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Review Article

Cityscapes, Climate, and Mental Health: Designing Cities for Thermal Wellbeing

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Abstract: The effects of the environment on human health have been a concern in society for centuries, and significant progress has been made in promoting public health by tackling environmental hazards. Similar to how sanitation and flood mitigation have become critical components of and indicators for urban life, we posit that urban heat poses a significant risk to human physical and mental health. Reflecting on origins of contemporary Western urban design, we see a significant amount of energy dedicated to addressing both physical and mental health through changes in urban design, ecosystems, and climate. Building from this, we advocate for a reframing of current issues in urban design that considers how urban climate affects our physical and mental health. This theoretical approach presents a fresh perspective on the intersection of design, climate, and mental well-being. It delves into the pathways that lead from elevated air temperature, exposure to sunlight, and interaction with natural environments to potential crises in mental health. We use urban climate as a lens through which we examine how urban design and mental health are connected and what solutions might exist to address previously identified urban design issues while also improving the mental health of communities.

Implications: This review of theoretical approaches examines the urban design, urban climate, and mental health nexus through the lens of urban climatology, highlighting the importance of the design of urban environments for urban climate on mental health. Empirical research affirms the conceptions proposed by Ebenezer Howard and Frederick Law Olmsted regarding the value of urban green space for psychological wellbeing. Therefore, urban design impacts on the atmosphere could be a causal pathway to mental health outcomes.

Keywords: urban heat; urban nature contact; environmental design; thermal equity; green infrastructure; thermal wellbeing; urban environmental health; schizophrenia; urban design; mental health

1. Introduction

Cities and their distribution of urban climate conditions are the physical manifestation of formal and informal social forces of urban design, policy, and management (Alberti, 2008). Planners, architects, urban designers, landscape architects, and engineers (i.e., the design community) all have a role in shaping urban infrastructure through influential built projects, policy, and design discourse. Design communities' decisions create urban landscapes resulting in cooler or hotter microclimates, which in turn impact physiological and mental health for people who live in and around them. These design communities are a legacy of Western urban design practice. Modern Western fields of research and practice in design emerged in response to 19th century public health emergencies of industrial cities (e.g., disease outbreaks, sanitation, and pollution exposure) centered on the physiological health of city dwellers (Snow, 1856).

The Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (6th IPCC) identifies urban heat as an emerging hazard and one that nearly

every city must grapple with due to the urban heat island (UHI) phenomena (Dodman et al., 2022; IPCC, 2021). Research is now providing stronger empirical evidence of urban landscapes' impact on mental health despite being acknowledged as a risk dating back to the days of Frederick Law Olmsted in the mid-19th century. Thus, scholarly research is revisiting the role of the design community in creating better urban landscapes to support mental health. One understudied intersection of urban landscapes and mental health is the role that urban climate (thermal and air-quality environments) play in mitigating or triggering mental disorders. This knowledge gap is unsurprising given the challenges in obtaining detailed data (and metadata) around mental disorders such as schizophrenia, as well as the causality of mental health disorders from environmental conditions. Adding to this gap, the field of urban climate design and management (Coseo, 2019; Kleerekoper, 2016; Stone et al., 2019) with the intentional design of urban microclimates for more thermally comfortable spaces is still in its early stages compared to responses for other environmental hazards such as stormwater flooding.

Current thinking about urban climate design might be in a similar phase of conceptualization as stormwater management was in the early part of the 20th century (Hamstead et al., 2020). In the 1930s, Gilbert White shifted society's worldview of flooding, reframing the societal impacts of flooding not as an 'act of nature' from the hazard itself, but rather as a consequence of human planning and design decisions to either build in flood plains or create vast landscapes of impervious surface that have amplified flooding (Rome, 2001). Here in the 21st century, we seek to similarly reframe extremely hot landscapes as human magnified disasters for both physiological and mental health impacts.

