THE EFFECTS OF TABLE LAMP SHADE SHAPE AND COMPACT FLUORESCENT LAMP BURNING POSITION ON UNIVERSITY STUDENTS' VISUAL COMFORT

by

ZAIDI BIN ABDULLAH, B.Sc., M.Sc.

A DISSERTATION

IN

CONSUMER ECONOMICS AND ENVIRONMENTAL DESIGN

Submitted to the Graduate Faculty
of Texas Tech University in
Partial Fulfillment of
the Requirements for
the Degree of

DOCTOR OF PHILOSOPHY

Approved

Accepted

August, 1999

ACKNOWLEDGEMENTS

I thank my God for giving me the inspiration and guiding me through this life. I would also like to express my gratitude to several persons who have helped me with this doctoral dissertation. First, my deepest appreciation to Henryk for his continued support and belief in me throughout my graduate studies. When times became rough, he was always there to listen to my difficulties and to provide the best and sincerest support that he can. I am forever indebted to him for trusting in me and sacrificing part of his life for me. Moving from New York to Lubbock was a great venture for us and we made it through. Thank you, Henryk.

Next, I want to thank my mom, D. Y. M. M. Tengku Ampuan Bariah for loving and supporting me throughout my life. I love you so much mom! I dedicated this work to my father, H. R. H. Tuanku Al- Sultan Mahmud for his love. I know you are watching over me. My sisters and my brothers who inspired me to get to this level. I feel fortunate to have grown up in such a large family. I thank my birth mother and father for giving me life and prosperity. I love both of you.

I thank University Science of Malaysia and Texas Tech University for supporting me throughout my graduate studies. This dissertation would not be possible without the help from my mentor, Dr. Marie Gentry. I cannot even begin to thank her enough for the endless hours that she has put into this research effort and my graduate studies

My committee members, Dr. Arturo Olivarez, Dr. Zane Curry and Dr. Randall Russ, have provided me endless encouragement and assistance that has made this research possible. Thank you. I also would like to thank Dr. Jo Ann Shroyer and Linda Gambles for guiding me through the program. Thanks to you all!

TABLE OF CONTENTS

ABSTRACT

To increase consumers' support of and market for compact fluorescent lamps (CFLs) retrofits in table lamps, visual comfort and task illumination distribution were assessed. The principal purpose of this study was to evaluate the effects of shade shape and CFL burning position on visual comfort. The second purpose of this study was to develop and evaluate a Comfort Scale (CS) for measuring table lamp users' visual comfort. One hundred and twenty university students volunteered to participate in the study, and ninety responses from students with 20/20 or corrected vision were used in the data analyses. For each of six conditions, fifteen students performed a visual task and completed a CS and a University Students' Survey (USS). Round, square, and polygon shades and a vertical and a horizontal CFL were tested. A GE™ light meter was used to measure task illumination. Validity of the instruments and procedures was determined by dissertation committee opinion, literature review, and factor analysis. Reliability of the scales was determined by Cronbach's alpha.

MANOVA indicated that shade shape affects visual comfort and task illumination. MANOVA demonstrated that CFL burning position affects visual comfort and task illumination. MANOVA also established that the interaction of shade shape and CFL burning position affects visual factors of comfort (preference, comfort, and brightness condition).

Lighting designers can select a shade appropriate for the type of CFL specified. Lighting manufacturers need to disseminate information regarding

shades and CFL burning positions so that consumers will be able to make appropriate choices. Future research needs to consider the effect of shade factors and various CFL types on other applications. Understanding the effect of a table lamp fixture on the users' well-being can accelerate the confidence in and use of CFLs by consumers.

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

In 1994, U. S. households used an average of 145 billion kWhrs of electricity for residential lighting (Page, Praul, & Siminovitch, 1997) which totals $10 billion (Siminovitch & Mills, 1995). According to Page et al. (1997), the energy cost of table and floor lamps constitutes more than half of the total residential lighting cost. For decades, illumination in the home has been principally provided by incandescent sources, and table lamp fixtures have been designed for incandescent lamps.

The compact fluorescent lamp (CFL) has been designed to replace the incandescent lamp in an effort to reduce energy consumption. An average compact fluorescent lamp increases the total lumen per watt by 75% over the incandescent application (Page et al., 1997). However, applications of CFL fail to result in the expected energy savings and the light distribution, quality, and quantity desired (Siminovitch et al., 1995).

According to Dasgupta (1997), CFL lamps are divided into retrofit and nonretrofit. The retrofit version is a direct placement of the incandescent lamp into the original lampholder and the retrofit CFLs have an electromagnetic gear integrated inside the lamp (Dasgupta, 1997). The nonretrofit category has a built in starter and the lamp holder are housed in a luminaire of a suitable design.

When selecting a table lamp, the user or lighting specifier often disregards the lamp shade's functional aspects and makes decisions based on aesthetics.

Davidson (1997) stated that "the lamp holder, the body, and the shade are all known collectively as a luminaire" (p. 13). Research at Lawrence Berkeley Laboratory concludes that energy saving is achieved when lamp, ballast, and lamp body are considered as a unified whole in a table lamp application (Siminovitch et al., 1995). Losses in light output, distortion of light and optical distribution (Page, 1998), and visual problems may result by simply replacing the CFL without considering the entire luminaire. Therefore, shade configurations may affect table lamp efficiency and light distribution. Consequently, the effects of varying the shade reflectance, transmittance, geometry, size, and material need to be examined.

Lamp operating temperature and ballast type (California University of Environmental Research, 1996; IESNA, 1993; Siminovitch, Pankonin, Praul, & Zhang, 1997) play significant roles in determining the efficacy of a CFL table lamp system. Orienting integral-ballast CFLs to the base-down position decreases light output by 20% or more because of the mercury etching phenomenon (Serres & Taelman, 1993; Siminovitch et al., 1995). Mercury etching occurs when mercury condenses at the top of a tube, then is pulled by gravity into the hot base in an operating compact fluorescent lamp (Siminovitch et al., 1995). Condensed mercury that is collected in the lamp base is vaporized and the mercury vapor pressure inside the lamp increases beyond the optimum level, reducing light output (Serres et al., 1993; Siminovitch et al., 1995; Siminovitch et al., 1997).

Shape and form of the lamp shade may also influence light distribution (Page et al., 1997), especially when the table lamp is used without any other type of lighting (Ilg, 1992). Replacing an incandescent lamp with a CFL without considering the existing shade may be inappropriate and may negatively affect the user's comfort and visual task performance (Essig, 1997; Page, 1998). A fixture with CFL that produces inefficient light distribution is not desired by consumers (Veitch, Hine, & Gifford, 1993), and may be a disadvantage over the fixture with an incandescent lamp (Page, 1998).

Consumers may not always understand current lighting technology, systems, and applications. However, recent research shows that consumers are increasingly attentive to the importance of lighting for their health and well-being (Institute for Research Construction, 1994; Veitch et al., 1993). Facility managers and building owners refused to use compact fluorescent lights when the technology was introduced because of the high initial cost and the uncertainty of the product's efficiency (Mekjavic & Banister, 1988; Steffy 1995). Lamp and replacement costs have been the main concerns of consumers (Veitch et al., 1993). According to Gardner and Hannaford (1993), "increased understanding of advantages of current lighting options may convince consumers and building owners to use CFLs for their own benefit" (p. 23). Researchers and manufacturers are struggling to produce a CFL fixture that can provide optimum consumer satisfaction with regard to users' health (Gulrajani, 1995), safety, expenditure, and aesthetic appeal (Serres, 1995).

Research regarding the orientation of the CFL lamp burning position is important to develop a better table lamp design that will increase consumer satisfaction (Page, 1998). Manufacturers, researchers, and designers need to collaborate to solve problems concerning compact fluorescent lamp and lamp shade effects. A table lamp that consists of a lamp that is oriented effectively and a shade that helps distribute the light evenly may result in improved luminaire efficiency, visual comfort, and task performance.

The Problem to be Investigated

The choice of lamp shades and compact fluorescent lamps (CFLs) that are available in the market varies. Table lamp shades and CFLs are of different geometry, size, and material. The amount and quality of light received by the user are controlled and manipulated by the lamp shades and the lamp (Gardner et al., 1993; Gulrajani, 1995). Varying shade reflectance, transmittance, and geometry will produce different task illumination in a table lamp system (Essig, 1997; Gardner et al., 1993).

Candlepower distribution and task illuminance affect users psychologically and physically (Dove, 1996; Essig, 1997). Light has a strong influence on human comfort (Veitch & Newsham, 1998) and behavior (Ilg, 1991; Steffy, 1995). According to Kolanowski (1992) and Tideiksaar (1997), higher illuminance and even distribution of lighting reduces psychological discomfort and stress.

Problems such as low visual clarity associated with residential and institutional lighting (Ilg, 1992; Kolanowski, 1992) may be lessened if the effects of lamp shades on light distribution are analyzed (Page et al., 1997). Consumers need to be presented with the information on light distribution and task illuminance of lamp shades in the purchase decision process (Page et al., 1997; Veitch et al., 1993). The information may help consumers select and use the luminaire appropriately. To develop a better luminaire, designers of luminaires need to consider and use research findings regarding candlepower distribution (Page et al., 1997) and task illuminance of different lamps shades with compact fluorescent lamps.

Orienting integral-ballast CFLs base-down decreases light output by as much as 20% compared to base-up position (Siminovitch et al., 1995). In a table lamp system, CFLs can only be installed base-down in an upright position or by retrofitting with a Circline (base-down horizontal position). With the incorporation of a thermal bridge assembly, a table lamp may operate at 97% lumen output for many tilting positions (Venderber, Rubinstein, & Siminovitch, 1988). However, comprehensive information on the tilting angle and the effect on light output is needed.

Page (1998) claims that the Circline CFL distributes light more symmetrically and vertically compared to an incandescent lamp and a base-down CFL. Circline CFLs operate base-down and horizontally. According to Page's (1998) goniometric study, the horizontal Circline lamp sends only 64% of the light to the shade; the study demonstrated the advantages of producing the light where it is most needed (see Appendix A). Likewise, a Circline CFL is more efficient and has longer life than an incandescent lamp and an upright positioned CFL. Improvements in base-down lamp performance are being developed by lamp manufacturers and universities' research laboratories. Page et al. (1997) stated that "effects of shade geometry, position, transmitivity, and reflectivity are being analyzed in an ongoing study" (p. 5). Page's (1998) study demonstrated the relationship between shade, lamp type, CFL position and candlepower distribution. However, the study did not examine the relationship between shade shape, lamp type and lamp position and human visual comfort.

Many users consider a table lamp as a decorative object rather than a functional machine (Loasby, 1992) . Lamp shades characterize a table lamp (Loasby, 1992), and consumers will not change a shade unless the shade causes major health and safety problems such as headache or nausea, or becomes aesthetically unappealing (Veitch et al., 1998). The function of a lamp shade is to control and manipulate light output. However, previous researchers did not consider the lamp shade affect when testing the table lamp.

Consumers may know that retrofitting a table lamp with a CFL will conserve energy. However, consumers may believe that the energy savings are not enough to offset the initial cost of a CFL (Siminovitch et al., 1995). According to Veitch et al., (1998), consumers do not know enough about the development of CFL to make an appropriate purchase decision.

Research findings in professional journals are not a typical source of information for consumers (Veitch et al., 1993). Thus, lighting researchers and lamp designers must inform consumers through other forms of media such as television, seminars, and lay magazines. Moreover, little effort is made by lighting researchers to consider all the research findings in a study (Gardner et al., 1993; Steffy, 1995), and more importantly many lighting researchers do not consider the effect of the table lamp fixture as a whole on the users (Siminovitch et al, 1995). For example, replacing a vinyl shade for table lamp with a frosted glass lamp shade may affect the table lamp light output (Loasby, 1992).

Qualitative aspects of lighting such as visibility, comfort, aesthetics, and psychological effects are essential to lighting design (Stannard, Keith, & Johnson, 1994). Therefore, using an approach that considers the qualitative aspects of lighting to predict the performance of an increasingly used CFL table lamp system (Siminovitch et al., 1995, 1997) is important to the users' health and comfort (Stannard et al., 1994).

Although lamp shades have been used in residential and commercial interiors for some time, research regarding the effects of the lamp shade on the user in terms of distribution, manipulation, and control of light have been limited. According to Siminovitch et al. (1997), the effect of lamp shade characteristics on the emotions, physical behavior, and activities of humans is not understood. Even IESNA (1993) does not provide any detailed information regarding lamp shades and table lamp lighting.

Siminovitch et al. (1995) stated that "to achieve energy savings, the lamp, the ballast, and the fixture need to be treated as a one" (p. 28). The table lamp system is a type of task lighting, and research concerning task lighting is limited. Light distribution from a table lamp system that is within the immediate visual field has a greater impact on users' perceptions and comfort than from a more remote source (Bernecker, Davis, Webster, & Webster, 1993).

Purpose and Hypotheses

The principal purpose of this study was to evaluate and determine the combination of shade shape and CFL burning position for task illumination that is most comfortable for university students. No instruments to measure visual comfort of table lamp lighting were located. Therefore, the second purpose of this study was to develop and evaluate a semantic differential scale used for measuring university students' visual comfort reading under a table lamp lighting.

The hypotheses were: (a) there is a difference in the overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to lamp shade shape, (b) there is a difference in overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to CFL burning position, and (c) there is an interaction between shade shape and CFL burning position based on the overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students and their responses to the CS. Multivariate Analysis of Variance (MANOVA) was used to answer hypothesis 1, hypothesis 2, and hypothesis 3.

Assumptions

The following assumptions were made for the study:

1. Retrofitting a table lamp designed for a standard incandescent A-lamp with a compact fluorescent lamp changes the fixture's light distribution.
2. Retrofitting a table lamp designed for a standard incandescent A-lamp with a CFL could saves energy.
3. For vertical base-down CFLs light output is different on top of the lamp than near the base.
4. Gravity pulls liquid mercury at the same strength and rate in base-down vertical position and base-down horizontal position.
5. The CFL's sides produce more light output than the tip or base.
6. Based on goniometric studies, Circline CFLs distribute light more symmetrically and vertically compared to vertical base-down CFLs and a standard incandescent A-lamp.
7. A lamp shade has the ability to transmit, reflect, refract, and absorb light from the light source.
8. Students' evaluation of comfort was not influenced by the light fixture

appearance. The students were advised not to evaluate how the lamp (light bulb) or the lighting fixture appears.

9. Students' evaluation of comfort was not influenced by the possibility of subjects mastering the reading material.

10. Time of the experiment was not a factor that influenced the students' responses regarding comfort and preference. A student's preference to read at a certain time of day were minimized by the controlled setting and were balanced by other students' responses or preferences.

11. Students' prior knowledge was not a variable that influences the responses regarding comfort. The study assumed that a student's knowledge of lighting was a representation of the general population.

12. Students' 20/20 vision may not be a perfect representation of the population. Not all people have perfect vision or are color blind free. This method of controlling may not eliminate all the confounding variables related to the vision. Other vision problems experienced by the students were assumed to not influence task performance and comfort.

Limitations of the Study

The study had the following limitations:

1. Although the students were advised not to evaluate the light fixture and the lamp, the students may have viewed the fixture. As a result, the students may be influenced by the presence of a specific fixture in the space. Preference for a certain shape may influence the subject's responses. Rounded shapes have

been proven to be more pleasing and more comfortable to the senses (Gerhardstein, 1995; Makioka, Inui, Yamashita, 1996).

2. Prior knowledge of lighting may also affect the response and the mood. A person who knows that a cylindrical shade distributes light evenly may prefer the condition and may feel more comfortable (Veitch et al., 1993).

3. According to Flynn (1977), a sample size of at least 40 or more subjects are desirable in order to achieve a statistical significance in lighting research. However, the literature does not specify the exact number of subjects recommended to achieve statistical significance in a study related to task illuminance and comfort. Also, no literature was found that stated the percentage of university student's age, gender, race, and other demographic characteristics needed for a sample to represent the general population.

4. Two additional light sources were used in the treatment to reduce sharp contrast between the lighting on the task and the surrounding. The light fixtures were the same and the lighting was consistent throughout the six conditions. However, the combination effect of the different light sources is unknown. External light sources and noise were blocked out in the experiment. Room temperature and ventilation were maintained at a comfort level and were consistent throughout the test conditions.

5. Table and partition wall surfaces that were glossy and bright colored were eliminated. However, in a real task situation, the combination of lighting and surface reflectances that is present in the space may affect

the students' responses. To measure comfort in a real task situation would be difficult because of the inability to control the confounding variables such as street noise and work load.

Definition of Terms

The following terms were defined for the purposes of the study.

Absorption: The act of a light being taken in by a material, rather than being reflected or transmitted. For example, a lamp shade may absorb visible and radiant energy that are generated from the light source.

Adequate task illumination: The amount of light recommended by the Illuminating Engineering Society of North America (IESNA) for performing a visual task, e.g. reading, writing, and typing.

Amalgam: Mercury alloy that is applied to compact fluorescent lamps as a source of mercury vapor pressure control (Serres et al., 1993).

Amalgam based technology: A double-folded discharge tube with a cover designed to control and stabilize mercury vapor pressure in compact fluorescent lamps. The tube cover helps to retain heat, increase wall temperatures of the bulb and generate an even temperature inside a CFL.

Ballast: Provides a starting voltage, power factor correction, and limits the current from burning the electrodes in a CFL (IESNA, 1993). The study used a high-frequency electronic ballast that consumes less energy, weighs less, offers dimming possibilities, eliminates flicker, and is quieter.

Brightness condition: Defined as subjects' responses to the semantic differential rating promoted by Flynn (1977) and Rohles & Miliken (1981). Subjects' impressions of the brightness condition under the tested lighting were evaluated using bipolar adjective pairs in the comfort scale (CS).

Burning position: Either a horizontal (Circlite™) or a vertical (base-down) position installed in a CFL table lamp system. According to Siminovitch (1997), lumen output generated is different when a CFL is burned in a different position.

Candlepower distribution: A distribution of light output generated by a light source. Candlepower distribution can be represented graphically in a candlepower distribution curve (IESNA, 1993).

Candlepower distribution curve: A graphic illustration of candlepower distribution that results from measuring candlepower at various angles around a light source (North American Philips Lighting, 1984).

Circline lamp: This study used an 8 inch diameter CFL with an adapter. According to Page (1998), a Circline CFL is designed to match the operating position of a base-down horizontal. The study used a GE warm white Circlite™ CFL 21 watts that is equivalent to a 75 watt incandescent and produces 1200 lumens light output and has a 40,000 hour life.

Color temperature: Defined as the color of the light output from the CFLs. The color of the light was compared with the color of a blackbody "complete radiator" (North American Philips Lighting, 1984). The color temperature of a the GE™ vertical CFL is 3500 °K (white) and the GE™ horizontal CFL is 3000 °K (warm white).

Comfort: Defined as subjects' responses to the semantic differential rating promoted by Flynn (1977) and Rohles & Miliken (1981). Subjects' impressions of visual comfort were evaluated using bipolar adjective pairs in the comfort scale (CS). Comfort adjective pairs were comfortable-uncomfortable, ease-unease, spacious-confined, satisfied-dissatisfied, relaxed-tense, free-closed, adequate-not adequate, and easy-difficult.

Comfort Scale (CS): A scale consisting of Bernecker et al.'s (1993) semantic differential rating scale and additional adjectives. The CS consisted of 22 bipolar adjective pairs for measuring comfort. Sixteen adjectives were from Bernecker et al.'s (1993) semantic differential rating scale that was used to evaluate impressions of visual comfort. Six additional adjectives were included in the CS based on face validity, literature review, and dissertation committee opinion.

Compact fluorescent lamp: A double folded fluorescent lamp with an electronic ballast mounted within a polycarbonate enclosure and fitted with a medium screw base (North American Philips Lighting, 1984). The study used a GE™ warm white 20 watt (equivalent to 75 watts incandescent) with 1200 lumens light output and 10,000 hour life. Also, the study used a GE Circlite™ warm white 21 watt (equivalent to 75 watts incandescent) with 1200 lumens light output and 40,000 hour life.

Compact fluorescent table lamp system: Consisted of a compact fluorescent lamp, a high-frequency electronic ballast, a lamp shade, and the lamp body.

Efficient task illumination: The amount of light that falls on the reading material from a table lamp that supports visual task performance.

Flux : A unit of measurement for a quantity of light emitted by a light source. The amount of light produced and distributed by a compact fluorescent lamp.

Goniophotometer: An instrument used to measure candlepower distribution of a light source. A goniophotometer can map the amount of light emitted from all angles of a fixture. The goniophotometer rotates a large mirror around all angles of a test fixture, allowing light to be reflected from the fixture to a centrally located light meter (Page et al., 1997). The apparatus claims to be accurate in generating candlepower plots of table lamps (IESNA, 1993).

Lamp shade: A part of a lamp fixture that can be replaced and purchased separately. Lamp shades are manufactured in various shapes, sizes, materials, designs, and colors. However, there are two basic types of lamp shades: hardbacks and silks (Loasby, 1992). Two main functions of a lamp shade are to hide the lamp and to accentuate the fixture. The shade also functions to control the candlepower distribution (Page, 1998).

Light output: The amount of light generated by a light source. Light output from a lamp may be different from a light output of a fixture.

Lighting conditions: Defined as subjects' subjective responses to the semantic differential rating promoted by Flynn (1977) and Rohles and Miliken

(1981). Subjects' impressions of the lighting condition were evaluated using bipolar adjective pairs in the comfort scale (CS). Lighting conditions adjective pairs were uniform-non uniform, focused-not focused, and large-small.

Lighting problems: Defined as subjects' responses to the semantic differential rating promoted by Flynn (1977) and Rohles and Miliken (1981). Subjects' impressions of the lighting problems were evaluated using bipolar adjective pairs in the comfort scale (CS). Lighting problems adjective pairs were problem-no problem and glare-no glare.

Mercury etching phenomenon: An incident where mercury condenses at the top of a tube then is pulled by gravity into the hot base in an operating CFL. Condensing and falling of mercury causes phosphor to corrode rapidly (Siminovitch et al., 1995).

Preference: Defined as subjects' subjective responses to the semantic differential rating promoted by Flynn (1977) and Rohles and Miliken (1981). Subjects' preferences for the lighting conditions were evaluated using bipolar adjective pairs in the comfort scale (CS). Preference adjective pairs were appealing- unappealing, pleasant-unpleasant, attractive-unattractive, like-dislike, favorable-not favorable, acceptable-unacceptable, and balanced-not balanced.

Reading or Task surface: measures 360 X 310 mm (14 X 12 in.) parallel with a desk top (IESNA, 1993). The bottom edge of the task plane is 76 mm (3 in.) from the front edge of the desk (IESNA, 1993).

Reflection: The act of light striking a surface (i.e., lamp shade) and bouncing back. Reflection may be specular, diffuse, spread, and mixed (North American Philips Lighting, 1984).

Refraction: The act of light bending when passing from one transparent medium to another. For example, the light from a CFL bent after being transmitted through a shade.

Semantic Differential Scale: A scale used to evaluate impressions of visual comfort and perceptions of lighting conditions. The scale was developed by Flynn (1972-1973) and has been used by many researchers to evaluate individual's preferences and impressions of lighting. The semantic differential scale that was used in this study was designed to pose questions to subjects about the condition of lighting and comfort associated with table lamps retrofitted with CFLs.

Shade reflectance: The shade property that provides the capability to bounce light (IESNA, 1993).

Shade transmittance: The shade ratio of transmitted light to incident light, affected by reflection and absorption (IESNA, 1993).

Task Illuminance: The amount of light generated from a light source that falls on the reading material in a treatment.

Thermal bridge assembly: The incorporation of a rippled copper strip, 0.02 by 0.375 inch around a CFL tubulation for greater heat transfer area of a CFL (Siminovitch et al., 1995). The conductive element conducts heat to a heat exchange fin in a cooler section of the ballast compartment (Page, 1998).

Transmittance: The act of light when passing through a transparent or a translucent material such as a shade.

University Students' Survey (USS): Contains 14 questions regarding the demographic characteristics of the subjects. The USS was developed for this study based on Eklund and Boyce's (1996) Office Lighting Survey, other literature, and dissertation committee opinion. According to Eklund et al. (1996), OLS is inexpensive, simple to administer and score, and easy to interpret. The USS was designed to identify subjects' characteristics such as gender, age, occupation, lighting education, visual problems, color preference, and shape preference.

Summary

The background and purposes of the study were introduced. The following sections reviewed previous literature related to this study, presented the study's methodology, presented the results, discussed the findings and made future recommendations.

CHAPTER II

LITERATURE REVIEW

Research on compact fluorescent lamps is relatively new, and no studies were discovered that analyze the effects of CFL burning position and lamp shades on overall comfort (preference, comfort, brightness conditions, lighting problems, and lighting conditions) and task illumination. Therefore, research studies similar in purpose to the present study were reviewed to identify the first independent variable as the lamp shade shape and the second independent variable as the compact fluorescent lamp burning position. The dependent variable was the students' overall comfort factors (preference, comfort, brightness condition, lighting problems, and lighting conditions).

The review of related literature is divided into nine sections as follows: (a) table lamp shade, (b) compact fluorescent lamp burning position, (c) task illumination and light distribution, (d) effects of lighting on visual performance, behavior, and perception, (e) lighting and visual comfort, (f) table lamp task illuminance requirements, (g) conceptual framework, (h) standards and procedures for measurement of lighting and responses, and (i) summary of literature review.

Table Lamp Shade

In a table lamp system which consists of the lamp holder, the body, and the shade, light travels directly and indirectly towards the task surfaces and the users. Indirect light from reflection occurs when light falls on the shade and surrounding surfaces and bounces off of those surfaces in a similar or different direction. A lamp shade can control light reflections whether the reflection is specular, spread, diffuse, compound, selective, or nonselective (Ellis, Amos, & Kumar, 1995; IESNA, 1993; North American Philips Lighting, 1984; Stannard et al., 1994). Thus, the primary function of a lamp shade is to control and manipulate light output.

