Bridging Visual Complexity and Well-being

A computational approach to photographic analysis in assessing visual stress in architectural environments

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Migraine is a complex neurological condition, often triggered and intensified by visual stimuli in the built environment. Perceptual visual complexity analysis has been a subject of study for many years. However, the intersection between architectural design and migraine management remains underexplored. Visual stress is "context-specific," yet previous research highlights the significant role of some visuospatial factors. Examples include flickering light sources and striped patterns, which can create visual stress and trigger migraine and epilepsy. Through the confluence of architecture, health sciences, and technology, this research introduces a practical visual analysis tool designed to assess visual complexity in built environments and identify potential visual stimuli. The aim is to assist architects, designers, and non-expert users in creating environments that prioritize well-being and bridge the gap between visual stress and architectural practices. By developing evidence-based design research, the study sets the groundwork for future migraine research to help individuals with low tolerance to visual triggers.

Keywords: *Architectural Design*, *Human Perception*, *Visual Complexity*, *Visual Stress*, *Photographic Analysis*, *Migraine Research*.

INTRODUCTION

Visually triggered diseases and disorders, such as epilepsy, photophobia, light sensitivity, and migraine, form a significant social burden. The disability caused by visual discomfort can emerge anywhere and rely heavily on visual elements. The disability caused by visual discomfort affects various aspects of an individual's private and professional life. By moving from the neurological model of visual stress toward an inclusive environmental approach, the study adopts a theoretical perspective of critical disability. It aims to explore challenges in designing inclusive spaces and develop guidelines for extended visual comfort. It, therefore, introduces an encounter by intersecting architectural design and health research from a unique context that is uneasy in its design considerations and complex in its ways of assessment, challenging in establishing methodologies to resolve.

While perceptual visual complexity analysis has been a field of investigation for many years, the intersection between architectural design and migraine management remains underexplored. Migraine is a complex neurological condition often triggered and intensified by visual stimuli within the built environment. While visual stress and discomfort are "context-specific" (Boyce and Wilkins, 2017), previous research highlights the

significant role of some visuospatial factors—such as flickering light sources and striped patterns — in creating visual stress and inducing migraine and epilepsy.

By building on this ground, the current study intends to create a computational and interpretive model for the perceptual load and visual stress and its application in architecture for users with visually induced migraine and epilepsy. This approach aims to bridge the gap between visuospatial triggers and architectural design, fostering safer environments, particularly for individuals with photosensitivity, visually induced migraine, and epilepsy.

COMPLEXITY IN THE VISUAL FIELD

Visual stress and people with low tolerance

A comprehensive work, Arnold J. Wilkins' book Visual Stress (1995), explains the mathematics of different elements that create visual stress and disturbing images. According to the author, the experience of visual discomfort depends on the strong physiological arousal caused by specific visual stimuli and the effects of overstimulation of the brain's visual cortex (Wilkins, 1995). According to Boyce and Wilkins (2018), the visual system is trying to create a model of the environment illuminated by lighting and surrounding the individual; therefore, this unwanted state of overstimulation is determined by a combination of the illumination of the space and environmental design. For example, the authors argue that protecting the eyes from glare is sufficient to identify the source of visual discomfort and define a tool to limit the formation of visual discomfort.

The neural mechanism of the visual cortex processes some images efficiently and others inefficiently. Wilkins (2016, 2021b) states that natural images are processed efficiently and comfortably by the visual system, and the least disturbing images correspond to the characteristic features of the natural visual environment. Many aspects of spatial coding in the visual system are matched with the 1/f spatial structure of the visual environment. Because images with different structures do not fully match the visual mechanisms, so they produce unnaturally strong neural responses and trigger individuals susceptible to migraine or epilepsy (Juricevic et al., 2010). In other words, the mind processes uncertain visual stimuli that it cannot predict with less efficiency, thus causing a stronger neural response and discomfort.

Visual stress/discomfort is significantly associated with light sensitivity, photophobia, headache, and migraine stimuli (Hayne and Martin, 2019). Furthermore, most studies show a positive relationship between visual disturbance and neural activation of the visual cortex and, therefore, oxygenation, including studies on individuals with migraine and fear of light (Boyce and Wilkins, 2018). Cortical hyperexcitability is thought to occur in migraine, epilepsy, and other neurological disorders where seizures are relatively common, such as autism (Wilkins, 1995).