For cities, recent urban climate initiatives are mainly focused on the reduction of the physical contributions of the UHI, such as modifying urban infrastructure to minimize air and surface temperature, while leaving out other important human-centered experiential impacts from heat. The UHI phenomena, also known as urban-induced warming, has been scientifically documented since the first half of the 19th century (Howard, 1833). Yet, it is only since the 1960s that urban climate research and design practice has begun to take elementary steps toward addressing the hazard.

The UHI phenomena creates neighborhoods that are warmer than their less urbanized surroundings. In this process, the atmosphere is warmed by contact with buildings, pavement, and urban materials that efficiently absorb shortwave radiation, store the energy, and release that energy at night, warming the atmosphere near the ground (Oke et al., 2017). Furthermore, these urban materials create differential heating within urban areas as well. The urban overheating of the City highlights the need for policy and actionable interventions within the City. City officials, real estate developers, planners and designers struggle to adequately address urban-induced heating in planning and design projects. Through discussions with practitioners, Hamstead and colleagues (2020) found that discourse overemphasized physical aspects of urban heat as a challenge at the detriment of a meaningful understanding of resident's thermal experience and social vulnerabilities.

These attempts at addressing urban-induced warming are often directed toward a primary focus on the physical environment with a secondary interest in human physiological health and little concern for psychological well-being. Yet, the environment as well as the physiological health also have significant impacts on the mental health of individuals, and by extension, social communities (Bratman et al., 2019; Frumkin, 2003). In most urban cities, the inequitable distribution of urban overheating exposes some communities more than others to the psychological and sociological stress from excessive heat exposure, resulting in climate injustice (Bolin et al., 2005; Harlan et al., 2006; Harlan et al., 2013). The correlations between urban-induced warming and psychological well-being of both individuals and communities residing in neighborhoods were proposed more than a century ago. Despite some contemporary research support for these correlations, they have not been given sufficient attention in the field of planning and design literature or practice.

Therefore, the objective of this theoretical approach is to provide a novel contribution connecting urban design theory with the production of urban microclimates and current understanding of mental health crises, providing a roadmap for making urban climate and mental health a central responsibility for the design community. First, we lay out a broad discussion of the 19th century design movements that addressed what today are often considered as urban climate challenges and their connection to human mental health.

This review of the theoretical framework for urban climate and mental health addresses how a better understanding of the interrelationships between urban infrastructure, urban climate, and mental health can provide better design pathways for healthier urban environments, which nurture higher levels of thermal wellbeing (Antonini et al., 2020; Nouri

& Matzarakis, 2019) with both physiological and mental components. By thermal wellbeing, we mean human that results from access to welcoming, comfortable, safe, and restorative thermal conditions (i.e., indoor and outdoor) during dangerous atmospheric conditions. We argue that by considering the urban landscape planning through the lens of urban climatology, we meld geography, landscape architecture, engineering, public health, social science, GIS, and atmospheric sciences in a unique manner that can provide tangible, evidence-based insights into how our cities and neighborhoods should be designed to leverage urban ecological processes for thermal wellbeing for all.

2. The Urban Design, Urban Climate, and Mental Health Nexus

From the dawn of industrial cities, design scholars of urban environments have alluded to a connection between design, urban environmental conditions, and human health (Thompson, 2011). This connection is foundational to the practice of city design. Connections between urban design, urban climate, and mental health appear in several prominent designer's calls for parks and green space to address mental health symptoms that result from negative urban climate conditions (Eisenman, 2016; Howard, 1898). These designers made recommendations based on anecdotal evidence, observations, personal experience, and unproven theories. Scientific evidence in public health started to inform city design decisions in the 20th Century, such as extreme air pollution events and other public health emergencies. Dr. W.P.D. Logan's work on the Great London Smog event in December 1952 is an example, where he attributed 4,000 deaths to the smog (Logan, 1953), but more rigorous and nuanced studies in more recent decades have made broader empirical connections between city design, climate, and health (Jacobs et al., 2018; Polivka, 2018). Yet, even early city designers recognized important urban climate patterns and attempted to address city design around three interrelated factors for health: heat, sunlight exposure, and nature contact.