Surface reflectance of the lamp shade interior and the surrounding planes are important considerations in a CFL table lamp system (Steffy, 1995). Also, room interior surfaces and finishes should produce reflections that are completely or partially diffuse (Ellis et al., 1995; Dove, 1996). Color of the lamp shade, task surfaces and surrounding objects varies under different light sources. Light that passes through any material (e.g., vinyl lamp shade) is controlled and manipulated by the material. Careful consideration is important when selecting lamp shades and materials, and finishes of surrounding objects or surfaces (Dove, 1996).

Speed and angle are altered when light enters a translucent material like glass, plastic, or fabric (Ellis et al., 1995; IESNA, 1993; North American Philips Lighting, 1984). Quantity of illuminance also changes depending on the density of the material, and presence of dirt, moisture, oil, cracks, and marks. Patterns on the translucent surfaces also influence the characteristics of light. Transmission through translucent materials is a light property that can be spread, diffused, or mixed (IESNA, 1993; North American Philips Lighting, 1984). The degree of transmission relies on light intensity, absorption and transmittance, and material thickness. Over a period of time lamp shades may change color, and therefore may affect the light output. Thus, maintaining the table lamp such as cleaning and replacing the shade is important to assure efficient light output.

Shades are produced from various materials, and users may select different shade forms, height, and size to suit their needs. Shades may be of different colors and of different materials (e.g., linen, polyester, glass, and paper mixture). Shade shapes that are typically available on the market are cone, square, cylindrical, and polyshape.

Manufacturers produce lamp shades with different characteristics (e.g., different sizes, different forms, and different materials) to serve consumers' needs. One conclusion yielded by nearly a decade of research on CFLs at Lawrence Berkeley Laboratory is that when the lamp, the ballast, and the light fixture are considered as one, energy savings can be achieved (Siminovitch et al., 1995). Likewise, consumers and interior designers need to consider the function of each part and how the parts work together to affect lighting quality. Lighting manufacturers and lighting researchers also need to examine the function of each part and how the parts affect the users.

Typically, consumers are not aware that simply replacing an incandescent light source with a screw-in CFL, without considering the entire luminaire, results in a loss of light output (Page, 1998; Siminovitch et al.,1995), severe degradation of optical distribution (Page et al., 1997), and visual discomfort caused by glare (Serres et al., 1993). Page (1988) stated that light from an incandescent lamp is transmitted or reflected by the shade and much of the light is absorbed adding to shade losses. Although Ji and Davis (1993), Page et al. (1997), and Serres et al. (1993) have evaluated lamp types and the effect of lamp burning positions on candlepower distributions, the researchers have not researched portable lamp fixtures and the effect of shades on visual comfort.

Most existing residential fixtures were designed for the operation of incandescent A-lamps with a uniform distribution. CFL distribution is more linear and asymmetrical (Siminovitch et al., 1997). Replacing an A-lamp with a CFL changes the optical distribution of the luminaire, potentially reducing the perceived brightness (Goldman & Aldich, 1990) and contributing to consumer dissatisfaction (Siminovitch et al., 1997). The relationship between the shapes of existing lamp shades designed for an A-lamp and the new CFL needs to be examined.

Gardner et al. (1993) stated that "the performance of a portable lamp is less important if the room is evenly lit" (p.84). However, in a room lit exclusively by a table lamp, the type of shade and location of the light source becomes more critical (IESNA, 1993). The shape, size, and material of the lamp shade significantly influence task illumination. Candlepower distribution that is manipulated and controlled by the lamp shade may have a direct impact on the user's health, safety, comfort, and performance.

Working with inadequate or inappropriate lighting may lead to eyestrain (Loasby, 1992), headache, and nausea (Sanders & McCormick, 1993; Steffy, 1995). For example, IESNA (1993) stated that "deep and narrow shades do not provide useful task illumination and restrict downward and upward spread of light" (p.350). Opaque shades create pools of light above and below, and the effect is visually uncomfortable. Gardner et al. (1993) made assumptions that shades with too high transmittance and too little diffusion are unattractive and distracting. Therefore, in searching for an appropriate shade, a customer not only has to consider the aesthetics, durability, and cost of the shade, the customer also needs to consider the direct effect the lamp shade or the overall fixture has on the person's health, comfort, and performance.

Compact Fluorescent Lamps and Burning Positions

Lower light output from base-down operation of CFLs has caused consumer dissatisfaction and problems in the marketplace. Utility companies are introducing management and customer service programs to increase CFL retrofits and efficiency of light outputs. Base-down integral-ballast CFLs may lose up to 20% of light output compared to base-up or horizontal orientations (Page et al., 1997; Siminovitch et al., 1995). Lamp power, ballast compartment ambient temperature, and lamp size contribute to the variation in lumen losses.

In a base-down operation, mercury condenses at the top of the lamp and then is pulled down by gravity into the hot base of the lamp (Siminovitch et al, 1995, 1997; Verderber et al., 1988). Mercury that is collected in the lamp tubulation encounters radiation, conduction, and convection heat transfer from nearby filaments and electronic ballast (Siminovitch et al., 1995; Verderber et al., 1988). As a result the mercury is rapidly vaporized and mercury vapor pressure is increased beyond optimal level resulting in lumen losses (Siminovitch et al., 1995).

Soules in Siminovitch et al. (1995) questioned the researcher regarding heat piping and mercury etching phenomena. Heat piping occurs when condensed mercury at the top of a base-down lamp absorbs heat from the lamp base. Mercury etching is the phenomena that occurs when mercury continually condenses and falls as a result of heat piping in an operating base-down CFL.

Amalgam technology installed in CFLs produced less than a 5% difference between base-up and base-down lumen output (Serres et al., 1993). Amalgam control systems integrate bulb, cover, and ballast into one unit and stabilize mercury vapor pressure to near optimal value (Serres et al., 1993). Center bulb-wall temperature control and end-chamber bulb wall temperature control are the two techniques used mostly in larger fluorescent lamps to stabilize and hold mercury vapor pressure. Modified bulb-wall temperature control may be used in CFLs, but the technique requires some changes in bulb structure. However, the development of an internal thermal bridge system may be the most effective method in solving the light output inefficiency of CFL burning positions (Siminovitch et al., 1995).

Thermal bridged lamps have shorter warm-up times and can cost less than amalgam lamps (Siminovitch et al., 1995). Finding the lamp burning position that distributes light efficiently and evenly may eliminate health problems associated with lighting and may conserve energy.

Circline fluorescent lamps were developed by lighting researchers and lamp manufacturers to provide more efficient and pleasing lighting. This horizontally oriented lamp distributes light where it is needed the most (at nadir) for reading and writing tasks (Page, 1988). Lighting manufacturers claim that Circline lamps are more efficient than a standard incandescent A-lamp (Page et al., 1997) and a base-down CFL (Page, 1998) . For example, a 21 watt GE Circlite™ produces the same amount of light (1,200 lumens) as a 75 watt GE incandescent lamp. Therefore, the more efficient the circline lamp is, the more energy it conserves. However, this study did not discover any research that assessed the effects of the circline lamp on human visual comfort.

Task Illumination and Light Distribution

Visual tasks can be performed accurately, safely, comfortably, and easily with adequate task illumination (North American Philips Lighting, 1984). The quantitative requirement for task illumination varies depending on the type of activity or task, the age of the users (Sanders et al., 1993), the accuracy and speed required for the task, and reflectance value of the task background (Steffy, 1995). Adequate task illumination may also be determined by the length of time a task is performed (Steffy, 1995), the surrounding conditions, and the physiological state of the eyes (Mekjavic et al., 1988; North American Philips Lighting, 1984). IESNA (1993) recommends 500 to 1000 lux (50 to 75 footcandles) for reading a copied print. However, this value may be higher or lower depending on the variables mentioned above.

The method for determining a target installed and maintained task illuminance can be determined by referring to IESNA (1993) or North American Philips Lighting (1984) guidelines. The amount of light emitted from a light source is correlated to the amount of task illuminance on an object. Using a light meter, a researcher can measure the illuminance on a task (Bernecker et al., 1993). The illuminance measurement on a task represents the light output from a fixture.

Lamp geometry, lamp position, and shade shape have significant effects on light output, light distribution (Page et al., 1997; Siminovitch et al., 1995), shade losses, and fixture efficiencies (Page et al., 1997). Page et al. (1997) concluded that "significant light distribution differences resulted when a table lamp originally designed for an A-lamp is replaced by a CFL" (p. 5).

Goniometric studies showed that a predominately horizontally oriented CFL source distributes light more efficiently than a symmetrical A-lamp and a predominately vertically oriented CFL source in a table lamp (Page, 1988). Page et al. (1997) stated that "a horizontally oriented lamp concentrates its flux in the critical nadir and zenith areas and does suffer CFL thermal losses from operating base-down. Changing the burning position of a CFL by tilting and changing the shade geometry, material, and color may increase the efficiency of CFL retrofits" (p. 8).

Perceived light from a CFL table lamp system is as important as the efficiency. Ji and Davis stated in Page et al. (1997) that shade losses of a horizontally positioned CFL with a lamp shade affects the users' perception of brightness and light distribution. Page (1998) also concluded that table lamp shade and lamp shape affect light distribution and users' visual perception.

Effects of Lighting on Visual Performance, Behavior, and Perception

The human eye consists of optical and neurological components that help convert light energy into electrical signals for the brain. Transmittance of light into the eye varies with wavelengths and with a person's age (IESNA, 1993). Ability to see small objects, to read fine prints, and to adapt decreases under low illuminance (Ellis et al., 1995; IESNA, 1993) and with age. Most people prefer higher illuminance, and as a person ages the amount of light needed to satisfy performance increases. Users' satisfaction levels appear to increase with an increased level of illuminance, followed by a decrease in satisfaction at a peak level (North American Philips Lighting, 1984; Sanders et al., 1993).

Individuals differ considerably in their response to task illumination (Sanders et al., 1993). Weston (1982) assumed that subjects' visual performance varies at different illumination levels. However, Sanders et al. (1993) did not clearly present the relationship of demographic characteristics and responses to task illumination. Bernecker et al.'s (1993) study found that there were differences in subjects' responses towards overhead lighting due to sex and age. Males and older age groups tended to be less sensitive to lighting changes (Bernecker et al., 1993). However, this study used only 16 subjects of the age of 40 and over

According to de Boer and Fisher (1991), age affects visual efficiency. As the age of an individual increases, the relationship between task illumination and visual performance changes (de Boer et al., 1991). The researcher found that age affects responses toward task illumination only after the age of 50. This study used subjects between the age of 18 and 36, and de Boer et al.'s (1991) study did not discover any effect for the subjects below the age of 40. A study that examines a relationship between subjects' demographic characteristics and table lamp lighting is needed.

Visibility of the object is influenced by the actual size of the object and the object's size as perceived by the observer (IESNA, 1993). For example, an object may look smaller to a person's eye when the object is in a dark surrounding. A white colored object may look larger when a person's vision is blurred (Ilg, 1991). Visibility also varies with the lighting conditions in the space. Likewise, observer's age, exposure time (Dove, 1996), and visual adaptation state affect visibility (Davidson, 1997; IESNA, 1993). The object's color and surface reflectance may also alter a user's perception (Sanders et al., 1993) and task performance.

Light influences human behavior and gives multiple impressions to human perception. People attract, circulate, and orient differently under varying light conditions. Lighting triggers a subjective judgement of preference (Aspinall & Dewar, 1988), and humans may perceive spaciousness, privacy, relaxation and pleasantness (Flynn, Spencer, Martyniuk, & Hendrick, 1979) depending on the lighting conditions.

Lighting can be designed intentionally and unintentionally to provide human visual experiences such as helping a person to focus on an object, creating visual interest (Aspinall et al., 1988; Gardner, 1993), and directing attention to an art work (Gardner, 1993). Lighting may also facilitate circulation in a building (Steffy, 1990), create romantic moods in a restaurant, and provide energy to a club setting. Increased task illumination may result in an increase of productivity (Sanders et al., 1993) and lessen complaints associated with glare (Steffy, 1990; Barnaby, 1989). Factors associated with user complaints such as direct glare, inadequate lighting, and bothersome shadows need to be eliminated to increase user satisfaction and improve working conditions (Champness, Hyland & Oliver, 1995; McMurdo & Gaskell, 1991).

Lighting and Visual Comfort

The amount of light required for the comfortable and efficient performance of a visual task is influenced by the size, color and brightness of the object, the contrast between the object and the its background, the reflectivity of the object's immediate surrounding, and the time allowed for seeing (IESNA, 1993; Sanders et al., 1993). In addition, visual comfort and efficiency depend on adequate illumination and the proper illumination of the field of view (Sanders et al., 1993). Therefore, there should be no great difference of brightness between the field of central vision and the larger surrounding. Glare, veiling reflections, surface reflectance value, reflectance area, and visual adaptation also affect task performance (Sanders et al., 1993).

Color temperatures of the GE™ vertical CFL (3500 °K) and the GE™ Circline CFL (3000 °K) were different and may be a factor that affected table lamp user's preferences and visual comfort. However, no studies were found that showed the effect of color temperature on human subjective responses. Previous research indicated that a factor such as color temperature exert strong effects on the lamp users' physical and psychological states (Fisher, Bell, & Baum, 1990; Sundstrom & Sundstrom, 1986).

Glare produces eye strain and reduces visibility (Anderson & Noell, 1994). Glare can be minimized with proper shielding of the lamp, i.e., the use of an appropriate lamp shade. A frosted glass lamp shade does not shield as much light as a lamp shade made of fabric. Translucent glass lamp shades often make the light seem brighter than it really is and may result in glare (Loasby, 1992). Proper positioning of the lamp and appropriate shade material may reduce glare and visual discomfort.

Lighting that is unevenly distributed bothers many table lamp users (Ilg, 1992) and further reduces the users' vision adaptation abilities. Inadequate lighting increases depression (Josephson, Fabacher, & Rubenstein, 1991; Pirkl, 1994), anxiety levels (Steffy, 1995), and fatigue (Sanders et al., 1993). Adequate lighting can provide a sense of relaxation and enhance comfort (Gardner, 1993; Sanders et al., 1993). However, these assumptions were made based on little or no empirical research.

No studies regarding the effects of table lamps on students or any other groups have been located in the literature. However, university students spend much time indoors studying, and the lighting conditions that the students experience may not be optimum for performing visual tasks. Task lighting has a major impact on the students' eyes because of the close proximity of the system (Pirkl, 1994).

Aside from energy efficiency, fluorescent lamps flicker at twice the rate of the incandescent lamps, and fluorescent light sources differ in the amount of light produced at various wavelengths (Economopoulos & Chan, 1989). However, no studies were found that investigate the effect of flickering CFL on human. According to Widowski, Keeling, and Duncan (1992), perceptual, physiological, and reproductive processes are sensitive to specific features of light, and therefore, it is possible that the different light sources may affect behavior in different ways. Findings by Widowski et al. (1992) and Zimmerman (1988) supported the concept that different CFL light sources affect behavior differently.

Table Lamp Task Illuminance Requirements

Through the use of daylight and electrical lighting, the interior of workplaces should provide optimum conditions for performing required tasks (Gardner et al., 1993) and the appropriate visual environment when looking away from the task for relaxation or change of task (Steffy, 1995). The visual impression of an interior is influenced by the floor and furniture surfaces, visual objects, background surfaces, and light source (ISO, 1989).

The 1995 IES Lighting Handbook provides standards and illuminance criteria for various tasks. Performance of visual tasks of high contrast or larger size (e.g., reading, and handwriting) requires a minimum of 50 to 75 footcandles (Sanders et al., 1993). However, performance of visual tasks of extremely low contrast and small size requires more than 1000 footcandles (IESNA, 1993). Because of varying task conditions, a table lamp system that is able to provide variable light output is desirable. A table lamp with a dimmer is recommended. A dimmer also provides control of visual glare and shadow. A self-ballasted CFL that can be used with a dimmer is now readily available on the market.

A visual distance of 16 to 36 inches for reading is recommended for a person with 20/ 20 vision (IESNA, 1993). Appropriate task lighting for an environment will provide adequate illumination for task performance, will aid the users' ability to see by enhancing visual clarity of the task, and will improve visual comfort.

Analyzing the visual demands of a table lamp's user before designing or specifying the lighting in a space is important (Siminovitch, 1995). According to Veitch et al. (1993) and Bernecker et al. (1993), a survey given to the interior occupant will help identify the user's visual needs. Interior designers and lighting specifiers need to provide lighting for their clients based on research findings and lighting requirements. Because people's lighting requirements are individualized and may change with the tasks performed, designing a lighting system that enables occupants to adjust as many aspects of lighting conditions as possible without having a negative impact on the other users in the space is important (Gardner et al., 1993).

Conceptual Framework

Page et al. (1997) developed a test protocol that uses a swing-arm goniophotometer to study light distribution associated with typical retrofits for a table lamp application. The tests followed the IESNA (1993) standards and procedures for measuring photometric data. The researchers concluded that lamp position and geometry affect light output, light distribution, shade losses, and fixture efficiencies. The research also found that candlepower distribution of a table lamp with a shade is different from a table lamp without a shade.

The findings of Page et al. (1997) and Page (1998) are consistent with the conclusions yielded by Serres et al. (1993) and Siminovitch et al. (1995) regarding the efficiency of a CFL burning position (see Appendix A). The researchers found that CFLs perform differently based on the operating positions. Serres et al. (1993) concluded that an amalgam-based CFL can provide significant advantages over many of the CFL designs by producing more than 90% of the maximum light output over a wide range of ambient temperatures. Siminovitch et al. (1995) also concluded that orienting integral-ballast CFLs base-down can decrease light output by as much as 20% and using a thermal bridge system in a CFL can mitigate most of the losses. Both techniques have the potential to solve the problem of CFL burning positions (Page et al., 1997).

Lamp shades have the ability to control and manipulate light output of a lamp. Page et al. (1997) found that lamp shades affected light distribution, luminous intensity, and luminous flux. Light distribution is the spread of light produced by a lamp. Distribution can be affected by the absorption, transmission, reflection, or refraction of light by a lamp shade. Luminous intensity is the light emitted in a specific direction by a lamp. The intensity of the light may be modified when the light is absorbed, reflected, or transmitted by a lamp shade.

Luminous flux is the light emitted in all directions by a lamp. The flux outside a table lamp with a shade may be less than the flux inside. The amount of shade losses may depend on the shape, size, material, and thickness of the shade. A shade also helps minimize potential glare and redirect flux to areas where light is needed for tasks. According to Page et al. (1997), tilting the CFL or changing the shade geometry and reflectance may affect the light output and characteristics of a table lamp.

Subjective evaluations of comfort have been completed using a semantic differential rating technique promoted by Flynn, Hendrick, Spencer, and Martyniuk (1979) and Rohles et al. (1981). Flynn and Spencer (1977) used a semantic differential technique to measure effects of light source color on user impression and satisfaction. John E. Flynn has used semantic differential techniques in many other studies of lighting and the interior occupants. Bernecker et al. (1993) studied subjects' visual comfort under different task lighting conditions using the semantic differential technique.

Standards and Procedures for Measurement of Lighting Responses

J. L. Phillips in Keeves (1988) argued that some attributes that were used in the semantic differential scale did not precisely measure users' comfort. The argument is that the adjectives may have double meaning and that the adjectives are not perfectly opposite (Keeves, 1988). However, semantic differential scales have been used by many lighting researchers in evaluating comfort and preference (Bernecker et al., 1993; Rea, 1981; & Flynn, 1979).

IERI Project 92 suggested that scaling and mapping procedures are methods that can measure subject impression, attitude, performance, and preference (Flynn, 1979; Flynn et al. 1979) toward lighting. The experience of a person in a lighted space can be measured (Flynn & Spencer, 1977; Flynn, 1979), and the changes in a person's visual perception can be studied. This study followed the guidelines and recommendations from IERI Project 92.

Initial surveys to measure lighting perceptions and preferences include Vischer's Lighting Comfort Scale (LCS) and Gillette and Brown's Occupant Questionnaire (OQ). The LCS is a questionnaire (Dillon & Vischer, 1988) used for assessment of overall office quality (Eklund et al., 1996). LCS is simple to administer for measuring poor lighting conditions in a workspace. However, according to Eklund et al. (1996), LCS is difficult to interpret, labor-intensive to score, and weak in identifying the lighting problem.

Gillette and Brown's Occupant Questionnaire (Gillette & Brown, 1986) is an instrument developed to quantify good office lighting. According to Eklund et al. (1996), OQ is simple to administer, less difficult to interpret, but is labor intensive to score. Thus, Eklund et al. (1996) developed the Office Lighting Survey (OLS) that is inexpensive, simple to administer and score, and easy to interpret. Eklund et al. (1996) claimed the OLS survey addresses most factors important in evaluating office lighting; also it is able to differentiate between acceptable lighting and unacceptable lighting. However, the survey heavily relies on the workers for the responses, and the researchers did not manipulate the settings. The researchers also did not have control over the confounding variables such as the room temperature and the surrounding surface reflectance that may affect the responses. No literature was found that demonstrated a relationship between university students' demographic characteristics and their responses toward semantic differential lighting scales.

Summary of Literature Review

Lamp shade geometry and compact fluorescent burning orientation may affect the students' comfort and task performance. Candlepower distribution and task illuminance that are not uniform or uneven may cause psychological and physiological problems such as headache, restlessness, nausea, and visual fatigue. Simply replacing a CFL in a table lamp designed for an incandescent lamp causes inefficiency in power use and may result in user complaints. Ji et al. (1993) and Siminovitch et al. (1995) stated that there have been numerous complaints by people who cannot perform tasks comfortably using a table lamp in the work environment.

Perhaps by changing the shade, many problems associated with table lamps can be solved. Lamp shade and lamp positions determine the efficiency and the evenness of a table lamp light output. Recent lighting research has focused on CFL burning position, but the importance of the table lamp shade has not been addressed. In a table lamp system, a lamp shade controls the light output more than the lamp. Shade losses occur when light is absorbed by the lamp shade, and the degree of shade loss varies with shade characteristics. Page (1998) and Siminovitch et al. (1997) concluded that the shade plays an important role in regulating light output from a fixture.

According to Veitch et al. (1993), manufacturers and researchers need to work together in solving the problems associated with task lighting. All standards and procedures related to task illuminance have to be considered in lighting research and application. Many lighting researchers are looking at the efficiency of a CFL without considering the effect on the user's comfort and without considering the shade effect. The intent of this study was to evaluate university students' comfort due to differences in table lamp shade and CFL burning positions.

CHAPTER III

METHODS

Introduction

From manufacturing, design, and health perspectives, task illumination of a compact fluorescent table lamp and university students' visual comfort associated with the table lamps are significant issues to be explored in lighting research and technology (Flynn, 1972-73; Flynn, 1977; Page et al., 1997; Siminovitch et al., 1995, 1997). The procedures for this study are addressed in the following sections: (a) methodology, (b) selection of the sample, (c) research instruments, (d) applied standards and procedures for measurement of lighting and lighting responses, (e) explanation of the procedures, (f) consistency and factor analysis, (g) collection of data, (h) variables for the study, and (i) statistical analysis of the data.

Methodology

The experiment was conducted in a windowless room at Texas Tech University, College of Human Sciences. The desk and other furniture were arranged to look like a study setting. The temperature, ventilation, and surface reflectance in the office were controlled and regulated at a comfort level. These conditions were kept consistent throughout the six test conditions. The dissertation committee chair and the researcher determined the comfort level of the room. The room was illuminated by a table lamp, a 75 watt overhead luminaire, and a 150 watt vertically mounted track light that was directed upward. The overhead light and the track light were positioned at a distance that would not affect the light distribution on the task surface. These lights were the same for all of the six conditions. The overhead light and the track light were used to decrease sharp contrast between the task area and the surrounding area.

University students from EDIT 2318 "Computing and Information Technology" class voluntarily signed up for one of six groups. All participants were enrolled for a lottery and received five points credit towards their course. Students' were randomly grouped and assigned to each treatment. Each group was tested at various times on Monday, Tuesday, Wednesday, and Thursday. Each student had an eye test prior to entering the test room. The researcher gave the students the eye test and the students were asked to read the Snelling™ eye chart at a distance of 24 inches as suggested in the chart manual. Students who had difficulties reading the smallest set of letters did not pass the eye test.

The reading material that was used in the study was photocopied from Journal of Interior Design and was selected based on the article content that was related to the EDIT 2318 class content (see Appendix D). The article was reviewed by experts in an education field from the Texas Tech University, College of Education to determine its readability level appropriate for subjects at a university level. A bell was sounded to remind the student in the station to stop reading. While still in the station, the student was asked to complete the comfort scale. Completing the comfort scale required no more than ten minutes.

According to Flynn et al. (1979), a subject's commitment of time to respond to a semantic scale should be 45 minutes or less to avoid subject fatigue. A bell was sounded to remind the student that the test was completed. The procedures for determining the time limits for reading the text and for responding to the CS were tested by the instructor for EDIT 2318 class and the researcher.

At the end of the test condition, the student was asked to complete the University Students' Survey under the same lighting condition. There was no time limit for completing the University Students' Survey. Another student from the same group was tested and followed the same procedure until all the students who participated in test condition 1 were tested. The same method was repeated for groups 2, 3, 4, 5, and 6 on different days.

