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EXAMINING THE VISUAL EFFECT OF TRYPOPHOBIC REPETITIVE PATTERN IN CONTEMPORARY URBAN ENVIRONMENTS: BAHRAIN AS A CASE FOR MIDDLE EAST COUNTRIES

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Abstract. New building materials and design technologies such as design parameterisation allow for the creation of unusual architectural elements composed of spatially repetitive patterns. Images with specific spatial properties, as from repetitive patterns, may cause psychological and physiological reactions, in some cases leading to severe discomfort, headaches or seizures. Clusters of roughly circular shapes, often hollow, are also known to create reactions such as sickness and vomiting in certain individuals. The phenomenon is known as trypophobia. Because trypophobia has only recently been described and is not widely recognised, we undertook a survey of the public reaction to trypophobic images, as well as to patterns that are known to have a neurological effect, *viz.* patterns of stripes. The study investigates whether the two types of pattern are similarly aversive and examines the extent of the aversion to find out whether trypophobia needs to be considered when designing buildings. We showed a variety of images to 405 members of the public to gauge their reaction. In some instances, the reaction was profound: one person vomited. The findings suggest that reactions to stimuli in the built environment are significant enough to provoke a debate on the role of visual discomfort in architecture and sustainable urbanism. It seems important to further investigate the properties of architectural shapes that induce discomfort so as to avoid a public health concern in contemporary urban environments.

Keywords: contemporary urban environments, sustainable urbanism, parametric architecture, visual discomfort, repetitive patterns, trypophobia, headaches.

Introduction

The design of buildings involves a complex interplay between economic, structural, ergonomic and aesthetic requirements. New materials and building technologies have relaxed the structural constraints that existed in the past, giving a greater freedom for design, including design that is parametric – the result of computer algorithms. Nevertheless, the greater freedom for designers is offset by new constraints. With the gradual advance of the social and biological sciences the ergonomic and aesthetic aspects of design are now imposing greater constraints than previously. This is because some designs are intrinsically uncomfortable to look at and are known to have adverse effects on health. For example, certain patterns of stripes can induce discomfort, headaches and even seizures. The patterns responsible for these adverse effects have been thoroughly described. In brief, the most provocative patterns subtend a large angle at the eye, and consist of repetitive high contrast contours, usually stripes, with a spatial frequency close to 3 cycles per degree. Sometimes, the patterns are a product of modular construction, but often they are simply used for decoration, see Figure 1.

Natural images mostly have consistent spatial properties that the human visual system processes efficiently, and little discomfort is stimulated by such images. However, when images have an excess of contrast energy at mid spatial frequencies relative to that expected in natural images they result in visual discomfort, and the possibility of headaches and seizures in vulnerable subjects (Fernandez & Wilkins, 2008). The patterns of stripes referred to above are one example. Aversive patterns such as these give rise to a relatively large usage of oxygen by the brain, even in healthy individuals (Cole & Wilkins, 2013), and this oxygen usage helps to explain why they are uncomfortable to look at. The excess oxygen usage is

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Figure 1. Examples of parametric architecture
(ArchDaily, 2019)

predicted by computational models of the visual cortex of the brain, which suggest that uncomfortable repetitive patterns induce a large neural excitation. This is true not only of patterns of striped lines, but also patterns of dots or holes. Some individuals find clusters of circular objects rather than stripes aversive, although the reasons for this aversion (named trypophobia) are not known. The phenomenon is nevertheless well documented, occurring in a substantial minority of the population.

Recent developments in parametric architecture result in building designs that feature repetitive patterns, including patterns with the potential for unwanted adverse effects. Because the phenomenon of trypophobia has only recently been described and is not widely recognised, we undertook a survey of the public reaction to trypophobic images, as well as to patterns that are known to have a neurological effect, such as patterns of stripes. We wished to see whether the two types of pattern were similarly aversive (as the computation models predict). We wished to study the extent of the aversion in order to find out whether trypophobia needs to be considered when designing buildings. We showed a variety of images to 405 members of the public. We wished to gauge their reaction. In some instances, the reaction was extreme: one member of the public vomited.

