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Independence and Interdependence of
Sustainable Spaces

DAYLIGHT VARIATION AND CONTRAST EFFECT ON HUMAN PERCEPTION OF SPATIAL QUALITY

A case study of selected contemporary residential spaces in Sri Lanka

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Abstract: Visual perception of space is influenced by the composition and behaviour of light. Daylight as a natural element creates different atmospheres in the same space through its variation of intensity, colour, and direction. It creates dynamic shadow patterns, fluctuating brightness, and contrast levels. Although the capacity to create variation - therefore contrast, is an important characteristic of daylight - it is often neglected in research, where comfort and visual performance take prominence. This is a research initiative to explore the effect of daylight variation on spatial quality and human perception. The research adopts a two-step process, where, digital images are first mapped to generate contrast diagrams, and secondly, the generated digital images form the basis for a survey utilising a seven-point semantic differential scale, to explore the relationship between daylight variability and human perception. The temporal variation of daylight is explored by diagramming spaces at selected times of the day and year. The scope of the study is limited to selected residential spaces as case studies and focuses on the manner of integrating daylight into spaces. Results show that the level of contrast correlates to the perception of 'low contrast – high contrast', 'unvaried – varied', 'calming – exciting', for the observer.

Keywords: *Daylight variability, Human perception, Contrast, Daylight integration*

1. Introduction

The most eloquent creations with light in the history of architecture have not been overly concerned with visual acuity and formal clarity. Throughout the ages and with a quiet, almost unspoken skill, masterful builders have sought to catch certain parts of the sky, and then carefully guide those oncoming rays into the spatial components and material fabric of buildings, so that some parts might darken and vanish, and others grow bright and shimmer. Light was projected, reflected, dimmed, focussed, diffused, and scattered not to expose the surface of things, but to bring into the deadened weight of the architecture a more enchanting and vibrant reality (Plummer, 1995 as cited in Perera, 1998).

As a subject 'light' touches on one of the most archaic and important symbolic structures in being human. Eyes have evolved because there was (day) light. The sustained power of the metaphor of sight in philosophy and theology arises because seeing/light is the principal medium of involvement with people and things. We still use 'see' to mean 'understand,' and 'understand' carries all the implications of position, orientation, intent, foreground/background (importance/ context), nuance, etc. that are the substance of visual perception. This archaism is still an element of natural light, as it remains authoritative with regard to how any material appears, that is, a material announces itself properly only in daylight (even plastic, let alone natural materials); and accordingly, daylight seems to carry with it this primordial materiality as well as its own character (Steane, 2011).

The perception of space is directly connected to the way light integrates with it. What we see, what we experience and how we interpret the elements are affected by how light interacts with us and with the environment. Regarding architecture, in whatever dimension it can be analysed, either as space, as material or as colour, it is essentially dependant on the lighting situation that involves both the object and the observer (Fontenelle, 2008).

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Daylight as a natural source of lighting is highly variable and has become the basis for studies on the threshold properties of lighting and its impact. The most obvious aspect of daylight is its capacity for change, leading to a great variety of appearance and quality of the daylit interior (Philips, 2004). Although there is an understanding of the minimum amount of illumination that is required for the human eye to perform visual tasks, there is little consensus on how much contrast or brightness makes that space more or less exciting (Rockcastle, 2011).

The capacity to create variation, therefore contrast - an important characteristic of daylight - is often neglected in research, where comfort and visual performance take prominence.

In this context, the primary aim of this research is to explore and emphasise the value of daylight variation - analysed in terms of contrast - on spatial quality and human perception.

The key motivation of the research is to explore how human perception changes with the temporal variation of daylight. The psyche of the users of a particular space is paramount in the creation of architecture and architectural placemaking. Further, the emotion and meaning the space conveys are deemed important. The temporal aspect of daylight offers the opportunity to create a single physical space that can naturally transform to communicate varied emotions. Thus, the motivation is to explore ways to achieve this, whilst highlighting ways of mapping and correlating these aspects in research, which can be then interpreted into application and therefore architectural practice.

The research is designed in two steps. The first step maps and analyses spaces in terms of contrast. The selected spaces are simplified and communicated as digital images, encompassing temporal variations. The objective of the step is to establish a measured contrast intensity level that informs and compares the next step in the process – the perception survey. In the next step, a perception survey is conducted, involving thirty participants, who rate the digital images presented to them in terms of the level of contrast, uniformity, variation, simplicity, excitement, and stimulation, utilising a seven-point semantic differential scale. The objective of this step is to explore the correlation between contrast intensity and the visual perception variation of the observer.

The scope of the study is limited to contemporary residential spaces in Sri Lanka. The residential typology is chosen due to its increased exploration of light as a key compositional element. Further, the extended occupation of the spaces, albeit during a particular day or spanning a particular year, impacts the residential user more than it would users in more temporarily occupied spaces in other building typologies. Two case studies are chosen, and the selected spaces explore only side lighting with minimum obstructions and top lighting with repetitive obstructions, as a further limitation.

The geographic location of Sri Lanka and therefore the Sun's path in the sky add a uniqueness to the temporal aspects of the case studies. With the Sun being high in the sky, the direct component of daylight becomes significant. The case studies are utilised as a means to explore the correlation between daylight variation, analysed in terms of contrast, on spatial quality and human perception. Thus, the study is more of an exploration of the method rather than a highlight of the case studies and therefore the Architect's work.

