A Study of Saliency, Based on Visual Complexity and Luminance Contrast with Implications for Urban Lighting

Navaz Davoudian[1]

University of Sheffield, School of Architecture,
Arts Tower, Western Bank, Sheffield S10 2TN, UK,

Abstract: *In recent decades, one of the main objectives of lighting masterplans has been to highlight important urban objects and landmarks at night to create a more pleasant ambiance. This process of lighting design, as with other types of visual design, needs to consider the relationship between the object and its context and how the background lighting could influence the design of the lighting applied on the urban objects. Previous studies have shown that salience is strongly influenced by visual context, which means the same target may or may not be salient, depending on how it is embedded in the scene. This study focuses on the impact of background density of lighting patterns and also the impact of proximity of background patterns to the target object on saliency of the target and also interaction between them and luminance contrast in object saliency. The result of the study could help to improve the understanding of the conspicuity in urban area and ultimately improve the guidelines in urban lighting to have more efficient lighting plans for cities.*

Introduction

During last three decades, changes in people's life styles enhanced the need to have more active nocturnal life. The modern style of life demands to extend the day life into the night atmosphere. As a result the city needs to be prepared to assure the same quality of life at day during the night besides solutions to fulfil the night life demands as well.

Urban lighting is assumed as one of the most effective means to perform the above objectives. Lighting masterplans during last few decades, beside their functional view towards lighting, have been trying to generate pleasant night image and ambiance in cities. To achieve this goal one of their main objectives are to select the important urban objects and landmarks to be highlighted in the nocturnal image of the city. In a study by Davoudian & Fotios [1], they pointed the inadequacy of lighting masterplans in prevention of light war and visual anarchy in

[1] PhD project supervised by Dr. Steve Fotios

nightscape of the city by merely technical guidelines in urban lighting. Traditionally, increasing luminance has been the main tool used to improve the saliency of a particular object. The studies and guidelines in this regards also are recommendations in about the luminance ratio between the object and its background to achieve different levels of conspicuity (saliency). One of the reference guide books in this regard is ILE “Outdoor Lighting Guide”[2] which has very clear defined rules in terms of luminance ratio between object and background. These recommendations are usually based on the conspicuity of the objects in front of the plane background. However, this is not exactly the same case when it comes to urban lighting in real situations.
A number of studies have shown the importance of scene factors in object search and recognition [3-6]. Architectural Lighting design, the same as other types of visual design, needs to consider the relation between the object and its context. The same way that a building is perceived in relation to its context during the day, the night image of the building created by applied lighting will be perceived in relation to its lighting context. This lighting context is not perceived just as luminance contrast exists in the scene, but it consist of several lighting patterns which apart from the luminance differentiation, they create 2-dimensional patterns on the urban envelopes which increases the visual complexity of the scene. This complexity influences the appearance of the building (or urban objects in general) in different ways including the perception of saliency.
Here it may be concluded that guidelines such as ILE’s and … about luminance ratio might not provide very precise rules without considering the surrounding lighting arrangement.

Complexity of Background

Visual Complexity of the scene could be analysed from different point of view, from purely semiotic arrangement of the scene to the structural composition of the image [7]. Analysis the Structural composition of the image studies the scene without concerning about the meaning that the scene might carry for the observer and just considers the visual properties of the image.

Having said this and look at the lighting of the scene as a composition of patterns, lead us to the question of how these patterns could influence our initial question of saliency. Several studies show that the background characteristics of the scene impacts the conspicuity of objects presented in the scene [8-17].
This study focuses on the two aspects of the background impact on saliency; density of background patterns of light and proximity of background patterns to the urban objects.

