A BEHAVIORAL APPROACH
TO LIGHTING PLEASANTNESS

by

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INTRODUCTION

The Illuminating Engineering Society (IES) defines "light" as "radiant energy that is capable of exciting the retina (of the eye) and producing a visual sensation" (IES Nomenclature Committee, North America, 1979). The sun is our biggest source of illumination during the day and we have to depend on it in many aspects of our life. But artificial illumination becomes a necessity when any activity is to be carried on indoors or at night.

McCormick and Sanders (1982) state, "The design of illumination systems have (sic) an impact on the performance and comfort of those using the environment as well as the affective responses of the people to the environment". They also say that "Illuminating engineering is both an art and a science. The scientific aspects include the measurement of various lighting parameters and the design of energy-efficient lighting systems. The artistic side comes into play when combining light sources to create, for example, a particular mood in a restaurant, highlight a display in a store, or complement a particular color scheme".

Light not only affects a person's mood, but can also be used to communicate ideas or reinforce impressions. These concepts have long been recognized by the designer of merchandizing lighting. Research carried out along these lines also suggests that behavioral studies may also find application in any luminous environment, from a residence to an office.

Definitions

Brightness. Brightness can be divided into two broad categories :

1) Subjective brightness, and 2) Photometric brightness.

Subjective brightness is the conscious light sensation resulting in the feeling of intensity. There is a vast range of words to describe the effect including : dark and light, dim and bright, etc.. This, of course, can be scaled. Photometric brightness refers to a physically measured amount of light. Photometric brightness is also called "luminance".

Visual acuity. The ability of the eyes to differentiate between the detailed features of visible things, such as reading fine print or identifying a person at a distance, is known as visual acuity. Acuity depends on the accommodation of the eyes, which is the adjustment of the lens of the eye to bring about proper focusing of the light rays on the retina. In normal accommodation, if one is looking at a distant object, the lens flattens, and the lens tends to bulge when looking at a near object, in order to bring about proper focusing of the image on the retina.

Dark adaptation. The adaptation of the eye to different levels of light and darkness is brought about by two functions. First, as one enters a darkened room, the pupil of the eye increases in size to allow entry of more light into the eyes; and in case of bright lights, the pupil tends to contract in order to limit the amount of light that enters the eye. The second function that affects how well one can see as one goes from the light into darkness is a physiological process in the retina in which "visual purple" is built up. Under such circumstances, the cones of the retina (which are sensitive to color and variations in brightness) lose much of their sensitivity. Color discrimination is limited in the dark since our vision in the dark depends on the rods of the retina which are not color sensitive.

It takes about 30 or more minutes to adapt oneself completely in the dark. The reverse ("light") adaptation, from darkness to light, takes place in some seconds or at most in a minute or two.

Factors that affect Visual Discriminations

The ability to make visual discriminations is dependent upon the visual skill, viz., visual acuity, of the individual. Besides these individual differences, however, there are certain conditions (variables), external to the individual, that affect visual discriminations. Some of these variables are listed below.

Luminance Contrast and Conspicuity. Luminance contrast is also referred to as "brightness contrast", and this means the difference in luminance of the features of the object being viewed, particularly the feature to be discriminated by contrast with its background. Luminance contrast can be expressed by the following relationship:

$$\text{Contrast} = \frac{B1 - B2}{B1} \times 100$$

where B1 = brighter of the two contrasting areas

B2 = darker of the two contrasting areas

The contrast between the object (target) and the background is one of the most important factors influencing the detectability of an object in one's environment. This introduces the concept of "conspicuity" or the discernability of an object. Man only perceives a small part of what is to be seen around him. The choice of viewing direction is an initial, rough selection. The observer's attention then determines the part that is consciously seen of what falls within the field of view. Something is noticed because it differs (is in contrast) from its environment in qualities such as shape, color, size, or brightness contrast against a background.

Time. It is known that the greater the discriminability the longer is the viewing time, within reasonable limits.

Luminance ratio. The luminance ratio is the ratio of the luminance of a given area (e.g., the work area) to the surrounding area. The IES has recommended luminance ratios for various areas relative to the visual task, for both office and industrial situations. These are shown in Table 1.

Amount of illumination. The importance of the amount of illumination necessary for good task performance is one controversial issue. Researchers (like Bennett, Hughes, et al., 1977) have concluded that age has an important role to play as a determiner of the amount of illumination and their performance. Ross (1978), however, concludes that increasing illumination above 500 lx (50 fc) results in little additional improvement in task performance. He also concluded that other variables, notably age and print quality, are more important determiners of

TABLE 1.

Recommended Luminance Ratios for Offices and Industrial Situations.

AREAS	Recommended maximum luminance ratio: Office	Industrial
Task and adjacent surroundings	3:1	
Task & adjacent darker surroundings		3:1
Task & adjacent lighter surroundings		1:3
Task & more remote darker surfaces	5:1	10:1
Task & more remote lighter surfaces	1:5	1:10
Luminaires (or windows, etc.) and surfaces adjacent to them		20:1
Anywhere within normal field of view		40:1

Source : *IES Lighting Handbook*, 1972, Figure 11-2, p.11-3, and Figure 14-2, p. 14-3.

performance than amount of illumination, which was contrary to the findings of other researchers, like Bennett, et al. (1977). Subjective evaluations of different lighting levels showed that the higher illumination levels were more satisfying (Hughes & McNelis, 1978). But it is not always wise to provide high levels of illumination. Besides the energy waste, it may also result in unwanted effects such as glare.

Glare. One of the unpleasant effects of high levels of illumination is "glare". Glare is produced by brightness within the field of vision that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort, or loss in visual performance and visibility. If there is a light source in the field of view, it is a cause of "direct glare". "Reflected" or "specular" glare is caused by reflections of high brightness from polished or glossy surfaces that are reflected toward an individual.

Age and vision. As mentioned earlier, an important fact to be noted is that visual skills, especially visual acuity, tend to deteriorate through age. Therefore, in situations which might involve designing of visual displays that might be used by elderly people, it is necessary that designers take this factor into account.

Movement. It has been found that the movement of a target object relative to the observer can result in reduction of his visual acuity. Burg (1966) had found that acuity deteriorates rapidly as the rate of motion exceeds 60 degrees per second.

Visual Response to Brightness

The light falling on an environment, illuminance, (which is expressed in footcandles or lux) is a standard measure used today to determine the acceptability of a lighting installation. However, the eye does not react to incident light, it responds to reflected or transmitted light, luminance or brightness, (which is expressed in footlamberts, or candelas/meter squared). Incident light is modified by the effects of a variety of factors, like object size, viewing time, etc. and it is mainly the reflectance of light from the object that aids the visual response to light and is directly involved in the seeing process. The degree to which the eye can adapt itself to differing levels of reflected or transmitted light is phenomenal. Under controlled conditions, the eye perceives minimum variations in brightness of approximately 2 to 1, and variations between the brightest and darkest areas of a seeing task can reach a maximum of 100 to 1. However, extreme contrasts between high and low areas of brightness can strain the eyes and slow the seeing process, particularly if the viewer is subjected to these conditions for long periods of time or engaged in detailed tasks. On the other hand, some contrast is essential (both physiologically and psychologically) if seeing is to be comfortable and effective. The problem is to control reflected light for optimum effects.

Phototropism

Lighting designers have made remarkable progress in designing lighting systems that supply the proper amount of illumination, with the proper spectral composition, without creating glare and doing it in an energy-efficient manner.

One of the most important concepts used by lighting designers is the concept of "phototropism", the tendency of the eyes to turn towards a light. Store owners and store window designers take advantage of this human tendency when they direct bright lights toward a particular part of the store or at a particular item in the window, specifically, articles to which they want the customer's attention drawn. However, phototropism can have negative effects for task performance and safety, particularly, if it draws the eyes away from the area of most important visual attention.

Determinants of Luminance Level

Research carried out in Europe has studied lighting levels at which observers report pleasantness. Actually, there is a sequence of responses to lighting --- orienting or attending, seeing, feelings of pleasantness and discomfort. This leads one to hope to find "convergence" between behavioral (i.e., directly observable) and subjective responses.

The luminance and the illuminance overall and for particular parts of the space are the most important points to be considered by the lighting designer. It may be desired to attract attention somewhere. There needs to be sufficient light in the place where some visual work is to be performed. But at the same time there should not be any discomfort from glare in such areas. Thus, attention-getting, visual performance and discomfort glare have a kind of utilitarian purpose.

A number of European studies (Fischer, 1973) have shown that office workers selected a "most pleasant" illuminance for offices. The mean was about 2000 lux which is more light than most offices have and higher than the illuminance needed for most office tasks. Response scales, which have responses like "uncomfortable" at higher luminance, and "pleasant" at lower luminances, have been used as subjective responses in some discomfort research.

Behavioral Approaches

Phenomena such as pleasantness and discomfort need a proper understanding and direct subjective responses play an important and dominant role in such cases. Convergence of methods and findings are important in scientific research and so it is necessary that we arrive at the same conclusions with quite different methods.

Some research has used behavioral approaches. Melton (1933) observed that 75% of museum visitors turn right when the environmental factors favoring a right or left turn are equivalent.

Flynn (1970) noted that lighting enables a person to readily identify and relate to various activity needs, and recommended a study of the effect of lighting on entry-egress and circulation (or movement) behavior.

In the area of phototropism ("phototaxis", to be precise), Taylor and Sucov (1974) carried out a behavioral study with humans. In this study, the subjects were asked to enter through a doorway from one room to another, in a kind of T-U maze, with a choice of two passageways which were illuminated at different levels. Lighting conditions were balanced between the two passageways to account for a right-turning bias which otherwise has been observed. Responses favored the higher luminance route. This selection of route behavior may be rather complex because it may involve an initial orienting response triggered by the higher attention getting value of the higher luminance and this may have resulted in greater visibility of details (such as texture) of the higher luminance end, as well as possibly greater pleasantness. If very high luminances had been used, the glare created could also have been a determinant of the route choice.

Reference can be made to two other studies --- one done by Hopkinson and Longmore (1959) and the other done by Lagiusa and Perney (1973) --- in the area of attention getting and sustenance. They have studied what may be called "orienting responses".

In the first study, Hopkinson and Longmore conducted experiments employing apparatus which enabled a simultaneous photographic record to be made of the visual scene together with the eye movements of an unsuspecting observer viewing the scene. A count of the number and duration of these eye movements revealed that sharp, intensely bright points of light distracted the attention in a series of jerky eye movements, whereas less bright but larger areas caused more eye movements of longer duration, probably because in the first case it was very likely a discomfort glare source.

In the second study, LaGiusa and Perney (1973) made observations on some school children who were supposed to be studying a display of spelling material. The number of times the children looked toward the display and their sustained viewing were recorded. Both of these responses increased with higher luminance (150 fL). The results of the study have also demonstrated how brightness variations can be used as an aid in attracting and holding student attention in a classroom. The study was done by using supplementary lighting to highlight the specific set of visual stimuli set before the students.

A second study was carried out by these same authors, (LaGiusa and Perney, 1974), to affirm the hypothesis that attention to visual aids can be enhanced by reinforcing brightness patterns. The study attempted to apply more vigorous control over the test procedure to minimize the possible effects of extraneous variables, namely, the data were collected from observations within a single classroom, always using the same students, teacher and trained observers. This study's findings were able to affirm the hypothesis that attention to visual aids could be enhanced by reinforcing brightness patterns. Further, it demonstrated that such manipulative lighting techniques could be an effective means of improving pupil attention while in long term use in an actual classroom.

A common human factors recommendation (Ireland, 1967) states that, for good target visibility, the area surrounding a display should not be brighter than the background area within the display. But there are a lot of situations where the surround brightness cannot be adequately controlled.

Ireland (1967) reported on the "Effects of surround illumination on visual performance". He reviewed literature to find out what had been discovered concerning the effects on target visibility of specific parameters of a surround-to-background relationship in which the surround was brighter than the display background. A lot of literature was reviewed and it would appear that the important parameters determining the visibility of a target, of a given angular subtense at the eye and centered on the display background, are (1) target-to-background contrast, (2) background brightness, (3) background angular subtense (which determines target-to-surround separation), (4) surround-to-background brightness ratio, and (5) surround angular subtense.

Numerous investigators have studied the quantitative effects of these parameters. Results of studies using extended surrounds, rather than point sources, have not been sufficiently comprehensive or consistent to support quantitative generalizations in this area.

Ireland, Kinslow, Levin and Page (1967) carried out an "Experimental study of the effects of surround brightness and size on visual performance". The purpose of this study was to determine, quantitatively, the degradation in visibility due to high surround brightness and thus to provide useful data for the display system designer. Measurements were made of the target-to-background contrast required for each of the five subjects to determine, with fifty percent accuracy, the orientation of a lighter Landolt ring target centered on a darker circular background. The target gap subtended 1.93 minutes of arc. Background angular subtense was varied from 5 degrees to 45 degrees, background brightness from 0.17 to 18.43 millilamberts and surround-to-background brightness ratio from 0:1 to 100:1. The rest of the visual field was a uniform surround whose brightness could be varied independently with respect to the background. The scene was viewed monocularly with the natural pupil.

The results showed that for surrounds brighter than the background, the contrast threshold was fairly sensitive to the surround-to-background ratio. The increase in a subject's contrast threshold appeared to be proportional to the increase in surround brightness. Also, there was evidence suggesting that surrounds considerably darker than the background also adversely affected visual performance, i.e., raised the contrast threshold. Changing background angle appeared to have a surprisingly small effect upon the contrast threshold, although there was reason to believe that it might not have the same effect with other tasks.

From a practical standpoint, the results of this experiment provided a basis for specifying increased display contrast requirements when the area surrounding the display was subtantially brighter than the background within the display.

Collins and Plant (1970) investigated the preferred luminance relationships to acheive a satisfactory character in a windowless interior. They could not draw any specific conclusions regarding preferred luminances of either rooms or furniture surfaces in relation to task luminances. Preferred luminance levels gave a degree of glare approaching IES (London) recommended limits at 500 lux, but a lower degree was required at higher levels. Preferred ceiling luminances with surface-mounted fittings were in the region of 150 - 200 cd/m^2. Since this study was carried out using a model of a landscape office, it was recommended that further investigations be made in some full-scale installations, preferably in offices where observations can be made and occupant reactions studied.

Helson and Lansford (1970) carried out a study entitled "The role of spectral energy of source and background color in the pleasantness of object colors". In this study, over 150,000 ratings of the pleasantness of colors were made of 125 colors on 25 backgrounds in five sources of illumination by five men and five women. The results showed that the pleasantness of object colors depends on the interaction of spectral energy of light source with background color, and the hue, lightness, and chroma of the object color. Specific factors like sex differences in color preferences in the five sources of illumination, preferred color families, and best backgrounds for enhancing ratings of object colors were also significant. The background color was found to be more important than color of the source in influencing pleasantness ratings since color contrast could drastically alter the appearance of object colors. The single factor that was found responsible for pleasant color harmonics was the lightness contrast between object and background colors. Good color combinations could be obtained by a greater lightness contrast.

In conclusion, Helson and Lansford formulated a universal "law" of behavior regarding aesthetic responses to stimuli : "a certain amount of variety, change, differentiation or contrast is pleasant; sameness, monotony, repetition tend to be unpleasant".

Flynn, Spencer, Martyniuk and Hendrick (1973) carried out a study to investigate the effect of light on impression and behavior. This study was done in a medium-sized conference room at the General Electric Lighting Institute at Nela Park near Cleveland. To implement this work the authors utilized scientific techniques for evaluating the subjective quality of a space--- most notably, (a) semantic differential rating scales for factor analysis, (b) multidimensional scaling, and (c) various observation and mapping methods. These methods were used to study a room in which the only physical changes were changes in the lighting arrangement. There were six different lighting arrangements used in the study.

The results of the rating studies tend to support the basic hypothesis that the users of a room share certain environmental impressions--- and that these impressions can be altered or reinforced by the lighting arrangement.

The three major categories of user impression affected by lighting changes were :

(1) General evaluative responses such as pleasantness and friendliness.

(2) Impressions of spatial clarity such as brightness, distinctness, and focusing.

(3) Impressions of spaciousness.

Observation of user behavior provided evidence that lighting may also have some influence on overt behavior, such as seat selection patterns, posture, comments, gestures and facial expressions.

Contrast and Visual Conspicuity

Contrast has been defined earlier as the difference in luminance of the features of the object being viewed.

Flynn (1972), in his preliminary observations, offered the following table:

	Target-to-Background Brightness Ratio
Barely recognized contrast as a focal point; negligible attraction power.	2:1
Minimum meaningful contrast as a focal point; marginal attraction power.	10:1
Dominating contrast as a focal point; strong attraction power.	approaching 100:1

Flynn also suggested that attention is involuntarily directed to color areas that contrast with a neutral visual background. He concluded by stating that an observer who is unfamiliar with a space will move toward areas where color is predominant and toward areas of highest brightness. Thus, in the above table, Flynn gives the brightness ratios to which people would be barely or strongly attracted depending on how meaningful the contrast is. This differs from the luminance ratios, recommended by IES (Table 1), which generally are applicable to offices and industrial situations.

In the field of visual conspicuity, Engel (1976) has done some extensive studies, particularly in the measurement of visual conspicuity and how it can act as an external determinant of eye movements and selective attention. He defined visual conspicuity in the following words: "Visual conspicuity is operationally defined as the external factor determining the probability that a visible object will be noticed against its background." His experiments have revealed that larger "conspicuity area", well-defined "visibility-area" and plain backgrounds greatly increase the visibility and consequently also the conspicuity of test objects in eccentric vision.

Pilot study

A pilot study or a preliminary study was conducted to determine whether there exists any pattern in the behavioral reactions of people regarding choice of lights.

Subjective responses were obtained from 15 subjects for evaluating the pleasantness of two "target lights" (each measuring 2"x2") placed 80 inches apart. There was a white screen placed behind these target lights and this provided a background for the lights. There were four floodlights on stands, each housing a 150 Watt incandescent lamp to illuminate the screen, and thus provide uniform background luminance for both the target lights. There was a cross afixed on the screen midway between the two target lights, at eye level.

At the start, the ceiling lights were turned off and the floodlights were turned on. The subjects were instructed to look at the cross and as soon as the target lights went on, they were asked to look at whichever light source they preferred to look at and then turn them off immediately by pressing a button. This button was also hooked to a timer, and this measured their reaction time, unknown to the subject.