Selection of the Sample

According to Flynn et al. (1979), a reasonable statistical significance may be achieved with a sample size of at least 40 subjects. Therefore, students from EDIT 2318 were asked to voluntarily sign up into eighteen time slots for each session (see Appendix B). There were six sign-up sheets for six sessions. Each sign-up sheet consisted of 18 twenty-minute time slots. A pamphlet was given to each student who signed up for the test describing the purpose, the criteria needed to qualify, the task description, the prizes that were given, the location, and the time of the session (see Appendix C). The students were divided into six groups, group C1, C2, C3, C4, C5, and C6. Eighteen students signed up for each session.

Students were tested for corrected visual acuity prior to the test condition to avoid the effects of confounding variables related to vision. Students that qualified for the study had 20/20 vision or wore corrective glasses or lenses. Ninety responses (15 from each session) from the students who passed the eye test were used in the data analyses.

Research Instruments

The reading material titled "Cruising the Internet highway: A wealth of information for interior design educators" was photocopied from Journal of Interior Design and was selected because it was related to the EDIT 2318 class content. The researcher suggested the text and the EDIT 2318 class instructor approved the text (see Appendix D).

A GE™ light meter was used to measure task illumination at the center of the test material, and 41 cm (16 in.) from the light source prior to the treatment. The light meter was used by Bernecker et al.'s (1993) study to measure task illumination in an open space.

Task illumination readings were recorded on the Illuminance Measurement Data Sheet (see Appendix E). The Illuminance Measurement Data Sheet (IMDS) was designed based on literature review and was reviewed by the dissertation committee. The illuminance measurement from one treatment will be compared to the measurement from other treatments. The CS contains 16 bi-polar adjectives from Bernecker et al.'s (1993) semantic differential scale. Six additional adjectives were included in the CS, and the 22 adjectives in the CS were reviewed by the dissertation committee (see Appendix F).

University Students' Survey (USS) that was administered to the subject after each treatment consisted of socio-demographic questions that were based on Eklund et al.'s (1996) OLS (see Appendix G). Additional questions in the USS were developed based on literature review and dissertation committee opinions.

Applied Standards and Procedures for Measurement of Lighting and Responses

A semantic differential rating technique was used in the study to measure comfort because there are no other known measures of visual comfort for task lighting. To measure visual comfort of task lighting, the semantic differential rating scale has been widely utilized by lighting researchers. The comfort scale (CS) that was used in this study incorporated Bernecker et al.'s (1993) semantic differential scale.

The 14 socio-demographic questions that were used in the University Students' Survey (USS) were based on OLS, literature reviews, and opinions of dissertation committee members. All tests conditions followed the IESNA (1993) standards and procedures for measuring photometric performance and manufacturers' recommendations. The experiment complied with the following guidelines that were derived from literature review:

1. Luminaires that were selected for the test were clean and representative of the manufacturer's regular product. CFLs were mounted in their suggested

locations by the fixture manufacturer within the luminaire and followed the manufacturer specifications for installing or retrofitting compact fluorescent table lamps.

2. Shades that were used were new and were similar in height and material. Shades were installed according to the manufacturers' specifications.

3. Extraneous light was eliminated and specular reflections from the surfaces were controlled and minimized.

4. The testing was conducted in a draft free environment, and the room temperature were set at a comfortable level of 77°F, ± 3°F, (25°C ± 1°C).

5. Lamps and ballasts were operated until thermal stabilization was reached before the experiment. The lamps were seasoned for 4 1/2 hrs. prior to each test.

6. Task illumination readings were taken with the lamp in a normal use position and as recommended by the Flynn et al. (1979).

7. Task illuminance readings were measured using a light meter at the center of the test material, 41 cm. (16 in.) from the light source. A visual distance of 16 to 36 inches for reading is recommended by IESNA (1993).

8. Test reports for this study described the lamp type, the mounting type, the shade, the reading plane task illuminance value, and diagrams that illustrated the luminaire shape, dimensions, the fixture center position, and the workspace.

9. The experiment was designed to eliminate and hold constant as many

confounding variables as possible. Flynn et al. (1979) suggested that the effect of learning is best controlled by randomization of the subjects. Therefore, the students that voluntarily participated for the test were randomly assigned to each treatment.

10. The instructions given to the subjects followed Flynn et al.'s (1979) recommendations in giving instructions for a bi-polar rating scale.

Explanation of the Procedures

A standard table lamp used in residential office environments was used for the experiments (see Figure 3.1). The table lamp that was purchased from a general lighting store was retrofitted with a CFL. The table lamp was retrofitted with a CFL base-down in an vertical position and with a Circlite™ CFL (base-down horizontal position). Since the same lamp body was used throughout the experiments, the effect of surface reflection differences from the lamp body were minimized. The total height of the fixtures was 30 inches with a socket height of 17 inches. The study used a GE compact fluorescent lamp that was rated at 1200 lumens, 20 watts (equivalent to 75 watts incandescent lamp) and has a 10,000 hour life. The study also used a GE Circlite™ CFL that is rated at 1200 lumens, 21 watts (equivalent to 75 watts incandescent lamp) and a 40,000 hour life (see Figure 3.2).

Before the tests began, each integral CFL was burned for a period of 4 1/2 hours to season the lamp (Serres, 1994) and to minimize lumen depreciation

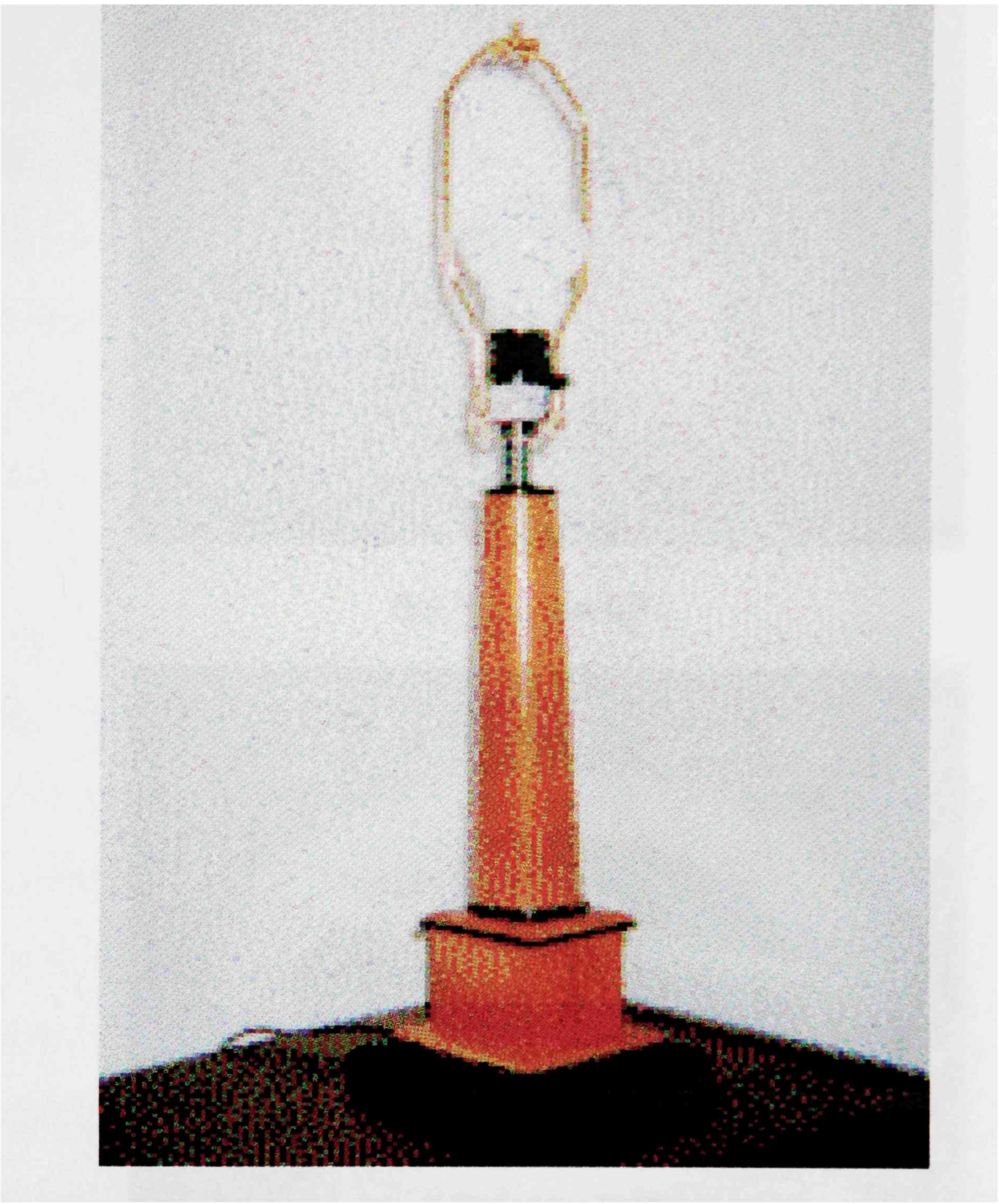
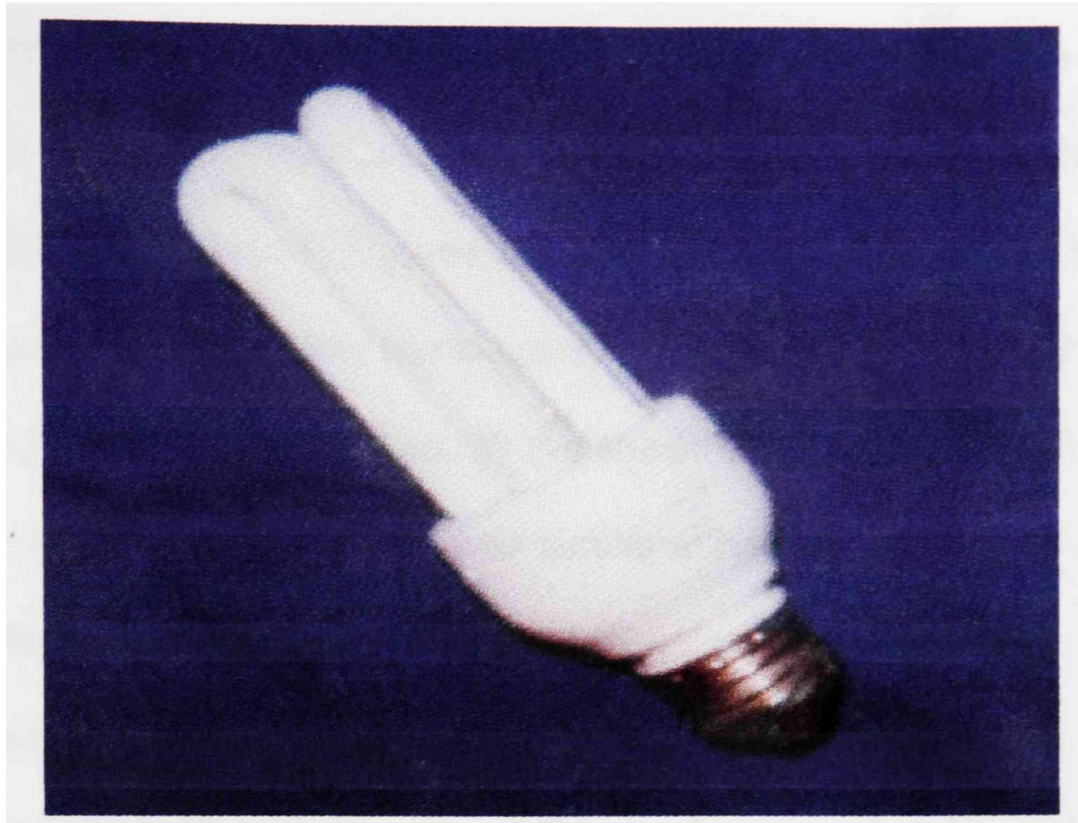
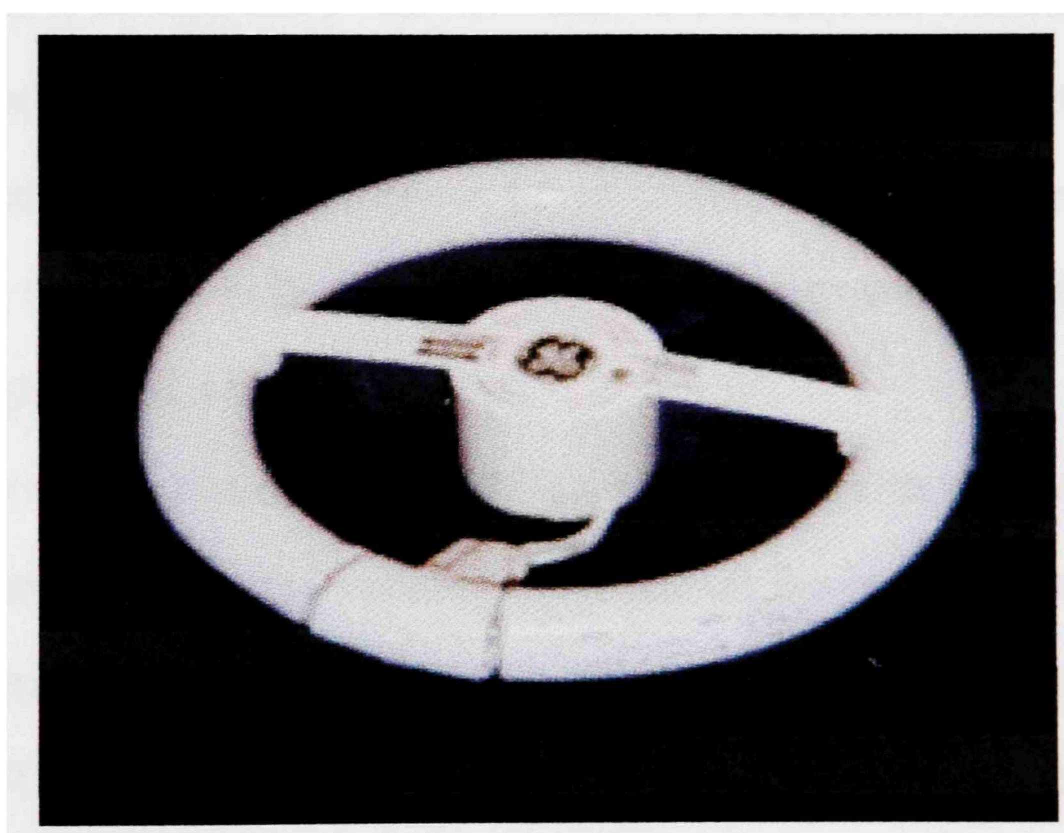


Figure 3.1: The table lamp that was used in the treatment.



GE ™ vertical CFL



GE™ horizontal CFL

Figure 3.2: The lamps that were used in the treatments (Compact biaxial CFL and Circline™).

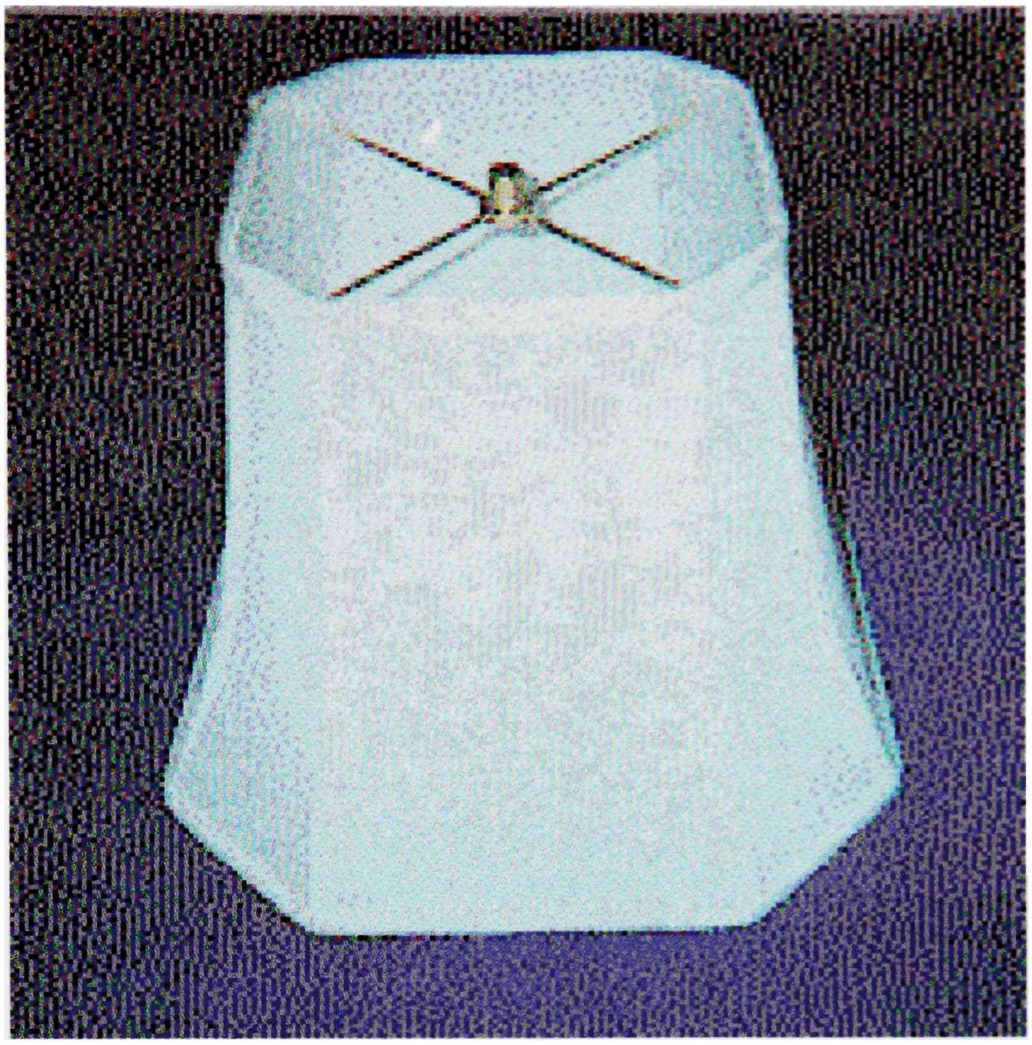
error (Siminovitch et al., 1995). The procedures in this study followed the IESNA (1993) standards and procedures when applicable. The three different shades that were tested are described in Figures 3.3, 3.4, and 3.5. The material that was used for all the shades was slightly translucent with matte finish, and high reflectance value; light transmitted through the shade diffused the light. Each shade that was used in the experiment was similar in height and surface area to minimize the effects of shade size.

The table lamp and the reading material were positioned to minimize the creation of shadows. The lower edge of the shade was not above or below the periphery vision, and the lamp was not visible to the subjects. Therefore, each subject was advised prior to the treatment to change the chair height if necessary. The luminaires were placed at 51 cm (20 in.) from the users and 41 cm (16 in.) from the center of the reading material as recommended by IESNA (1993) and Sanders et al. (1993).

The surface of the surrounding task surface materials was nonglossy and of 40-50% reflectance. The reading material was placed in the center of a primary task plane that measured 360 X 310 mm (14 X 12 in.), parallel with the desktop (IESNA, 1993). The reading material was printed on 8½ X 11 in. white copy paper. Since all treatments were conducted in the same location, the effects of surface reflectance or room temperature were minimized. The desk that was used in the experiment is a typical residential office desk purchased from a furniture store. Figures 3.6, 3.7, and 3.8 illustrate the view and condition of the

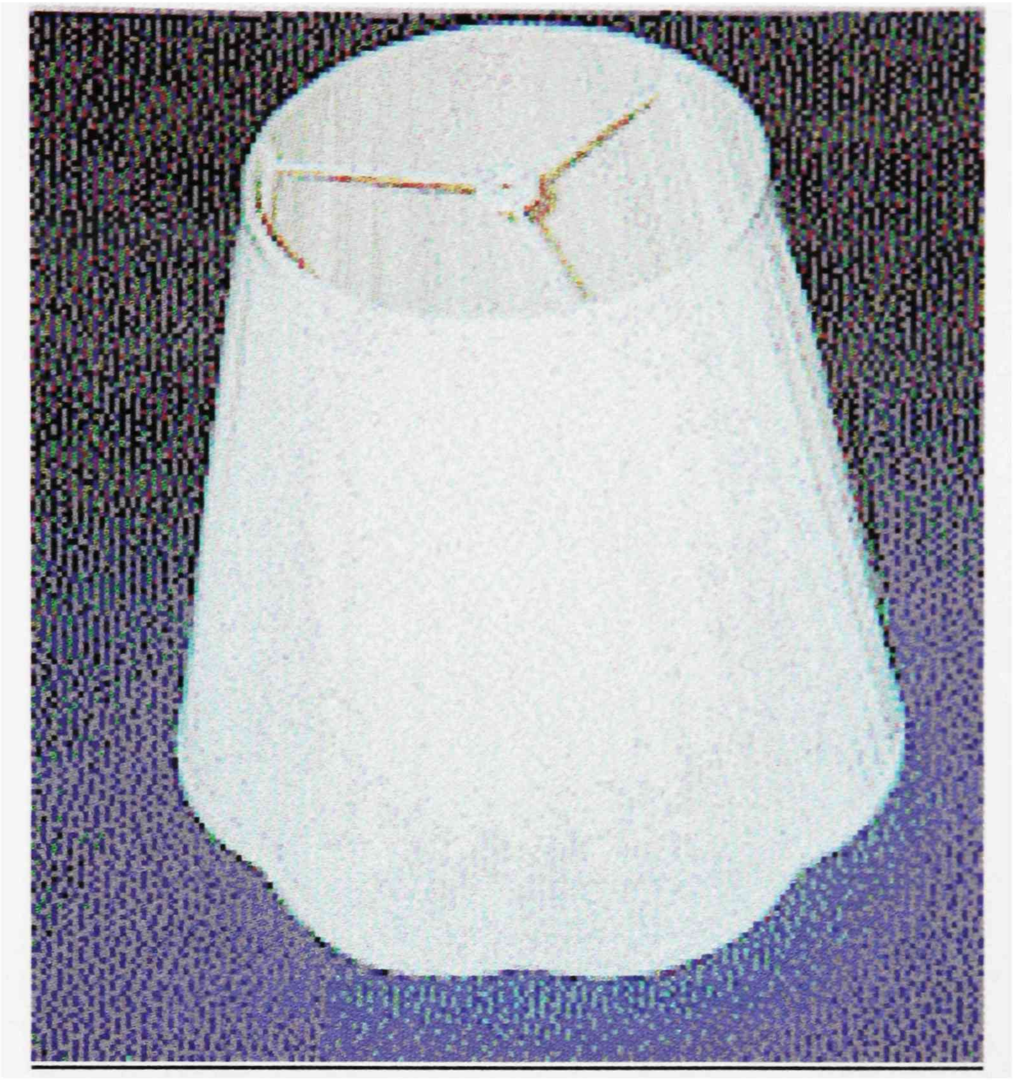
Round shape
Manufacturer GE™
Style: 534GS
Height: 14.75 in.
Minor diameter: 8 in.
Major diameter: 16 in
Shade angle: 20 degrees
Material: White linen

Figure 3.3. The type of shade that was tested and the description (round shape).



Square shape
Manufacturer GE™
Style: 534GS2
Height: 14.75 in.
Minor diameter: 8 in.
Major diameter: 16 in
Shade angle: 20 degrees
Material: White linen

Figure 3.4. The type of shade that was tested and the description (square shape).



Polygon shape
Manufacturer GE™
Style: 534GS2
Height: 14.75 in.
Minor diameter: 8 in.
Major diameter: 16 in
Shade angle: 20 degrees
Material: White linen

Figure 3.5. The type of shade that was tested and the description (polygon shape).

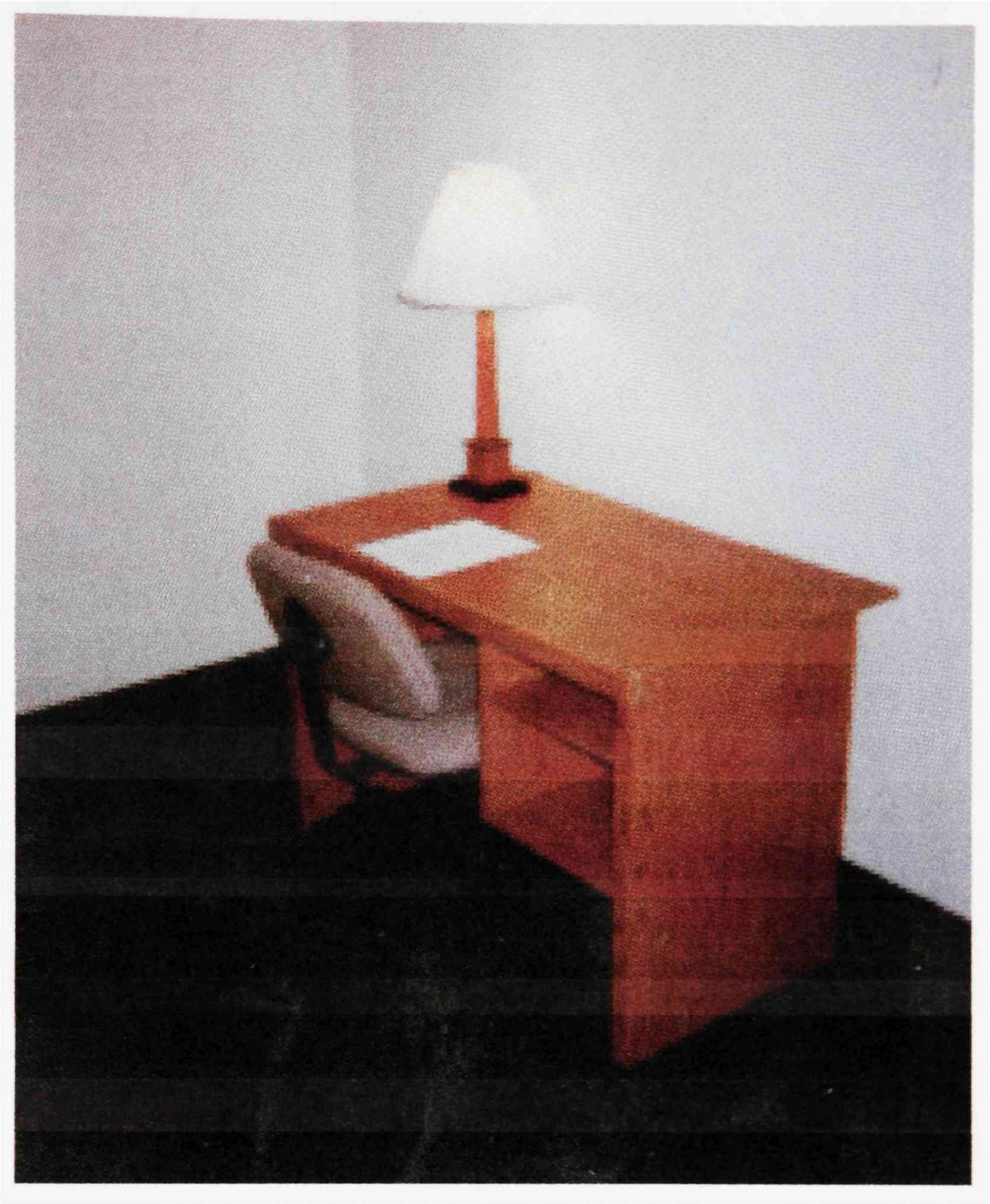


Figure 3.6. The view and condition of station 1 and station 4 (vertically positioned CFL or horizontally positioned CFL with a round shade).

