

Light and Color in Low-Arousal Design: a Review Towards Inclusive Sensory Environments for Neurodiversity

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ABSTRACT

The increasing attention to neurodivergent people in the built environment is exposing the limits of architectural models still calibrated on neurotypical assumptions. In many everyday settings, visual conditions are optimised for a presumed “average” user, with little consideration for how light and color can generate overload, discomfort, or avoidance for those with atypical sensory processing. This article asks how lighting and chromatic design can more effectively respond to diverse sensory profiles, and what it means to treat perceptual differences as a question of equity rather than exception. Drawing on work in neuroscience, environmental psychology, autism studies, and inclusive design, it reviews evidence on how visual environments shape arousal, attention, and participation for neurodivergent users. The paper then discusses low-arousal strategies, circadian-informed lighting concepts, and guideline frameworks such as WELL, highlighting recurring patterns such as reduced visual complexity, controlled luminance and reflections, stable and flicker-free systems, and layered user control over light and color. On this basis, it introduces perceptual justice as a way of understanding lighting design in terms of fair access to sensory conditions and to decision-making power over them, developed through participatory and co-design processes with neurodivergent communities. Light and color are thus framed not only as technical parameters, but as central levers in the ethical project of creating environments that are genuinely inclusive of perceptual diversity.

KEYWORDS Neurodiversity, Inclusive design, Light, Color, Perceptual justice, Low-arousal environments

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1. Introduction

In recent years, debates on inclusion have shifted from a narrow focus on physical access to a broader attention to cognitive and sensory differences. Instead of assuming a single, standard way of perceiving and processing the world, the neurodiversity perspective foregrounds multiple perceptual profiles, including those associated with autism, ADHD and sensory processing differences (Robertson and Baron-Cohen, 2017). This shift is reshaping how the built environment is discussed, framing spaces not only as containers of activity but as active mediators of how stimuli are organised, filtered or intensified (Mostafa, 2015). At the same time, many buildings and interiors still rely on standards that implicitly assume neurotypical users as the norm (Manning, Williams and MacLennan, 2023), so that visual conditions optimised for an “average” user can become sources of discomfort, confusion, or emotional strain for people with atypical sensory processing (Zaikina *et al.*, 2025). Light and color should therefore not be regarded as neutral background conditions, but as core perceptual variables shaping how spaces are perceived and lived (Hidayetoglu, Yildirim and Akalin, 2012). Key factors such as illuminance, flicker, spectral distribution, correlated color temperature, and surface reflectance influence visual comfort, arousal, and perceived control over the environment (Küller *et al.*, 2006; Boyce, 2010; Rossi, 2019b), with effects that become particularly marked among individuals who are hyper- or hyposensitive to visual stimuli (Yoshimoto *et al.*, 2020; Nair *et al.*, 2022).

Research in environmental psychology and neuroscience shows that poorly managed visual conditions, particularly when excessive or unstable, can impair attention, increase stress, and limit participation in everyday activities (Westland, Pan and Lee, 2017; Rossi, 2021; Nair *et al.*, 2022; Finnigan, 2024). This review builds on these findings to explore how sensory-aware, low-arousal design can inform more inclusive approaches to lighting and color in architecture, and introduces perceptual justice as a framework for analysing how sensory conditions and control are shared among users within prevailing design standards (Mostafa, 2015; Abdelmoula, Bouayed Abdelmoula and Abdelmoula, 2024).

It reframes discussions on neurodiversity and the built environment by focusing on light and color as primary drivers of arousal, perceptual organisation and everyday participation (Black *et al.*, 2022). This builds on reviews linking color and light to psychological functions and emotional responses, while extending their insights to neurodivergent sensory profiles and low-arousal design (Westland, Pan and Lee, 2017; Bortolotti *et al.*, 2022; Jonauskaitė and Mohr, 2025; Zaikina *et al.*, 2025).

Building on this, the article advances perceptual justice as a central interpretive and ethical lens to analyse how lighting and color conditions allocate sensory risks and opportunities for control, and it interrogates existing standards and guidelines by foregrounding their neurotypical assumptions instead of treating them as neutral technical references (Manning, Williams and MacLennan, 2023; Chidiac, Reda and Marjaba, 2024). In this way, the review connects empirical evidence, design practice and regulatory discourse, showing how light and color can be mobilised to promote more equitable sensory conditions for neurodivergent users (Higuera-Trujillo, Llinares and Macagno, 2021; Narenthiran, Torero and Woodrow, 2022).