The subject's task was to rate the pleasantness of the light he/she preferred to look at, using a "Pleasantness scale", and, then, write down a word that was displayed on a card just below the chosen light. The Pleasantness scale was a relative scale which had ratings from -3 to 3 with corresponding specifications from "Very Unpleasant" to "Very Pleasant". The word that the subject wrote corresponded to the chosen light and this enabled the experimenter to determine which target light (left or right) was chosen by the subject. This way an attempt was made to eliminate the subject's thinking in terms of left or right and thereby eliminating the introduction of any such bias in his/her orienting behavior.

There were five levels of target luminances and three levels of background luminances, providing 15 levels of different combinations of target and background luminances.

The results showed that there was no left or right turning bias in the subjects' orienting behavior. There were significant differences in the response times and the pleasantness ratings between luminances. Significant differences were also observed in the number of people choosing these luminances and there was no evidence of the existence of interaction between the target luminances and the background luminances.

In summary, there was no specific pattern observed in the people's behavior regarding the choice of lights and probably the choice of one particular luminance depended on what luminance was presented at the same time on the other source of light, thus indicating unpredictable behavior.

Present study

Purpose. The present study is an extension of the pilot study and was undertaken to investigate further and determine if there exists any pattern in the behavioral and subjective responses of people regarding the pleasantness of lights. In other words, the number of times that people look at the lights or their orienting behavior is expected to have a relation with their pleasantness responses. These pleasant lighting levels are expected to be above levels which attract attention. Also, the luminance of the lights is expected to be an important factor in determining the speed of attention-getting.

Further, should any relationship exist between the responses and the predictor variables, regression models could be built for each of the responses.

Differences from pilot study. The present study is different from the pilot study in the way the experiment was carried out. Unlike the pilot study, here each target light was contrasted with a different background luminance and the target lights were placed closer together with a partition in between. The subject could look at both the lights at the same time and, when the lights were turned on, had to look at only that particular light which attracted his/her attention first.

There were six levels of target luminances used in the present study --- 10 fL, 32 fL, 100 fL, 320 fL, 1000 fL, and 3200 fL. These values were arrived at after arranging the initial values 10 and 32 in some geometrical order. All the other higher values, viz., 100, 320, 1000, and 3200 were obtained from the multiplying factors 10 and 32. In the pilot study, only the first five levels of target luminances were used. It was decided to extend the number of levels. The number of levels of the background luminance was also increased from three to five.

PROBLEM

This study was undertaken with the objective to determine whether there exists any relationship in the behavioral and subjective responses of people regarding the pleasantness of lights.

Specifically, the objectives of this study are :

1) To determine the lighting conditions at which the orienting and/or movement responses of people are the same as or similar to those which produce pleasantness responses.

2) To determine whether the speed of attention-getting increases with a greater luminance/contrast with the background.

3) A third objective of this experiment is to build predictive models for each of the response variables, pleasantness ratings, number of times looked at the lights, and the response time.

METHOD

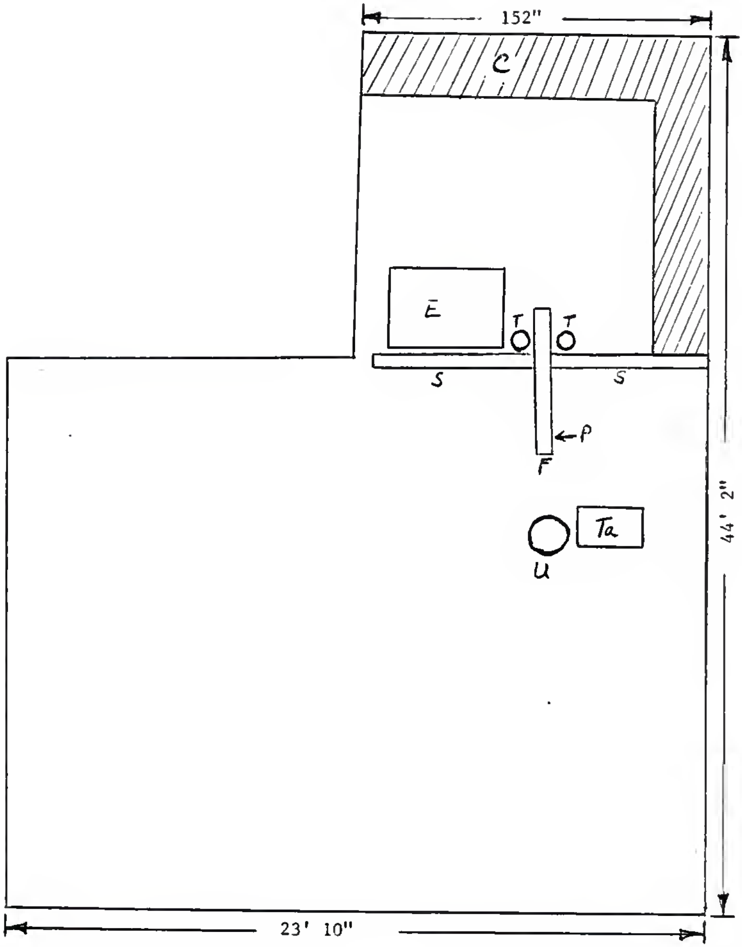
The experimental method of this study can be broken down into the following divisions :

1. Experimental set-up
2. Experimental design
    - Independent variables
    - Dependent variables
    - Power of the tests
3. Subjects
4. Apparatus
5. Controls
6. Assignment and sequence of conditions
7. Pleasantness scale
    - Criteria
8. Procedure
    - Task

Experimental Set-up

The experiment was carried out in the Department of Industrial Engineering, Durland Hall, Kansas State University.

The experiment was set up at the far end of a room measuring 44 feet and two inches on the longest side and 23 feet and 10 inches wide (Refer to Figure 1). As shown in the figure, only the right-end corner of the room was used for the experiment and thus a screen to cover this width (152 inches) was hung up from the ceiling. Actually there were two layers of white cloth and this had a reflectance power of 0.68.



Ta - Table for subject
F - Position of Floodlights
E - Table for equipment
P - Partition

S - Screen
T - Stools for target lights
U - Subject

Figure 1. Plan of the room and experimental set-up.

There was a gap left at the middle to allow a partition with the screen hung on both sides. This arrangement separated the right and the left half of the screen and enabled the presentation of different background luminances on the two sides at the same time.

The height of the board was 78 inches and it measured 81 inches from the front to the back end. The front edge had a width of 2 inches. White paper was pasted on the board and this created a colorless uniform background in the subject's line of vision.

The height of the ceiling was 11 feet but it did not matter since the ceiling lay outside the subject's vision. The distance between the screen and the wall behind was 110 inches and thus there was enough space for the experimenter to move around with ease, and make the necessary changes as and when required.

The distance between the subject and the front edge of the board was 42 to 45 inches. The screen provided a background for two light sources called "target lights", and was illuminated by floodlights. The target lights enclosed within wooden casings were placed on stools and stood at a height of 34 inches from the floor. Each target light was positioned at a distance of six inches from the edge of the board on either side.

There were four floodlights, each housing a 300 Watt incandescent lamp, and all of them being snapped on to a single stand at the front end of the partition board. These floodlights were fixed at a height of 66 inches from the floor such that the subject sitting in the chair positioned in front of the board could not notice them overhanging from the stand, nor did these lights fall within the periphery of the subject's vision.

A sketch and a photographic view of the experimental set-up are shown in Figures 1 and 2 (a), (b), & (c) respectively. A sketch of the wooden casing, enclosing the tungsten halogen lamp, is shown in Figure 2 (d).

Experimental Design

Based on previous studies and also the pilot study, it was decided that a "same subjects" design would be used. In other words, all the subjects would be run through all the treatment combinations.

The selection of the treatments was another procedure. Because of the high number of levels for each of the independent variables and the concept of using the left and right side of the partition, the number of treatment combinations turned out to very large. To reduce the number of conditions it was decided to go through a procedure of "confounding" the design.

Independent variables. There were two independent variables used in the experiment. They were : (1) Target light luminance, and (2) Background light luminance.

There were six levels of target luminance, viz., 10, 32, 100, 320, 1000, and 3200 footLamberts (fL), and they were balanced between left and right sides.

There were five levels of background luminance used, viz., 2, 5, 10, 20, and 50 fL, and they too were balanced between the left and the right sides.

Figure 2(a). Photographic view of the experimental set-up and a subject in front of the screen and lights.

Figure 2(b). Photographic view of the experimental set-up and a subject in front of the screen.

Figure 2(c). Photographic view of the equipment and controls behind the screen.

W - Wooden Casing
S - Scale
L - Tungsten Halogen Lamp

B - Sliding base for the lamp
F - Slots for filters
M - Opening of size 2"x2"

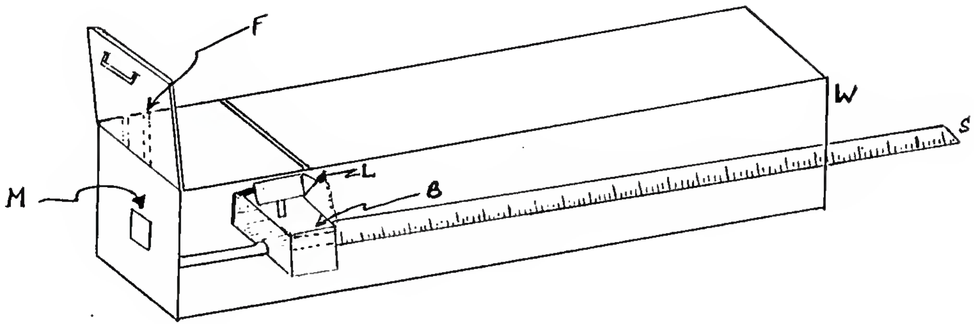


Figure 2(d). Wooden casing for Tungsten Halogen Lamp

If each target luminance was combined with every other level, without repeating any combination or pairs, a total of 15 pairs or combinations of target luminances would result. Likewise, if each background luminance were paired with every other level, a total of ten pairs or combinations would be obtained. Thus, a combination of 15 target luminances and 10 background luminances would have given 150 treatment combinations for each subject, and hence an equal number of trials. Such a task is not impossible, but would have been lengthy. To avoid this, a method was adopted to "confound" the design.

<u>Confounding</u> is a device which enables the investigator to use a relatively small sized block in order to increase precision, at the expense of a sacrifice of information on certain interactions that are expected to be negligible. In other words, when one variable co-varies with another such that their separate effects cannot be found, then they are confounded.

In this experiment, it was decided to design the treatment combinations on the basis of the factor called luminance ratio which as mentioned earlier, is the ratio of one luminance to another luminance.

With the available levels of target and background luminance, it was possible to obtain (6x5) = 30 levels of luminance ratios. Of these, eight levels of luminance ratios could be obtained by two different combinations of target and background luminances. For example, the luminance level of 50 could be obtained by target/background combination of 100 fL / 2 fL and also 1000 fL / 20 fL. Hence, in all 22 levels of target/background luminance ratios were obtained.

An observation of these luminance ratios revealed that two of the levels could be eliminated when compared with the rest of the other levels. These two levels were 0.64 and 1600. The reasons for eliminating these levels were based on the pilot study. There were two levels of "negative luminance ratio", viz., 0.2 and 0.5, used in this experiment. The luminance ratio is called "negative" when the background is brighter than the target. The level 1600 was eliminated in this study because the pilot study had revealed that the level 500 was bright enough and almost all the subjects did not like to look at lights at this luminance level. Since a different experimental set-up was used here, it was decided to test this level once again and also go a step higher in the use of the luminance level, than that used in the pilot study.

With the elimination of the two luminance levels, it was decided to form a 20x20 square matrix with the twenty levels of luminance ratios (Figure 3). Now, smaller sized 4x4 matrices were formed along both the diagonals. Along the first diagonal, which went from the left-hand top-corner downwards to the right, and within each 4x4 matrix, the combination of each contrast with every other level was considered. This resulted in six treatment combinations for each matrix along this diagonal. Since there were five sets of matrices, it resulted in (6x5) = 30 treatment combinations along this first diagonal. Along the other diagonal, only those treatment combinations which were unique and were different from any other combination, were selected. Only eight

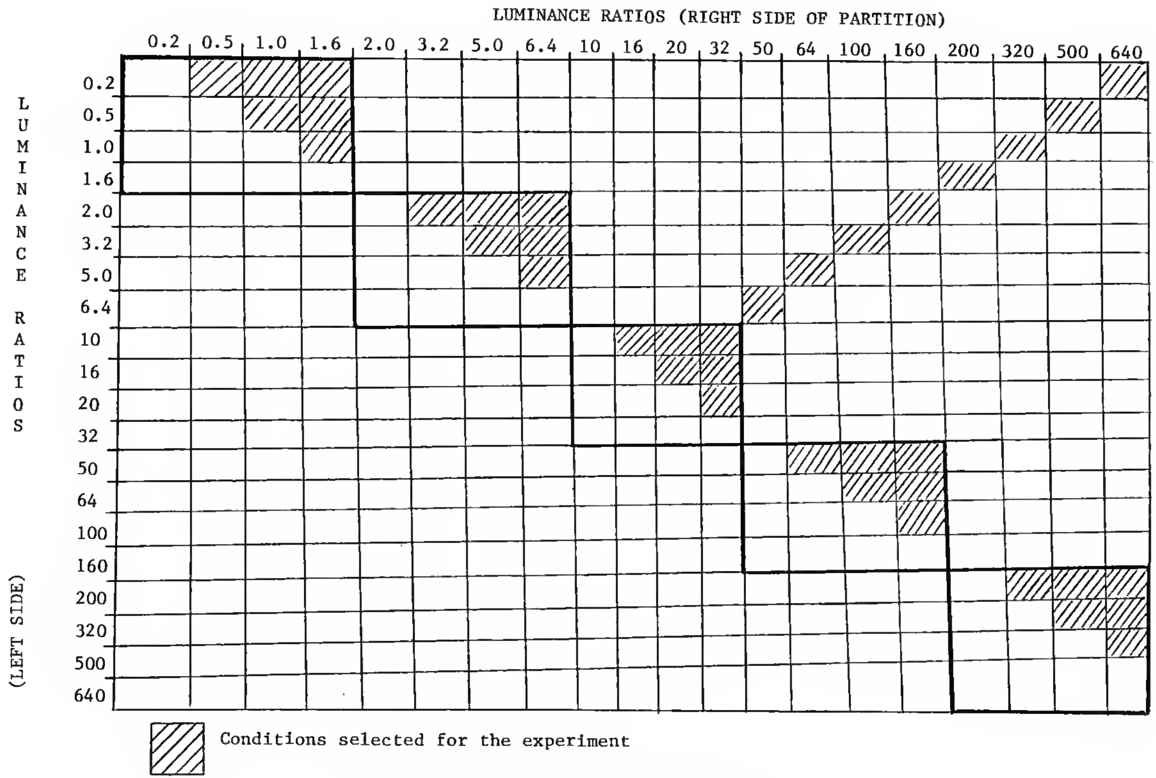


Figure 3. Plan of Design of Experiment.

such possible combinations could be obtained. Thus, a total of (30+8) = 38 treatment combinations were made possible. Consequently, the number of trials for each subject was also 38.

Dependent variables (Responses). Three kinds of responses were measured :

1. The number of times the subjects looked at the lights at each level of luminance.
2. Subjective response on the pleasantness of the lights.
3. Time taken to respond.

Power of the test. Cohen (1969) defines power of a statistical test as : " The power of a statistical test of a null hypothesis is the probability that it will lead to the rejection of the null hypothesis, i.e., the probability that it will result in the conclusion that the phenomenon exists". The power of the test depends mainly on thr sample size and the effect size. In Cohen's words (1969), "effect size means the degree to which the phenomenon is present in the population, or the degree to which the null hypothesis is false".

For this experiment, the effect size was assumed to be "medium", i.e., in Cohen's terminology, $d = 0.50$

Significance level, $a = 0.05$

Number of subjects or sample size, $n = 20$

Therefore, the power of the test (obtained from Cohen's power tables) = 0.46

This meant that the likelihood a statistically significant result could be achieved in this experiment was 0.46. In other words, under the assumptions, the probability that the phenomenon in the hypotheses would be proved is 0.46. Significant test results would suggest that actual effect sizes are larger than hypothesized.

Subjects

Unless material incentives are offered, it is always difficult to recruit subjects for this kind of experiment. Since this experiment did not involve the study of responses of people belonging to any particular group, they were drawn incidentally from the population of students at Kansas State University. An essential factor was the willingness of the subjects to participate and co-operate in the experiment. Another important criterion on which the subjects were recruited was that they should have a pair of properly functioning eyes or at least have corrected vision.

Most of the subjects recruited for this study were friends and acquaintances of the experimenter. The subjects belonged to different ethnic origins and educational backgrounds. Besides Americans, there were subjects from India, China, Pakistan, Japan and Iraq. Most of them were graduate students and were from the following educational backgrounds : Industrial Engineering, Civil Engineering, Mechanical Engineering, Computer Science, Chemistry, Education, and Arts.

Each subject took about 60 minutes to run through the experiment. Twenty subjects were recruited and their ages varied from 18 years to 48 years. Sixteen male and four female subjects were used.

Apparatus

Besides the floodlights to illuminate the screen and the partition, there were tungsten halogen projector lamps for the target lights, a transformer to meet the fixed voltage requirement of these lights, a timer, a desk lamp, a Variac for each pair of floodlights (left and right of the partition) and a switch panel to control all.

Each target light was enclosed within a long wooden casing and it had a scale (in inches) attached to it through an opening at one end (as shown in the sketch, Figure 2 d). This enabled one to know the position of the light, in inches, within the box from the other end, by directly reading off from the scale. The other end had a 2"x2" opening and was covered by a milk glass, cut to that size, to diffuse the high intensity projector lamps. This end also had slots inside the casing for two neutral density filters (having transmittances of 10 % and 1 %). These filters were used to control the transmittance and hence the luminance of each target light without changing color. A fan was provided for each target light to dissipate the heat generated, through another opening at the side of the casing.

There was a transformer used to control the luminances, for each pair of floodlights on either side of the partition. A timer was used to measure the response time of the subjects. This was the time that the subjects took to look at one or the other light as soon as the target lights were turned on. The timer was connected to a circuit such that one switch (for the experimenter) could turn it on and another switch (for the subject) could turn it off.

There was also a desk lamp behind the screen on the table along with the other equipment to help the experimenter do his work during the experiment when the ceiling lights were turned off. A second desk lamp was provided for the subject to aid him/her write observations.