Density of Background Patterns and Saliency

Studies in psychophysics suggest that density of background noise could affect the target detection by luminance contrast [11, 17, 18]. Jenkins & Cole [18] in their study show that the density of background patterns up to a certain level decreases conspicuity of the target. However, above that level of background density conspicuity rate does not change significantly. In their study density of background was based on the number of identical discs which all had smaller size than the target disc.
Nothdurft [19] showed that for targets defined by luminance contrast, saliency would vary with texture density. In less density of texture the saliency of targets increases compare to the more dense texture. Also some subjects in his studies report that even when there is no feature contrast targets in sparse arrangement appear more salient.
From these studies it can be hypothesised that increasing the background density, more amount of light might be needed to have the same visibility of the target as in lower background density. Generalising this hypothesis to the aim of this study it could be assumed that increasing background density of patterns of light in urban lighting could decrease the conspicuity (saliency) of urban objects in the scene.

Proximity of Background Noise to the Object and Its Impact on Saliency

Studies in psychophysics show that closer the background noise to the target could reduce the visibility of the target [20, 21].

Baylis & Driver[21] found that, the interference from distractors was only found when they were close to the target; beyond about 1 ", they had little or no effect. This distance effect has been replicated many times, although there is some controversy over the existence of a critical separation beyond which interference from distractors is completely eliminated. Distractors close to this focus will be processed more fully than will distractors that are farther away, since only the close distractors fall within the "illuminated" or "magnified" region. Hence, near distractors produce more response competition than do far distractors. [20]
To generalise this to urban lighting it could be hypothesised that the closer the proximity of background patterns of light to urban object could reduce the saliency of the urban objects; therefore more luminance contrast could be required to have the same saliency.
In order to study the effect of background density and proximity of background patterns in saliency of illuminated urban objects following pilot studies have been carried out.

Effect of Background Density of Patterns of Light on Saliency

Differences of the target saliency due to the density of background and also proximity of the background noise to the target were separately tested in two experiments. In psychophysical studies in the same situation pair comparison is adopted as a general methodology [22]. By pair comparison we mean pairs of images will be compared with each other in order to compare the saliency of the target in different conditions. Two different methodologies were used to examine this fact; spatial two-interval-forced choice (or for short “side by side comparison”) and temporal two-interval-forced choice. The reason is to reduce the risk of experimental errors due to a certain adopted method.
There were eleven subjects (six male) mostly students of the school of architecture, University of Sheffield have participated. The age range is between 25 to 50 years old (just one subject is in 45-55 band). They all had self reported normal or corrected vision of 10/10.

Method 1) spatial two-interval-forced choice

The study used the side-by-side identical computer monitors with the following specifications; 15 inch Viglen VD 695, resolution 1280 x 1024 / 60 Hz, Dot Pitch / Pixel Pitch 0.24 mm.
Microsoft PowerPoint software was used to present the images,
The images were 10^o high and 13^o wide. The target was 3^o high and 1^o wide and appeared each time in the same place. Images all were the same scene only the luminance contrast of the target object to the background and also the combination and number of lighting patterns in the background change. The luminance contrasts were derived from the following equation:

$$C_L = (L_B - L_T)/L_B$$

Which C_L is luminance contrast and L_B and L_T are Background luminance Mean and Target luminance Mean. Mean luminance was calculated by Photoshop software.

Figure 1. A sample of the image used in the pilot study in Low Density of Background Lighting Patterns condition

Four levels of background patterns densities were assumed; No patterns of light, low density of lighting patterns, medium density of lighting patterns and high density of background patterns. A grid of 1^o x 1^o on the scene was employed and number of boxes containing light patterns was counted. Between each level of background density to the next there were 50% differences in the number of boxes counted; i.e. if in the low density background 100 boxes are containing the light patterns in medium level it would be 150 boxes. The luminance contrast of 0, 3, 5, 10 recommended by ILE (Table.1.) were adopted combined with different levels of background density. [2]
The image presented was an urban night scene which was modified by Photoshop software to be suitable for the test. There were 16 different images of the same scene in different lighting conditions in the way described above and all Images

were in black and white. In total 120 comparisons were done.

The test was carried out in a blacked out laboratory which the only source of light was from a 60W GCS desk lamp directed to illuminate well behind the person. Twenty minutes adaptation time is assumed to adjust the subjects' eyes to the low level of light in the room. Meantime subjects are asked to read the information sheet and also fill the consent form.

