An Examination of Visual Comfort in Transitional Spaces

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Abstract: This study investigated the issue of visual comfort at building entrances as the user moves from darker interior spaces to the brighter exterior. The effects on visual comfort of several design features such as overhead trellises, solid overhangs, vertical fins, and solid sidewalks were assessed. These features were tested individually and in various combinations. Visual comfort was expressed in terms of the luminance ratios at equidistant station points along the user's path in the transition entry zone. Discomfort sensations resulting from the difference in luminance ratios according to various design combinations ranged from "dramatic" (high visual discomfort or shock) to "subtle" (little visual discomfort). It was found that several design features significantly affect visual comfort. In particular, a deep canopy with combined transmittance characteristics (partially and entirely blocking daylight penetration) extending over the entrance of the building leads to the greatest visual comfort, but a simple 4.8m overhang was also found to be adequate, leading to reasonable visual comfort.

Keywords: Daylighting, Entrances, Transitional spaces, Visual comfort

The Problem

This paper explores the issue of light adaptation and visual discomfort due to drastic variations in light intensity near building entryways. It is often the case that the passage from a normally lit or shaded interior space to a brightly lit outdoor one takes place abruptly without a transitional zone that would ease users into adequate transition from dark to bright conditions. Although the human eye is capable of adjusting to high range of luminance levels without producing discomfort, the continually changing illuminance, luminance, and contrasts levels during such transition could represent a potential cause for acute visual discomfort for many; especially for the elderly, for whom such visual shock may be detrimental, painful (Steffy, 2002), and potentially harmful (Rea, 2000). The Illuminating Engineering Society of North America indicates that among the more common and extensive list of symptoms are red, sore, itchy, and watering eyes; headaches and migraine attacks, gastrointestinal problems; aches and pains (Rea, 2000). However, it was referred that it is necessary to consider other possible causes before ascribing an occurrence of any of these symptoms to the lighting conditions.

When it comes to designing transitional entryways, the physical and psychological dimensions and accessibility requirements should be restored within the visual comfort range. Although there is a body of literature that addresses the issue from the aesthetical side (a relevant example is the shadows aspect of lighting that can reveal the form of three-dimensional elements, yet susceptible to visual discomfort because it reduces light levels while causing perceptual confusion and increasing luminance ratios (Rea, 2000)), it is important to present and discuss design strategies as well as understand and document the quantitative aspects of luminosity and visual comfort. Over the last couple of decades, research from a wide range of disciplines has provided valuable insights into environmental experiences and conditions that are necessary for visual comfort. However, little work has been explicitly directed at identifying design strategies whose impact can be qualified in terms of visual comfort in transitional spaces.

Background

Architecture is experienced with all our senses including vision. Architects are supposed to design spaces where users can communicate and operate with relative ease and comfort, be it thermal, luminous or aesthetical. The ability of users to adapt to changing dynamic conditions of the environment around them is very important. Luminous conditions can change drastically as users transit from indoor to outdoor spaces or vice versa. The human eye has physical, neural and photochemical mechanisms for adapting to changing light conditions (Rea, 2000).
Physical adaptation is caused by changes in the size of the pupil. The iris of the eye will adjust based on the levels of retinal illumination, constricts with increased levels and dilates with decreased levels. In this process, the pupil size will vary with individuals and for a particular individual at different times. Even with age, people tend to have smaller pupils.

Retinal neurons are responsible for neural adaptation at successive stages of the visual chain in the retina. Adaptation reports a quick change in sensitivity produced by synaptic interactions in the visual system. It accounts for the transitory changes in sensitivity of the eye where bleaching of photopic visual photopigments do not occur. These conditions are typically encountered in interior spaces, or where luminance levels are below 600 cd/m² (Rea, 2000). Neural adaptation may not be completely able to handle the changes necessary for visual function with exterior situations when the capillaries of rapid neural adaptation are exceeded.