Controls

The experimenter was in control of the timer and the independent variables, the target luminances and the background luminances on both sides of the partition.

The luminance of the target lights was varied by changing the position of the tungsten-halogen projector lamp within the wooden casing, moving it either towards or away from the subject. The neutral density filters, mentioned earlier, were also used to control the target luminance.

The background luminance was controlled by means of a Variac to vary the voltage of each set of floodlights separately. Thus, different background luminances could be obtained on both sides of the partition.

The timer was hooked on to two switches --- one for the experimenter, to turn it on, and the other for the subject to turn it off. The subject was not informed regarding the function of this switch to eliminate introduction of any bias. Another factor that was taken into account to eliminate bias was in making the changes in the target and background luminances for each trial. The experimenter made these changes alternately for both the sides so that the subject would not look to one side, e.g., the side in which the experimenter always made the changes first. Depending on the target and the background luminances, it took about 50 to 70 seconds to effect the changes for each trial.

Assignment and sequence of conditions

The thirty-eight treatment combinations of target luminance and background luminance, and their luminance ratios are shown in Table 2. Each of these luminance ratio combinations was randomly assigned to the subjects. This randomization of the luminance ratios for each subject helped eliminate any kind of bias in the pattern of presentation of the conditions.

Observation of the table reveals that almost all the luminance ratios were presented four times, twice on each side (left and right). But there were four levels of luminance, viz., 10, 16, 20, and 32 which did not follow suit. These were presented only three times each and was the result of the design of the experiment.

Pleasantness scale

The Pleasantness scale provided to the subjects had labels from "Very Unpleasant" to "Very Pleasant" with corresponding numbers from "-7" to " 7" (Figure 4).

Criteria. The subjects were told that there was nothing right or wrong in their judgment on the pleasantness of the lights. It was entirely their opinion using the Pleasantness scale, mentioned above.

Procedure

Upon arrival, the subject was asked to read the

TABLE 2

Treatments or Conditions presented on the left and right sources.

Trial number	Luminance Ratio Left	Right	Trial number	Luminance Ratio Left	Right
1.	0.2	0.5	20.	100.0	50.0
2.	1.0	0.2	21.	50.0	160.0
3.	0.2	1.6	22.	64.0	100.0
4.	0.5	1.0	23.	160.0	64.0
5.	1.6	0.5	24.	100.0	160.0
6.	1.0	1.6	25.	200.0	320.0
7.	2.0	3.2	26.	500.0	200.0
8.	5.0	2.0	27.	200.0	640.0
9.	2.0	6.4	28.	320.0	500.0
10.	3.2	5.0	29.	640.0	320.0
11.	6.4	3.2	30.	500.0	640.0
12.	5.0	6.4	31.	640.0	0.2
13.	10.0	16.0	32.	0.5	500.0
14.	20.0	10.0	33.	320.0	1.0
15.	10.0	32.0	34.	1.6	200.0
16	16.0	20.0	35.	160.0	2.0
17.	32.0	16.0	36.	3.2	100.0
18.	20.0	32.0	37.	64.0	5.0
19.	50.0	64.0	38.	6.4	50.0

TABLE 2 (Supplement).

Target and Background Luminances for each Luminance Ratio.

Luminance Ratio	Targ Luminance (fL)	Bckgrnd Luminance (fL)
0.2	10	50
0.5	10	20
1.0	10	10
1.6	32	20
2.0	10 100	5 50
3.2	32	10
5.0	10 100	2 20
6.4	32 320	5 50
10	100	10
16	32 320	2 20
20	100 1000	5 50
32	320	10
50	100 1000	2 20
64	320 3200	5 50
100	1000	10
160	320 3200	2 20
200	1000	5
320	3200	10
500	1000	2
640	3200	5

```
      -¦-
       ¦
 7    -¦-   Very Pleasant
       ¦
 6    -¦-
       ¦
 5    -¦-   Pleasant
       ¦
 4    -¦-
       ¦
 3    -¦-   Moderately Pleasant
       ¦
 2    -¦-
       ¦
 1    -¦-   More Pleasant than Unpleasant
       ¦
 0    -¦-   Average
       ¦
-1    -¦-   More Unpleasant than Pleasant
       ¦
-2    -¦-
       ¦
-3    -¦-   Moderately Unpleasant
       ¦
-4    -¦-
       ¦
-5    -¦-   Unpleasant
       ¦
-6    -¦-
       ¦
-7    -¦-   Very Unpleasant
       ¦
      -¦-
```

Figure 4. Pleasantness Scale

instruction sheet (Figure 5) and sign the "informed consent form" (Figure 6) before starting with the main experiment.

The subject was seated in front of the target lights and the screen at a viewing distance of 102 - 105 inches. The partition board between the target lights extended 58 inches from the screen to the subject, leaving a clearance of 44 - 47 inches between the front end of the board and the subject.

The subject was instructed to sit upright in his chair such that he/she could look at both the target lights at the same time, without having to move his/her head. The ceiling lights were turned off during the whole period of the experiment. The floodlights were turned on and set at the required levels for the first trial.

At the start, the subject was instructed to look straight ahead and concentrate on a black round "spot" , about an inch in diameter, painted on a white background on the front edge of the partition board. This spot was kept at the eye level.

<u>Task</u>. The target lights, also set at the required levels of luminance for the first trial, were then turned on. As soon as these lights went on, the subject's task was to look at one or the other light, whichever he/she chose. He/she then pressed a red button immediately and this (unknown to the subject) recorded the time on the timer. The target lights were still turned on, and the subject was instructed to rate the pleasantness of both the lights (the target light on the left was called source "A" and the one on the right was called source "B"), using the pleasantness scale. He/she was also instructed to make a check

INSTRUCTIONS

You are about to participate in an experiment involving different levels of illumination. There is nothing right or wrong in this experiment. You should not be worried about your performance. It is not what I am looking for.

A sheet of paper and a pencil are provided to be used during the course of this experiment. A "Pleasantness Scale" is also provided for you to rate the pleasantness of the light.

Before we start with the experiment, let me assure you that there is no risk involved.

There are two light sources (called target lights) in front of you with a partition separating one from the other. Sit upright in the chair such that when you look straight both the target lights come into your line of sight without having to move your head. The screen at the front provides a background and it shall be illuminated by floodlights to different levels on both sides of the partition.

At the start you will look straight and concentrate on the "spot" between the target lights. The ceiling lights will be turned off and the floodlights turned on.

The target lights will now be turned on. As soon as these lights go on, quickly look at one or the other light. Quickly press the red button of the switch given to you. Now, using the ratings of the "Pleasantness Scale", from -7 (very unpleasant) to 7 (very pleasant), rate the pleasantness of the

Figure 5. Instruction sheet for the subjects.

selected combination of lights. Then rate the pleasantness of the other combination. It is important that you press the red button before doing anything, even writing!

Write down the ratings of both the combinations in the appropriate places on the sheet of paper provided. Make a check mark beside the combination you looked at first. The target lights will now be turned off. This is the end of trial 1.

Once again you will concentrate on the "spot" between the target lights ready for the next trial while I change the illumination levels. The target lights will be turned on again. You will react and look at one source or the other and follow the same steps as before.

This will be continued for different illumination levels.

After going through 38 trials as above, you will go through 11 more trials. During the first six trials, the background luminance will be held constant while the target luminances will be varied. You will rate these combinations again using the "Pleasantness Scale" and also write whether each source was "glaring" or "not glaring". Likewise, during the next five trials, the target luminance will be held constant and the background luminances varied while you rate these combinations and write whether they were "glaring" or "not glaring".

In cook-book style, the instructions can be summed up in the following steps:

1. Look straight on the "spot" between the lights.

Figure 5 (contd.). Instruction sheet for the subjects.

2. Choose one of the combinations of lights as soon as target lights are turned on.
3. Press the red button given to you.
4. Rate the pleasantness of the selected combination of lights.
5. Rate the pleasantness of the other combination of lights.
6. Write down the ratings in the appropriate places.
7. Make a check mark beside the combination looked at first.
8. Repeat above steps for the first 38 trials.
9. Now rate each combination of lights as they would be presented and write whether "glaring" or "not glaring" beside each of them.

As mentioned earlier, there will be no discomfort nor risk in this experiment. However, you are free to stop your participation at any time. Naturally I would prefer that you continue until the end so that I can get all of the needed data.

If you have any questions, now or later, feel free to ask. Thank you for your co-operation.

Figure 5 (contd.). Instruction sheet for the subjects.

INFORMED CONSENT

Having read the attached instructions, I hereby freely agree to be a subject in the research entitled " A Behavioral Approach to Lighting Pleasantness ".

________________ ______________________

Date Signature of subject.

NAME _____________________

AGE___________ SEX________

EDUCATION_____________________

Figure 6. Informed Consent Sheet for the Subjects.

mark beside the the light whichever he/she looked at first. The observation sheet for the subject is shown in Figure 7. The timer recorded the response time and this was noted by the experimenter on the observation sheet for the experimenter (Figure 8).

After the subject had finished rating the lights and made the check mark, he/she told the experimenter and the target lights would then be turned off.

The necessary changes for the target lights and the background lights were then made for the next trial and once again the subject went through the above steps. This was continued for the 38 different combinations or treatments.

Having gone through these 38 trials, the subject was asked to rate only one set of lights (source "A" or source "B") once again and give their opinion as to whether they were "glaring" or "not glaring" as the case may be. At first, the middle value of the background luminances used, viz., 10 fL, was held constant and the target luminances were varied. Subjective responses were obtained from each of these. Next, the target luminance was held constant at a middle value, viz., 210 fL, and the background luminances varied. Subjective responses were obtained as before. There were five levels of background luminance and six levels of target luminance, and hence 11 such trials for each subject.

OBSERVATIONS

TRIAL NO.	SOURCE 'A' RATING	*	SOURCE 'B' RATING	*	TRL NO.	SOURCE 'A' RATING	*	SOURCE 'B' RATING	*
1.	______	___	______	___	20.	______	___	______	___
2.	______	___	______	___	21.	______	___	______	___
3.	______	___	______	___	22.	______	___	______	___
4.	______	___	______	___	23.	______	___	______	___
5.	______	___	______	___	24.	______	___	______	___
6.	______	___	______	___	25.	______	___	______	___
7.	______	___	______	___	26.	______	___	______	___
8.	______	___	______	___	27.	______	___	______	___
9.	______	___	______	___	28.	______	___	______	___
10.	______	___	______	___	29.	______	___	______	___
11.	______	___	______	___	30.	______	___	______	___
12.	______	___	______	___	31.	______	___	______	___
13.	______	___	______	___	32.	______	___	______	___
14.	______	___	______	___	33.	______	___	______	___
15.	______	___	______	___	34.	______	___	______	___
16.	______	___	______	___	35.	______	___	______	___
17.	______	___	______	___	36.	______	___	______	___
18.	______	___	______	___	37.	______	___	______	___
19.	______	___	______	___	38.	______	___	______	___

* Make check mark beside combination looked at first.

Figure 7. Observation sheet for the subject.

OBSERVATIONS (CONTD.)

TRIAL NO.	RATING	GLARING (G) OR NOT GLARING (NG)	TRIAL NO.	RATING	GLARING (G) OR NOT GLARING (NG)
1.	_______	_______	7.	_______	_______
2.	_______	_______	8.	_______	_______
3.	_______	_______	9.	_______	_______
4.	_______	_______	10.	_______	_______
5.	_______	_______	11.	_______	_______
6.	_______	_______			

Figure 7 (contd.). Observation sheet for the subject.

TREATMENTS & OBSERVATIONS

TRIAL NO.	LEFT BCKGR (fL)	LEFT TARG (fL)	LEFT CONT	RIGHT BCKGR (fL)	RIGHT TARG (fL)	RIGHT CONTR	RESPONSE TIME (secs)
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
21.							

Figure 8. Observation sheet for experimenter.

TREATMENT AND OBSERVATION

TRIAL NO.	LEFT BCKGR (fL)	LEFT TARG (fL)	LEFT CONT	RIGHT BCKGR (fL)	RIGHT TARG (fL)	RIGHT CONTR	RESPONSE TIME (secs)
22.							
23.							
24.							
25.							
26.							
27.							
28.							
29.							
30.							
31.							
32.							
33.							
34.							
35.							
36.							
37.							
38.							

Figure 8 (contd). Observation sheet for experimenter.

RESULTS

There were three kinds of responses --- the subjective ratings on the pleasantness of the lights, the number of times that the subjects looked at the lights and the response time. The raw data for each of these responses are furnished in Appendix A. Each kind of response was analyzed independently and is presented below.

Pleasantness Ratings

The treatments were randomized for each subject and the subjects rated both the lights (lights on both sides of the partition).

The pleasantness ratings were analyzed in two different ways : (1) a one-way classification with respect to the luminance ratio, and (2) a two-way classification with respect to the independent variables, target luminance and background luminance.

The Statistical Analysis System (SAS) was used to perform the analysis of variance (ANOVA) procedure on the data. When the data were analyzed two-way with respect to the target luminance and the background luminance there were 560 observations; and when the data were analyzed as a one-way design with respect to the luminance ratio there were 400 observations. This decrease in the number of observations was due to the repetition of eight of the levels of luminance ratios obtained from different combinations of target and background luminances.

Analyzing the data on pleasantness ratings as a one-way design, the ANOVA (Table 3) showed that there were significant

TABLE 3

Analysis of Variance Procedure for Ratings

Source	DF	Sum of Squares	Mean Square	F Value	PR > F
Luminance Ratio	19	850.885	44.783	10.28	0.0001
Error	380	1656.026	4.358		
Corrected Total	399	2506.911			

differences in the ratings among the different luminance ratios, at the 0.05 level. Duncan's Multiple Range Test was also performed and an observation of the table (Table 4) showed that the mean rating was highest, 2.53, for the luminance ratio 10, and was the lowest, -2.83, for the luminance ratio 640. A plot of these mean ratings versus the logarithm of the luminance ratios is shown in Figure 9.

When the data were analyzed as a two-way design, the target luminance and the background luminance were the factors. The ANOVA carried out on this data set revealed that there were significant differences in the ratings among the target luminances but no significant differences among the background luminances, at the 0.05 level. There was also an interaction between the target and the background luminances (Table 5).

A pairwise comparison was done on the target luminances. The upper and lower confidence limits of the pleasantness ratings and the difference between means were also computed. The pairs which were statistically significant are indicated in this table (Tables 6). The mean ratings of the different combinations of target and background luminances are shown in Table 7. The highest rating was 2.875 --- it corresponded to the target luminance 320 fL and background luminance 5 fL. The lowest rating (-2.825) was found to correspond to the target luminance of 3200 fL and background luminance of 5 fL. Duncan's Multiple Range Test was done on the ratings for each of the target luminances (Table 8). There was no significant difference between the luminances 100 and 320 or 30 and 100 fL. Among the

TABLE 4

Duncan's Multiple Range Test for Variable: Rating

Duncan Grouping					Mean	N	Contrast
		A			2.5325	20	10
		A					
		A			2.5170	20	32
		A					
B		A			2.2250	20	16
B		A					
B		A			2.2250	20	6.4
B		A					
B		A			1.8375	20	5
B		A		C			
B		A		C	1.7250	20	3.2
B		A		C			
B		A		C	1.5250	20	50
B		A		C			
B		A		C	1.4625	20	20
B		A		C			
B		A		C	1.4125	20	1.6
B		A		C			
B		A		C	1.3750	20	200
B		A		C			
B		A		C	1.3625	20	100
B		A		C			
B	D	A		C	1.0250	20	64
B	D	A		C			
B	D	A		C	0.9625	20	2
B	D			C			
B	D			C	0.7125	20	500
B	D			C			
B	D			C	0.7000	20	160
	D			C			
	D			C	0.6250	20	1
	D						
	D		E		- 0.3750	20	0.5
			E				
F			E		- 1.4500	20	0.2
F							
F					- 2.2000	20	320
F							
F					- 2.8250	20	640

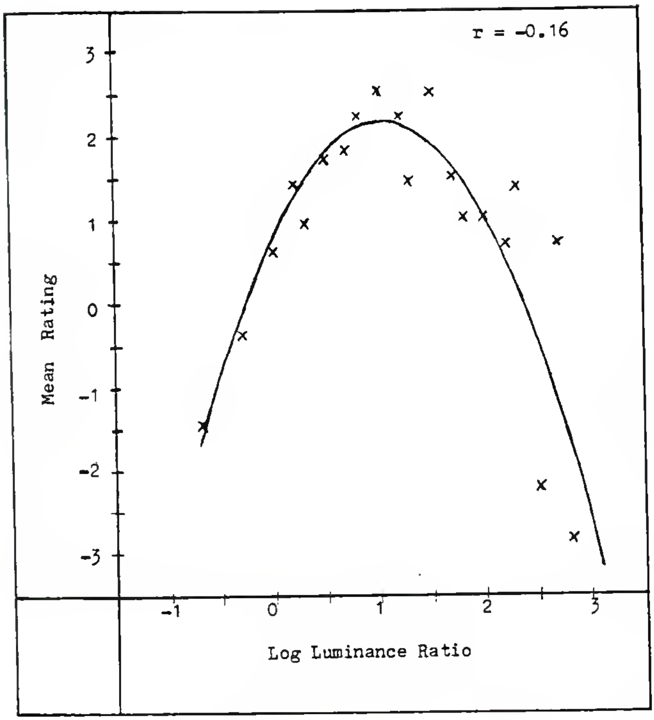


Figure 9. Plot of Mean Rating Vs Log Luminance Ratio

TABLE 5

Two-Way Analysis of Variance Procedure on Ratings

Source	DF	Sum of Squares	Mean Square
Model	27	1316.004	48.741
Error	532	3013.210	5.664
Corrected Total	559	4329.215	

PR > F = 0.0001

Source	DF	Type I SS	F Value	PR > F
Target	5	1130.294	39.91	0.0001
Bckgrd	4	17.263	0.76	0.5504
Target*Bckgrd	18	168.448	1.65	0.0440

TABLE 6.

