sustainability

MDPI

Article

Planning Artificial Light at Night for Pedestrian Visual Diversity in Public Spaces

Antonella Radicchi [1,*] and Dietrich Henckel [2]

[1] Department for the Built Environment, Birmingham City University, Birmingham B4 7XG, UK
[2] Institute of Urban and Regional Planning, Technical University of Berlin, 10623 Berlin, Germany; dietrich.henckel@tu-berlin.de
* Correspondence: antonella.radicchi@bcu.ac.uk

Abstract: This article makes the case for addressing pedestrian visual diversity when planning artificial light for public spaces at night, by drawing upon original findings from an exploratory study where twenty-one open-ended interviews were conducted with experts in the fields of artificial lighting, urban planning and health studies. Specifically, this article provides (1) the introduction of the concept of pedestrian visual diversity, defined as the condition, capabilities and needs of visually impaired pedestrians, (2) a systematization of overlooked issues in the planning of artificial light for visual diverse pedestrians in public spaces and (3) the proposition of a participatory framework for the application of lightwalks as an experiential method for involving visual diverse pedestrians in the data collection on and analysis of artificial lighting in public spaces at night. In conclusion, it identifies five strands for further research at the nexus of pedestrian visual diversity, public space and night studies for inclusive light planning.

Keywords: public spaces; artificial light; night; urban planning; universal design; visual diversity; vision; inclusivity; light walks

Citation: Radicchi, A.; Henckel, D. Planning Artificial Light at Night for Pedestrian Visual Diversity in Public Spaces. *Sustainability* **2023**, *15*, 1488. https://doi.org/10.3390/su15021488

Academic Editors: Ramchandra Pode, Simona Tondelli, Elisa Conticelli, Valerio Carelli, Meike Bartels, Deborah Mascalzoni, Don Slater and Aitziber Ortega

Received: 28 August 2022
Revised: 23 December 2022
Accepted: 3 January 2023
Published: 12 January 2023

1. Introduction

For decades, the planning of artificial light at night has mainly been approached as a technical issue that focuses on providing sufficient light levels for vehicular traffic and pedestrians in cities. Recently, the matter of lighting for public spaces has become more and more complex due to the increasing use of new lighting technology (LED) that makes lighting more efficient, less costly and more widespread [1]. Parallel to this, the number of diverse actors and stakeholders providing light is growing [2,3]—which is one explanation as to why public light (providing street lighting by one public "switch") is shrinking in its proportional importance for a city's overall lighting output [4]. During the past few decades, many municipalities have developed integrative lighting strategies and plans which consider artificial light to be:

- an economic issue—considering the cost of providing artificial light and the possibilities of much higher efficiency at a lower cost due to new technologies.
- a prerequisite for extending activity and activities into the night—supporting visibility and therefore a sense of safety, security and well-being at night-time.
- an environmental stressor—acknowledging the negative effects of artificial light on human health and the environment due to ever-increasing lighting levels enhanced by the spread of LED-based technology.
- a placemaking resource—shaping a place identity, creating atmosphere and providing information and orientation in a public space.

However, making the night open and accessible for everyone is an issue that has been insufficiently explored, with one valuable exception represented by Colaboratória [5],

which took account of the general accessibility of the night, but overlooked the integration of visually impaired people.

The increasing complexity and interdisciplinarity in the planning of artificial light in public spaces (the spatial framework of this study) have led to conflicts and tensions across the sustainability dimensions: environmental, social and economic. It is imperative to reduce light pollution and conserve dark areas to protect biodiversity and human health against the detrimental effects of excessive light. However, it is also necessary to provide light in public spaces at night to ensure visibility, readability, orientation and a sense of security—for pedestrians from all walks of life, and/or those with certain restricted abilities. Furthermore, bearing in mind the current energy crisis, it is urgent that energy-reduction measures are implemented. In this regard, the use of the new LED technology is promising in terms of allowing for a relevant reduction in energy consumption, but it will probably cause rebound effects, because the higher efficiency makes lighting less costly. This in turn increases demand, which results in an even higher energy consumption [1].

Against this backdrop of different lighting issues, the failure to sufficiently take into account visual impairments in the integrative light-planning discourse is remarkable (see Section 1.1.), and it reflects the limited knowledge about the lighting conditions required by pedestrians in public spaces at night [6,7]. There are also insufficient data about the numbers of visually impaired persons, and in many countries, there are no updated statistics available at all (e.g., Germany, [8]). However, a study conducted by the World Health Organization between 1990 and 2002 showed that the number of visually impaired people has increased by 80% in Denmark, Finland, Great Britain, Iceland, Ireland, Italy and Netherlands—mainly due to the aging of the population and the increase in life expectancy [9]. These figures suggest the urgency of applying a more inclusive approach to artificial light planning that takes into account the needs of visually impaired people, too.

Similarly, at the Responsible Outdoor Lighting at Night conference, Salva Bará suggested that light should be used in a sensible way that takes into account light pollution and gives more consideration to *inclusivity* in society [10]. This recommendation can be used as an overarching request for inclusive light planning that addresses the increasing number of different visual (dis)abilities of people in advanced societies due to a growing proportion of elderly people with age-dependent visual degradation and of persons with different kinds of visual impairments. It should be noted that elderly people suffer a high proportion of eye maladies, such as macular degeneration, cataracts and glaucoma, in addition to a greater sensitivity to glare, reduced visual acuity, reduced contrast sensitivity and reduced colour discrimination, due to the adverse effects of aging. Thus, inclusive light planning "is set to become pivotal in urban outdoor spaces design" [11] (p. 951), and, considering that "[s]treet lighting is one environmental factor that can either encourage or discourage the use of outdoor spaces after dark", public outdoor lighting "could encourage more active lifestyles later in our lives" if properly planned and supported by evidence-based design [12] (p. 45).