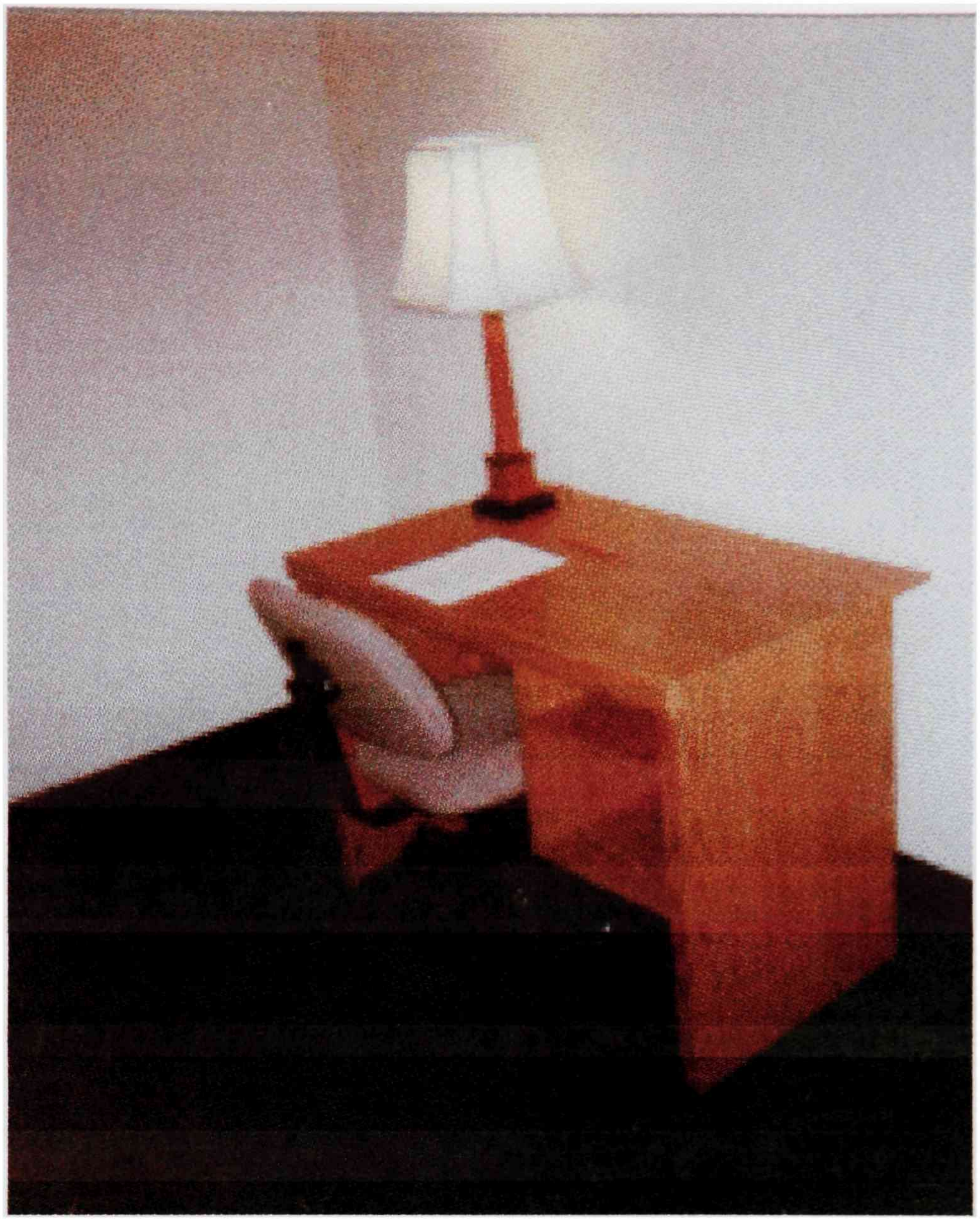


Figure 3.7. The view and condition of station 2 and station 5 (vertically positioned CFL or horizontally positioned CFL with a square shade).

Figure 3.8. The view and condition of station 3 and station 6 (vertically positioned CFL or horizontally positioned CFL with a polygon shade).

three stations with lamp shade variations. The desk was placed in a windowless room that was illuminated by the tested table lamp and two background lights.

All subjects were advised not to judge the content of the text and the appearance of the lamp fixture. Each subject was given ten minutes to complete the reading task and ten minutes to complete the comfort scale in the station. At the end of the treatment, the student was asked to complete the University Students' Survey in the same station. All students completed the survey in less than ten minutes. Fifteen students from a group were exposed to each treatment. Group C1 was tested on Monday evening. Group C2 was tested on Tuesday morning and group C3 was tested on Tuesday afternoon. Group C4 was tested on Wednesday afternoon. Group C5 was tested on Thursday morning and group C6 was tested on Thursday afternoon.

According to Flynn et al. (1979), randomizing or sequencing subjects may eliminate or hold constant many confounding variables. Therefore, the students randomly signed up to participate for each treatment, assuring that the lighting stimulus and the students' socio-demographic characteristics were randomized.

University Students' Survey was administered to the students after the students had completed the reading task and the CS. The students were asked to provide socio-demographic information for the survey. Students were told that the responses were for statistical purposes and that the data would remain confidential. Task illumination was measured for each treatment with a GE™ light meter at the center of the test material, 41 cm (16 in.) from the light source prior to each test. The readings were recorded in the IMDS. Task Illumination readings of each portable luminaire were compared to the subjects' CS responses.

Students' visual acuity was tested outside the treatment room prior to each treatment. The eye test was conducted using the Snelling™ eye chart (see Figure 3.9). The eye chart used in this study was a modified version to be administered from two feet. The purpose of the eye test was to assure that every participant had 20/20 vision or wore corrective eyewear or glasses during the test. Responses from students who did not comply with the criteria above were not included in the data analysis.

Consistency and Factor Analysis

Reliability of the Comfort Scale (CS) was determined by Cronbach's coefficient alpha. The CS contained 22 adjectives that were used in a semantic differential scale to measure comfort. Factor analysis was performed for the adjectives used in the CS. This study made use of attributes that have a factor of .70 or higher.

The 14 socio-demographic questions in USS were based on Eklund et al.'s (1996) Office Lighting Survey (OLS). The questions were revised from literature review and opinions of the dissertation committee to identify the demographic characteristics of the students. Students' comments were compared with their responses to the CS.

Figure 3.9. The view and condition of the eye test station.

The Task Illuminance Data Sheet (IMDS) was developed from the literature review. Members of the dissertation committee reviewed the IMDS to assure the face validity. The IMDS was used to record the illuminance readings on the task for each condition. A GE™ triple range light meter was used to measure task illumination on the center of the reading material.

The effects of race, age, and vision were minimized because the students that participated were homogeneous and had a 20/20 vision or corrected visual acuity. By having the students sign up for a selected time and assigning the students to a single test condition, the effect of learning from task was minimized. Assigning students to one condition also lessened the possibility of fatigue.

Collection of Data

Task illumination from each portable luminaire was measured using a triple range GE™ light meter at the center of the test material, 41 cm (16 in.) from the light source. Task illumination was measured prior to each treatment and after the lamp had operated for 4 ½ hours. The readings from the six lighting conditions were recorded in the IMDS (see Appendix E).

Data were obtained from the students' responses to the Comfort Scale for each treatment. Responses from the six treatments were organized in chronological order and were labeled as C1, C2, C3, C4, C5, and C6. Factor analysis was performed to determine if the CS consists of one scale or several subscales (see Appendix F).

After completing the treatment and the comfort scale, students were asked to complete the University Students' Survey (USS). The survey identified subjects' socio-demographic characteristics (see Appendix G).

Variables for the Study

The variables for the study were:

1. Shade shape (a three-category independent variable; round, square, and polygon);

2. Compact fluorescent burning position (a two-category independent variable; base-down vertical and base-down horizontal);

3. Overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) as measured by the CS, and

4. Socio-demographic characteristics that were defined as gender, age, ethnicity, eye condition, occupation, hours exposed to a table lamp, problem using a table lamp, lighting education, color preference, and shape preference. Socio-demographic characteristics were measured by the USS.

Gender--The gender was measured by the summation of responses to question 1 in the USS. Frequency distribution was performed for the purpose of describing the students' responses on gender.

Age--The age variable was measured by a summation of like responses to question 2. Analysis of the frequency distribution was performed to determine the age classifications. Based on an opinion of a statistician and that the age distribution of the students sample was unknown, the question for age was open ended. Frequency distribution was performed for the purpose of describing the responses on age.

Ethnicity--The ethnicity variable was measured by a summation of like responses to question 3. The ethnicity variable was collapsed into five segments consisting of (a) Caucasian (b) African American, (c) Hispanic, (d) Asian, and (e) other. Frequency distribution analysis was performed for the purpose of describing the responses on ethnicity.

Eye condition and visual problems--The eye condition variable was measured by a summation of like responses to questions 4, 5, 6, 7. Factor analysis was performed to the four questions to determine if the questions measure only one variable. The eye condition variable was measured for the purpose of describing the students. The intent of the frequency distribution analysis was to describe the responses on eye conditions and visual problems.

Occupation--The occupation variable was measured by a summation of like responses to questions 8. Frequency distribution analysis was performed for the purpose of describing the responses on occupation.

Hours exposed to table lamp lighting--The hours exposed to table lamp lighting was measured by a summation of the like responses to question 9. The purpose of frequency distribution analysis was to quantify hours students were exposed to table lamp lighting.

Problems using a table lamp--The problems using a table lamp variable was measured by a summation of like responses to question 10.

Frequency distribution analysis was performed to identify the problems using a table lamp.

Lighting education--Lighting education variable was measured by a summation of like responses to question 11. Frequency distribution analysis was performed for the purpose of describing the responses on lighting education.

Color preference--Color preference variable was measured by a summation of like responses to question 12. Frequency distribution of the color preference variable was used to describe the students' color preferences.

Shape preference--Shape preference variable was measured by a summation of like responses to question 13. Frequency distribution of the shape preference was compared with frequency distribution of other variables.

Statistical Analysis of the Data

The study has a three-category independent variable (round, square, and polygon), a two-category independent variable (vertical and horizontal positions) and five dependent variables of overall comfort (preference, comfort, brightness condition, lighting problems and lighting conditions). The statistical analysis of the data was organized in the following order:

1. Calculation of CS rating means to provide a clear 'picture' of subjective reactions to the different lighting conditions as recommended by Flynn et al. (1979).
2. Factorial analysis was performed on the CS responses to determine if the CS consists of one scale or several subscales. Estimation on the number of factors

(subscales), presence of outliers, and factorability of correlation matrices were recommended by Flynn et al. (1979).

3. Correlation was performed to ascertain the relationship between the subscales. Flynn et al. (1979) and Huberty and Morris (1989) stated that variables with high loading were tied together to arrive at a label (name) for each factor.

4. Cronbach's alpha was performed to determine the reliability coefficient for each subscale (factor).

5. Multivariate Analysis of Variance (MANOVA) was performed to the CS responses to test hypothesis 1. The total of all scores for subjects in condition 1, condition 2 and condition 3 were used in the analysis.

H1 stated that there will be a difference in overall comfort (preference, comfort, brightness condition, lighting problems, lighting conditions) of the university students due to lamp shade shape.

$H1 = \mu S1 \neq \mu S2 \neq \mu S3$ (S= shade shape)

6. MANOVA was performed to the CS responses to test hypothesis 2. The total scores for subjects in condition 1 and condition 4, condition 2 and condition 5, or condition 3 and condition 6 were used in the analysis.

H2 stated that there will be a difference in overall comfort (preference, comfort, brightness condition, lighting problems, lighting conditions) of the university students due to CFL burning position.

$H2 = \mu P1 \neq \mu P2$ (P= CFL position)

7. MANOVA was also performed to the CS responses to test hypothesis 3. The total of all scores for subjects in condition 1, 2, 3, 4, 5, and 6 were used in the analysis.

H3 stated that there will be an interaction between shade shapes and CFL burning positions based on the CS responses.

H3 = The effect of shade shape on overall comfort (preference, comfort, brightness condition, lighting problems, lighting conditions) of the university students depends on the CFL burning position.

MANOVA was used to test hypothesis 1, 2, and 3 because of the need to look at the interaction and main effects present between the two independent variables (shade shape and CFL position) and the five dependent variables (preference, comfort, brightness condition, lighting problems, and lighting conditions).

8. Tukey Honestly Significant Difference Test (HSD) was used to determine where the differences were between the treatments. The result from Tukey's HSD was also used to describe in detail the relationship between the IVs and the DVs.

9. Descriptive analysis and means comparison were used to describe the relationship among the IVs and DVs and the MANOVA results.

10. Descriptive statistics were used to evaluate the task illumination readings (measured on the center of the task surface prior to each treatment) and the CS responses. The purpose of the analysis was to develop the relationship between task illumination readings and the CS responses from each treatment. Task

illumination from the six task conditions were compared to criteria identified in the literature reviews and IESNA illumination standards. Task illumination may be affected by the light source, the lamp shade and CFL position (Page et al., 1997). However, task illumination cannot affect the lamp shade shape and CFL burning positions. Task illumination was the direct outcome of the lighting conditions. Therefore, task illumination was not considered as a covariate.

11. Descriptive statistics, such as frequency distributions and means were used in describing the students' socio-demographic characteristics.

CHAPTER IV

RESULTS

Introduction

For the purpose of detecting the comfort level differences for the students and analyzing the Task Illumination, the CS, and the USS, the scale factorial analysis and reliability, correlation, two-way MANOVA, Tukey's Post Hoc test and descriptive statistics were conducted. The results of this study are addressed in the following sections: (a) the CS and the responses, (b) relationship between CS subscales and shade shape and CFL position, (c) hypothesis tests, (d) hypothesis 1, (e) hypothesis 2, (f) hypothesis 3, (g) task illumination measurement, (h) task illumination measurement and the CS responses, and (i) USS responses.

The Comfort Scale and the Responses

CS responses means. Table 4.1 describes the responses mean for each adjective. Flynn et al. (1979) suggested the calculation of rating means for comparison and to provide a clear 'picture' of subjective reactions to the different lighting conditions. Through descriptive analysis of the responses for CS adjectives, there were significant differences between the means. The comparison was also made to describe where the differences were in the significance tests. For a vertically positioned CFL with a round shade, students rated the means for all adjectives higher than the means for a vertically

Table 4.1

Responses Mean for CS Adjectives (with N = 90)

Condition:	C1	C2	C3	C4	C5	C6
Adjectives	P1+ S1	P1 + S2	P1 + S3	P2 + S1	P2 + S2	P2 + S3
Comfortable	5.40	4.53	4.47	6.40	6.00	5.27
Adequate	5.13	4.27	4.27	6.07	5.67	5.00
Easy	4.87	4.80	4.13	6.00	5.67	5.47
Free	4.90	4.27	4.13	5.27	5.40	4.80
Ease	5.27	4.87	3.80	5.67	5.60	5.33
Relaxed	5.67	5.07	4.93	6.47	6.42	6.40
Spacious	5.27	4.20	4.06	6.00	5.20	4.80
Satisfied	5.47	4.93	4.06	6.20	5.40	5.33
Uniform	5.20	4.87	4.33	5.73	5.00	4.80
Focused	4.80	4.67	4.60	6.13	5.53	5.13
No Problem	5.00	5.20	5.67	5.73	5.53	5.26
No Glare	5.20	5.27	5.47	6.07	5.80	4.73
Bright	4.40	2.87	2.93	4.67	3.93	3.80
Clear	5.20	3.93	4.60	5.62	5.60	5.00
Favor	5.13	3.87	3.80	5.67	4.53	4.73
Like	5.07	4.13	4.00	5.27	4.53	4.86
Acceptable	5.60	4.93	4.40	5.93	5.20	5.06
Attractive	5.73	4.53	3.93	6.06	4.87	4.53
Large	3.60	3.20	3.13	3.67	3.60	3.33
Appealing	5.00	4.40	4.00	5.47	4.80	4.80
Balanced	4.47	4.60	4.20	4.87	5.00	4.60
Pleasant	5.07	4.87	4.06	6.13	5.20	4.93

Notes:
C1 = Condition 1 (vertical CFL position with round shade)
C2 = Condition 2 (vertical CFL position with square shade)
C3 = Condition 3 (vertical CFL position with polygon shade)
C4 = Condition 4 (horizontal CFL position with round shade)
C5 = Condition 5 (horizontal CFL position with square shade)
C6 = Condition 6 (horizontal CFL position with polygon shade)
S1 = round shade, S2 = square shade, S3 = polygon shade
P1 = vertically positioned CFL and P2 = horizontally positioned CFL

positioned CFL with a square shade except for three adjectives, nonproblematic. nonglare and balanced. For a vertically positioned CFL with a round shade, students rated means of all adjectives higher than the mean ratings for a vertically positioned CFL with a polygon shade except for two adjectives, nonproblematic and nonglare. However, the means for a vertically positioned CFL with a polygon shade was rated higher on the adjectives of nonproblematic, nonglare, bright and clear than the means for a vertically positioned CFL with a round or square shade.

The means of adjectives for a horizontally positioned CFL with a circular shade were rated higher than the means for a horizontally positioned CFL with a square shade except for the adjectives of free and balanced. Students rated the means of all adjectives for a horizontally positioned CFL with a square shade higher than the means for a horizontally positioned CFL with a polygon shade except for the adjectives favor, like, and appealing.

Students' ratings of the means of adjectives for a horizontally positioned CFL with a round shade were also greater than the means for a horizontally positioned CFL with a polygon shade. The means of adjectives for a horizontally positioned CFL with a round shade were rated higher than the means of a vertically positioned CFL with the same shade. Students rated means of all adjectives for a horizontally positioned CFL with a square shade higher than for a vertically positioned CFL with a similar shade shape. Students' ratings of all means for a horizontally positioned CFL with a polygon shade were higher than the means for a vertically positioned CFL with the same shade.

Factor analysis. According to Flynn et al. (1979), the inspection of the rating scale that loads highly on a factor indicates the nature and the name of the factors. The naming of the scales was also based on theoretical background and the investigator's knowledge. The CS was found to have five distinct subscales. The subscales were labeled as preference, comfort, brightness condition, lighting problem, and lighting condition. The five factors were retained because the grouping of the adjectives was similar to Bernecker et al. (1993) and Rea's (1981) studies. The adjectives were also grouped into five factors based on Flynn et al.'s (1979) recommendations and theoretical background.

Principal factors' extraction with varimax rotation was performed through the Kaiser Normalization rotation method on 22 items from the CS for a sample of 90 students. Principal components' extraction was used prior to principal factors' extraction to estimate number of factors, presence of outliers, absence of multicollinearity, and factorability of the correlation matrices. Five factors were extracted (see Table 4.2). As indicated by CS, all factors were internally consistent and well defined by the variables; the lowest of the CS for factors from variables was for the adjective large (.30) and the highest factor was appealing (.83). The factorial analysis generated five subscales that were labeled as acceptable, and balanced were labeled as preference. Comfort, ease, spacious,

Table 4.2

Rotated Factor Matrix for the CS

Adjectives	Preference Factor 1	Comfort Factor 2	Brightness Factor 3	L. Problem Factor 4	L. Condition Factor 5	Eigen E. V.	Variance %
Appealing	.83					9.64	43.8
Pleasant	.75					1.69	7.7
Attractive	.63					1.39	6.3
Like	.63					1.19	5.4
Favor	.61					1.06	4.8
Acceptable	.58					.98	4.4
Balanced	.48					.80	3.6
Comfort		.47				.70	3.2
Ease		.70				.69	3.1
Spacious		.61				.62	2.8
Satisfied		.59				.49	2.2
Relaxed		.58				.43	1.9
Free		.56				.42	1.9
Adequate		.56				.36	1.6
Easy		.55				.28	1.3
Bright			.62			.25	1.1
Clear			.57			.24	1.1
No Problem				.73		.22	.99
No Glare				.62		.18	.83
Uniform					.58	.17	.78
Focused					.34	.13	.57
Large					.30	.10	.39

Notes: Factor 1: preference, Factor 2: comfort, Factor 3: brightness condition, Factor 4: lighting problem, Factor 5: lighting condition.
E. V. = Eigen values
% = percent of variance

adjectives bright and clear were labeled as brightness condition, the adjectives nonproblematic and nonglare were labeled as lighting problem, and the adjectives uniform, focused and large were labeled as lighting condition. Although the CS consisted of five subscales, the adjectives were all designed to measure comfort, and the adjectives were found to have a high correlation with each other (see Table 4.3).

Reliabilities. Reliabilities of the subscscales (Preference, Comfort, Brightness Condition, Lighting Problem, and Lighting Condition) of the CS were assessed by calculating Cronbach's alpha coefficient. As a result, alpha coefficients of .92, .89, .85, .78, and .74 were obtained for Preference, Comfort, Brightness Condition, Lighting Problem, and Lighting Condition (see Table 4.3). All subscales' reliabilities were above .70.

Relationship between CS Subscales and Shade Shape and CFL Position.

Table 4.4 illustrates the relationship between preference, comfort, brightness condition, lighting problems, and lighting conditions and shade shape and CFL burning positions. This analysis was conducted to clearly describe the subscales' relationship with the independent variables (shade shape and CFL burning position).

Preference. The preference mean for the horizontally positioned CFL with a round shape was more (5.60) than the preference mean for vertically positioned

Table 4.3

Correlation Matrix Between CS Subscales for University Students

Subscales	1	2	3	4	5
			Students (N = 90)		
1. Preference	--	.79**	.62**	.26*	.21*
2. Comfort	.79**	--	.61**	.24*	.26*
3. Brightness condition	.62**	.61**	--	.21*	.56**
4. Lighting problems	.26*	.24*	.21*	--	.23*
5. Lighting condition	.21*	.26*	.56**	.23*	--

Notes:
**. Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
1 = Preference, 2 = Comfort, 3 = Brightness Condition, 4 = Lighting Problems, 5 = Lighting Condition and -- indicates no estimation.
Reliability Coefficients:
Preference = .92 (number of items = 7)
Comfort = .89 (number of items = 8)
Brightness condition = .85 (number of items = 2)
Lighting problems = .78 (number of items = 2)
Lighting condition = .74 (number of items = 2)

Table 4.4

Description of the Five Subscales and the Shade Shape and CFL Burning Position

Subscales	Shape	Position	Mean	Std. Deviation	N
Preference	1	1	5.2	1.05	15
		2	5.6	.71	15
		Total	5.4	.92	30
	2	1	4.5	1.30	15
		2	5.0	.96	15
		Total	4.8	1.16	30
	3	1	4.1	1.33	15
		2	5.1	1.17	15
		Total	4.6	1.34	30
	Total	1	4.6	1.29	45
		2	5.3	.98	45
		Total	4.9	1.19	90
Comfort	1	1	5.3	. 72	15
		2	6.1	.60	15
		Total	5.6	.77	30
	2	1	4.6	1.09	15
		2	5.8	.66	15
		Total	5.1	1.06	30
	3	1	4.2	. 92	15
		2	5.3	.74	15
		Total	4.8	.98	30
	Total	1	4.7	1.00	45
		2	5.7	.72	45
		Total	5.2	1.00	90
Brightness	1	1	4.8	1.19	15
		2	5.1	.99	15
		Total	5.0	1.09	30
	2	1	3.4	1.61	15
		2	4.9	.80	15
		Total	4.2	1.47	30
	3	1	3.8	1.05	15
		2	4.5	1.27	15
			4.2	1.21	30
	Total	1	4.0	1.41	45
		2	4.9	1.05	45
		Total	4.4	1.31	90
Lighting Problems *	1	1	5.1	1.49	15
		2	5.9	1.20	15
		Total	5.5	1.39	30
	2	1	5.2	1.24	15
		2	5.7	.99	15
		Total	5.5	1.12	30
	3	1	5.6	.86	15
		2	5.2	1.54	15

Table 4.4 Continued.