Contrast	Effect
1:1	Not noticeable
1:3	Just noticeable
1:5	Low drama
1:10	High drama

Table 1. Effect of different contrasts[2]

The test starts with practise trials after explaining the procedure of the test to the subjects. Practise sequences continue until the subject is confidence enough to carry out the real test.

Pairs of images were shown following black screen intervals. Each time subjects were asked to identify in which screen, left or right, the target appears more salient. Arbitrary choice had to be made if not sure. The presentation sequences were adopted in a way to have a balanced stimulus frequency, meaning the number of predicted answer for left and right were counterbalanced. Score 1 was assumed for the image which the more salient target was identified and 0 for the image with none-salient target in each pair. Different stimulus conditions in each experiment were randomized.

Method 2) temporal two-interval-forced choice

The apparatus in this test was almost the same as the previous method. However, in this method just one monitor was used and pairs of images were shown one after the others. The sequences were in the way that, two successive stimulus intervals were presented in each trial. Before each image interval there was a neuter[2] image for a period of one second. In each stimulus interval an image is presented for 3 second. The subjects had to indicate in which image the target was more salient, arbitrary choice had to be made if not sure. Different stimulus conditions in each experiment were randomized.

[2] Neuter image refers to a modified version of the image used in the experiment which light patterns and target object are removed from the image.

Effect of Proximity of Background Patterns of Light to Urban Objects on Saliency

In this experiment 4 different levels of proximity of light patterns from the object have been considered; 0, 1, 2, 3 degree visual angle.
For this reason all the patterns of light in those radiuses have been removed from the images. The same urban scene as the Experiment 1 is employed in this test. Also the same levels of luminance contrast;1, 3, 5 and10, is assumed in this experiment.16 different images are created and 120 comparisons are being done. The design and procedure, also the condition of the lab in this test is the same as the previous test.

Figure 2. A sample of the image used in the pilot study in 2 degree visual angle Proximity of Background patterns Noise

Results of the first Study:

The results obtained from the 11 people attending in the experiment are presented in Figure 1. The graph shows the trends in saliency under different conditions of background lighting patterns density.

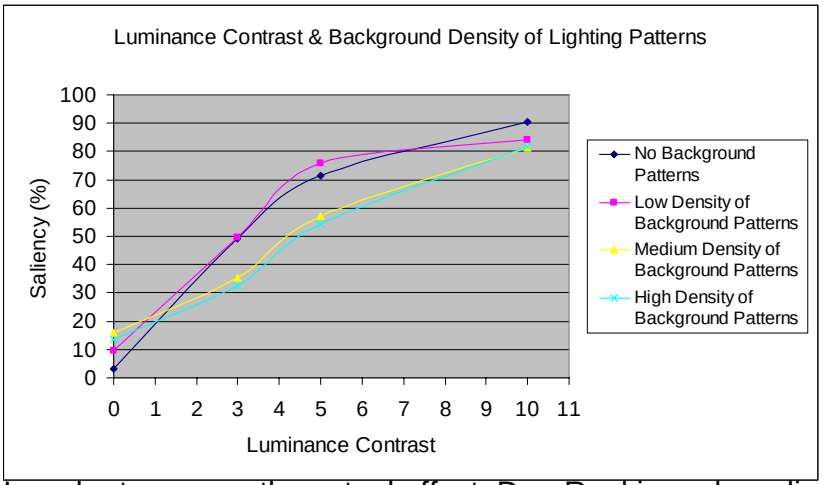


Figure 3. Change of saliency with background density and luminance contrast in spatial test.

