for glare control (IESNA Merchandise Lighting Committee, 2001).

Lighting affecting impressions

Flynn, Spencer, Martynink and Hendrick (1975) found that as the designer changes lighting modes, i.e., the character of the pattern of light in the room, the composition and relative strength of visual signals and cues are changed. This in turn alters some shared impressions of spatial meaning for the room occupants. A video recording by the IESNA (1996) explains that responses to visual stimuli can be categorized in terms of visual clarity (that is, the ability to be able to distinguish between the edges of the surface); spaciousness (the ability to perceive the space in between objects); relaxation (the ability to feel relaxed while seeing something) and privacy (not feeling an encroachment of privacy by the lighting). Mania (2001) restates Flynn's categories as perceptual (including visual clarity, spaciousness, spatial complexity, color tone, glare and so on), behavioral (such as public vs. private space and impressions of relaxing vs. tense space) and the third category of overall preference (such as like vs. dislike or impressions of pleasantness). Mania's interpretation of Flynn's categories of impression seems more generic and suited for this research. Flynn, et al. (Boyce, 1981) had conducted the study for a conference room and later transferred it to an auditorium. They conclude that impressions could be transferred to other contexts. Mania (2001) and Boyce (1981) stated confirmation of Flynn's belief that lighting provides a number of cues which people use to interpret a space and that these cues are partly independent of the room that is being experienced. Boyce in 1981 however stated that the generality of the cues will remain open to question until a much wider set of interiors and lighting conditions have been examined.

The impressions that Flynn, et al. used for the study were inspired guesses (Boyce, 1981) produced by the inspection of the rating scales most strongly related to the impressions. The scales were semantic differential scales that had been created from the observer's impressions of the room. For example, consider the group of scales large / small, long / short and spacious / cramped. These form Flynn's category of "impression of spaciousness." Osgood (as cited in Chowdhary, 1983) developed a semantic differential technique using sets of pairs of words that represent meaning of a particular concept expressed on a linear scale. Each pair of words are opposite in meaning and correspond to a linear scale. The scale is divided into segments that are assigned numerical values in ascending or descending order. It can be employed to discover relationships between the form of the physical environment and those who occupy it and also to provide a basis for understanding the "why" of the relationship. The limitations of a scale come from the use of adjectival descriptions. The adjectives used should not be too specific. The variations in the environment are almost infinite and hence impossible to describe completely (Hersheberger, 1972). It is also important to note that a semantic differential scale is a generalized technique in the measurement of meaning; there are no standard scales. The scales depend on the purpose of the research. The scales yield 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 (Chowdhary, 1983). See Figure 2-2.

Clear	1	2	3	4	5	6	7	Fuzzy

The scale is defined as:

1. Very Clear
2. Clear
3. Slightly Clear
4. Neutral
5. Slightly Fuzzy
6. Fuzzy
7. Very Fuzzy

Figure 2-2. Example of a semantic differential scale

Semantic differential scales have distinct pairs of antonyms on either side. Although subjects cannot make their judgments of difference on any basis they wish as in the case of difference / multi-dimensional scales, they can understand a semantic differential scale better (Boyce, 1981). Stating the importance of range in a rating scale, Boyce (1981) explains that when asked to make a subjective judgment, an observer will always use something as a reference. It may be a midpoint of the range of conditions to which the observer has been exposed in the experiment or, in the absence of such exposure, a relevant previous experience. To enable this, it would be necessary to firmly establish a context for the interior to be judged and to have it judged by a sample of people representative of those who would use such a space.

Computer graphics as a research tool

Lighting experiments using real or proposed physical spaces are expensive, time consuming, and difficult to manipulate experimentally (Chowdhary, 1983). Color slides or models have been tried as valid substitutes for the actual spaces. According to Boyce (1981), subject ratings of a real scene and color slides of the scene showed strong similarities. This suggests that substitutes, if created correctly, could replace real spaces in research studies. Since the potential of the computers to undertake large numbers of computations in a relatively short period of time has been established, the computer science of lighting has now, 2003, developed to a stage that provides formal descriptions of the physical properties of light and the objects that reflect, absorb and transmit light (Roy, 2000). Roy reports that a wide range of design tools have been developed based on these descriptions and that these tools allow designers to meet most of the basic requirements of lighting in their designs. The modeling packages developed so far have proved their ability to produce realistic visual representation of the scene along with accurate estimation of the properties of light. A researcher with aid from such packages will definitely have more precise control over the variables accounted for in the design.

According to Roy (2000) there are two approaches to select the desired effect in a study. A photorealistic model can be made to "look right" by "tweaking" a range of parameters in the generated images. This however will not allow extraction of quantitative data from the models if the designer is required to meet particular design requirements, like light levels and other performance criteria. A photometric model is usually very complex but can be made simpler by selecting parts of the scene, such as a wall, a work surface, etc., that are critical to the design. Autodesk Viz 4, a product of Autodesk, Inc., includes Global Illumination (GI) technology which takes into account specular reflection and diffusion which eliminates the need for a file to be exported to Lightscape, a lighting simulation application developed by and large for the entertainment industry, for realistic rendering. Shalaby (2002) points out that GI uses two principal algorithms: ray-tracing and radiosity. Ray-tracing traces the rays in the reverse of actual lighting, i.e. from the destination to the source. Each ray of light must be traced through the 3D scene to a light source or a reflecting surface and beyond if the surface is reflecting. The major problem according to Roy (2000) is that for each viewing location, a new computation must be done. In radiosity, all the surfaces on the scene are divided into planar surface patches, generally triangles. The distribution of light is then computed iteratively by computing how much light is reflected from each surface patch into each other surface patch. Given a sufficient number of iterations and a fine surface grid, the results can quite satisfactorily imitate a scene as if it had been built and both photographed and had its lighting measured (Roy, 2000). In her discussion of results from the study to assess whether subjective impressions to illumination could be identified after exposure to a "virtual environment," Mania (2001) stated that a computer graphic scene (virtual environment) was validated for assessing subjective responses to varied lighting or rendering quality scenes.

The College of Architecture and Planning Design (CAPD) at Kansas State University (KSU) has Autodesk Viz 4 installed on the college network, making it more accessible than possible and appropriate lighting design programs.

Light sources

The IESNA Merchandise Lighting Committee (2001) recommends an average of 150 footcandles to 250 footcandles for lighting fresh fruits and vegetables. Metal halide (MH) lamps and ceramic metal halide (CMH) lamps belong to the high intensity discharge family of lamps. Steffy (2000) says that a standard MH lamp provides "white" light, but less consistent color quality and relatively poor color rendering. A high-pressure sodium lamp produces an obvious "yellow" light that makes many food-stuffs appear unattractive. In the more than hundred years as the primary artificial light source, humans have grown accustomed to the particular spectrum of incandescent lamps to the point they seem "normal." A CMH can offer near-incandescent light in appearance and quality. The warm tone of CMH is around 3000K and its cooler tone is around 4000K. It is recommended as best for merchandising and is best suited for ceiling of height ten feet or greater.

Case study- Semantic differential scale

Flynn, Spencer, Martynink and Hendrick (1975) carried out a study at the General Electric lighting institute at Nela Park, Cleveland, Ohio, to apply the semantic differential technique to questions of subjective responses to illumination and see if this rating scheme provides worthwhile and significant insight into the subjective implications of lighting design. The basic lighting variations employed in the study were the distributions of light from the luminaries, location of luminaries in the room, intensity of light on the horizontal plane and the color tone of the light (warm or cool). The arrangements were:

1. Overhead down lighting / low intensity
2. Peripheral wall lighting all walls
3. Overhead diffuse / low intensity,
4. Combination of 1 and end walls
5. Overhead diffuse / high intensity
6. Combination of 1, 2, and 3.

Subjects were well distributed in background and age and were randomly divided into two groups. Two techniques were employed in getting the ratings of the room. The first group was to have the subjects rate the room when they first entered, where each group saw only one arrangement and were naive about the focus of the experiment. In the second group, the subjects were shown various light settings and were informed about the focus of the experiment. Providing a frame of reference, as in the second group, served to enhance the effectiveness of the rating scales by producing more significant differences in mean ratings. The researchers concluded that the second method was a more efficient use of subjects. The subjects were shown each light setting for approximately fifteen seconds to provide a general frame of reference. The first light-setting was then presented and after a minute period of adaptation, subjects rated the settings. The scales were presented in a randomized order. Each of the light-settings was presented one at a time, but in a different order for each group. The ratings were factor analyzed to find areas of redundancy and repetition in the use of scales. The findings suggested five independent dimensions namely: evaluative, perceptual clarity, spatial complexity, spaciousness and formality (Boyce, 1981). The mean ratings for each installation were located on each rating scale. For example, for the pleasant / unpleasant, the two installations that were considered most pleasant used a combination of lighting of the table and the walls. The two most unpleasant installations provided diffuse lighting only on the table. Flynn, et al. (Boyce, 1981) inferred that such information can tell the designers that combination lighting on table and walls for a conference room is preferred over a light setting that offers only diffuse light.

Purpose of this study

The above studies need substantial research to carry the theories over to a more concrete form. Some of the important issues that following research must address are getting a clearer understanding of the lighting parameters that affect impressions and using a variety of interior settings to be studied to generalize the subjective cues making it applicable on a wider scale. This research is an attempt to address such issues using the semantic differential scale and computer generated models, independently proved as valid research tools.

CHAPTER III

Methodology

Research hypotheses

Past studies and design guidelines have shaped the hypotheses for this research. For example, Chowdhary (1983) and Stein and Reynolds (2000) in their studies showed that visual clarity or visual acuity increase with brightness or adaptation levels. The IESNA Merchandise Lighting Committee (2001) has published several guidelines about the luminance ratios, recommending them to be at least three, five or even ten times higher than the ambient levels for dramatic emphasis on focal points. There have been several studies reporting the relationship between color and illuminance. The most important being that of Kruithof stating that people prefer "warm" light at low illumination levels and "cool" light at high illumination levels (Birren, 1969). Boyce (1981) and Loe and Rowlands (1996) showed that low levels of illumination were enough to achieve satisfying visual clarity if the lamp had good color properties. The research mainly investigated the combination or independent effects of luminance ratio and the correlated color temperature (CCT) of the accent and the ambient lighting in the retail context on subjective responses. Computer generated models (CGMs) or scenes were modeled to exhibit lighting environments to represent the aspects being investigated.

The following hypotheses will be tested for the present study.

1. Accent lighting designed with higher luminance ratio will present a more perceptually clear interior than one with a lower luminance ratio; both having same the same ambient lighting conditions.
2. Accent lighting using a combination of high luminance ratio and high CCT will present a more visually clear interior than the one with low luminance ratio and low CCT, both under the same ambient lighting condition provided by fluorescent lamps.
3. Accent lighting introduced within an ambient lighting will be preferred over only ambient lighting, when the ambient lighting is provided by metal halide (MH) lamps.
4. Ambient lighting with fluorescent lamps with higher CCT will be preferred over an ambient lighting with MH lamps with a lower CCT.
5. Accent lighting using a combination of high CCT and low luminance ratio will be preferred over a combination of low CCT and high luminance, both under the same ambient lighting provided by MH lamps.

The hypotheses concerning luminance ratios are derived from the observation that higher luminance supports better visual acuity (Chowdhary, 1983; Stein & Reynolds, 2000).

Research design

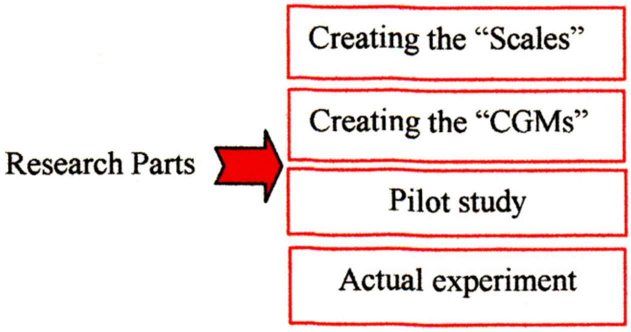


Figure 3-1. Schematic flow of research methods

Creating the "scales"

Flynn, et al. (as cited in Boyce, 1981) have already validated the use of semantic differential scales to assess these responses. This research, in a continuing attempt to determine aspects of lighting that determine preference of one system over the other, uses the semantic differential scale and CGMs of a retail space instead of the real space. Preference was measured using the three categories of impressions, viz., perceptual, behavioral, and overall preference (Mania, 2001). Under the perceptual category, bright / dim, distinct / vague and warm / cool were used. The relaxing / tense scale was used for the behavioral category. The overall preference was measured through a direct question asking the subject to choose the preferred scene. These scales were shuffled so that they alternated in their direction on each scale and avoided grouping under its category of impression. See Appendix B for a copy of the response from presented to the subjects for each pair of images.