Results and analyses encompass a comparative data collation for twelve images, chosen out of fifty-six digital images that represent seven times of a particular day, and eight selected days of the year. The primary research objective is to explore the temporal nature of the daylit space.

2. Literature Review

Light is a fundamental element of architecture; it interacts with the space, affecting the way we perceive it. The way lighting acts can change the spatiality, the atmosphere, and the visibility. The lit environment deals with brightness, shadows, lighting distribution, colour and many other aspects that influence our visual experience and plays with our mood (Fontenelle, 2008).

2.1. HUMAN PERCEPTION OF DAYLIGHT AND ITS VARIATION

Lighting is not only an essential requirement but also the medium by which human beings can see. The way light is distributed in spaces and its intensity influence visual perception. Good lighting design requires the enhancement of the visual experience, which promotes an effective working ability as well as a feeling of well-being in a particular environment, while at the same time enhancing the aesthetic qualities of the space.

While enhancing the intellectual pleasure and purity of geometrical objects in space, rewarding the mind's search for clarity, quantity, and measurement, giving order to the chaos of appearance, this kind of logical light is stripped of its deeper reach of sensibility (Plummer, 1992). The need for light to exceed mere illuminance is emphasised, especially in the difference between the static nature of artificial light and the temporality of daylight. Steane emphasises that "While artificial light sources can be carefully combined to match a desired composition, they produce a static effect and can never match the "nuance of mood created by the time of day and the wonder of the seasons" (Steane, 2011).

The light changes continuously over time. Such fluidity gives life to the space as if it were a living object. Thus, the light gives different feelings to the same physical space as time changes, and such altered feelings affect the sentiment of people. The space itself is in three dimensions. However, the light enables people to experience it in four dimensions by embracing the dimension of time when it is joined with light (Kim,2000).

As a research initiative to link light, human perception with the spatial quality, Flynn et. al., 1979, found that psychological procedures for rating subjective impressions and experiences can be applied usefully in lighting research and supports the theory that the experience of lighted space is, to some extent, a measurable experience. Furthermore, the findings tend to sustain the idea that lighting can be discussed and measured as a vehicle that alters the information content of the visual field and we may now be able to document how this intervention affects impressions and sensations of well-being (Flynn, et al., 1979). In this study, Flynn introduced the use of semantic differential scales to gather subjective assessments of daylight quality in terms of visual clarity, spaciousness, evaluation, relaxation, social prominence, complexity, modifying influence, and spatial modifiers (Flynn, et al., 1979).

Numerous studies thereafter have employed the use of these scales to conduct daylight quality research in real spaces and simulated or photographed views. (Newsham, et al., 2002; Newsham, et al., 2005; Vogels, 2008; Demers, 2007; as cited in Rockcastle and Anderson, 2015). These studies establish the basis on which the semantic scale was adopted in Rockcastle and Anderson, 2015 and utilised for this study (see Section 3.2.1).

2.2. BRIGHTNESS AND CONTRAST

Brightness and contrast are two basic components in visual perception which are often mentioned together. Brightness is the perceived illuminance as the result of direct and reflected light. Human eyes always capture the relative brightness which is known as contrast. In simple words, contrast is the balance between light and darkness. The eye's ability to perceive those differences and the brain's ability to extract that information is essential in order to understand the depth and complexity of the surrounding (Rockcastle, 2011).

Existing studies that have assessed the impact of contrast in daylit space have relied primarily on subjective surveys to explore the relationship between simple photometric measurements and perceived impressions of interior space (Flynn, et al., 1979; Wymelenberg and Inanici, 2009; Newsham, et al., 2005; Newsham, et al., 2010. as cited in Rockcastle and Andersen, 2015).

Studies on perceptual daylight performance have linked subjective ratings of contrast and brightness to simple global measures in digital images, yet the conclusions are varied and lack robust consensus. These 'global' contrast measures do not account for the composition of luminance values within a scene and while more robust methods have been developed in computational graphics, vision research, and psychology, they have not been applied to studies in qualitative lighting research. As daylight-driven visual effects are not only dependent on composition but are heavily influenced by dynamic sky conditions, (Rockcastle and Andersen, 2015).

The problem of generic contrast measure in natural images is a complex task. The degree of error pointed out by subjective tests turns out to be influenced by scarcely definable factors, which can alter the result in a relevant way. Emotional, cultural, and other high-level factors play an important role in the subjective evaluation of contrast in context. Subjects are influenced by the interpretation of the image and by their personal taste; these are concepts difficult to define, to detect and in particular to quantify (Rizzi, et al., 2008).

2.3. CONTRAST METRICS

The perceptual contrast of an image depends on the observer's vision and experience. Perceived contrast is influenced by the surrounding and the spatial arrangement of the image. Parameters such as resolution, viewing distance, lighting conditions, image content, memory, and colour, affect how the observer perceives contrast (Simone et al., 2012). The same authors divide the existing contrast measures into two categories, as global contrast measures and as local contrast measures.

Global measures are based on the claim that the human visual system depends on the absolute illuminance and not on its local variations (Simone et al., 2012). As an example, the Michelson formula (C^M) measures the contrast as the deviation range of maximum luminance (L_{max}) and minimum luminance (L_{min}).

$$C^M = \frac{(L_{max}) - (L_{min})}{(L_{max}) + (L_{min})} \qquad (1)$$

As per this method, different images with the same maximum and minimum luminance can produce the same contrast measurement, which is criticised by Simone, who states that "two single points of extreme brightness or darkness cannot determine the measure of contrast in the whole image."

