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Neuroscience, Wellbeing, and Urban Design: Our Universal Attraction to Vitality

Colin Ellard
Department of Psychology, University of Waterloo, cellard@uwaterloo.ca

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Colin Ellard
Department of Psychology, University of Waterloo

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Abstract
Although urban planners and architects understand that there is a relationship between the design of urban settings and our thoughts and emotions, it is only recently that we have had the tools to properly dissect this relationship. New methods for measuring affective, physiological, and cognitive states in people immersed in virtual reality have generated a host of novel findings, but a consistent theme is the idea that human beings have a deep affinity for vitality at every level, from home interiors to urban streetscapes. Recent evidence also suggests that we respond to the vitality of scenes almost immediately, even after exposures as brief as 50 milliseconds, possibly using ambient visual processing mechanisms that rely on our peripheral visual field. Further, when we sense and respond to vitality, positive affect increases, which in turn promotes affiliation and protects us from urban loneliness. This paper presents findings from laboratory and field experiments that show the power of vitality to positively change behavior and improve psychological wellbeing. Harnessing this power in urban design is one of the keys to building a psychologically sustainable city.
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Keywords
Urban design, Urban streetscape, Vitality of scene, Neuroscience

In his book The Phenomenon of Life (2003), the first volume of a monumental four-volume opus, architectural theorist Christopher Alexander sets out to reach the foundation of the phenomenon of life in the built environment. Arriving at a set of 15 fundamental properties that he says imbue built spaces with life, he argues that these properties, and the liveliness that they convey, are the key to establishing design principles that promote wellbeing. Early in the book, Alexander presents pairs of images that he has shown to many people, asking them to indicate which of the two images contains more life. Though in some contexts the question may seem an odd one, Alexander claims, and I concur from my own informal investigations during lectures, that a resounding majority of people have no difficulty at all with this task, and most arrive at the same kinds of answers. For example, if you glance at Figure 1, you will likely arrive rapidly at an easy response, even though you may not be able to identify exactly which factors led you to this response. Alexander's work has certainly had its detractors—in part because of his tendency to answer key questions through intuition rather than through the conduct of careful experiments—but there is little doubt that his ideas regarding the possibility of deeply rooted design principles, some perhaps even written into our biology, have gained increasing traction in the emerging field of urban and architectural psychology. Though it almost seems as though Alexander's agenda has been to identify the meaning of life itself, emerging tools and ideas in scientific psycholo-

Corresponding Author:
Colin Ellard
University of Waterloo, 200 University Ave W, Waterloo, ON, N2L 3G1, Canada
Email: cellard@uwaterloo.ca
ORCID: https://orcid.org/0000-0003-3791-9996

Figure 1. *A pair of images of different styles of nature. Which one has more life?*

gy mean that we may be close to being able to categorize and analyze the ineffable. In the words of author Douglas Adams (1987), we should "…prepare to grapple with the ineffable itself and see if we may not eff it after all, (p. 150)."

In an entirely different realm of discourse, noted urban planner Jane Jacobs, delivering a speech in Hamburg in 1981 at a conference on urban renewal (Zipp & Storring, 2016), argued against what she called "big planning," which is the kind of urban planning that is conducted from the top-down, where entire neighborhoods might be orchestrated by a few strokes of a mighty pen in the hands of a mega-planning department. Railing against this way of designing cities, Jacobs argued that "diversity is a small-scale phenomenon. It requires collections of little plans (p. 226)." Her meaning here was that the best neighborhoods are built by collectives of individuals, each working on a small part of a larger mosaic, rather than by sweeping edicts from a centralized authority. As we will see later, there may be a straightforward connection between Jacobs' musings on what makes a good city and what recent findings in neuroscience and psychology have told us about the inherent design preferences of the human mind.

In this paper, I intend to draw the connections between these two sets of grand ideas – the deep-rooted determinism of Alexander's list of life-giving properties of built spaces and Jacobs' "vital little plans"— using ideas that have emerged from efforts to relate the building sciences to biology and neuroscience. In short, I will argue that good design for human environments at any scale, whether it be the inside of a house or the plan for a city, is good precisely to the extent that it captures the "life-stuff" that Alexander described, which, in turn, might emerge from the kind of bottom-up, local urban planning practices espoused by Jane Jacobs.