Complexity in the visual field creates a computational charge, leading to excessive neural activity and high metabolic demand for oxygenation, eventually causing visual discomfort. High contrasts, frequency in repetitive patterns, and distribution of light and shadow also provoke hyper neuronal activity (Wilkins, 1995).

VISUAL STRESS IN ARCHITECTURAL ENVIRONMENTS

Some environmental factors are decisive in designing built environments and measuring spatial comfort and livability. There are prominent studies that are concerned with the spatial comfort and livability criteria in its greater complexity (Preiser, 1983; Mahdavi, 1998), comfortable interior designs (Bluyssen et al., 2009), and for production of guidelines for accessible spaces (Preiser and Smith, 2010).

Wolfgang F. E. Preiser (1983) explores the relationship between human behavior and the built environment and evaluates them based on the topics of habitability, thermal comfort (air conditioning and ventilation), noise control-acoustics, lighting systems (access to natural light), and access to nature (planting). The author defines them as aesthetic and performative components.

Since individuals with migraine are more sensitive to certain qualities of light, sound, odor, or otherwise (Friedman and Dye, 2009), they have varying threshold tolerances and respond to the built environments differently. These qualities can effectively form migraine attacks and pain, singularly or cumulatively. Oliver Sacks (1995) defines migraine caused by such stimuli as "conditional migraine." Therefore, the same physical environment that is habitable and comfortable for healthy individuals may affect people with migraine differently. Sacks mentions the conditions where the perception of space is disturbed by the experience of these debilitating conditions.

Researchers working with the methods of environmental psychology and architecture have long studied user experience and the effects of environments on people. The literature includes an extensive set of experimental studies on migraine and visual stress conducted from a neurological and psychological perspective.

Reflecting on "the visual system is most sensitive" to discomfort (Wilkins, 2025), studies on visual factors primarily focus on light, glare, patterns, and color chromaticity. For example, some patterns are known to create visual stress (Wilkins, 1995, 2021b; Gilchrist et al., 2015) with their dazzling and vibrating effect (pattern glare) and stimulate migraine (Harle et al., 2006; Shepherd et al., 2013; Imaizumi et al., 2015), even some can lead to epileptic seizures (Wilkins, 1980). When we look at the effect of light as another stimulus, it is seen that some situations provoke migraine by creating fear of light and visual stress (Wilkins, 2016, 2021a; Harle et al., 2006). These experiments are limited to two dimensions. Spatial conditions such as depth, level differences, movement, and other dynamic factors in the production and experience of space still need to be included in the migraine literature.

According to a study conducted in the USA, nearly 90 percent of daily activity is spent indoors. Artificial light sources, technological tools, and digital screens bring high visual stress to these environments.

Through the confluence of architecture, health sciences, and technology (Figure 1), this research offers a practical visual analysis tool for designers and non-expert users. It promotes environments that prioritize well-being and bridges the gap between environmental stimuli and architectural practices. This study aims to develop evidence-based design guidelines that contribute to the development of built environments that prioritize visual comfort and health.

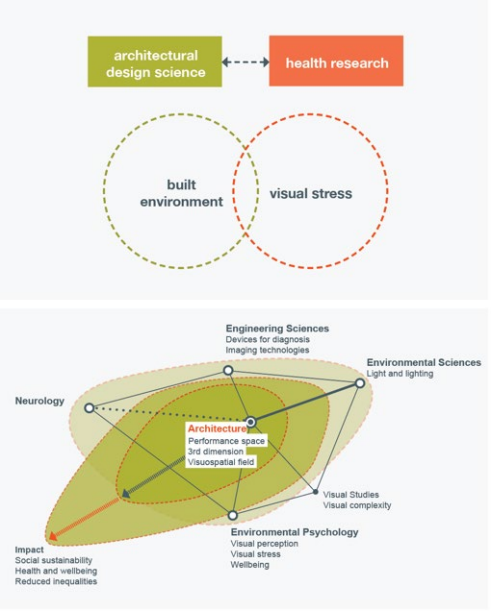

Figure 1
The formation of the proposed interdisciplinary research area, the confluence of architecture, health sciences, and technology.