In order to assess the actual effect, Dun-Rankin rank scaling method were used.[23]

The results show that there is a significant difference between saliency in low density of background and medium density of background but the difference is not significant between conditions of no background patterns and low background

patterns and also between medium level and high density of background. Also the increase of saliency score increases sharply between luminance contrast 0 to 5 but this increase does not continue in the same way to the C_L= 10. No significant differences were found between the two experimental methods. For example in C_L=5 saliency rates in different background density are as follow:

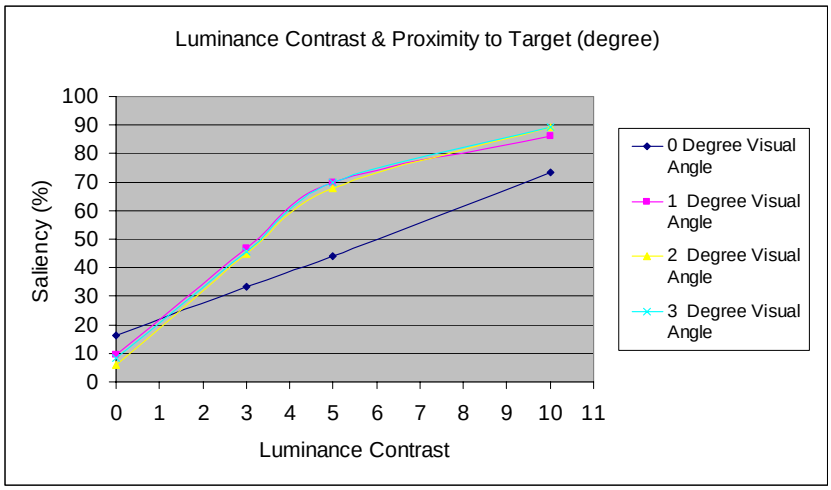
Density of Background	Spatial Design	Temporal Design
No	50	54
Low	54	57
Medium	70	71
High	78	75

Table 2. Comparison of Data in two different methods of experiment in the first test

Results of the second Study:

The Figure 3 below illustrates the main characteristics of the correlation between proximity of background patterns of light to the illuminated target and saliency of the target.

Figure 4. Change of saliency with luminance contrast at different level of Proximity.



It is apparent from this graph that the saliency of the target significantly increases when the background noise are as far as 1 degree or more. However there is no significant difference in saliency of the target when patterns of light are farther than 1 degree.

No significant differences were found between the two experimental methods. For example in C_L=5 saliency rates in different degree of proximity are as follow:

Proximity (Degree of Visual angle)	Saliency in Spatial Design Test	Saliency in Temporal Design test
0	44	41.8
1	70	62.4
2	68	69.1
3	70	71.5

Table 3. Comparison of two methods of experiment in the second test.

Conclusion:

The present studies were designed to determine the effect of background patterns of light in saliency of the illuminated target. It was hypothesized that density of background patterns and proximity of them to the target could affect the saliency of the target. Although it has been suggested that increasing the background density decreases the saliency, this study did not show the exact expected results. A possible explanation for this might be that the differences between different conditions of background density have not been occurred to the subjects. In other words there could be an error in the classification system of the images based on background density which needs to be revised. This issue is currently being tested. The results of the second pilot study indicate that proximity of the background noise to the target affects the saliency of the target; however this effect beyond about 1^o is not noticeable which this finding is in agreement with Erikson and Erikson's [20] and also Balysis's [21]. In the same time it seems possible that the effective range should be explored in distances less than 1 degree. Considering the size of the target (1 degree width) it seems possible to hypothesise that the effective distance range is between 0 to visual angle size of the target. A study carried out by Nakamura and Akashi (2003) about the effect of background on visibility of traffic signs supports this hypothesis. [24].

Further research should be done to investigate the more precise impact level of background density and proximity of background lighting patterns compare to luminance contrast in saliency of objects.