Creating the "CGMs"

Autodesk Viz 4 was used to model a part of a typical produce section in a grocery store. The model geometry did not represent an actual scene as permission to measure on-site in a local grocery store was denied, but a reasonable virtual facsimile was created by inspection of a produce section of a local grocery store and by common knowledge and experience. According to Roy (2000), a photometric model, usually a very complicated process, can be made simple by depicting only the crucial part of the scene like a wall, etc. The research here did not require a very complicated scene for the proposed investigations. The CGMs were created within a simple setting. See Figure 3-2. It consisted of a display table with oranges piled higher away from the viewer, framed by a

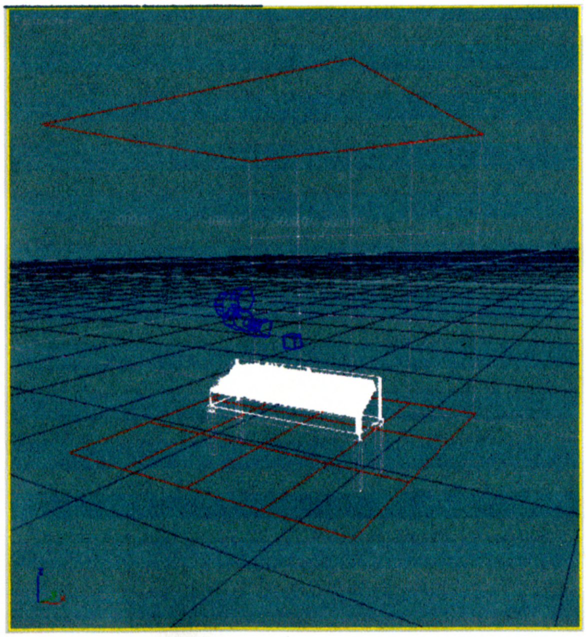


Figure 3-2. A simple CGM in Autodesk Viz 4

floor plane, a ceiling plane and a front wall plane. The dimensions of the model space were thirty-six feet by thirty-six feet and a height of eighteen feet. The height of the display table was four feet from the floor at the rear end and sloped to three feet at the front end. The display table consisted of a truncated wooden box fixed within a metal frame. The oranges were modeled using an "editable mesh." "Editable meshes" are the simpler models compared to "editable poly," or "editable patch" and save time when it comes to rendering. The objects were then assigned textures from the "material editor" in Autodesk Viz 4. The "material editor" acts like a palette where one can create appropriate textures. Textures were assigned to the display table, floor, front wall and the oranges. The display table had a wooden finish for the box holding the oranges and a metal finish for the frame holding the box. The floor had a combination of two materials, grout and tile. The front wall had a bitmap image of a scanned photo of the interior of Sentry Foods --- Hilldale, Madison, Wisconsin, (personal visit, August 2002). The image presented a "fuzzy" impression of a store interior serving as the appropriate background for the model, setting the context, but not distracting too much attention from the pile of oranges. See Figure3-3.

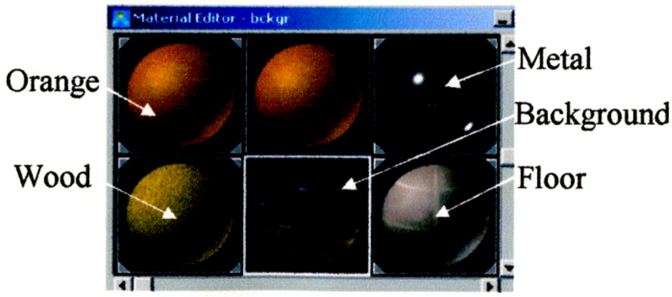


Figure 3-3. Part of the Material Editor box showing the textures assigned

Once the basic model was prepared, the lighting design was introduced. A four feet by four feet grid was centrally positioned over the area of thirty-six feet by thirty-six feet for placing the lamps for accent lighting and ambient lighting. The grid spacing and the approximate lamp specifications were referenced from Zimmer's design for Baker's at Eagle Run, Omaha, Nebraska (personal communication, February, 2001). See Figure 3-4 for the lamp spacing for "scene 1" in "pair 1." The pairs of scenes were created in accordance with the hypotheses set for the research. "Pair 1" was designed to test

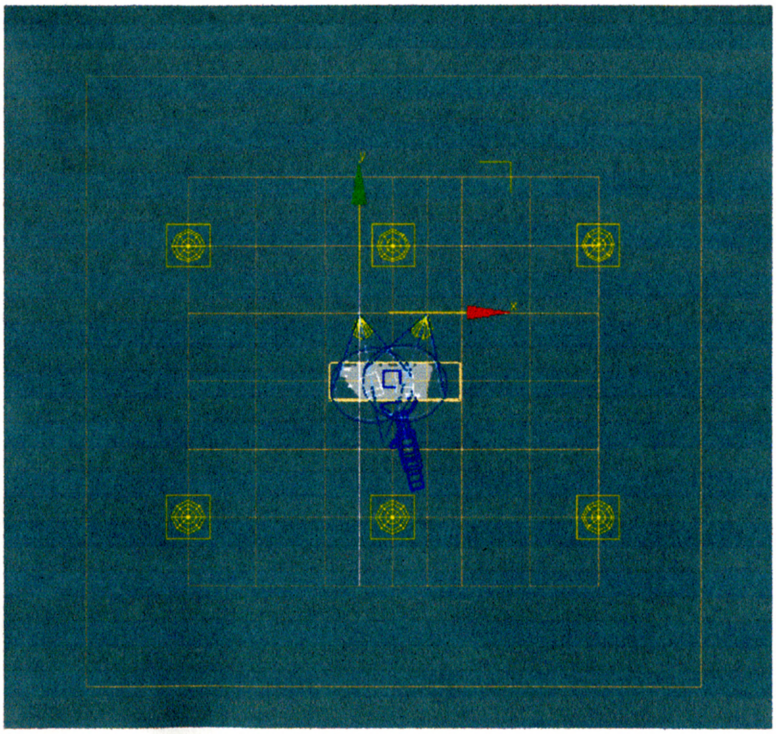


Figure 3-4. Plan showing the grid spacing

the effect of luminance ratios of two different accent lightings under the same ambient lighting; "pair 2" and "pair 5" were designed to test the effects of the combination of luminance ratio and CCT; "pair 3" was designed to study the effects of accent lighting in a scene and "pair 4" was designed to test the CCT of the ambient lighting. Appendix C furnishes the photometric data used for the pairs. The lamp sources were Photometric lights in Autodesk Viz 4. The program allowed the photometric data of the lamps to be changed according to suit one's requirements. To design the ambient lighting in "scene 1" in "pair 1" MH lamps were used due to its good color properties (Steffy, 2000; B. Zimmer, personal communication, February, 2001). After consulting with J.Lewis-Smith (personal communication, February, 2003), it was decided to use six MH lamps, each of 20,500 lumens to give a total illuminance (E) of 310 lux. See Appendix D for the calculations of illuminances for ambient and accent lighting and luminance ratios. There was a difference of approximately 200 lux here between the above illuminance obtained and the horizontal illuminance specified by Rea (2000) as a part of the IESNA recommendations. This difference was not considered very critical after J. Lewis-Smith, (personal communication, February, 2003) obtained these two levels of illuminance within the same room using an illuminance meter. These two spots did not have any significant difference in brightness that could be visually observed. Hence it was decided to use six MH lamps at a height of eighteen feet. The photometric data was taken from the Hubbell Lighting Guide (1992). Figure 3-5 shows the manual data input from the lighting guide into the Autodesk Viz 4 file. Under light type, "area" was selected for

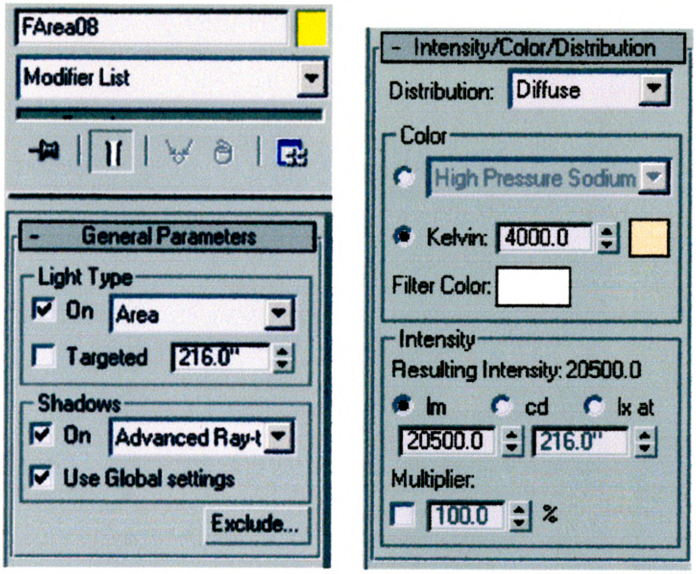


Figure 3-5. The photometric data entry box for a diffuse lamp source

ambient lighting. "Diffuse" lighting distribution was selected according to the recommendations by the IESNA Merchandise Lighting Committee (2001). The rest of the data such as CCT and "intensity," were directly taken from the guide. Two 70 watt PAR 38 Medium, ceramic metal halide (CMH) lamp were selected for the accent lighting, mounted at a height of twelve feet (Lamp Specification and Application Guide for Philips, 2001/2002). A CMH lamp has better color properties than a MH lamp and is suited more for the purpose of accent lighting (Steffy, 2000). This gave a luminance ratio of around seven which is quite desirable according to the IESNA Merchandise Lighting Committee (2001). The light type here is "point" and the distribution consequently is "spotlight." In addition to the types of parameters for the ambient lighting, accent lamp sources have "spotlight" parameters. these describe the beam spread of the luminaire.

See Figure 3-6. The shadow option under the "general parameters" is selected at

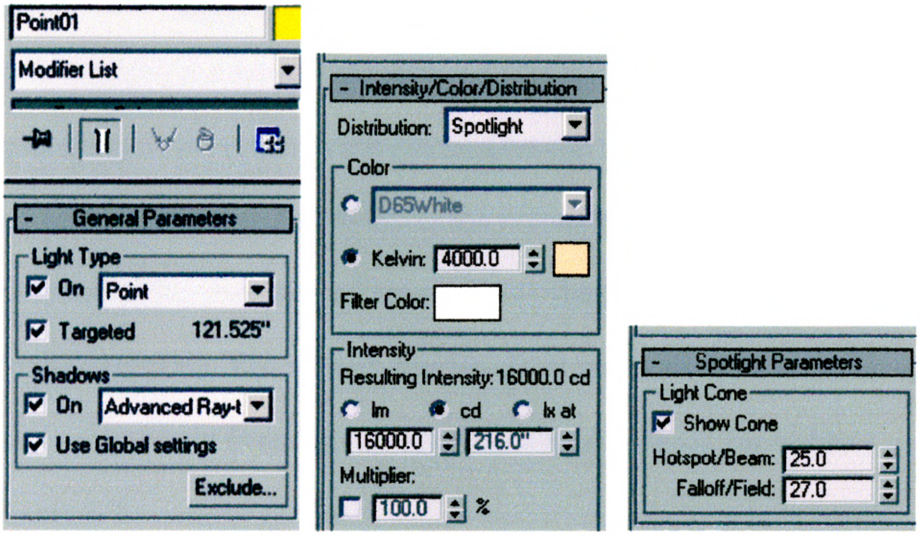


Figure 3-6. The photometric data entry box for a spotlight

"advanced ray- traced." Such a mode supports transparency and opacity map if transparency is on, uses very little RAM, and is recommended for complex scenes with many lights or faces (Autodesk Viz 4 User Reference). Finally, the "radiosity" panel was used to render the scenes. Under the "radiosity" processing parameters, "initial quality" was kept at eighty percent and "refine iterations" was kept at four for all the scenes. In the "initial quality" stage, the distribution of diffuse lighting in the scene is calculated by essentially mimicking the behavior of real photons. It is a statistical sampling process, which means that the greater the number of rays used in the approximation, the greater the accuracy of the solution. During the "initial quality" stage, the overall appearance of the lighting level of the scene is established. Because of the random nature of the sampling during the initial quality stage, some of the smaller surfaces or mesh elements in the scene might miss being hit by enough rays (or any rays at all). These small surfaces remain dark, and result in the appearance of dark spots. Roy (2000) had suggested the importance of iterations which can be effected here. To alleviate these artifacts, the "refine stage" regathers light at every surface element. One can perform the "refine stage" for the entire scene, or for selected objects in the scene (Autodesk Viz 4 User Reference). Under the rendering parameters, "render direct illumination" was selected as this is the default rendering mode. VIZ renders shadows from the lights at each rendering frame, and then adds indirect light from the radiosity solution (Autodesk Viz 4 User Reference). See Figure 3-7.