This article is a narrative review that brings together evidence and concepts from neuroscience, environmental psychology, autism and neurodiversity studies, and lighting and color research and design. The literature was identified through database searches and citation chaining, prioritising peer-reviewed empirical studies, scoping or systematic reviews, post-occupancy evaluations, and standards or guideline documents explicitly addressing lighting, color and sensory accessibility. The focus is on visual environments in everyday educational, workplace, healthcare and public settings relevant to neurodivergent users. As a narrative review, it does not aim at exhaustive coverage and is limited by the predominance of studies conducted in Western contexts and by the uneven level of actionable detail available for design applications.

2. Neurodivergent Sensory Processing and Visual Environment

Neurodivergent individuals—such as those with autism, ADHD, or sensory processing differences—often perceive their surroundings in ways that differ from typical expectations. Rather than treating these differences as impairments, the neurodiversity perspective emphasises varied thresholds and responses to sensory input, including hypersensitivity or reduced responsivity to visual stimuli and difficulties in filtering irrelevant information. These patterns shape how environments are perceived, interpreted and navigated (Ben-Sasson *et al.*, 2008; Schauder and Bennetto, 2016; Robertson and Baron-Cohen, 2017). Clinical and design research indicates that visual environments can become significant sources of stress for people with atypical sensory processing (Kwon *et al.*, 2023; Tancredi and Abrahamson, 2024).

When visual input is overly complex—for example due to high contrast, crowded stimuli or abrupt changes in lighting—arousal levels may rise, interfering with

concentration and prompting avoidance strategies. In settings such as schools and offices, these conditions can turn formally accessible spaces into places that require substantial cognitive and emotional effort to use over time (Tola *et al.*, 2021; Liu, 2024).

Common design practices often rely on strong visual cues, repetitive patterns and dynamic surfaces, which can increase perceptual load, especially when users cannot anticipate or modulate sensory input (Mostafa, 2015; Nair *et al.*, 2022). For many neurodivergent individuals, having a visual field that remains relatively stable and can be adjusted when needed is crucial for feeling safe, managing emotional responses, and staying actively engaged in the space (Riordan *et al.*, 2024).

These insights suggest that sensory accessibility cannot be reduced to removing physical barriers alone, but requires careful calibration of intensity, organisation, and dynamics to align spatial conditions with diverse perceptual profiles (Leshkov *et al.*, 2024). This provides a basis for low-arousal approaches that explicitly address the relationship between neurodivergent sensory processing and spatial experience (Lukava, Morgado Ramirez and Barbareschi, 2022; Weber *et al.*, 2024).

3. Light and Color as Perceptual Variables in Sensory-Inclusive Design

Light and color jointly structure spatial experience, influencing perceptual organisation and affective responses. Luminous and chromatic configurations actively mediate sensory integration, with direct implications for arousal, comfort, and engagement (Hidayetoglu, Yildirim and Akalin, 2012). For neurodivergent users, whose sensory thresholds and modulation patterns may differ from neurotypical norms, these variables can significantly amplify or attenuate perceptual load (Mostafa, 2014; Black *et al.*, 2022).

3.1. Luminous parameters and visual discomfort

Research on lighting and environmental psychology identifies several luminous conditions that contribute to visual discomfort and sensory overload, including high luminance levels, strong discontinuities between task and background areas, glare (direct and reflected), and temporal instability of light.

Studies on temporal light modulation indicate that flicker, even when not consciously perceived, can induce visual fatigue, headaches, and a general sense of discomfort in visually sensitive individuals (Wilkins, Veitch and Lehman, 2010; Yoshimoto *et al.*, 2020; Miller *et al.*, 2023). In educational and therapeutic environments, unstable or

poorly diffused lighting has been associated with reduced engagement and increased avoidance behaviours among neurodivergent users, underscoring the role of luminous parameters in shaping perceptual comfort and arousal (Pence, Wagoner and St Peter, 2019; Nair *et al.*, 2022).

3.2. Color, materials, and visual complexity

Chromatic choices and material properties interact with light to determine overall visual complexity and stimulus salience. Experimental studies show that highly saturated colors, strong value contrasts and intricate patterns tend to increase arousal and perceptual load, whereas moderated contrasts and lower chromatic saturation are more often associated with calm, legibility and comfort (Gifford, 1988; Kaya and Epps, 2004; Hidayetoglu, Yildirim and Akalin, 2012).