The implementation of an inclusive light-planning approach requires a methodological and design shift to counterbalance the limitations embedded in the approaches taken by "most of the technicians who now control our luminous environments [and] have reduced the criteria for illumination to simple numbers, which are basically unrelated to vision, perception, comfort, or pleasure" [13]. Furthermore, these numbers, when turned into standards, can be critical and "need to be reviewed" as "they do not appear to be founded in robust empirical evidence" [14]. Moreover, it should be noted that these numbers may originate from studies biased by design, having been conducted with healthy young male participants and thus not accounting for gender- and age-dependency in light perception [15,16]. Therefore, an increased consideration of pedestrian visual diversity in planning artificial light at night in public spaces is an urgent research desideratum, especially for planners and designers who aim to foster health and social inclusion in urban planning.

1.1. Planning Artificial Light at Night for Visually Impaired Pedestrians in Public Spaces—Notes from the Literature

An exploratory research approach was applied to search for studies and projects about planning artificial light at night in public spaces with a focus on visually impaired pedestrians. The literature screening was conducted across several databases (e.g., PubMed, Google Scholar, Researchgate) and scientific fields such as urban and mobility planning, light planning and design, sociology, health, disability studies and universal design. The results are summarised below.

In the field of health and disabilities studies, the majority of studies analyse

- the implications of visual impairment in relation to indoor artificial light and reading lighting [17,18] and
- indoor emergency lighting and wayfinding systems for visually impaired people studying the walking speed of the visually impaired [19].
- In the field of urban planning and mobility studies, the majority of the research studies address:
- the design of artificial light for traffic signs and signposts, the illumination of potential barriers (e.g., steps) or potential points of danger, the legibility of lettering [11,20,21];
- street lighting at night for driving performance and from the drivers' perspective [22–24];
- artificial lighting for elderly people [12,25];
- visual tasks and artificial light for sighted pedestrians. Davoudian and Raynham [26], for example, performed a study to investigate what pedestrians look at when it is dark, finding that only between 40% and 50% of their time is spent looking at the footpath, thus raising questions about how appropriate it is to specify the lighting on residential roads using illuminance on the road and pavement. Furthermore, Johansson, Rosén and Küller [27] studied the mobility of young women, the elderly and the disabled at night to investigate how individual factors, i.e., visual accessibility and danger, influence the assessment of the outdoor lighting of an urban footpath, concluding that the influence of individual characteristics should be considered in the design of exterior lighting for urban footpaths.

Among the guidelines used in the field of universal design, a few recommendations for exterior lighting for the visually impaired in pedestrian spaces were found in [20], with a focus on measures for light provision without glare, for wayfinding and for providing a gradual reduction in illuminance from inside to outside at night.

Overall, the results showed that there is a scarcity of studies and projects that address the needs for artificial lighting among visually impaired pedestrians at night in public spaces, thus revealing "a burning gap in knowledge which requires urgent addressing" [28].

1.2. From Visually Impaired to Visual Diverse Pedestrians as Subjects of Planning Artificial Light at Night in Public Spaces

We introduce the notion of *pedestrian visual diversity* here to request that the diversity of pedestrians' vision abilities and impairments be acknowledged in planning artificial light at night for public spaces. The creation of this term is inspired by and refers to scholarship across the fields of diversity, soundscape and sound studies, particularly the term "aural diversity" [29,30]. This proposition is based on a change of perspective following "a sea change in how a standard in acoustics may regard hearing: not as a fixed, universal and generalizable metric predicated on the ontologically normal [. . .], but as a shifting, unsteady human trait that we individually, tacitly know from day to day experience" [29] (p. 1). Transferred to the question of vision, the proposition/introduction of the term visual diversity brings with it several theoretical and methodological implications that could contribute to a paradigm shift from considering vision as a fixed metric towards seeing it as a variable human trait. Accordingly, visual impairments and visual aids should be included as factors that influence vision within the criteria of international standards and planning frameworks for artificial lighting in public spaces. In addition, as with hearing in acoustics [29], questions about whose vision is taken into account in design standards

and in the planning of artificial light in public spaces should be raised and addressed. To further seek solutions to these questions, the needs, the experiences and the perspectives of different visual diverse subgroups should be acknowledged, including, e.g.,

- ageing people,
- young and adult people with visual diverse abilities,
- people with different kinds of visual impairments,
- people suffering from visual impairments as a side effect of non-visual or neurological conditions or temporary factors.

Accounting for these heterogeneous subgroups and the many types of visual impairment with different degrees of sensitivity to light is certainly an ambitious and challenging task, one that nevertheless should be confronted by the scientific community, practitioners and policymakers. By embracing a *visual diversity* paradigm and adopting a more visually inclusive approach to light design and planning in public spaces, more well-being could be provided to a heterogeneous and ageing population of visual diverse pedestrians.

Against this backdrop, this article makes the case for inclusive light planning for visual diverse pedestrians drawing upon an exploratory study based on twenty-one open-ended interviews conducted with experts in the fields of health studies, urban planning and light planning. Based on the original data stemming from these interviews, the article presents a systematisation of the issues in inclusive planning of artificial light for pedestrians in public spaces. Then, it proposes a participatory framework for the application of *lightwalks* as an inclusive experiential method for involving visual diverse pedestrians when assessing and planning artificial lighting in public spaces at night [31–33]. Lastly, the article examines the limitations of this study and indicates directions for further investigation, for instance, addressing different types of visual impairments and tailoring specific solutions.