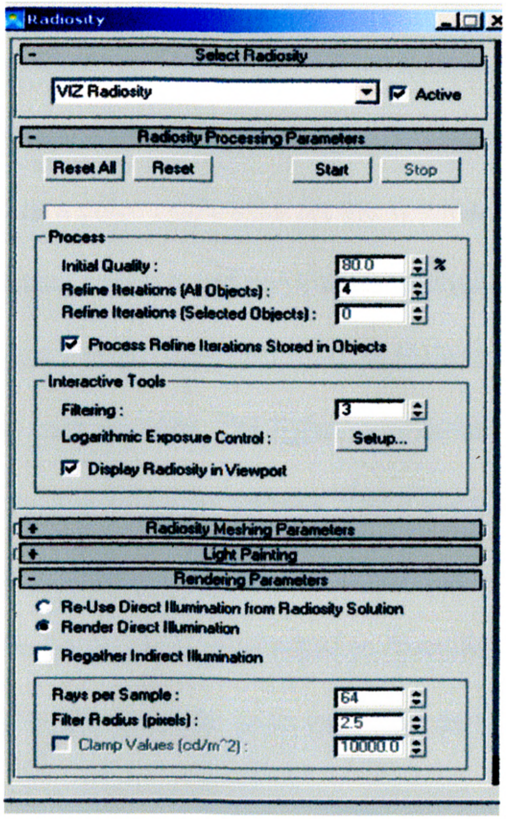


Figure 3-7. Radiosity panel

Every scene was created in the above manner except for the photometric data for the lamps. The luminance ratios are calculated directly from the illuminance measurements. Luminance is the product of illuminance and reflectance factor. The reflectance factors for this study, being the same in each scene, have been ignored to avoid complications and luminances has been calculated directly from the illuminance values after consulting with J. Lewis-Smith (personal communication, February, 2003).

Pilot study

The pilot study took place in the computer laboratory in Seaton Hall in the College of Architecture and Planning Design (CAPD) at Kansas State University (KSU). Each pair was loaded in separate PCs. All PCs had a common blue background for their desktop, which was used as a color calibration for the screens. The monitors were calibrated by using the brightness, contrast and color tones controls on each monitor. Having both scenes of a pair on a single monitor eliminated bias to some extent due to a different color balance on each monitor. The lights were switched off in the laboratory to eliminate reflecting glare on the computer screens. There were four participants for the pilot study; they were all students in the CAPD. The researcher used an additional instrument to the rating scales. The participants were asked to describe each scene in terms of pairs of adjectives. This would allow for some judgment on the subject's part rather than just having words put in their mouth (R. Hoag, personal communication, March, 2003). Participants were informed about the focus of the research to get more effective results (Flynn, et al., 1975). Each participant saw the pairs in a randomized order. A coin was tossed to decide which scene in each pair was seen first. They were given the option to go back and forth between the scenes in each pair with the help of the mouse button.

The findings of the pilot study were quite significant with respect to the nature of the scales. Initially a seven-point semantic differential scale was used. The responses obtained from the pilot study showed that the participants did not understand the subtle difference between the number 2 and 3; 5 and 6. It was thus decided in consultation with O. J. Selfridge (personal communication, March, 2003) to collapse the scale to a five-point scale like a Likert scale. Figure 3-8 shows the collapsing of the scales. The

Clear 1 2 3 4 5 6 7 Fuzzy

Clear 1 2 3 4 5 Fuzzy

The scale now is defined as:

1. Very Clear
2. Clear
3. Neutral
4. Fuzzy
5. Very Fuzzy

Figure 3-8. Collapsing the scale

participants also came up with adjectives describing the appearance of fruits in the scenes, for example fresh / rotten and juicy / dry. It was thought appropriate to add these adjectives pairs to the existing scales under the category of perceptual clarity. The actual experiment was conducted after making these amendments. Appendix B shows the rating scales used in the actual experiment.

Actual experiment

The actual experiment was carried out also at the computer laboratory at the CAPD. The pairs were kept on the same PCs. The computer set-up and the room conditions were unchanged from the pilot study. The participants were all students from the CAPD and were well distributed in their year-of-study from freshman to graduate students. There were thirty subjects and all were handed a consent form, stating that they could withdraw their participation any time they wanted (Appendix A). Each subject retained a copy of the consent form and a signed form provided admission to the experiment. Approximately sixty-three percent of the population was male. The time taken by each participant was about three minutes for each pair. The summary of participants' responses can be seen in Appendix H. The forms from each subject were collected and any questions about the study were answered. The responses were entered into a computer database, followed by "data cleaning." The data was then analyzed using a t-test to find out if there were any significant differences between the two scenes in a pair at a significance level of five percent; it was executed through the software program called Statistical Analysis System (SAS). This was followed by a correlation analysis of the scales and the categories of impression used in the research which was executed using the software program called Minitab, Release 13.30.

CHAPTER IV

Results and discussion

The hypotheses structured for the research were to test whether an accent lighting with a higher luminance ratio would be preferred over a lower luminance ratio ("pair 1"); whether a combination of high luminance ratio and high correlated color temperature (CCT) would be preferred over a low luminance ratio and low CCT ("pair 2"); whether introducing an accent lighting would make a difference ("pair 3"); whether the color of ambient lighting would matter ("pair 4") and whether a combination of higher CCT with low luminance ratio would be preferred over a lower CCT and high luminance ratio ("pair 5"). The subjective responses were measured in six five-point rating scales as well as a direct question of preference. The scales were distinct / vague, warm / cool, juicy / dry, bright / dim, relaxing / tense and fresh / rotten. As Boyce, in 1981, stated Flynn's explanation of the results of his study through a comparison of the means for each installation, it was thought appropriate for this research to carry out a comparison of means followed by a correlation analysis of the scales. One scale was taken at a time and the means of the responses were calculated for each scene in each pair. A t-test was used to find out if there were any significant differences between the two scenes in a pair at a significance level of five percent; it was executed through the software program called Statistical Analysis System (SAS). This was followed by a correlation analysis of the scales and the categories of impression used in the research. This was executed using the software program called Minitab, Release 13.30.

For viewing the t-test and correlation results refer Appendices F and G. The images for the five pairs are presented in Appendix E. These images are JPEG formats (i.e. 2D bitmaps) of the actual files used in the study and are not as effective as the images viewed in the experiment which were 3D models from the Autodesk Viz 4 simulations. Also refer Appendices C and D for relevant information on lamp specifications and calculations. The results showed that for the scales distinct / vague and warm / cool there were no significant differences between the mean responses in any "pair" and that "pair 2" did not have any significant differences between its "scenes" on any of the scales.

"Pair 1" had its "scene 1" as having a higher luminance ratio over "scene 2." "Scene 1" in "pair 5" was designed to have a combination of higher luminance ratio but lower CCT as against its "scene 2." "Pair 1" and "pair 5" were rated similarly and on the same scales of bright / dim, relaxing / tense and fresh / rotten. See Figures 4-1 and 4-2 for

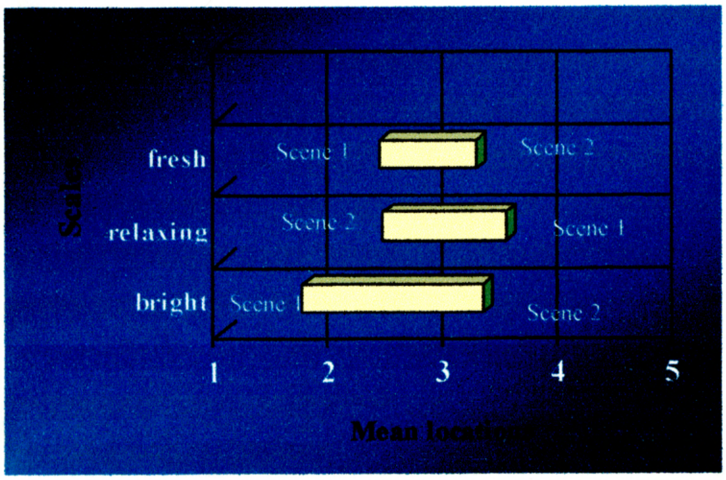


Figure 4-1. The mean locations of the scenes in Pair 1

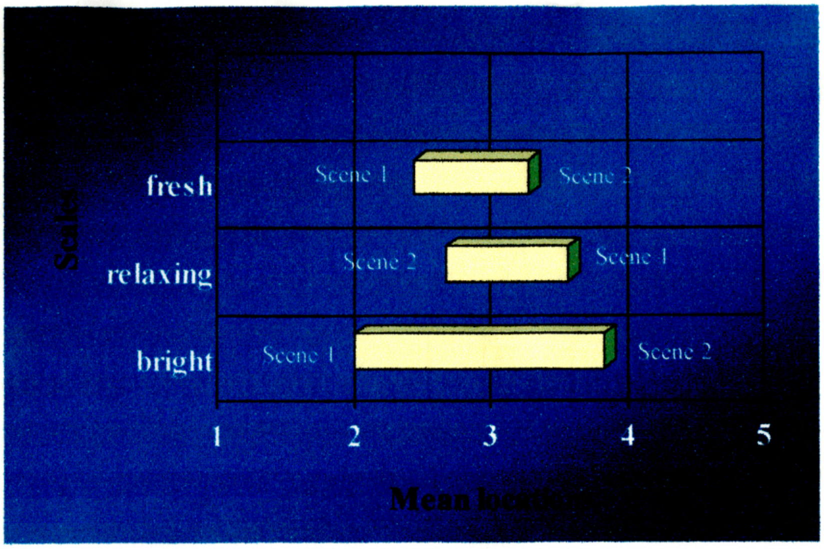


Figure 4-2. The mean locations of the scenes in Pair 5

the locations of the means of the scenes in both pairs. The results of "pair 1" directly support Chowdhary (1983) and Stein and Reynolds (2000); similar results for "pair 5" also show that a higher luminance ratio presents a "brighter" and "fresher" scene. The scales bright / dim and fresh / rotten show a significant correlation justifying their grouping under perceptual clarity. It can be said from the t-test results that the ratings of "pair 1" and "pair 5" show that perceptual clarity is higher when luminance ratios are high. The t-test results on the behavioral impression of relaxing vs. tense, along with a significant negative correlation between the scales of bright / dim and relaxing / tense, show that the scene with a better perceptual rating made the subjects "more tense." This can be interpreted as: high levels of illuminance improve clarity in seeing but could make the customers less relaxed while shopping. It should be noted that there was no significant correlation between the scales fresh / rotten and relaxing / tense. Hence, the t-test results on relaxing / tense in "pair 1" might have been brought about by the effects of brightness rather than the perception of freshness. In the context of "pair 5," there was also no significant correlation between the scales warm / cool and relaxing / tense. Hence, here too it can be said that the t-results on the relaxing / tense scale can be attributed more significantly to the change in luminance ratio rather than the effects of CCT, measured on the warm / cool scale. It can also be noted that the inability of the warm / cool scale to correlate to the distinct / vague scale under perceptual category makes it a doubtful measure of perceptual clarity. Hence, the results of "pair 5" are insufficient to confirm the belief that although a lamp has low illuminance level, if it had a good CCT it would be visually satisfying over a lamp which had a low CCT and high illuminance level (Boyce, 1981; Loe & Rowlands, 1996). Also, there was no significant differences on the preferences of one scene over the other in "pair 1" and "pair 5" which keeps their respective hypotheses partially as open research questions.

"Pair 3" supports past research on accent lighting, confirming strongly that accent lighting having a luminance ratio of over nine is preferred overall over an interior with no accent lighting. The scene with accent lighting was rated higher on the scales juicy / dry, bright / dim and fresh / rotten; all significantly correlated and hence justifiable under the perceptual clarity category. See Figures 4-3 and 4-4. There were no significant differences for the relaxing / tense scale in the behavioral category leaving the effects of accent lighting on this category still unclear.