Local contrast measures are developed to overcome the limits of global measures. They compare illuminance in pixels or desired points. Rockcastle and Anderson, 2014, compares the two methods of contrast measures using the same number of black and white pixels (15 from each) with three different arrangements (Figure 1).

The RAMMG method is an algorithm for the measure of local and global contrast in digital images developed by Rizzi, et al., 2008. It adopts a multi-level approach to compute mean local pixel variations across a subsampled pyramid structure, to account for perceived differences in brightness across multiple image resolutions. (Rockcastle and Anderson, 2015). (Figure 2)

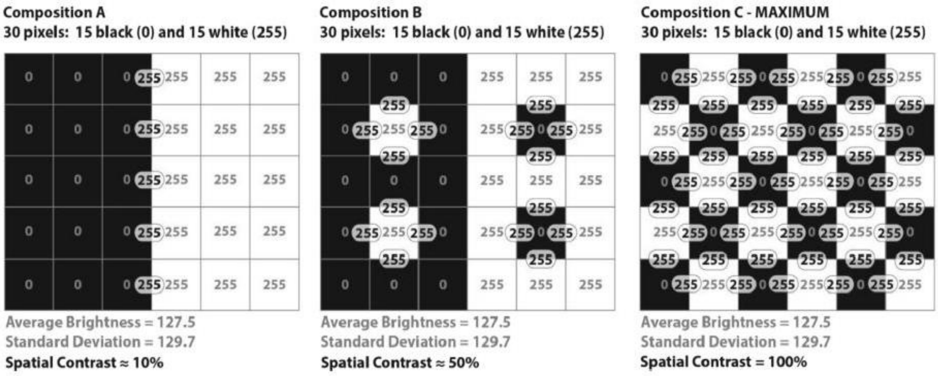
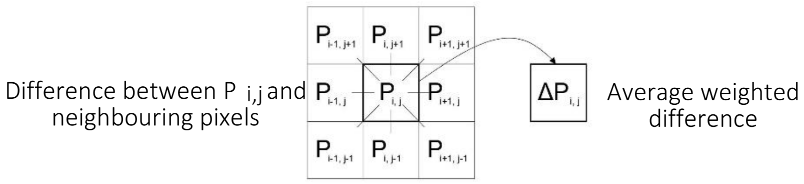


Figure 1, Image contrast of three compositions with same number of black and white pixels
(*Source: Rockcastle and Anderson.*)

3. Method

The research method encompasses two main components.



$$\Delta P_{i,j} = \frac{1}{8} \times \left(|P_{i,j} - P_{i,j+1}| + |P_{i,j} - P_{i,j-1}| + |P_{i,j} - P_{i+1,j}| + |P_{i,j} - P_{i+1,j-1}| + |P_{i,j} - P_{i+1,j+1}| + |P_{i,j} - P_{i-1,j-1}| + |P_{i,j} - P_{i-1,j}| + |P_{i,j} - P_{i-1,j+1}| \right) \quad (2)$$

Figure 2, The average difference between each pixel pi,j and its four neighbouring pixels.
(*Source: Rockcastle and Anderson.*)

1. Daylight variation and contrast
2. Contrast variation and human perception

3.1. STEP 01: DAYLIGHT VARIATION AND CONTRAST

3.1.1 Categorisation of naturally lit spaces and case study selection

The performance of daylight depends on the way that daylight is integrated into the space. The primary way of introducing natural light into an interior is through fenestration. The design and shape of fenestration has evolved over the centuries, but the primary purpose remains the same. Two types of fenestrations are used in building design and are defined as, side lights and roof lights. (Philips, 2004).

Spaces can be categorised according to the type of fenestration.

1. Completely open top-lit spaces
2. Top-lit spaces with repetitive obstructions
3. Completely open side-lit spaces
4. Side-lit spaces with minimum obstructions
5. Side-lit spaces with repetitive openings
6. Side-lit spaces with thick openings

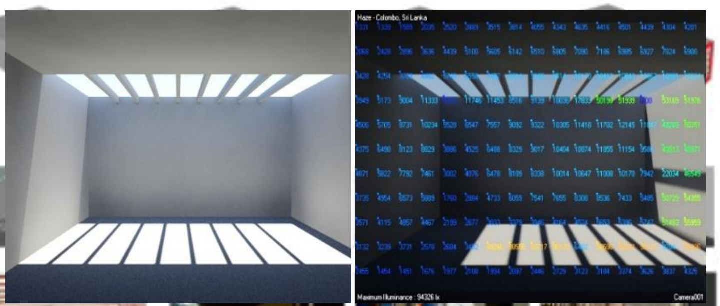


Figure 4, Rendered Image, and Intensity Map produced by Autodesk 3ds Max (*Source: Author*)