1. Literature review

The design of buildings has a significant impact on the quality of the urban environment and the wellbeing of city residents. It is already known that the shape of a building and the buildings' form, design, patterns, colours as well as daylighting can affect the visual comfort of people (Belichambers & Godby, 1972; Shen et al., 2014). Dornbusch and Gelb (1977) consider the aesthetics of buildings as the most important criterion in evaluating environmental quality and users' productivity. The aesthetics of buildings were also linked to visual recognition -a significant cognitive phenomenon of visual reasoning- in the theories of Design Emergence that can be reflected in architecture (Oxman, 2002).

The new algorithmic design parametrization process often leads to a lack of critical understanding of the logic behind the architectural forms produced today. These newly defined algorithms result in unconventional accidental shapes consisting mainly of hollow, curved and striped forms that may affect the visual perception, judgment and recognition of people (Bar & Neta, 2006). Yuan and Yi (2012) weighed the advantages and disadvantages of parametric design, arguing that parametric architecture emphasizes a sense of movement and fluidity that is

different from traditional architecture and that although parametric designs are considered strange, they are generally comfortable, unique and induce a positive psychological feeling.

Trypophobia is a bizarre, but common, irrational fear of clusters of holes with roughly circular shapes (Cole & Wilkins, 2013; Kupfer & Le, 2017). The word "Trypophobic" is relatively new, and researchers have been trying to come up with a well-accepted definition of the condition (Chaya et al., 2016). The finding that clusters of convex shapes did not induce significantly less discomfort than clusters of concave shapes of similar contrast, suggests that what has been previously known, as "The fear of holes" is actually an aversion to images with a particular spectral profile (Le, 2015). It has been suggested that not only clusters of holes or bumps cause discomfiture, but also clusters of other entities, like eyes, could stimulate disgust (Chaya et al., 2016). The former challenges the belief that trypophobia merely relates to the fear or disgust of the presence of parasites and infectious diseases. Cultural differences might also be a factor because, Japanese speakers were found to experience more discomfort than English speakers (Chaya et al., 2016). No empirical evidence has looked at the existence of such reactions in other cultures as yet. Thus, this study will look at the existence of similar reactions in the middle east with a particular focus on Bahrain.

The discomfort upon viewing such clusters of shapes has been associated with the disease avoidance emotion, disgust, in addition to other symptoms of anxiety and fear. Skin related symptoms like itchiness or skin crawling were observed and, in some cases, physiological symptoms like nausea and shortage of breath (Kupfer & Le, 2017; Le et al., 2015; Le, 2015). It is still unclear why the trypophobic populations feel the way they do, and in many attempts to justify their reactions, trypophobia has been allied with psychological disorders such as depression, general anxiety, and obsessive-compulsive disorder. Recent studies showed that although the majority of the trypophobic population experienced disgust rather than fear, they are more likely to meet DSM-5 criteria for specific phobia than for obsessive- compulsive disorder (Vlok-Barnard & Stein, 2017).

There is no widely accepted figure for the percentage of the population that experience trypophobia. Numbers between 13-17% are suggested in the literature for the UK and most were generalized from relatively small research samples of about 200 participants. Vlok-Barnard and Stein (2017) suggested that women are more affected by trypophobia than men and that the condition was persistent and chronic with an average onset in the teenage years. They also observed that a family history of the condition was common and that the majority of self-diagnosed individuals had never sought treatment.

It is evident from the increasing number of online support groups and blogs that trypophobia is common; an increasing number of the population is becoming aware of the condition. While Ruggiero et al. (2009) suggested that traditional architecture was typically linked to visual comfort, (Ostwald, 2004) claimed that digital architecture has become a nihilistic playground for many designers who are enthusiastic about generating new forms. Little empirical evidence links architecture and visual discomfort and very few peer- reviewed articles have assessed the effect of contemporary architecture on the trypophobic population. Ruggiero et al. (2009) discussed the correlation between visual discomfort and the main principles of traditional architecture such as symmetry and repetitive simplicity. Wilkins et al. (2018) argued that aversive patterns are unusual in the natural environment but predominant in contemporary designed environments. Their study proposed some simple ways of avoiding adverse effects from visual environments. They stressed the importance of including visual stress as a criterion in urban design.