METHODOLOGY

The study intends to create a computational and interpretive model for the perceptual load and visual stress and its application in architecture, especially for users with photosensitivity, visually induced migraine, and epilepsy. For this, architectural photographic documentation is proposed to assess the perceived visual complexity. Employing photographic images to anticipate visual discomfort is a meaningful method as it allows us to accurately measure spatial frequency distributions for any viewing direction and assess how significantly they deviate from the desired distribution (Boyce and Wilkins, 2018). The methodology integrates a multi-dimensional analysis. By calculating visual stimuli through 2D photographic data, we can understand how visual complexity contributes to perceptual load.

Procedure

An app, PhotoVisCompAnalysis (Figure 2), has been generated in *Replit* [online] (*Link is BLINDED*) to help evaluate the visual complexity of architectural environments by analyzing the photographs. The visual data is assessed through (1) Basic Heatmap Analysis, (2) (Canny) Edge Detection for contour lines, and (3) White Space Detection.

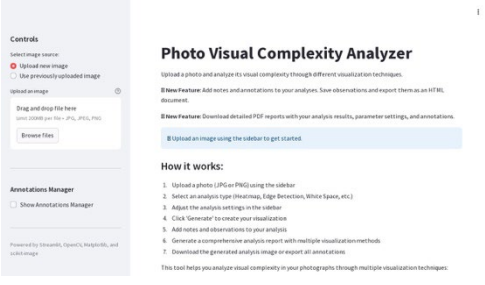

Figure 2
Screenshot of PhotoVisCompAnalysis Application

The Basic Heatmap Analysis visualizes intensity and brightness distribution. The intensity slider controls how strongly the rainbow color mapping is applied to the image. The intensity amplifies the contrast between different brightness levels in the image, making those differences more visually apparent through the rainbow color scheme. It does not change what is being analyzed (the brightness variations in the photograph) but rather how strongly those variations are visualized in the final heatmap.

Edge Detection visualizes boundary complexity and contours. The edge detection is based on Gestalt principles of grouping and proximity (Wertheimer, 1938).
The algorithm within the app is set to use two thresholds to identify edges. "Threshold 1" isolates edge pixels (noise), while "Threshold 2" determines definite edges.

The White Space Detection feature visualizes white space as pure white and makes it much easier to analyze the distribution of white space in the photographs without any visual distractions. With a grayscale scheme, a "composite" mode superimposes three different threshold values (primary, primary-20, and primary+10).

Case

The selected case to test the model is Galeri Nev Kırlangıç (See credits). It is a space for art located in Ankara, Turkiye. This space is an appropriate case since the major gallery area is a single space with an almost symmetrical formation and has controlled sunlight (Figure 3). It is an adaptive exhibition environment that transforms in each exhibition/event. A freestanding wall that can rotate around is "a spatial variable that can be placed at different rotations in different art exhibitions" (Motto Architecture). Since the space functions as an art gallery, natural light is occasionally allowed into the main space. The distribution of artificial lighting varies depending on the size and arrangement of artworks.

DATASET

At various setups of exhibitions, the space is documented with wide angle photography, and comparable photographs of the entry space (Figure 4), a main space (Figure 5) and a partial view (Figure 6) have been brought together as 3 sets of visual data for analysis. In each photograph, there is variation in surface colors, the formation of the space (wall rotation), lighting and the arrangement of exhibited elements.