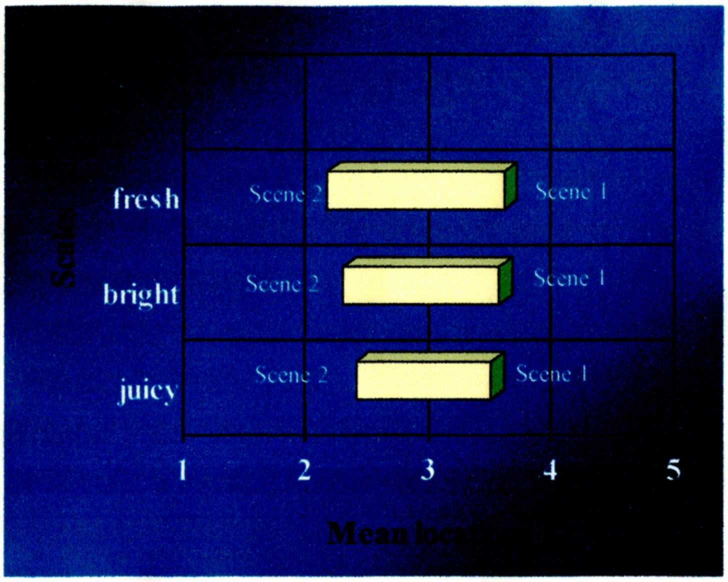


Figure 4-3. The mean locations of the scenes in Pair 3

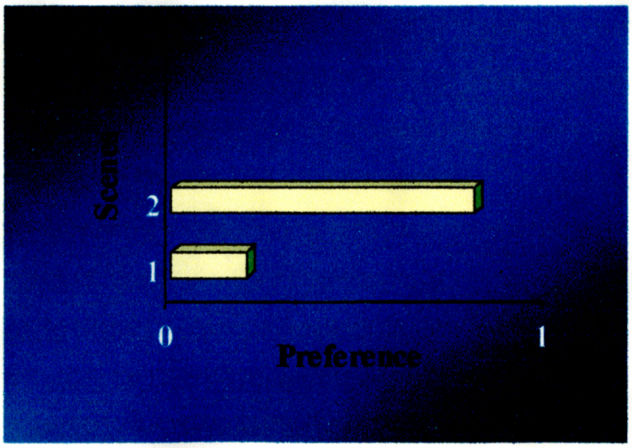


Figure 4-4. Comparative means of preference of scenes in Pair 3

The results of "pair 4," designed to test the effects of CCT of ambient lighting, also showed that "scene 1" with fluorescent lighting with a higher CCT, was rated as "juicier," "brighter," and "fresher" than "scene 2," with metal halide (MH) ambient lighting with a lower CCT. See Figure 4-5. These scales, as with "pair 3," also fall under the perceptual clarity category, leaving the question of effects of CCT on the behavioral impression of relaxing vs. tense open to more research. This is supported by the lack of correlation between the scales warm / cool and relaxing / tense. Again, as for "pair 1" and "pair 5," there was no significant difference in preference of one scene over the other.

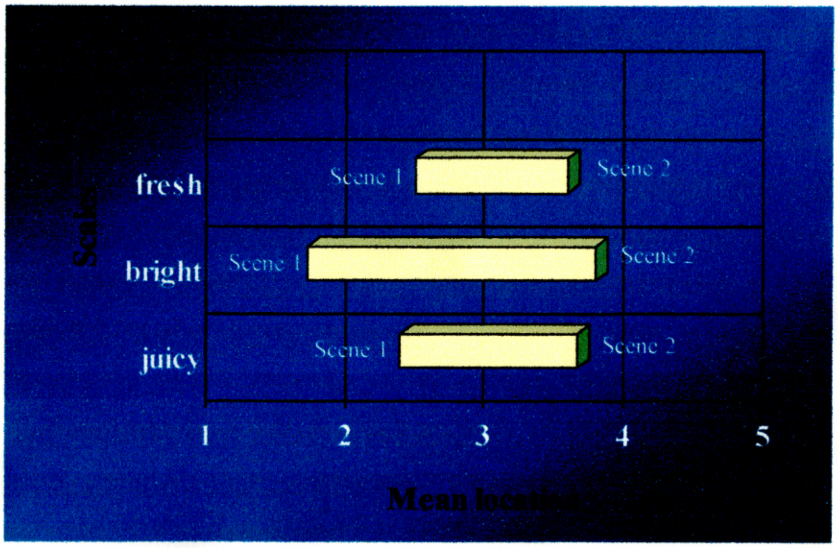


Figure 4-5. The mean locations of the scenes in Pair 4

The research had hoped to evince, through the design of "pair 2," that either a preference for a combination of higher CCT with higher luminance levels or a combination of lower CCT with low illuminance levels would build on Kruithof's (Birren, 1969) belief that people prefer "warmer" color at low illuminances and "cooler" color at higher illuminances. The inability to find any significant differences from this sample of subjects for "pair 2" makes it a question for further research.

It can be stated from the above discussion that at higher illuminance levels visual clarity improves, but that is not necessarily more conducive to a shopping environment as it may make the customers less relaxed. Having accent lighting is preferred over not having it in a retail environment when it comes to visual clarity and overall preference. When only ambient lighting is used in a retail interior, a higher CCT is preferred over a lower CCT in terms of perceptual clarity. Both "pair 2" and "pair 5," designed to obtain a clearer understanding of the relationships between color and illuminance, did not show any clear trends towards the current holdings on the relationships between color and illuminance.

Correlations were found between all the scales under the category of perceptual clarity, except that of warm / cool. This scale, warm / cool, did not bear significant correlation to the scale distinct/ vague; both scales being unable to obtain significant differences on any pair. As discussed earlier, the scale warm / cool may not be an appropriate scale to measure color. Lack of significant correlation between the scales warm / cool and relaxing / tense could not explain the effects of CCT on impression of relaxing vs. tense. However, the scale bright / dim had a negative correlation with the relaxing / tense scale, explaining the trends observed in the ratings of "pair 1" and "pair 5." A correlation between the categories of impression showed that overall preference bore a negative correlation with impression of relaxing vs. tense. See Figure 4-6. This

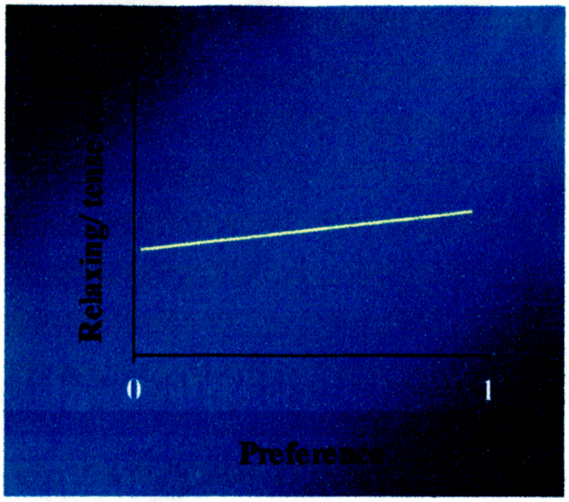


Figure 4-6. A negative correlation between relaxing / tense and preference

finding illustrates the shortcomings of research design, such as sample size, a relatively uniform sample, as well as sequential viewing of the "scenes" rather than viewing them simultaneously (which introduces an unreliable factor of memory of the subjects for their responses), and the technological inadequacies in preparing the computer generated models. There was also a negative correlation between overall preference and perceptual category might be discounted to an extent due to the inconsistencies in correlation between the scales within the perceptual category.

The efficiency of the scales across the pairs can be seen in Figure 4-7. All the scale ratings were within 1.6 and 4 on the five-point scales. "Pair 4" was rated to have the

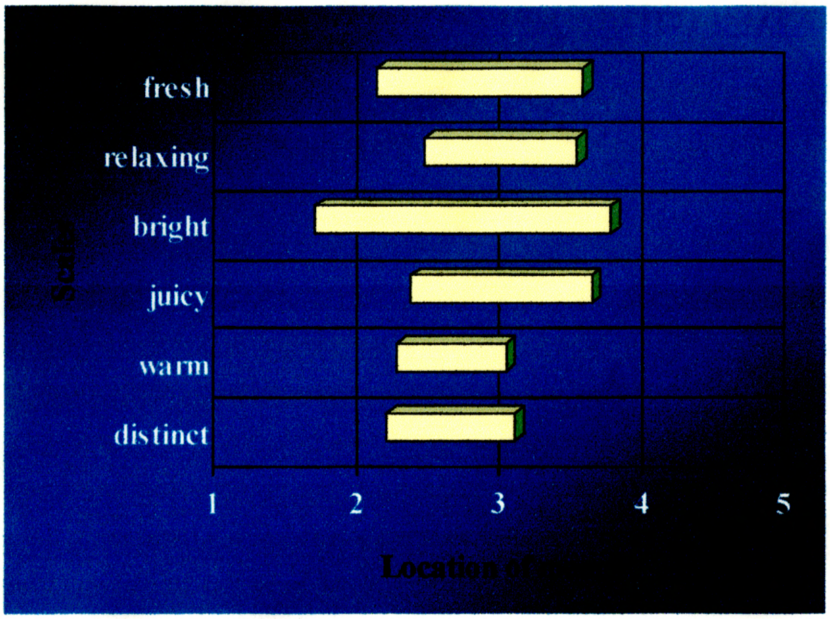


Figure 4-7. Performance of the scales

widest differences on warm / cool (a statistically non significant difference), juicy / dry and bright / dim scales. "Pair 3" had the widest differences on the distinct / vague (also a statistically non significant difference) and the fresh / rotten scales. "Pair 1" had the widest difference on the relaxing / tense scale.

The bright / dim scale had the widest difference of the means in "pair 4. It is interesting to note here that the scene rated the brightest was not "scene 2" in "pair 3" which because of its highest luminance ratio of over nine would be expected to be rated as brightest, but was “scene 1” in “pair 4,” which had a fluorescent ambient lighting with a CCT of 5000 K. This observation can be partly explained by the paper by Fitzgerald and Scherer in 2000/2001, where they describe the quality of light produced by a 5000 K fluorescent source. The paper states that the functioning of pupils is affected by the color spectrum of the light source. According to the paper, a 5000 K fluorescent light is twenty-five percent more pupilary efficient than common cool white and it requires fourteen percent less energy to achieve the same brightness perception. It can be inferred that the people are likely to find the light produced by a 5000 K fluorescent source brighter than another source at a lower CCT and at comparable intensity. In the research, the scene with the 5000 K fluorescent light was compared with a 4000 K metal halide light which surprisingly also had a higher illuminance.

CHAPTER V

Summary and conclusion

Conclusion

The intention of this research was to use Autodesk Viz 4 in creating simulations of lighting in a retail space and see how effective they were in evoking impressions to illumination of produce at point-of-sale. Rating scales were used to measure these impressions. The impressions and scales were inspired from Flynn's study (Boyce, 1981; Flynn, et al., 1975) for the General Electric lighting institute at Nela Park, Ohio. The lighting variations used in the study were the research hypotheses. They were:

1. Accent lighting designed with higher luminance ratio will present a more perceptually clear interior than one with a lower luminance ratio; both having same the same ambient lighting conditions.
2. Accent lighting using a combination of high luminance ratio and high correlated color temperature (CCT) will present a more visually clear interior than the one with low luminance ratio and low CCT, both under the same ambient lighting condition provided by fluorescent lamps.
3. Accent lighting introduced within an ambient lighting will be preferred over only ambient lighting, when the ambient lighting is provided by metal halide (MH) lamps.

4. Ambient lighting with fluorescent lamps with higher CCT will be preferred over an ambient lighting with MH lamps with a lower CCT.

5. Accent lighting using a combination of high CCT and low luminance ratio will be preferred over a combination of low CCT and high luminance, both under the same ambient lighting provided by MH lamps.

To advance the research, a pilot study was conducted prior to the actual experiment to check the usefulness of the scales to record the impressions. There were some amendments on the scales from the findings of the pilot study such as collapsing the scale range from seven points to five points and including additional scales suggested by the participants of the pilot study.