2. Materials and Methods

Given the results of the literature search, open-ended interviews were identified as a suitable research method [34] to run an exploratory survey on the topic of artificial light planning in public spaces for visual diverse pedestrians.

Twenty-five experts were contacted, leveraging the authors' networks, the Berlin "Allgemeiner Blinden- und Sehbehindertenverband" (General Association for the Blind and Visually Impaired) and the "Unione italiana ciechi e ipovedenti" (Italian Union of the Blind and Visually Impaired) and using the snowball effect of recommendations given by the interviewees. Out of the twenty-five experts contacted, twenty-one agreed to be interviewed either on the phone or in a Zoom call or per email correspondence depending on their availability and considering the COVID-19 restrictions in place during the time of this study. The fact that different means were used to conduct the interviews was assessed as not affecting the robustness of the results given the exploratory nature of the study and the subject under investigation.

The interviewees work in the fields of health, urban and mobility planning, in light planning and in organisations for blind and visually impaired people. Specifically, three interviewees are medical doctors/oculists, six are academic researchers and professors specialising in lighting, four are representatives of Associations/Unions for the Blind and Visually Impaired People, four are lighting designers and artists, two are activists in community groups/associations, one is a planner and one a biologist.

Depending on the specialisation and the role of the interviewees, from two to four op-ed questions were posed and used as a basis for developing a conversation (see Table 1). The questions aimed to gather knowledge about issues, studies and hands-on projects for designing and planning artificial light at night for visually impaired pedestrians in public spaces. Furthermore, one specific question addressed the potential reasons for the scarcity of research into outdoor light for visually impaired pedestrians in public spaces versus indoor places, as the literature screening highlighted. Technical questions have intentionally not been included in the survey at this stage of the study.

Table 1. List of the questions used as a basis for the op-ed interviews.

No.	Questions Used as a Basis for the Open-Ended Interviews
1	Do you have any specific knowledge and expertise on designing and planning artificial light at night for visually impaired pedestrians in public spaces?
2	Are you aware of any studies and case studies that address artificial light at night for visually impaired pedestrians in public spaces?
3	From the literature review, it emerged that more work has been undertaken regarding indoor light for visually impaired pedestrians, while little research has been conducted into outdoor light in public spaces for visually impaired pedestrians. Can you comment on this discrepancy and discuss the reasons?
4	What are the most important topics regarding visual impairment and artificial light based on your experience?

Data from the interviews were examined applying an inductive approach by means of qualitative content analysis and theme coding [35]. Accordingly, eight themes emerged:

- The scarcity of studies and projects focusing on planning outdoor lighting for visually impaired pedestrians;
- The relevance of the topic in connection to the ageing population;
- Kinds of visual impairments in relation to planning artificial lighting;
- Public versus private lighting in the public realm at night;
- Impacts of artificial lighting on health and well-being;
- Standards, norms and recommendations;
- New technology for designing and planning artificial lighting in public spaces at night;
- Best practices that take into account visually impaired pedestrians when planning public lighting;
- Lighting features such as contrast, dynamic lighting, lighting on demand, flickering, glare, legibility of signs, lighting levels, light colour and light colour rendering, lighting fixtures and poles, light uniformity and wavelength range.

These themes are discussed in the following section. They aim to provide a systematisation of the still unresolved issues in the planning of artificial light for visual diverse pedestrians in public spaces at night.

3. Results and Discussion

Given that little research has been conducted on artificial light for pedestrians [25], the interviewees were not surprised that even less empirical evidence was found in the literature of studies taking into account visual diverse pedestrians' special needs for public lighting and their reactions to the existing lighting conditions in public spaces. Furthermore, it was noted that artificial lighting in public spaces is so complex that scholars like [25] tend to focus only on street lighting for pedestrians, as "there is a limited treatment of lighting for off-street facilities, such as plazas and pedestrian paths in parks, waterfronts, or similar settings, [that] are very important, but less often walked for utility trips, and their pedestrian environments vary so greatly that guidance is more difficult" [25]. It is no wonder, therefore, that interviewees expressed partially differing opinions on the specific needs of visual diverse pedestrians in public spaces, although there was agreement on some general issues. For instance, one overarching result of the interviews was that planning of public lighting has become a much more complex task that requires an interdisciplinary approach to address the different requirements for good, sustainable and efficient public lighting [3,36]. Hence, inclusive design and planning of public lighting should become a much more important topic; this would help visual diverse pedestrians, but also sighted ones, to deal with, e.g., the increasing overload of sensual impressions [36]. A rather commonplace formula for planning lighting in a sustainable way recommends providing light only where, when and to the extent it is needed, or, in other words, taking into account the local, temporal and quantitative aspects of lighting and its specificities. However, such a formula

would overlook the needs of visual diverse pedestrians, who are much more sensitive and less adaptable to bad implementation of illumination in public spaces [37]. Therefore, for visual diversity to be properly addressed, several topics need closer discussion:

- The reasons why there are few studies and projects focusing on planning outdoor lighting for visually impaired pedestrians;
- Standards, norms and recommendations;
- Lighting features;
- New digital technologies for designing and planning artificial lighting in public spaces at night;
- Best practices that take into account visually impaired pedestrians when planning public lighting.

In the following sections, these topics are introduced, and the main discourses about them that emerged from the interviews are systematized to provide a basis for further studies.