Description of the Five Subscales and the Shade Shape and CFL Burning Position

Subscales	Shade	Position	Mean	Std, Deviation	N
		Total	5.4	1.25	30
	Total	1	5.3	1.21	45
		2	5.6	1.27	45
		Total	5.4	1.25	90
Lighting Condition	1	1	4.5	.84	15
		2	6.7	6.19	15
		Total	5.6	4.49	30
	2	1	4.9	2.31	15
		2	4.8	.69	15
		Total	4.9	1.68	30
	3	1	4.0	1.00	15
		2	4.5	.82	15
			4.2	.93	30
	Total	1	4.5	1.54	45
		2	5.3	3.68	45
		Total	4.9	2.84	90

Notes:
Shade 1 = round, shade 2 = square, and shade 3 = polygon
CFL position 1 = vertical, CFL position 2 = horizontal
* = Higher rating mean fewer problems.

CFL with the similar shade (5.26). The preference mean for horizontally positioned CFL with a square shade (5.00) was much higher than the preference mean for vertically positioned CFL with the similar shade (4.50). For a polygon shade, the preference mean was much higher (5.10) for a horizontally positioned CFL than the preference mean for a vertically positioned CFL (4.10). Students preferred a horizontally positioned CFL with a square and a polygon shade to a vertically positioned CFL with similar shades.

Comfort. The comfort mean for a horizontally positioned CFL with a round shade was 6.10 and the comfort mean for a vertically positioned CFL with a round shade was 5.25. The comfort mean for a horizontally positioned CFL with a square shade was higher (5.80) than the comfort mean for a vertically positioned CFL with a similar shade (4.60). For a polygon shade, comfort mean of a horizontally positioned CFL is 5.30 and the comfort mean of a vertically positioned CFL was 4.23. Students rated a horizontally positioned CFL with any of the three shade shapes as more comfortable than a vertically positioned CFL with similar shades.

Brightness condition. The brightness condition was rated higher (5.10) for a horizontally positioned CFL with a round shape than for a vertically positioned CFL with a similar shade (4.80). Students' ratings on the brightness condition for a horizontally positioned CFL with a square shape was 4.93 and students' rating on the brightness condition for a vertically positioned CFL with a similar shade was 3.40. For a polygon shade, the brightness condition was rated 4.53 and for a vertically positioned CFL with similar shade, the brightness condition was rated 3.77 Students rated brightness condition for a horizontally positioned CFL with a round shade, a rectangular shade, or a polygon shade higher than brightness condition for a vertically positioned CFL with similar shades.

Lighting problem. Lighting problem (no problem, no glare) was rated 5.90 for a horizontally positioned CFL with a round shape and 5.10 for a vertically positioned CFL with a similar shade. Lighting problems rating was also higher for a horizontally positioned CFL with a square shade (5.70) than a vertically positioned CFL with a similar shade (5.20). However, the lighting problems rating for a horizontally positioned CFL with a polygon shade was lower (5.17) than a vertically positioned CFL with a polygon shade (5.57). Lighting problem ratings for a horizontally positioned CFL were higher (i.e., less problematic and less glare) for a round shade and a square shade than for a vertically positioned CFL with similar shades.

Lighting condition. Students rated lighting conditions for a horizontally positioned CFL with a round shade more (6.73) than a vertically positioned CFL with a similar shade (4.47). However, for a horizontally positioned CFL with a square shade, the rating was less (4.84) than a vertically positioned CFL with a square shade (4.91). Students rated lighting conditions for a horizontally positioned CFL with a polygon shade higher (4.47) than for a vertically positioned CFL with a similar shade (4.02). Lighting condition ratings for a horizontally positioned CFL were higher for all shades shape compared to lighting conditions for a vertically positioned CFL with similar shades.

Significance Tests

A 3 X 2 between-subjects multivariate analysis of variance was performed on five dependent variables: preference, comfort, brightness condition, lighting problems, and lighting conditions. Independent variables were shade shape (round, square, and polygon) and CFL burning position (vertical and horizontal). SPSS 8.0 MANOVA was used for the analyses with the sequential adjustment for nonorthogonality. Order of entry of independent variables was shade shape, then CFL position. Results of evaluation of assumptions of normality, homogeneity of variance-covariance matrices, linearity, and multicollinearity were satisfactory.

Hypothesis 1

Hypothesis 1 stated that there is a difference in overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to lamp shade shape. A 3 x 2 between-subjects multivariate analysis of variance was performed on the five dependent variables: preference, comfort, lighting problems, brightness condition, and lighting condition. Independent variables of this study were shade shape and CFL burning position.

SPSS MANOVA was used for the analysis with the hierarchical (default) adjustment of nonorthogonality. Order of entry of IVs was shade shape, then CFL burning position. The results of MANOVA for hypothesis 1 are presented in Table 4.5 and Table 4.6. Significant main effects were observed for preference,

Table 4.5

The Effect of Shade Shape on Comfort

ShadeEffect	Test Name	Value	F	Hypothesis df	Error df	Sig. p-level
	Pillai's Trace	.22	2.04	10	162	.03*
	Wilks' Lambda	.78	2.09	10	160	.03*
	Hotelling's Trace	.27	2.14	10	158	.03*
	Roy's Largest Root	.24	3.85	5	81	.00*

Note:
* = Significance at the .05 level.

Table 4.6

Follow-up Univariate F-test on Shade Shape Effects

Shape Effect	Dependent Variables	df	Mean square	F	Sig.
	Preference	2	5.65	4.61	.01*
	Comfort	2	5.60	8.53	.00*
	Brightness	2	6.54	4.70	.01*
	Lighting Problem	2	.14	.09	.92
	Lighting Condition	2	13.80	1.78	.18

Note:
* = Significance at .05 level.

comfort, brightness condition, lighting problems, and lighting conditions. With the use of Wilks' criterion, the combined DVs were significantly affected by shade shape, F (5, 90) = 2.09, $p < .05$.

Follow-up Univariate F-test demonstrated a significance in preference F (1, 90) = 4.61, $p < 0.5$, significance in comfort F (1, 90) = 8.53, $p < .05$, significance in brightness condition F (1, 90) = 4.70, $p < .05$, non-significance in lighting problems F (1, 90) = .09, $p < 0.5$, and non-significance in lighting condition F (1, 90) = 1.78, $p < .05$ for lamp shade shape differences.

Tukey's honestly significance difference test (HSD) was performed to the CS responses to compare individual treatments (see Table 4.7). With $\alpha = .05$, the test showed that students' lighting preferences for round and polygon shades were different. Students' comfort level under test lighting for round and polygon shades were different and students' brightness perception under test lighting for round, square, and polygon shades were different. Post hoc analysis also showed that student's perception of lighting problems and lighting conditions under the test lighting were not different for the three shades tested.

Hypothesis 2

Hypothesis 2 stated that there is difference in overall comfort (preference. comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to the CFL burning position. A 3 x 2 between-subjects multivariate analysis of variance was performed on the five dependent variables:

Table 4.7

Tukey HSD Post Hoc Comparison

Dependent Variables	(I) Shape	(J)Shape	Mean Difference	Std. Error	Sig.
Preference	1	2	.64	.28	.07
		3	.83	.28	*.01
	2	1	.64	.28	.07
		3	.19	.28	.78
	3	1	.83	.28	*.01
		2	.19	.28	.78
Comfort	1	2	.48	.21	.07
		3	.86	.21	*.00
	2	1	.48	.21	.07
		3	.39	.21	.16
	3	1	.86	.21	*.00
		2	.39	.21	.16
Brightness Condition	1	2	.80	.31	*.03
		3	.82	.31	*.02
	2	1	.80	.31	*.03
		3	.67	.31	.99
	3	1	.82	.31	*.02
		2	.67	.31	.99
Lighting Problems	1	2	.50	.32	.99
		3	.13	.32	.91
	2	1	.50	.32	.99
		3	.33	.32	.96
	3	1	.13	.32	.91
		2	.33	.32	.96
Lighting Conditions	1	2	.72	.72	.58
		3	.35	.72	.15
	2	1	.72	.72	.58
		3	.63	.72	.65
	3	1	.36	.72	.15
		2	.63	.72	.65

Note:
* = The mean difference is significance at the .05 level.

preference, comfort, lighting problems, brightness condition, and lighting condition. Independent variables were shade shape and CFL burning position.

SPSS MANOVA was used for the analysis with the hierarchical (default) adjustment of nonorthogonality. Order of entry of IVs was shade shape, then CFL burning position. The results of MANOVA for hypothesis 2 are presented in Table 4.8 and Table 4.9. Significant main effects were observed for preference, comfort, brightness condition, lighting problems, and lighting conditions. With the use of Wilks' criterion, the combined DVs were significantly affected by CFL burning position, $F(5, 90) = 7.92$, $p < .05$.

Follow-up Univariate F-test showed a significance in preference $F(1, 90) = 8.71$, $p < .05$, significance in comfort $F(1, 90) = 33.53$, $p < .05$, significance in brightness condition $F(1, 90) = 12.46$, $p < .05$, non-significance in lighting problems $F(1, 90) = 1.12$, $p < .05$, and non-significance for lighting condition $F(1, 90) = 2.25$, $p < .05$ for CFL burning position differences.

Hypothesis 3

Hypothesis 3 stated that there is an interaction between shade shape and CFL burning position based on the comfort responses. A 3 x 2 between-subjects multivariate analysis of variance was performed on the five dependent variables: preference, comfort, lighting problems, brightness condition, and lighting condition. Independent variables were shade shape and CFL burning position.

Table 4.8

The Effect of CFL Position on Comfort

Position Effect	Test Name	Value	F	Hypothesis Df	Error df	Sig. p-level
	Pillai's Trace	.331	7.92	5	78	.00*
	Wilks' Lambda	.669	7.92	5	78	.00*
	Hotelling's Trace	.495	7.92	5	78	.00*
	Roy's Largest Root	.495	7.92	5	78	.00*

Note:
* = Significance at .05 level.

Table 4.9

Follow-up Univariate F-test on CFL Position Effects

CFL Position	Dependent Variables	df	Mean square	F	Sig.
	Preference	1	10.68	8.71	0.00*
	Comfort	1	22.00	33.53	0.00*
	Brightness	1	17.34	12.46	0.00*
	Lighting Problem	1	1.74	1.12	0.29
	Lighting Condition	1	17.48	2.25	0.14

Note:
* = Significance at .05 level.

SPSS MANOVA was used for the analysis with the hierarchical (default) adjustment of non orthogonality. Order of entry of IVs was shade shape, then CFL burning position. The results of MANOVA for hypothesis 3 are presented in Table 4.10 and Table 4.11. Significant interaction effects were observed for preference, comfort, and brightness condition. The analysis did not show any significant effect for lighting problems and lighting conditions.

With the use of Wilks' criterion, the combined DVs were significantly affected by the interaction of shade shape and CFL burning position, F (5, 90) = 1.95, $p <$ .05. The results reflected a strong association between the CFL burning position and the DVs.

Follow-up Univariate F-test showed a significance in preference F (1, 90) = 4.61, $p < .05$, a significance in comfort F (1, 90) = 8.53, $p < .05$, a significance in brightness condition F (1, 90) = 4.70, $p < .05$, a non-significance in lighting problems F (1, 90) = .09, $p < .05$, and a non-significance for lighting condition F (1, 90) = 1.78, $p < .05$ for CFL burning position differences. These findings support the results from the Post Hoc test.

Task Illumination Measurement

Task illumination for the six task conditions was measured in order to compare the readings with previous findings on candlepower distribution and the CS responses. Task illumination readings taken prior to each test are presented in Table 4.12. The task illumination reading for the table lamp with the vertically positioned CFL and round shade were higher (68 footcandle) than task

Table 4.10

The Interaction Between Shade Shape and CFL Burning Position on Comfort

Interaction Effect	Test Name	Value	F	Hypothesis df	Error df	Sig. p-level
	Pillai's Trace	.222	1.97	10	158	.040*
	Wilks' Lambda	.790	1.95	10	156	.042*
	Hotelling's Trace	.251	1.93	10	154	.045*
	Roy's Largest Root	.151	2.39	5	79	.045*

Note:
* = Significance at .05 level.

Table 4.11

Follow-up Univariate F-test on CFL Position and Shade Shape Interaction

Shape and Position	Dependent Variables	df	Mean square	F	Sig.
	Preference	2	5.65	4.61	.01*
	Comfort	2	5.60	8.53	.00*
	Brightness	2	6.54	4.70	.01*
	Lighting Problem	2	.14	.09	.92
	Lighting Condition	2	13.80	1.78	.18

Note:

* = Significance at .05 level.

illumination reading for the table lamp with the vertically positioned CFL and polygon shade (60 fc). Task illumination for the vertically positioned CFL and a polygon shade (60 fc) was higher than the vertically positioned CFL with a square shade (56 fc).

The task illumination reading for the table lamp with a horizontally positioned CFL and a round shape was higher (78 fc) than task illumination reading for a horizontally positioned CFL with a polygon shade (74 fc). The task illumination reading for a horizontally positioned CFL with a polygon shade shape was higher (74 fc) than the task illumination reading for a horizontally positioned CFL with a square shade (72 fc). Task illumination readings for the CFLs with a round shade shape were higher than task illumination readings for CFLs with a polygon shade and CFLs with a square shade. Readings for table lamp shades with a horizontally positioned CFL were higher than readings for table lamp shades with a vertically positioned CFL. A horizontally positioned CFL with a round shade shape had the highest task illumination reading compared to other CFL position and shade shape combinations.

Task Illumination and the CS Responses

The relationship between task illumination measured for each treatment and the CS responses is presented in Table 4.13. Task illumination for a table lamp with a vertically positioned CFL and a round shade was rated with a mean of 5.15 on preference, 5.25 on comfort, 4.80 on brightness condition, 5.10 on

Table 4.12

Task Illumination readings in Zone 1 (center of the task plane, 41 cm or 16 in from the light source).

	P1+S1	P1+S2	P1+S3	P2+S1	P2+S2	P2+S3
Readings (fc)	68	56	60	78	72	74

Notes:

P= CFL burning position where P1= Vertical and P2= Horizontal.

S= shade shape where S1= Round shade, S2= Square shade and S3= Polygon shade.

All measurements are in foot-candles (fc).

lighting problems, and 4.47 on lighting condition. Task illumination for a table lamp with a vertically positioned CFL and a square shade was rated with a mean of 4.48 on preference, 4.58 on comfort, 3.40 on brightness condition, 5.23 on lighting problems, and 4.91 on lighting condition. Task illumination for a table lamp with a vertically positioned CFL and a polygon shade was rated with a mean of 4.06 on preference, 4.23 on comfort, 3.77 on brightness condition, 5.57 on lighting problems, and 4.02 on lighting condition.

With a vertically positioned CFL, preference, comfort, and brightness conditions were rated highest for a table lamp with a round shade. Lighting problems (i.e., nonproblematic and nonglare) were rated highest for a table lamp with a vertically positioned CFL and a polygon shade. For a vertical CFL, lighting conditions were rated highest for a table lamp with a square shade.

Task illumination for a table lamp with a horizontally positioned CFL and a round shade was rated with a mean of 5.64 on preference, 6.01 on comfort, 5.13 on brightness, 5.90 on lighting problems (i.e., no problem and no glare), and 6.73 on lighting condition.

Task illumination for a table lamp with a horizontally positioned CFL and a square shade was rated with a mean of 5.04 on preference, 5.73 on comfort, 4.93 on brightness, 5.67 on lighting problems, and 4.84 on lighting condition. Task illumination for a table lamp with a horizontally positioned CFL and a polygon shade was rated with a mean of 5.08 on preference, 5.30 on comfort,

Table 4.13

Description on the Relationship between Task Illumination and Comfort Factors

Task Illumination		Preference	Comfort	Brightness Condition	Lighting Problems*	Lighting Condition
T1: 68 fc	Mean	5.15	5.25	4.80	5.10	4.47
	SD	1.05	.74	1.19	1.49	.84
T2: 56 fc	Mean	4.48	4.58	3.40	5.23	4.91
	SD	1.30	1.09	1.61	1.24	2.31
T3: 60 fc	Mean	4.06	4.23	3.77	5.57	4.02
	SD	1.33	.92	1.05	.86	1.00
T4: 78 fc	Mean	5.64	6.01	5.13	5.90	6.73
	SD	.71	.60	.99	1.20	6.19
T5: 72 fc	Mean	5.04	5.73	4.93	5.67	4.84
	SD	.96	.66	.80	.99	.69
T6: 74 fc	Mean	5.08	5.30	4.53	5.17	4.47
	SD	1.17	.74	1.27	1.54	.82

Note:

N = 15 and fc = footcandle

* = Lack of lighting problems (i.e., no problem and no glare)

4.53 on brightness condition, 5.17 on lighting problems, and 4.47 on lighting condition.

Preference, comfort, brightness condition, lack of lighting problems, and lighting conditions were rated highest for task illumination of a horizontally positioned CFL with a round shade. Comfort, brightness condition, lighting problems (i.e., no problem and no glare), and lighting conditions were rated higher for a table lamp with a horizontally positioned CFL and a rectangular shade than the same table lamp with a polygon shade. However, the students preferred a table lamp with a horizontally positioned CFL and a polygon shade to the same table lamp with a square shade.

Students rated preference, comfort, brightness condition, lighting problems, and lighting condition highest for a horizontally positioned CFL with a round shade compared to a horizontally positioned CFL with a square or a polygon shape shade. Likewise, students rated all factors (preference, comfort, brightness condition, lack of lighting problems and lighting conditions) highest for a horizontally positioned CFL with a round shape shapes.

University Students' Survey Responses

One hundred and eight Texas Tech University students (45 males and 63 females) signed-up to participate in the study. One hundred and five students agreed to participate and four students did not pass the eye test. Ninety responses were randomly selected from the remaining one hundred and one responses. The ninety responses were used in the final data analysis. Descriptive statistics were performed for the USS to identify students' demographic characteristics. The results are presented in the following sections.

There were a total of 31 male and 59 female students used in the data analysis. The female students constituted the majority (66%) of the sample. There were 14 18-year-olds, 34 19-year-olds, 12 20-year-olds, 11 21-year-olds, 7 22-year-olds, 5 23-year-olds, 1 25-year-olds, 2 26-year-olds, and 1 29-,30-, 33-, and 36-year-old students used for the study. There were 65 Caucasians, six African Americans, 17 Hispanics, one Asian, and one other ethnic students (American Indian) used for the study. Fifty students wore corrective eyewear or glasses, and 40 students had 20/ 20 vision.

There were six students who had difficulty seeing text close, fifty-one had difficulty seeing text far, and two students who had problems seeing text close and far. Six students had astigmatism and twenty students experienced no visual problems. There were three students who had a combination of astigmatism, difficulty seeing text close and difficulty seeing text far. There were 38 students who had problems with their eyes but did wear corrective eyewear or glasses.

There were 10 students who worked as student assistants, seven who performed clerical or secretarial work, eight who were professionals (nurse, teacher, manager, etc.), 14 who worked in sports, 14 who worked in the food service industry, seven who were involved in sales, one who was in agriculture, and 29 who were unemployed.

There were thirteen students who did not use a table lamp for study. Each day, eleven students used a table lamp for one hour, 20 students used a table lamp for two hours, 16 students used a table lamp for three hours, 13 used a table lamp for four hours, 10 students used a table lamp for five hours, and five students used a table lamp for six hours. One student used a table lamp for eight hours a day and one student used a table lamp for ten hours a day. A total of 85.6% of the students who participated used a table lamp for study everyday.

Twenty-four students stated that they had a problem using a table lamp at home. Sixty-six students stated that they did not have any problem using a table lamp at home. Glare, inadequate brightness, lack of uniformity, and lack of clarity were major problems identified. Eight students stated that inadequate lighting caused them to feel tired and fall asleep. Only one student had taken a lighting course.

There were 44 students who preferred blue over any other color. This constituted 48.9% of the total students. Sixteen students preferred green, ten students preferred red, four students preferred yellow, and sixteen students preferred other colors (purple, pink, etc.).

There were 69 students who preferred a polygon shape over other shapes. This constituted 76.7% of the total students. Fourteen students preferred a round shape and seven students preferred a square shade over other shade shapes.

CHAPTER V

DISCUSSION

Introduction

Task visibility and perceived visual comfort are important issues to be considered (Bernecker et al., 1993) for university students' working environment. The principal purpose of this study was to measure and determine the combination of shade shape and CFL burning position for task illumination that was most comfortable for university students. The second purpose of this study was to develop and evaluate a semantic differential scale used for measuring university students' visual comfort when reading under table lamp lighting.

The hypotheses were: (a) there is a difference in overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to lamp shade shape, (b) there is a difference in overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to CFL burning position, and (c) there is an interaction between shade shape and CFL burning position based on the overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students and their responses to the CS.

The discussion for this study is addressed in the following sections: (a) the development and evaluation of a measure of university students' comfort, (b) hypothesis 1, (c) hypothesis 2, (d) hypothesis 3, (e) relationship between the subscales, shade shape and CFL position, (f) task illumination measurement, (g) task illumination and the CS responses, (h) USS and the responses, (i) conclusions, (j) implications, (k) limitations of the study, (l) future considerations, and (m) summary of the study.

Development and Evaluation of a Measure of University Students' Comfort

CS mean rating. Flynn et al. (1979) suggested the calculation of rating means to provide a clear 'picture' of subjective reactions to the different lighting conditions. Through descriptive analysis of the responses for CS adjectives, there were significant differences among the means. This study further confirmed previous studies such as Flynn et al. (1979) and Bernecker et al. (1993) on the ability of a semantic differential scale to measure subjective impressions on lighting. Keeves (1998) stated that the adjectives in semantic differential scales did not accurately measure users' comfort and that the adjectives were not perfectly opposite. Therefore, the CS adjectives did not have a midpoint because the words used for each scale did not represent perfect negatives or opposite endpoints. The words had their own meaning. For example, the word visual comfort in this study was defined as a person's comfort perception towards the lighting conditions. Visual comfort in this study was not defined only as being glare-free. This study did not use a zero interval on the CS because of the argument by Forthman (1973) that a zero or a midpoint implied neutrality, ambivalence, and irrelevance.

Students rated all adjectives higher for a vertically positioned CFL with a rounder shade shape (round and polygon) except nonproblematic, nonglare, and balanced. The students also rated all adjectives higher for a horizontally positioned CFL with a rounder shade shape except favor, like, appealing, free, and balanced. Lighting that was distributed by a round shade and a polygon shade were perceived as being more comfortable, brighter and providing better lighting conditions than a square shade. The lighting distributed by rounder shades was also much preferred and was perceived to have fewer lighting problems than the lighting with a square shade.

Page et al. (1997) suggested that changing the shade geometry may improve the candlepower distribution of a CFL. Findings from this study suggest that a rounded shade shape distributes light much more comfortably, produces fewer lighting problems, and provides better lighting conditions and brightness. The students also preferred the lighting that was distributed by rounded shapes to that by square shades. Because the students were asked not to judge the fixture, there was no direct analysis on the relationship between shape shade preference identified in the USS and visual comfort.

Students rated the adjectives for a horizontally positioned CFL with a round, a square, and a polygon shade higher than the adjectives for a vertically positioned CFL with similar shade shapes. The table lamps with a horizontally positioned CFL were perceived as being more comfortable, more bright and providing better lighting conditions. Table lamps with a horizontally positioned

CFL were also preferred and were perceived to have fewer lighting problems than the lighting from table lamps with a vertically positioned CFL. The findings support Page's (1998) study regarding candlepower distribution of a vertically and a horizontally positioned CFL. According to Page (1998), a horizontally positioned CFL distributed the majority of the flux vertically and produced fewer brightness problems.

Principal factors. The CS was found to have five distinct subscales. The subscales were labeled as preference, comfort, brightness condition, lighting problem, and lighting condition. This finding agrees with Flynn et al.'s (1979) study that the adjectives used can be categorized into pertinent factors. The CS was developed to measure comfort of university students' reading under various table lamp lighting, and the use of the CS is suitable for this purpose only. Flynn et al. (1979) stated that there is no one set of scales suitable for all purposes, and the selection of the adjectives should represent pertinent factors.

Correlation. The CS consisted of five subscales that were found to be highly correlated with each other. This finding was consistent with Flynn et al.'s (1979) study that stated "if subjects tend to use each of the evaluative scales in a consistent manner, then the researcher would expect the scales to have high correlation (p. 101). Bernecker et al.'s (1993) study demonstrated that subjects were able to differentiate between uniform and non uniform lighting, and that the responses were highly correlated with visual comfort.

This study also revealed that the correlation power depends on the nature of the factors. For example, students' preference for a certain type of lighting depended more on comfort than on the lighting conditions or lighting problems. Brightness condition was more strongly related to lighting conditions than to lighting problems.

Reliabilities. Calculation of Cronbach's alpha showed that all the subscales had high reliability. All the reliabilities were more than .70. Bernecker et al. (1993) used a reliability of greater than .70 for subscales of visual comfort.

The Method. The investigator had access to a growing body of technical literature on the performance of CFL systems. Therefore, this study was able to utilize much relevant literature. Veitch et al. (1998) stated that poor research design, small sample sizes, and inappropriate use of statistical tests were factors that caused the poor quality and limited quantity of literature reviews on luminous conditions and the human needs. Therefore, previous theories, suggestions, and guidelines were incorporated into this study. The study was also documented with regard to the testing method and controlled for many confounding variables.

This research has considered and applied the findings and theoretical framework from previous research. However, there were limitations that should to be investigated and applied in the future studies to produce a more comprehensive result. No literature was found that identified the composition of students' age, gender, race, and other demographic characteristics needed for a sample to represent the general population. The study used university students as sample. The study assumed that the students represented a population of table lamp users. The degree of generalization to the population of table lamp users needs to be determined.

Hypothesis 1

Hypothesis 1 stated that there is a difference in overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions) of the university students due to lamp shade shape. Multivariate analysis showed that there was a significant difference in the students' comfort level based on the differences in shade shape.