Facing Buildings

Research in cognitive neuroscience has consistently shown that there is something specialized about our perception of faces. For one thing, faces appear to be processed holistically rather than in piecemeal fashion. One piece of evidence for this comes from the remarkable Thatcher illusion (Thompson, 1980) in which the distorted face of a famous person (Margaret Thatcher) is inverted, and the distortion is unrecognizable until the face is shown in its normal orientation. Perhaps the strongest evidence for the "specialness" of faces, however, has come from human neuroimaging studies (Kanwisher, et al., 1997), which have shown that there is a specialized module in the human brain (the fusiform face area; FFA) that shows selectively increased activity in response

Figure 2. *Image of a building illustrating pareidolia.*

to presentations of human faces.

What does this have to do with perception of the built environment and vitality? In a strange phenomenon called pareidolia, we seem to be predisposed to sometimes perceive non-face objects—even buildings—as if they are faces (see Figure 2). This phenomenon is something that most people have experienced to one degree or another, and it has been argued to underlie at least part of the aesthetic response to non-face objects. Chalup et al., 2009), for example, have shown that face processing software designed to detect emotional expressions, when used with non-face stimuli, will not only classify those stimuli but to some degree those classifications will agree with the impressions of human observers. This tantalizing finding is just one piece of evidence for the importance of vital features of the human aesthetic response, which might be relevant to our emotional relationship with the built environment.

Moving Buildings

In 1973, Swedish psychologist Gunnar Johansson began to transform our understanding of motion perception with his discovery of the phenomenon of biological motion, in which point light displays (PLDs) were used to produce compelling impressions of the movements of biological figures Johansson (1973). In early experiments, PLDs were generated by attaching lights to different parts of an actor's body and then filming their movements for presentation to observers. More recently, computer programs have been used to generate patterns of biological motion in PLDs. The general finding of Johansson's early experiments, and the many that have followed (for a review, see Blakemore & Decety, 2001), is that most humans are exquisitely sensitive to the motion parameters of PLDs and can use them to accurately assess the gender and mood of actors, for example, and can interpret even quite complex PLDs consisting of many different moving actors.

Just as the FFA is specialized for face perception, there appears to be an area of the neocortex that is dedicated to the processing of biological motion, called the superior temporal sulcus (Saygin, 2007). Interest in this area of the brain has intensified considerably with the recent discovery of the relationship between so-called mirror neurons (Rizzolatti & Sinigaglia, 2016) and the neural circuitry involved in biological motion processing (Centelles et al., 2011). These mirror neurons are part of a sophisticated neural system that interprets motive and intention in others by simulating their observed physical movements. Although, to my knowledge, nobody has yet tried to extend ideas about biological motion processing to the domain of environmental or architectural perception, such extensions may become possible with advances in interactive environments that move and shape themselves to a user's needs. For present purposes, my intent in mentioning these findings is related to my argument that the human mind is innately receptive to evidence of vitality and, in most cases, responds positively to such evidence in natural and built settings.

Related to the phenomenon of biological motion, the landmark experiments of Heider and Simmel (1944) showed that we are also very much prone to imbuing even seemingly random patterns of motion with life. In a somewhat informal demonstration of this, Heider and Simmel presented participants with an animated display of a small number of geometric shapes moving in a coordinated pattern. Participants were instructed to describe their observations, providing phenomenological data. Uniformly, participants interpreted the objects as behaving like animate characters, with goals, motivations, and even emotions. These observations showed that humans tend to take seamless streams of movement and parse them into a series of meaningful events. In other words, we have an innate tendency to process the motion of inanimate objects by imposing a narrative structure upon it. In Heider and Simmel's experiment, there was patently no real biological vitality in the patterns displayed. However, the human brain is predisposed to find life and, therefore, imposes such properties on random non-biological patterns. It is this capacity that also makes it difficult for us to respond to the actions of robots (even simple devices like robotic arms) as if the machines were alive.