3.1. Why Is There so Little Evidence for Lighting for Visually Impaired Pedestrians in Public Spaces at Night?

Paradoxically enough, in our culture so heavily dominated by vision, the level of attention to lighting that addresses visual diversity and visual impairments has been extremely low so far [38]. According to the interviewees, there are several reasons why our knowledge of lighting for sighted and visual diverse pedestrians, in particular, is so limited. The most important reasons derive from the complexity and variety of the lighting sources in pedestrian settings—sources that are underregulated and managed by different actors—and the more erratic, or less directional, movement of people in public spaces, which is more difficult to monitor than motorised traffic. Another reason for the lack of consideration of visual diversity, e.g., in standards, norms and regulations that usually take average thresholds as references, can be linked to the many different visual impairments that would entail different and specific requirements for supporting a relatively small segment of the population, thus making this a minority problem that cannot be easily regulated [15,39]. Furthermore, the interviewees reported that it is usually much easier to obtain funding for and conduct research into indoor settings (such as the workplace or the home) where the variables are more controllable and, hence, solutions are more easily available than in public spaces [15]. Nevertheless, although addressing visual diversity would involve allowing for a higher degree of subjectivity in perception and of individuality in requirements, the increasing aging of the population and the increasing numbers of visual diverse pedestrians make the call for inclusive light planning and design in public spaces vital.

3.2. Standards, Norms and Recommendations

The interviewees indicated that there are a few recommendations for planning artificial light for visual diverse pedestrians in indoor environments for the provision of signs and for the marking of obstacles to make them more visible, but they also said that there is an overall lack of guidance for outdoor lighting in public spaces [38]. In fact, in indoor settings—e.g., in workplaces and even more so in private homes—it is much easier to care for the specific needs of visual diverse people, because the lighting can be personalized more easily. This is reflected in the existing research, norms and recommendations for visual diverse people in indoor settings, as suggested by the interviewees. Contrary to this, for outdoor environments, the existing norms mainly focus on street lighting for drivers, while some do consider lighting for pedestrians on streets, but less so for other public spaces [38,40]. However, the validity of and the extent to which these norms and standards are empirically supported is generally questioned, before even considering the aspect of visual diversity. This argument made by the interviewees is confirmed by the literature, where a study on road lighting reports that standards "do not appear to be founded in robust empirical evidence. Such evidence is needed, first to show that the assumed benefits of lighting do exist (i.e., improved visibility, improved safety, improved

feeling of safety), and second to show how these benefits might be affected by changes in context and changes in lighting" [14]. Furthermore, as an interviewee pointed out, lighting standards and norms are based on research and tests usually carried out with young sighted persons (e.g., young white male students) [14], thus reducing "the remarkable diversity of the human population" to a "single 'standard' observer" [41] (p. 701).

Moreover, in recent years, developments in the technology of road lighting and advances in our understanding of vision and of the side-effects of road lighting have occurred that might give rise to a need for new types of recommendations that include maximum levels in addition to the minimum levels indicated in the current standards and norms [37]. The need for new types of regulations is also the result of "an arms race in illumination" [36]: as most types of lighting are independently becoming brighter and brighter (i.e., the headlights of cars, motorcycles, bicycles, light in windows, screens, signs, shops, restaurants, entertainment venues etc.), the street illumination has had to become brighter and brighter to avoid excessive contrasts.

Even where there is extensive experience with and use of different types of outdoor lighting, as per the standards, norms and regulations, there is little material available with a special emphasis on pedestrian visual diversity. This issue is becoming more pronounced, not only because of the increasing numbers of ageing people, but also due to the massive rollout of a new technology, LED, which is on track to replace the lighting technologies for which ample evidence existed. This is not yet the case with LED, despite the increasing number of studies on the different impacts of LED lighting [38].

3.3. Lighting Features

Even if diverse visual impairments can be addressed more easily in controlled indoor settings than in public spaces, where the variable factors to consider are numerous and complex, the interviews with the experts showed that there are several lighting features that can be especially problematic for visual diverse pedestrians and that deserve further study to achieve inclusive planning of artificial lighting in public spaces at night. These lighting features are related to glare, contrast, uniformity, illuminance, light colour and flicker.

3.3.1. Glare

Glare depends on excessive luminance or extreme differences in luminance in the field of vision resulting from looking directly at a badly shielded light source within the field of vision. Glare can have physiological and psychological effects: it can objectively hamper and limit visibility (disability glare) and can reduce comfort (discomfort glare). The risk of glare can depend on multiple factors, such as the type of lighting installations (e.g., lighting poles and fixtures, see below). To avoid glare exposure, interviewees recommend strict shielding and the avoidance of light shining upwards [37,42]. Another special aspect of glare that is gaining relevance for visual diverse pedestrians and sighted one is the heavy increase in the brightness of light coming from bicycles, scooters and the headlamps of joggers in public spaces. The impact of these quickly and rather randomly moving lights seems to be a mixture of disability and discomfort glare and flicker. They produce discomfort for many (depending on individual sensitivity), but especially for visual diverse pedestrians [36]. Beyond a return to less light or lights less bright, which is highly improbable, the problem is not amenable to simple solutions. Nevertheless, as the sensitivity to glare increases with age and is generally higher for visual diverse individuals, controlling glare is therefore of high importance for inclusive lighting planning [36,40].