These patterns are consistent with broader reviews that document robust links between color, emotional responses and psychological functioning across a range of environments (Westland, Pan and Lee, 2017; Bortolotti *et al.*, 2022; Jonauskaite and Mohr, 2025).

Beyond chromatic attributes, visual complexity is shaped by how information is distributed in space.

From a visual neuroscience perspective, spatial organisation and frequency content are equally critical, as shown in work on receptive fields and spatial frequency coding in the primary visual cortex (Grzywacz, Watamaniuk and Mckee, 1995; Seriès, Lorenceau and Frégnac, 2003). Because the visual system is highly sensitive to edges and gradients, perceptual load depends not only on which colors are present, but on how contrasts and transitions are distributed across the field of view. Both overly simplified scenes, with low spatial frequency content, and highly cluttered, high-contrast patterns can increase visual strain, especially for individuals with atypical sensory processing (Wilkins, 2016; Yoshimoto *et al.*, 2020; Price, Sumner and Powell, 2025).

For low-arousal design, the objective is therefore not simply to minimise stimulation, but to calibrate the structure of visual information so that patterns, contrasts and chromatic transitions remain readable and sustainable over time.

In line with the literature on sensory-friendly design, Figure 1 illustrates a low-saturation Color palette contrasted with highly saturated Colors that tend to increase visual load.

In neurodivergent-inclusive contexts, visual complexity is not solely a function of color itself, but of how chromatic elements are organised within the spatial field and combined with textures, patterns, and surface reflectance.

Excessive visual density may compromise predictability and increase cognitive demand, particularly for users with difficulties in filtering or prioritising visual information

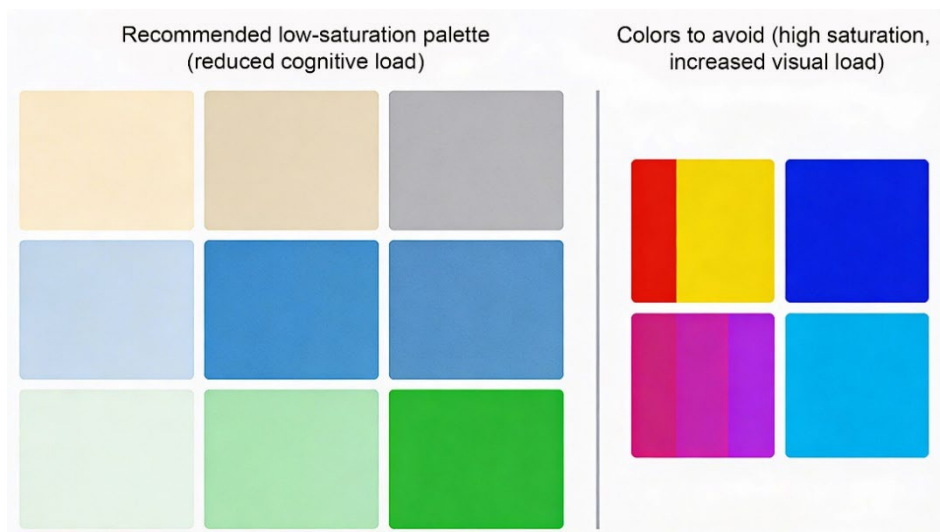


Fig. 1. Low-arousal Color palette. Left: recommended low-saturation background Colors; right: highly saturated Colors that increase visual load and should be limited on large surfaces

In practical terms, this suggests avoiding both featureless, uniformly lit expanses and highly intricate, high-contrast motifs that saturate the visual field with edge information. Medium-scale patterns, graded surface transitions and moderated value and chroma contrasts can support perceptual legibility while limiting unnecessary arousal in visually sensitive users.

3.3. Light dynamics and user control

Changes in light levels and spectral content influence how a space feels, alertness, comfort, and overall atmosphere—particularly when changes occur suddenly or without clear rhythm. Studies show that perceived control over lighting can reduce discomfort and support sensory regulation (Houser and Esposito, 2021).

What emerges as especially important in this context are smooth transitions and the availability of adjustments that help ensure temporal consistency and predictability, both of which are essential in creating environments that support diverse sensory needs (Karyono *et al.*, 2020). Within this logic, light and color become adjustable variables that can be used to prevent peaks of sensory overload and support self-regulation strategies.