Concluding from the actual research: Autodesk Viz 4 was found to be fairly effective in representing the certain lighting variations in the scenes. These variations were decided by analyzing the subjective responses in relation to them. The variations in the pairs that yielded significant differences in the mean responses were concluded as being represented effectively via the computer generated models (CGMs). The findings were that higher illuminance levels, higher luminance ratio and higher CCT independently present a better scene in terms of visual clarity. In terms of the relaxing / tense behavioral scale, lower illuminance levels were preferred. In terms of overall preference, a higher luminance ratio was preferred. The research also found the rating scales of distinct / vague and warm / cool to be inarticulate scales in measuring perceptual clarity. The lack of any significant differences in responses to the combined effects of color and illuminance may mean that the quality of the CGMs may not have been adequate to represent these changes effectively. The lack of all the pairs to evoke ratings on the behavioral scale of relaxing / tense also indicate that the CGMs might have been inadequate to make the subjects feel the notion of relaxation or tense in the environments.

Such information can be used by designers for food markets to enhance the environments of the interiors. It also has the potential to be transferred to other interior spaces like museums and theaters, where lighting also is crucial. Lighting designers must follow the rationale of choosing the right illuminances levels that would produce as far as possible the most balanced ambience of relaxation and perceptual clarity, compromising if needed, on one or the other depending on the use. An appropriate luminance ratio and good CCT can cut back the requirements of spending too much energy along with providing the functional requirements of better vision.

Limitations

Method

This research focused on the visual cues of lighting to evoke subjective reactions without considering olfactory and tactile cues, even though smell and touch are recognized as important signals when it comes to buying fruits and vegetables. This was because it wanted to test the ability of a CGM to be used in lighting studies. The model used in this research for the creation of the CGMs was not a real space. This might have been responsible for some inaccuracies in the making of the CGMs which can be avoided in future studies by using a real space to verify simulation estimates. The main assumption in making a CGM here was that any photometric data entered into it would represent one lamp as realistically to the other. This is a fundamental assumption in dealing with CGMs because no CGM, however accurate, can represent the "real" environment. A real environment has too many parameters to be reproduced literally in a CGM. In changing the lamp color, this research used the temperature entry for CCT instead of the lamp source, like MH or fluorescent. This is because the temperature option offered more flexibility for the design. Beyond these, there were other inaccuracies involving the illuminance levels. There was a discrepancy between the lighting code requirements and the actual illuminance levels used for this research, though it was seen by the researcher that the difference could be discounted. For calculating the luminance ratios, reflectance factors were ignored to avoid complications. The PCs used for the experiment had different monitors. Even though they were manually calibrated to look the same, a more sensitive calibration tool would help to achieve the same image quality across more than one computer. The scenes for each pair were sequentially presented to the subjects; this introduced an unreliable factor of memory while rating the scales.

Population

The participants were all associated with the College of Architecture and Planning Design (CAPD) at Kansas State University (KSU). All had some familiarity with colors and light, and were rather uniform in their ethnic and cultural background. Future studies should select larger and more diverse population from which to select a sample. Future studies could also focus on gender biases to see if females are more sensitive to the lighting in retail areas due to more frequent visits than males.

Recommendations

The experience gained in setting up this research includes the following recommendations for creating a CGM using Autodesk Viz 4. First, remember to delete planes in the objects that are not seen in camera's view, because what is seen by the camera is what matters in the end result. Also use the "bleed" and "reflectance" in the "material editor" to control excessive hue saturation and reflectance.

Future research

The research done here holds much opportunity for future research in terms of refining the process of making CGMs an accurate representation of real spaces, as well as understanding the effects of lighting on behavioral issues and on the relationships between color and illuminance. The discussion on scales suggests more evaluation is required on the techniques to measure subjective impressions. Conclusions from this research indicate that a more sophisticated lighting software program would ensure the representation of a wider range of lighting variations.

There has been research carried out on exploring ways to incorporate presence in lighting simulations to present a more real-world experience through the use of head mounted display with monocular or stereo imagery and interacting interfaces such as common mouse or head tracking (Mania, 2001). Currently the research question is how to incorporate real-world responses for both presence and lighting in computer graphics simulations in addition to geometry and illumination simulations (Mania, 2001). It will be interesting to see the extent to which virtual environments can depict real-world experience. Such simulation studies should contribute significantly to areas of lighting design, especially for designing and for testing the performance of lighting inside buildings.

REFERENCES

Barr, V. (2002, February 1). Supermarket sweep. *Lighting Dimensions*. Retrieved September 25, 2002, from http://lightingdimensions.com/ar/lighting_supermarket_sweep/index.htm

Birren, F. (1969). Psychological implication of color and illumination. *Illuminating Engineering,* 64, 397-402.

Boyce, P.R. (1981). *Human factors in lighting.* London: Applied science publishers.

Chowdhary, Z. (1983). *Subjective criteria for lighting systems design using a scale model.* Master's thesis, Department of Industrial Engineering, Kansas State University, Kansas.

Fitzgerald, P. & Scherer, J. (2000/2001). *Enhance your vision: Lighting in libraries.* Retrieved April 25, 2003, from http://institute21.stanford.edu/programs/workshop/facilities/scherer_tech.pdf

Flynn, J.E., Spencer, T.J., Martynink, O., & Hendrick, C. (1975). *The influence of spatial light on human judgment.*

Gary Steffy Lighting Design Inc. (2000). *Time-saver standards for architectural lighting.* New York: McGraw-Hill.

Gettu, S. (1983). *Lighting cues to visual clarity.* Master's thesis, Department of Industrial Engineering, Kansas State University, Kansas.

Harwood, R. (1988). Lighting a supermarket from produce to check out. *Architectural Lighting.* 27-31.

Hersheberger, R.G. (1972). Towards a set of semantic scales to measure the meaning of architectural environments. In Mitchels, W.J. (Ed.), *Proceedings of the Third conference of Environmental Design: Research and Practice.* CA: Regents of the University of California.

Hubbell lighting Inc. (1992). [Brochure].

The IESNA Merchandise Lighting Committee. (2001). *Recommended Practice for Lighting Merchandise Areas: A Store lighting Guide.* New York: Author.

Jay, P.A. (1978). Lighting and the search for meaning. . In Lynes J.A. (Ed.), *Developments in lighting – I* (pp. 77-111). Essex, England: Applied Science Publishers Ltd.

Kaufman, P.R., C.R. Handy, E.W. McLaughlin, K. Park & G.M. Green, (2000). *Understanding the dynamics of produce markets.* (Agricultural Information Bulletin No. 758). Education Research Service.

Lamp and specification guide for Philips. (2001/2002). [Brochure].

Loe, D.L. & Rowlands, E. (1996). The art and science of lighting: A strategy for lighting design. *Lighting Research and Technology*, 28, 153-164.

Mania, K. (2001). *Connections between lighting impressions and presence in real and virtual environments: an experimental study.* Retrieved March 12, 2003, from http://portal.acm.org/citation.cfm?id=513893&coll=portal&dl=ACM&ret=1#Fulltext

Mayo, J. (1993). *The American grocery store.* Westport, Connecticut: Greenwood Press.

Pegler, M.M. (1999). *Specialty food store design.* New York: Visual Reference Publication.

Rea, M.S. (2000). *The IESNA lighting handbook* (9th ed.). New York: IESNA.

Roy, G.G. (2000, October). *A Comparative study of lighting simulation packages* *suitable for use in architectural design.* Retrieved March 12, 2003, from http://eng.murdoch.edu.au/FTPsite/LightSim.pdf

Shalaby, M.A. (2002). *Evaluating Lightscape's accuracy for prediction daylighting illuminance compared to an actual space.* Master's thesis, Department of Interior Design, University of Florida, Florida.

Stein, B., & Reynolds, J.S. (2000). *Mechanical and electric equipment for building* (9th ed.). (pp. 1049 -1105). New York: John Wiley & Sons, Inc.

Sources:

Zimmer, B. (2001, February). Personal communication.

Lewis-Smith, J. (2003, February). Personal communication.

Selfridge, O.J. (2003, March). Personal communication.

Hoag, R. (March, 2003). Personal communication.

Other source:

Art and Science of Lighting [Video recording], (1996). Vol. 1. *Illuminating Engineering Society of North America.*

APPENDICES

Appendix A - Consent form

Consent form
The following study is for a Master's thesis in Architecture. It will evaluate subjective responses to lighting conditions in five pairs of computer graphical representations of a produce department in a grocery store. I sincerely appreciate your time and effort to complete the survey.

TERMS OF PARTICIPATION: I understand this project is research, and that my participation is completely voluntary. I also understand that if I decide to participate in this study, I may withdraw my consent at any time, and stop participating at any time without explanation, penalty, or loss of benefits, or academic standing to which I may otherwise be entitled.
I verify that my signature below indicates that I have read and understand this consent form, and willingly agree to participate in this study under the terms described, and that my signature acknowledges that I have received a signed and dated copy of this consent form.

Participant Name: ______________________________

Participant Signature: ______________________________ **Date:** ____________________

Barnali Nandy
Seaton Hall 201
College of Architecture, Planning and Design
785-532 0659
barnali@ksu.edu

or

Dr. John Selfridge
Seaton Hall 313
College of Architecture, Planning and Design
785-532 1120
ojs@ksu.edu

Appendix B – Response form (shown for Pair 1 only)

Response Form

Subject number: Year of study:
Sex: Major:
Sequence of viewing the pairs:

Please follow the sequence of the pairs on your form to go to the machine with the same number.

Circle the appropriate step on the scale from 1 to 5 after going back and forth between the two scenes on the screen in front of you. Please wait till a coin is flipped to decide which scene you see first in each pair.

PAIR 1
Scene 1

Vague	1	2	3	4	5	Distinct
Warm	1	2	3	4	5	Cool
Dry	1	2	3	4	5	Juicy
Bright	1	2	3	4	5	Dim
Tense	1	2	3	4	5	Relaxing
Fresh	1	2	3	4	5	Rotten

Scene 2

Vague	1	2	3	4	5	Distinct
Warm	1	2	3	4	5	Cool
Dry	1	2	3	4	5	Juicy
Bright	1	2	3	4	5	Dim
Tense	1	2	3	4	5	Relaxing
Fresh	1	2	3	4	5	Rotten

Please circle the scene you would prefer to select the oranges from.

Scene 1 Scene 2

Appendix C - Photometric data of lamps

Pairs	Scenes	Ambient lighting			
		Product No.	No. of lamps	Intensity (lumens)	CCT (K)
1	1	BL-250HX-LB1 (Hubbell Lighting, Inc.)	6	20,500	4000
	2	BL-250HX-LB1 (Hubbell Lighting, Inc.)	6	20,500	4000
2	1	27315-1 (Philips)	49	2,950	5000
	2	27315-1 (Philips)	49	2,950	5000
3	1	BL-250HX-LB1 (Hubbell Lighting, Inc.)	9	20,500	4000
	2	BL-250HX-LB1 (Hubbell Lighting, Inc.)	9	20,500	4000
4	1	27315-1 (Philips)	49	2,950	5000
	2	BL-250HX-LB1 (Hubbell Lighting, Inc.)	9	20,500	4000
5	1	BL-250HX-LB1 (Hubbell Lighting, Inc.)	6	20,500	4000
	2	BL-250HX-LB1 (Hubbell Lighting, Inc.)	6	20,500	4000

Table C-1. Photometric data of the luminaires for ambient lighting

Pairs	Scenes	Accent lighting				
		Product No.	No. of lamps	Intensity (candlepower)	CCT (K)	Spot (degrees)
1	1	28873-8 (Philips)	2	16,000	4000	25
	2	28874-6 (Philips)	2	4,000	4000	60
2	1	28874-6 (Philips)	1	16,000	4000	60
	2	23221-5 (Philips)	1	10,000	3000	40
3	1	-	-	-	-	-
	2	28872-0 (Philips)	1	42,000	4,000	15
4	1	-	-	-	-	-
	2	-	-	-	-	-
5	1	23221-5 (Philips)	2	10,000	3000	40
	2	28874-6 (Philips)	2	4,000	4000	60

Table C-2. Photometric data of the luminaires for accent lighting

Appendix D - Calculations for illuminances and luminance ratios

Formulae:

A) For illuminance of ambient lighting

$$\text{Illuminance (E)} = \frac{\text{Coefficient of utilization x Light loss factor x Lumens}}{\text{Area}}$$

Room cavity ratio (RCR) is required to calculate the coefficient of utilization

$$\text{RCR} = 2.5 \times \frac{\text{Vertical surface area}}{\text{Horizontal surface area}}$$

$$= 2.5 \times \frac{4 \times 36 \times 18}{36 \times 36} = 5$$

for RCR = 5, the coefficient of utilization (CU) for the luminaire BL-250HX-LB1 is 0.47 (Hubbell Lighting Inc.,1992). For the same RCR, for 27315-1, the CU is 0.5 (Lamp Specification and Application Guide for Philips, 2001/2002). Light loss factor (LLF) is estimated at 0.7 (J.Lewis-Smith, personal communication, February, 2003). Lumens for ambient lighting is the total for all the lamps used, got by multiplying the luminous output of each lamp by the number of lamps.