Photochemical adaptation is caused by changes in photopigment concentrations. According to the theory of vision, within the human retina there are two types of light-sensitive photoreceptors: the rods that dominate the outside of the fovea, and the cones that are cells concentrated in the tiny rod-free fovea. During the day, or when the illumination is high, vision is mediated by the cones system. This phenomenon is referred to as photopic or light-adapted vision. It provides the capability for seeing color and resolving fine details. At night, or when the illumination is low, vision is mediated by the rods system and the vision phenomenon is referred to as scotopic or dark-adapted vision. It is characterized by poor quality, reduced resolution, and provides the ability to see only in black and white, while any sense of color comes either from memory or from a psychological judgment based on relative brightness. It is common knowledge that the sensitivity to light level changes if these cell systems vary in two different ways:

1. The sensitivity of the rod system is about 1,000 times greater than that of the cones
2. The peak sensitivity of the rods is about 507 nm while the cones sensitivity peak near 555 nm (Williamson & Cummins, 1983)

Whether the light is bright or dim, the human eye adapts to brightness and maintains a wide range of light sensitivity based on these two vision systems. It can function effectively to the changes in brightness of as much as 1 000 million times. For instance, the eye can function well in a bright sunlight (as much as 3 183 000 kcd/m²) and during dim moonlight conditions (as low as 3.183 kcd/m²; Miller & Tredici, 1992; Turk, 2006).

Both rods and cones function over a wide range of light intensity levels. Scotopic vision functions in the range below 0.034 cd/m², whereas photopic vision functions in the range above 3.4 cd/m². At intermediate levels of illumination (low but not quite dark lighting situations), both systems function simultaneously presenting the transition zone, namely mesopic vision. Light changes in transitional spaces often present a potential case for the mesopic vision, which might be of primary importance to the person experiencing these spaces during which each eye adjusts from a high luminance setting to a low one and vice versa.

The sensitivity lag of the cone system adapts in about 5-7 minutes (Miller & Tredici, 1992) or 10-12 minutes (Rea, 2000) with high levels of luminance. The rod system will take 30-45 minutes or longer to adapt with fully dark situations to attain maximum sensitivity after exposure to bright light (adaptation is about 80% complete within 30 minutes; Rea, 2000).

Even though the human eye can adjust over a wide range of brightness levels, the retina is highly sensitive to damage by light such as the cas of laser surgeries, or unprotected sun gazing (e.g. a person walking from a dimly lit interior to a sunny exterior). All of these cases present a potential for light injury (Miller & Tredici, 1992).

Elderly peoples adaptation to darkness and brightness occurs much more slowly, mostly due to age-related transformations that take place within the eye such as changes in the iris muscle function and pupil size and to the development of non-cataract lens opacities (Rea, 2000). During transitions from bright to dark environments, slower pupillary dilation means less light reaching the retina, delaying or reducing adjustment. Conversely, the pupil is slow to constrict when moving from a dark to a light environment. According to IESNA (Rea, 2000), a transition zone with a gradually reducing illuminance is desirable for elderly. This zone allows their visual system more time to make the necessary changes in adaptation. In an extensive long-term field study, it was noticed that the quality of life of the elderly improved by increasing the quality of lighting (Sorensen & Brunnstrom, 1995). However, providing excessive light is not the solution and glare should be controlled (Rea, 2000). The Commission Internationale de l’Éclairage (CIE, 1987) defines glare as “the condition of vision in which there is discomfort or a reduction in the ability to see details or objects, or both, due to an unsuitable distribution or range of luminance or to extreme contrasts in space or time.” Mainly, there are two distinct forms of glare, namely, discomfort glare and disability glare. They are different both in a physical as a well as a psychological sense (Inkarjir, 2005). The first causes discomfort without necessarily impairing vision and the second impairs vision without necessarily causing discomfort. Disability glare occurs when excessive light of high luminance from a given light source falls on the retina overwhelming the ocular chamber, causing a severe reduction in or even impairing vision. With discomfort glare, light of high luminance of a background surrounding an object is seen against a low luminance object. This creates discomfort because of a luminance contrast but may not reduce necessarily the observers’ ability to see the object. Vision of the details of the object may be lost however. Therefore, light must be provided through which both disability and discomfort glare are controlled.