T TESTS (LSD) FOR VARIABLE: RATING (Pairwise Comparison)
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE, NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 CONFIDENCE=0.95 DF=532 MSE=5.66393
CRITICAL VALUE OF T=1.96443

COMPARISONS SIGNIFICANT AT THE 0.05 LEVEL ARE INDICATED BY '***'

TARGET COMPARISON	LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	UPPER CONFIDENCE LIMIT	
320 - 100	-0.2893	0.3719	1.0331	
320 - 32	0.1065	0.8078	1.5090	***
320 - 1000	0.8772	1.5384	2.1996	***
320 - 10	1.8772	2.5384	3.1996	***
320 - 3200	3.6096	4.3109	5.0122	***
100 - 320	-1.0331	-0.3719	0.2893	
100 - 32	-0.2654	0.4359	1.1371	
100 - 1000	0.5053	1.1665	1.8277	***
100 - 10	1.5053	2.1665	2.8277	***
100 - 3200	3.2377	3.9390	4.6403	***
32 - 320	-1.5090	-0.8078	-0.1065	***
32 - 100	-1.1371	-0.4359	0.2654	
32 - 1000	0.0294	0.7306	1.4319	***
32 - 10	1.0294	1.7306	2.4319	***
32 - 3200	2.7639	3.5031	4.2423	***
1000 - 320	-2.1996	-1.5384	-0.8772	***
1000 - 100	-1.8277	-1.1665	-0.5053	***
1000 - 32	-1.4319	-0.7306	-0.0294	***
1000 - 10	0.3388	1.0000	1.6612	***
1000 - 3200	2.0712	2.7725	3.4738	***
10 - 320	-3.1996	-2.5384	-1.8772	***
10 - 100	-2.8277	-2.1665	-1.5053	***
10 - 32	-2.4319	-1.7306	-1.0294	***
10 - 1000	-1.6612	-1.0000	-0.3388	***
10 - 3200	1.0712	1.7725	2.4738	***
3200 - 320	-5.0122	-4.3109	-3.6096	***
3200 - 100	-4.6403	-3.9390	-3.2377	***
3200 - 32	-4.2423	-3.5031	-2.7639	***
3200 - 1000	-3.4738	-2.7725	-2.0712	***
3200 - 10	-2.4738	-1.7725	-1.0712	***

TABLE 7

Means of Ratings for Each Target and Background Luminances

Target	Bckgrd	N	Rating
10	2	20	0.850
10	5	20	0.525
10	10	20	0.625
10	20	20	-0.375
10	50	20	-1.450
32	2	20	2.250
32	5	20	1.675
32	10	20	1.725
32	20	20	1.413
100	2	20	1.700
100	5	20	2.550
100	10	20	2.533
100	20	20	2.825
100	50	20	1.400
320	2	20	2.500
320	5	20	2.875
320	10	20	2.517
320	20	20	2.200
320	50	20	2.775
1000	50	20	0.713
1000	5	20	1.375
1000	10	20	1.363
1000	20	20	1.350
1000	50	20	0.375
3200	5	20	- 2.825
3200	10	20	- 2.200
3200	20	20	- 1.100
3200	50	20	- 0.825

TABLE 8

Duncan's Multiple Range Test on Ratings for Each Target Luminance

Duncan Grouping		Mean	N	Target
	A	2.5734	100	320
	A			
B	A	2.2015	100	100
B				
B		1.7656	80	32
	C	1.0350	100	1000
	D	0.0350	100	10
	E	- 1.7375	80	3200

others, 10, 1000 and 3200 seemed to be significantly different from one another and also from the other values, viz., 32, 100 and 320 fL.

Number of times subjects looked at the different lights

Because of the way that the experiment was designed, every luminance level, but four, was presented four times during the experiment at random intervals. The four levels which were presented only three times each during the experiment, at random intervals, were 10, 16, 20 and 32. The other sixteen levels were presented twice on each side of the partition at different times.

The number of times that each subject looked at the lights was counted and an attempt was made to relate their looking behavior to the luminance ratio of the lights. There were times when some subjects completely avoided looking at lights of a certain luminance ratio, i.e., they never looked at certain lights.

An ANOVA procedure was done on the raw data and the results showed (Table 9) that there were significant differences in the number of times that people looked at the different lights at the 0.05 level. A Duncan's Multiple Range Test (Table 10) was done and it showed that the mean number was highest, 3.2, for the luminance ratio 640, while the least number was 0.4 for the luminance ratio 0.2. A plot of these mean numbers against the logarithm of the luminance ratios is shown in Figure 10.

TABLE 9

Analysis of Variance Procedure on Number

Source	DF	Sum of Squares	Mean Square
Luminance Ratio	19	249.248	13.118
Error	380	221.950	0.584
Corrected Total	399	471.198	

Model F = 22.46 PR > F = 0.0001

TABLE 10.

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: NUMBER
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE, NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 DF=380 MSE=0.584079

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN	GROUPING			MEAN	N	LUM_RATO
		A		3.2000	20	640
		A				
B		A		3.0000	20	160
B		A				
B		A	C	2.7000	20	1.6
B		A	C			
B		A	C	2.7000	20	320
B			C			
B			C	2.6000	20	100
B			C			
B		D	C	2.5000	20	6.4
		D	C			
E		D	C	2.4000	20	64
E		D	C			
E		D	C	2.3500	20	500
E		D	C			
E		D	C	2.3000	20	32
E		D				
E		D	F	2.0000	20	1
E			F			
E			F	1.9000	20	5
			F			
		G	F	1.7500	20	50
		G	F			
H		G	F	1.7000	20	20
H		G	F			
H	I	G	F	1.5500	20	200
H	I	G				
H	I	G	J	1.2500	20	3.2
H	I		J			
H	I		J	1.2000	20	16
	I		J			
	I		J	1.1500	20	0.5
			J			
		K	J	0.8000	20	10
		K				
		K		0.6000	20	2
		K				
		K		0.4000	20	0.2

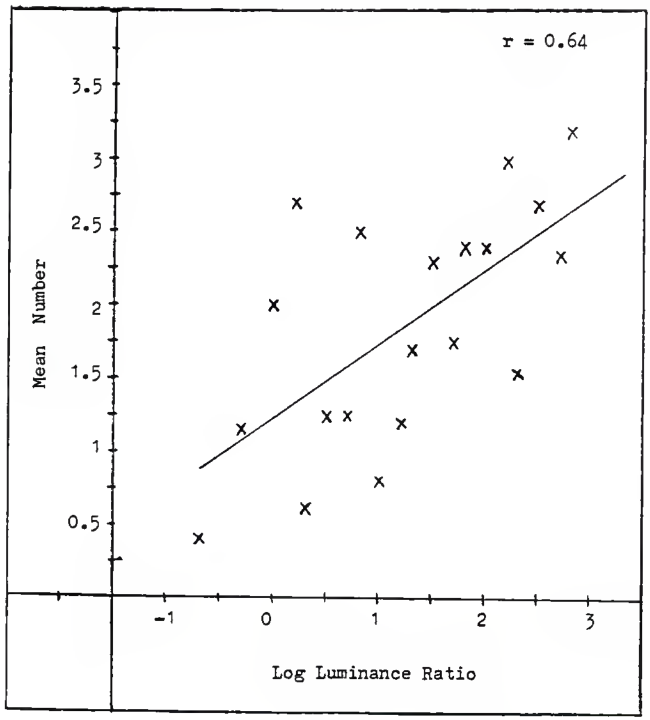


Figure 10. Plot of Mean Number Vs Log Luminance Ratio

Response Time

Like the pleasantness ratings, the response time data (the time taken by the subjects to look at one or the other light) was analyzed in two ways: (1) First, classifying the data as a one-way design with respect to the luminance ratio, and (2) analyzing the data as a two-way design with respect to the major factors, target luminance and background luminance.

On analyzing the data as a one-way design, the 20 luminance ratios were regarded as the treatments as before and the ANOVA (Table 11) showed that there were significant differences in the response times between the treatments at the 0.05 level. A Duncan's Multiple Range Test was also carried out (Table 12) and an observation of the means showed that the longest reaction time was 1.36 seconds at the luminance ratio 1.6, while the shortest value was 0.43 second at the luminance ratio 0.2. These means were then plotted against the logarithm of the luminance ratios (Figure 11).

When the response time data were analyzed as a two-way design, the ANOVA (Table 13) showed significant differences in the response times between the target luminances, the background luminances, and there was an interaction between these two factors at the 0.05 level. Tables 14 (a) and 14 (b) show the pairwise comparisons of the target and background luminances respectively. Duncan's Test was carried out individually on the response times for each of the variables target luminance and background luminance (Tables 15(a) and 15(b)). Also, the mean response times for the different combinations of target and

TABLE 11

Analysis of Variance Procedure for Response Times

Source	DF	Sum of Squares	Mean Square
Luminance Ratio	19	23.697	1.247
Error	380	267.126	0.703
Corrected Total	399	290.822	

Model F = 1.77 PR > F = 0.0240

TABLE 12

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: TIME
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 DF=380 MSE=0.702962

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN	GROUPING		MEAN	N	LUM_RATO
	A		1.3590	20	1.6
	A				
	A		1.3260	20	1
	A				
	A		1.2805	20	160
	A				
	A		1.2520	20	6.4
	A				
	A		1.2355	20	100
	A				
	A		1.2295	20	32
	A				
	A		1.2220	20	5
	A				
	A		1.2150	20	500
	A				
	A		1.1730	20	3.2
	A				
	A		1.1710	20	50
	A				
B	A		1.0970	20	0.5
B	A				
B	A		1.0600	20	640
B	A				
B	A		1.0510	20	320
B	A				
B	A		1.0455	20	64
B	A				
B	A	C	1.0030	20	16
B	A	C			
B	A	C	0.8895	20	200
B	A	C			
B	A	C	0.8395	20	20
B	A	C			
B	A	C	0.8350	20	10
B		C			
B		C	0.5405	20	2
		C			
		C	0.4265	20	0.2

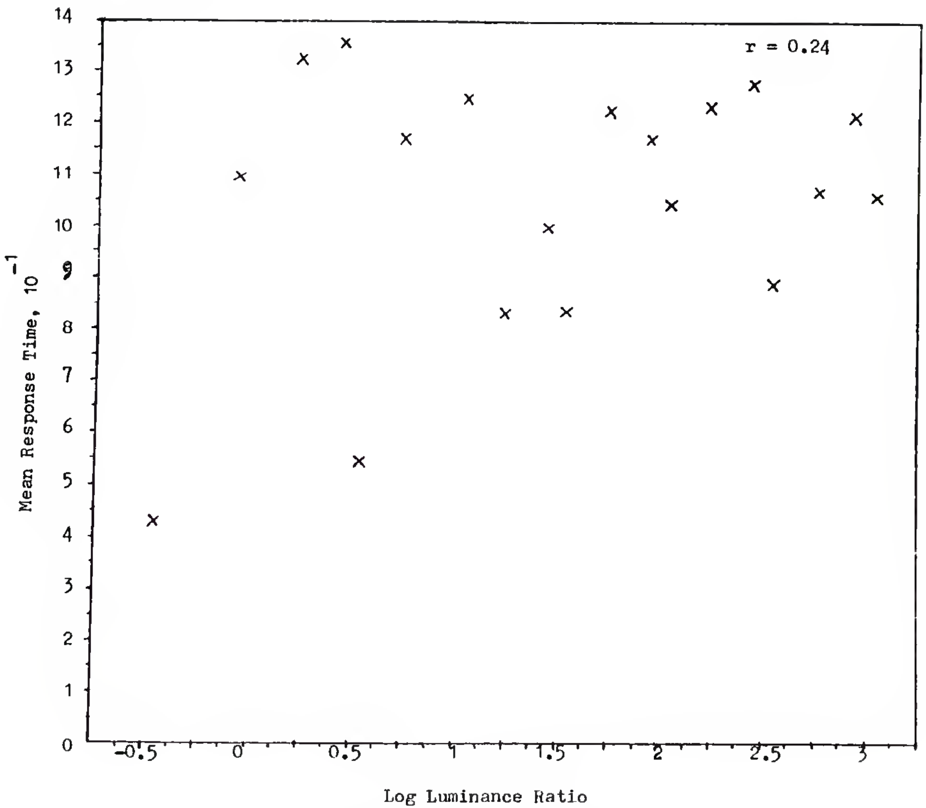


Figure 11. Plot of Mean Response Time Vs Log Luminance Ratio

TABLE 13

Two-Way Analysis of Times for Each Target and Background Luminances

Source	DF	Sum of Squares	Mean Square
Model	27	60.078	2.225
Error	532	382.610	0.719
Corrected Total	559	442.688	

Model F = 3.09 PR > F = 0.0001

Source	DF	Type I SS	F Value	PR > F
Target	5	11.895	3.31	0.0061
Bckgrd	4	17.886	6.22	0.0001
Target*Bckgrd	18	30.297	2.34	0.0015

TABLE 14(a).

T TESTS (LSD) FOR VARIABLE: TIME (Pairwise comparison).
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE, NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 CONFIDENCE=0.95 DF=532 MSE=0.719191
CRITICAL VALUE OF T=1.96443

COMPARISONS SIGNIFICANT AT THE 0.05 LEVEL ARE INDICATED BY '***'

TARGET COMPARISON	LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	UPPER CONFIDENCE LIMIT	
320 - 3200	-0.2138	0.0361	0.2859	
320 - 1000	-0.1839	0.0517	0.2873	
320 - 32	-0.0706	0.1793	0.4292	
320 - 10	0.0839	0.3195	0.5551	***
320 - 100	0.1333	0.3689	0.6045	***
3200 - 320	-0.2859	-0.0361	0.2138	
3200 - 1000	-0.2342	0.0156	0.2655	
3200 - 32	-0.1202	0.1432	0.4067	
3200 - 10	0.0336	0.2834	0.5333	***
3200 - 100	0.0830	0.3328	0.5827	***
1000 - 320	-0.2873	-0.0517	0.1839	
1000 - 3200	-0.2655	-0.0156	0.2342	
1000 - 32	-0.1223	0.1276	0.3775	
1000 - 10	0.0322	0.2678	0.5034	***
1000 - 100	0.0816	0.3172	0.5528	***
32 - 320	-0.4292	-0.1793	0.0706	
32 - 3200	-0.4067	-0.1432	0.1202	
32 - 1000	-0.3775	-0.1276	0.1223	
32 - 10	-0.1097	0.1402	0.3901	
32 - 100	-0.0603	0.1896	0.4395	
10 - 320	-0.5551	-0.3195	-0.0839	***
10 - 3200	-0.5333	-0.2834	-0.0336	***
10 - 1000	-0.5034	-0.2678	-0.0322	***
10 - 32	-0.3901	-0.1402	0.1097	
10 - 100	-0.1862	0.0494	0.2850	
100 - 320	-0.6045	-0.3689	-0.1333	***
100 - 3200	-0.5827	-0.3328	-0.0830	***
100 - 1000	-0.5528	-0.3172	-0.0816	***
100 - 32	-0.4395	-0.1896	0.0603	
100 - 10	-0.2850	-0.0494	0.1862	

TABLE 14(b).

T TESTS (LSD) FOR VARIABLE: TIME (Pairwise comparison).
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 CONFIDENCE=0.95 DF=532 MSE=0.719191
CRITICAL VALUE OF T=1.96443

COMPARISONS SIGNIFICANT AT THE 0.05 LEVEL ARE INDICATED BY '***'

BCKGRD COMPARISON	LOWER CONFIDENCE LIMIT	DIFFERENCE BETWEEN MEANS	UPPER CONFIDENCE LIMIT	
10 - 20	-0.1277	0.0874	0.3025	
10 - 2	0.1237	0.3493	0.5748	***
10 - 50	0.1777	0.4033	0.6288	***
10 - 5	0.2198	0.4348	0.6499	***
20 - 10	-0.3025	-0.0874	0.1277	
20 - 2	0.0363	0.2618	0.4874	***
20 - 50	0.0903	0.3158	0.5414	***
20 - 5	0.1323	0.3474	0.5625	***
2 - 10	-0.5748	-0.3493	-0.1237	***
2 - 20	-0.4874	-0.2618	-0.0363	***
2 - 50	-0.1816	0.0540	0.2896	
2 - 5	-0.1400	0.0856	0.3111	
50 - 10	-0.6288	-0.4033	-0.1777	***
50 - 20	-0.5414	-0.3158	-0.0903	***
50 - 2	-0.2896	-0.0540	0.1816	
50 - 5	-0.1940	0.0316	0.2571	
5 - 10	-0.6499	-0.4348	-0.2198	***
5 - 20	-0.5625	-0.3474	-0.1323	***
5 - 2	-0.3111	-0.0856	0.1400	
5 - 50	-0.2571	-0.0316	0.1940	

TABLE 15(a).

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: TIME
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE,
NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 DF=532 MSE=0.719191

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES=92.3077

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN	GROUPING	MEAN	N	TARGET
	A	1.0583	100	320
	A			
	A	1.0222	80	3200
	A			
	A	1.0066	100	1000
	A			
B	A	0.8790	80	32
B				
B		0.7388	100	10
B				
B		0.6894	100	100

TABLE 15(b).

DUNCAN'S MULTIPLE RANGE TEST FOR VARIABLE: TIME
NOTE: THIS TEST CONTROLS THE TYPE I COMPARISONWISE ERROR RATE, NOT THE EXPERIMENTWISE ERROR RATE.

ALPHA=0.05 DF=532 MSE=0.719191

WARNING: CELL SIZES ARE NOT EQUAL.
HARMONIC MEAN OF CELL SIZES=111.111

MEANS WITH THE SAME LETTER ARE NOT SIGNIFICANTLY DIFFERENT.

DUNCAN GROUPING	MEAN	N	PCKGPD
A	1.1417	120	10
A			
A	1.0542	120	20
B	0.7924	100	2
B			
B	0.7384	100	50
B			
B	0.7068	120	5

background luminances are shown in Table 16.

Correlations between the variables

The correlations between the independent and the dependent variables were computed. Luminance ratio was treated as the third independent variable besides target and background luminances. Also, the logarithms of the luminance ratios ("LUMRAT") was considered as another variable. The mean values of the dependent variables, rating, number of times people looked at the lights, and response time corresponding to each of the luminance levels, formed the data set. These correlation coefficients are shown in Table 17.

The treatments or the conditions to which all the subjects were exposed are shown in Table 18. Specifically, the conditions that were presented --- the luminance level on the left (LFT_CON) and the luminance level on the right (RGT_CON) --- for each trial, are shown in the table. They were randomized for each subject. The ratio of the left to the right luminance levels was calculated too ("L_R_RATO"). The number of subjects that looked at the higher or the lower luminance levels was determined. It was observed that the subjects almost always tended to look at the brighter lights. Quantitatively, subjects looked at the brighter lights 87 percent of the time. Table 19 shows the correlation between the different variables. A plot of the mean ratings versus the mean number of people looking at the different lights was obtained and these observations are shown in Figure 12.

TABLE 16.

Mean Response Times for combinations of target and background luminances.