Visual discomfort is common in migraine. Marcus and Soso (1989) investigated the relationship between migraine and stipe-induced visual discomfort. In their study 82% of migraineurs were stripe sensitive. According to previous studies summarized by Afra et al. (1998) migraine patients are found to be more sensitive to environmental light stimuli and report discomfort after visual stimulation with grating patterns. Moreover, Huang et al. (2003) indicated that migraineurs with visual aura are found to be highly susceptible to visual distortion caused by parallel lines or stripes and regularly spaced patterns, as can be seen in parametric architecture building forms and facades. The recent four studies conducted by Le et al. (2017) linked the effect of photographs of buildings and their modern urban settings that were sometimes uncomfortable to look at. The cortical hemodynamic response was of higher amplitude in response to urban images that had unnatural statistics and were uncomfortable. Hence, the visual properties of buildings and their urban settings are important for brain metabolism and occupant health and comfort.

The present study shows that some of the contemporary architectural design solutions depart from the spatial properties the visual system processes with ease, and that some may pose a health hazard.

2. Methods

A group of seven senior architecture students were hired by the research team to visit diverse public places in Bahrain (Locations are detailed in Table 1) to collect responses to the survey. To avoid bias in the selection of the sample of participants, the research team chose the second person that passed by them regardless of the persons' gender, background, nationality or ethnicity. Furthermore, due to the possible adverse reactions to the pictures in the survey, all participants were screened to ensure that they were at least 18 years of age and and were able to give consent for their participation in the survey. Prior to their consent, participants were briefed about the conditions of their voluntary participation in the study and the possible psychological and physiological reactions they could encounter.

Table 1. List of public places and the socio-economic status of the sample

Areas	Shopping Malls	Public Markets	Public Parks	Villages	Gyms	Hospitals	Universities
Varied	Middle-High Income	Low-Middle Income	Low-Middle Income	Low income	Middle-High Income	Varied	Varied
Buquwah	Saar Mall	Riffa Central Market	Budaya Park	Saar Village	AlNakheel Gym	Alsalmaniya Medical Complex	University of Bahrain, Isa Town
Salmaniya	AlNakheel Center	Manama Central Market	Khalifa Park-Hidd-	Bani Jamrah Village			
Isa Town	AlAali Mall	Muharraq Central Market	Dohat Arad				
Saar	Dana Mall	Bukuwara Street					
Budaya	City Center Bahrain						
Riffa	Seef Mall-Manama-						
Amwaj	Seef Mall-Muharraq-						
Hidd	The Avenues						
Adliya	Oasis Mall-Muharraq-						
Janabiya	Mercado						

The project received ethical approval from the Research Ethical Committee at the University of Bahrain.

A 17-item questionnaire was administered at the outset to obtain baseline data. The participants were asked to select their preferred language and were then asked to fill in the survey in English or Arabic using an iPad with a 9.7″ Retina display. From the 17 questions, four referred to demographic data and four pertained to the logistics of administering the questionnaire to record when and where it was administered and by whom. Two of the remaining nine questions were taken from the Trypophobia Questionnaire (TQ) (Le et al., 2015).

As in the TQ; question 6 of the survey showed two images of natural objects that are likely to induce trypophobic reactions. The photographs depicted a lotus seed pod and a honeycomb. Both images were shown in colour and are given in Figure 2. Upon viewing the images, participants were asked to rate on a scale from "5. Extremely" to "1. Not at all" the degree to which they felt the reactions listed below:

- Feel skin crawl.
- Feel aversion, disgust or repulsion.
- Feel uncomfortable or uneasy.
- Shiver.
- Feel freaked out.
- Feel itchiness.
- Chills.
- Have goosebumps.
- Feel nervous (e.g., heart pounding, butterflies in stomach, sweating, stomach ache, etc.).
- Feel anxious, full of dread or fearful;
- Feel sick or nauseous.
- Feel like going crazy.
- Feel like panicking or screaming.
- Have an urge to destroy the holes.
- Have trouble breathing.
- Feel like crying.
- Vomit.

The reactions above consist of three categories of symptoms 1. Cognitive related 2. Skin-related 3. Physiological (Le et al., 2015). In addition to the TQ questions, question 7 of the survey presented another two images of parametric architectural design elements (Figure 3) for the participants to rate in a similar way. The images that induce discomfort headache and seizures are well described and they share spectral features in common with images that induce trypophobia. Question 9 asked the participants to rate on an 11-point scale ranging from "Never" to "2-3 times a day" the frequency of headaches they have had in the last year. Question 10 asked the participants if they suffer from migraines and if yes, to indicate if their migraine symptoms usually occur with or without an aura. A definition of migraine aura was provided to the participants with this question.