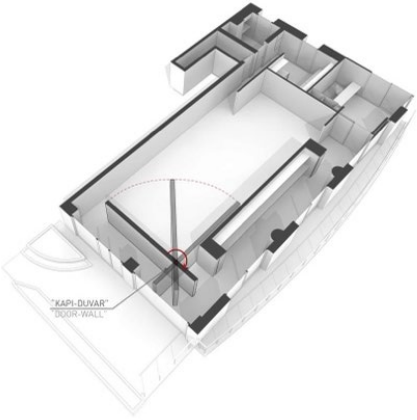

Figure 3
Diagram model of Galeri Nev Kırlangıç. Source: Motto Architecture

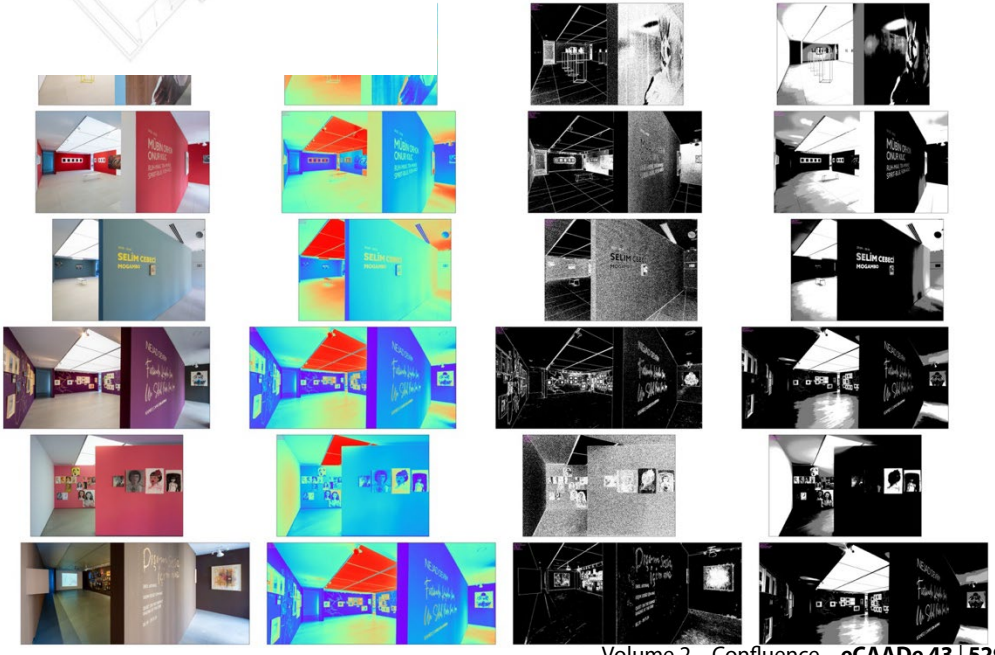

Figure 4
Viewing Direction 1: Entry space

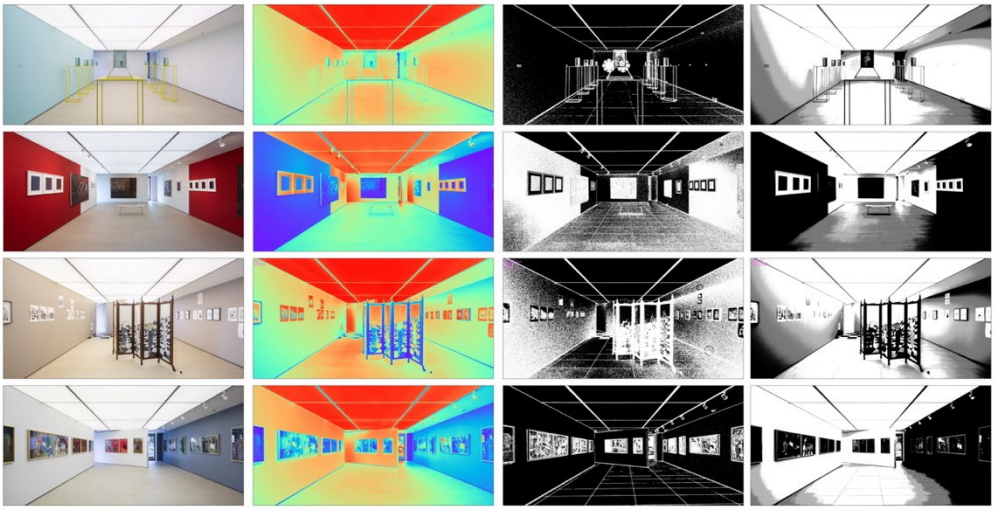

Figure 5
Viewing Direction 1: Main space

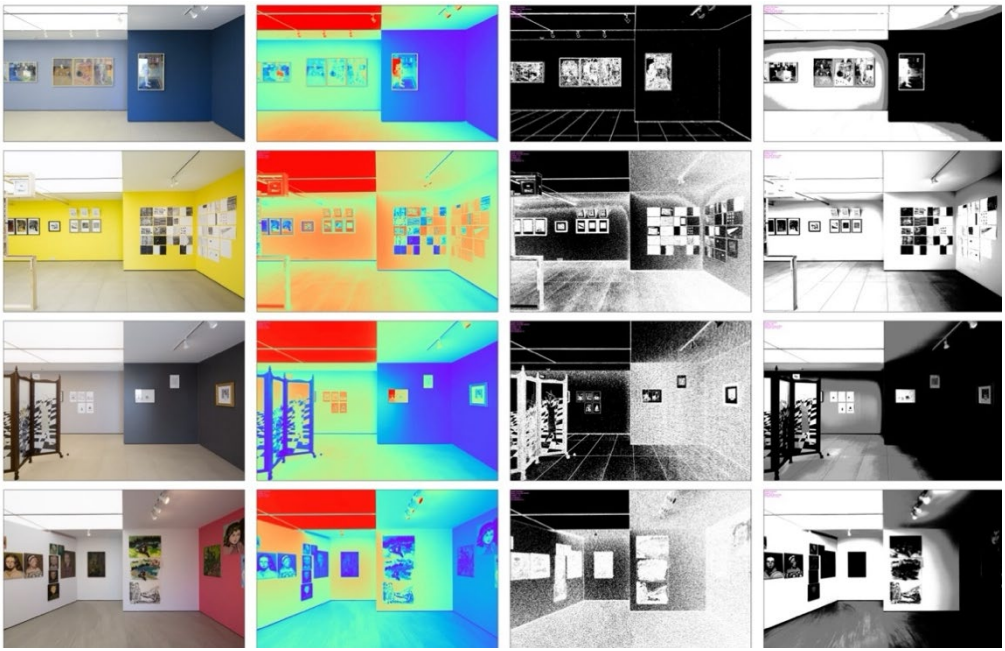

Figure 6
Viewing Direction 3: Partial view

DISCUSSION

Conventional visual analysis often relies heavily on subjective perception. Our approach provides objective, algorithm-based measurements across multiple dimensions. The computational model establishes a ground for interpretation. By combining different analysis types, it is possible to reduce the predetermination inherent in any single method and create a more vigorous evaluation of visual complexity for possible perceptual load and visual stress.

By providing actionable insights, the visual analysis's contrast and intensity allow one to identify abrupt changes in color, lighting, and material and isolate individual elements that contribute to complexity. It reveals underlying patterns that might not be immediately apparent to the viewer. For instance, some patterns known to create visual stress and trigger migraine are "unintentional and are the result of modular construction" (Wilkins, 1995). The app's Edge Detection feature makes the edges resulting from the modulation visible. It is possible to compare the set of photographs (Figure 4, 5, 6) with tiles on the ground and photographs in which tiles are replaced with a smooth material. It becomes much more comfortable for the visual field.

The social contribution of this study is to raise awareness about the problematic situation of individuals with low threshold tolerances to visual stress. Building standards and universal design studies are not yet comprehensive in this area.