MEANS

TARGET	BCKGRD	N	TIME
10	2	20	0.76500000
10	5	20	0.07950000
10	10	20	1.32600000
10	20	20	1.09700000
10	50	20	0.42650000
32	2	20	0.23100000
32	5	20	0.75300000
32	10	20	1.17300000
32	20	20	1.35900000
100	2	20	0.53850000
100	5	20	0.70000000
100	10	20	0.83500000
100	20	20	0.91250000
100	50	20	0.46100000
320	2	20	1.21250000
320	5	20	0.74700000
320	10	20	1.22950000
320	20	20	0.82950000
320	50	20	1.27300000
1000	2	20	1.21500000
1000	5	20	0.88950000
1000	10	20	1.23550000
1000	20	20	1.00050000
1000	50	20	0.69250000
3200	5	20	1.07200000
3200	10	20	1.05100000
3200	20	20	1.12700000
3200	50	20	0.83900000

TABLE 17

Correlation Between Different Variables

	Contr	Bckgrd	Trgt	Rtg	Time	No.	LUMRAT
Contrast	1.000	-0.378	0.804	-0.613	0.117	0.559	0.753
Bckgrnd	-0.378	1.000	-0.153	0.007	-0.254	-0.221	-0.475
Target	0.804	-0.153	1.000	-0.677	0.029	0.549	0.708
Rating	-0.613	0.007	0.677	1.000	0.228	-0.241	-0.160
Time	0.117	-0.254	0.029	0.228	1.000	0.675	0.242
Number	0.560	-0.221	0.546	-0.241	0.675	1.000	0.644
Lumrat	0.753	-0.475	0.708	-0.160	0.242	0.644	1.000

TABLE 18

Analysis of Number of People Looking at Brighter or Dimmer Contrast

Obs	Lft-Con	Rgt-Con	L-R-Ratio	Brghtr	Dimmer
1	0.2	0.5	0.40	17	3
2	1.0	0.2	5.00	17	3
3	0.2	1.6	0.13	19	1
4	0.5	1.0	0.50	18	2
5	1.6	0.5	3.20	16	2
6	1.0	1.6	0.63	12	4
7	2.0	3.2	0.63	12	8
8	5.0	2.0	2.50	16	4
9	2.0	6.4	0.31	18	2
10	3.2	5.0	0.64	13	7
11	6.4	3.2	2.00	16	4
12	5.0	6.4	0.78	14	6
13	10.0	16.0	0.63	16	4
14	20.0	10.0	2.00	10	10
15	10.0	32.0	0.31	18	2
16	16.0	20.0	0.80	13	17
17	32.0	16.0	2.00	18	2
18	20.0	32.0	0.63	11	9
19	50.0	64.0	0.78	10	10
20	100.0	50.0	2.00	17	3
21	50.0	160.0	0.31	15	5
22	64.0	100.0	0.64	12	8
23	160.0	64.0	2.50	9	11
24	100.0	160.0	0.63	16	4
25	200.0	320.0	0.63	14	6
26	500.0	200.0	2.50	16	4
27	200.0	640.0	0.31	18	2
28	320.0	500.0	0.64	6	14
29	640.0	320.0	2.00	14	6
30	500.0	640.0	0.78	14	6
31	640.0	0.2	3200.00	19	1
32	0.5	500.0	0.00	20	0
33	320.0	1.0	320.00	19	1
34	1.6	200.0	0.01	19	1
35	160.0	2.0	80.00	20	0
36	3.2	100.0	0.03	19	1
37	64.0	5.0	12.80	18	2
38	6.4	50.0	0.13	18	2

TABLE 19

Correlation Coefficients Between Computed Variables

	Lft-Con	Rgt-Con	L-R-Rato	Brghtr	Dimmer
Lft-Con	1.000	0.459	0.504	-0.087	0.039
Rgt-Con	0.459	1.000	-0.115	-0.139	0.084
L-R-Rato	0.504	-0.115	1.000	0.190	-0.176
Brighter	-0.087	-0.139	0.190	1.000	-0.912
Dimmer	0.039	0.084	-0.176	-0.912	1.000

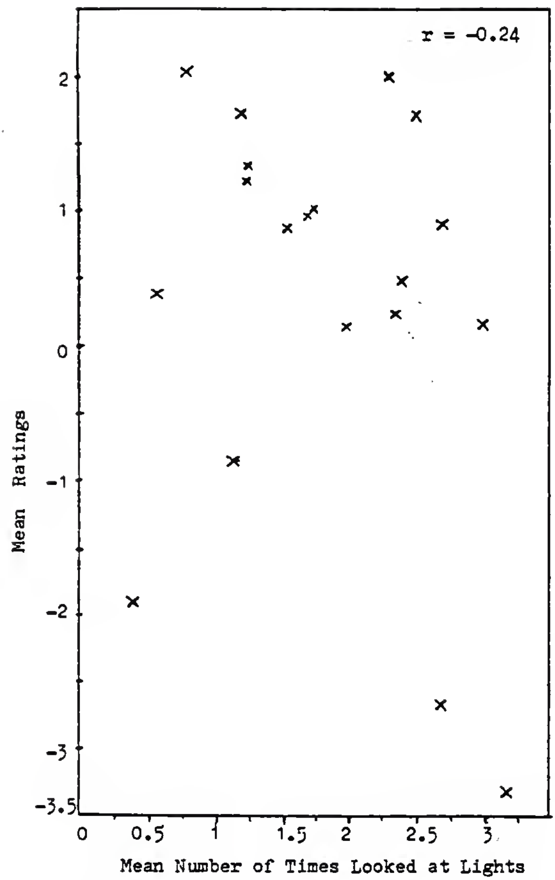


Figure 12. Plot of Mean Rating Vs Mean Number

Independent Ratings for each luminance level

In a second part of the experiment, the subjects were instructed to rate, independently, the pleasantness of the lights at each luminance ratio, presented only on one side of the partition. At the beginning, the background luminance was held constant at the middle value, 10 fL, and the target luminance varied. For each level, the subject was asked to rate the lights and also indicate whether that particular level was "glaring" or "not glaring". Then, the target luminance was held constant at 210 fL, the median of the target luminances used and the background luminance varied and the subjects were asked to give the same kind of responses as before. The mean ratings were computed for each of the conditions and the number of subjects for both the comments --- "glaring" and "not glaring" --- was also found. These results are shown in Tables 20(a) and 20(b). Also, a summary of the observations of the mean ratings and the mean number of times looked at the lights is shown in Table 21.

Regression Models

The functional relationship between the independent and the dependent variables may be expressed or approximated by some simple mathematical function. This model building is an iterative process whereby the relation between the independent and the dependent variables or the unknown parameters are estimated under certain assumptions with the help of available data and a fitted equation is obtained. This method of analysis is called regression analysis.

TABLE 20 (a)

Independent Ratings of each Luminance ratio.

(Constant background luminance)

Bckgrd Lumnce (fL)	Target Lumnce (fL)	Average Rating	Number of times Glaring	Number of times not Glaring
10	10	1.75	0	20
10	32	2.9	1	19
10	100	2.8	2	18
10	320	1.8	9	11
10	1000	-0.55	18	2
10	3200	-3.3	20	0

TABLE 20 (b)

Independent Ratings of each Luminance ratio.

(Constant target luminance)

Bckgrd Lumnce (fL)	Target Lumnce (fL)	Average Rating	Number of times Glaring	Number of times not Glaring
2	210	1.45	5	15
5	210	2.4	4	16
10	210	2.9	2	18
20	210	2.4	3	17
50	210	1.8	4	16

TABLE 21

Summary Table for Ratings and Number

Luminance Ratio	Logarithm of Luminance Ratio	Rating	Number	Percent of Number (Out of 4)
0.2	-0.699	-1.45	0.4	10
0.5	-0.30	-0.375	1.15	28.75
1	0	0.625	2	50
1.6	0.204	1.41	2.7	67.5
2	0.30	0.96	0.6	15
3.2	0.505	1.73	1.25	31.25
5	0.699	1.84	1.9	47.5
6.4	0.806	2.23	2.5	62.5
10	1	2.53	0.8	26.67 *
16	1.2	2.23	1.2	40 *
20	1.3	1.46	1.7	56.67 *
32	1.505	2.52	2.3	76.67 *
50	1.699	1.53	1.75	43.75
64	1.806	1.03	2.4	60
100	2	1.36	2.6	65
160	2.204	0.70	3.0	75
200	2.30	1.38	1.55	38.75
320	2.505	-2.2	2.7	67.5
500	2.699	0.71	2.35	58.75
640	2.806	-2.83	3.2	80

* - Percentage calculated out of 3.

The ANOVA on the dependent variables, ratings and the response times (Tables 5 and 11, respectively) showed that there was evidence of the existence of interaction between target and background luminances for both the dependent variables. Also, when the data was plotted against the logarithm of the luminance ratio, there seemed to be a definite trend in the curve and a better plot of the responses at the initial values of luminance ratios was obtained. Therefore, the logarithm of the luminance ratio was considered as the third independent variable and it was found that this factor had a high correlation with the target luminance. For the dependent variable "number", which was the number of times the subjects looked at the lights, there was no interaction effect and the analysis to fit the best equation was done with the three independent variables, target luminance, background luminance and the logarithm of the luminance ratio.

Draper and Smith (1966) suggested model building methods and these have been used to arrive at the "best" regression equation for each of the response variables. Four methods of model building were used for each dependent variable --- forward selection procedure, backward elimination procedure, stepwise regression method and the R_Square method.

Ratings. In the forward selection method for the ratings (Appendix B), an observation of the probability value or the F_value showed that the final model would consist of the following terms: the intercept, the logarithm of the luminance, ratio, the background luminance, the target luminance and the interaction factor (target luminance x background luminance). The corresponding R-square value was 0.769 and the Mean Square Error 0.65. The backward elimination procedure gave the following terms in the model: intercept, logarithm of the luminance ratio, target luminance and the interaction factor (target luminance x background luminance). The corresponding R-square value was 0.76 and the Mean Square Error was 0.63. The stepwise regression method gave the same result as the forward procedure. A comparison of the R_Square values and the corresponding mean square error (MSE) values showed that the model with the logarithm of the luminance ratio, the target luminance and the interaction factor was the best. The R_Square value for this model was 0.76 and the corresponding mean square error, 0.63.

Number. This variable did not require any interaction factor for its model. The forward selection procedure included target luminance and the logarithm of the luminance ratio as the predictor variables in the model. The corresponding R_Square value was 0.43 and the Mean Square Error 0.42. The backward elimination and the stepwise regression methods gave similar results and included only the logarithm of luminance ratio in the model. The corresponding R_Square value was 0.41 and an observation of the mean square error values revealed that this was 0.41. This is not a significant difference in the Mean Square Values, and because of a high R-square value in the former cases, the model obtained by those methods has been selected as the "best" one.

Response Times. The forward selection method for the response times showed that the background luminance was the only term to be included in the model with a corresponding R-square value of 0.06 and Mean Square Value of 0.059. The backward elimination procedure, however, showed different results and the model built was a simple linear regression equation with only the intercept and no independent variables. The corresponding R-square value was 0 and the Mean Square Error was 0.06. The stepwise regression showed the same result as the forward method. A comparison of the R_Square values (in the R-Square procedure) revealed that none of the models could really be described as the "best" model since these values were very low. The highest R_Square value was observed to be 0.1099 and this model included all the independent variables besides the interaction factor. Because of these low R_Square values and as shown in the backward elimination method, it is not possible to build a model for the dependent variable time.

Estimation of the Parameters of the Model

Having built the models for the dependent variables, ratings and number, the estimation of the parameters of the models was necessary. This involved computing the values of the intercepts (B_0) and the slopes (B_1, B_2, B_3, etc.) for each of the independent variables. The slope is the rate of change in the mean of the dependent variable at a given value of the independent variable.

Ratings. The estimates of the parameters, the actual and predicted values, and the lower and upper 95 percent means of the dependent variable, rating, are shown in Table 22. The following were the estimates of the parameters :

TABLE 22

Actual and Predicted Values and Confidence Interval of Ratings

Obs	Actual	Predict Value	Lower 95% Mean	Upper 95% Mean	Lower 95% Predict	Upper 95% Predict
1	-1.450	-.049	-.964	0.866	-1.969	1.870
2	- .375	0.345	-.396	1.086	-1.498	2.188
3	0.625	0.649	0.024	1.273	-1.151	2.448
4	1.413	0.833	0.278	1.389	- .943	2.610
5	0.963	0.955	0.423	1.487	- .815	2.724
6	1.725	1.128	0.641	1.614	- .494	2.884
7	1.828	1.251	0.805	1.698	- .275	2.997
8	2.225	1.503	0.942	2.063	- .233	3.281
9	2.533	1.515	1.058	1.972	- .233	3.264
10	2.225	1.832	1.315	2.349	0.067	3.597
11	1.463	2.033	0.539	3.527	- .221	4.287
12	2.517	1.647	1.155	2.138	- .111	3.404
13	1.515	1.100	0.553	1.647	- .674	2.874
14	1.025	1.884	1.282	2.485	0.092	3.675
15	1.025	0.961	0.476	1.446	- .795	2.841
16	0.700	2.248	1.477	3.020	0.396	4.104
17	1.375	1.046	0.436	1.656	- .748	2.841
18	-2.200	-2.379	-3.533	-1.225	-4.423	- .334
19	0.713	1.320	0.525	2.114	- .546	3.185
20	-2.830	-2.785	-4.010	-1.561	-4.870	- .700

Intercept,	B0	=	0.666
Slope of the logarithm of luminance ratio,	B1	=	1.024
Slope of target luminance,	B2	=	-0.0022
Slope of interaction (T x B),	B3	=	0.000045

The values for the lower and the upper 95 percent confidence interval were also calculated (Table 22).

Number. As for the variable, rating, the estimates of the different parameters of the model for "number" were obtained (Table 23), and are shown below :

Intercept,	B0	=	1.26
Luminance ratio,	B1	=	0.409
Target luminance,	B2	=	0.00015

The values for the lower and upper 95 percent confidence interval were computed (Table 23).

TABLE 23

Actual and Predicted Values and Confidence Interval of Numbers

Obs	Actual	Predict Value	Lower 95% Mean	Upper 95% Mean	Lower 95% Mean	Upper 95% Mean
1	0.400	0.974	0.249	1.699	- .577	2.525
2	1.150	1.137	0.553	1.721	- .353	2.627
3	2.000	1.260	0.769	1.751	- .196	2.716
4	2.700	1.347	0.908	1.785	- .092	2.786
5	0.600	1.383	0.966	1.800	- .050	2.816
6	1.250	1.470	1.086	1.853	0.046	2.893
7	1.250	1.560	1.201	1.919	0.143	2.977
8	2.500	1.637	1.304	1.970	0.226	3.048
9	0.800	1.683	1.317	2.048	0.264	3.101
10	1.200	1.756	1.340	2.172	0.323	3.188
11	1.700	1.944	1.606	2.281	0.531	3.355
12	2.300	1.923	1.525	2.321	0.496	3.350
13	1.750	2.106	1.767	2.446	0.694	3.519
14	2.400	2.046	1.562	2.531	0.592	3.500
15	2.400	2.230	1.836	2.624	0.803	3.656
16	3.000	2.209	1.586	2.832	0.703	3.715
17	1.550	2.353	1.874	2.832	0.901	3.805
18	2.700	2.773	1.837	3.709	1.113	4.432
19	2.350	2.516	1.899	3.132	1.013	4.018
20	3.200	2.896	1.991	3.800	1.253	4.538

DISCUSSION

This study was mainly carried out to determine whether there was correspondence between reported pleasantness and orienting behavior for particular lighting conditions. Also, it was expected that the speed of attention-getting or the response time of the subjects to look at the lights would decrease as the luminance ratio between the target and the background luminances increased. Further, it was expected that the dependent variables or the responses could be predicted for different values of luminances and luminance ratios and hence build regression models for each of the responses.

Pleasantness Ratings

The one-way ANOVA procedure on the pleasantness ratings showed that the subjects did find differences in the pleasantness levels between the luminance ratios presented. This was consistent with the pilot study. The ratings ranged from -7 to 7 on the pleasantness scale, and the Duncan's Multiple Range Test showed that the highest mean rating was 2.5 for the luminance ratio 10, i.e., when the background was 10 fL and the target luminance 100 fL. The lowest rating was observed to be -2.8 and it corresponded to the luminance ratio 640, i.e., background luminance 5 fL and target luminance 3200 fL. The other levels at which subjects reported pleasantness to a progressively lesser degree are shown in Table 4. The ratings seemed to lie on the positive side of the pleasantness scale up to the luminance ratio 64. The gradual decrease in the ratings, however, was not proportional to the luminance ratio. This was also consistent with the findings of the pilot study. As can be observed from the plot (Figure 9), there were lots of ups and downs in the curve and the ratings did not seem to have any specific pattern with the logarithm of the luminance ratios.

An observation of the correlation coefficients showed the presence of a considerably high negative correlation (-0.68) with target luminance. In other words, the rating decreased with the increase in target luminance. Also, a negative correlation with the number (-0.24) indicated a decrease in rating resulted in an increase in the number of times looked at the lights, and vice versa.

The pleasantness ratings showed significant differences among target luminances, a finding which was consistent with the pilot study. In other words, the target luminance had a bigger role to play in the judgments of pleasantness than the background luminance. This suggests that the range of background luminances used was not large enough and any future study could use a wider gamut of background luminances. There was evidence of the existence of an interaction between target and background luminances. This finding is, however, different from that found in the pilot study in which no interaction of these variables was observed. A possible explanation for this difference could be the difference in the way the experiment was conducted and the use of a wider range of target luminances.

These findings can be compared with those of Helson and Lansford (1970). Their study dealt with the pleasantness of object colors, and interaction of spectral energy with background color was found to be important in determining pleasantness. Also, lightness contrast was found to be the single factor responsible for pleasant color harmonics. In the present study, no colored lights were used and background luminance did not seem to play a major role in enhancing the conspicuity of the target or the object source. But, the luminance ratio between the target and the background luminances was found to be an important factor in orienting the behavior of subjects and determining pleasantness of lights.