3.3.2. Contrast

Contrast perception depends on luminance-dependent contrasts and is generally more important than illuminance, especially for visual diverse pedestrians [42]. Thus, there was agreement among the interviewees that contrast and illuminance uniformity should be implemented equally in outdoor lighting. High differences in illuminance levels—due to, e.g., different light sources such as street lighting, cars, billboards, shop

windows, etc.—often cause environmental darkness or even environmental blindness (Umgebungsdunkelheit or Umgebungsblindheit) that can be dangerous for all pedestrians. The effects are, however, even worse for persons with reduced visual adaptability or other kinds of visual impairment [36]. Accordingly, the interviewees suggested that uniform illumination should be provided in public spaces, and islands of dark as well as dark sections in a lit space should be avoided so as not to exacerbate problems with light-dark adaptation, especially for visually impaired pedestrians. Providing reasonable and balanced contrasts remains an imperative yet challenging requirement [36,43].

3.3.3. Uniformity

As mentioned above, there is a close relationship between contrast and uniformity. Uniformity seems to be a standard aim in public lighting. With respect to uniformity, the positions of the experts interviewed were rather contradictory. The majority of the interviewees agreed that lighting uniformity would be very helpful and the avoidance of dark islands necessary e.g., [44]. Hence, they suggested that uniformity could be achieved by installing more lighting poles emitting lower illuminance levels, because uniformity is easier to achieve with lower lighting levels [38]. Other interviewees expressed different positions that take subjective perceptions into greater account e.g., [35,39]. For instance, one interviewee clearly stated that, although "[i]n the US, public lighting guidelines call for flat, uniform illumination, [. . .] pools of light or intentional patterns of shadow or colour facilitate movement and directionality. The pedestrian can subliminally "count" the number of lines or pools to understand better the distance yet to go, which in turn elevates a sense of assurance. This has not been rigorously tested, however" [43]. These recommendations aligned with the positions of other interviewees who noted that complete uniformity might produce monotony, contribute to a reduction in aesthetics and have disadvantages for safety, as shown in the literature [25], concluding that uniformity is a fairly complicated subject for inclusive light planning [35,39]. Only in-depth research—looking at objective and subjective data—could contribute to more evidence-based solutions that acknowledge the needs of visual diverse pedestrians.

3.3.4. Illuminance

The interviewees highlighted that whether higher illuminance levels might be more supportive for visually impaired people, rather than the minimum illuminance levels recommended in the norms, depends on the type of vision impairment. Overall, the interviewees stressed that providing general recommendations for optimal lighting levels is difficult due to the various types of visual impairment with different degrees of sensitivity to light. However, they recommended as a general guideline to selectively increase illumination levels, while improving contrast and paying attention to avoiding glare [44].

3.3.5. Light Colour

To protect vulnerable groups of people, including visual diverse pedestrians, the interviewees recommended avoiding emissions of short-wave, high-energy blue light and UV light (e.g., HEVL) and opting instead to use warmer lights [16]. Furthermore, for optimal contrast, the use of warm light with a spectral composition that enables a contrast perception similar to that of daylight was recommended [37].

3.3.6. Flicker

To some extent, flicker is widely diffused and normally not noticed; however, especially nowadays with the retrofitting or replacement of public lighting with LED light systems, it is necessary to opt for flicker-free installations—even for dimmable fixtures, because sometimes the risk of flicker increases with dimming, unless the costly installation of the appropriate drivers is carried out. Flicker can in fact become a health hazard, and, depending on the intensity, it is generally disliked [37]. In addition to entertainment venues, where even extreme flicker—stroboscope—is usually installed on purpose, the diffusion

of flicker is becoming more common, even in public spaces, due to cheap access to LED lighting and the use of screens that flicker to attract attention to shops, restaurants, leisure venues, etc. Even in private residential buildings, flickering installations are becoming more and more common—especially towards the end of the year. An "arms race" [36] of flickering installations can often be seen in specific zones of cities with a lot of entertainment venues. Depending on the dimensions, the light intensity and the frequency, the irritating and damaging effect is worse for visual diverse and visually impaired people in particular, for whom these kind of lighting environments might even become inaccessible [16].

3.3.7. Lighting Fixtures and Poles

According to the interviewees, the risk of glare especially is dependent on the type of lighting fixtures and poles. For light poles, besides shielding, the ratio of the pole height to the distance between poles should be carefully considered when seeking a lighting design and planning that is optimal for visual diverse pedestrians [42]. The greater the distance between the poles, the higher the poles must be, as the risk of increasing the glare if the light is emitted at a flat angle. Furthermore, to cater to the needs of light-sensitive and visual diverse pedestrians, the following should be avoided: low bollard luminaires that radiate upwards, luminaires that are not shielded in the direction of the viewer and, in particular, ground luminaires/recessed floor lights situated in walking areas [37]. Conversely, low bollards which do not emit light above the horizontal might be preferred by visually impaired pedestrians if they provide light on the ground without glare.

3.4. New Digital Technologies for Designing and Planning Artificial Lighting at Night in Public Spaces

New developments in digital technology for artificial light in public spaces at night include the use of motion detectors or targeted lighting to provide light on demand or only when needed. One interviewee noted that the concept of adaptive lighting includes a minimum lighting level everywhere, with individual light luminaires that increase their light level when a pedestrian is detected [40]. Overall, the reduction of lighting levels was seen as the biggest problem by one interviewee [37], and, further, it was stressed that the implementation of these new technologies can make orientation along the further distance on the path more difficult for visually impaired and visual diverse people with delayed adaptation, because they might find themselves in a light bubble in the midst of darkness [37]. However, it was also pointed out that adaptive lighting is discussed mostly in connection with planning lighting in peripheral areas and not in public spaces in cities and therefore, currently, it is of little relevance for visual diverse pedestrians in cities [37]. Caution was also recommended concerning the application of motion detectors for security reasons, depending on the context, because motion-dependent lighting also exposes the moving person. Similarly, the use of other devices for lighting on demand, e.g., apps or SMS to activate luminaires, should also be considered in a critical light. In addition, the interviewees highlighted that "being seen" is an important factor that should be taken into consideration for inclusive lighting planning at night in public spaces, for instance, by illuminating crossing aids such as pavement extensions or central islands in a similar way to pedestrian crossings [44].