Therefore, it is highly critical to make photographic assessment of Visual Complex Analysis accessible, even to those without technical expertise in image processing, which is why we created it in the first place. The application prioritizes visual communication by showing results as images that can be interpreted without understanding the algorithms. This visual approach means users do not need to be familiar with terms like " Canny edge detection algorithm" to benefit from the analysis. They can experiment and see results without understanding the underlying calculations. Instead of abstract metrics, the model provides visual representations that reveal patterns and relationships directly. It also brings relatable insights about visual complexity and how people experience spaces. By focusing on these accessibility features, the study democratizes powerful image analysis techniques, making them available to designers, photographers, artists, educators, and anyone interested in understanding visual complexity - regardless of their technical background.

CONCLUSION

This study aimed to visualize spatial factors to understand the built environments' effects on well-being and health, especially those creating visual stress and discomfort. The proposed visual analysis tool provides architects and designers with predictions at the design stage and actionable insights for non-expert users. The future work will include studying participants with migraine and their daily spaces to validate design criteria.

CREDITS

Galeri Nev Kırlangıç: https://galerinev.art/tr
Design: Namık Erkal, Onur Özkoç (Motto Architecture, https://www.mottomimarlik.com/)
Photography: Author

REFERENCES

Bluyssen, P. M., Bayon, R., and Hamilton K. (2009). *The Indoor Environment Handbook: How to Make Buildings Healthy and Comfortable.* London: Earthscan.