Contrast is also a key factor that relates to visual comfort. It is generally acknowledged that large luminance contrasts in the field of view should be avoided. According to ISO Standard 9241-6 (ISO, 2000), the most important factors for ensuring good lighting is an even distribution of luminance and contrasts. However, research has indicated that dull or uniform luminance distribution is not desirable, and that the best luminance contrast to provide interest without the maximum value becoming a glare source is still not known (Dubois, 2002).

Similar to the elderly, younger people can suffer from vision problems such as reduced visual acuity, reduced contrast
sensitivity, reduced color discrimination, increased color taken to adapt to large and sudden changes in luminance, and increased sensitivity to glare (Rea, 2000). They should be provided with proper lighting design to compensate partially for vision problems (Rea, 2000).

Studies suggest that the importance of the luminance of elements located in the visual field is increasingly recognized as a major determinant of visual comfort (Dubois, 2002). Parameters such as balancing of light intensities, colors, field of view, and/or scenes that affect the process of visual perception execute the problem of light adaptation in transitional spaces, the episode through which the preceding conditions might take place.

**Method and Procedure**

The design of indoor-outdoor transitional spaces involves a large number of physical features. In this paper, we first examined the impact of each physical variable alone on visual comfort, and then tested their combined effects in different combinations.

The quality of daylighting in transitional spaces was evaluated by measuring horizontal illuminance levels reflected off a diffused ground surface (40% reflectance) at 1.7m height from the ground. The measurements were taken at that level to simulate the average human height. The obtained values were then converted to luminance values. The method assumed a linear relationship between horizontal diffused illuminance and adaptation luminance as discussed in the experimental procedure section. Data were based on multiple measurements since this approach is appropriate with physical scale modeling. The physical variables tested are described below and shown in Figure 1 a-d.

**Description of Physical Variables Tested**

The sequence is defined as a transition space between the building interior lobby or foyer and the outside space immediately adjacent to the building entrance. The entrance opening is made from clear glass and maintains the same width as the design features shaping the transitional space. These design features include physical features that block sunlight completely or partially (Figure 1 a-d). The interior ceiling is punched to maintain an ambient illuminance level at 150 lux.

Nine design scenarios were tested, including the base-case that consists of what one might consider an entrance sequence of a typical building that has no transitional space (Figure 2).

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**Figure 1:** Individual design features of transitional spaces.

**Figure 2:** Base case scenario showing entrance sequence with no transition elements.
The various combinations of the physical variables tested are shown and described in Figure 3 a-h. The figure is showing the base case model with the design features added to serve as a relative comparison case.

**Experimental Procedure**

The experiments were conducted using scale models tested in a mirror box sky simulator (13 000 Lumen/m² apparatus) that reproduces the relative luminance distribution of a CIE Standard Sky. Although the simulation was to address the passage from a normally lit interior space to a brightly lit outdoor one, the study limited itself to glare experienced under diffused sky conditions only. Further measurements for sunny conditions will be required in order to give a further set of design recommendation.

The model was built from foam-core panels at a scale of 1:100 taking into account the 17mm height of the LiCor Photometer light-sensor to be equal to 1.7m, the average human height. Eleven station points were located equidistant at 2.4m apart along the main axis of the entrance sequence (Figure 2). In the same order, eleven LiCor lightsensors connected to a data acquisition system were used to collect horizontal illuminance levels reflected of diffused ground surface of 40% reflectance at the station points. The

**Figure 3:** Combinations of the tested design variables.
Table 1: Travel times between station points of luminance measurements based on an average walking speed of 1.2 m/second (4 ft/second).

| Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | Point 6 | Point 7 | Point 8 | Point 9 | Point10 | Point11 | Point 1 | Point 2 | Point 3 | Point 4 | Point 5 | Point 6 | Point 7 | Point 8 | Point 9 | Point10 | Point11 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| 0 sec   | 2 sec   | 4 sec   | 6 sec   | 8 sec   | 10 sec  | 12 sec  | 14 sec  | 16 sec  | 18 sec  | 20 sec  | 0 sec   | 2 sec   | 4 sec   | 6 sec   | 8 sec   | 10 sec  | 12 sec  | 14 sec  | 16 sec  | 18 sec  | 20 sec  |