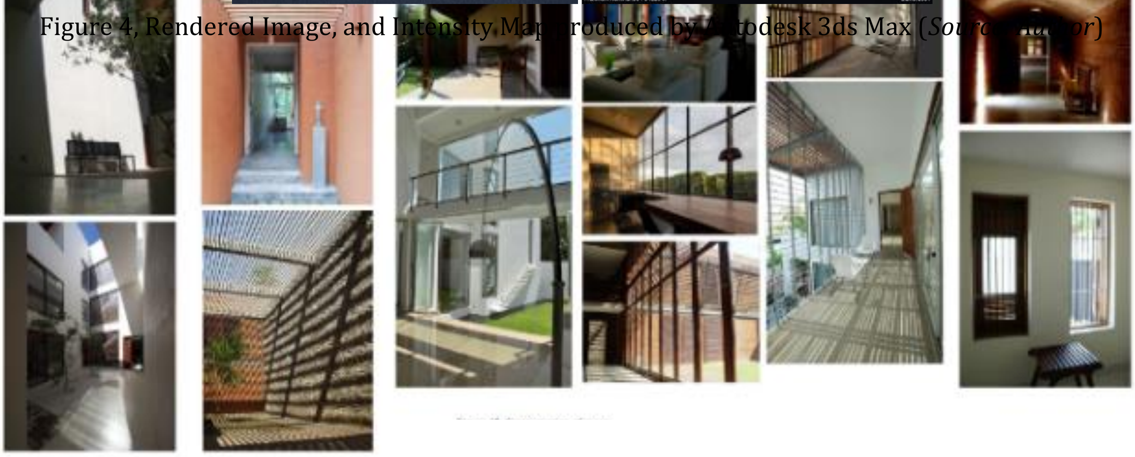


Figure 3, Categorising of spaces according to the type of opening (*Source: Author*)

Although, side and top opening options are extensive in their permutations and combinations, for the purpose of in-depth analysis of spaces, two residences designed by Archt. Perera and by Archt. Horombuwa were explored, and daylit spaces were selected. The selection, though random in terms of contemporary residences, was based on data availability and the Architect's conscious utilisation of daylight for architectural effect. Both case study residences were recognised by the Sri Lanka Institute of Architects for Design Excellence. The selected spaces within the two case studies fall into the identified Category 2 - Top-lit spaces with repetitive obstructions, and Category 4 - Side-lit spaces with minimum obstructions.

3.1.2 Computer simulation protocol and Contrast Intensity Mapping

Daylighting analysis methods have evolved and two primary types are defined, as physical modelling and computer-based simulations. Since daylighting performance cannot be predicted like in artificial lighting, simulated analysis systems are used to evaluate the performance of daylight before the completion of the building. Illuminance levels and spatial variations can be studied and developed before the finalisation of the design. Yet, these methods are not completely dependable. As Kensek and Suk state, "It is not easy to get accurate, predictable or often matching values between techniques due to the multitude of variables, including sky selection" (Kensek and Suk, 2011).

In this context, the primary mode of mapping spaces and communication adopts computer simulations. The modelling software, Autodesk 3ds Max, (formerly 3D Studio and 3D Studio Max), a professional 3D computer graphics program is utilised. Each image of a space, on the 56-point temporal matrix, is rendered and mapped for contrast intensity utilising the NVIDIA Mental Ray for Autodesk 3ds Max plugin. The Autodesk 3ds Max lighting analysis tool produces an intensity map for the camera view and the given pixel gap (Figure 4). Using the RAMMG method (outlined in section 2.3), the contrast of each point is calculated related to the eight points around it.

Eight days of the year with an equal number of days between them were selected. Seven times of each day were selected considering the time of sunrise and sunset. These days and time-of-day establish the temporal matrix utilised for the next stage of the research process. The rendered images presented as a matrix is shown in Figure 5. These images form the format used to communicate the spatial qualities and variances to the participants.

Thereafter, a mean value of contrast intensity of each image is calculated and communicated as assigned colours, depicting intensity as a percentage, as shown in Figure 5.

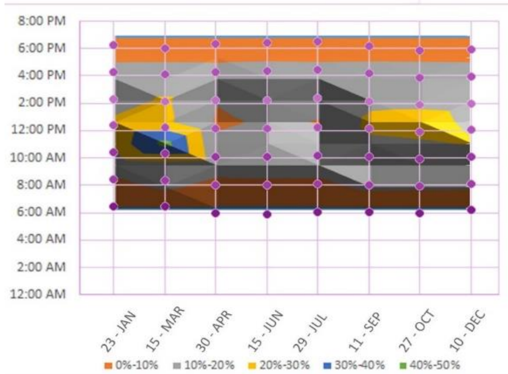


Figure 5, Mean value of contrast and Contrast diagram (*Source: Author*)

3.2 STEP 02: CONTRAST VARIATION AND HUMAN PERCEPTION

3.2.1 Survey Design

To explore the contrast variation and human perception component of the research, the approach utilised by Rockcastle and Anderson, 2015, was adopted, where "for each space, the subjects were shown an image and asked to rate the daylight composition using the following seven-point semantic differential scales: low contrast to high contrast, uniform to non-uniform, unvaried to varied, simple to complex, calming to exciting, sedating to stimulating" (Rockcastle and Anderson, 2015) (Figure 6).

How would you rate the daylight compostion in this image?

low contrast	O	O	O	O	O	O	O	high contrast
uniform	O	O	O	O	O	O	O	non-uniform
unvaried	O	O	O	O	O	O	O	varied
simple	O	O	O	O	O	O	O	complex
calming	O	O	O	O	O	O	O	exciting
sedating	O	O	O	O	O	O	O	stimulating

Figure 6, The rating scale used for the survey. (*Source: Rockcastle and Anderson, 2015*)

The perception of thirty (30) subjects were surveyed, to explore the correlation between contrast intensity and visual perception of the observer. The selected participants were between the ages of 21 to 24, and female, who have no relation to the field of lighting design or analysis. The limitation of the participants was chosen such that the sampling can be focussed as possible, and also due to the nature of the perception study, where personal factors can affect responses.

3.2.2 Analysis Protocol

The analytical study attempts to explore the relationship between spatial quality and human perception by using contrast as a research tool. A comparison is expressed between the measured contrast (quantitative data) and recorded human perception (qualitative data) to achieve the task.