3.5. Best Practices Considering Visually Impaired Pedestrians When Planning Public Lighting

An important best-case study reported by the interviewees is the lighting plan of Lyon, where people with disabilities were consulted for the revision of the plan [39]. Similarly, in Munich, a lighting study for the main train station conducted by the Deutsche Bahn involved visual diverse pedestrians in the planning process for identifying appropriate specifications for the luminaires [42]. These examples confirm that a more intense involvement of the general public in lighting planning is a widespread demand that should include visual diverse pedestrians. However, according to the interviewees, what kind of inclusive methods and planning tools could be used to gain in-depth knowledge still remains an

unresolved issue across research and practice. To contribute to this line of research, in the context of this article, a participatory framework for conducting lightwalks with visual diverse pedestrians is proposed, as described below.

4. Contribution of This Study

Along with the concept of visual diversity and the systematisation of issues for planning artificial light for visual diverse pedestrians, this study provides a participatory framework based on *lightwalks* as an experiential method for involving visual diverse pedestrians in assessing and planning artificial lighting in public spaces at night. This framework is composed of six phases (Figure 1).

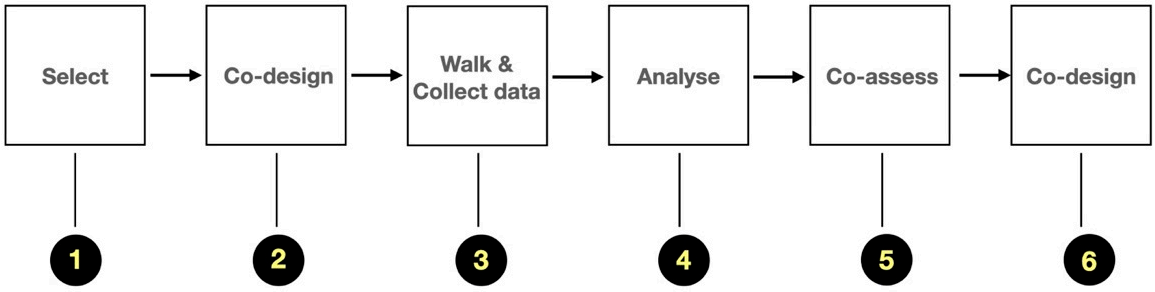

Figure 1. Illustration of the participatory framework for visually diverse light planning and co-design. (Image source. Authors' contribution).

- Phase (1) *Select*: Participants with visual diverse abilities and sighted participants (control group) are recruited to form two groups with the same number of participants. Criteria for selecting participants with visual diverse abilities can include kind of visual impairment, age and gender.
- Phase (2) *Co-design*: The lightwalk route and the evaluation points along it are co-designed with the visual diverse participants, using criteria such as the presence of a high variance of different lightscapes, lighting technologies and fixtures. Furthermore, these co-designed lightwalks can be conducted with the same groups along the same route in different seasons and under different weather conditions.
- Phase (3) *Walk and Collect data*: The lightwalk is conducted, at the same time and along the same route, with the group of visual diverse pedestrians and the control group. One researcher leads the lightwalk with the groups and stops the groups at the evaluation points. At each evaluation point, both the sighted and the visual diverse participants orally fill in an audio-questionnaire providing feedback on the lighting conditions using their smartphones. While the questionnaire is filled in by the participants, two other researchers take measurements and collect pictures. At the end of the lightwalk, a group discussion with both groups is facilitated and recorded by the researchers.
- Phases (4) *Analyse* and (*5) Co-assess*: The researchers analyse the mixed data collected during the lightwalks and share the results with the sighted and the visual diverse participants for discussion and further assessments by the participants.
- Phase (6) *Co-design*: On the basis of the outcomes from Phases (4) and (5), the researchers along with the visual diverse participants define recommendations for inclusive light planning in the areas assessed during the lightwalk.

This participatory framework has been developed based on the recognition of the relevance of providing inclusive light planning in public spaces, the limited knowledge on planning artificial light at night for visual diversity, and the experience gained by the authors through conducting lightwalks and combined sound- and lightwalks in Berlin, Rome and Florence [31–33]. This participatory framework has the potential of being applied within the context of academic studies, practice-based projects, urban planning

and policymaking. A pilot study is being prepared by the authors to test the feasibility of this participatory framework.

5. Conclusions and Future Work

Limited research has been done and few applications have been developed that address pedestrian visual diversity in planning artificial lighting at night. In addition, they have mostly focused on indoor environments, such as workplaces and residential contexts. However, given the growing number of elderly and visually impaired people, the need for research and planning lighting in complex and diverse outdoor environments and for more heterogeneous requirements is becoming a pivotal issue for societies that claim inclusiveness and sustainability. Against this backdrop, this article i) introduced the concept of pedestrian visual diversity defined as the condition, the capabilities and the needs of visually impaired pedestrians; ii) systematized the issues that still remain unaddressed in the planning of artificial light for visual diverse pedestrians in public spaces (i.e., standards and norms, lighting features, new technologies, best practices) and iii) introduced a participatory framework for the application of lightwalks as an experiential method for involving visual diverse pedestrians in data collection and in the analysis of artificial lighting in public spaces at night to inform light planning.