The study established a relationship between shade shape and overall comfort (preference, comfort, brightness condition, lighting problems, and lighting conditions). Therefore, varying shade dimensions and geometry had an effect on overall comfort. This study supported Page et al.'s (1997) assumption that shade size, thickness, material, color, and form affect overall comfort.

The study also supported the statement made by Lawrence Berkeley Laboratory that lamp, ballast, and light fixture need to be considered as one. Therefore, when selecting a table lamp, users may want to consider the function of shade shape and the table lamp as a whole. By considering the function of each part and the entire luminaire, the users may eliminate many visual problems such as blinding glare, optical distortion, and excessive brightness associated with table lamp lighting.

The literature review suggested that there is a relationship between loss of light output (Page, 1998; Siminovitch et al., 1995), severe degradation of optical distribution (Page et al., 1997), and visual discomfort caused by glare (Serres et al., 1993). Thus, considering shape shade as a selection factor may minimize light output loss and optical distribution degradation.

The follow-up univariate F-test on shade shape effects showed that there were significant differences in preference, comfort, and brightness conditions due to shade differences. Although the follow-up Univariate F-test did not suggest differences in the lack of lighting problems and lighting conditions, overall tests on the CS produced a difference. Analysis of the relationship between the CS f factors with shade shape showed that students preferred and felt most comfortable reading under a table lamp with round shade as compared to square or polygon shades.

Preference for a rounder shade is a good indication that the consumers' will select the best shade shape that assures efficient light distribution. Round shades were much preferred and provided better comfort and better brightness conditions. The selection of rounder shades will also assure that the lighting will provide better comfort. Veitch et al. (1993) concluded that people believe that lighting is important to the achievement of a healthy and productive life, and that preference for lighting products that can benefit them will increase their belief in the product. Thus, more comprehensive information on how users respond to a shade factors and better communication of that information to the people who make decisions about lighting is needed.

Therefore, the researcher suggests seminars for building managers, engineers, and designers to educate them about the technologies that are available for retrofitting. Conway and Leslie (1992) suggested demonstration sites, serial publications, and testing on humans for new shades to develop a data base of information regarding lighting preferences.

The follow-up univariate F-test did not show differences in lighting problems and lighting conditions. This may due to the number of adjectives that related to lighting problems and lighting conditions. More adjectives may be required to measure lighting problems and lighting conditions. The insignificant differences may due to the adjective itself. The adjective pair, problem-no problem, may not be clear The adjectives may have been able to differentiate between the shades tested.

Mean comparison showed that students perceived a table lamp with a square shade as least comfortable and as having more lighting problems (i.e., glare). The students also perceived a table lamp with a square shade to have lower brightness and lighting conditions (i.e., uniform, focused and large). A square shade is more narrow in form and therefore restricts more of the lighting downward. This finding agreed with the IESNA (1993) statement that deep and narrow shades restrict downward and upward light.

A comparison of task illumination readings for table lamps used with round shades and similar table lamps used with square or polygon shades demonstrated that the former were perceived to be more bright and to provide better lighting conditions. However, Bernecker et al. (1993) stated that subjects may prefer a lighting environment that is neither too bright nor too dim, and that more light is not necessarily better. Therefore, the selection of shade shape depends on the table lamp application and the task performed. By considering the lamp shade and the shade factors such as size, material, color, and reflective properties, lighting designers and lighting manufacturers may able to increase consumers' acceptance of CFL lighting.

Hypothesis 2

Hypothesis 2 stated that there is a difference in comfort due to CFL burning position. Multivariate analysis showed that there is a significant difference in the students' comfort level based on the differences in CFL position. This finding supported the statement made by California University of Environmental Research (1996), Page et al. (1997), and Siminovitch et al. (1997) that lamp operating position plays a significant role in determining the efficacy of a table lamp system. The finding also supported the statement made by Page et al. (1997) that changing CFL angle or position helps light to be distributed efficiently and evenly.

This study added another dimension to previous findings that a table lamp retrofitted with a horizontally positioned CFL not only is more efficient, but also is much preferred, more comfortable, and brighter than a vertically positioned CFL. A horizontally positioned CFL also was perceived to have fewer lighting problems and to produce better lighting conditions. According to Dove (1996) and Essig (1997), differences in light output affected users' physical and psychological conditions. Veitch et al. (1998) also stated that light has a strong influence on human comfort.

The follow-up univariate F-test on CFL position effects showed significant differences in preference, comfort, and in brightness conditions based on CFL burning position. The follow-up Univariate F-test did not show any differences in lighting problems and lighting conditions. However, overall analysis of the CS showed that there is a significant difference in comfort level based on CFL burning position differences.

Users' belief in a certain type of lighting influences their preferences and perceived comfort (Veitch et al., 1993). Therefore, to increase the users' belief, preference, and perceived comfort, the users need to be knowledgeable about lighting. The proactive solution to this problem is twofold: better information about how users respond to CFL lighting and better communication of that information to the people who use CFLs.

The follow-up univariate F-test on CFL position effects did not show differences in lighting problems and lighting conditions. This may be due to the number of adjectives that related to lighting problems and lighting conditions. More adjectives may be required to measure lighting problems and lighting conditions. The insignificant differences may due to the adjective itself. The adjective pair problem-no problem may not be clear. The adjectives may not be able to differentiate between the CFL position tested.

This study supports the findings of Dove (1996), Essig (1997), and Veitch et al. (1998) that differences in lighting conditions can affect the user's physical and psychological responses. A comparison of task illumination readings for table lamps used with a vertical CFL and similar table lamps used with a horizontal CFL demonstrated that the latter were perceived to be more bright and to provide better lighting conditions. Therefore, a table lamp retrofitted with a horizontal CFL provides lighting that is more comfortable than a table lamp retrofitted with a vertical CFL. A table lamp retrofitted with a horizontal CFL is preferred more and is perceived to have better brightness condition. This finding supported Page et al.'s (1998) study that a table lamp retrofitted with a horizontal CFL not only provides better task illumination, but also better visual comfort.

Hypothesis 3

Hypothesis 3 stated that there is an interaction between shade shape and CFL burning position on visual comfort. Studies by Bodmann and Toison (1994), Bodmann, Haubner, and Marsden (1979), and Toison (1997) demonstrated that there is a relationship between brightness and illuminance. Toison's (1997) study showed that brightness and illuminance from different task sources affect visual behavior and visual comfort. Many of the experiments involved simple tasks such as reading and writing on a flat surface under different lighting conditions.

According to Toison (1997), many studies on visual comfort have demonstrated that this procedure is valid for real and complex situations. Therefore, this study replicated many of the experiments that measured visual comfort under different task lighting conditions.

Multivariate analysis indicated that there were significant differences in students' preference, comfort, and brightness condition due to the interaction of shade shape and CFL burning position. However, MANOVA did not indicate significant differences in students' impressions of lighting problems and lighting conditions. Page's (1998) study determined that a horizontally positioned CFL distributed light where users needed the most. This study supported Page et al.'s (1997) findings that not only is a horizontally positioned CFL more efficient but also it is perceived as more comfortable.

The result of the multivariate test also demonstrated that shade shape affected the light distribution and subjects' preference, comfort, and impressions of the brightness conditions. This finding supported Davis and Ji's assumption in Page et al. (1997) that both the lamp shape and the shade are likely to affect light distribution and users' behavior.

Bernecker et al. (1993) stated that visual comfort is an important factor to be considered in selecting task light. Aspects of visual comfort such as brightness condition and lighting condition were used to distinguish task lighting conditions (Bernecker et al., 1993). Therefore subjects' visual comfort also relates to brightness condition. Preference, visual comfort and brightness condition are important evaluating aspects to be considered when evaluating lighting conditions. Preference, comfort, and brightness conditions are important indications of the users' acceptance of a lighting product.

The follow-up univariate F-test on CFL position and shade shape interaction did not show any significant differences on lighting problems and lighting conditions due to shade shape and CFL position combination. This may due to the number of adjectives that related to lighting problems and lighting conditions. More adjectives may be required to measure lighting problems and lighting conditions. The insignificant differences may due to the adjective itself. The adjective pair problem-no problem may not be clear. The adjectives may not be able to differentiate between the lighting conditions tested. According to Flynn et al. (1979), the adjectives may not be appropriate to measure the lighting conditions differences. Thus, these adjectives may not be useful in measuring students' overall comfort due to shade shape and CFL position lighting.

The results from the analysis for each subscale with shade shape and CFL position were not as important as the main interaction between visual comfort and the shade shape and CFL position. This is because the subscales were found to be highly correlated and functioned to measure visual comfort. The direction of the relationship between the overall visual comfort and shade shape and CFL position is presented in the following section.

A horizontally positioned CFL used with a round shape was perceived to be brighter than a vertically positioned CFL used with similar shade. The study also found that a horizontally positioned CFL used with a round, a square, and a polygon shade emitted more light than a vertically positioned CFL used with similar shades.

Bernecker et al. (1993) indicated that perception of visual comfort is more dependent on the lighted surfaces than the lighting on the task. Rea's (1981) study did not support Bernecker et al.'s (1993) suggestion that perception of visual comfort depends on the lighted surface. Rea (1981) stated that variations in the reflective properties on the task and the lighting geometry strongly influenced the perceived contrast and performance of the visual task. Lighting geometry is defined as the shape of lighting on the task surface (Rea, 1981). Because this study used the same surface areas, it was concluded that the effect on preference and comfort came only from the lighting projected on the task. Based on Rea's (1981) study and this study, it can be concluded that lighting geometry affected perceived contrast and that lighting geometry was determined by the shade shape and CFL burning position.

Analysis of the relationship between the CS subscales and shade shape and CFL position showed that students preferred a horizontally positioned CFL used with a round, a square and a polygon shade to a vertically positioned CFL used with similar shades. Veitch et al. (1993) concluded that people believe that lighting is important to the achievement of a healthy and productive life, and in general they prefer the type of lighting that they believe will help them reach that end. Therefore, marketing the information on visual comfort for a horizontally positioned CFL to be used with a round, a square, and a polygon shade may help increase the consumers' acceptance of CFLs.

The study also found the students' preference and comfort was greater for a table lamp used with a horizontally positioned CFL regardless of the shade shapes. Stannard et al. (1994) stated that qualitative aspects of lighting such as visibility, comfort, aesthetics, and psychological effects are important to lighting design. The findings of this study further support conclusions made by Siminovitch et al. (1995 and 1997) that the qualitative aspects of lighting can predict the performance of an increasingly used CFL table lamp system with regard to user's health and physical comfort. Therefore, further study is needed to develop efficient methods to measure these qualitative aspects in order to understand the physical and psychological effects of light.

Analysis of the relationship between the CS subscales and shade shape and CFL position showed that students' perceived fewer lighting problems for a vertically positioned CFL used with a polygon shade. However, by means' comparison, lighting problems were fewer for a horizontally positioned CFL when used with a square and a round shade as compared to lighting problems when a vertically positioned CFL was used with a round and a square shade. This finding supports the hypothesis that there is a difference in students' comfort based on the shade shape and CFL position interaction.

Analysis of the relationship between CS subscales and shade shape and CFL position showed that students' perceived lighting conditions for a vertically positioned CFL used with a polygon shade were better than the perceived lighting conditions for the same CFL used with a round or a square shade. However, lighting conditions were perceived to be better for a horizontally positioned CFL when used with a round or a polygon shade. The study found that a square shade helped a vertically positioned CFL to direct the light output to where the light was needed the most. Comparison of the CS responses means further supported hypothesis 3 that there is a difference in visual comfort due to the interaction between shade shape and CFL burning position.

Relationship Between the Subscales, Shade Shape and CFL

A comparison between the five subscales with shade shape and CFL position suggests that the CS was able to measure what it was supposed to measure. The comparison showed that students preferred a horizontally positioned CFL to the vertically positioned CFL. Also task illumination for horizontally positioned CFLs were higher than vertically positioned CFLs. According to Ellis et al. (1995) and IESNA (1993), a user's ability to see small objects, to read fine print, and to adapt decreases under low illuminance. Therefore, students' ability to see objects, read fine print, and to adapt will be better under a table lamp with a horizontally positioned CFL.

According to Champness et al. (1995), factors associated with user complaints such as direct glare, inadequate lighting, and bothersome shadows need to be eliminated to increase user satisfaction, improve working conditions, and boost productivity. This study found that students clearly felt comfortable reading under a table lamp with a horizontally positioned CFL and a round shade. Therefore, shade variables and CFL factors, when considered, may eliminate other user complaints such as direct glare, inadequate lighting, and bothersome shadows.

According to Ellis et al. (1995) and Sanders et al. (1993), users' satisfaction levels increased with increased levels of illumination and were followed by a decrease in satisfaction at peak level. However, Bernecker et al. (1993) concluded that more lighting does not mean better lighting. By mean comparison, this study found that the students perceived a table lamp with a horizontally positioned CFL as having fewer lighting problems than a vertically positioned CFL.

This finding demonstrated that a horizontally positioned CFL not only distributed the light where it is most needed for visual tasks, but also was able to provide the best comfort, lighting conditions, and brightness conditions. A table lamp with a horizontally positioned CFL was also preferred by the students and perceived to have the least lighting problems.

Task Illumination Measurement

Task illumination readings for rounder (round and polygon) shades were higher than task illumination readings for a square shade used with the same CFL burning position. According to Sander et al., (1993) and Steffy's (1995) assumptions, the task illumination requirement for each student depends on many variables such as the age, the task type, and the reflectance value of the task surrounding. This study provides another variable, shade shape, to consider for task illumination.

Task illumination readings from a horizontally positioned CFL are much higher than task illumination readings from a vertically positioned CFL used with similar shades. The findings are consistent with Page's (1998) study that demonstrated a horizontally positioned CFL distributes light more effectively on task surfaces as compared to a vertically positioned CFL .

The burning position of a CFL is an important variable to consider in task illumination requirement. Ji et al. (1993) concluded that base-down operation of a CFL reduces the light output from the rated value and alters the light distribution. Ilg (1992) and Josephson et al. (1991) stated that lighting that is unevenly distributed bothers many table lamp users and further reduces the user's vision adaptation abilities. This study found that a horizontally positioned CFL when used with a round shade was able to provide the best uniformity.

Task illumination and CS Responses

Task illumination readings that were taken for each treatment can be compared with the responses for each treatment. This comparison was made to support the findings for the hypothesis and to link the previous studies on light distribution and fixture efficiency with this study.

Task illumination readings for treatments with a round shade were higher compared to the readings for other treatments with a square and polygon shade. This difference is consistent with the findings of hypothesis 1 in which there was a significant difference in visual comfort due to shade shape. The difference in task illumination readings is also consistent with the univariate analysis where visual comfort was rated the best for CFLs used with a round shade compared to other types of shades. This finding supported the comment Davis and Ji made in Page's (1998) study that lamp shades affect light distribution and perceived brightness. This study found that brightness conditions for CFLs used with a round shade were better than brightness conditions for CFLs used with other shade shapes.

Task illumination readings for treatments with a horizontally positioned CFL were higher compared to task illumination readings for treatments with a vertically positioned CFL. This difference is consistent with the findings of hypothesis 2 in which there was a difference in visual comfort due to CFL position. The differences in task illumination readings were also consistent with the univariate analysis where visual comfort was rated better for a table lamp with a horizontally positioned CFL compared to the vertically positioned CFL. This finding is consistent with Page's (1998) finding in which a horizontally positioned CFL distributed the light more evenly on the task surface compared to the vertically positioned CFL and therefore, increased user satisfaction.

Students felt most comfortable reading under a table lamp with a round shade and a horizontally positioned CFL (condition 4) compared to other shades and CFL position combinations. The students rated all subscales higher for a horizontally positioned CFL with a round shade than other shade and CFL position combinations.

The task illumination reading from condition 4 was the highest compared to the readings from other conditions. This difference is consistent with the finding in hypothesis 3 in which there was a significant difference in visual comfort due to shade shape and CFL position interaction. The difference in task illumination readings is also consistent with the univariate analysis in which visual comfort was rated the best for a horizontally positioned CFL with a round shade as compared to other types of shade and CFL position combinations. This supports the findings of Page et al. (1997) and Page (1998) in which a horizontally positioned CFL distributed light more evenly on the task surface compared to the vertically positioned CFL.

USS and the CS Responses

The study made the assumptions that the students were homogeneous and that the subjects' demographic characteristics would not influence the responses on CS. The assumptions were made because this study found no literature or theoretical framework that suggested subjects' demographic characteristics affected responses on visual comfort for table lamp lighting. The University Students' Survey (USS) was used in the study for identification of university students' demographic characteristics and the comments were used for descriptive purposes.

Individuals differ considerably in their response to task illumination (Sanders et al., 1993). Weston (1982) assumed that subjects' visual performance varies at different illumination levels. However, Sanders et al. (1993) did not clearly present the relationship of demographic characteristics and responses to task illumination. Bernecker et al.'s (1993) study found that there were differences in subjects' responses towards overhead lighting due to sex and age. Males and older age groups tended to be less sensitive to lighting changes (Bernecker et al., 1993). However, this study used only 16 subjects of the age of 40 and over. This study did not find any differences in the overall comfort responses due to sex and age.

According to de Boer and Fisher (1991), age affects visual efficiency. As the age of an individual increases, the relationship between task illumination and visual performance changes (de Boer et al., 1991). The researcher found that age affected responses toward task illumination only after the age of 50. This study used subjects between the age of 18 and 36, and de Boer et al.'s (1991) study did not discover any effect for the subjects below the age of 40. A study that examines a relationship between subjects' demographic characteristics and table lamp lighting is needed.

Based on the comments written on the USS, students perceived the lighting conditions for the table lamp with a vertically positioned CFL and a round shade to be pleasant and the atmosphere to be relaxing and comfortable.

However, there were a few students who thought that the lighting was a little dim and made the text look smaller. These comments were similar to responses on the CS. The adjectives comfort and relaxed were higher for a vertically positioned with a round shade than a square or a polygon shade. The mean for the adjective large was low compared to other means. Therefore, the students' comments supported their CS responses.

Students commented that the lighting for a table lamp with a vertically positioned CFL and a square shade was dim and made the text appear unclear. Dimness and glare were also detected in a table lamp with a vertical CFL and a polygon shade. The students' comments were consistent with the overall means for the adjectives bright and clear. This study found that a vertically positioned CFL used with a square shade provided task illumination that was lower than a round shade and a polygon shade. Findings from hypothesis 3 also suggested that a vertically positioned CFL used with a round and a square shade was perceived to have more lighting problems such as glare than a polygon shade.

There were two students who commented on the table lamp with a horizontally positioned CFL and a round shade. Both comments indicated that the lighting condition was sufficient and good for studying. According to the students, this type of lighting condition helped them focus on the reading material. The CS responses means on most adjectives for a horizontally positioned CFL and a round shade were high. Therefore, the students' comments in the USS were consistent with their responses for the CS. The responses means on comfortable and relaxed were the highest.

Many students thought that the lighting conditions in conditions 4 (horizontal CFL with round shade), 5 (horizontal CFL with square shade), and 6 (horizontal CFL with polygon shade) were excellent. However, several students stated that the lighting in conditions 5 and 6 were dim. CS response means also indicated that a horizontally positioned CFL used with a polygon shade and a square shade produced lower brightness. Because only one person took a lighting course, the study assumed that the students were not knowledgeable about lighting and the responses were based mostly on their perceptions.

Based on the USS responses, 48.9% of the students preferred blue over any other color. Warm lamp color temperatures may induce negative effects relative to comfort conditions (Anderson, 1989; Baron, Rea, & Daniels, 1992). Exposure to warm white lighting may cause a person to feel tired faster than when exposed to cool white lighting (North American Philips Lighting, 1984). However, this study did not find any relationship between color preference and overall comfort responses.

Color temperatures of the GE™ vertical CFL (3500 °K) and the GE™ Circline CFL (3000 °K) may were different and may have affected the students' preferences and visual comfort. In the future, researchers may investigate the effect of different color temperatures of CFLs on preference and visual comfort.

There were 76.7% students who preferred a polygon shape and 15.5% students who preferred a round shape. This study found that visual comfort of a CFL used with a round and a polygon shade were much better than a CFL used with a square shade. The students were advised not to look at the fixture and to concentrate their responses based on the lighting condition on the task. Therefore, the investigator concluded that the preference for rounder shapes was a good indication that consumers will select a shade shape that will provide better visual comfort and efficiency for the CFL table lighting system.

Numerous studies have demonstrated a relationship between shade shape and preference (Gerhardstein, 1995; Humphrey, Symons, Herbert, & Goodale, 1996; Makioka et al., 1996). Humphrey et al. (1996) concluded that rounder shapes were perceived as more delightful and comfortable. However, no studies were found that examined a relationship between shade shape and preference. Future studies on shade shape and preference will help lighting manufacturers market a shade that is suitable for CFL table lamps and a shade that provides both aesthetic value and comfort.

Conclusions

Understanding the psychological and physical effects of CFL lighting is important to accelerate the implementation and acceptance of CFL lighting in residential and commercial settings. Researchers and manufacturers agree that to increase users' satisfaction and energy savings, the table lamp components need to be considered as one. Thus far, research has focused mainly on the CFLand its function. However, shade shape played a very important part in regulating the light output and the lighting perceptions of the users.

This study was conducted with careful consideration of previous findings on the measurement and effect of shade shape and CFL burning position on users' visual comfort. The study found that the CS was able to measure subjects' impressions or perceptions of visual comfort. Therefore, this study helps confirm previous studies on the ability of the semantic differential scale to measure subjective impressions. Factor analysis was able to categorize the adjectives into factors that were highly correlated. This study concluded that all factors can be used to measure visual comfort, but the correlation power depends on the meaning of the factors. This conclusion supports Flynn et al. (1979) study.

Assumptions made by lighting researchers that shade shape may affect the psychological and physical comfort associated with the use of CFL table lamp were supported. Preference, comfort, and brightness conditions were affected by the differences in shade shape. Consideration of shade characteristics, such as shape, size, and material, may help reduce visual problems associated with CFL table lamps. For example, this study suggested that a polygon shade was able to compensate for the perceived problems of a vertically positioned CFL. To accelerate the acceptance of the vertically positioned CFL and the horizontally positioned CFL, marketers need to include the information about the effect of the shade shape on visual comfort and light distribution. This research may be the first study to assess the effects of lamp shade shape on visual comfort. CFL burning position was found by several researchers to affect light distribution. A horizontally positioned CFL was found to be more efficient in distributing the light where it is needed the most for task performance.

Findings from this study strongly supported the research on CFL burning positions. The study added another dimension to the previous findings in that a table lamp retrofitted with a horizontally positioned CFL not only is more efficient than a vertically positioned CFL, it also is much preferred and perceived as more comfortable and brighter. Future researchers need to assess the effect of triple tube lamps and helical lamps on visual comfort and responses.

The study supported many assumptions made by previous researchers that changing CFL burning orientation and shade type affect the light distribution and users' perceptions. A horizontally positioned CFL was more effective regardless of shade shape. However, what can we do with the vertical CFLs that are already in the market? This study found that a vertically positioned CFL was perceived to have fewer lighting problems (i.e., glare) when used with a polygon shade. However, overall analysis of the visual comfort indicated that a vertically positioned CFL performs best with a round shade.

By considering the findings of this study and other research findings we will be able to determine the optimal shade to use with the vertical CFLs that are on the market. It is unfortunate that the effects of shade shape were not evaluated before the lighting manufacturers marketed the vertical CFLs. Lighting manufacturers and lighting designers are concentrating on the development of CFL and are ignoring the effect of the whole fixture on human comfort.

The measurement of task illumination and the comparison of previous findings on candlepower distribution have helped to validate the findings of this study. Table lamps retrofitted with a horizontal CFL and a round shade were found to be most efficient and perceived to be most effective in enhancing visual comfort. Additionally, the horizontal CFL was perceived as having the least lighting problems. According to Page (1998), a horizontal CFL also distributes light most efficiently on the task area compare to other lamp.

This study is merely the beginning in our understanding of the effect of CFL fixtures on human psychological and physiological well-being. A comprehensive program of testing of CFL systems on the consumers' well-being needs to be established. Consumers, manufacturers, retailers, and designers need to collaborate to improve the functioning of the CFL fixture. The future of the CFL will be bright if consumers understand and have confidence in CFLs.

Implications

The findings from this study suggest that the procedures for rating subjective impressions and comfort can be applied usefully in lighting research. This work affirmed previous theories and findings that visual comfort and perceptions associated with lighting are measurable. More specifically, this study reinforces and articulates the need for engineers and designers to be sensitive to lighting performance that is broader than the fundamental task-oriented quantitative standards designed to support reading, writing, typing and other similar visual tasks. This study suggests that lighting designers and manufacturers can manipulate visual comfort and work conditions. While there has been substantial research in this area, further study is needed to develop comprehensive data on the effects of light from CFLs and shades on subjective environmental quality.

The study substantiated the importance of considering the lamp fixture wholistically and the effect of CFL burning orientation and shade shape on users' comfort. This study further increased the understanding of the advantages of current lighting options and may help to convince consumers and building owners to use CFLs for their visual comfort and operating cost benefits. Consumers need to be presented with information on light distribution and task illuminance of lamp shades in the purchase decision process. Problems such as low visual clarity and glare associated with residential and institutional lighting will be minimized if information about the effects of lamp shades and CFL position on visual comfort and light distribution is used in the product labeling of CFL products.

Lighting researchers, lamp designers, and lighting manufacturers could inform consumers through other forms of media such as television, seminars, and lay magazines. The information may help consumers select and use the luminaire appropriately. To develop a better table lamp and retrofitting process, designers of luminaires must consider and apply research findings regarding candlepower distribution and task illumination of different lamp shades with various CFL types.