Regression Model. The regression model that was found to best fit the data on pleasantness ratings included the independent variables, the logarithm of the luminance ratio, the target luminance and the interaction factor between target luminance and background luminance. Mathematically, this model can be expressed by the following equation :

$$R = B0 + B1\ X1 + B2\ X2 + B3\ X2\ X3 \quad \text{------------} \quad (1)$$

where R = Rating

X1 = logarithm of the luminance ratio

X2 = target luminance

X3 = background luminance

The estimates of the constant parameters for this model (B0, B1, B2, B3) are shown in Table 21. Substituting these values in the model in equation (1), we have the following resulting equation :

$$R = 0.666 + 1.024\ X1 - 0.0022\ X2 + 0.000045\ X2\ X3 \quad \text{---} \quad (2)$$

This represents the model or the regression equation for predicting the values of ratings. From the equation, it can be said that ratings are generally positive, and an increase in the logarithm of the luminance ratio, a decrease in the target luminance and a simultaneous increase in the interaction factor would result in an increase in the ratings.

The actual ratings for the different luminance ratios and the predicted values are also shown in Table 22. Besides these, the lower 95 percent and the upper 95 percent predicted values are also listed in this table. The lower and upper 95 percent confidence limits were also computed and are listed in the same table. An observation of the plot of the Mean Ratings versus the logarithm of the luminance ratios (Figure 9) showed no definite relationship between the two variables. A possible explanation for this behavior could be attributed to the presence of the interaction factor in the model.

A curve was then drawn (using the HP 9872B plotter) to best fit these observations, and this is also shown in Figure 9. This curve indicated an increasing trend in the ratings as the logarithm of the luminance ratio increased to the value of 1 (one) which corresponded to the luminance ratio of 10 (Table 21). Thereafter, the ratings fell and seemed to decrease with an increase in the logarithm of the luminance ratio. An observation of the correlation coefficients revealed that the Mean Ratings and the logarithm of the luminance ratio had a negative correlation of 0.16.

Number

The ANOVA on the number of times the subjects looked at the lights, for each luminance ratio, showed that there were differences among the luminance levels. This supported the findings of the pilot study. Duncan's Test (Table 16) shows the groupings of the means that are significantly different from each other with respect to the luminance levels. A plot of these means versus the logarithm of the luminance ratios (Figure 10) showed a different trend than the plot of the ratings versus the logarithm of the luminance ratios (Figure 9). An observation of the correlation coefficients showed a positive correlation (0.55) of number with target luminance and a correlation of 0.64 with the logarithm of the luminance ratio. This meant that the number increased with target luminance. "Number" was also observed to have a positive correlation (0.67) with "time". This means that subjects took a longer time to look at lights which they looked at a higher number of times.

These findings can be compared with those of LaGiusa and Perney (1974) in which they found that the number of times the children looked at the displays increased with the higher luminance (150 fL). To a certain degree, this study too revealed that the highest number of times that people looked at the lights was when the luminance ratios were also high, viz., 640, 500, 320 and 160. Thus, it can be said that attention of the subjects could be held by the higher luminance levels of the lights. Reference can also be made to the findings of Ireland, Kinslow, Levin and Page (1967) in which they recommended increased contrast requirements for better performance. The findings of the present study were consistent with these recommendations in that people were attracted a higher number of times to the higher luminance levels.

Regression Model. The model for the dependent variable, number, contained two independent variables, logarithm of the luminance ratio and target luminance. Mathematically, the equation to express this model is :

$$N = B0 + B1\ X1 + B2\ X2 \qquad \text{---------} \quad (3)$$

where N = dependent variable, number

X1 = logarithm of the luminance ratio

X2 = target luminance

The estimates of the constant parameters for this model are shown in Table 23. Substituting these values in equation (3), we have the following regression equation:

$$N = 1.26 + 0.409\ X1 + 0.00015\ X2 \qquad \text{--------} \quad (4)$$

This represents the model or the regression equation for making predictions of the variable, number. This model indicates that an increase in the target luminance and/or the logarithm of the luminance ratio would also result in the increase in the number of times subjects looked at the lights.

The actual and predicted values of the variable, number for different luminance ratios are also shown in Table 23. Besides these, the lower 95 percent and the upper 95 percent predicted values are also listed in this table. The lower and upper 95 percent confidence limits were also computed and are listed in the same table. An observation of the plot of the values of number versus the logarithm of the luminance ratios (Figure 10) revealed that there could be a linear relationship between the two variables. A straight line was drawn (using the HP 9872B plotter) to best fit these observations, and this is also shown in Figure 10. The linear relationship indicated that the number of times looked at the lights seemed to increase with a corresponding increase in the logarithm of the luminance ratio.

Response Time

Significant differences were observed in the times between the luminance ratios. A positive correlation with the logarithm of the luminance ratio indicated a gradual increase in response time with higher luminance ratios.

The two-way analysis done on the same data of response times showed significant differences between target and background luminances (Table 13). This was in conformance with the findings of the pilot study. Table 13 also revealed existence of interaction between the target and background luminances, a result which was not found in the pilot study. The reason for this difference in findings can again be attributed to the use of a wider range of target luminances, a separate background for each of the target lights, and most important of all, a change in the instructions to the subjects. In the pilot study, the subjects were instructed to look at the lights which they preferred. In this study, the subjects were asked to look immediately, as soon as the target lights were turned on, at one or the other light but were not told to look at the ones they preferred. This resulted in the decrease of the average response time than that found in the pilot study.

A pairwise comparison of the target luminances for the response times (Table 14) showed significant differences for the following pairs: (1) 320 fL and 10 fL, (2) 320 fL and 100 fL, (3) 3200 fL and 10 fL, (4) 3200 fL and 100 fL, (5) 1000 fL and 10 fL, and (6) 1000 fL and 100 fL. A similar pairwise comparison of the background luminances (Table 15) showed significant differences in the response times for the following pairs: (1) 10 fL and 2 fL, (2) 10 fL and 50 fL, (3) 10 fL and 5 fL, (4) 20 fL and 2 fL, (5) 20 fL and 50 fL, and (6) 20 fL and 5 fL. No significant pattern has been observed and no conclusive statements can be made at this stage.

The mean response time for every combination of target luminance and background luminance are shown in Table 16. The highest value was 1.36 seconds for the target luminance 32 fL and background luminance 20 fL, and the lowest value was 0.08 second for the target luminance 10 fL and background luminance 5 fL. There was no definite relation between the luminance levels and the response time and a lot of irregularity in the behavior, viz., speed of looking was observed. This is contrary to what was expected in the second part of the hypothesis, viz., the speed of looking would increase with luminance/contrast. No specific reason could be found to explain this phenomenon.

Relationship between Pleasantness Ratings and Number of Times Looked at Lights.

The conditions or treatment conditions presented to the subjects on the left and right side of the partition are shown in Table 18. An observation of this table revealed that subjects almost always looked at the higher luminance ratio or the bright light, irrespective of its position, left or right. This was consistent with Taylor and Sucov's findings (1974), in which it was found that two-thirds of the people preferred a brighter path.

An observation of the summarized values of ratings and numbers in Table 20 showed that there were a lot of times when subjects rated the lights on the negative side of the pleasantness scale in spite of looking at the corresponding brighter luminance ratios, a higher number of times. For example, subjects looked 80% of the times at the luminance ratio 640, but rated it -2.83 on the pleasantness scale, which almost corresponded to "Moderately unpleasant". In another case, subjects looked at the lights 75% of the times and also rated it "Moderately pleasant". This probably could be a case where the orienting behavior of the subject converges with his/her pleasantness response. This was also observed, to a lesser degree, at the luminance ratio 100. Here, subjects looked at the lights 65% of the time and the mean rating was 2.6 which was between "More pleasant than unpleasant" and "Moderately pleasant" on the Pleasantness Scale. Another such response was observed at the luminance ratio 32. At this level, subjects looked at the lights 77% of the time and also rated it almost the same as the previous case. This was not noticed at all luminance levels and there seemed to be a lot of fluctuation in the ratings of the lights as well as the number of times looked at the lights. It was not possible to explain the reason for this peculiarity in the orienting or the pleasantness response behavior of the subjects.

The negative correlation (-0.24) between number and rating indicated that these variables are inversely proportional to each other. Hence, the only conclusive statement that can be made from an observation of these phenomena and peculiarities in behavior is that the ratings will decrease as the number of times that subjects look at the lights increase. This, in turn, depends on the target luminance and the number increases with target luminance. But, it is still not known at what level of high luminance people will look away from the lights and hence decrease the number of times looked at them. An observation of the plot of mean ratings versus the mean number of times looked at the lights (Figure 12) did not reveal any significant pattern in the orientings and pleasantness behavior and hence no definite conclusions could be arrived at regarding the ranges of luminances that people reported as "pleasant".

Future Research

This study made an attempt to find some relationship between the orienting behavior and subjective response of people regarding the pleasantness of lights. The results showed that these two behavioral responses were not the same at all luminance levels. It was not possible to find any reason for the lack of consistency in these results nor was it possible to notice any specific pattern in the behavior.

Further research is needed to determine when behavioral and subjective responses are the same. Also, it would be interesting to know the luminance levels at which both these responses do not "converge", so that definite guidelines could be set for the lighting designer. Also, the number of times looked at the lights seemed to increase with target luminance. It would be desirable to determine the level of target luminance at which the number would drop or hold itself at a constant number.

The design of the experiment could be an important factor which researchers might consider to deal with and extend this study further. Another possible area of modifying the experiment could be in the use of bigger target lights and wider background areas. The pilot study had a task for the subjects during the experiment besides rating the lights, viz., reading and writing a displayed word. The present study did not use such a task. But it would not be improper to suggest the use of some task which would aid the subjects in making concrete decisions about the pleasantness of lights. To increase the power of the test, further study should consider increasing the number of subjects or the sample size.

Practical implications

From the practical point of view, this study should prove helpful to any practitioner who is interested in the movement of people, especially in commercial or safety situations. The luminance levels at which behavioral and subjective responses are the same, is an important finding of this study. This should help set initial guidelines for the lighting designer interested in aiding people making judgments regarding preferences for lights.

This study revealed that time to respond was not an important factor to be considered when it is desired to attract people in a certain direction. In other words, people would not take much time to react and select the preferred luminance. Also, it cannot be said conclusively that people always look at the brighter lights. In this study, 87 percent of the times people did look at the brighter lights. However, the behavior of the people looking at the dimmer lights the other 13 percent of the times could not be attributed to any particular reason.

CONCLUSION

The conclusions that can be drawn from the results of this study are summed up below :

1. The behavioral and subjective responses of the subjects were not the same at all luminance levels. The number of subjects that were attracted to higher luminance levels was high but they did not necessarily rate those levels on the positive side of the pleasantness scale. The opposite phenomenon, viz., higher ratings but a lesser degree of attraction, was also observed at some other luminance levels. There was no specific pattern in such a behavior and no definite relation was found between the luminance levels and attraction.

2. The speed of looking did not increase with a higher luminance/contrast. There were significant differences in the response times of the subjects between the luminance ratios, but an observation of the mean times did not reveal any significant relation between the luminance ratios and the orienting behavior.

3. People looked at the brighter lights 87 percent of the times.

4. Significant interaction was observed in the pleasantness ratings between the target and background luminances. Because of the absence of significant differences in the ratings in most of the pairs of the background luminances, the pleasantness ratings seemed to depend mostly on the target luminances, and hence their orienting behavior was controlled by the target luminance.

5. Regression models for predicting future values of ratings

and number, i.e., number of times looked at the lights, have been built. The model for the dependent variable, rating, included the independent variables, target luminance, background luminance and the interaction of both these factors. The regression equation for number included only the luminance ratio as the independent variable or the predictor variable for its model.

REFERENCES

Bennett, C., Chitlangia, A., and Pangrekar, A. Illumination levels and performance of practical visual tasks. Proceedings of the Human Factors Society 21st Annual Meeting, Santa Monica, Calif.: Human Factors Society, 1977.

Cohen, Jacob. Statistical power analysis for behavioral sciences. New York : Academic Press, 1969.

Collins, J.B. and Plant, C.G.H. Preferred luminance distribution in windowless spaces. Lighting Research and Technology, 1971, 3 (3), 219-231.

Draper, N.R. and Smith, H. Applied Regression Analysis. New York. John Wiley & Sons, Inc., 1966.

Engel, F.L. Visual conspicuity as an external determinant of eye movements and selective attention. Philips Research Reports Supplements, 1976, 6.

Flynn, J.E., Spencer, T.J., Martyniuk, O. and Hendrick, C. . Interim study of procedures for investigating the effect of light on impression and behavior. Journal of Illuminating Engineering Society, 1973, 3, 87-94.

Helson, H. and Lansford T.. The role of spectral energy of source and background color in the pleasantness of object colors. Applied Optics, 1970, 9, 1513-1562.

Hopkinson, R.G. and Longmore, J. Attention and distraction in the lighting of workplaces. Ergonomics, 1959, 2, 321.

Hughes, P., and McNelis, J. Lighting, productivity, and work environment. Lighting Design and Application, May, 1978, pp. 37-42.

IES Nomenclature Committee. Proposed American national standard nomenclature and definitions for illuminating engineering. Journal Illuminating Engineering Society, 1979, 9(1), 2-46.

Ireland, F.H. Effects of surround illumination on visual performance. An Annotated Bibliography. Aerospace Medical Research Laboratories (MRHEP), 1967, AMRL-TR-67-103.

Ireland, F.H., Kinslow, W., Levin, E. and Page, D. Experimental study of the effects of surround brightness and size on visual performance. Aerospace Medical Research Laboratories, 1967, AMRL-TR-67-102.

LaGiusa, F.F. and Perney, L.R. Brightness patterns influence attention spans. Lighting design and application, 1973, 3(5), 26-30.

LaGiusa, F.F. and Perney, L.R. Further studies on the effects of brightness variations on attention span in a learning environment. Journal of Illuminating Engineering Society, 1974, 3(3), 249-252.

McCormick, Ernest J. and Sanders, Mark S. Human Factors in Engineering and Design. New York. McGraw Hill, 1982.

Nuckolls, J.L. Interior lighting for environmental designers. New York, John Wiley & Sons, 1975.

Taylor, L.H. and Socov, E.W. The movement of people toward lights. Journal of Illuminating Engineering Society, 1974, 3(3), 237-241.

APPENDIX A

RAW DATA (OBSERVATIONS) FOR DIFFERENT RESPONSES

RAW DATA ON RATING

OBS	LUM_RATO	RATING
1	0.2	-1.25
2	0.2	0.25
3	0.2	3.00
4	0.2	-5.50
5	0.2	1.75
6	0.2	1.25
7	0.2	-2.50
8	0.2	-1.25
9	0.2	-7.00
10	0.2	-1.50
11	0.2	-0.75
12	0.2	-5.00
13	0.2	0.75
14	0.2	0.25
15	0.2	-1.50
16	0.2	-3.75
17	0.2	-1.00
18	0.2	-2.00
19	0.2	0.25
20	0.2	-3.50
21	0.5	-0.50
22	0.5	1.50
23	0.5	2.50
24	0.5	-3.25
25	0.5	0.75
26	0.5	2.50
27	0.5	-1.25
28	0.5	-1.00
29	0.5	-4.50
30	0.5	-2.50
31	0.5	0.25
32	0.5	-1.50
33	0.5	1.75
34	0.5	-0.25
35	0.5	3.00
36	0.5	-2.75
37	0.5	-0.25
38	0.5	-0.50
39	0.5	0.00
40	0.5	-1.50
41	1.0	2.00
42	1.0	4.25
43	1.0	2.00
44	1.0	-2.75
45	1.0	0.75
46	1.0	3.00
47	1.0	-1.25
48	1.0	-1.75
49	1.0	-1.50
50	1.0	0.75
51	1.0	1.00
52	1.0	0.25
53	1.0	1.50
54	1.0	-1.00
55	1.0	1.00

OBS	LUM_RATO	RATING
56	1.0	2.00
57	1.0	4.50
58	1.0	0.00
59	1.0	0.25
60	1.0	-2.50
61	1.6	1.25
62	1.6	4.00
63	1.6	4.25
64	1.6	-1.00
65	1.6	1.75
66	1.6	3.75
67	1.6	0.00
68	1.6	1.50
69	1.6	1.75
70	1.6	2.00
71	1.6	0.75
72	1.6	2.00
73	1.6	3.75
74	1.6	0.50
75	1.6	4.25
76	1.6	-1.25
77	1.6	1.50
78	1.6	0.00
79	1.6	-1.25
80	1.6	-1.25
81	2.0	0.50
82	2.0	4.25
83	2.0	2.25
84	2.0	-1.00
85	2.0	1.50
86	2.0	3.25
87	2.0	-0.25
88	2.0	-1.25
89	2.0	-1.75
90	2.0	2.75
91	2.0	-1.25
92	2.0	0.00
93	2.0	3.75
94	2.0	0.50
95	2.0	2.00
96	2.0	0.00
97	2.0	1.25
98	2.0	1.75
99	2.0	3.00
100	2.0	-2.00
101	3.2	1.75
102	3.2	2.75
103	3.2	4.75
104	3.2	1.50
105	3.2	1.25
106	3.2	4.00
107	3.2	-0.75
108	3.2	0.50
109	3.2	-0.25
110	3.2	3.50

OBS	LUM_RATO	RATING
111	3.2	1.50
112	3.2	0.00
113	3.2	4.00
114	3.2	1.00
115	3.2	1.75
116	3.2	0.75
117	3.2	2.25
118	3.2	2.75
119	3.2	1.50
120	3.2	0.00
121	5.0	1.75
122	5.0	0.75
123	5.0	2.50
124	5.0	1.00
125	5.0	1.25
126	5.0	2.75
127	5.0	0.25
128	5.0	0.75
129	5.0	1.25
130	5.0	3.50
131	5.0	2.00
132	5.0	1.00
133	5.0	4.50
134	5.0	3.25
135	5.0	0.00
136	5.0	1.50
137	5.0	2.25
138	5.0	3.00
139	5.0	3.50
140	5.0	0.00
141	6.4	2.50
142	6.4	0.25
143	6.4	4.50
144	6.4	2.75
145	6.4	2.00
146	6.4	2.00
147	6.4	1.75
148	6.4	1.75
149	6.4	4.00
150	6.4	4.50
151	6.4	0.75
152	6.4	3.00
153	6.4	3.75
154	6.4	2.75
155	6.4	3.50
156	6.4	-0.75
157	6.4	2.25
158	6.4	2.00
159	6.4	0.50
160	6.4	0.75
161	10.0	1.00
162	10.0	3.67
163	10.0	4.33
164	10.0	2.33
165	10.0	1.33