The measurement plane was defined to be at 1.7m height from the ground. These sensors, with a built-in color-correction, mimic the human eye response to color sensitivity and cosine correction to represent the true illumination falling on the photocell irrespective of the angle of incidence of light. They were calibrated to minimize internal error between heads and to eliminate any confounding factor that might exist between the head variable and the station point variable. Surface reflectances of the inside and the outside surfaces were identical. These surfaces were taken to be Lambertian surfaces, namely, diffusely reflecting, whereby, there was a linear relationship between illumination falling on a flat surface and the luminance of the surface (Equation 1). This property of diffusely reflecting surfaces was noted by Johann Lambert in 1760 and is called Lambert's cosine law. The fact that a surface obeying Lambert's law has the same luminance in every direction will be taken as limitation to this study. Therefore, we were able to translate illuminance readings into corresponding luminance values by using the well-known relationship between illuminance and luminance under diffuse light conditions:

\[ L = \frac{RE}{\pi} \]  

where:
- \( L \) is the luminance of the surface [cd/m²],
- \( R \) is the reflectance of the surface [%],
- \( E \) is the illuminance [lux]

Results and Discussion

The walking speed and the amount of time required for pedestrians of all ages to travel within transitional space are very important. Studies have found that travel speed for older pedestrians is less than for younger ones and that within both age groups, women walk more slowly than men (MUTCD, 2003). On average, a speed of 1.2 m/sec for normal walking speed for all age groups was used.

Equation 2 provides the amount of time \( T \) required for a walking person to travel within the given transitional space. It is equal to the distance \( D \) being covered along the main axis of the entrance sequence divided by the average walking speed \( V \) being used, then:

\[ T = \frac{D}{V} \]  

where:
- \( T \) is the time (sec)
- \( D \) is the distance between two consecutive station points (m),
- \( V \) is the average walking speed (m/sec)

Therefore, the time required to travel through the eleven station points equals 20 sec [20 sec = (2.4m x 10) / 1.2m/sec]. Given such a relationship, the travel time between various station points of measurements in the transition space are presented in Table 1.

Computed luminance levels are presented in Figure 4. These were measured as the building occupants moved from the

Figure 4: Computed luminance levels and its corresponding Standard Deviation values at various station points for the base-case and eight design combinations.
most interior station point (point 1) to the most exterior one (point 11). Note that, the computed luminance levels for the interior station points 1–3 show 0 cd/m² in Figure 4. However, the actual illuminance values indicate a normally lit interior condition. Table 2 shows these values that are merely based on daylighting conditions.

According to the Chartered Institution of Building Services Engineers (CIBSE) Code for Interior Lighting (CIBSE, 1994), the ratios between the object and "Objective Display Illuminance Ratios", and "Subjective Apparent Brightness Ratios" can be described on a scale ranging from subtle to dramatic as indicated in Table 3. The current method relates measured data against CIBSE guidelines. When describing changes in luminance ratios between the various station points, luminance ratios were computed and then matched on the four-point scale of "Subjective Apparent Brightness Ratios", ranging from "subtle" to "dramatic" (Table 4). It is very important to note that although the CIBSE guidelines were not initially intended to be used for assessing visual comfort in transitional spaces, they measure visual comfort based on subjective apparent brightness ratios and thus the authors feel that there is no reason not to use them in transitional spaces. Nevertheless, this can be considered as a limitation to the study.

Table 2: Measured illuminance levels and corresponding standard deviation values between station points for the base-case and all design combinations.