Accelerating the penetration of CFLs into the residential and commercial markets will require strong industry participation that could be coordinated through relevant national technical groups and design associations including the Illuminating Engineering Society of North America (IESNA), American Society of Interior Designers (ASID), Association of Energy Engineers (AEE), American Institute of Architects (AIA), Interior Design Educators Council (IDEC). and IIDA (International Interior Design Association). In addition home building organizations, including the manufactured home industry and the National Association of Home Builders, could get involved. Many of these groups have experience introducing technologies to the home market (Siminovitch et al., 1995).

The 1994 Electric Power Research Institute survey found that consumers have four major complaints about CFLs: they are too expensive, they do not work with dimmers, they are unattractive, and consumers do not know where to use them (Page, 1998). By, considering the shade and the CFL type, many of the complaints can be solved. The high initial cost of CFLs may be offset by the improvement of visual comfort and lighting conditions. Consumers need to use the appropriate CFL fixture in places where it has the most effect on the visual comfort and performance, such as in a study or a visual task area.

Consumers, manufacturers, retailers, and energy providers could all benefit from improved information on the functioning of the fixture and the performance of CFL products. A comprehensive program of testing CFL systems in residential and commercial applications could enhance the basic technical understanding, while more research on CFLs and the fixture could improve the understanding of users' preferences, comfort, and satisfaction.

Better understanding of performance and consumer preferences could be used to develop a lighting performance labeling system. The Federal Trade Commission's Energy Guide labeling system or the National Fenestration Rating Council's model for windows may be transferable to lighting fixtures. Information on lighting end-use patterns, market structure, and consumer buying habits would help utilities to more accurately understand the contribution of lighting to their system loads, and to pinpoint specific market segments where the greatest energy savings can be achieved.

The incremental cost of higher-performance fixtures is clearly a hurdle that must be faced. Electric utilities have thus far led the nation in the use of financial incentives to build markets for energy-efficient technologies (Siminovitch et al., 1995). The most successful programs may offer significant financial incentives to manufacturers; buying down manufacturing costs translates into lower retail prices. Consumer financial incentives programs coordinated with demonstration programs can also help. Current rebate programs for screw-based technology could be balanced with progressively increased rebates for dedicated fixtures.

Another strategy is to offer a national design competition for the application and development of high-efficiency residential and commercial fixture, separately targeting specific fixture types, e.g., table lamps, or specific room applications, e.g., home office. This activity could be coordinated with the lighting design community and be given high visibility via lighting and interior design magazines.

A third complementary approach is to marshal the buying power of large purchasers. Buyer groups comprised of home builders, lighting retailers, housing management companies, and others could collectively demand large numbers of very efficient products, thereby reducing the risks fixture manufacturers must face when considering whether to modify their product lines.

Education is central to the goal of saving energy in residential lighting. To this end, efforts should be made to augment the IESNA reference, training and education programs and research nationally and regionally. Full-scale demonstrations, coordinated by manufacturers and utilities, can direct such efforts. Most manufacturers and utilities already have comprehensive educational demonstration centers and training programs that can be leveraged by a CFL program (Siminovitch et al., 1995).

Unlike utilities, states, or other regional organizations, the federal government is well positioned to craft a national program. Such a program could foster cooperation among various sub-industries and non-industry parties. Considerable past government investment in research and development and in information and technology transfer can be leveraged in this process. Toward this end, government bodies can provide state-of-the-art information: government resources channeled through the national laboratory network could be used to develop and operate a national technical center with an information dissemination program for manufacturers, lighting designers, and utilities.

The federal government could, likewise, legislate more stringent energy policies related to lighting. Voluntary and mandatory codes that require the use of dedicated CFLs or other highly efficient sources in new construction could be implemented. This would greatly accelerate the adoption of CFLs in the home and within the construction industry. This would also create a clear market for the fixture and lamp manufacturers. The government could also use its purchasing power: e.g., the US Department of Housing and Urban Development's public housing program and the Department of Defense's military housing could require the selective use of dedicated fixtures. These programs could be coordinated with a national competition wherein the winners receive contracts to provide the fixtures. With more than one million housing units, the public housing market would provide a significant market, sending a clear message to lighting manufacturers.

With few exceptions, current efforts to accelerate residential use of compact fluorescent systems have focused on rebate programs for screw-based, CFL retrofit systems. While such systems represent a simple approach to replacing incandescent lamps, they are at best a short-term solution. Several inherent technical, economic, and aesthetic integration problems with screw-based CFLs severely limit the long-term application of energy efficient lighting in the home (Page, 1998).

Dedicated fixtures using pin-based compact fluorescent lamps have the potential to successfully overcome those barriers (Page, 1998). However, the pin-based CFLs cannot function effectively without the consideration of the entire luminaire. Therefore, by considering the lamp fixture, lamp shade, and the utilization of dedicated fixtures, performance and aesthetics will be optimized. This also will significantly improve consumers' confidence in the new technology and in energy efficiency in general.

Recommendations for Future Research

Future research needs to test other shapes of CFLs such as diffuse types (bullet shape, globe shape), twin-tube, quad-tube, double-coiled tube, and triple-coiled tube. Different shapes of CFLs will produce different results. Ji and Davis (1993) demonstrated that diffuse types of CFLs that were vertically oriented, provided much higher illuminance on the ceiling compared to incandescent lamps and other vertically oriented lamps.

Siminovitch et al. (1994) concluded that fixture efficiency of CFLs used in recessed downlights can be increased by incorporating a thermal bridged system in the CFL and by tilting the lamp compartment. Therefore, future studies need to test the effect of different CFL positions on visual comfort and light distribution in other types of applications such as downlights, wall-mounted units, and pendants.

According to Economopoulos and Chan (1989), fluorescent lamps flicker at twice the rate of the incandescent lamps, and fluorescent light sources differ in the amount of light produced at various wavelengths. According to Widowski, Keeling, and Duncan (1992), perceptual, physiological, and reproductive processes are sensitive to specific features of light, and therefore, it is possible that the different light sources may affect behavior in different ways. Findings by

Aspinall et al. (1988), Widowski et al. (1992) and Zimmerman (1988) supported the concept that different CFL light sources affect behavior differently. In the future, the effects of different CFLs on animal and human behavior and on visual comfort need to be assessed.

Future studies need to address how materials and sizes of table lamp shades affect visual comfort and light distribution. According to Davis and Ji (cited in Page et al. 1997) perceived light from a table lamp system is as important as the efficiency. Both the lamp shape and the lamp shade affect light distribution and perceived brightness. Zonal lumens within the region of the shade are less for the circular CFL that the vertical CFL (Ji and Davis, 1993). Therefore, researchers may want to examine the effect of zonal lumens on user's visual comfort, brightness perception, and preference.

This study used a 20 watt, 1200 lumen GE™ vertical CFL and a 21 watt, 1200 lumen GE™ Circline. The results may be different for higher or lower lumen packages. Therefore, future studies need to test the performance of other lumen packages. Serres et al.'s (1993) study found that amalgam-based technology produced less than 5% difference between base-up and base-down lumen output. Unfortunately, amalgam CFLs take longer than standard CFLs to achieve full brightness and are less desirable in table lamp applications (Page et al., 1997). In the future, researchers may investigate the effect of a table lamp with an amalgam based design on user's visual comfort and preference.

Siminovitch et al.'s (1995) study found that internal thermal bridge system solved the light output inefficiency of CFL burning positions. Thermal-bridged lamps were claimed to have shorter warm-up times and cost less than amalgam lamps (Siminovitch et al., 1995). A table lamp consists of many parts, and future studies need to examine how a thermal bridged CFL interacts with different shade shapes, sizes, and materials.

According to Serres (1994), CFL designs are increasingly small because of the use of integral electronic ballasts. However, the reduction in size has increased thermal stress on electronic and plastic components and increased loading of the discharge tube (Hammer & Nerone, 1993; Serres, 1994). Future studies may want to look at the design of the CFL and the effect of reducing the size on human visual comfort. Will a smaller lamp require a different shade design? How will the combination of the new CFL with the new shade affect the visual comfort of the users? Therefore, the trend towards increasingly small CFLs provides a continuous challenge for the lighting designer.

The study investigated the visual comfort of university students reading under different task lighting conditions. Studies that examine the effect of a retrofitted CFL table lamp on other tasks are encouraged. Will the visual comfort change when other type of tasks such as writing or typing are performed? For example, what is the best task lighting condition when working with a computer? Collins, Treado, and Ouellette (1994) and Steffy (1995) suggested that the use of CFLs should be based on the task performed. However, no research has shown a correlation between task performance and the type of CFLs to be used.

Research that can establish a relationship between task performance and the CFL type is needed.

Future studies may want to examine consumers' acceptance of the findings from this study. Will the consumer be willing to trade aesthetic preferences for function? Studies by Biederman (1987) and Enns (1992) suggested that there is a strong relationship between shape and preference. The preference for a certain shape may influence purchase decision for a lamp shade.

Improving fixture design, incorporating retrofit products, and introducing skilled retrofitters may improve retrofits and increase consumer satisfaction (Page et al., 1997). Will consumers be willing to spend extra to hire a retrofitter, to buy additional products for retrofit or will they simply throw away their fixture?

The cost of CFL lamps is already a factor that discourages consumers from retrofitting A-lamps with CFLs (Page, 1998). Therefore, studies that examine the marketability of retrofit accessories, retrofitters, and fixtures that support retrofitting are needed. This study is a first effort to examine these aspects of task lighting. However, much additional work is necessary. Methodology needs to be refined. One should study the difference in performance as a result of lighting changes, the effects of contrast changes and changes in color, and the effects of lighting conditions. The investigator hopes that the techniques will be used and refined.

Summary of the Study

Compact fluorescent lamps have been used to replace incandescent lamps for energy savings. However, reports of negative user reactions to CFLs and CFL related products are common. In many cases the consumer are unsure of and dissatisfied with the performance of CFLs. Various attempts have been made to correct the problems and to increase the market for CFLs. Consumers will not replace their standard incandescent lamps just because the lighting manufacturers claim that CFLs are more efficient and can save money.

There are two important factors that need to be considered when retrofitting CFLS. First, is the users' visual comfort and second is the performance of the fixture as a whole. How effective is a Circline lamp if the consumer retrofits it into a forty-year-old portable lamp? People spend most of their time indoors and the effects of artificial lighting on human psychological and physiological well-being are documented. This study may be one of the first that addresses the importance of visual comfort of CFLs and may be the first that considers the shade shape and CFL fixture holistically.

The CS was developed to measure the users' comfort, and the study demonstrated its ability to measure what it is intended to measure. The findings further confirmed previous studies (e.g., Bernecker et al., 1993; Flynn et al., 1979) and demonstrated that the scale can be used in future studies to measure subjects' impressions of table lamp lighting. For a scale to perform effectively, the adjectives have to be highly correlated and have high reliabilities.

Varying shade geometry has a significant effect on visual comfort and light distribution on the task. This study confirmed the assumption made by previous researchers on the effects of shade on light distribution. Lighting designers, lighting manufacturers, and lighting retailers need to provide information to the consumers regarding the shade effect and shade efficiency for CFL table lamps. Lighting researchers and the media also must collaborate in marketing this information. This information can increase consumers' support of the product and accelerate the penetration of CFLs in the marketplace.

Differences in CFL burning position affects visual comfort and light distribution on the task. The study supported previous findings on the effect of CFL burning position on light distribution and provided new information that CFL burning position also affects users' visual comfort. Lighting researchers and lighting manufacturers need to further test the effects of various CFL types on users' visual comfort. The results of these studies may help eliminate the confusion and uncertainty that the CFL consumers are experiencing. Visual comfort and light distribution are affected by the interaction of shade shape differences and CFL burning position differences. This study confirmed the assumption made by previous researchers that CFL table lamp fixtures need to considered as a whole when evaluating light distribution. Lighting designers can select the appropriate shade for the type of CFL specified. Lighting manufacturers may want to market the information to consumers so that they will be able to appropriately choose the shade for the type of CFLs used. Future researchers may want to study the effect of the shade and CFL type on other applications such as wall mounted units or computer terminal use.

The information from this study can be used by lighting researchers, lighting designers, lighting manufacturers, and federal government agencies to increase the penetration of CFLs into residential and commercial markets. This study can be viewed as a first step in resolving perceived limitations of CFLs by consumers. This study emphasized that visual comfort associated with CFL table lamp systems is a very important issue and should not be ignored by lighting researchers, product designers, manufacturers, and retailers.

REFERENCES

Anderson, C, A. (1989). Temperature and aggression: Ubiquitous effects of heat on occurrence of human violence. Psychological Bulletin, 106, 74-96.

Anderson, L., & Noell, E. (1994). The aging population: Everyone would benefit from a fresh approach. Lighting Design and Application, 24(3), 32-36.

Aspinall, P. A., & Dewar, J. (1988). Lighting and perceived guilt. Lighting Research and Technology. 12(3), 14-27.

Barnaby, J. F. (1989). Lighting for productivity gains. Lighting Design and Application. February, 10(2), 121-140.

Baron, R. A., Rea, M. S., & Daniels, S. G. (1992). Effects of indoor lighting (illuminance and spectral distribution) on the performance of cognitive tasks and interpersonal behaviors: The potential mediating role of positive affect. Motivation and Emotion, 16(1), 1-33.

Bernecker, C. A., Davis, R. G., Webster, M. P., & Webster, J. P. (1993). Task lighting in the open office: A visual comfort perspective. Journal of the Illuminating Engineering Society, Winter, 18-25.

Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. Psychology Review, 94. 115-147.

Bodmann, H. W., Haubner, P., & Marsden, A. M. (1979). A unified relationship between brightness and luminance. Proceedings CIE 19th Session, Kyoto. 99-102.

Bodmann, H. W., & Toison, M. L. (1994). Predicted brightness-luminance phenomena. Lighting Research Technology, 26(3). 135-143.
California University Center for Environmental Research. (1996). Field Measurements of Light Shelf Performance in a Major Office Installation. Berkeley, CA: California University.

Champness, B., Hyland, M., & Oliver, K. (1995). Effects of fluorescent lighting on social behavior and judgements. Architectural Psychological Newsletter, 8,1.

Collins, B. L., Treado, S. J., & Oulette, M. J. (1994). Evaluation of compact fluorescent lamp performance at different ambient temperatures. National Institutes of Standards and Technology Reference, 11. 204-211.

Conway, K. M., & Leslie, R. P. (1992). Hurdling barriers to efficient lighting. Lighting Design and Application, 22(2), 26-31.

Dasgupta, S. (1997). Compact fluorescent lamps-the world standard in eco-friendly lighting. Electrical India, October. 33-40.

Davidson, J. (1997). The Complete Lighting Book: Contemporary Interior and Exterior Lighting for The Home. New York: Overlook Press.

de Boer, J. B., & Fisher, D. (1991). Interior Lighting. New York: Philips Technical Library.

Dillon, R., & Vischer, J., (1988). The Building in Use Assesment Methodology, 2. Ottawa, Canada: Public Works Canada.

Dove, M. (1996). Measurement of Illumination Levels and Workers' Perception of Lighting Quality in Office and Non-office Settings. OH: Medical College of Ohio.

Economopoulos, O. and Chan, K. M. (1989). Lighting Reference Guide. Ontario Hydro: Toronto, ON.

Eklund, N. H., & Boyce, P. R. (1996). The development of a reliable, valid, and simple office lighting survey. Journal of the Illuminating Engineering Society, Summer, 25-40.

Ellis, R. D., Amos, S., & Kumar, A. (1995). Guidelines for Workzone Illumination Design. Gainesville, FL: National Cooperative Highway Research Program.

Enns, J. T. (1992). The nature of selectivity in early human vision. Percepts, Concepts and Categories, 84(1). 39-74.

Essig, L. (1997). Lighting and The Design Idea. Madison, WI: Harcourt Brace College.

Fisher, J. D., Bell, P. A., & Baum, A. (1990). Environmental Psychology. New York: Holt, Rinehart, & Winston.

Flynn, J. E. (1972-73). The psychology of light. Electrical Consultant, series of eight articles, 88(12) - 89(7).

Flynn, J. E. (1977). A study of subjective responses to low-energy and nonuniform lighting systems. Lighting Design and Application, February, 7(2), 6-15.

Flynn, J. E. (1979). A guide to methodology procedures for measuring subjective impressions in lighting. Journal of the Illuminating Engineering Society. January, 95-110.

Flynn, J. E., Hendrick, C., Spencer, T. J., & Martynuik, O. (1979). A guide to methodology procedures for measuring subjective impressions in lighting. Journal of the Illuminating Engineering Society, 8(2), 6-14.

Flynn, J. E., & Spencer, T. J. (1977). The effects of light source color on user impression and satisfaction. Journal of the Illuminating Engineering Society, 6(3), 167-179.

Flynn, J. E., Spencer, T. J., Martynuik, O., & Hendrick, C. (1979). Interim study of procedures for investigating the effect of light on impression and behavior. Journal of the illuminating Engineering Society, 3(1), 87-94.

Forthman, J. H. (1973). The effects of a zero interval on semantic differential rotated factor loading. Journal of Psychology. 84, 23-32.

Gardner, C., & Hannaford, B. (1993). Lighting Design: An Introductory Guide for Professionals. New York: Wiley & Sons.

Gerhardstein, P. C. (1995). Viewpoint-dependent mechanisms in visual object recognition. Journal of Experimental Psychology: Human Perception and Performance, 21(1), 1506-1514.

Gillette, G., & Brown, M. (1986). Occupant Evaluation of Commercial Evaluation of Commercial Office Lighting, 1. Oak Ridge, TN: Oak Ridge National Laboratory.

Goldman, J., & Aldich, F. (1990). Optical discomfort from VDTs and fluorescent lighting. Journal of the American Medical Association, September 5, 264, 174.

Gulrajani, R. P. (1995). Physical environmental factors affecting patients' stress in the accident and emergency department. Accident and Emergency Nursing, 3(1), 22-27.

Huberty, C. J., & Morris, J. D. (1989). Multivariate analysis versus multiple univariate analyses. Psychological Bulletin, 105(2). 302-308.

Humphrey, G. K., Symons, L. A., Herbert, A. M., & Goodale, M. A. (1996). A neurological dissociation between shape from shading and shape from edges. Behavioral Brain Research, 76. 117-125.

Illumination Engineering Society of North America (IESNA). (1993). Lighting Handbook: Reference and Application. New York: Illuminating Engineering Society of North America.

Ilg, D. (1992). Senior communities. The Construction Specifier, 45(6), 120-122.

Institute for Research in Construction National Research Council of Canada (1994). Future Prospects in Lighting Research Development. Ottawa, Canada: Canadian Electrical Association.

International Safety Organization (ISO). (1989). ISO International Standard 8995.

Ji, Y., & Davis, R. (1993). Application testing of compact fluorescent lamps: table lamps and recessed downlights. IESNA Annual ConferencePaper. 1-22.

Josephson, K. R., Fabacher, D. A., & Rubenstein, L. Z. (1991). Home safety and fall prevention. Geriatric Home Care, 7(4), 708-731.

Keeves, J. P. (1988). Educational Research, Methodology, and Measurement: An International Handbook. Melbourne, Australia: Pergamon Press.

Kolanowski, A. (1992). Restlessness in the elderly: The effect of artificial lighting. Nursing Research, 39(3), 181-183.

Loasby, W. (1992). Creative Interiors. Nairn, Scotland: David and Charles.

Makioka, S., Inui, T., Yamashita, H. (1996). Internal representation of two-dimensional shape. Perception, 25, 949-966.

McMurdo, M. E. T., & Gaskell, A. (1991). Dark adaptation and falls in the elderly. Gerontology, 37, 221-224.

Mekjavic, I., & Banister, E. (1988). Environmental Ergonomics: Sustaining Human Performance in Harsh Environments. Philadelphia, PA: Taylor & Francis Publishing.

North American Philips Lighting. (1984). Lighting Handbook. Somerset, NJ: North American Philips Lighting.

Page, E. (1998). New research tool for energy-efficient residential fixtures. Lighting System Research. [On-line]. Available: Internet. File: http://eande.lbl.gov/cbs/newsletter/NL7/Gonio.html.

Page, E., Praul, C., & Siminovitch, M. (1997). Comparative candlepower distribution analysis for compact fluorescent table lamp systems. Journal of the Illuminating Engineering Society, Winter, 3-9.

Pirkl, J. J. (1994). Transgenerational Design: Products for an Aging Population. New York: Van Nostrand Reinhold.

Rea, M. S. (1981). Visual performance with realistic methods of changing contrasts. Journal of the Illuminating Engineering Society, 10(4), 164-177.

Rohles, F. H. Jr., & Miliken, G. A. (1981). A Scaling Procedure for Environmental Research. Paper for Presentation at the 1981 Proceedings of the Human Factors Society. Brooklyn, NY.

Sanders, P., & McCormick, E. (1993). Human Factors in Engineering and Design. New York: John Wiley & Sons, Inc.

Serres, A. W. (1993). On the photometry of integrated compact fluorescent lamps. Journal of Illumination Engineering Society, 8(2), 58-67.

Serres, A. W. (1995). On the photometry of integrated compact fluorescent lamps II. Journal of the Illuminating Engineering Society, Winter, 26-32.

Serres, A. W., Taelman, W. (1993). A method to improve the performance of compact fluorescent lamps. Journal of the illuminating Engineering Society, Summer, 40-48.

Siminovitch, M., & Mills, E. (1995). Dedicated CFL fixtures for residential lighting. Lighting Design and Application, March, 28-32.

Siminovitch, M., Pankonin, E., Praul, C., & Zhang, C. (1997). Improving the performance of integral screw-base compact fluorescent lamps in a base-down burning position using thermal bridge systems. Journal of the illuminating Engineering Society, Winter, 94-95.

Stannard, S., Keith, D., & Johnson, K. (1994). Predicted performance of a controlled lighting systems. Journal of the Illuminating Engineering Society, Winter, 69-78.

Steffy, G. (1990). Architectural Lighting Design. New York: Van Nostrand Reinhold.

Steffy, G. (1995). Lighting The Electronic Office. New York: Van Nostrand Reinhold.

Sundstrom, E., & Sundstrom, M. G. (1986). Workplaces: The Psychology of The Physical Environment in Offices and Factories. London: Cambridge University Press.

Tideiksaar, R. (1997). Falling in Old Age: Its Prevention and Treatment. New York: Springer Publishing Co.

Toison, M. L. (1997). Perceived contrast and visual comfort in interior lighting. Lighting Research Technology, 29(2). 80-82.

Veitch, J. A., Hine, D. W., & Gifford, R. (1993). End users' knowledge, beliefs, and preferences for lighting. Journal of Interior Design, 12(4). 40-52.

Veitch, J. A., & Newsham, G. R. (1998). Lighting quality and energy-efficiency effects on task performance, mood, health, satisfaction, and comfort. Journal of the Illuminating Engineering Society. Winter. 107-124.

Verderber, R., Rubinstein, F., & Siminovitch, M. (1988). Control of a Lamp Wall Temperature, Paper presented at the IEEE-IAS Annual Conference, Minneapolis, MN.

Weston, H. C. (1982). Sight, Light and Work. London: H.K. Lewis & Co.

Widowski, T. M., Keeling, L. J., and Duncan, I. J. (1992). The preferences of hens for compact fluorescent over incandescent lighting. Canada Journal of Animal Science, 72 (6), 203-211.

Zimmerman, N. G. (1988) Broiler performance when reared under various light source. Poultry Science, 67. 43-51.

APPENDIX A

CANDLEPOWER PLOTS

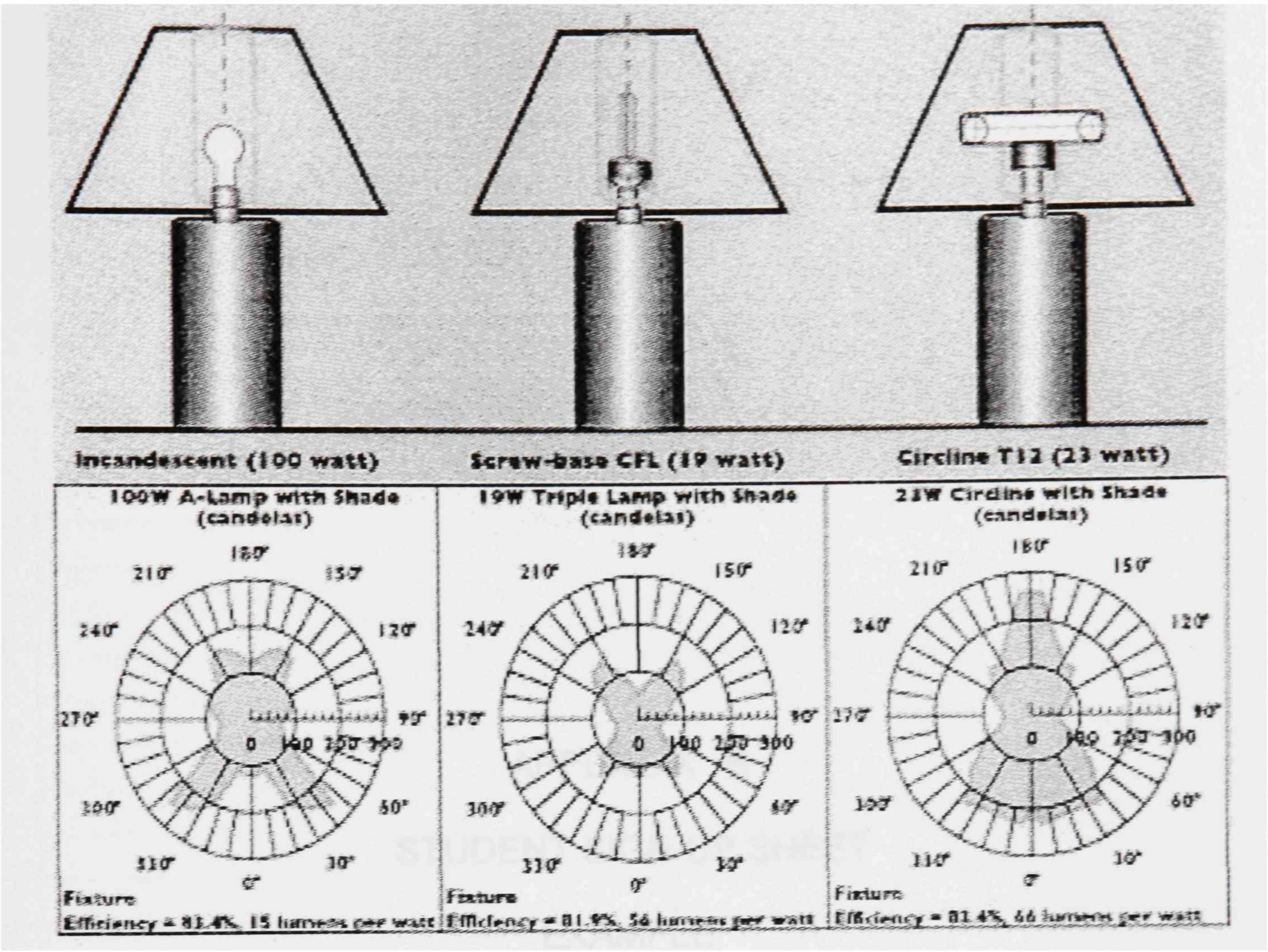


Figure A.1

From "New research tool for energy-efficient residential fixtures." by E. Page, 1998, *Lighting System Research.* [On-line]. Available: Internet. File: http://eande.lbl.gov/cbs/newsletter/NL7/Gonio.html.