Heat, Sunlight Exposure, and Nature Contact

19th century revolutions in city building also called for revolutions in infrastructure — green infrastructure, or nature itself, as a building material was a key innovation. As early as the 1830s, cities began to have design ambitions to integrate natural systems and their associated services into cities in more intentional ways to resolve poor environmental quality and improve livability. This ambition led to many city greening intentions with cities such as Chicago adopting a vision of the "Urbs in Horto" or "City in the Garden" as a centralizing pathway of good city design (Klinkhamer, 2016; "Park Districts," 2005). Early ambitions needed urgency and design champions to take the movement to actual implementation.

First, Frederick Law Olmsted (in the United States in the mid-1800s) and later Sir Ebenezer Howard (in England in the early 1900s) became leaders in interspersing green spaces and eco-services within cities of the U.S. and England (Eisenman, 2013; Howard, 1898). Their work focused on the ecological benefits of designing with the natural world, but they also explicitly endeavored to improve the quality of life and wellbeing for city-dwellers through green infrastructure design. The town-country magnet of Sir Ebenezer Howard's vision included attractive greening features drawing the city-dweller to this garden city with benefits such as: "No Sweating", "Pure Air and Water", "Good Drainage", "No Smoke", and "Bright Homes and Gardens" (Howard, 1898). While dated in terms of language, Howard's intended outcomes for his Garden Cities point to some of the underlying issues associated with urban materiality and form. Though less apparent today, Howard's town-country model addresses those issues through cooling grey and green strategies.

Although in the 19th century, design advocates might not have had an explicit awareness of urban climate dynamics, they used observation to build theories of how design impacted urban environments and people. Howard's efforts were focused on improving the urban climate of the city by creating a "Garden City" that allowed city-dwellers to experience important health benefits from green infrastructure that were unavailable within the city due to the form of the urban city center. He envisioned life for city-dwellers where cooler air temperatures, better ventilation, improved sanitation, and healthier indoor conditions prevailed. These grand visions of a "Garden City" have materialized in Singapore where "City in Nature" has been a primary theme of the country's design goals since the 1960s (Er, 2021). Over a hundred years later, current design theory is a hybrid between these early normative hunches and decades of empirical evidence (Anderson, 1989; Kuo & Sullivan, 2001; Lewis, 1992; McGregor & Vanos, 2018) to create grey and green infrastructure that improves these same issues for city-dwellers (Figure 2).