Daylight variability and contrast levels of case study spaces are explored in two stages.

Firstly, the Rendered images of fifty-six instances were arranged sequentially to observe how the same space changes its spatial quality during a year. The use of digital tools are a distinct advantage in this instance, where the sequence of images was generated within a short period of time.

Thereafter, in the second step, six images were selected from each case study (from within the fifty-six images that were generated in the previous step). The selection of images is taken as a limitation of scope, where a survey utilising all fifty-six images was deemed to be excessive. Further, the levels of contrast were too similar to generate a perception response. The selected images represent different and distinct contrast levels, and represent a particular time of day and day of a year. These images established the basis of the survey, ensuring variation of contrast and temporality.

The survey results are then correlated to the selected image and its mean contrast intensity.

This is done in two steps, where at the first step, the two case study spaces – the side-lit and the top-lit – are analysed separately. Here, the semantic scale responses are mapped to ascertain patterns of perception at different levels of contrast intensity.

Secondly, the perception survey results are correlated to the measured contrast intensity, irrespective of the manner in which daylight is integrated into the spaces. To do these analyses, the mean value of the perception responses at each contrast level is calculated by giving relative weightage to the seven-point semantic scale.

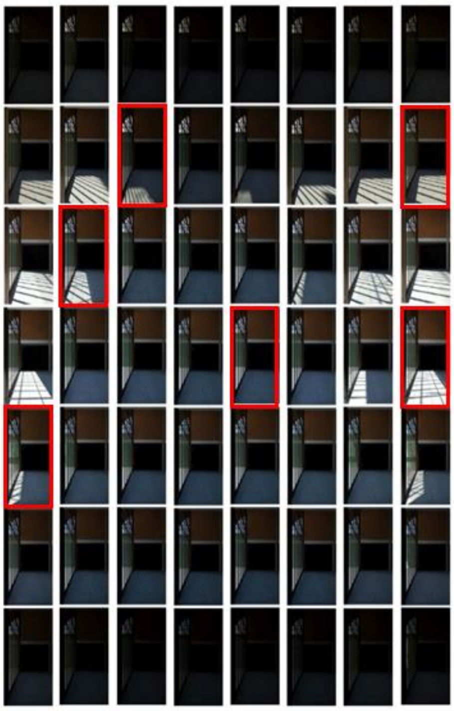
4. Results and Discussion

4.1. CASE STUDY 1 - "ENIGMA" BY ARCHT. NAREIN PERERA

The space used for evaluation is categorised as a "Side-lit space with minimum obstructions." The primary opening faces towards the South-East direction. Clear shadow patterns are visible only for a few months of the year and spatial contrast is relatively high during that period (See Figure 7).

Overall, for the side-lit space, the measured contrast levels are low within the space and the contrast differences are small. The responses show the perception of the contrast level within the space is also low (Figure 7 and 8).

A significant difference in perceived contrast is shown in the highest measured contrast level of 16.8%. Therefore, the perception survey shows that the measured value of contrast corresponds to the perceived 'contrast' level for the observer. However, it is seen that the correlation of the pattern of shadows is not significant, where relatively higher contrast diagrams show the varied perception of contrast intensity, unlike in the low contrast diagrams. (Figure 8)



23-Jan	15-Mar	30-Apr	13-Jun	29-Jul	11-Sep	27-Oct	10-Dec
1.1%	1.1%	9.0%	0.9%	0.9%	0.7%	1.0%	1.0%
8.4%	7.2%	6.6%	5.2%	8.5%	10.6%	12.2%	12.2%
10.6%	10.0%	5.9%	5.9%	5.9%	7.8%	15.1%	14.5%
11.2%	5.8%	5.8%	5.7%	5.7%	5.8%	14.0%	16.8%
9.2%	4.7%	4.7%	4.7%	4.6%	4.5%	4.5%	10.8%
5.2%	5.2%	5.3%	5.3%	5.4%	5.4%	5.4%	5.2%
2.2%	2.2%	2.3%	2.3%	2.3%	2.2%	2.2%	2.2%

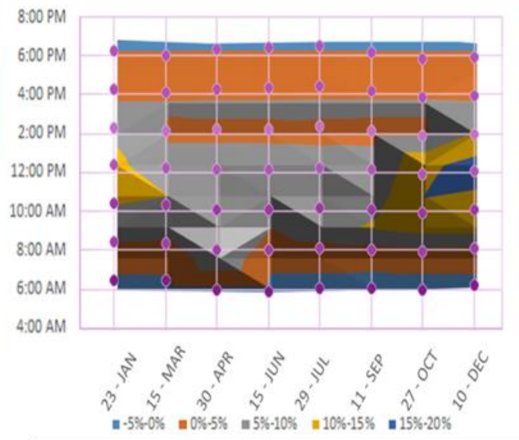


Figure 7. CASE STUDY 1 - Annual temporal renderings (left), calculated contrast (top right), contrast diagram (bottom right) (*Source: Author*)