OBS	LUM_RATO	RATING
166	10	3.33
167	10	0.00
168	10	3.00
169	10	4.00
170	10	3.00
171	10	1.00
172	10	-1.00
173	10	4.00
174	10	5.00
175	10	3.33
176	10	2.33
177	10	5.00
178	10	2.67
179	10	1.00
180	10	1.33
181	16	0.75
182	16	0.75
183	16	3.75
184	16	3.50
185	16	1.75
186	16	1.75
187	16	-0.50
188	16	3.00
189	16	4.25
190	16	4.75
191	16	0.75
192	16	4.00
193	16	3.75
194	16	-1.50
195	16	-0.50
196	16	1.25
197	16	5.25
198	16	3.00
199	16	2.50
200	16	2.25
201	20	-0.75
202	20	-0.50
203	20	-0.25
204	20	3.00
205	20	1.25
206	20	1.25
207	20	2.00
208	20	0.25
209	20	6.00
210	20	4.25
211	20	-1.25
212	20	2.50
213	20	3.50
214	20	0.00
215	20	2.50
216	20	0.25
217	20	1.50
218	20	0.75
219	20	2.00
220	20	1.00

OBS	LUM_RATO	RATING
221	32	-0.33
222	32	-2.00
223	32	4.67
224	32	6.00
225	32	1.33
226	32	2.00
227	32	1.00
228	32	-1.00
229	32	5.67
230	32	6.33
231	32	3.00
232	32	5.00
233	32	3.67
234	32	2.67
235	32	2.00
236	32	3.33
237	32	1.33
238	32	2.00
239	32	1.00
240	32	2.67
241	50	0.00
242	50	2.00
243	50	2.00
244	50	4.00
245	50	-0.25
246	50	3.00
247	50	1.00
248	50	-0.75
249	50	3.00
250	50	4.75
251	50	-0.25
252	50	1.00
253	50	4.00
254	50	-0.25
255	50	1.00
256	50	1.25
257	50	1.75
258	50	1.25
259	50	1.25
260	50	0.75
261	64	-2.50
262	64	1.25
263	64	0.00
264	64	3.00
265	64	0.25
266	64	0.75
267	64	2.75
268	64	-0.25
269	64	5.25
270	64	5.00
271	64	1.00
272	64	4.00
273	64	1.75
274	64	0.00
275	64	0.25

OBS	LUM_RATO	RATING
276	64	1.75
277	64	-1.25
278	64	-1.25
279	64	-1.50
280	64	0.25
281	100	-2.50
282	100	-0.50
283	100	1.25
284	100	5.00
285	100	0.25
286	100	-1.25
287	100	1.25
288	100	3.25
289	100	6.50
290	100	4.50
291	100	0.75
292	100	4.00
293	100	0.25
294	100	-0.50
295	100	3.25
296	100	2.25
297	100	-0.75
298	100	0.50
299	100	-0.75
300	100	0.50
301	160	-3.25
302	160	0.75
303	160	0.00
304	160	5.25
305	160	-1.00
306	160	0.50
307	160	1.75
308	160	-1.00
309	160	5.50
310	160	4.00
311	160	-0.25
312	160	3.00
313	160	0.75
314	160	-1.75
315	160	0.25
316	160	1.50
317	160	-1.50
318	160	0.00
319	160	-1.00
320	160	0.50
321	200	-2.75
322	200	0.25
323	200	-1.25
324	200	4.75
325	200	-0.75
326	200	1.50
327	200	2.00
328	200	1.25
329	200	5.25
330	200	3.50

OBS	LUM_RATO	RATING
331	200	2.50
332	200	0.00
333	200	2.50
334	200	-0.50
335	200	2.50
336	200	2.25
337	200	0.75
338	200	-0.25
339	200	1.75
340	200	0.25
341	320	-4.50
342	320	-4.00
343	320	-5.00
344	320	3.75
345	320	-2.75
346	320	-1.00
347	320	1.25
348	320	0.00
349	320	-6.75
350	320	2.75
351	320	-1.25
352	320	-1.00
353	320	-2.00
354	320	-7.00
355	320	0.75
356	320	-2.75
357	320	-4.50
358	320	-3.25
359	320	-3.25
360	320	-3.50
361	500	-2.00
362	500	-2.25
363	500	-2.50
364	500	4.25
365	500	-1.00
366	500	2.25
367	500	1.50
368	500	2.00
369	500	5.50
370	500	5.00
371	500	-0.75
372	500	2.50
373	500	2.75
374	500	-3.25
375	500	0.50
376	500	2.25
377	500	1.50
378	500	-2.25
379	500	-2.25
380	500	0.50
381	640	-4.25
382	640	-4.50
383	640	-5.50
384	640	-1.00
385	640	-2.25

OBS	LUM_RATO	RATING
386	640	1.00
387	640	0.00
388	640	-0.75
389	640	-7.00
390	640	2.00
391	640	-0.75
392	640	-1.00
393	640	-1.50
394	640	-6.75
395	640	-1.00
396	640	-3.75
397	640	-4.75
398	640	-5.25
399	640	-5.50
400	640	-4.00

RAW DATA ON NUMBER

OBS	LUM_RATO	NUMBER
1	0.2	0
2	0.2	0
3	0.2	2
4	0.2	0
5	0.2	2
6	0.2	2
7	0.2	1
8	0.2	0
9	0.2	0
10	0.2	0
11	0.2	1
12	0.2	0
13	0.2	0
14	0.2	0
15	0.2	0
16	0.2	0
17	0.2	0
18	0.2	0
19	0.2	0
20	0.2	0
21	0.5	1
22	0.5	1
23	0.5	0
24	0.5	2
25	0.5	0
26	0.5	0
27	0.5	1
28	0.5	2
29	0.5	1
30	0.5	1
31	0.5	3
32	0.5	1
33	0.5	1
34	0.5	2
35	0.5	1
36	0.5	1
37	0.5	1
38	0.5	1
39	0.5	1
40	0.5	2
41	1.0	3
42	1.0	2
43	1.0	1
44	1.0	1
45	1.0	2
46	1.0	1
47	1.0	1
48	1.0	3
49	1.0	2
50	1.0	2
51	1.0	2
52	1.0	2
53	1.0	4
54	1.0	1
55	1.0	2

OBS	LUM_RATO	NUMBER
56	1.0	2
57	1.0	3
58	1.0	2
59	1.0	2
60	1.0	2
61	1.6	2
62	1.6	3
63	1.6	3
64	1.6	3
65	1.6	2
66	1.6	3
67	1.6	3
68	1.6	1
69	1.6	3
70	1.6	3
71	1.6	3
72	1.6	3
73	1.6	2
74	1.6	3
75	1.6	3
76	1.6	3
77	1.6	2
78	1.6	3
79	1.6	4
80	1.6	2
81	2.0	1
82	2.0	0
83	2.0	1
84	2.0	0
85	2.0	0
86	2.0	1
87	2.0	2
88	2.0	1
89	2.0	0
90	2.0	1
91	2.0	0
92	2.0	0
93	2.0	1
94	2.0	1
95	2.0	1
96	2.0	0
97	2.0	1
98	2.0	0
99	2.0	1
100	2.0	0
101	3.2	1
102	3.2	1
103	3.2	1
104	3.2	1
105	3.2	1
106	3.2	2
107	3.2	2
108	3.2	1
109	3.2	1
110	3.2	1

OBS	LUM_RATO	NUMBER
111	3.2	1
112	3.2	1
113	3.2	1
114	3.2	0
115	3.2	2
116	3.2	1
117	3.2	2
118	3.2	1
119	3.2	1
120	3.2	3
121	5.0	1
122	5.0	3
123	5.0	3
124	5.0	2
125	5.0	2
126	5.0	2
127	5.0	0
128	5.0	2
129	5.0	2
130	5.0	1
131	5.0	3
132	5.0	2
133	5.0	2
134	5.0	3
135	5.0	1
136	5.0	2
137	5.0	2
138	5.0	2
139	5.0	2
140	5.0	1
141	6.4	3
142	6.4	3
143	6.4	2
144	6.4	3
145	6.4	3
146	6.4	1
147	6.4	2
148	6.4	2
149	6.4	3
150	6.4	3
151	6.4	2
152	6.4	3
153	6.4	3
154	6.4	2
155	6.4	3
156	6.4	3
157	6.4	2
158	6.4	3
159	6.4	2
160	6.4	2
161	10.0	3
162	10.0	0
163	10.0	0
164	10.0	1
165	10.0	1

OBS	LUM_RATO	NUMBER
166	10	1
167	10	0
168	10	1
169	10	1
170	10	0
171	10	1
172	10	0
173	10	1
174	10	2
175	10	1
176	10	1
177	10	1
178	10	0
179	10	1
180	10	0
181	16	2
182	16	2
183	16	2
184	16	2
185	16	1
186	16	1
187	16	1
188	16	1
189	16	1
190	16	1
191	16	1
192	16	1
193	16	0
194	16	2
195	16	1
196	16	1
197	16	2
198	16	1
199	16	0
200	16	1
201	20	0
202	20	1
203	20	2
204	20	0
205	20	2
206	20	1
207	20	2
208	20	2
209	20	2
210	20	2
211	20	2
212	20	3
213	20	3
214	20	0
215	20	2
216	20	1
217	20	2
218	20	2
219	20	3
220	20	2

OBS	LUM_RATO	NUMBER
221	32	1
222	32	3
223	32	2
224	32	3
225	32	2
226	32	3
227	32	3
228	32	2
229	32	2
230	32	3
231	32	2
232	32	2
233	32	2
234	32	2
235	32	2
236	32	3
237	32	1
238	32	3
239	32	2
240	32	3
241	50	3
242	50	2
243	50	3
244	50	2
245	50	2
246	50	1
247	50	2
248	50	1
249	50	2
250	50	1
251	50	2
252	50	1
253	50	2
254	50	1
255	50	1
256	50	2
257	50	1
258	50	1
259	50	4
260	50	1
261	64	3
262	64	2
263	64	1
264	64	2
265	64	2
266	64	2
267	64	3
268	64	3
269	64	2
270	64	3
271	64	2
272	64	2
273	64	3
274	64	3
275	64	4

OBS	LUM_RATO	NUMBER
276	64	2
277	64	1
278	64	3
279	64	2
280	64	3
281	100	1
282	100	3
283	100	4
284	100	3
285	100	4
286	100	4
287	100	2
288	100	2
289	100	3
290	100	3
291	100	2
292	100	4
293	100	1
294	100	2
295	100	1
296	100	3
297	100	3
298	100	2
299	100	2
300	100	3
301	160	3
302	160	2
303	160	1
304	160	3
305	160	2
306	160	3
307	160	3
308	160	4
309	160	3
310	160	3
311	160	4
312	160	3
313	160	3
314	160	4
315	160	3
316	160	3
317	160	4
318	160	4
319	160	2
320	160	3
321	200	2
322	200	1
323	200	1
324	200	2
325	200	2
326	200	2
327	200	1
328	200	2
329	200	1
330	200	1

OBS	LUM_RATO	NUMBER
331	200	1
332	200	1
333	200	3
334	200	1
335	200	2
336	200	2
337	200	3
338	200	1
339	200	1
340	200	1
341	320	3
342	320	3
343	320	2
344	320	4
345	320	2
346	320	2
347	320	3
348	320	2
349	320	3
350	320	3
351	320	4
352	320	2
353	320	1
354	320	3
355	320	3
356	320	3
357	320	3
358	320	3
359	320	2
360	320	3
361	500	1
362	500	2
363	500	4
364	500	2
365	500	3
366	500	3
367	500	2
368	500	2
369	500	2
370	500	2
371	500	2
372	500	3
373	500	3
374	500	4
375	500	2
376	500	1
377	500	2
378	500	2
379	500	2
380	500	3
381	640	4
382	640	4
383	640	3
384	640	2
385	640	3

OBS	LUM_RATO	NUMBER
386	640	3
387	640	4
388	640	4
389	640	4
390	640	4
391	640	1
392	640	4
393	640	2
394	640	2
395	640	3
396	640	4
397	640	2
398	640	4
399	640	4
400	640	3

RAW DATA ON TIME

OBS	LUM_RATO	TIME
1	0.2	0.00
2	0.2	0.00
3	0.2	1.30
4	0.2	0.00
5	0.2	1.48
6	0.2	3.78
7	0.2	0.67
8	0.2	0.00
9	0.2	0.00
10	0.2	0.00
11	0.2	1.30
12	0.2	0.00
13	0.2	0.00
14	0.2	0.00
15	0.2	0.00
16	0.2	0.00
17	0.2	0.00
18	0.2	0.00
19	0.2	0.00
20	0.2	0.00
21	0.5	1.16
22	0.5	1.86
23	0.5	0.00
24	0.5	1.90
25	0.5	0.00
26	0.5	0.00
27	0.5	1.01
28	0.5	1.10
29	0.5	0.80
30	0.5	3.90
31	0.5	0.95
32	0.5	1.44
33	0.5	1.75
34	0.5	0.73
35	0.5	0.70
36	0.5	1.06
37	0.5	0.45
38	0.5	0.65
39	0.5	1.36
40	0.5	1.12
41	1.0	0.95
42	1.0	1.10
43	1.0	0.83
44	1.0	2.11
45	1.0	1.37
46	1.0	4.15
47	1.0	0.91
48	1.0	1.63
49	1.0	1.05
50	1.0	1.44
51	1.0	2.13
52	1.0	1.63
53	1.0	0.67
54	1.0	1.09
55	1.0	1.00

OBS	LUM_RATO	TIME
56	1.0	0.88
57	1.0	0.17
58	1.0	0.81
59	1.0	1.44
60	1.0	1.16
61	1.6	1.14
62	1.6	1.46
63	1.6	0.86
64	1.6	2.90
65	1.6	1.68
66	1.6	3.03
67	1.6	0.88
68	1.6	1.19
69	1.6	0.93
70	1.6	1.98
71	1.6	2.45
72	1.6	1.66
73	1.6	0.80
74	1.6	0.85
75	1.6	0.97
76	1.6	1.26
77	1.6	0.38
78	1.6	0.66
79	1.6	1.04
80	1.6	1.06
81	2.0	0.76
82	2.0	0.00
83	2.0	0.56
84	2.0	0.00
85	2.0	0.00
86	2.0	3.30
87	2.0	0.94
88	2.0	0.95
89	2.0	0.00
90	2.0	1.18
91	2.0	0.00
92	2.0	0.00
93	2.0	0.64
94	2.0	0.41
95	2.0	0.78
96	2.0	0.00
97	2.0	0.45
98	2.0	0.00
99	2.0	0.84
100	2.0	0.00
101	3.2	0.88
102	3.2	2.43
103	3.2	0.60
104	3.2	1.74
105	3.2	1.06
106	3.2	3.20
107	3.2	0.94
108	3.2	1.83
109	3.2	0.76
110	3.2	1.37

OBS	LUM_RATO	TIME
111	3.2	1.25
112	3.2	1.35
113	3.2	0.73
114	3.2	0.00
115	3.2	1.47
116	3.2	0.77
117	3.2	0.13
118	3.2	0.48
119	3.2	1.52
120	3.2	0.95
121	5.0	0.70
122	5.0	1.07
123	5.0	0.61
124	5.0	1.72
125	5.0	0.71
126	5.0	2.50
127	5.0	0.00
128	5.0	4.89
129	5.0	1.00
130	5.0	0.65
131	5.0	1.85
132	5.0	1.24
133	5.0	0.48
134	5.0	0.64
135	5.0	0.96
136	5.0	2.67
137	5.0	0.51
138	5.0	0.55
139	5.0	0.86
140	5.0	0.83
141	6.4	0.86
142	6.4	0.68
143	6.4	1.76
144	6.4	1.76
145	6.4	1.65
146	6.4	1.89
147	6.4	1.11
148	6.4	2.76
149	6.4	0.76
150	6.4	0.76
151	6.4	2.35
152	6.4	3.18
153	6.4	0.48
154	6.4	0.64
155	6.4	0.77
156	6.4	0.85
157	6.4	0.16
158	6.4	0.65
159	6.4	0.97
160	6.4	1.00
161	10.0	0.74
162	10.0	0.00
163	10.0	0.00
164	10.0	2.20
165	10.0	1.30

OBS	LUM_RATO	TIME
166	10	4.55
167	10	0.00
168	10	1.67
169	10	1.10
170	10	0.00
171	10	1.04
172	10	0.00
173	10	0.47
174	10	0.68
175	10	0.60
176	10	0.85
177	10	0.21
178	10	0.00
179	10	1.29
180	10	0.00
181	16	0.84
182	16	0.89
183	16	0.69
184	16	1.70
185	16	1.59
186	16	2.26
187	16	0.69
188	16	3.69
189	16	1.00
190	16	0.76
191	16	0.98
192	16	0.84
193	16	0.00
194	16	0.68
195	16	0.85
196	16	0.69
197	16	0.45
198	16	0.62
199	16	0.00
200	16	0.84
201	20	0.00
202	20	0.68
203	20	0.53
204	20	0.00
205	20	1.19
206	20	2.50
207	20	0.73
208	20	1.09
209	20	0.78
210	20	2.18
211	20	0.79
212	20	1.48
213	20	0.78
214	20	0.00
215	20	0.80
216	20	0.45
217	20	0.46
218	20	0.50
219	20	1.02
220	20	0.83

OBS	LUM_RATO	TIME
221	32	0.62
222	32	0.94
223	32	0.59
224	32	1.66
225	32	1.37
226	32	4.90
227	32	0.71
228	32	2.01
229	32	0.91
230	32	1.59
231	32	1.84
232	32	1.32
233	32	0.40
234	32	0.75
235	32	0.68
236	32	0.91
237	32	0.62
238	32	0.41
239	32	1.44
240	32	0.92
241	50	0.71
242	50	1.27
243	50	1.67
244	50	2.37
245	50	1.05
246	50	5.68
247	50	0.71
248	50	0.78
249	50	0.77
250	50	0.75
251	50	1.39
252	50	1.04
253	50	0.51
254	50	0.75
255	50	0.85
256	50	0.65
257	50	0.10
258	50	0.51
259	50	1.13
260	50	0.73
261	64	0.67
262	64	2.90
263	64	1.04
264	64	1.87
265	64	1.16
266	64	3.00
267	64	0.75
268	64	0.98
269	64	0.87
270	64	0.78
271	64	0.81
272	64	1.05
273	64	0.38
274	64	0.70
275	64	0.77

