Developing a virtual urban oasis design to reduce urban stress in warm-humid climate

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Abstract. Dense cities around the world, including those in the warm-humid climate, develop very fast by urbanization. Natural sceneries are commonly limited in those cities, which some experts said links to urban stress syndrome. The urban oasis, a relatively small pocket park located in urban gaps or between buildings easily accessible to the surrounding community, is needed to reduce the urban stress. However, designing an urban oasis and building it for granted does not guarantee its therapeutic effect. Meanwhile, current advanced virtual reality technology offers the ability to explore the therapeutic impact of urban oasis design before it is built. This research reports the development of a virtual urban oasis based on its effect on human stress. The experiment adopted a virtual reality method with Unreal Engine 4 software to construct a virtual urban oasis based on preceding theoretical reviews on reducing urban stress. Three respondents wore Head Mounted Display (Oculus Rift S) submerged in the virtual urban oasis while POLAR H10 recorded their heart rate (HR) and heart rate variability (HRV). The experiment found that the virtual urban oasis decreased the HR and increased the HRV by consecutively, 11% and 8%. Thus, the virtual urban oasis helped reducing stress.

Keyword : Unreal engine, urban stress, heart rate variability

1. Introduction

Feeling or experiencing natural conditions has been scientifically proven to provide many positive effects on the human body and mind, such as stress recovery [1], mental fatigue, and depression [2], as well as concentration, attention, memory, stress, and mood [3]. Research also shows that looking at natural photographs can positively affect emotional states and performance [4].

However, in today's modern life, the natural atmosphere is increasingly difficult to obtain, especially in crowded big cities. High levels of stress in urban areas are mostly caused by adverse environmental conditions such as low housing quality, high-density population, excessive noise, and air pollution. Those stresses trigger negative behaviors (social pathologies) such as drug addiction and alcohol, excessive drug use, rape, and other criminal acts [5]. That is known as urban stress and is commonly found in big cities.

Bringing nature into urban areas balances the natural environment and the built environment that is useful for the community [6]. However, getting nature into the city has problems and challenges. In urban planning, the benefits of nature on health and well-being are not fully recognized yet, so there are many conflicts of interest in land use [7].

The increasing urbanization disturbs the availability of green spaces in the city. Green spaces are reduced, causes a lack of space for greening or public open space in the city area. People who live and
work in urban environments become far from natural environments. They need to travel a long distance to reach a natural environment. Urban greening should be easily achieved and enjoyed for free by all levels of society. Urban parks, for example, offer many benefits for humans [8][9][10].

The urban oasis is a concept to present the natural environment in urban areas. In contrast to urban parks, urban oases are public spaces in the form of pocket parks located between buildings or formed by nearby buildings in urban areas, aiming as a resting place to escape from urban stressing conditions. Many theories and studies have proven that a natural environment has a restoration effect on the human. However, there is still little discussion about the effectiveness of an urban oasis in reducing stress. Therefore, it is difficult for urban designers and architects to design urban oases. This research tested a virtual urban oasis design's effectiveness in lowering urban stress before it proceeds to the construction stage.

2. Theoretical Review

2.1 Restorative environment
Enjoying the atmosphere and natural beauty provides tranquility and relief for the human body and mind. Contradictory, an urban atmosphere, especially a crowded city center, triggers mental stress called urban stress. The surrounding physical environment influences the psycho-physiological stress conditions of the human body. A natural environment that provides renewal to one's adaptive resources to meet everyday life demands is called a therapeutic or restorative environment [1].