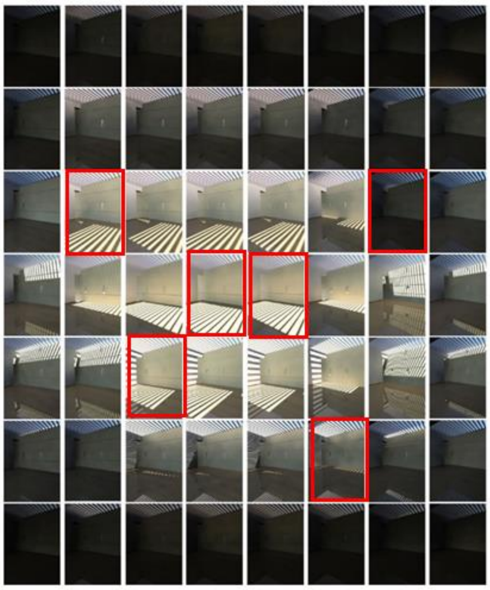
Figure 8. CASE STUDY 1 - Annual temporal renderings and corresponding recorded perception analysis. (*Source: Author*)

The correlation to the level of 'uniformity', where the observers see the space as 'uniform or non-uniform' does not correspond to either the measured or perceived contrast levels. Similarly, this is also seen in the analysis of the space as 'simple or complex', where a clear pattern is not evident.

The perception of the level of variation is seen as 'unvaried' at most contrast level scenarios surveyed. Although the shadow patterns change significantly during the day and the time of year, the perception is that the side-lit space remains unvaried. Similarly, the patterns of perception see the space as 'calming' as opposed to 'exciting'.

As seen in the relatively 'calming' and 'unvaried' spatial perception, the factors that determine if the space is 'sedating or stimulating' show that the space is perceived as 'sedating'. Thus, it is clear with relatively low contrast levels, the participants' perception gravitates toward a subdued spatial experience. Although, significant factors such as shadows falling on the floor of the space are seen, for the "Side-lit space with minimum obstructions", the impact is minimal.

4.2. CASE STUDY 2 - "MINIMALIST HOUSE" BY ARCHT. CHANNA HOROMBUWA



23-Jan	15-Mar	30-Apr	13-Jun	29-Jul	11-Sep	27-Oct	10-Dec
2.9%	3.0%	5.4%	4.1%	2.5%	3.8%	5.0%	4.8%
3.1%	5.2%	4.4%	4.4%	4.2%	3.7%	4.9%	3.2%
3.1%	13.7%	11.3%	11.2%	17.0%	6.7%	4.9%	3.4%
15.9%	10.4%	16.9%	35.2%	20.8%	9.4%	7.8%	4.9%
6.0%	7.6%	18.5%	16.6%	18.0%	12.7%	8.1%	6.1%
3.1%	3.0%	11.1%	9.0%	9.9%	10.0%	3.7%	3.3%
3.1%	3.5%	4.2%	4.5%	3.5%	4.1%	2.7%	3.1%

Figure 9. CASE STUDY 2 - Annual temporal renderings (left), calculated contrast (top right), contrast diagram (bottom right) (Source: Author)

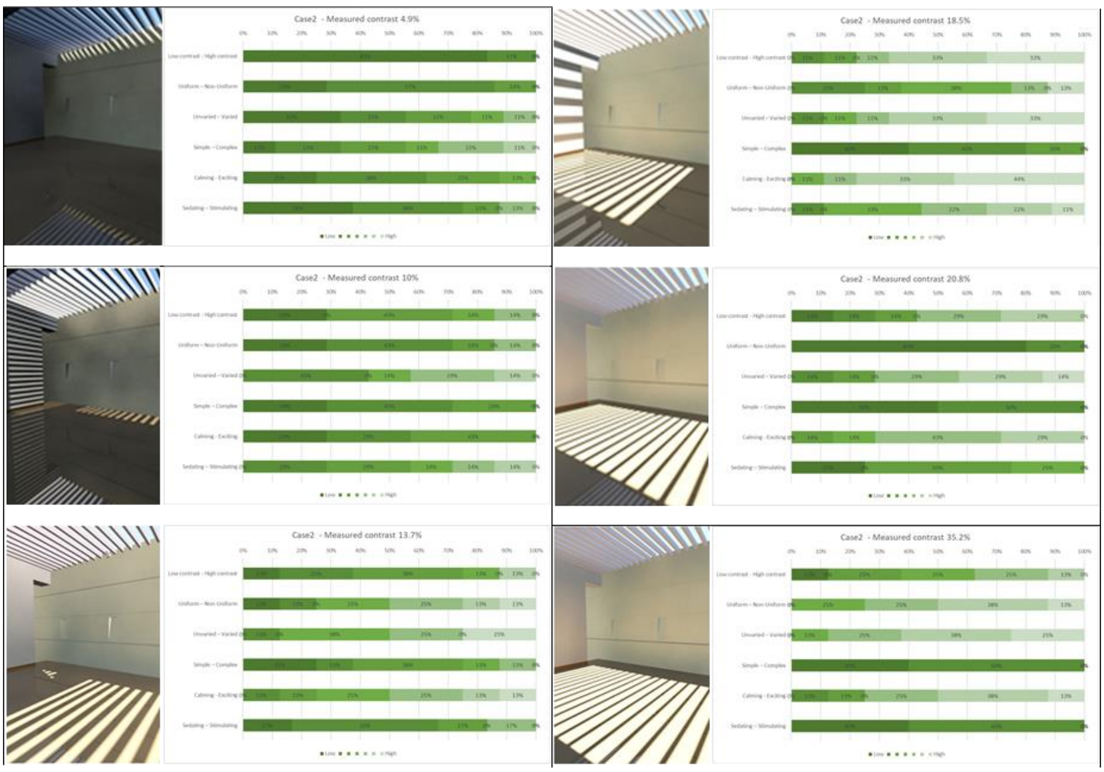


Figure 10. CASE STUDY 2 - Annual temporal renderings and corresponding recorded perception analysis. (*Source: Author*)

The space selected for evaluation falls within Category 2 - Top-lit spaces with repetitive obstructions. The considered space receives a good amount of daylight throughout the year. The material and colour selection enhances the reflection of light within the space. Sharp shadows are created during the daytime hours. The contrast diagram shows a high contrast during the middle months of the year (Figure 9).