B) For illuminance of accent lighting

$$\text{Illuminance (E)} = \frac{\text{Intensity (candlepower)}}{\text{Distance}^2\ \text{(feet)}^2}$$

Illuminance (E) for accent lighting is calculated after taking an average of the source intensities. It is calculated in footcandles (fc). To convert illuminance into lux, multiply by 10.

C) For Luminance ratio

$$\text{Luminance ratio} = \frac{\text{Accent E (fc)}}{\text{Ambient E (fc)}}$$

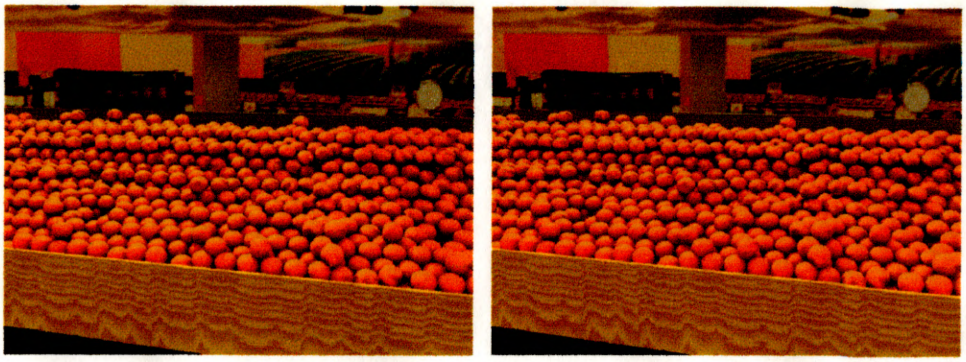
Pair	Scene	Ambient			Accent		Luminance ratio
		CU	LLF	E(fc)	Distance (feet)	E(fc)	
1	1	0.47	0.7	31	10.20	231	7.40
	2	0.47	0.7	31	10.20	57	1.85
2	1	0.50	0.7	39	8.70	213	5.47
	2	0.50	0.7	39	8.70	145.50	3.7
3	1	0.47	0.7	47	-	-	-
	2	0.47	0.7	47	10	430.7	9.2
4	1	0.50	0.7	39	-	-	-
	2	0.47	0.7	47	-	-	-
5	1	0.47	0.7	31	10.20	144	4.62
	2	0.47	0.7	31	10.20	57	1.85

Table D-1. Calculations of illuminances and luminance ratios

Appendix E – JPEG formats of the Pairs

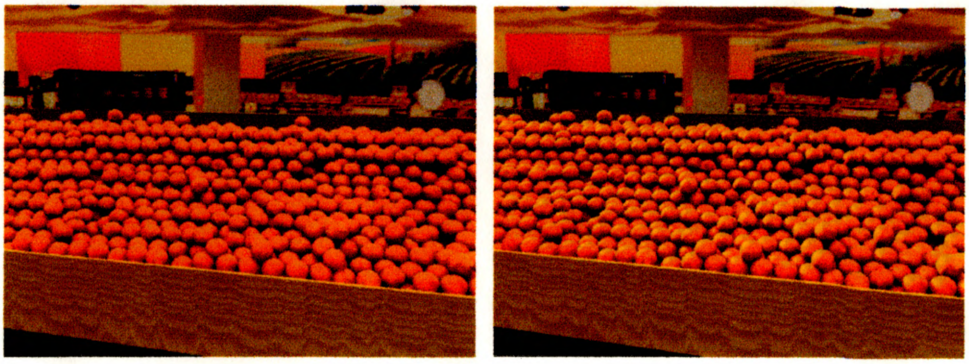
Scene 1 Scene 2

Figure E-1. Pair 1 - Varying in luminance ratio



Scene 1 Scene 2

Figure E-2. Pair 2 – Varying in luminance ratio and CCT



Scene 1 Scene 2

Figure E-3. Pair 3 – Varying in luminance ratio

Scene 1 Scene 2

Figure E-4. Pair 4 – Varying in CCT

Sc

Scene 1 Scene 2

Figure E-5. Pair 5 – Varying in luminance ratio and CCT

Appendix F – Results of T-test for comparison of means between "pairs" on all six scales as well as the direct question of preference

For the scale distinct / vague (dv)

---------------------------- pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
dv	1	30	2.5667	0.8795
dv	2	30	2.7333	0.91
dv	Diff (1-2)		-0.167	0.9512

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
dv	Pooled	Equal	58	-0.57	0.5679

---------------------------- pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
dv	1	30	2.6667	0.7041
dv	2	30	2.7667	0.8543
dv	Diff (1-2)		-0.1	0.8321

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
dv	Pooled	Equal	58	-0.39	0.6950

---------------------------- pair=3 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
dv	1	30	3.0667	0.9338
dv	2	30	2.1667	0.8123
dv	Diff (1-2)		0.9	0.9302

For the scale warm / cool (wc)

---------------------------- pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
wc	1	30	2.3	0.891
wc	2	30	2.3333	0.8707
wc	Diff (1-2)		-0.033	0.9364

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
wc	Pooled	Equal	58	-0.12	0.9075

---------------------------- pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
wc	1	30	2.6667	0.8707
wc	2	30	2.5333	0.7751
wc	Diff (1-2)		0.1333	0.8762

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
wc	Pooled	Equal	58	0.50	0.6197

---------------------------- pair=3 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
wc	1	30	2.4333	0.8283
wc	2	30	2.4333	0.9739
wc	Diff (1-2)		0	0.9609

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
dv	Pooled	Equal	58	3.17	0.0024

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
dv	1	30	2.6333	0.9694
dv	2	30	2.6	0.8261
dv	Diff (1-2)		0.0333	0.9573

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
dv	Pooled	Equal	58	0.11	0.9095

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
dv	1	30	2.8333	0.9373
dv	2	30	2.9333	0.8857
dv	Diff (1-2)		-0.1	0.9692

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
dv	Pooled	Equal	58	-0.34	0.7364

For the scale juicy / dry (jd)

------------------------------ pair=1 ----------------------------

The TTEST Procedure

Statistics

Variablc	sccnc	N	Mcan	Std Dcv		
jd	1	30	2.7497	3.1667	3.5837	0.8894
jd	2	30	2.8576	3.2333	3.6091	0.8014
jd	Diff (1-2)		-0.616	-0.067	0.4827	0.8998

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
wc	Pooled	Equal	58	0.00	1.0000

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
wc	1	30	2.2333	1.0178
wc	2	30	3	0.9584
wc	Diff (1-2)		-0.767	1.0508

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
wc	Pooled	Equal	58	-2.39	0.0200

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
wc	1	30	2.7333	0.8348
wc	2	30	2.7667	0.904
wc	Diff (1-2)		-0.033	0.9249

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
wc	Pooled	Equal	58	-0.12	0.9063

For the scale bright / dim (bd)

------------------------------ pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
bd	1	30	1.7333	0.9569
bd	2	30	3.3	0.7867
bd	Diff (1-2)		-1.567	0.9311

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
jd	Pooled	Equal	58	-0.24	0.8089

------------------------------ pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
jd	1	30	3.1667	0.9373
jd	2	30	2.9667	0.9917
jd	Diff (1-2)		0.2	1.0256

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
jd	Pooled	Equal	58	0.64	0.5251

------------------------------ pair=3 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
jd	1	30	3.4333	0.9739
jd	2	30	2.3333	0.7637
jd	Diff (1-2)		1.1	0.9302

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
jd	Pooled	Equal	58	3.88	0.0003

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
jd	1	30	2.3333	0.7918
jd	2	30	3.6	0.8774
jd	Diff (1-2)		-1.267	0.8883

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
jd	Pooled	Equal	58	-4.68	<.0001

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
bd	Pooled	Equal	58	-5.52	<.0001

------------------------------ pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
bd	1	30	2.4	0.7713
bd	2	30	2.6	0.8774
bd	Diff (1-2)		-0.2	0.8781

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
bd	Pooled	Equal	58	-0.75	0.4582

------------------------------ pair=3 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
bd	1	30	3.5	0.856
bd	2	30	2.2333	0.9512
bd	Diff (1-2)		1.2667	0.9618

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
bd	Pooled	Equal	58	4.32	<.0001

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
bd	1	30	1.6667	0.7637
bd	2	30	3.7333	0.6916
bd	Diff (1-2)		-2.067	0.7744

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
bd	Pooled	Equal	58	-8.75	<.0001

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
jd	1	30	3.0667	0.8857
jd	2	30	3.2333	0.904
jd	Diff (1-2)		-0.167	0.9512

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
jd	Pooled	Equal	58	-0.57	0.5679

For the scale relaxing / tense (rt)

------------------------------ pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
rt	1	30	3.5	0.83
rt	2	30	2.4333	0.7737
rt	Diff (1-2)		1.0667	0.8528

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
rt	Pooled	Equal	58	4.10	0.0001

------------------------------ pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
rt	1	30	3.2667	0.7522
rt	2	30	2.8667	0.8028
rt	Diff (1-2)		0.4	0.8268

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
rt	Pooled	Equal	58	1.59	0.1182

------------------------------ pair=3 ----------------------------

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
bd	1	30	1.9333	0.6916
bd	2	30	3.7667	0.6836
bd	Diff (1-2)		-1.833	0.7309

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
bd	Pooled	Equal	58	-8.22	<.0001

For the scale fresh / rotten (fr)

------------------------------ pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev			
fr	1	30	2.0519	2.4	2.7481	0.7424
fr	2	30	2.8841	3.2333	3.5826	0.7448
fr	Diff (1-2)		-1.316	-0.833	-0.351	0.7904

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
fr	Pooled	Equal	58	-3.46	0.0010

------------------------------ pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
fr	1	30	3.0333	0.823
fr	2	30	3.0667	0.8606
fr	Diff (1-2)		-0.033	0.895

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
fr	Pooled	Equal	58	-0.12	0.9032

------------------------------ pair=3 ----------------------------

The TTEST Procedure

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
rt	1	30	2.7	0.8141
rt	2	30	2.7667	1.0599
rt	Diff (1-2)		-0.067	1.0045

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
rt	Pooled	Equal	58	-0.22	0.8285

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
rt	1	30	3.6667	0.9196
rt	2	30	3.1333	0.9523
rt	Diff (1-2)		0.5333	0.995

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
rt	Pooled	Equal	58	1.76	0.0841

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
rt	1	30	3.5	0.7755
rt	2	30	2.6	0.7991
rt	Diff (1-2)		0.9	0.837

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
rt	Pooled	Equal	58	3.53	0.0008

For the direct question of preference

------------------------------ pair=1 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
fr	1	30	3.5333	0.8807
fr	2	30	2.1	0.8959
fr	Diff (1-2)		1.4333	0.9443

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
fr	Pooled	Equal	58	4.98	<.0001

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
fr	1	30	2.4333	0.9739
fr	2	30	3.5333	0.975
fr	Diff (1-2)		-1.1	1.0358

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
fr	Pooled	Equal	58	-3.48	0.0010

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
fr	1	30	2.3667	0.7087
fr	2	30	3.2	0.7365
fr	Diff (1-2)		-0.833	0.7682

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
fr	Pooled	Equal	58	-3.56	0.0008

Statistics

Variable	scene	N	Mean	Std Dev
p	1	30	0.4333	0.4014
p	2	30	0.5667	0.4014
p	Diff (1-2)		-0.133	0.4267

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
p	Pooled	Equal	58	-1.02	0.3098

------------------------------ pair=2 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
p	1	30	0.3667	0.3903
p	2	30	0.6333	0.3903
p	Diff (1-2)		-0.267	0.4149

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
p	Pooled	Equal	58	-2.11	0.0394

------------------------------ pair=3 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
p	1	30	0.2	0.324
p	2	30	0.8	0.324
p	Diff (1-2)		-0.6	0.3444

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
p	Pooled	Equal	58	-5.71	<.0001