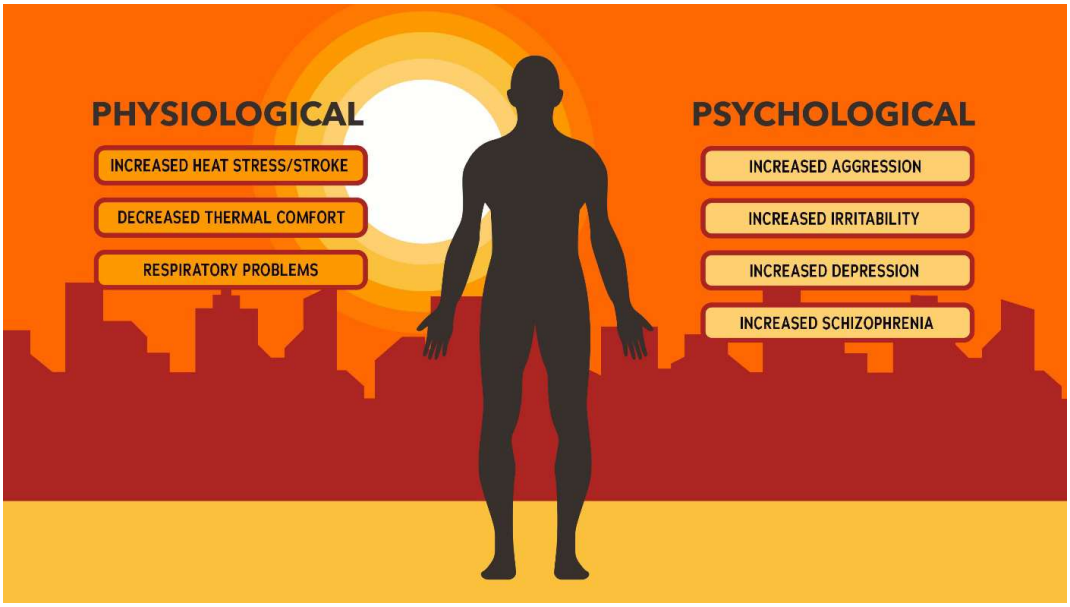

Figure 1. The physiological and psychological impacts of the urban environment on the human body for heat.

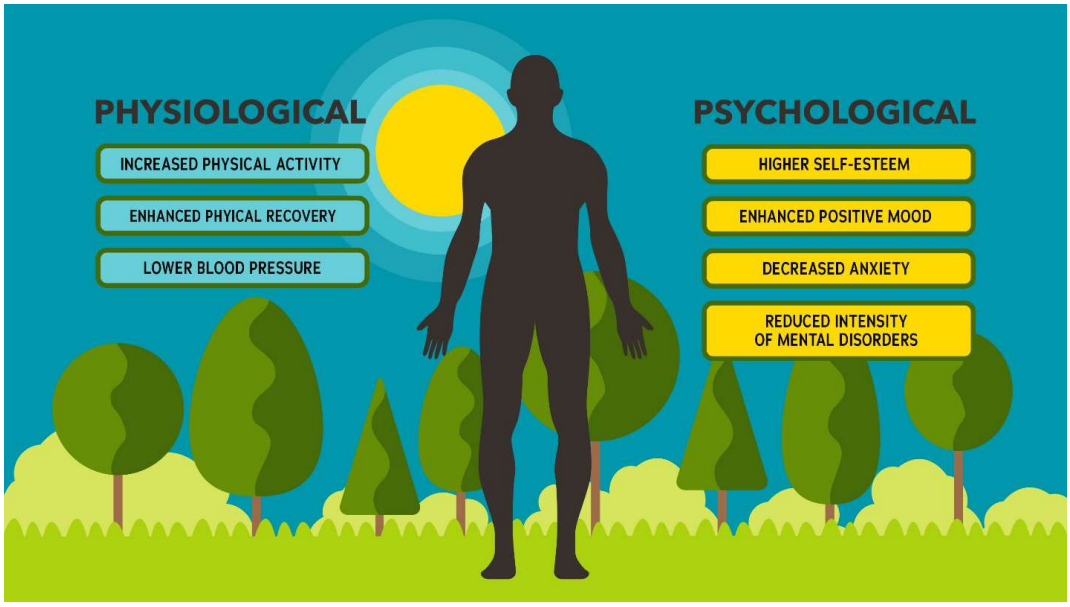

Figure 2. The physiological and psychological impacts of nature contact on the human body.

Olmsted brought and preserved nature in the city in the United States of America. His "Emerald Necklace" in and around Boston, Massachusetts, built in the mid to late 1800s, provided other designers such as Howard with concepts about greening and the benefits to the urban population by having green spaces to escape from city life (Eisenman, 2013). Yet, both of these urban designers were not exclusively focused on the physical improvements to the city and health of the city-dweller. There were also mental wellbeing concerns woven into the fabric of their arguments and designs. Howard and Olmsted were convinced that increased contact with the natural world improves mental wellbeing, from reducing incidence of depression, and alleviating less understood issues such as schizophrenia and other manic disorders (Berry et al., 2010). In 2020, the isolating lockdowns associated with the COVID-19 pandemic reinforced the importance of nature contact for mental wellbeing (Pouso et al., 2020).