For the top-lit space, the perception survey shows a significant correlation between measured and perceived 'contrast' for the lower contrast levels, but perception is varied at the higher contrast level patterns (See Figure 10). Thus, it can be deduced that although the respondents recognise that the space experiences a higher value of contrast, it is difficult to ascertain the comparative level of intensity.

Similarly, the 'non-variability' within the perceived space, and the ability to create 'excitement' within it, are positively correlated to contrast. Therefore, high contrast spaces are perceived as 'non-variable' and 'exciting'.

The aspect of 'uniformity' does not show a pattern, even in consideration of the presence of shadows on the surfaces. Similarly, in consideration if the space demonstrates 'simplicity' or 'complexity', and if the space is 'sedating' or 'stimulating', does not show a pattern in the perception survey (Figure 10).

Therefore, it is ascertained that the contrast intensity perception of the top-lit space evaluated is perceived to be correlated to only particular parameters explored in the semantic survey.

4.3 OVERALL CORRELATION OF PERCEPTION PARAMETERS

The collected data is analysed for both the side-lit and the top-lit case studies. The overall correlation of recorded perception is compared for each parameter explored in the perception survey against the contrast intensity value communicated by the images. The objective is to ascertain if a relationship is evident between the measured contrast intensity and the parameters, independent of the manner in which the spaces are lit (Figure 11).

4.3.1 Measured contrast vs Low contrast - High contrast

The correlation between the measured contrast level and that of the perceived is relatively strong. With an R^2 value of 0.482, the mean perception values do not directly correspond at all levels, yet a clear pattern is evident. This was seen in the analysis of the side-lit and top-lit spaces when considered separately as well. Therefore, it can be ascertained that the respondents perceive contrast relative to contrast values, yet they fail to effectively communicate the intensity levels. Further, the perception of 'low contrast' is much stronger than that of 'high contrast.'

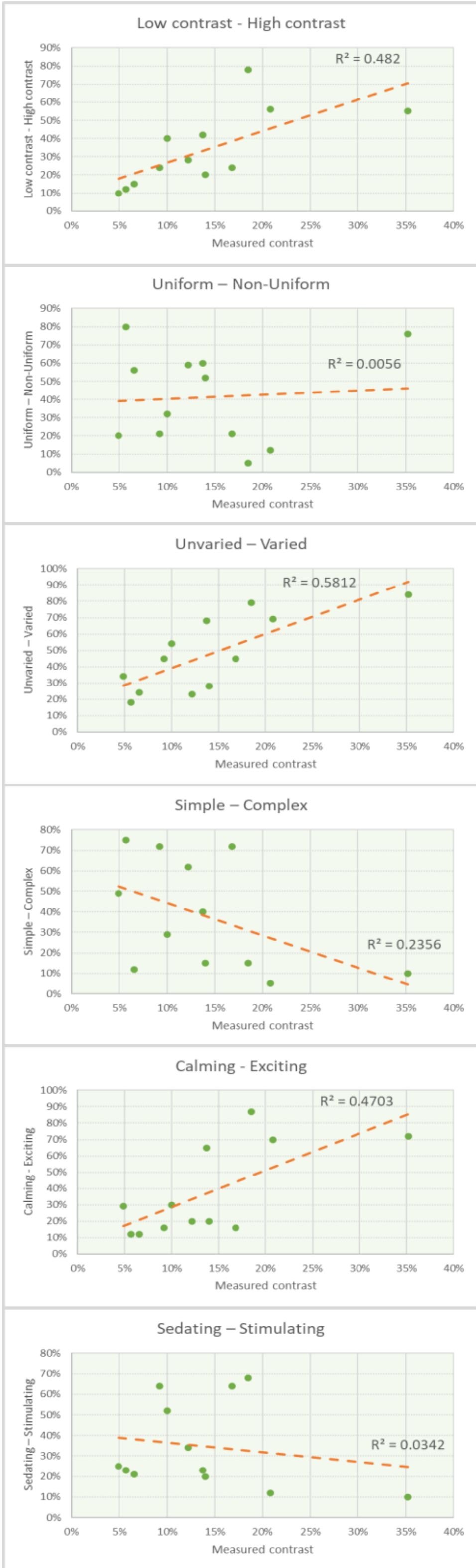


Figure 11. Overall correlation of perception parameters (Source: Author)

4.3.2 Measured contrast vs Uniform – Non-Uniform

The correlation of contrast to the level of uniformity of the space is very weak. (R^2=0.0056) The space is perceived as 'uniform' at lower contrast levels, although there is no clear pattern. Similarly, the perception of 'non-uniformity' is seen at the highest contrast value mapped. Therefore, it is understood that the perceived level of uniformity is made clearer at extremes of the contrast range.

With contrast in lighting the ability of surfaces and materials to demonstrate their imbued properties is heightened. Therefore, the degree of detail is better perceived, rendering the spaces more non-uniform.

4.3.3 Measured contrast vs Unvaried – Varied

It can be expected that the level of variation in the space will be heightened by the level of contrast, especially with spaces that are enlivened by the presence of shadows falling on surfaces and constantly change temporally. The perception study shows that a definite pattern is evident. ($R^2 = 0.5812$). The respondents see the space as 'unvaried' at lower contrast levels and 'varied' at higher contrast levels.