------------------------------ pair=4 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
p	1	30	0.5333	0.4041
p	2	30	0.4667	0.4041

p	Diff (1-2)		0.0667	0.4295	

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
p	Pooled	Equal	58	0.51	0.6128

------------------------------ pair=5 ----------------------------

The TTEST Procedure

Statistics

Variable	scene	N	Mean	Std Dev
p	1	30	0.5333	0.4041
p	2	30	0.4333	0.4014
p	Diff (1-2)		-0.1	0.4281

T-Tests

Variable	Method	Variances	DF	t Value	Pr > |t|
p	Pooled	Equal	58	0.77	0.4469

Appendix G – Correlation between the scales and the categories of impression

Correlation between scales

	dv	wc	bd	jd	rt
wc	0.023 0.697				
bd	0.273 0.000	0.277 0.000			
jd	0.379 0.000	0.146 0.012	0.274 0.000		
rt	0.217 0.000	-0.008 0.890	-0.202 0.000	0.229 0.000	
fr	0.247 0.000	0.226 0.000	0.482 0.000	0.429 0.000	0.009 0.879

Cell Contents: Pearson correlation
P-Value

Correlation between categories of impression; overall preference, perceptual clarity and impression of relaxing vs. tense

	Overall preference	Perceptual clarity
Perceptual clarity	-0.329 0.000	
Relaxing vs. tense	-0.174 0.003	0.066 0.254

Cell Contents: Pearson correlation
P-Value

Appendix H – Participants' responses

am_lux -- illuminance levels for ambient lighting

am_cct -- correlated color temperature for ambient lighting

ac_cct -- correlated color temperature for accent lighting

ac_lr -- luminance ratio of accent over ambient lighting

Sub	Pr	Sc	am_lux	am_cct	ac_cct	ac_lr	dv	wc	jc	bd	rt	fr	p
1-M	5	1	312.2	4000	3000	4.62	4	3	1	2	3	1	1
		2	312.2	4000	4000	1.85	3	2	4	3	2	3	0
	3	1	468.3	4000	0	0	4	2	4	4	3	4	0
		2	468.3	4000	4000	9.2	2	3	2	3	2	2	1
	1	1	312.2	4000	4000	7.4	3	4	2	2	4	2	1
		2	312.2	4000	4000	1.85	2	2	4	3	2	3	0
	4	1	390.3	5000	0	0	2	2	1	3	2	1	1
		2	468.3	4000	0	0	3	3	5	4	4	4	0
	2	1	390.3	5000	4000	5.47	3	4	2	2	4	3	0
		2	390.3	5000	3000	3.7	2	3	2	2	2	2	1
2-F	3	1	468.3	4000	0	0	3	4	4	4	3	5	0
		2	468.3	4000	4000	9.2	3	1	4	1	4	2	1
	1	1	312.2	4000	4000	7.4	1	3	5	1	4	4	0
		2	312.2	4000	4000	1.85	4	2	4	4	1	5	1
	5	1	312.2	4000	3000	4.62	2	1	1	2	2	2	1
		2	312.2	4000	4000	1.85	4	4	3	5	1	4	0
	2	1	390.3	5000	4000	5.47	1	3	4	2	3	1	0
		2	390.3	5000	3000	3.7	2	3	1	1	3	1	1
	4	1	390.3	5000	0	0	1	1	3	1	5	3	0
		2	468.3	4000	0	0	1	1	3	2	3	3	1
3-F	4	1	390.3	5000	0	0	1	1	2	1	5	1	1
		2	468.3	4000	0	0	3	4	2	5	3	5	0
	1	1	312.2	4000	4000	7.4	2	1	2	1	4	3	1
		2	312.2	4000	4000	1.85	3	4	5	3	3	4	0
	5	1	312.2	4000	3000	4.62	4	2	2	1	3	2	1
		2	312.2	4000	4000	1.85	4	4	5	4	3	2	0
	3	1	468.3	4000	0	0	5	5	5	3	3	5	0
		2	468.3	4000	4000	9.2	1	1	1	1	1	1	1
	2	1	390.3	5000	4000	5.47	4	3	5	2	4	5	1

		2	390.3	5000	3000	3.7	5	3	5	5	3	4	0
4-M	5	1	312.2	4000	3000	4.62	3	1	3	1	4	3	1
		2	312.2	4000	4000	1.85	2	4	5	3	3	4	0
	3	1	468.3	4000	0	0	2	3	4	2	3	4	1
		2	468.3	4000	4000	9.2	4	2	2	1	5	2	0
	2	1	390.3	5000	4000	5.47	3	2	3	2	4	3	1
		2	390.3	5000	3000	3.7	3	3	3	3	3	4	0
	4	1	390.3	5000	0	0	4	1	3	1	5	3	0
		2	468.3	4000	0	0	2	3	3	4	3	3	1
	1	1	312.2	4000	4000	7.4	3	1	3	1	3	3	1
		2	312.2	4000	4000	1.85	3	4	3	4	3	3	0
5-M	4	1	390.3	5000	0	0	4	4	1	2	3	1	1
		2	468.3	4000	0	0	2	1	5	4	2	4	0
	3	1	468.3	4000	0	0	4	1	5	5	3	4	0
		2	468.3	4000	4000	9.2	2	4	1	5	3	1	1
	1	1	312.2	4000	4000	7.4	2	2	2	1	3	1	1
		2	312.2	4000	4000	1.85	2	3	3	3	3	4	0
	5	1	312.2	4000	3000	4.62	2	4	2	2	3	2	1
		2	312.2	4000	4000	1.85	4	2	5	4	3	4	0
	2	1	390.3	5000	4000	5.47	2	2	1	2	3	2	0
		2	390.3	5000	3000	3.7	2	2	2	1	3	2	1
6-H	1	1	312.2	4000	4000	7.4	1	1	3	1	4	2	1
		2	312.2	4000	4000	1.85	4	2	3	4	3	4	0
	3	1	468.3	4000	0	0	4	3	3	4	3	4	0
		2	468.3	4000	4000	9.2	2	2	3	2	2	3	1
	4	1	390.3	5000	0	0	1	1	3	1	5	3	0
		2	468.3	4000	0	0	5	1	3	5	4	5	1
	5	1	312.2	4000	3000	4.62	1	3	3	2	3	3	1
		2	312.2	4000	4000	1.85	5	1	3	4	2	4	0
	2	1	390.3	5000	4000	5.47	2	1	3	2	3	3	0
		2	390.3	5000	3000	3.7	2	1	3	3	1	3	1
7-M	5	1	312.2	4000	3000	4.62	2	2	3	2	3	3	0
		2	312.2	4000	4000	1.85	2	1	2	3	2	3	1
	1	1	312.2	4000	4000	7.4	2	3	3	1	4	2	0
		2	312.2	4000	4000	1.85	2	2	3	4	2	3	1
	3	1	468.3	4000	0	0	2	3	3	3	2	3	0
		2	468.3	4000	4000	9.2	2	2	4	2	2	3	1
	4	1	390.3	5000	0	0	3	2	3	1	5	1	0
		2	468.3	4000	0	0	2	3	3	4	2	3	1
	2	1	390.3	5000	4000	5.47	2	3	4	2	3	2	0
		2	390.3	5000	3000	3.7	2	3	4	2	3	3	1
8-M	2	1	390.3	5000	4000	5.47	3	3	3	1	2	4	0
		2	390.3	5000	3000	3.7	2	2	2	2	4	2	1
	3	1	468.3	4000	0	0	4	2	4	4	2	4	0
		2	468.3	4000	4000	9.2	1	2	2	1	5	2	1
	4	1	390.3	5000	0	0	2	2	2	1	5	5	0
		2	468.3	4000	0	0	4	3	5	4	4	4	1
	5	1	312.2	4000	3000	4.62	4	3	4	2	5	3	0

		2	312.2	4000	4000	1.85	4	4	4	3	2	3	1
	1	1	312.2	4000	4000	7.4	2	3	2	4	5	2	0
		2	312.2	4000	4000	1.85	4	2	4	4	2	4	1
9-M	2	1	390.3	5000	4000	5.47	1	2	1	3	1	3	1
		2	390.3	5000	3000	3.7	1	2	1	1	1	4	0
	4	1	390.3	5000	0	0	1	5	2	1	2	2	1
		2	468.3	4000	0	0	1	2	3	2	2	1	0
	1	1	312.2	4000	4000	7.4	1	1	3	1	2	2	0
		2	312.2	4000	4000	1.85	1	1	3	2	1	2	1
	5	1	312.2	4000	3000	4.62	4	2	4	3	3	2	1
		2	312.2	4000	4000	1.85	1	1	1	1	4	1	0
	3	1	468.3	4000	0	0	3	1	2	3	3	1	1
		2	468.3	4000	4000	9.2	5	1	2	1	5	1	0
10-M	4	1	390.3	5000	0	0	4	3	4	2	4	3	0
		2	468.3	4000	0	0	2	3	5	3	5	3	1
	2	1	390.3	5000	4000	5.47	3	2	4	1	4	3	1
		2	390.3	5000	3000	3.7	3	2	4	2	3	2	0
	3	1	468.3	4000	0	0	3	2	4	4	3	4	0
		2	468.3	4000	4000	9.2	1	3	2	1	3	1	1
	5	1	312.2	4000	3000	4.62	4	2	3	1	3	2	1
		2	312.2	4000	4000	1.85	5	2	5	4	4	3	0
	1	1	312.2	4000	4000	7.4	1	2	2	1	4	1	1
		2	312.2	4000	4000	1.85	4	4	5	3	2	4	0
11-M	1	1	312.2	4000	4000	7.4	4	3	3	2	4	3	0
		2	312.2	4000	4000	1.85	2	1	2	3	2	2	1
	4	1	390.3	5000	0	0	4	1	4	1	5	5	0
		2	468.3	4000	0	0	3	4	2	4	3	2	1
	5	1	312.2	4000	3000	4.62	4	3	4	2	3	2	1
		2	312.2	4000	4000	1.85	2	4	3	4	3	4	0
	3	1	468.3	4000	0	0	4	2	4	4	2	4	0
		2	468.3	4000	4000	9.2	2	1	3	2	4	2	1
	2	1	390.3	5000	4000	5.47	2	3	3	2	2	4	0
		2	390.3	5000	3000	3.7	2	3	3	3	2	4	1
12-M	5	1	312.2	4000	3000	4.62	2	2	4	1	5	3	0
		2	312.2	4000	4000	1.85	4	4	2	5	2	3	1
	2	1	390.3	5000	4000	5.47	3	2	4	3	3	1	1
		2	390.3	5000	3000	3.7	2	3	2	4	3	2	0
	4	1	390.3	5000	0	0	4	1	2	1	5	3	0
		2	468.3	4000	0	0	3	5	4	4	3	3	1
	1	1	312.2	4000	4000	7.4	4	2	4	2	3	1	0
		2	312.2	4000	4000	1.85	2	3	2	4	2	2	1
	3	1	468.3	4000	0	0	3	3	1	2	1	3	0
		2	468.3	4000	4000	9.2	2	1	2	2	3	3	1
13-M	1	1	312.2	4000	4000	7.4	3	1	3	2	3	2	1
		2	312.2	4000	4000	1.85	4	2	4	4	3	3	0
	4	1	390.3	5000	0	0	4	2	2	4	3	4	1
		2	468.3	4000	0	0	4	4	5	5	4	5	0
	2	1	390.3	5000	4000	5.47	4	4	5	4	4	4	0
		2	390.3	5000	3000	3.7	4	4	5	4	4	4	1
	3	1	468.3	4000	0	0	5	1	5	5	3	5	0
		2	468.3	4000	4000	9.2	4	2	5	5	5	3	1