OBS	LUM_RATO	TIME
276	64	0.68
277	64	0.16
278	64	0.46
279	64	0.94
280	64	0.94
281	100	0.62
282	100	1.52
283	100	0.54
284	100	1.76
285	100	1.43
286	100	2.55
287	100	0.68
288	100	4.09
289	100	0.76
290	100	1.05
291	100	1.84
292	100	2.32
293	100	0.38
294	100	0.71
295	100	1.19
296	100	0.91
297	100	0.13
298	100	0.43
299	100	0.92
300	100	0.88
301	160	0.82
302	160	1.86
303	160	1.85
304	160	2.14
305	160	1.38
306	160	2.25
307	160	0.77
308	160	2.01
309	160	0.71
310	160	0.75
311	160	2.20
312	160	1.99
313	160	0.57
314	160	0.66
315	160	0.69
316	160	1.89
317	160	0.27
318	160	0.57
319	160	1.41
320	160	0.82
321	200	0.77
322	200	1.22
323	200	0.49
324	200	1.45
325	200	1.21
326	200	2.80
327	200	1.38
328	200	0.69
329	200	0.65
330	200	0.61

OBS	LUM_RATO	TIME
331	200	0.68
332	200	0.91
333	200	0.63
334	200	0.45
335	200	0.80
336	200	0.57
337	200	0.17
338	200	0.63
339	200	0.88
340	200	0.80
341	320	0.84
342	320	1.46
343	320	1.70
344	320	1.88
345	320	1.00
346	320	1.92
347	320	0.86
348	320	1.37
349	320	0.77
350	320	1.13
351	320	1.80
352	320	1.05
353	320	0.41
354	320	0.84
355	320	0.84
356	320	0.70
357	320	0.28
358	320	0.47
359	320	0.74
360	320	0.96
361	500	0.74
362	500	0.78
363	500	0.99
364	500	1.93
365	500	0.88
366	500	2.93
367	500	0.67
368	500	2.32
369	500	0.85
370	500	0.95
371	500	3.55
372	500	2.04
373	500	0.59
374	500	0.62
375	500	0.94
376	500	0.70
377	500	0.18
378	500	0.52
379	500	1.28
380	500	0.84
381	640	0.74
382	640	1.14
383	640	0.62
384	640	1.69
385	640	1.29

OBS	LUM_RATO	TIME
386	640	2.15
387	640	0.72
388	640	3.26
389	640	0.90
390	640	1.27
391	640	0.94
392	640	1.12
393	640	0.68
394	640	0.60
395	640	0.73
396	640	1.13
397	640	0.15
398	640	0.42
399	640	0.81
400	640	0.84

APPENDIX B

MODEL BUILDING PROCEDURES USED TO BUILD MODELS FOR RATING, NUMBER AND TIME

MODEL BULDING FOR RATINGS W.R.T. LUMINANCE RATIO, TARG & BCKGRD

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE RATING

STEP 1 VARIABLE TARGET ENTERED R SQUARE = 0.45850422
C(P) = 19.21964543

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	19.42212950	19.42212950	15.24	0.0010
ERROR	18	22.93763225	1.27431290		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.53849357				
TARGET	-0.00105523	0.00027029	19.42212950	15.24	0.0010

STEP 2 VARIABLE LUMRAT ENTERED R SQUARE = 0.66309051
C(P) = 7.91306632

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	28.08835584	14.04417792	16.73	0.0001
ERROR	17	14.27140591	0.83949447		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.85784738				
LUMRAT	0.92953259	0.28930672	8.66622634	10.32	0.0051
TARGET	-0.00176234	0.00031075	27.00081528	32.16	0.0001

STEP 3 VARIABLE TB ENTERED R SQUARE = 0.76060082
C(P) = 3.57085842

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	32.21886966	10.73962322	16.94	0.0001
ERROR	16	10.14089209	0.63380576		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.66624987				
LUMRAT	1.02416852	0.25409697	10.29674728	16.25	0.0010
TARGET	-0.00220022	0.00031989	29.98465285	47.31	0.0001
TB	0.00004469	0.00001750	4.13051382	6.52	0.0213

MODEL BUILDING FOR RATINGS W.R.T. LUMINANCE RATIO, TARG & BCKGRD

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE RATING

STEP 4 VARIABLE BCKGRD ENTERED R SQUARE = 0.76937767
C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	32.59065479	8.14766370	12.51	0.0001
ERROR	15	9.76910696	0.65127380		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.99943320				
LUMRAT	0.88027948	0.32033265	4.91815647	7.55	0.0149
BCKGRD	-0.01530152	0.02025212	0.37178513	0.57	0.4616
TARGET	-0.00224711	0.00033015	30.17121449	46.33	0.0001
TB	0.00005903	0.00002599	3.36075426	5.16	0.0383

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BUILDING FOR RATINGS W.R.T. LUMINANCE RATIO, TARG & BCKGRD

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE RATING

STEP 0 ALL VARIABLES ENTERED R SQUARE = 0.76937767
C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	32.59065479	8.14766370	12.51	0.0001
ERROR	15	9.76910696	0.65127380		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.99943320				
LUMRAT	0.88027948	0.32033265	4.91815647	7.55	0.0149
BCKGRD	-0.01530152	0.02025212	0.37178513	0.57	0.4616
TARGET	-0.00224711	0.00033015	30.17121449	46.33	0.0001
TB	0.00005903	0.00002599	3.36075426	5.16	0.0383

STEP 1 VARIABLE BCKGRD REMOVED R SQUARE = 0.76060082
C(P) = 3.57085842

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	32.21886966	10.73962322	16.94	0.0001
ERROR	16	10.14089209	0.63380576		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.66624987				
LUMRAT	1.02416852	0.25409697	10.29674728	16.25	0.0010
TARGET	-0.00220022	0.00031989	29.98465285	47.31	0.0001
TB	0.00004469	0.00001750	4.13051382	6.52	0.0213

ALL VARIABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.0500 LEVEL.

MODEL BULDING FOR RATINGS W.R.T. LUMINANCE RATIO, TARG & [illegible]

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE RATING

STEP 1 VARIABLE TARGET ENTERED R SQUARE = 0.45850432
C(P) = 19.21964549

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	19.42212950	19.42212950	15.24	0.0010
ERROR	18	22.93763225	1.27431290		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.53849357				
TARGET	-0.00105523	0.00027029	19.42212950	15.24	0.0010

STEP 2 VARIABLE LUMRAT ENTERED R SQUARE = 0.66309051
C(P) = 7.91306632

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	28.08835584	14.04417792	16.73	0.0001
ERROR	17	14.27140591	0.83949447		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.85784738				
LUMRAT	0.92953259	0.28930672	8.66622634	10.32	0.0051
TARGET	-0.00176234	0.00031075	27.00081528	32.16	0.0001

STEP 3 VARIABLE TB ENTERED R SQUARE = 0.76060082
C(P) = 3.57085842

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	32.21886966	10.73962322	16.94	0.0001
ERROR	16	10.14089209	0.63380576		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.66624987				
LUMRAT	1.02416852	0.25409697	10.29674728	16.25	0.0010
TARGET	-0.00220022	0.00031989	29.98465285	47.31	0.0001
TB	0.00004469	0.00001750	4.13051382	6.52	0.0213

MODEL BUILDING FOR RATINGS W.R.T. LUMINANCE RATIO, TARG & BCKGRD

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE RATING

STEP 4 VARIABLE BCKGRD ENTERED R SQUARE = 0.76937767
C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	32.59065479	8.14766370	12.51	0.0001
ERROR	15	9.76910696	0.65127380		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.99943320				
LUMRAT	0.88027948	0.32033265	4.91815647	7.55	0.0149
BCKGRD	-0.01530152	0.02025212	0.37178513	0.57	0.4616
TARGET	-0.00224711	0.00033015	30.17121449	46.33	0.0001
TB	0.00005903	0.00002599	3.36075426	5.16	0.0383

STEP 5 VARIABLE BCKGRD REMOVED R SQUARE = 0.76060082
C(P) = 3.57085842

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	32.21886966	10.73962322	16.94	0.0001
ERROR	16	10.14089209	0.63380576		
TOTAL	19	42.35976175			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.66624987				
LUMRAT	1.02416852	0.25409697	10.29674728	16.25	0.0010
TARGET	-0.00220022	0.00031989	29.98465285	47.31	0.0001
TB	0.00004469	0.00001750	4.13051382	6.52	0.0213

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BUILDING USING R_SQUARE

N= 20 REGRESSION MODELS FOR DEPENDENT VARIABLE RATING

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
1	0.00004286	BCKGRD
1	0.02567391	LUMRAT
1	0.04376931	TB
1	0.45850422	TARGET
2	0.03192706	LUMRAT BCKGRD
2	0.05274385	LUMRAT TB
2	0.05696272	BCKGRD TB
2	0.46813996	BCKGRD TARGET
2	0.51752232	TARGET TB
2	0.66309051	LUMRAT TARGET
3	0.05711648	LUMRAT BCKGRD TB
3	0.65327323	BCKGRD TARGET TB
3	0.69003930	LUMRAT BCKGRD TARGET
3	0.76060082	LUMRAT TARGET TB
4	0.76937767	LUMRAT BCKGRD TARGET TB

MODEL BULDING FOR NUMBER W.R.T. LUMINANCE RATIO TARG & BCKGD

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE NUMBER

STEP 1 VARIABLE LUMRAT ENTERED R SQUARE = 0.41490941
C(P) = 0.36596159

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	5.23325235	5.23325235	12.76	0.0022
ERROR	18	7.37974765	0.40998598		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.23412089				
LUMRAT	0.50995697	0.14273557	5.23325235	12.76	0.0022

STEP 2 VARIABLE TARGET ENTERED R SQUARE = 0.43102074
C(P) = 2.10979349

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	5.43646455	2.71823227	6.44	0.0083
ERROR	17	7.17653545	0.42214914		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.25834412				
LUMRAT	0.40914915	0.20515522	1.67905175	3.98	0.0624
TARGET	0.00015289	0.00022036	0.20321220	0.48	0.4972

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BUIDING FOR NUMBER W.R.T. LUMINANCE RATIO TARG & BCKGD

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE NUMBER

STEP 1 VARIABLE LUMRAT ENTERED R SQUARE = 0.41490941
C(P) = 0.56596159

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	5.23325235	5.23325235	12.76	0.0022
ERROR	18	7.37974765	0.40998598		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.23412089				
LUMRAT	0.50995697	0.14273557	5.23325235	12.76	0.0022

STEP 2 VARIABLE TARGET ENTERED R SQUARE = 0.43102074
C(P) = 2.10979349

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	5.43646455	2.71823227	6.44	0.0083
ERROR	17	7.17653545	0.42214914		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.25834412				
LUMRAT	0.40914915	0.20515522	1.67905175	3.98	0.0624
TARGET	0.00015289	0.00022036	0.20321220	0.48	0.4972

STEP 3 VARIABLE TARGET REMOVED R SQUARE = 0.41490941
C(P) = 0.56596159

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	5.23325235	5.23325235	12.76	0.0022
ERROR	18	7.37974765	0.40998598		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.23412089				
LUMRAT	0.50995697	0.14273557	5.23325235	12.76	0.0022

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BULDING FOR NUMBER W.R.T. LUMINANCE RATIO TARG & BCKGRD

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE NUMBER

STEP 0 ALL VARIABLES ENTERED R SQUARE = 0.43489852
C(P) = 4.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	5.48537497	1.82845832	4.10	0.0245
ERROR	16	7.12762503	0.44547656		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.16059304				
LUMRAT	0.45230950	0.24775184	1.48478140	3.33	0.0866
BCKGRD	0.00378972	0.01143717	0.04891043	0.11	0.7447
TARGET	0.00012969	0.00023695	0.13345453	0.30	0.5917

STEP 1 VARIABLE BCKGRD REMOVED R SQUARE = 0.43102074
C(P) = 2.10979349

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	5.43646455	2.71823227	6.44	0.0083
ERROR	17	7.17653545	0.42214914		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.25834412				
LUMRAT	0.40914915	0.20515522	1.67905175	3.98	0.0624
TARGET	0.00015289	0.00022036	0.20321220	0.48	0.4972

STEP 2 VARIABLE TARGET REMOVED R SQUARE = 0.41490941
C(P) = 0.56596159

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	5.23325235	5.23325235	12.76	0.0022
ERROR	18	7.37974765	0.40998598		
TOTAL	19	12.61300000			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.23412089				
LUMRAT	0.50995697	0.14273557	5.23325235	12.76	0.0022

ALL VARIABLES IN THE MODEL ARE SIGNIFICANT AT THE 0.0500 LEVEL.

MODEL BUILDING USING R_SQUARE

N= 20 REGRESSION MODELS FOR DEPENDENT VARIABLE NUMBER

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
1	0.04870394	BCKGRD
1	0.29790001	TARGET
1	0.41490941	LUMRAT
2	0.31718013	BCKGRD TARGET
2	0.42431780	LUMRAT BCKGRD
2	0.43102074	LUMRAT TARGET
3	0.43489852	LUMRAT BCKGRD TARGET

MODEL BUILDING FOR TIMES W.R.T. LUMINANCE RATIO TARG & BCKGD

FORWARD SELECTION PROCEDURE FOR DEPENDENT VARIABLE TIME

STEP 1 VARIABLE BCKGRD ENTERED R SQUARE = 0.06459842
C(P) = -0.23562776

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	0.07355000	0.07355000	1.24	0.2796
ERROR	18	1.06509324	0.05917185		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.11249998				
BCKGRD	-0.00390664	0.00350405	0.07355000	1.24	0.2796

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BULDING FOR TIMES W.R.T. LUMINANCE RATIO TARG & BCKGD

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE TIME

STEP 0 ALL VARIABLES ENTERED R SQUARE = 0.10994974
C(P) = 5.00000000

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	4	0.12519352	0.03129839	0.46	0.7617
ERROR	15	1.01344971	0.06756331		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.02011564				
LUMRAT	0.08303044	0.10317510	0.04375583	0.65	0.4335
BCKGRD	-0.00204015	0.00652295	0.00660916	0.10	0.7588
TARGET	-0.00006325	0.00010634	0.02390604	0.35	0.5608
TB	0.00000027	0.00000837	0.00006879	0.00	0.9750

STEP 1 VARIABLE TB REMOVED R SQUARE = 0.10988932
C(P) = 2.00101818

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	3	0.12512473	0.04170824	0.66	0.5904
ERROR	16	1.01351851	0.06334491		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.01733350				
LUMRAT	0.08419664	0.09342440	0.05144944	0.81	0.3808
BCKGRD	-0.00188809	0.00431283	0.01214037	0.19	0.6674
TARGET	-0.00006157	0.00008935	0.03007576	0.47	0.5007

STEP 2 VARIABLE BCKGRD REMOVED R SQUARE = 0.09922718
C(P) = 1.18070697

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	2	0.11298436	0.05649218	0.94	0.4114
ERROR	17	1.02565888	0.06033288		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.96863762				
LUMRAT	0.10569970	0.07755800	0.11205940	1.86	0.1907
TARGET	-0.00007312	0.00008331	0.04648682	0.77	0.3923

MODEL BULDING FOR TIMES W.R.T. LUMINANCE RATIO TARG & BCKGRD

BACKWARD ELIMINATION PROCEDURE FOR DEPENDENT VARIABLE TIME

STEP 3 VARIABLE TARGET REMOVED R SQUARE = 0.05840068
C(P) = -0.13124476

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	0.06649754	0.06649754	1.12	0.3047
ERROR	18	1.07214570	0.05956365		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	0.98022331				
LUMRAT	0.05748446	0.05440494	0.06649754	1.12	0.3047

STEP 4 VARIABLE LUMRAT REMOVED R SQUARE = 0.00000000
C(P) = -1.14701922

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	0	0.00000000	0.00000000	0.00	1.0000
ERROR	19	1.13864324	0.05992859		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.05077500				

NO VARIABLES ARE SIGNIFICANT AT THE 0.0500 LEVEL.

MODEL BULDING FOR TIMES W.R.T. LUMINANCE RATIO TARG & BCKGRD

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLE TIME

STEP 1 VARIABLE BCKGRD ENTERED R SQUARE = 0.06459442

C(P) = -0.23562776

	DF	SUM OF SQUARES	MEAN SQUARE	F	PROB>F
REGRESSION	1	0.07355000	0.07355000	1.24	0.2796
ERROR	18	1.06509324	0.05917185		
TOTAL	19	1.13864324			

	B VALUE	STD ERROR	TYPE II SS	F	PROB>F
INTERCEPT	1.11249998				
BCKGRD	-0.00390664	0.00350405	0.07355000	1.24	0.2796

NO OTHER VARIABLES MET THE 0.5000 SIGNIFICANCE LEVEL FOR ENTRY

MODEL BUILDING USING R_SQUARE

N= 20 REGRESSION MODELS FOR DEPENDENT VARIABLE TIME

NUMBER IN MODEL	R-SQUARE	VARIABLES IN MODEL
1	0.00081234	TARGET
1	0.00568202	TB
1	0.05840068	LUMRAT
1	0.06459442	BCKGRD
2	0.01407120	TARGET TB
2	0.06470446	BCKGRD TARGET
2	0.06669640	BCKGRD TB
2	0.08347564	LUMRAT BCKGRD
2	0.08647053	LUMRAT TB
2	0.09922718	LUMRAT TARGET
3	0.07152170	BCKGRD TARGET TB
3	0.08895454	LUMRAT BCKGRD TB
3	0.10414532	LUMRAT TARGET TB
3	0.10988932	LUMRAT BCKGRD TARGET
4	0.10994974	LUMRAT BCKGRD TARGET TB

A BEHAVIORAL APPROACH

TO LIGHTING PLEASANTNESS

by

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AN ABSTRACT OF A MASTER'S THESIS

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ABSTRACT

This study was conducted with the objective to determine a relationship, if any, between the orienting behavior and subjective responses of people regarding lights. Subjective responses were obtained from 20 subjects regarding the pleasantness of two target lights (left and right sources, with a partition in between), specifically, the luminance ratio of the target and the background (luminances). There were six levels of target luminance and five levels of background luminance. The treatments or conditions of the experiment were designed on the basis of the luminance ratios, i.e., ratio of target to background luminances. The results showed that the pleasantness ratings depended significantly on the luminance ratios and there was interaction between target and background luminances for both rating and response time. The higher luminance levels attracted the attention of the subjects 87 percent of the times. Convergence of behavioral and subjective responses did not occur at all luminance levels. There did not seem to be any pattern in the orienting behavior of the subjects and their choice of pleasant lights. Also, no observable change in the speed of attention-getting with higher luminances was found. Regression models were built for the response variables, pleasantness rating and the number of times looked at the lights.