Moving Façades

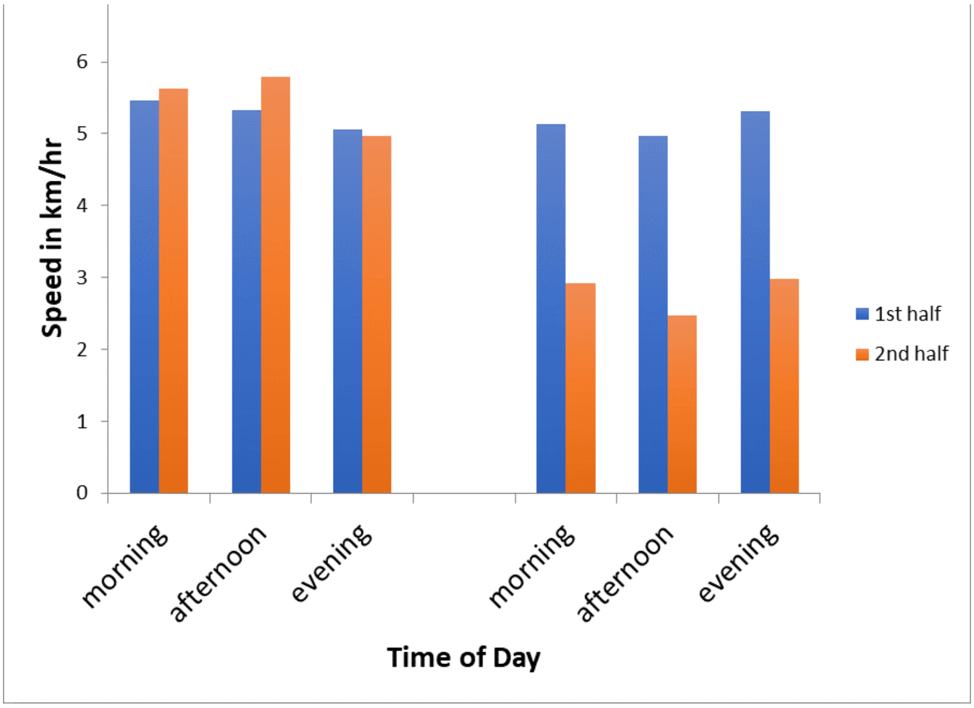
In a pilot study conducted at a pair of field sites in Toronto, Canada, we studied the effect of façade design on the overt behavioral responses of pedestrian passersby (Ellard, 2014). The experimental site was a chain-link fence that surrounded a brown field in the city. Because the site was hazardous and would take many years to refurbish, the city had commissioned a public art competition to beautify the site. The winners of the competition had constructed a set of simple laser-cut plywood panels depicting features of the local environment, including vegetation, birds, and silhouettes of historic buildings that once occupied the site but were demolished (see Figure 3). The control site consisted of a simple chain-link fence, with nothing more than a few small advertisements on it, in front of a construction site. Both sites were of approximately equal size, flat in elevation, and quite close to the city. Both locations were also on busy pedestrian streets near subway train stations.

For our experiment, we predicted that pedestrians would be affected by the artistic designs on the fence at the experimental site to such an extent that there would be measurable differences in pedestrians' overt behavior at the public art site compared to the control site. To test this hypothesis, we placed a discreet observer on the street at both sites, at different times of the day, who measured the time it took each pedestrian to walk to a midpoint on the site and from the midpoint to the end of the site. To control for site differences in elevation, wind, and other noise variables, we measured pedestrians walking in both directions as a natural counterbalance (though we could not control for the possibility that there might have been subtle differences in intentions between pedestrians walking in one direction and those walking in the other). In addition to measuring walking speed, the observer also monitored the number of times each pedestrian turned their head, the direction of the head turn, and the number of times they paused walking.

Figure 3. ***Photographs of the designed fence (upper) and control fence (lower) used in the study of the influence of façade design on pedestrian behaviour.***

Our findings were dramatic. At the control site, pedestrians walked at an average speed of about five kilometers per hour. At the public art site, pedestrians initially walked at around the same speed but eventually slowed to speeds that were sometimes only half of the average walking speed at the control site (see Figure 4). In addition, pedestrians paused more often in front of the public art fence and turned their heads toward it significantly more often the simple chain-link fence at the control site (Ellard, 2014). The message of this simple study, which was based on field methods pioneered first by urbanist William Whyte (1980) and later elaborated by master planner Jan Gehl (reviewed in Gehl & Svarre, 2014), is

Figure 4. *A bar graph showing mean walking speed as a function of time of day, segment, and façade design. The graph shows that pedestrians slowed down during the walk along the designed fence.*



that even subtle interventions in the urban landscape can have a remarkably robust impact on human behavior, often visible from afar with nothing more than a set of curious eyes, a stopwatch, and a counter.