Taken together, luminous intensity, temporal stability, chromatic organisation and control options constitute core perceptual variables shaping sensory experience. Understanding how these variables interact provides the basis for design approaches that reduce sensory stress while supporting participation, framing low-arousal environments not as uniformly dim or neutral, but as configurations in which visual conditions are carefully calibrated to minimise overload and enhance perceptual legibility.

4. Design Guidelines and Low-Arousal Strategies for Neurodivergent-Inclusive Spaces

Low-arousal design originates in autism-related contexts, where sensory overload and difficulties in filtering stimuli are well documented.

More recent studies show that similar environmental stressors—such as excessive visual complexity, glare, flicker and unpredictable changes—also affect individuals with ADHD and sensory processing disorders, although reactions vary across profiles (Price, Sumner and Powell, 2025). Autism-specific frameworks like the Autism ASPECTSS™ Design Index (Mostafa, 2013) have been central in translating sensory concerns into explicit spatial criteria, focusing on domains such as acoustics, spatial flow, escape spaces and sensory zoning, all aimed at making environments more predictable and manageable (Mostafa, 2018). Post-occupancy evaluations of classrooms applying ASPECTSS™ principles report higher engagement and fewer avoidance behaviours when indirect, glare-free lighting and low-saturation color schemes are used consistently across learning and transition spaces (Black *et al.*, 2022).

Beyond autism-specific settings, sensory-friendly design literature highlights the value of reducing visual distractions, with recurring strategies such as controlling glare and flicker, softening contrast levels and limiting intense saturated colors (Felix, 2022; Watchorn *et al.*, 2025).

Experimental work in therapeutic rooms for neurodivergent children suggests that diffuse lighting, neutral to warm color temperatures, and simplified visual

palettes tend to lower physiological arousal and support longer voluntary engagement (Tola *et al.*, 2021). At the same time, evidence indicates that there is no single “ideal” sensory environment for all neurodivergent users; low-arousal design should therefore be understood as a flexible set of strategies aimed at reducing sensory stressors while supporting individual balance across different sensory profiles (Narenthiran, Torero and Woodrow, 2022).

Mainstream certification systems such as WELL v2 (IWBI, 2025) establish baseline requirements for illuminance, glare control, spectral quality and lighting controls to support visual comfort and circadian health (Figueiro *et al.*, 2019; Rossi, 2019a), yet they mostly reflect average responses and only partially address heightened sensitivities common in neurodivergent groups (Finnigan, 2024).

Studies of flexible offices and public interiors with user-adjustable lighting show that perceived control over illuminance and color temperature is associated with improved comfort and reduced reported sensory stress among neurodivergent adults, pointing to the value of layered systems rather than fixed “optimal” settings (Karyono *et al.*, 2020).

Across the reviewed literature, a set of recurrent operational principles emerges for translating low-arousal concepts into lighting and color strategies for neurodivergent-inclusive environments.

These principles do not prescribe fixed solutions, but identify conditions that consistently reduce sensory stress while supporting perceptual regulation and participation.

The main operational principles include:

1. Reducing visual load through organised layouts and calm background fields, limiting unnecessary visual stimuli and improving perceptual legibility (Harwell, 2025),
2. Controlling luminance and reflections by favouring indirect lighting strategies and matte surface finishes, to minimise glare and high-contrast visual discontinuities (Altenmüller-Lewis, 2017; Ghazali, Md Sakip and Samsuddin, 2019),
3. Moderating spectral composition and chromatic saturation, reserving high contrast and vivid colors primarily for functional cues and wayfinding (Zaikina *et al.*, 2025),
4. Ensuring temporal stability and flicker-free systems, as even imperceptible temporal modulation can contribute to visual fatigue and discomfort among visually sensitive users (Parmar *et al.*, 2021; Nair *et al.*, 2022).
5. Creating zones with differentiated sensory intensity, allowing users to move between areas with varying levels of visual stimulation and supporting individual self-regulation strategies (Abdelmoula, Bouayed Abdelmoula and Abdelmoula, 2024).