APPENDIX B

STUDENT SIGN-UP SHEET

EXAMPLE

Sign-up Sheet

Date: Monday March 08/1999

Section 1

Name (First, Last)	Address	Phone	Time Slot	Edit Password	Note

Note: Research will be conducted in Room 63 Human Science Building. (basement).

APPENDIX C

PAMPHLET

Lighting Research
Information Sheet

Purpose of the study:

The purpose of the study is to evaluate the effects of table lamp shade shape and compact fluorescent lamp burning position on university student's visual comfort.

The criteria needed to qualify:

The student has to have a good vision and the student does not have to know about lighting.

What you will be doing?

All participants will be go through an eye test. Those who qualifies will be given ten minutes to complete a reading task and ten minutes to complete a comfort scale under a table amp lighting in a room. After the treatment, the participants will be asked to complete a questionnaire on their demographic characteristics. The responses will be used for this study only and will be destroyed after the study is completed.

The Prize

All participants will get a chance to enroll for a lottery. A $40 check will be given to one participant who participates per night. Check will be randomly drawn from the list of all students who present. The winners will be phoned no later than Friday, February the 12th.

Free Doughnut, Pizza and beverages will be served. You will also be informed on the result of the study.

Where do you need to go?

Go to the **human science building** by the memorial circle. Enter through the shorter part of the building. Take the elevator or stairs to the **basement** on the east side of the building. Watch for arrow and direction. The testing will be in **room 63.**

For more questions?

Please contact:

Researcher:	Zaidi Abdullah	745-5678
Research advisor:	Dr Marie Gentry	742-3050

Your time slot.
(write your time slot in below)

Monday (Feb. 08): ____________________

Tuesday (Feb 09): ____________________

Wednesday (Feb 10): ____________________

Thursday (Feb 11): ____________________

APPENDIX D

READING TEXT / ARTICLE

Cruising the Internet Highway: A Wealth of Information for Interior Design Educators

JANET M. SCHROCK, PH.D.

INTERNET ADDRESS: JANETS@SFSUVAX1.SFSU.EDU

■ ISSUE

A diversity of useful electronic information is available to interior design educators on the Internet.

■ APPLICATION

Interior design educators and practitioners can use their computers and terminals to find electronically stored information that is useful for lectures and presentations, course reading materials, advising, research, and travel.

■ GOAL

The Internet may be used to improve the efficiency of acquiring information for teaching and research.

■ DESCRIPTION

The Internet is a vast electronic network that has been developing for the last 20 years and it is becoming more user-friendly with more data useful to design and education than in years past. It is becoming a very valuable information source for educators from all disciplines, and it is free through most school computer networks.

■ CONCLUSION

Learning how to use the Internet can save a teacher time, money, and energy. An electronic search through the world's finest libraries takes hours instead of days and can reveal references that might be missed in a manual search. To find travel information an educator can sit in an office and search on-line data bases. There is no need to walk or drive to the library. Telecommuting can become a reality, leaving more time for interaction with students.

■ The following quotation was copied from an electronic file posted June 1, 1993, on the Internet, the world's largest computer network:

> Dear Friends:
>
> Part of our commitment to change is to keep the White House in step with today's changing technology. As we move ahead into the twenty-first century, we must have a government that can show the way and lead by example. Today, we are pleased to announce that for the first time in history, the White House will be connected to you via electronic mail. Electronic mail will bring the Presidency and this Administration closer and make it more accessible to the people.[1]

The Internet is the electronic highway of the future that gives cruisers (users of the network) an information advantage unparalleled anywhere else in time and place. The Internet is becoming easier to use and is constantly adding new sources of information. Museums such as the Smithsonian and the National Gallery of Art are coming on line with pictures, data bases, and articles and information about their collections (Gaffin, 1994, p. 24).

Museums such as the Smithsonian and the National Gallery of Art are coming on line with pictures, data bases, and articles and information about their collections.

Background and Accessibility

The Internet began twenty years ago as a communication tool for the U.S. military. Since then it has grown into an interconnected series of networks run by U.S. government agencies such as the National Science Foundation and NASA, institutions of higher education such as the universities of California, Michigan, and Illinois, and large corporations such as AT&T and IBM. It is accessible to scientists at large research centers, teachers in community colleges and high schools, junior high students, and anyone who has a computer with a modem or a terminal connected to a computer linked to the Internet. Most of the information and services on the Internet are free. A few are fee-based. If you have an account on a university computer, access to the Internet is free. If you do not, access is still available, but fees may be charged.[2]

The successful network user is a persistent learner who continues to ask questions and views the search for knowledge as an academic version of an exciting treasure hunt.

Most educators and students in the field of interior design can gain free access through their school's computer services. The usual procedure is to apply to computing services for an account on a mini or mainframe computer to connect to the campus network that attaches to the Internet. To log on to the account a user needs a computer terminal directly connected to the mainframe or mini or a PC equipped with special hardware and software that allows access. To access the network from home a person needs a PC with communication software such as CrossTalk or Procomm and a modem. The best way to acquire access is to contact computing services at your school and ask questions. Most campus computing services teach short courses on various aspects of computer use. These are wonderful sources of information and great points of departure for learning, but sometimes they leave novice computer users with more questions than answers. The successful network user is a persistent learner who continues to ask questions and views the search for knowledge as an academic version of an exciting treasure hunt.

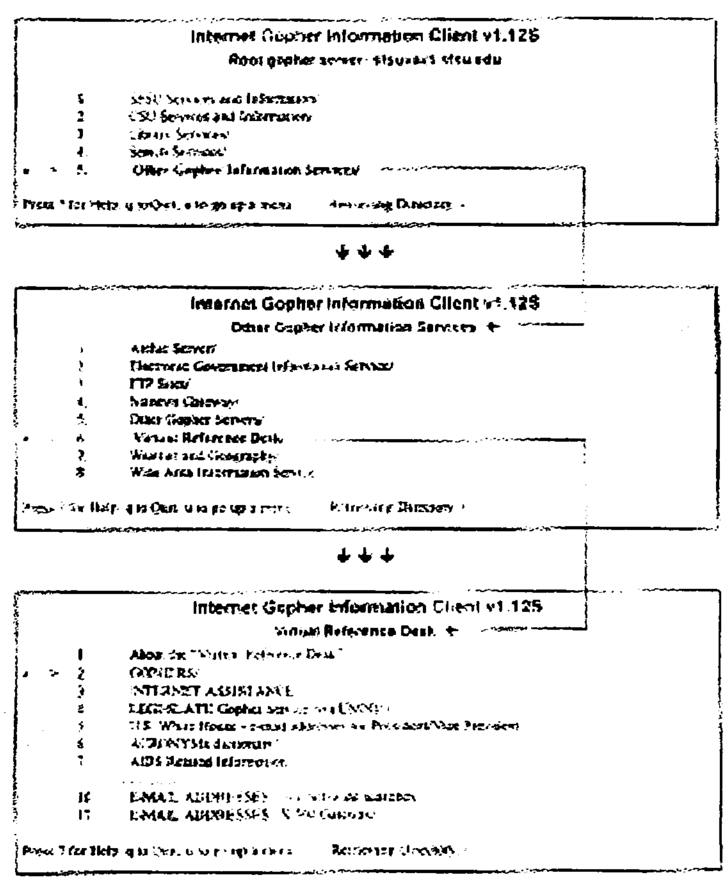


Figure 1

A series of typical "GOPHER" menus.

Once one is logged on to a large computer, several programs may be used to access information on the Internet. The easiest to use is Gopher, which provides an interface of menus (see Figure 1) that makes navigating the Internet and finding information easier than the other programs. Telnet and FTP (File Transfer Protocol) also provide access to information, but they are command driven rather than menu driven. Again, most schools provide classes that teach users how to use these programs.

Some of the Information Available on the Internet

The following is a partial list of data bases and items within them that an interior design educator or researcher might find of interest.

Library Catalogs. The most valuable resources for academicians are the catalogs of libraries around the world. The Library of Congress catalog is available for searching. The University of California Libraries and other state university libraries such as the University of Michigan and Penn State University are on line. A teacher can type in a few key words and acquire an extensive list of sources for any topic of interest. The list can be saved and plugged into a word processor for use in class bibliographies and research projects.

Government and Organization Information. The names, addresses, and descriptions of professional organizations such as IDEC and ASID are available on the Library of Congress network. To access them, log on to the Library of Congress through Gopher. Select the menu item, "organizations." Use the search term "interior design." For educators who are political activists or who simply want to communicate with their government representatives, telephone numbers and fax numbers for members of Congress are listed on line. Job information is available on various university bulletin boards attached to the Internet. Many university catalogs are on line and can provide an adviser with information about transfer courses.

Specialized Servers. The Americans with Disabilities Act (complete text) and related information and full text articles on such topics as learning disabilities are available on the Disabilities Network. This information can be valuable for teaching a class on design for special needs. Information even more specific to interior design is available from the University of Michigan College of Architecture and Urban Planning ArchiGopher, "a server dedicated to the dissemination of architectural knowledge." Archives available include:

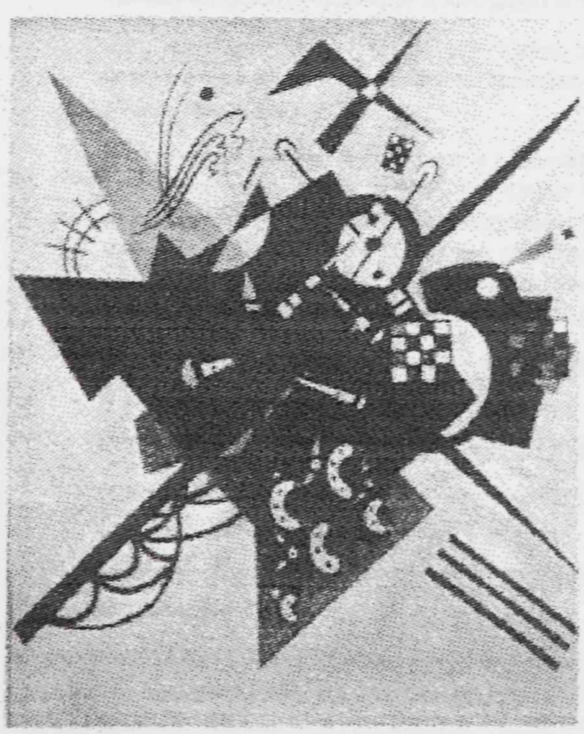


Figure 2

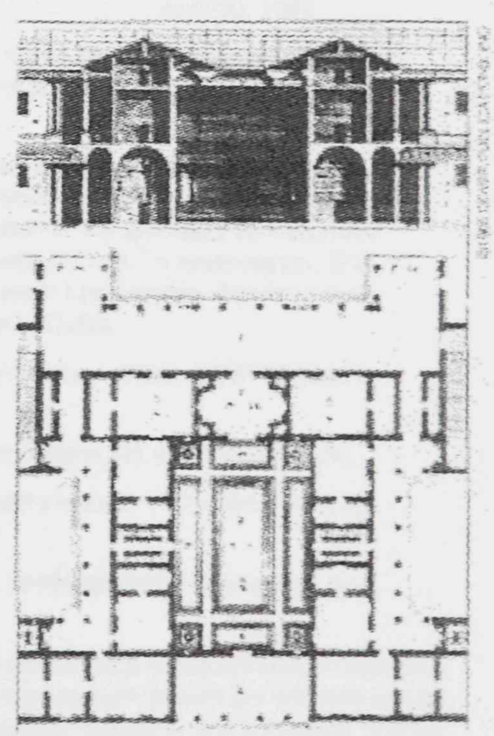


Figure 3

The Kandinsky Image Archive and the Palladio Archive were placed on the Internet by Wassim Jabi, University of Michigan, College of Architecture, Ann Arbor, MI.

1. The Kandinsky archive: A sample of five Wassily Kandinsky paintings. *On White II*, 1923, a GIF file downloaded to a PC and printed on a laser printer, can be seen in Figure 2.

2. The Palladio archive: A sample of Andrea Palladio's architectural projects. "Tuscan Atrio (plate XVIII)," Figure 3, is an example from this archive.

3. The CAD group's collection of computer models.

4. Collages of lunar architecture by Ted Hall.

5. Campus maps and street scenes from Ann Arbor, Michigan.

6. PhotoCD images of French architectural projects.

7. Links to other gophers including the Vatican library exhibit.

ERIC (Educational Resources Information Center) is on line.

Works of Literature. The complete texts of great works of literature and articles of scholarly interest are available. Finding the perfect quotation for a lecture on color or form or the architecture of Palladio is easy when you can search for it using key words typed into a computer.

Government Resources. Census Bureau information and statistics are available. For research on countries throughout the world the "CIA World Fact Book" is available on line. If you are doing research on interior design markets around the world, this source can give basic information about each country. For example, the following data concern Singapore:

> Natural resources: fish , deep water ports. Land use: arable land 4%; permanent crops 7%; meadows and pastures 0%; forest and woodland 5%; other 84% . . . . In the 1960s, the economy expanded rapidly, achieving an average annual growth rate of 9%. Per capita GDP is among the highest in Asia.

If you are planning a sabbatical in another part of the world, travel advisories from the U.S. State Department can be browsed. For example, the following excerpt was found, downloaded, and inserted into a word processing program in about 15 minutes:

> STATE DEPARTMENT TRAVEL INFORMATION—United Kingdom
> ==
>
> United Kingdom—Consular Information Sheet April 30, 1993
>
> Country Description: The United Kingdom is a highly developed European nation with a modern economy. Tourist facilities throughout the United Kingdom are highly developed.
>
> Entry Requirements: A passport is required. Tourists are not required to obtain a visa for stays up to six months. For further information concerning entry requirements travelers can contact the Consular Section of the Embassy of the United Kingdom and Northern Ireland at 19 Observatory Circle, in Washington, D.C. 20008, tel: 202-986-0205 or the nearest consulate in Los Angeles, San Francisco, Atlanta, Chicago, Boston, New York, Cleveland or Dallas.
>
> U.S. Embassy and Consulate Locations: U.S. Embassy, London: 24/31 Grosvenor Square, tel. (44-71) 499-9000.
>
> U.S. Consulate, Edinburgh, Scotland: 3 Regent Terrace, tel. (44-31) 556-8315.
>
> U.S. Consulate, Belfast, Northern Ireland: Queen's House, 14 Queen Street, tel. (44-232) 328239, fax (44-232) 248482.
>
> U.S. Consulate, Hamilton, Bermuda: Crown Hill, 16 Middle Road, Devonshire, telephone (809)295-1342.

Information about Other Electronic Forums. A listing of government computer bulletin boards is posted on various servers on the Internet. Most of the listed bulletin boards are free and can be accessed over telephone wires using a PC, communication software, and a modem. The following may be of interest to interior design educators:

DC	Dept of Education OERI Department of Education TOPICS: Dept. of Ed programs, software	DATA LINE: 202-219-2011 202-219-2012
MD	ADA Information Center Dept. of Defense TOPICS: Info on ADA programming Voice line for more info: 703-685-1477	DATA LINE: 301-459-3865 703-614-0215
MD	Census Bureau Bureau of the Census	DATA LINE: 301-763-4576

Listings of E-Mail addresses are available on line including addresses for the president and vice-president:

President Clinton: PRESIDENT@WHITEHOUSE.GOV

Vice-President Gore: VICE.PRESIDENT@WHITEHOUSE.GOV

Miscellaneous References. Webster's dictionary and acronyms dictionary are on line and are useful references for any researcher or teacher. For the gourmand, recipes and nutritional information are available. Information on specific dates in history could add interesting facts to design history lectures and materials, for example:

Wednesday 14 July

1776 George Washington refuses a letter from Gen. Howe addressed to George Washington Esq. rather than General Washington

1789 The Bastille is stormed in Paris, the French revolution begins

1850 1st public demonstration of ice made by refrigeration

1853 Commodore Perry requests trade relations with the Japanese

1865 the 1st ascent of the Matterhorn

Born: 1899 James Cagney, movie actor and notorious screen gangster; 1912 Woodie Guthrie, folk singer; 1913 Gerald R. Ford, 38th President (1974–1976); 1918 Jay Forrester, inventor of core memory, who later modeled the world

Internet Gopher Information Client v1.12S

GOPHERS

1. United States Gophers/
2. United States GOVERNMENT Gophers/
3. United States Library Gophers/
4. Africa Gophers/
5. Asia Gophers/
6. California Gophers/
7. Canada Gophers/
8. Canada Library Gophers/
9. Discipline (Subject) Specific Gophers/
10. Europe Gophers/
11. Europe Library Gophers/
12. French Speaking Gophers around the World/
13. German Gopher Servers/
14. Gopher NEWS ARCHIVES at the University of Minnesota SEARCH <?>
15. Gopher NEWS/
16. Gophers: Frequently Asked Questions (FAQ) about GOPHERS
17. International Organization Gophers/
18. Medical Library Gophers/
19. Mexico Gophers/
20. Middle East Gophers/
21. NETWORK GOPHERS/
22. Pacific Gophers/
23. Pacific Library Gophers/
24. South America Gophers/
25. VERONICA: Frequently Asked Questions (FAQ) about VERONICA
26. VERONICA: Search "the world" using Veronica
27. Worldwide listing of gopher servers
28. Terminal Based Information/
29. WAIS Based Information/

Press ? for Help, q to Quit, u to go up a menu   Page: [illegible]

Figure 4

A list of categories of "GOPHER" servers. Selection of number 6, California Gophers, revealed 114 server sites.

Summary

Interior designers within the university community need to "keep in step with today's changing technology as we move ahead into the twenty-first century."[4] The Internet is one area of technology that has the potential to improve the job environment and performance of all educators. E-mail messages and text files can be sent to research colleagues and friends in other parts of the United States and in other countries with no cost and very little time (minutes instead of days). In three to five minutes a listing of scheduled art exhibits of a museum can be downloaded and run off for students. Electronic pictures can be obtained for multimedia presentations within 30 minutes.[3] In the future even faster ways to gather information from the Internet will be provided.

There is a down side to using the Internet. Often university systems become so clogged with users that logging on to explore is impossible. Occasionally remote systems "hang" (stop working) and an explorer has to restart a search. The learning curve is steep, especially for people who have little experience with computers. It is an understatement to say that the system is not yet user friendly. In addition, there are so many servers on line that it is sometimes difficult to find the one with needed information. Figure 4 lists a menu of server locations. Selecting number 6, "California Gophers," revealed 114 server sites. This diversity, however, is also an indicator of the value of the Internet. The enormous body of information already available makes learning to access the Internet a very valuable tool for knowledge acquisition.

References

Gaffin, A. (1994, March–April). *Visiting museums on the internet. Internet World, 5*(2), 24–29.

Krol, E. (1992). *The whole Internet user's guide and catalog.* Sebastopol, CA: O'Reilly & Associates.

Kehoe, B. P. (1994). *Zen and the art of the Internet: A beginner's guide to the Internet* (3rd edition). Englewood Cliffs, NJ: Prentice-Hall.

Further Reading

Documents available on line:

Krol, E., & Hoffman, E. (1993). *What is the Internet?*

LaQuey, T., with J. C. Ryer. (1992). *The internet companion.*

Malkin, G., & Marine, A. (1992). *FYI on questions and answers: Answers to commonly asked "new Internet user" questions.*

Books:

Braun, E. (1994). *The Internet directory.* New York: Fawcett-Columbine (Ballantine).

Frey, D., & Adams, R. (1991). *A directory of electronic mail addressing and networks* (2nd edition). Sebastopol, CA: O'Reilly & Associates.

Kehoe, B. P. (1993). *Zen and the art of the Internet: A beginner's guide* (2nd edition). Englewood Cliffs, NJ: Prentice-Hall.

LaQuey, T., with Ryer, J. C. (1993). *The Internet companion: A beginner's guide to global networking.* Reading, MA: Addison-Wesley.

Endnotes

[1] Letter from the President and Vice President in announcement of White House electronic mail access, June 1, 1993.

[2] Single user fees range from $10 to $20 per month with unlimited connect time.

[3] Picture files are larger and take more time to download.

[4] Letter from the President and Vice President in announcement of White House electronic mail access, June 1, 1993.

APPENDIX E

ILLUMINATION MEASUREMENT DATA SHEET

(IMDS)

Illuminance Measurement

Data Sheet

Task illuminance will be recorded in the six treatments at the center of each task (41 cm or 16 in from the light source).

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
T1						
T2						
T3						
T4						
T5						
T6						

Note: T1 = Treatment 1 (Vertical positioned CFL with a round shade)

T2 = Treatment 2 (Vertical positioned CFL with a square shade)

T3 = Treatment 3 (Vertical positioned CFL with a polygon shade)

T4 = Treatment 4 (Horizontal positioned CFL with a round shade)

T5 = Treatment 5 (Horizontal positioned CFL with a square shade)

T6 = Treatment 6 (Horizontal positioned CFL with a polygon shade)

All measurements are in footcandle (fc).

APPENDIX F

COMFORT SCALE

(TO MEASURE USERS' COMFORT)

Comfort Scale

(Note: Will not have a title when given to subjects)

Use this set of adjective pairs to record your overall impressions of the lighting on the task. Do not evaluate based on the appearance of the lamp fixture; instead, evaluate your impressions of the lighting on the task. Avoid looking directly at the fixture. Please rate the condition of lighting available to you on this work surface when reading by circling a number for each adjective.

Comfortable	7	6	5	4	3	2	1	Uncomfortable
Not adequate	1	2	3	4	5	6	7	Adequate
Easy	7	6	5	4	3	2	1	Difficult
Free	7	6	5	4	3	2	1	Closed
Ease	7	6	5	4	3	2	1	Unease
Relaxed	7	6	5	4	3	2	1	Tense
Spacious	7	6	5	4	3	2	1	Confined
Satisfied	7	6	5	4	3	2	1	Dissatisfied
Uniform	7	6	5	4	3	2	1	Nonuniform
Focused	7	6	5	4	3	2	1	Blurred
Problematic	1	2	3	4	5	6	7	Nonproblematic
Glare	1	2	3	4	5	6	7	Nonglare
Bright	7	6	5	4	3	2	1	Dim
Hazy	1	2	3	4	5	6	7	Clear
Not favorable	1	2	3	4	5	6	7	Favorable

Dislike	1	2	3	4	5	6	7	Like
Acceptable	7	6	5	4	3	2	1	Unacceptable
Attractive	7	6	5	4	3	2	1	Unattractive
Small	1	2	3	4	5	6	7	Large
Appealing	7	6	5	4	3	2	1	Unappealing
Balanced	7	6	5	4	3	2	1	Not balanced
Pleasant	7	6	5	4	3	2	1	Unpleasant

APPENDIX G

UNIVERSITY STUDENTS' SURVEY

University Students' Survey

The following information is needed for statistical purposes only. Circle one:

1. Are you a) Male b) Female
2. What is your age?

   ____

3. Of what ethnic descent are you?

   a) Caucasian b) African American c) Hispanic

   d) Asian e) Other _________

4. Do you wear glasses or contact lenses? a) Yes b) No
5. If yes, please describe why

   a) Difficult seeing objects close up (like reading).

   b) Difficult seeing things far away (like a road sign).

   c) Both a and b

   d) astigmatism

   e) Other (please specify) ______________________________

6. Do you have a history of difficulty distinguishing colors? a) Yes

   b) No

7. Do you have a history of problem with your eyes (e.g., cataract, glaucoma, injury, etc.)?

   a) Yes (please describe) ____________________________ b) No

8. Aside from being a student, please state your other current

occupation?

List all: ________________________________

9. How many hours a day do you use a table lamp for work or study? ____

10. Do you have any problem when using a table lamp at home?

____

If yes, please explain____________________________

11. Have you ever taken a lighting course? a) Yes b) No

12. What color you like the most? __________

13. Which of the shapes below do you like the best? Circle One.

14. If you have any other opinions or comments about the lighting in this study please free to write in the space below.

____

____

Your comments will be kept confidential and will be destroyed after the study. I thank you for your participation in the study and filling out this survey. Any questions or additional comments regarding this research please feel free to contact:

Zaidi Shahibullah Abdullah

Department of Merchandising, Environmental Design,

and Consumer Economics

College of Human Sciences, Texas Tech University

Lubbock, TX 79409

Tel. and Fax: (806) 742 3050