In the 150 years since Howard and Olmsted contributed to design theory, research has indicated the potential correlation between urban living and a heightened prevalence

of mental illness. Modern approaches now use birth records and census data to statistically analyze differences in schizophrenia based on location of birth (Vassos et al., 2016), suggesting a detrimental relationship between the urban infrastructure and the mental health of city-dwellers. Howard identified the city features such as "isolation of crowds", "crowded dwellings" and an assortment of stressful environmental and social factors that he believed an increase of contact with nature could counteract. Many of these design, climate, and health observations were made separately or linked in very simplistic manners. Figure 2 describes current evidence from research that point to the physiological and psychological benefits of nature contact which further support and extend the foundational work of both Howard and Olmsted (Barton & Pretty, 2010; Bratman et al., 2019; Kruize et al., 2020; Santamouris et al., 2018; Ulrich, 1984; Ulrich et al., 1991; White et al., 2019). Although the physical aspects of urban climate and ecological patterns were acknowledged by early planners and designers, their social drivers were inadequately scrutinized. The interrelationships between design, climate, and health were under-examined due to complexity; however, today they are being integrated into green infrastructure and urban design.

3. Contemporary Concepts on Green Infrastructure

One of the key aspects of urban infrastructure (e.g., grey, green, blue, and turquoise as described in (Childers et al., 2015) is the intentional manipulation of the ecological systems to serve (and sometimes disserve) human communities (Cutter et al., 2014; Döhren & Haase, 2015; McPhearson et al., 2016). Urban infrastructure (biotic and abiotic) is developed through social and technological processes (Childers et al., 2015) and thus are endowed with all the politics, injustices, and complexities of any human system. Urban climatologists study the impacts of urban infrastructure on atmospheric conditions surrounding and interacting with urban development and human activities (such as waste heat).

A modern means of delineating the effects that ecosystems exert on society is through ecosystem services, also referred to as eco-services (Duraiappah et al., 2005). Ecosystems provide a host of societal benefits that are typically non-monetized and researchers commonly categorize them as provisioning, regulating, cultural, and supporting services. This framework considers the benefits (services) and burdens (disservices) of urban ecosystems for human society (Childers et al., 2015; Döhren & Haase, 2015). The way in which eco-services or disservices are intentionally designed into city neighborhoods through social processes determine the extent of modifications to the atmosphere near the ground. Evidence is mounting that neighborhoods with abundant green infrastructure provide both climate regulation (i.e., increased thermal comfort) and cultural services (i.e., mental wellbeing) (Barton & Pretty, 2010; Bratman et al., 2019; Frumkin, 2003; Ulrich, 1984). As the fields of planning and city design emerged in the 1800s, early designers recognized some of the physical aspects of urban land cover composition and configuration, urban climate conditions, and patterns of ecosystem services/disservices (Eisenman, 2013; Howard, 1833; Thompson, 2011).

More recently, the United Nations and World Meteorological Organization have created a framework that integrates urban ecosystem services and urban climate services into Integrated Urban Services (IUS) (Baklanov et al., 2020). To examine urban climate's role in IUS, it is useful to review some baseline concepts in urban climatology. Urban climate is the study of the regional, meso-, and micro-scale climate-land dynamics that are peculiar to cities (Oke et al., 2017). Cities create unique surface to boundary-layer meteorological patterns that modify the regional climate through the composition and configuration of urbanized land cover and human activities (Oke et al., 2017). Stewart and Oke (2012) developed the Local Climate Zone (LCZ) as a typology of the built environment defines the effect of the urban form (i.e., composition and configuration) on urban climate.