Question 11 of the survey showed two images of stripes common in the urban environment, one of an exterior façade of a building with stripe panels and the other of shade and shadow created by a striped shading panel, see Figure 4. Participants were asked to evaluate on a five-point scale ranging from 1. "not at all" to 5. "extremely",

the likelihood of the buildings shown in the image to give them a headache.

At the end of each completed survey, the observers from the data collecting team used the same questionnaire to report if they thought that the participant was trypophobic or not, based on their apparent reaction on seeing the photos. The gathered data was collated and stored online on a secure platform. The data were initially assessed using the tools made available online via the platform, then organized using Microsoft Excel and processed using Microsoft Excel and SPSS.

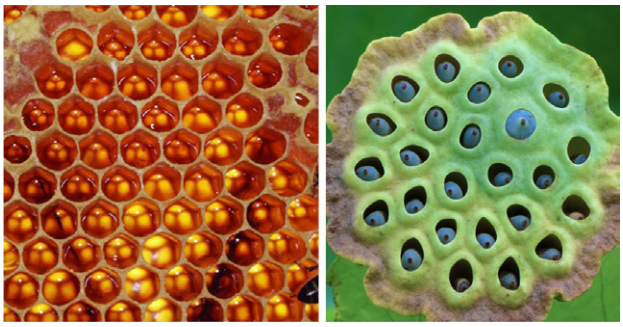

Figure 2. The honeycomb and the lotus seed pod

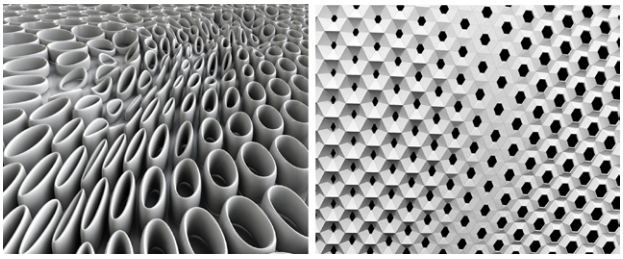

Figure 3. Design elements created using parametric design with similar spatial properties to the natural images

Figure 4. Stripes in the contemporary urban environment

A pilot study with 117 participants (73 English and 44 Arabic) was used to test the questionnaire. Some of the questions were then adjusted for easier data processing and the questions for the internal quality control were added. The results of the pilot study were presented at the Sustainability and Resilience 2018 conference.

3. Results

The survey was administered to 264 English and 141 Arabic speaking residents of Bahrain. Overall, 233 female and 172 male participants took the survey. The average response time was approximately 9 minutes.

3.1. The trypophobic population in Bahrain

57.5% of the participants indicated that trypophobic images never affect them and can therefore be unequivocally classified as non-trypophobic. 42.5% of the participants indicated that trypophobic images had an effect on them at least once every few years, see Table 2. A larger number showed more severe reactions towards natural stimuli; 17.3% of the participants indicated that trypophobic images affect them once every month or more and 10.4% of the participants indicated that trypophobic images affect them once every week or more. Le et al. (2015) suggested that TQ should be used as an initial measurement for trypophobia and that a score above 31 (in a range from 17-85) is likely to be drawn from the cohort of participants who report trypophobia.

Table 3 shows that 74 out of 405 participants reported average TQ scores above 31 to the natural images, which would indicate that 18.3% of the sample were trypophobic using the criteria suggested by Le et al. (2015), 13.3% of the sample had high TQ scores using the same criterion (TQ score above 34).