While our study is a convincing and simple demonstration of the power of façades, it tells us little about the subjective experience of observing an urban façade. To determine how different types of urban environments, and specifically environments with different levels of complexity, might influence both the mental and physiological states of urban pedestrians, we designed a protocol in which participants responded to a series of location-specific questions while walking through an urban environment (Ellard & Montgomery, 2011). The participants were urban pedestrians who were recruited at a central meeting point and invited to walk with us for about an hour, during which time we presented them with a range of urban settings. One of our variables of interest was façade complexity. In earlier studies, we quantified façade complexity using simple self-assessment methods, but in later work, we tried to measure it using a variety of definitions of environmental entropy (Dzebic & Ellard, 2015). In different urban settings throughout the world (Toronto, Manhattan, Brooklyn, and Berlin), we found that participants reported low levels of positive affect in settings that were rated as low in complexity. Not only this, but when we monitored autonomic arousal (i.e., skin conductance) using simple wrist-worn sensors, we found a relationship between façade complexity and physiological arousal. Overall, our results demonstrated that low-complexity settings produced a combination of low positive affect and low arousal.

Although urbanists like William Whyte and Jan Gehl would have found such findings unsurprising, based on their simple observations of human behavior, the history of our understanding of the relationship between environmental complexity and aesthetic preference runs deeper and has its origins in the work of Canadian psychologist Daniel Berlyne. From early in his career, Berlyne believed that curiosity is a powerful driver of behavior, comparable to better-known drives such hunger or sex (Berlyne, 1960; 1971). He eventually parlayed these ideas into a comprehensive theory of human aesthetics, which he based on experimental evidence that curiosity was positively motivating and that it heightened physiological arousal.. According to Berlyne, too much environmental complexity is overly stimulating and negative, but so is too little stimulation.

More recent experimental evidence, both from our lab (Dzebic, 2018) and from others (see Dzebic, 2018 for an extensive review), has suggested that the inverted-U function that Berlyne described is an oversimplification and neglects many other factors that influence aesthetic attraction (e.g., cognitive factors outlined by Kaplan, 1979; 1987)). Nevertheless, there is still some evidence in support of Berlyne's model, especially from simple field studies of the influence of building façades on affective state. Furthermore, the idea that there are deep, basic properties, such as visual complexity, that influence our attraction to a setting is very much in line with the underlying ideas of theorists like Alexander (2003), who argued that what attracts us to a setting is our feeling that it is alive. By its very nature, life is unpredictable and chaotic, which manifests in the generation of patterns through "ordered disorder."

The idea of nature as "ordered disorder" is taken up explicitly in experiments aimed at understanding the so-called human restorative response to natural settings. This response was first observed by Roger Ulrich (1984) in a landmark paper in which he observed lower levels of pain and shorter periods of recovery for patients who resided in rooms that had a view of nature rather than those that faced a blank wall. This single small-scale study energized the field of environmental psychology, resulting in thousands of studies attempting to both document and understand the phenomenon (see review by Joye & van den Berg, 2018).

Two markedly different theories have arisen to account for the effect observed by Ulrich, both of which have evidence in their favor. Ulrich's theory was couched in psycho-evolutionary terms, suggesting that the restorative response is adapted from a fundamental inclination for natural settings. His stress reduction theory (SRT; Ulrich, 1983) posits that natural environments contain a set of features that lower stress in humans (including complexity, as well as other elements such as a geometry that affords safety). Others have instead argued for an attention restoration theory (ART; Kaplan & Kaplan, 1989; Kaplan, 1995, 2001). The foundational idea of ART is that being in a natural setting engages cognition in a particularly beneficial way. Kaplan, for example, describes the phenomenon of "soft fascination" in which attention is gently and involuntarily captured by a succession of fascinating natural images that release attentional processes from the focal demands present in most built settings (Kaplan, 1987). Both theories posit an essentially bottom-up process for the restorative response. SRT is undergirded by the idea of an innate affective response to natural scenes derived from our evolutionary lineage, while ART proposes that particular types of visual patterns in nature elicit soft fascination, thereby producing regeneration in the cognitively taxing systems underlying selective attention. There is even evidence from imaging studies (Biederman & Vessel, 2006; Yue et al., 2007) that the areas in visual cortex that are sensitive to scene properties may also contain the mechanisms that underly the positively reinforcing effects of exposure to scenes of nature.