The LCZ helps to define the thermal environment of the urban form. Key variables to the thermal environment are surface temperature, air temperature, and radiation (often measured by mean radiant temperature). Surface temperature is driven by the surface material characteristics (albedo and emissivity) and the amount of shortwave radiation reaching the surface. Ambient air temperature is a metric for measuring the internal energy of the atmosphere at a given location relative to the specific heat (Society, 1960). While ambient air temperature is the most recognized atmospheric variable, it is insufficient to depict the entirety of the thermal environment. Mean Radiant Temperature (T_{MRT}) is defined as 'uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body equals the radiant heat transfer in the actual non-uniform enclosure' (Ashrae, 2001). This definition was established for indoor environments before being

adapted for outdoor use (Guo et al., 2020; Nikolopoulou et al., 2001; Spagnolo & de Dear, 2003; Thorsson et al., 2007). T_{MRT} incorporates the radiative load (direct and reflected shortwave radiation) on a point or volume and the thermal energy of the atmosphere to define the environmental heat stressors on a body. T_{MRT} represents a better proxy environmental term for thermal comfort than surface or air temperature and depicts the difference in thermal exposure between unshaded, shaded by passive cooling, and shaded by vegetation.

The concept of thermal comfort, which incorporates the physiological and psychological conditions of an individual including levels of comfort/discomfort in the environment (Dzyuban et al, 2022) is the subjective perception of the thermal environment. The “condition of mind” defines perceived thermal comfort and is the internationally accepted understanding of how thermal comfort is assessed (ISO, 2005). Thus, thermal comfort connects the thermal environment to the human psyche. Yet, due to this subjectivity, thermal comfort has not been frequently utilized to understand humans interaction with the urban environment.

All of these measures can help cities identify hot spots and reduce thermal exposure of residents. Most cities concentrate on three main types of urban heat mitigation strategies (cooling grey blue, and green infrastructure) to engineer cooler environments that incorporate more ecosystem services. These cooling strategies have a long history of improving cities' climate and health; however, the scientific evidence of the connection between these ecosystem services and mental health is nascent (Bratman et al., 2019).

4. Building Theories for Practice

Schizophrenia as a proxy for broader mental health concerns

There is growing concern around the state of mental health in the United States and the stigma around seeking help for mental disorders (Larkin & Hurford, 2014). Given the steady prevalence of schizophrenia in the U.S. population (~2% of adult population) (McGrath et al., 2008) and the stringent guidelines for diagnosis, schizophrenia is a good proxy for the broader mental health impacts and we, in this commentary, are using schizophrenia as a “canary in the coal mine” for the impacts of urban heat on mental health.

The evidence for linking exposure to environmental stressors with schizophrenic episodes

Over the past thirty years, medical and atmospheric research has taken a more nuanced approach in estimating the influence of weather and microclimatic conditions on a variety of personal and community factors including mental health. Hasegewa et al. (2005) found that neurotransmission impairment to the pre-optic anterior hypothalamus results in a breakdown in the thermoregulatory function of the brain. This neurotransmission impairment directly affects manic mental health disorders, such as manic depression, bipolar disorders, and schizophrenia. Such neuro-psychiatric research is necessary for the medical and atmospheric sciences to understand the possible connections between atmospheric and medical conditions. Research on ambient air temperatures above varying thresholds (dependent on location) have been connected to increases in the risk of hospitalization due to schizophrenia (Crank et al., 2023; Hansen et al., 2008; Kim et al., 2014; Lee et al., 2018; Nitschke et al., 2011; Nori-Sarma et al., 2022; Sung et al., 2011; Wang et al., 2014). Ambient air temperature and internal brain core temperature are both linked to disruptions in thermoregulatory function of the brain in the literature.

Thermally and Psychologically Inequitable Landscapes

The 19th century greening movement made progress toward more equitable distribution of urban green infrastructure throughout industrial metropolises for some, but not for all. The greening processes by majority Anglo-led governments and nonprofits, particularly in North America, served to entrench legacies of oppression and environmental racism (Agyeman, 2005; Agyeman et al., 2003). Centuries of environmental racism have resulted in more vulnerable communities of color as compared to white communities (Harlan et al., 2013). These inequities can be reinforced by white dominance in framing environmental priorities.