As per the outlooks, five roads for further research are identified, which would lead to:

1. Systematically incorporating visual diverse pedestrians in tests and experiments in outdoor settings.
2. Conducting lightwalks with visual diverse pedestrians to collect fine-grained data about artificial light, as per the participatory framework introduced in this article.
3. Leveraging qualitative data stemming from people's subjective perceptions and feelings in addition to quantitative metrics, with the aim of providing evidence for existing standards, norms and recommendations.
4. Revising current lighting levels and sources resulting from private and public lighting, brightness, dynamics, etc. for more inclusive lighting in public spaces; this would require coordination of the different actors and a stricter regulation of lighting.
5. Developing tools for multi-stakeholder management as well as new kinds of recommendations, standards and regulations for inclusive lighting planning.

Addressing inclusive lighting planning for pedestrians with higher sensitivity and visual diversity is certainly an ambitious demand due to complex factors such as personal and cultural differences, the need for high-context specificities and the lack of objective and subjective data and evidence, as well as the economic and political interests at stake. However, even progress made by what might seem like minor achievements—such as the transition from bad to indifferent lighting (if the good remains out of reach because of its often-unclear definition)—would be great progress [7].

To fulfil all of these requirements, highly complex, interdisciplinary and context-specific approaches are needed. This demand does not make the task of light planning for visual diversity in public spaces easier; however, it should be worth the effort considering the global goals of sustainability, inclusivity and health.

Author Contributions: Conceptualization, A.R. and D.H.; methodology, A.R. and D.H.; interviews, A.R. and D.H.; data analysis, A.R. and D.H.; writing—original draft preparation, A.R. and D.H.; writing—review and editing, A.R. and D.H.; visualization, A.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no funding.

Acknowledgments: The authors would like to acknowledge the valuable contributions of the interviewees and thank Carmen Rosas-Pérez and Mattia Cobianchi for their feedback on the use of the terms visual diversity and visual diverse in relation to the scholarship on aural diversity.

Conflicts of Interest: The authors declare no conflict of interest.

References and Notes

1. Kyba, C.C.M.; Hänel, A.; Hölker, F. Redefining Efficiency for Outdoor Lighting. *Energy Env. Sci* **2014**, *7*, 1806–1809. [CrossRef]
2. Meier, J.; Pottharst, M. *Gesellschaftliche Akteure der Künstlichen Beleuchtung*; Universitätsverlag der TU Berlin: Berlin, Germany, 2013; ISBN 978-3-7983-2504-3.
3. Zielinska-Dabkowska, K. Urban lighting masterplan—Origins, definitions, methodologies and collaborations. In *Urban Lighting for People. Evidence-Based Lighting Design for the Built Environment*; Davoudian, N., Ed.; RIBA Publishing: London, UK, 2019; pp. 19–41.
4. Kyba, C.C.M.; Ruby, A.; Kuechly, H.; Kinzey, B.; Miller, N.; Sanders, J.; Barentine, J.; Kleinodt, R.; Espey, B. Direct Measurement of the Contribution of Street Lighting to Satellite Observations of Nighttime Light Emissions from Urban Areas. *Light. Res. Technol.* **2021**, *53*, 189–211. [CrossRef]
5. Colaboratória, Grupo Interdisciplinar. *Manifesto Da Noite/Night Manifesto*; Invisíveis Produções: São Paulo, Brazil, 2014.
6. Fotios, S. Using Street Lighting to Support Pedestrian Safety at Night. Available online: https://www.sheffield.ac.uk/social-sciences/news/using-street-lighting-support-pedestrian-safety-night (accessed on 27 August 2022).
7. Boyce, R. *Human Factors in Lighting*.; Routledge: London, UK, 2014.
8. Deutscher Blinden- und Sehbehindertenverband Zahlen & Fakten. Available online: https://www.dbsv.org/zahlen-fakten.html (accessed on 27 August 2022).
9. Resnikoff, S.; Pascolini, D.; Etya'ale, D.; Kocur, I.; Pararajasegaram, R.; Pokharel, G.P.; Mariotti, S.P. Global Data on Visual Impairment in the Year 2002. *Bull. World Health Organ.* **2004**, *82*, 844–851. [PubMed]
10. Bará, S. A Note on the Overall Efficiency of Outdoor Lighting Systems. 2022. preprint. Available online: https://zenodo.org/record/6588230#.Y76AJuzP0-Q (accessed on 11 January 2023).
11. Laurìa, A.; Secchi, S.; Vessella, L. Visual Wayfinding for Partially Sighted Pedestrians—The Use of Luminance Contrast in Outdoor Pavings. *Light. Res. Technol.* **2019**, *51*, 937–955. [CrossRef]
12. Davoudian, N. *Urban Lighting for People. Evidence-Based Lighting Design for the Built Environment*; RIBA Publishing: London, UK, 2019; ISBN 978-1-85946-821-0.
13. Borra, F.; Cane, L. Daylight Impacts on Elderly People with Visual Impairments. Available online: http://thedaylightsite.com/daylight-impacts-on-elderly-people-with-visual-impairments/ (accessed on 27 August 2022).
14. Fotios, S.; Gibbons, R. Road Lighting Research for Drivers and Pedestrians: The Basis of Luminance and Illuminance Recommendations. *Light. Res. Technol.* **2018**, *50*, 154–186. [CrossRef]
15. Fotios, S. Interview. *Conducted by Interviewers Antonella Radicchi and Dietrich Henckel*, 6 May 2022.
16. Blaschke, M. Personal communication, 2 June 2022.
17. Evans, B.; Sawyerr, H.; Jessa, Z.; Brodrick, S.; Slater, A. A Pilot Study of Lighting and Low Vision in Older People. *Light. Res. Technol.* **2010**, *42*, 103–119. [CrossRef]
18. Butler, M.; McMullan, K.; Ryan, S.E. Lighting Prescriptions for Low Vision. *J. Hous. Elder.* **2019**, *33*, 189–203. [CrossRef]
19. Wrigbt, M.S.; Cook, G.K.; Webber, G.M.B. Emergency Lighting and Wayfinding Provision Systems for Visually Impaired People: Phase of a Study. *Light. Res. Technol.* **1999**, *31*, 35–42. [CrossRef]
20. Tulla, A. LF07 Design and Assessment of Exterior Lighting Schemes. *Soc. Light Light. Factfile* **2019**, *7*. Available online: https://www.cibse.org/knowledge-research/knowledge-portal/design-and-assessment-of-exterior-lighting-schemes-lighting-factfile-7-2019-pdf (accessed on 11 January 2023).
21. Progetto Lettura Agevolata Questione Di Leggibilità. *Se Non Riesco a Leggere Non è Solo Copla Dei Miei Occhi*; Comune di Venezia: Venezia, Italy, 2005.
22. Fotios, S.; Cheal, C.; Fox, S.; Uttley, J. The Effect of Fog on Detection of Driving Hazards after Dark. *Light. Res. Technol.* **2018**, *50*, 1024–1044. [CrossRef]
23. Fotios, S.; Cheal, C.; Fox, S.; Uttley, J. The Transition between Lit and Unlit Sections of Road and Detection of Driving Hazards after Dark. *Light. Res. Technol.* **2019**, *51*, 243–261. [CrossRef]
24. Fotios, S.; Robbins, C.; Fox, S.; Cheal, C.; Rowe, R. The Effect of Distraction, Response Mode and Age on Peripheral Target Detection to Inform Studies of Lighting for Driving. *Light. Res. Technol.* **2021**, *53*, 637–656. [CrossRef]
25. Markowitz, F. *Outdoor Lighting for Pedestrians: A Guide for Safe and Walkable Places*; Routledge: New York, NY, USA, 2022; ISBN 978-0-367-71196-2.
26. Davoudian, N.; Raynham, P. What Do Pedestrians Look at at Night? *Light. Res. Technol.* **2012**, *44*, 438–448. [CrossRef]
27. Johansson, M.; Rosén, M.; Küller, R. Individual Factors Influencing the Assessment of the Outdoor Lighting of an Urban Footpath. *Light. Res. Technol.* **2011**, *43*, 31–43. [CrossRef]
28. Amore, F. Interview. Conducted by Interviewers Antonella Radicchi. 13 July 2022.
29. Drever, J.L. The case for auraldiversity in acoustic regulations and practice: The hand dryer noise story. In Proceedings of the 24th International Congress on Sound and Vibration (ICSV24), London, UK, 23–27 July 2017.
30. Renel, W. "Auraldiversity": Defining a Hearing-Centred Perspective to Socially Equitable Design of the Built Environment. *Built Environ.* **2018**, *44*, 36–51. [CrossRef]
31. Henckel, D. Lichtsituationen/Lightscapes in Berlin Friedrichshain-Kreuzberg. Ergebnisse Eines Light Walks im November 2017. Available online: http://unsichtbare-stadt.de/light-walks-in-berlin/ (accessed on 27 August 2022).