While the evidence for the restorative effect of natural settings is quite clear, the mechanism through which natural scenes exert their effect remains unclear. One idea is that the deep mathematical structures of scenes are responsible for the effect. Richard Taylor (2006) and his colleagues (Taylor et al., 2011) have argued that the inherent power of self-similarity—that is, visual elements that repeat at a number of different scales--influences both aesthetic preference and physiological state. Taylor and colleagues have experimentally demonstrated that images containing fractal dimensions seen most commonly in natural scenes (those with fractal dimensions of approximately 1.4-1.5), are those that elicit the strongest positive affective responses. This idea makes sense in that it suggests that the mechanism for the effect of natural scenes on the restorative response and positive affect is tied to a low-level visual property that is a kind of 'signature' for nature. It is also consistent with the general idea being espoused in this paper, which is that among all the human responses to urban design, our attraction to vitality is the most important.

There are other possible explanations for restorative responses to natural settings, which are not completely at odds with Taylor's findings. In our lab, we demonstrated that spatial frequencies are one of the main drivers of aesthetic preference and eye movement patterns that are characteristically produced by images of nature. Using Fourier analysis, every image can be described as a spectrum of spatial frequencies that range from high frequencies, which contain information about fine detail, to low frequencies, which contain information about basic shape and contrast. Our findings suggest that only visual information contained within certain spatial frequencies will differentiate between images that either do or do not have restorative potential (Valtchanov & Ellard, 2015). One nice feature of this finding is that, in contrast to fractal patterns, spatial frequency preference is an extremely well-characterized property of visual perception areas in the brain (DeValois & Devalois, 1991). In addition, our specific findings for spatial frequency preferences match nicely with the spatial frequency properties of cortical brain areas thought to underlie scene processing (Fintzi & Mahon, 2014).

Regardless of the fine details of the nature and mechanism of the restorative response, research in this area makes one thing very clear: underlying successful design at any scale, whether it is explicitly natural or not, is a connection between the features of that design and the human affinity for vitality. If it is true that this affinity comes from low-level mathematical properties of images, it is not necessary that an image must be of actual nature. Indeed, in our experiments (Valtchanov & Ellard, 2015), some scenes were not recognizable at all, and yet they influenced aesthetic preference and eye movement.

How Our Visual System Processes Information

In some of our most recent work (Srikantharajah, Condia & Ellard, submitted), we have begun to explore how different parts of the visual field are processed, both from natural and built scenes, with explicit focus on the contrasting roles of central and peripheral visual processing.

The human visual system, beginning in the retina, contains two markedly different regions: 1) a foveal region composed of cone cells, which mediate high image resolution and color vision through low convergence on retinal ganglion cells, and 2) a peripheral region mostly populated with rod cells that, although responsible for lower image resolution, are highly sensitive because of high convergence on retinal ganglion cells. Functionally, we generally think of the fovea and the surrounding parafovea, subtending about the central five degrees of the visual field, as underlying the basic process of object recognition or, as classically described by Trevarthen (1968), focal vision. In contrast, Trevarthen argued that the peripheral visual field contributes to ambient vision. That is, visual processes that encompass large swaths of the peripheral visual field, though lacking in visual detail, are exquisitely well-tuned to picking up the gist of a scene. According to Trevarthen, ambient and focal vision work hand-in-hand: rapid scene processing is undertaken in the periphery by the ambient vision system, which guides subsequent focal vision processes that help to flesh out the finer details of a scene. An enormous amount of research supports this broad conception of the human visual system. For example, participants who are presented with scenes for a very brief duration, even when restricted to the peripheral field, are capable of accurately processing the gist of a scene (Oliva & Schyns, 1997).