Reference:

1. Davoudian, N. and S. Fotios. *Alternatives to Brightness for Achieving Night-time Conspicuity*. in *Urban Nightscape*. 2006. Athens, Greece: Hellenic Illumination Committee.
2. ILE, *The Outdoor Lighting Guide*. The Institution of Lighting Engineers. 2005, New York: Taylor & Francis.
3. Chun, M.M., *Contextual Guidance Of Visual Attention*, in *Neurobiology of Attention*, L. Itti, G. Rees, and J.K. Tsotsos, Editors. 2005, Elsevier Academic Press: London. p. 246-250.
4. Henderson, J.M. and A. Hollingworth, *High-Level Scene Perception.* Annual Review of Psychology, 1999. **50**: p. 243-271.
5. Oliva, A. and A. Torralba, *Modeling the shape of the scene: A holistic representation of the spatial envelope.* International Journal of Computer Vision, 2001. **42**: p. 145-175.
6. Palmer, S.E., *The effect of contextual scenes on the identification of objects.* Memory and Cognition, 1975. **3**: p. 519-526.
7. Kress, G. and T.V. Leeuwen, *Reading Images: the Grammar of Visual Design*. 1996, London: Routledge.
8. Cole, B.L. and S.E. Jesws, *The Effect Of Variability Of Background Elements On The Conspicuity Of Objects.* Vision Research, 1984. **24**(3): p. 261-270.
9. Brusque, C., G. Paulmier, and V. Carta. *Study of the influence of background complexity on the detection of pedestrians in urban sites*. in *24th session of the CIE*. 1999. Warsaw.
10. Boynton, R.M. and W.R. Bush, *Recognition of form against a complex background.* Journal of the Optical Society of America, 1956. **46**: p. 758.

11. de Jong, J. and W. Duijnhower, *Conspicuity Area and Background Density Explorative Experiments*, in *Report no. 225*. 1972, Institution of Perceptional Research.
12. Rolland, J.P. and H.H. Barrett, *The Effect of Random Background Inhomogenity on Observer Detection Performance.* Journal of Optical Society of America A, 1992. **9**(5): p. 649-658.
13. Eckstein, M.P., A.J. Ahumada, and A.B. Watson, *Visual signal detection in structured backgrounds. II. Effects of contrast gain control, background variations, and white noise.* Journal of Optical Society of America A, 1997. **14**(9): p. 2406-2419.
14. Engel, F.L., *Visual Conspicuity and Selective Background Interference in Eccentric Vision.* Vision Research, 1974. **14**: p. 459-471.
15. Neider, M.B. and G.J. Zelinsky, *Searching for camouflaged targets: Effects of target-background similarity on visual search.* Vision Research, 2006. **46**: p. 2217–2235.
16. Aks, D.J. and J.T. Enns, *Visual Search for Size Is Influenced by a Background Texture Gradient.* Journal of Experimental Psychology: Human Perception & Performance, 1996. **22**(6): p. 1467-1481.
17. Monk, T.H. and B. Brown, *The effect of target surround density on visual search performance.* Human Factors, 1975. **17**: p. 356.
18. Jenkins, S.E. and B.L. Cole, *The Effect Of The Density Of Background Elements On The Conspicuity Of Objects.* Vision Research, 1982. **22**: p. 1241 to 1252.
19. Nothdurft, H.-C., *Salience from feature contrast: variations with texture density.* Vision Research, 2000. **40**: p. 3181–3200.
20. Eriksen, B.A. and C.W. Eriksen, *Effect of Noise Letters upon the Identification of a Target Letter in a Nonsearch Task.* Perception and Psychophysics, 1974. **16**(1): p. 143-149.
21. Baylis, G.C. and J. Driver, *Visual Parsing and Response Competition: The Effect of Grouping Factors.* Perception and Psychophysics, 1992. **51**: p. 145-162.

22. Nothdurft, H.-C., *The Conspicuousness of Orientation and Motion Contrast.* Spatial Vision, 1993. **7**(4): p. 341-363.
23. Dunn-Rankin, P., et al., *Scaling Methods*. 2nd ed. 2004, London: Lawrence Erlbaum Associates, Publishers.
24. Nakamura, Y. and Y. Akashi, *The effect of immediate background size on target detection.* Journal of the Illuminating Engineering Society 2003. **32**(2): p. 67-76.