32. Radicchi, A.; Henckel, D. Combined sound- & lightwalks. A perception based method to analyze and evaluate the sonic and light environment of our cities at night. In Proceedings of the 11th European Congress and Exposition on Noise Control Engineering (Euronoise 2018), Crete, Greece, 27–31 May 2018; pp. 2405–2410.
33. Radicchi, A. Combined sound- and lightwalks. A novel, mixed method to assess sound and artificial light of the urban environment at night. In *Experiential Walks for Urban Design*; Piga, B.E.A., Siret, D., Thibaud, J.-P., Eds.; Springer: Cham, Germany, 2021; pp. 77–91. ISBN 978-3-030-76693-1.
34. Corbin, J.; Strauss, A. *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 3rd ed.; SAGE Publications, Inc.: Thousand Oaks, CA, USA, 2008; ISBN 978-1-4129-0644-9.
35. Gibbs, G. *Analyzing Qualitative Data*, 2nd ed.; SAGE: Los Angeles, CA, USA; London, UK, 2018; ISBN 978-1-4739-1581-7.
36. Appelt, S. Interview. Conducted by Interviewer Dietrich Henckel. 9 May 2022.
37. Roemhild, T. Interview. Conducted by Interviewer Dietrich Henckel. 22 May 2022.
38. Krop-Benesch, A. Interview. Conducted by Interviewers Antonella Radicchi and Dietrich Henckel. 1 June 2022.
39. Asfuroglu, K. Interview. Conducted by Interviewer Antonella Radicchi. 10 May 2022.
40. Markowitz, F. Interview. Conducted by Interviewer Antonella Radicchi. 19 May 2022.
41. Royer, M. Editorial: Visual Diversity and Equity in Lighting. *Light. Res. Technol.* **2020**, *52*, 701. [CrossRef]
42. Stockmar, A. Interview. Conducted by Interviewer Dietrich Henckel. 19 August 2021, 12 October 2021, 13–14 March 2022.
43. Schwendinger, L. Interview. Conducted by Interviewer Antonella Radicchi. 16 May 2022.
44. Woltersdorf, P. Interview. Conducted by Interviewer Dietrich Henckel. 2 July 2021.