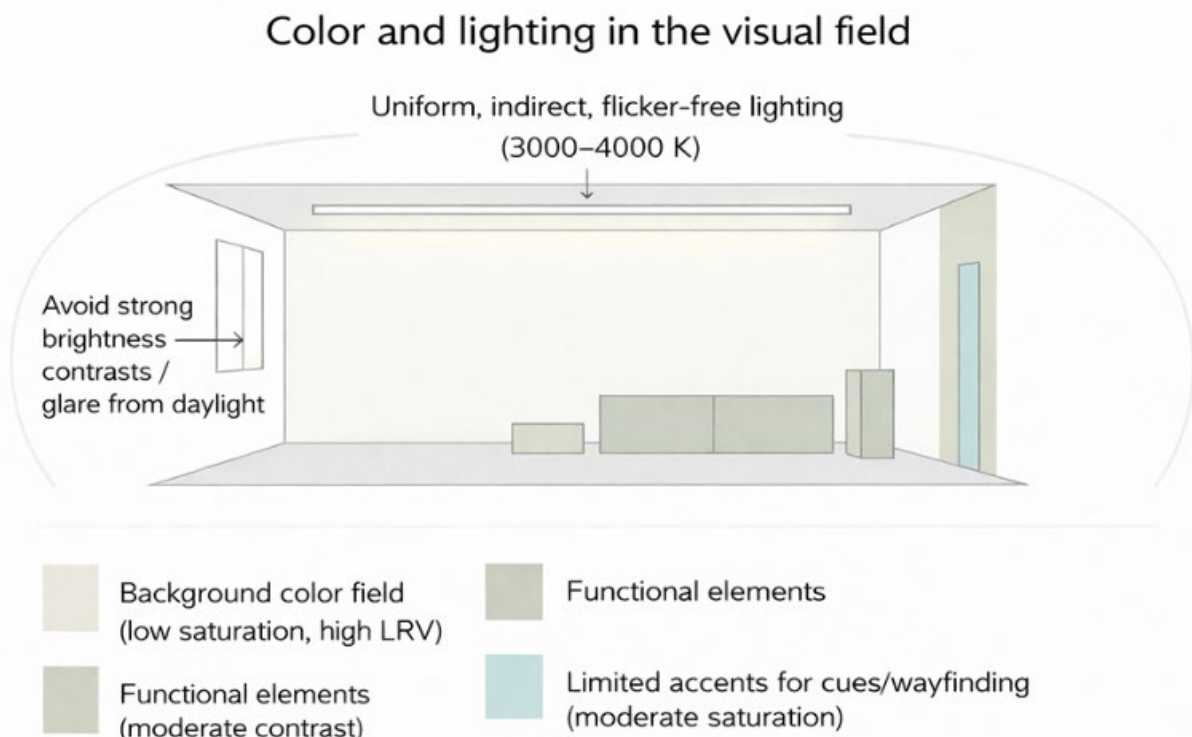


Fig. 2. Color and lighting in the visual field. Low-saturation backgrounds, limited accents, and uniform, indirect, flicker-free lighting support low-arousal conditions.

The effectiveness of these strategies depends on their integration within participatory design processes. Co-design (Binder, Brandt and Gregory, 2008; Sanders and Stappers, 2008) with neurodivergent users is essential to ensure that adjustable lighting and color systems are truly responsive to diverse sensory profiles (Black *et al.*, 2022; MacLennan *et al.*, 2023; Wohofsky *et al.*, 2023), preparing the ground for a broader discussion of perceptual justice in lighting and color design.

5. Towards Perceptual Justice: Framework and Design Implications

Perceptual justice offers a framework for examining lighting and color not only in terms of comfort or aesthetics, but in relation to how sensory conditions and degrees of control are differentially distributed among users. Environments designed around “average” standards may systematically privilege some sensory profiles over others, so that discomfort, disorientation or overload become forms of exclusion as concrete as physical barriers (Tola *et al.*, 2021). In this sense, lighting and color conditions operate as channels of both inclusion and exclusion in everyday spaces. From a regulatory perspective, a perceptual justice approach calls for moving beyond comfort standards based on an “average” user and explicitly recognising diverse sensory thresholds and the need for adjustable visual conditions. Building codes, guidelines and certification schemes should therefore include criteria that address not only illuminance, glare and spectral quality but also temporal stability, spatial complexity, predictability and the extent of user control over lighting and color settings. Framed in this way, light and color become tools for upholding sensory rights in the built environment, embedding perceptual equity within compliance processes rather than treating it as an optional goal (Houser and Esposito, 2021).