At higher anatomical levels of the visual system, where many different areas of the visual cortex contribute to our ability to understand and move through the world, this pattern of specialization continues. It is sometimes said that we can characterize most visual cortical areas as belonging to one of two main pathways: 1) the dorsal or "where and how" pathway, which receives preferential input from the visual periphery and helps us to answer questions about where things are and how to interact with them, and 2) the ventral or "what" pathway, which is mostly invested in foveal vision and keenly involved in identifying the details of objects so that they can be recognized (Milner & Goodale, 1995). Although it is important not to overstate the independence of these two pathways—because for most ordinary visual tasks, there must be communication and cooperation between them—the distinction between "where and how" and "what" has been a valuable heuristic for those of us trying to understand exactly what visual perception is meant to accomplish and what processes it has available to do so.

With this background in mind, and motivated by Rooney's et al., (2017) argument that the peripheral visual field and ambient vision are largely responsible for the visual perception of architectural atmosphere, we designed a pilot study (Srikantharajah et al., submitted) in which participants were invited to explore public squares rendered in virtual reality and presented to either the central or peripheral visual field. Figure 5 presents the images and reveals that one feature of our study was an attempt to compare responses to classical and modernist designs of essentially the same square. In terms of vitality, the classical design contains many more of the kinds of features that are present in natural settings. In this experiment, participants moved through each of the settings using a kind of immersive slide show in which images of the environment were flashed in glimpses. At the same time, a mask, as illustrated in Figure 5, was presented to either the central or peripheral visual field to ensure that participants could not scan each image. In other words, we were careful to restrict each successive view to either the central or peripheral visual field. Participants were outfitted with equipment that allowed us to measure physiological arousal and they were also asked to complete brief questionnaires probing their affective and cognitive state immediately following exposure to each environment.

Our findings showed that participants were easily able to recognize scenes presented in the peripheral visual field (where they could only see views outside of the fovea) but not in the central field. Though the contrasting effects of classical and modern design were subtle, there was some preliminary indication that classical designs were associated with more positive affect than the modern designs, even when presented only to the peripheral visual field. What is remarkable about this finding is that it suggests that even when deprived of central vision, which is regarded as the main system for processing detailed visual information, scenes presented only in the periphery were able to elicit affective responses. This suggests that the coarse processing of the peripheral visual field is sufficient to drive the human preference for vitality.

Following our virtual reality study, we have conducted research in which participants are very briefly presented (66.6 milliseconds) with chimeric stimuli, consisting of images of natural settings presented to one part of the visual field (center or periphery) and images of built settings presented to the other part of the field (Srikantharajah & Ellard, in preparation). Our

Figure 5. ***View of the modern glass plaza, looking back toward a classical facade, in one of the immersive VR environments created for the study of central and peripheral vision. The chrome egg was included as a feature of interest to aid in legibility***

results have shown that participants can reliably identify the gist of the scenes presented to the periphery. Not only this, but this recently completed work suggests that such brief peripheral presentation of an image can elicit preferences that suggest a bias toward stimuli that show vitality.

Conclusion

There is currently a groundswell of interest in the idea that we can promote good design at all scales, from the interior of rooms to urban streetscapes, by establishing principles based on our accumulated knowledge of sensory systems, neuroscience, and cognitive science (Ellard, 2015; Goldhagen, 2017). This interest is driven in part by emerging methodologies that allow novel, previously impossible, approaches. In the laboratory, immersive virtual reality can be used to build convincing simulations of built or natural settings. In the field, wearable biometric sensors allow us to collect unprecedented details about physiological function in a naturally moving observer. Collectively, these methods and their application are beginning to reveal some of the most important underlying principles in successful urban design. Among them, and perhaps at the root of them all, is an intrinsic human response to vitality, which can be seen not only in our strong positive response to natural scenes but also in other forms, such as in our positive response to complex façades and perhaps also in our specialized systems for detecting faces and face-like stimuli and patterns of movement that are inherently biological.

When urban designs take advantage of these intrinsic responses, they are more likely to engender positive affective states in those who are exposed to them. As cities throughout the world try to sensibly respond to expanding urbanization, population density and overcrowding are destined to become significant barriers to psychological sustainability and urban mental health. Thus, increasing importance should be placed on enhancing any design feature that might improve urban mood and remove barriers to social cohesion, hence reducing urban loneliness and the vast human suffering that will otherwise result.

Declaration of Conflicting Interest

The author has no conflicting interest in the publication of this manuscript.

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