Table 2. Frequency of disturbance by trypophobic stimuli (Natural)

Never	At least once every few years	At least once per year	At least once every 6 months	At least once every 3 months	At least once per month	At least once every fortnight	At least once every week	Two to three times each week	Daily	Two to three times a day
57.5%	6.2%	9.6%	4.2%	5.2%	4.9%	1.7%	3.5%	1.7%	4.0%	1.5%

Table 3. Trypophobia Questionnaire (TQ) scores to the natural images

TQ Score	>17	>31	>34	>35	>50
Number	246	74	54	51	20
Percentage	60.7%	18.3%	13.3	12.6%	4.9%

3.2. Reactions towards natural stimuli

The most severe reaction reported during data collection was not actually logged. One participant vomited immediately after seeing the images. The data collector comforted the participant and made sure that he was okay, but he was unable to complete the survey. The most and least commonly reported emotions experienced are outlined in Table 4. The three emotions least commonly reported were, surprisingly, the three that best separated the trypophobic population from the non-trypophobic. Since 18.3% of the sample of 405 participants reported a TQ score > 31, based on a confidence level of 95% and a confidence interval of 4.9%, we can infer that between 13.4% and 23.2% of the population of Bahrain might suffer from trypophobia. 13.3% of the population in Bahrain suffers from trypophobia to a high degree (TQ score > 34) with confidence limits of 10.4–17.0%.

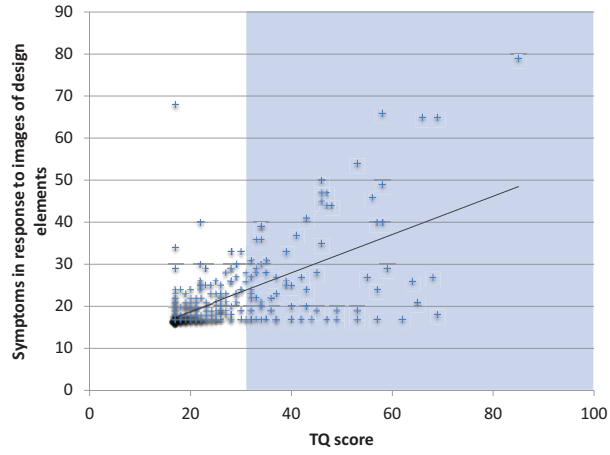

Figure 5. Number of symptoms in response to images of design elements as a function of the number of symptoms in response to the lotus seed pod and honeycomb (i.e. TQ score)

3.3. Difference in reactions to natural stimuli between Arabic and English Speakers

There were no significant differences between Arabic and English speakers. For the natural stimuli, 23 (16.4%) of the Arabic speakers (140 participants) scored above 31 in the TQ compared to 51 (19.2%) for the English speakers (265 participants).

3.4. Difference in reaction between natural and designed stimuli

The TQ showed images of the lotus seed pod and the honeycomb, and responses to these images were subsequently compared to two images of parametrically designed building elements (Figure 3). The number of symptoms in response to the seed pod and honeycomb was significantly greater than to the design elements ($t(404) = 7.96$, $p < 10^{-13}$), but there was a positive correlation of 0.64 between the number of symptoms reported to the design elements and those to the lotus seed pod and honeycomb, as reflected in the TQ score, see Figure 5.

3.5. Relationship between headaches, stripes in buildings and trypophobia

Table 5 shows the frequency of headaches experienced by the participants in the last few years. 27.9% participants indicated that they suffer from migraines: 73/233 (31.3%) of the females, and 40/172 (23.3%) of the males. 18.3% of respondents reported that they suffer from migraines without aura and 9.6% reported an aura. The reports of migraine are therefore almost double the estimated global prevalence of migraine (14.7%; Steiner et al., 2013) suggesting that many of the participants experienced headache that would not typically be classified as migraine.

62.0% of respondents indicated that striped buildings were likely to cause them headaches to some extent. The details of the effects of striped buildings on the participants are outlined in Table 6. 13.6% of the participants indicated that it is considerably or extremely likely that striped buildings will cause them headaches. This relationship between striped images and the precipitation of headache has been described before (Marcus & Soso, 1989).