<table>
<thead>
<tr>
<th>Combinations</th>
<th>Indoor</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PL-01</td>
<td>PL-02</td>
</tr>
<tr>
<td>No transition elements</td>
<td>1836</td>
<td>1722</td>
</tr>
<tr>
<td>Overhead trellis</td>
<td>1313</td>
<td>1399</td>
</tr>
<tr>
<td>Solid overhang</td>
<td>1205</td>
<td>1291</td>
</tr>
<tr>
<td>DC 2 with vertical fins</td>
<td>990</td>
<td>1076</td>
</tr>
<tr>
<td>DC 2 with solid side walls</td>
<td>990</td>
<td>1076</td>
</tr>
<tr>
<td>DC 3 extended with DC 1</td>
<td>1088</td>
<td>1184</td>
</tr>
<tr>
<td>DC 4 extended with DC 1</td>
<td>990</td>
<td>1076</td>
</tr>
<tr>
<td>DC 4 extended with DC 6</td>
<td>862</td>
<td>906</td>
</tr>
<tr>
<td>DC 5 extended with DC 6</td>
<td>775</td>
<td>861</td>
</tr>
</tbody>
</table>

| Standard deviation  | 258       | 258       | 894       | 12982     | 28988     | 28211     | 36203     | 24483     | 20835     | 11119    | 0       |

The study used the artificial sky simulator to reproduce similar sky conditions during the experiment. Accordingly, there is no time of day/year or location that is specific to the results.

Table 3: Visual comfort sensation and relative brightness ratios according to the CIBSE (1994) Code for Interior Lighting.

<table>
<thead>
<tr>
<th>Display Effect</th>
<th>Objective display illuminance ratio</th>
<th>Subjective apparent brightness ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subtle</td>
<td>5:1</td>
<td>2:5:1</td>
</tr>
<tr>
<td>Moderate</td>
<td>15:1</td>
<td>5:1</td>
</tr>
<tr>
<td>Strong</td>
<td>30:1</td>
<td>7:1</td>
</tr>
<tr>
<td>Dramatic</td>
<td>50:1</td>
<td>10:1</td>
</tr>
</tbody>
</table>

Table 4: Measured brightness ratios between consecutive station points for the base-case and all design combinations.
Base-case: No Transition Elements

The base-case scenario represents the entrance sequence with no transitional elements. Figure 4 indicates little difference in luminance levels between the first three interior station points one, two and three and the exterior points four, five, six, seven and eight. A drastic jump in luminance takes place as soon as the individual leaves the building and walks from station point three to station point four and subsequently from station point four to station point five. Luminance levels at zone three, four and five are 75.16 cd/m², 1 019.11 cd/m², and 2 267.52 cd/m² respectively leading to luminance ratios of 13.6:1 between point three and point four, a ratio of 2.2:1 between point four and point five and of 1:1 between point five and point six. The travel/adaptation time between all these consecutive points is 2 seconds.

According to the CIBSE Code for Interior Lighting, a luminance ratio of 10:1 (Table 3) (CIBSE, 1994) occurring in a period of less than 2 seconds (Adelson, 1982) during the transition phase from indoors to outdoors is considered extreme. As a result, the luminance ratio between station point three and point four is “dramatic” (Table 4) and has the potential to provoke a visual shock. Though luminance ratios between subsequent station points five and six are considered “subtle” transition sensation because of little difference in luminance levels, the user is still undergoing extreme discomfort for a longer period of time (Table 4 and Figure 4). Furthermore, more than 80% of sensitivity recovery in the rod system occurs within the first 2 seconds according to Adelson (Adelson, 1982).

Design Combination 1: Overhead Trellis

The overhead trellis is 4.8m deep and canopies over the entrance of the building. Point five is under the canopied area and point six at the edge of it. The overhead trellis delays the drastic jump in luminance as soon the moment a person walks out the door. As in the base-case, luminance levels between the three interior station points one, two and three are nearly the same but increase to higher levels at point four albeit less sharply as in the base-case (Figure 4). Luminance levels at zones three, four, five, six, and seven are 38.22 cd/m², 267.52 cd/m², 891.72 cd/m², 1 477.71 cd/m², and 2 343.95 cd/m² respectively leading to luminance ratios of 7:1, 3:1, 1.7:1 and 1:1 between these consecutive points starting from point three to point seven. Although this design feature impacts positively the transition between point three and point four, the luminance ratios between these points is still uncomfortable since the transition sensation is rated as “strong” between three and four and “moderate” between points four and point five (Table 4). Overall, the users would still experience visual shock as they move from the canopied area to the open-air area.