Boyce, P. R. and Wilkins, A. J. (2018). 'Visual discomfort indoors,' *Lighting Research & Technology*, 50(1), pp. 98–114. https://doi.org/10.1177/1477153517736467.

Donderi, D. C. (2006). 'Visual complexity: A review,' *Psychological Bulletin*, 132(1), pp. 73–

97. https://doi.org/10.1037/0033-2909.132.1.73.
Friedman, D. I. and Dye, T. (2009). 'Migraine and the Environment.' *Headache: The Journal of Head and Face Pain*. 49, 941-952. https://doi.org/10.1111/j.1526-4610.2009.01443.x
Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Psychology Press. Atylor & Francis.
Gilchrist, J. M. and Allen, P. M. (2015). 'Lexical decisions in adults with low and high susceptibility to pattern-related visual stress: a preliminary investigation,' *Frontiers in Psychology*, 6. https://doi.org/10.3389/fpsyg.2015.00449.
Harle, D. E., Shepherd, A. J., and Evans, B. J. W., (2006). 'Visual stimuli are common triggers of migraine and are associated with pattern glare,' *Headache the Journal of Head and Face Pain*, 46(9), pp. 1431–1440. https://doi.org/10.1111/j.1526-4610.2006.00585.x.
Imaizumi, S., Honma, M., Hibino, H., and Koyama, S. (2015). 'Illusory visual motion stimulus elicits postural sway in migraine patients.' *Frontiers in psychology.* 6, 542. https://doi.org/10.3389/fpsyg.2015.00542
Juricevic, I., Land, L., Wilkins, A., and Webster M. A. (2010). 'Visual discomfort and natural image statistics,' *Perception*, 39(7), pp. 884–899. https://doi.org/10.1068/p6656.
Machado, P., Romero, J., Nadal, M., Santos, A., Correia, J., Carballal, A. (2015) 'Computerized measures of visual complexity,' *Acta Psychologica*, Volume 160, pp. 43-57. https://doi.org/10.1016/j.actpsy.2015.06.005.
Mahdavi, A. (1998). "Steps to a General Theory of Habitability." *Human Ecology Review*. 5(1), 23–30.
Motto Architecture: Galeri Nev Kırlangıç. (n.d.) Available at: https://www.mottomimarlik.com/1732
Podoll, K. and Robinson, D. (2008). *Migraine Art: The Migraine Experience from within*. North Atlantic Books.
Preiser , W. F. E. and Smith, K. (2010) *Universal Design Handbook* (2nd edn). New York: McGraw-Hill.
Preiser, W. (1983). 'The habitability framework: a conceptual approach towards linking human behaviour and physical environment,' *Design Studies*, 4(2), pp. 84–91. https://doi.org/10.1016/0142-694x(83)90038-8.
Sacks, O. (1970/1995). *Migraine*. Picador.
Shepherd, A. J., Hine, T. J., and Beaumont, H. M. (2013). 'Color and Spatial Frequency Are Related to Visual Pattern Sensitivity in Migraine'. *Headache: The Journal of Head and Face Pain.* 53, 1087-1103. https://doi.org/10.1111/head.12062
Wertheimer, M. (1938). 'Laws of organization in perceptual forms,' in: W.D. Ellis (Ed.), *A source book of Gestalt psychology,* Kegan Paul, Trench, Trubner & Company, pp. 71–88.
Wilkins, A. (2025) 'Visual discomfort, neural inefficiency and the cortical haemodynamic response,' *Academia Biology. Academia.edu Journals*, 3(1). http://dx.doi.org/10.20935/AcadBiol7618
Wilkins, A. J. (1995). *Visual Stress.* Oxford University Press: Oxford, UK.
Wilkins, A. J. (2016). 'A physiological basis for visual discomfort: Application in lighting design,' *Lighting Research & Technology*, 48(1), pp. 44–54. https://doi.org/10.1177/1477153515612526.
Wilkins, A. J. (2021). 'Visual stress: origins and treatment.' *CNS*, 6, 74-86.
Wilkins, A. J., Binnie, C. D., and Darby, C. E. (1980). 'Visually-induced seizures,' *Progress in Neurobiology*. 1980;15(2), pp. 85-117.