	5	1	312.2	4000	3000	4.62	5	4	5	5	5	3	1
		2	312.2	4000	4000	1.85	5	3	5	5	5	5	0
14-F	2	1	390.3	5000	4000	5.47	4	3	4	3	4	3	1
		2	390.3	5000	3000	3.7	4	4	3	4	3	4	0
	4	1	390.3	5000	0	0	1	1	2	1	3	3	1
		2	468.3	4000	0	0	3	4	4	4	2	4	0
	1	1	312.2	4000	4000	7.4	3	2	3	5	4	2	1
		2	312.2	4000	4000	1.85	2	3	2	3	2	3	0
	5	1	312.2	4000	3000	4.62	2	3	2	2	3	2	1
		2	312.2	4000	4000	1.85	2	2	3	5	2	3	0
	3	1	468.3	4000	0	0	3	4	3	4	2	4	0
		2	468.3	4000	4000	9.2	2	3	2	4	3	2	1
15-M	4	1	390.3	5000	0	0	4	4	2	1	4	1	1
		2	468.3	4000	0	0	4	2	3	3	3	3	0
	1	1	312.2	4000	4000	7.4	3	2	4	2	2	3	1
		2	312.2	4000	4000	1.85	2	3	3	3	3	4	0
	5	1	312.2	4000	3000	4.62	2	3	4	2	3	3	1
		2	312.2	4000	4000	1.85	2	4	3	3	2	4	0
	3	1	468.3	4000	0	0	3	2	4	4	2	3	0
		2	468.3	4000	4000	9.2	2	4	2	3	1	1	1
	2	1	390.3	5000	4000	5.47	3	3	3	3	3	3	0
		2	390.3	5000	3000	3.7	2	2	2	2	2	2	1
16-F	5	1	312.2	4000	3000	4.62	4	2	4	2	3	2	0
		2	312.2	4000	4000	1.85	2	4	2	4	2	3	0
	4	1	390.3	5000	0	0	4	1	1	2	4	4	0
		2	468.3	4000	0	0	2	4	4	4	2	2	1
	2	1	390.3	5000	4000	5.47	3	3	4	3	3	4	1
		2	390.3	5000	3000	3.7	4	3	3	3	3	4	0
	1	1	312.2	4000	4000	7.4	4	2	3	2	4	2	0
		2	312.2	4000	4000	1.85	4	3	2	3	3	3	1
	3	1	468.3	4000	0	0	2	3	2	3	2	3	0
		2	468.3	4000	4000	9.2	3	3	2	3	2	2	1
17-M	4	1	390.3	5000	0	0	4	1	1	1	5	2	0
		2	468.3	4000	0	0	2	3	4	3	1	2	1
	3	1	468.3	4000	0	0	2	2	2	2	5	1	1
		2	468.3	4000	4000	9.2	4	2	3	3	1	3	0
	2	1	390.3	5000	4000	5.47	3	4	4	3	5	2	0
		2	390.3	5000	3000	3.7	1	2	2	3	1	4	1
	1	1	312.2	4000	4000	7.4	4	4	5	1	5	3	0
		2	312.2	4000	4000	1.85	2	2	2	5	1	3	1
	5	1	312.2	4000	3000	4.62	4	4	4	2	4	1	0
		2	312.2	4000	4000	1.85	2	2	2	4	2	5	1
18-M	3	1	468.3	4000	0	0	4	2	4	4	2	5	0
		2	468.3	4000	4000	9.2	2	2	2	2	3	1	1
	4	1	390.3	5000	0	0	3	2	3	3	3	4	1
		2	468.3	4000	0	0	3	3	3	4	3	5	0
	5	1	312.2	4000	3000	4.62	2	3	3	3	4	3	1
		2	312.2	4000	4000	1.85	2	4	3	4	3	4	0
	2	1	390.3	5000	4000	5.47	1	2	2	4	4	3	1
		2	390.3	5000	3000	3.7	1	2	2	3	3	4	0
	1	1	312.2	4000	4000	7.4	1	2	2	1	4	2	1

		2	312.2	4000	4000	1.85	2	3	4	4	2	4	0
19-M	1	1	312.2	4000	4000	7.4	2	4	2	2	3	2	0
		2	312.2	4000	4000	1.85	3	2	3	4	2	2	1
	4	1	390.3	5000	0	0	3	4	2	2	2	2	1
		2	468.3	4000	0	0	4	2	4	4	4	4	0
	5	1	312.2	4000	3000	4.62	2	3	3	2	3	2	0
		2	312.2	4000	4000	1.85	4	2	3	4	2	2	1
	3	1	468.3	4000	0	0	4	2	4	4	2	3	0
		2	468.3	4000	4000	9.2	2	4	2	2	3	2	1
	2	1	390.3	5000	4000	5.47	3	2	4	3	3	4	1
		2	390.3	5000	3000	3.7	3	2	4	3	3	4	0
20-F	4	1	390.3	5000	0	0	4	1	1	1	4	3	0
		2	468.3	4000	0	0	1	4	4	4	2	4	1
	1	1	312.2	4000	4000	7.4	3	4	4	4	4	4	0
		2	312.2	4000	4000	1.85	2	2	4	4	3	4	1
	2	1	390.3	5000	4000	5.47	2	1	2	2	2	2	0
		2	390.3	5000	3000	3.7	4	1	3	1	2	4	1
	5	1	312.2	4000	3000	4.62	1	4	4	2	1	3	0
		2	312.2	4000	4000	1.85	1	4	4	3	1	3	1
	3	1	468.3	4000	0	0	5	2	5	4	1	4	0
		2	468.3	4000	4000	9.2	1	5	2	1	1	5	1
21-F	4	1	390.3	5000	0	0	1	4	2	1	3	2	1
		2	468.3	4000	0	0	4	5	5	5	5	5	0
	1	1	312.2	4000	4000	7.4	2	3	5	1	5	1	0
		2	312.2	4000	4000	1.85	3	1	2	3	5	3	1
	5	1	312.2	4000	3000	4.62	3	3	4	2	4	3	0
		2	312.2	4000	4000	1.85	2	2	3	3	2	3	1
	2	1	390.3	5000	4000	5.47	2	5	4	3	4	4	0
		2	390.3	5000	3000	3.7	2	5	3	3	3	4	1
	3	1	468.3	4000	0	0	2	3	5	4	3	5	0
		2	468.3	4000	4000	9.2	1	1	3	2	3	1	1
22-F	4	1	390.3	5000	0	0	3	1	4	1	5	1	0
		2	468.3	4000	0	0	3	3	1	2	1	1	1
	3	1	468.3	4000	0	0	1	1	1	1	1	2	1
		2	468.3	4000	4000	9.2	2	2	2	3	2	1	0
	2	1	390.3	5000	4000	5.47	3	5	3	1	5	3	0
		2	390.3	5000	3000	3.7	3	1	5	1	1	1	1
	1	1	312.2	4000	4000	7.4	1	1	1	1	1	1	1
		2	312.2	4000	4000	1.85	5	5	5	5	5	5	0
	5	1	312.2	4000	3000	4.62	2	1	1	1	4	1	0
		2	312.2	4000	4000	1.85	3	4	1	5	2	1	1
23-M	4	1	390.3	5000	0	0	2	2	3	2	3	2	1
		2	468.3	4000	0	0	2	3	4	4	3	3	0
	3	1	468.3	4000	0	0	2	2	2	3	3	2	0
		2	468.3	4000	4000	9.2	2	2	2	3	3	2	1
	1	1	312.2	4000	4000	7.4	4	3	4	2	3	3	0

		2	312.2	4000	4000	1.85	2	2	3	1	2	2	1
	2	1	390.3	5000	4000	5.47	3	3	4	3	4	4	1
		2	390.3	5000	3000	3.7	4	2	4	4	4	4	0
	5	1	312.2	4000	3000	4.62	3	3	3	3	3	3	0
		2	312.2	4000	4000	1.85	3	2	2	4	3	3	1
24-M	3	1	468.3	4000	0	0	1	1	3	1	5	2	1
		2	468.3	4000	4000	9.2	1	4	2	4	1	5	0
	2	1	390.3	5000	4000	5.47	3	3	2	3	2	2	0
		2	390.3	5000	3000	3.7	3	3	2	2	3	3	1
	1	1	312.2	4000	4000	7.4	2	4	3	5	1	4	0
		2	312.2	4000	4000	1.85	1	1	2	1	3	2	1
	5	1	312.2	4000	3000	4.62	4	1	5	1	4	1	1
		2	312.2	4000	4000	1.85	3	3	3	4	3	3	0
	4	1	390.3	5000	0	0	2	2	3	3	2	3	1
		2	468.3	4000	0	0	3	4	2	5	1	5	0
25-F	1	1	312.2	4000	4000	7.4	2	1	3	1	3	2	1
		2	312.2	4000	4000	1.85	3	1	3	2	3	2	0
	4	1	390.3	5000	0	0	2	2	3	2	3	2	0
		2	468.3	4000	0	0	3	2	3	3	4	3	1
	5	1	312.2	4000	3000	4.62	3	3	2	3	3	3	0
		2	312.2	4000	4000	1.85	3	4	3	4	3	3	1
	2	1	390.3	5000	4000	5.47	3	1	2	1	3	4	0
		2	390.3	5000	3000	3.7	3	4	5	4	5	4	1
	3	1	468.3	4000	0	0	3	4	2	3	4	3	1
		2	468.3	4000	4000	9.2	3	4	4	3	4	4	0
26-M	4	1	390.3	5000	0	0	2	2	4	1	4	1	1
		2	468.3	4000	0	0	2	1	5	3	4	4	0
	2	1	390.3	5000	4000	5.47	2	3	3	2	4	3	0
		2	390.3	5000	3000	3.7	2	3	3	2	4	2	1
	1	1	312.2	4000	4000	7.4	4	1	4	1	4	3	0
		2	312.2	4000	4000	1.85	2	4	3	3	2	3	1
	5	1	312.2	4000	3000	4.62	2	4	2	2	3	2	1
		2	312.2	4000	4000	1.85	3	2	4	4	4	4	0
	3	1	468.3	4000	0	0	2	4	2	3	2	4	0
		2	468.3	4000	4000	9.2	2	4	1	2	1	2	1
27-F	5	1	312.2	4000	3000	4.62	4	1	2	1	3	1	1
		2	312.2	4000	4000	1.85	3	1	3	3	4	3	0
	1	1	312.2	4000	4000	7.4	4	1	2	1	4	2	0
		2	312.2	4000	4000	1.85	2	1	3	3	2	2	1
	2	1	390.3	5000	4000	5.47	2	1	1	2	2	1	0
		2	390.3	5000	3000	3.7	3	1	1	2	3	1	1
	4	1	390.3	5000	0	0	2	3	1	1	2	1	1
		2	468.3	4000	0	0	2	1	4	4	4	4	0
	3	1	468.3	4000	0	0	1	2	3	4	4	3	0
		2	468.3	4000	4000	9.2	2	1	1	1	1	1	1
28-F	3	1	468.3	4000	0	0	3	2	4	5	2	4	0

		2	468.3	4000	4000	9.2	2	1	3	1	3	2	1
	2	1	390.3	5000	4000	5.47	2	3	4	2	3	4	0
		2	390.3	5000	3000	3.7	4	3	2	2	3	3	1
	1	1	312.2	4000	4000	7.4	3	2	3	1	3	4	0
		2	312.2	4000	4000	1.85	1	1	2	4	1	4	1
	4	1	390.3	5000	0	0	2	3	1	3	3	3	0
		2	468.3	4000	0	0	1	4	2	3	5	5	1
	5	1	312.2	4000	3000	4.62	1	4	3	2	5	5	0
		2	312.2	4000	4000	1.85	2	2	3	4	1	3	1
29-M	2	1	390.3	5000	4000	5.47	4	1	2	5	4	3	1
		2	390.3	5000	3000	3.7	4	2	3	4	4	4	0
	5	1	312.2	4000	3000	4.62	1	4	4	1	5	2	0
		2	312.2	4000	4000	1.85	3	3	4	4	2	3	1
	1	1	312.2	4000	4000	7.4	2	2	5	1	3	3	1
		2	312.2	4000	4000	1.85	5	2	5	2	3	4	0
	4	1	390.3	5000	0	0	1	5	2	4	2	3	1
		2	468.3	4000	0	0	2	4	4	4	5	5	0
	3	1	468.3	4000	0	0	4	3	4	4	4	4	0
		2	468.3	4000	4000	9.2	1	4	2	1	4	2	1
30-F	2	1	390.3	5000	4000	5.47	4	3	5	1	3	4	0
		2	390.3	5000	3000	3.7	4	2	5	2	4	3	1
	3	1	468.3	4000	0	0	4	2	5	5	3	4	0
		2	468.3	4000	4000	9.2	2	2	2	2	3	1	1
	1	1	312.2	4000	4000	7.4	4	4	5	1	5	3	0
		2	312.2	4000	4000	1.85	4	2	4	4	2	4	1
	4	1	390.3	5000	0	0	4	3	3	1	4	1	1
		2	468.3	4000	0	0	2	4	4	3	3	2	0
	5	1	312.2	4000	3000	4.62	4	4	3	1	5	3	0
		2	312.2	4000	4000	1.85	3	2	4	3	4	3	1