Design Combination 2: Solid Overhang

This design combination is similar to the previous combination especially in terms of size and proportions, but not in terms of light transmittance characteristics. The top cover is 4.8m deep and canopies over the entrance of the building. It provides an enhanced (decreased) luminance levels particularly between zones three and four, and zones four and five compared to Design Combination 1. However, a sharp increase in luminance appears as soon as the user leaves the area under the overhang. Luminance levels at zones three, four, five, six, and seven are 38.22 cd/m², 178.34 cd/m², 509.55 cd/m², 1 528.66 cd/m², and 2 343.95 cd/m² respectively leading to luminance ratios of 4.7:1, 2.1:1, 3:1 and 1.5:1 between these consecutive point starting from points three to seven respectively as shown in Table 4 and Figure 4. The travel/adaptation time between each point is 2 seconds. The first two luminance ratios are better than those in Design Combination (DC) 1 (overhead trellis) since the luminance ratio is restored to a transition sensation of “moderate” level between these consecutive points three and four, four and five, and five and six. Therefore, this design feature leads to smaller or moderate visual shock in the transitional space.

Design Combination 3: DC 2 with Vertical Fins

This combination incorporates a porch entrance that gives a sheltered appearance to the transitional space. The overhang is 4.8m deep with vertical fins that filter a certain amount of light without blocking it entirely. Luminance levels at zone three, four, five, six and seven are 30.57 cd/m², 1 273.39 cd/m², 382.17 cd/m², 1 656.05 cd/m², and 2 343.95 cd/m² respectively leading to luminance ratios 4.2:1, 3:1, 4.3:1, and 1:4:1 between the 5 consecutive station points from point three to point seven. It was noticed that all luminance ratios between these points are restored to transition sensation of “moderate” levels. However, it is apparent that the third luminance ratio between point five and point six is higher than what was registered under Design Combination 2 due to reduced luminance under the canopied area because of the vertical fins suggesting some potentially higher discomfort in this zone. In addition, this combination would be more expensive than Design Combination two because of additional vertical fins.

Design Combination 4: DC 2 with Solid Side Walls

The results from Design Combination four, where the top is a solid overhang supported by two solid side walls, reveal a smoother curve of luminance levels and lower luminance ratios between the first three consecutive points three, four and five but a sharp increase in luminance with a “strong” luminance ratio rating between points five and six signaling visual discomfort or possibly even shock (Table 4).

Design Combination 5: DC 2 Extended with DC 1

The top cover is 9.6m deep, and includes a 4.8 m long overhang and a 4.8m long trellis canopying over the entrance of the building. Points four, five, six, and seven are under the canopied area. This design combination offers lower luminance ratios and a longer adaptation time as opposed to the previous combinations. Luminance levels at zone three, four, five, six, seven, eight, and nine are 38.98 cd/m², 193.63 cd/m², 407.64 cd/m², 917.20 cd/m², 968.15 cd/m², 1 656.05 cd/m², and 2 343.95 cd/m² respectively leading to luminance ratios of 5:1, 2:1:1, 2:3:1, 1.1:1, 1.7:1, and 1.4:1 between consecutive points respectively. Clearly, these values indicate a better transition as opposed to the previous results especially with the existing extra time for adaptation. However, there is a rating of “moderate” discomfort as the user transits between point three and point four. The overall results are acceptable and encounter no strong or dramatic visual shock in the transitional space.
Design Combination 6: DC 3 Extended with DC 1