4.3.4 Measured contrast vs Simple – Complex

The graph shows that the perception of 'simplicity' or 'complexity' within the space varies with varied contrast intensity, and therefore does not show a strong relationship. (R^2=0.2356)

4.3.5 Measured contrast vs Calming - Exciting

The results show a relatively clear pattern, where, at low contrast intensity values, the spaces are perceived as 'calming' and 'exciting' at higher contrast levels. (R2=0.4703). Thus, it is evident, that for the spaces to create excitement, the temporal nature of daylight, and the shadows it creates need to be emphasised by contrast.

4.3.6 Measured contrast vs Sedating – Stimulating

Contrast-driven properties do not correspond to the notion of whether a space is 'sedating' or 'stimulating'. (R^2=0.0342) Thus, it is deemed that other factors need to play a role in its spatial configuration.

5. Conclusions

5.1. KEY FINDINGS AND IMPLICATIONS FOR DESIGN

5.1.1 The measured value of contrast shows a pattern of correlation to the perception of 'low contrast – high contrast'; 'unvaried – varied'; 'calming – exciting' for the observer.

The results show with the perception of contrast within the case study spaces, the respondents were able to visualise and relate to semantic pairs relating to the level of variation and excitement of the space. This was not evident for the pairs relating to uniformity, complexity, and the level of stimulation. Thus, it is understood that mere perception of contrast is enough to trigger a response in the parameters that showed a correlation, while the parameters that did not, needed more detail to communicate.

For design and daylight integration for effect, the lesson here is that, in the exploration of a lighting application, the designer needs to create an envelope of space, albeit with light. The light entering an interior space needs to illuminate, create patterns, and embrace the temporal character of light. Openings need to be oriented, sized and placed such that either horizontal and vertical surfaces – or both - of the physical envelope of space is illuminated with pattern and/or intensity. Patterns created by elements included in the fenestration detailing will help create shadow and therefore interest.

5.1.2 For the side-lit space, the measured value of contrast is relatively low. Therefore, perception correlation was strongest towards a subdued spatial experience.

Daylight variability perception for the side-lit space showed that the spaces were seen as relatively 'calming', 'unvaried' and 'sedating'. This is deemed due to the low contrast values seen in the temporal exploration of the space.

Thus, It is understood that, unlike the top-lit space, shadow and defining boundaries of light and shadow elements were not as defined. Therefore, in image comparison by the observer, the differentiating factors were limited. Further, with the selected orientation, the ability of the side lighting aperture to admit light into a space is limited, especially direct sunlight components that create shadows.

5.1.3 For the top-lit space, the measured value of contrast is relatively high. Therefore, perception correlation was strongest towards a 'non-variable' and 'exciting' space.

The top-lit space effectively characterises the intensity and temporal qualities of the daylight integrated. This is affected by the repetitive elements within the opening (pergolas) and adjacent vertical surfaces that can 'catch' shadow. The top-lit option can be more easily oriented, given that the Sun's path over Sri Lanka is high in the sky, throughout the year. Even where the direct sun is shaded for solar heat gain prevention, the alternate mode of integrating daylight is effective because of the brightness of the sky in the Sri Lankan context.

Utilising top lighting strategies for light and therefore architectural effect has potential. With a clear definition of strategy and appropriate design of the interior envelope to receive the positive elements of the integration, the space created can be meaningful.

5.2. LIMITATIONS AND DIRECTIONS FOR FUTURE STUDY

The study utilised digital images and mapping techniques to measure and research the variability of daylight and its perception. Although a well-developed and utilised method was adopted, the greatest limitation is seen as the difference between experiencing a space physically and viewing it digitally, especially for communicating architectural effect. The challenges posed by the temporal nature and range of study render it impractical to be experienced physically. Future research needs to attempt to increase the understanding of the space the observer is expected to experience. Careful choice of image, which portrays architectural space rather than a mere graphic image can help.

Section 2 of this paper defined numerous ways of integrating light through fenestration. An expansion of the scope of study to include other typologies is encouraged.

Data collation and analysis were done graphically using graphs and bar charts. A more in-depth statistical study with a larger data set, which includes a wider range and quantum of participants will help show patterns that are not evident at this stage.

5.3. CONCLUSION

Daylight; as a combination of direct sunlight and diffused skylight, ensure the vision and wellbeing of the user. The variation of daylight creates a dynamic effect in a space without much effort. The research is an attempt to highlight and appreciate its variable quality. The key objective was to research how human perception changes with the temporal variation of daylight.

Contrast is used as a tool to build up a relationship between daylight integration and human perception, primarily for architectural effect. The research findings confirm established literature that contrast has an impact on the perception of users. The exploration of residential spaces, with definition and limitation in the way the spaces are lit, offers insight. It is not only the level of contrast but the way in which light interacts with the envelope of space, creating a varied experience for the user. This is a key contribution of the study, where a detailed consideration of the means of integration of daylight has an impact on the total perceptive experience. This is a clear impetus for the architect to incorporate spatial episodes driven by contrast patterns or events for architectural effect.

The correct and conscious integration of daylight into architectural space is essential to create spaces that convey meaning by utilising contrast to communicate uniformity, variability, simplicity, or complexity, creating spaces that are calming or exciting, and that can sedate or stimulate the user. Thus, create an 'architecture in light' that ensures the emotional and physical wellbeing of the occupant.

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