Research on neurodivergent experiences of the built environment consistently reports that lighting issues, excessive visual complexity and a lack of predictability can trigger distress at work, in education and in public settings, calling into question design and regulatory standards that prioritise typical visual responses (Narenthiran, Torero and Woodrow, 2022; Rattray *et al.*, 2026).

Neurodivergence, however, encompasses a wide range of sensitivities: what feels appropriate for one person may be overwhelming for another, which challenges any single notion of “normal” sensory conditions (Taylor, 2019).

A perceptual justice perspective therefore shifts attention from fixed norms towards environments that can adapt and respond to diverse needs, treating flexibility, gradation and control as core design requirements rather than optional

refinements (Finnigan, 2024). In practical terms, applying perceptual justice to lighting and color involves three main directions.

- **First**, recognising and minimising sensory risk factors—such as glare, flicker, harsh contrast and crowded visual fields—even when they fall within standard comfort metrics (Wilkins, Veitch and Lehman, 2010; Zaikina *et al.*, 2025).
- **Second**, implementing layered lighting and color systems that allow variations in brightness, distribution and spectrum across zones and activities, rather than relying on uniform “one-size-fits-all” settings (Mostafa, 2018; Chrysikou *et al.*, 2025).
- **Third**, integrating areas with consistently low-arousal conditions into layouts, offering spaces for retreat, regulation and quiet focus within otherwise more stimulating environments (Abdelmoula, Bouayed Abdelmoula and Abdelmoula, 2024).

Equally important is how these choices are made. Participatory and co-design methods ensure that decisions reflect lived experiences rather than assumptions.

Perceptual justice, in this sense, reframes inclusion not as mere access but as agency, placing users in active roles in shaping how their sensory environment works (Beck *et al.*, 2026).

Perceptual justice: design directions

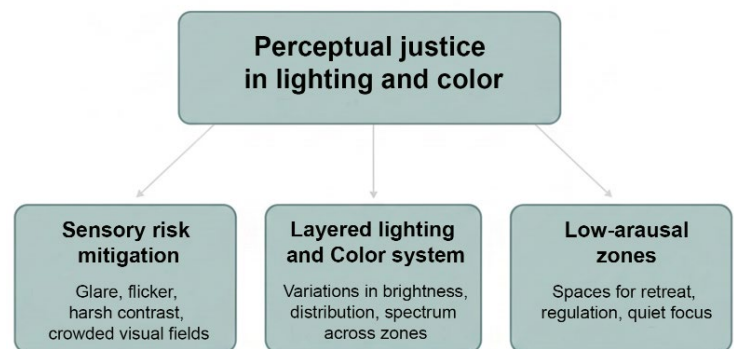


Fig.3. Perceptual justice in lighting and Color: three main design directions (sensory risk mitigation, layered systems, low-arousal zones)

By treating light and color as instruments of perceptual justice, they cease to be purely technical parameters and become part of the ethical evaluation of design choices, supporting a broader rethinking of standards and practices towards environments that are genuinely inclusive of perceptual diversity (Higuera-Trujillo, Llinares and Macagno, 2021; Chidiac, Reda and Marjaba, 2024).

6. Conclusions

This paper explored how light and color shape not just the appearance of space, but the way it is felt and lived, especially for people with different sensory needs. They actively influence perception, behavior, and inclusion. It has drawn on interdisciplinary research to show that visual conditions can either support or undermine people's ability to focus, feel safe, or participate in everyday environments. When not well managed, they risk creating invisible barriers that exclude neurodivergent individuals. A key contribution of this work is to frame perceptual justice as a lens that makes explicit who can feel at ease, regulate arousal and exercise meaningful control over lighting and color, shifting inclusive design from compliance with average comfort standards toward a more equitable distribution of sensory conditions and control.

From a practical standpoint, the findings underscore the importance of lighting and color systems that reduce unnecessary sensory stress while still offering clarity and usability, positioning flexibility and user agency as core values of sensory-inclusive design. More broadly, it calls for a shift in how inclusion is defined— not just as access to space, but as access to perception itself, making light and color central to evaluating how built environments accommodate perceptual diversity.

7. Conflict of interest declaration

The author of this piece of research declares no known conflict of interest with other people and/or organisations.

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9. Short biography of the author

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