Currently, the advancement of greening initiatives is frequently hindered by insufficient financial resources allocated for establishment and upkeep of cooling gray or green infrastructure. Moreover, there exists a contentious dichotomy between prioritizing the development of cooling gray infrastructure versus preserving green space, as well as investing in transportation, utilities, and other forms of gray infrastructure. Power, greed, and

other more utilitarian, technological or economically-centered values have resulted in limited successes in the implementation of cool gray infrastructure and green space. The successes in green space interventions are too often uneven in their implementation and hide their Anglo-orientation as “normal” or “default” (Bolin et al., 2005).

Legacies of environmental injustices have created the current uneven distribution of cooling gray infrastructure and urban forests with their resultant climate regulation services producing more heat-vulnerable households in many mid- to-large metropolitan areas (Bolin et al., 2005). Heynen et al. (2006) found uneven shade tree distribution in Milwaukee, Wisconsin where Hispanics saw decreased canopy cover compared to the general population. Land surface temperatures have also been found to be higher in lower-income, communities of color (Huang & Cadenasso, 2016). Jenerette et al. (2016) found that low-income Latino neighborhoods in Phoenix, Arizona had higher exposure to high surface temperatures than whiter, wealthier neighborhoods. Thus, many communities of color tend to also be more heat vulnerable than other communities. Reid et al. (2009) define heat vulnerability as a combination of exposure, sensitivity, and adaptive capacity. However, heat vulnerability indices fail to comprehensively address mental health as they primarily concentrate on physical health outcomes which only indirectly contribute to the well-being of one’s mental state. Therefore, people of color and individuals belong to marginalized groups are disproportionately subjected to the adverse effects of high air temperature, which consequently engenders physiological susceptibilities. Moreover, urban centers’ attempts to pinpoint vulnerable communities are inadequate as they fail to account for the psychological ramifications of high air temperature on vulnerability, subsequently engendering ecological gentrification (Bowler et al., 2010; Dale & Newman, 2009; Kong et al., 2016).

Although this review cannot (and does not attempt to) delineate all pathways for repairing these issues, it does aim to demonstrate how adopting a more holistic approach towards neighborhood design can shed light on historical practices of environmental injustices that have resulted in uneven exposure to heat, mental health concerns, and racial discrimination. Furthermore, it seek to elevate the issue of ecological gentrification.

5. Conclusions

The understanding of how our thermal environment is connected to community and public health burdens is necessary as heat-related health concerns are nearly fully preventable (Guardaro et al.) and as the COVID-19 pandemic has shown the opportunities and hazards of urban life. The heat-related and crisis-related health concerns are most acutely felt by the physically and socially vulnerable, which includes those of the minority groups who take the brunt of a pandemic’s toll. Urban climate and urban design drastically impact the individual’s experience of urban space and subsequently influence their physical and mental health. As crowded urban dwellings and spaces have become sources of anxiety during the pandemic, urban nature contact can be utilized to mitigate a myriad of health concerns for the urban population.

Through the lens of urban climate, we can see the potential benefits of cooling grey and green infrastructure for the communities that have discriminated against through implicit and explicit acts of environmental racism. By positioning these interventions in communities that have long been under-served, the city can begin to improve the environmental quality of the entire city through steps to address environmental and thermal equity. This can be used to design a future of thermal wellbeing in cities, which are greener and cooler (relative to the nearby suburban and rural communities). Interventions, when ethically and culturally contextually designed, can be an effective strategy in creating healthy urban environments for all. By reframing the discussion of urban landscape design through an urban climate lens, mental health and the psychological impacts of the UHI can be brought into better focus for the fields of landscape architecture, urban design and development. By integrating green infrastructure into urban communities, hot neighborhoods can become physical and psychological oases, creating Garden Cities for thermal wellbeing.

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