Table 4. The most and least reported emotions

Most reported emotions				Least reported emotions		
Feeling uncomfortable or uneasy	Having an urge to destroy the holes	Feeling aversion, disgust or repulsion	Feeling skin crawl	vomiting	Having trouble breathing	Feeling like crying
15.1%	11.9%	9.9%	8.9%	3.0%	1.7%	1.5%

Table 5. Frequency of headaches

Never	At least once every few years	At least once per year	At least once every 6 months	At least once every 3 months	At least once per month	At least once every fortnight	At least once every week	Two to three times each week	Daily	Two to three times a day
16.8%	2.0%	4.7%	7.7%	6.4%	17.5%	6.2%	15.3%	11.4%	10.2%	2%

Table 6. The likelihood of striped buildings to cause headaches as indicated by the male and female participants

	Gender	Not at all	Slightly	Moderately	Considerably	Extremely
Number	Female (N = 232)	79	72	43	35	4
Percentage		34.00%	31.00%	18.50%	15.10%	1.70%
Number	Male (N = 171)	75	50	31	13	3
Percentage		43.86%	29.24%	18.13%	7.60%	1.75%

Nevertheless, no empirical evidence of such relationship exists in relation to architecture.

13.6% of the sample reported that the stripes on buildings were "considerably" or "extremely" likely to induce a headache. Interestingly, the correlation between TQ score and headache incidence was low (0.13). 29/74 (39.2%) Individuals with TQ scores > 31 professed migraine whereas only 84/331 (25.4%) with TQ scores below 32 did so, a significant association of migraine with trypophobia (p = .024).

4. Discussion

Individuals who gave symptoms suggestive of trypophobia when exposed to natural images were also adversely affected by the samples of designs from parametric architecture. A substantial proportion of those who professed migraine thought that striped buildings were likely to induce headache. These findings suggest that designers could take into account the adverse effects of repetitive designs on the significant proportion of the population who are sensitive to such patterns. The spatial properties of the striped patterns that give rise to discomfort, headaches and seizures have been well described in the literature. The designs that give rise to trypophobia are less well described, although they can be quantified by Fourier analysis. When applied to an image, Fourier analysis describes that image in terms of the variation in contrast, spatial scale and orientation of component simple patterns from which the image can be constructed. It shows that images from nature have the characteristic that the amplitude of components is proportional to their wavelength, i.e. to 1/f. Both categories of aversive images have an amplitude spectrum that departs from 1/f, with an excessive amplitude at mid-spatial frequencies (Cole & Wilkins, 2013; Fernandez & Wilkins, 2008).

The proportion of the population affected by clusters of circular objects in this study is broadly similar to that reported by Cole and Wilkins (2013) and Le et al. (2015) and slightly lower than that reported by Chaya et al. (2016).

The reaction of the participants was stronger to the Lotus Seed Pod and honeycomb stimuli than to the images designed by parametric algorithms. That is in line with the idea that the reaction induced by trypophobic stimuli reflects ancestral threat and has survival importance (Van Strien & Van der Peijl, 2018). Nevertheless, the aversion to the stimuli are still substantial enough to provoke a debate on the role of trypophobia in architecture and the urban environment as highlighted by Le et al. (2017).

Given that uncomfortable visual stimuli can be identified in terms of their spectral content, it should be possible to set guidelines within design software that draw attention of designers to the possibility of their designs being problematic. The algorithm developed by Penacchio and Wilkins (2015) could be useful in this regard. Ostwald (2004) suggested that contemporary digitalised architecture is now becoming a destructive concourse for architects who are attentive to generating atypical forms. This shift in contemporary architecture has challenged the expectations, theories and basic design principles that were for long the basis of a solid architectural education (Terzidis, 2004).

Some researchers have questioned the effectiveness of the TQ in accurately identifying the existence of the condition and measuring its scope, but no alternative measuring instrument for the condition yet exists. Imaizumi and Tanno (2018) investigated the Rasch-based psychometric properties of the questionnaire assessing proneness to trypophobia. Their research concluded that although they were able to marginally improve the psychometric properties by using the Rasch model, their results were not conclusive enough to decide whether another version of the TQ should be adopted.

Conclusions

Parametric architecture is becoming increasing popular in architectural design, both in the profession and in academia. This research has presented empirical evidence that trypophobic images are a common component of parametric architecture. It is therefore recommended that generative computational software like Grasshopper add an algorithmic plug-in that calculates the level of trypophobia and visual discomfort from its generated architectural designs. In this way the type and depth of the cluster of holes and lines generated for a building skin could be balanced to a comfortable level for both the occupants and viewers. It is also recommended that students of architecture be educated about the phenomena of trypophobia and visual stress and their effect on users. We propose that visual discomfort from design be considered within building codes and regulation so as to permit creativity within the built environment without jeopardizing occupants' health.

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