This combination includes Design Combination 3 extended with a 4.8m deep overhead trellis. Luminance levels at zone three, four, five, six, seven, eight, and nine are 28.03 cd/m², 101.91 cd/m², 221.66 cd/m², 713.38 cd/m², 917.20 cd/m², 1,656.05 cd/m², and 2,343.95 cd/m² respectively leading to luminance ratios of 3.6:1, 2.2:1, 3.2:1, 1.4:1, 1.8:1, and 1.4:1 between consecutive points respectively. To some extent, the overall transition sensations under this design combination are similar to the ones under Design Combination five by in large with a small difference noticed between point three and point four, and point five and point six (Table 4). No drastic or strong visual transition sensation is experienced. However, like Design Combination five, the transition space is 9.6m deep requiring a solid overhead, overhead trellis, and vertical fins.

Design Combination 7: DC 4 Extended with DC 1

Figure 4 indicates no difference in luminance levels between exterior points seven, eight, and nine. The unexpected jump in luminance occurring between zones five and six is exhibiting a ‘strong’ transition sensation, and provokes a visual shock in the transition. Luminance levels at zone three, four, five, six, seven, eight, and nine are 22.93 cd/m², 45.86 cd/m², 112.10 cd/m², 662.42 cd/m², 917.20 cd/m², 1,656.05 cd/m², and 2,343.95 cd/m² respectively leading to luminance ratios of 2:1, 2.4:1, 5.9:1, 1.4:1, 1.8:1, and 1.4:1 between consecutive points.

Design Combination 8: DC 4 Expanded with DC 6

Luminance levels at zone three, four, five, six, seven, eight, nine, ten, and eleven are 22.93 cd/m², 35.67 cd/m², 56.05 cd/m², 140.13 cd/m², 259.87 cd/m², 662.42 cd/m², 917.20 cd/m², 1,554.14 cd/m², and 2,343.95 cd/m² respectively leading to luminance ratios of 1.6:1, 1.6:1, 2.5:1, 1.9:1, 2.5:1, 1.4:1, 1.7:1, and 1.5:1 between consecutive points. The top cover with its combined transmittance characteristics (partially and entirely blocking daylight penetration) is 14.4m deep and canopies over the entrance of the building. Points five, six and seven are under the entirely canopied area. Points eight and nine are under the partially canopied area. This design combination offers extra time for the eye to adapt easily as the person experiences the space. All the luminance ratios are restored within the “subtle” transition sensation. This design combination leads to the best visual comfort transition between indoors and outdoors.

Conclusion

In relation to this study, there are three major factors of movement in space, namely distance, time, and perceived sensation of visual discomfort. It might be argued that humans, whether they are temporal visitors to the building or working in it, should access the building through comfortable transitional spaces. These spaces ought to permit the user’s visual system more time to make the necessary changes in adaptation.

While relating physical measurements with perceptions of visual comfort, our experiments indicated that Design Combination 8 (Figure 3b) – a deep cover with combined transmittance characteristics (partially and entirely blocking daylight penetration) extending over the entrance of the building – works best. In this scenario, transition sensation between all zones was “subtle.” Design Combinations 6, 3 and 2 indicated no “strong” or “dramatic” visual shock between transitions zones. However, Design Combination 8 is the costliest and requires the most space. Design Combination 2, which includes a solid overhang, provides adequate transition leading to reasonable visual comfort and is the least costly.

We need to remind again the following limitations: The first is the fixed distance interval between station points along the main axis of the entrance sequence. This limitation offers equal travel time for a walking person to move from a station point to another. The second limitation is the overcast sky condition used in the study. The contrast luminance ratios between interior and exterior spaces may be more severe and could present a different set of conclusions.

Overall, it is clear that there should be a conventional approach to the design of the luminous environment. The possible number of variations on a model is endless, but the designer can use the data included in this study as the base line to create solutions that are more elaborate. There are simple design strategies such as simply providing a solid overhang with a certain amount of depth (in our case 4.8m) over the entrance of a building that will alleviate problems of visual shocks. The key ingredient is progressive reduction in luminance levels and allowing ample time for adaptation. If space requirements and cost are no object, better visual comfort can be obtained by using Design Combination 8 from this study.

References