Research on the stimulating environment has been done for a long time. There have been many studies and theories produced and developed to uncover the natural environment's therapeutic ability. Problems regarding the urban stress and nature’s ability to restore it were answered in the 19th century with the theory of intuitive-based beliefs, which later resulted in Central Park's design in New York City by Frederick Law Olmsted in 1857. That continued to bring changes to urban parks and urban design today [11]. In addition to Olmsted (1865) intuitive-based views, several other ideas include arousal, overload, evolutionary, which then produce theories including psycho-evolutionary theory, stress recovery theory, and attention recovery theory. Opinions agree that the natural environment will provide healing to one’s psychological or physiological state, but have different ideas about why or how it happened. In summary, theories of the restoring effects of an environment can be seen in Table.

| No. | Theory or outlook          | Idea of recovery                                    | Results                        |
|-----|---------------------------|----------------------------------------------------|--------------------------------|
| 1   | Intuitive                 | trees, water, and other natural elements           | improve psychological health and reduce stress |
| 2   | Arousal                   | passion, complexity, intensity, and movement hinder recovery | recovery of excessive passion and stress        |
| 3   | Overload                  | low complexity and other stimulation               | stress recovery                  |
| 4   | Evolutionary              | natural physical environment (vegetation, water, etc.) | stress recovery                  |
| 5   | Psychoevolutionary        | safe natural environment (not dangerous or threatening) | stress recovery                  |
| 6   | Stress Recovery Theory (SRT) | natural physical environment                        | recovery of psychological stress |
| 7   | Attention Restoration Theory (ART) | the natural environment that meets aspects of being away, soft fascination, extension, and compatibility | recovery of mental fatigue (focus and concentration) |
There are several different approaches regarding the value of natural restoration to humans. Still, all are interrelated and support one another in arguing that contact with nature has a physical and mental restoring effect on a person. For example, Attention Restoration Theory has long claimed that exposure to the natural environment improves concentration [12]. The following theories are worth considering to trigger restoration (recovery) effects on a physical environment:

- Natural physical environment, such as trees and water are preferable [13]. Visual contact with nature improves well-being [14]. Natural sounds (even artificially made) have been proved to give health benefits [15][16]. Natural forms offer a tremendous impact on health, whether in natural or artificial elements [17].
- Distracting (annoying) elements should be avoided. However, a soft fascination that attracts someone's effortless attention, such as views of clouds, sunset, snow, foliage movements, is desirable.
- Certain physical environments, such as historical artifacts, can form a unique atmosphere that washes away or carries away someone's feeling immersed in that environment.
- Informative (non-confusing) environment is advantageous as people can enjoy the atmosphere and move around effortlessly.
- Impression of a dangerous environment, either physically hazardous or making someone have the appearance of looking strange or misbehaving, should be absent.
- The environment elements should not remind someone of his/her works or daily tasks.
- The environment should not require preparation or anticipation of difficult situations.

2.2. Urban oasis in the warm-humid tropical climate

By history, an oasis is a fertile place in the desert where water is found. Nowadays, an oasis is also used to represent a comfortable and quiet place within a busy or crowded environment [18]. An urban oasis can be interpreted as a place that is comfortable and quiet in the middle of urban areas. An urban oasis in the city is a public space in a park or plaza located between buildings or formed by surrounding buildings in urban areas, usually under 1000m² [19]. A study on warm and humid urban areas proves that a city park will be colder than the built area surrounding it and create a Park Cool Island (PCI). Oke explains this phenomenon as an oasis effect produced by vegetation [20].

Warm-humid cities receive a large amount of solar radiation that heat them. Those heat must be released immediately. Urban structures reduce wind speed in the cities that those cities cannot disperse the heat. Therefore, the urban structures must be appropriately designed so that the wind can remove the heat trapped in the urban areas [21].

The evapotranspiration of plants and evaporation of water reduce urban heat islands. Water that has a lower temperature than the environment will work as a cooler. In this method, water has a role as a buffer for the diurnal temperature cycle to cool the environment throughout the day and make it cold at night. The problem occurs when the water reaches higher temperature levels during the summer. They will act as a night-warming element and be detrimental to thermal comfort [22].

2.3 Human experience in a public space

There are several ways to deconstruct and articulate public spaces to make them useful for users [23]. Some ways focus on how a public space affects the user’s emotion. The other ones consider how users see and feel those spaces and how they influence users' psychological comfort. All ways show that space affects one's emotions, sense, and comfort through the human sensory system.

Stress is the body's response to maintain a stable (homological) state to stimulation that damages mental and physical balance and body stability [24]. When experiencing stress, the human body undergoes specific physical changes. Chemicals in the form of adrenaline, noradrenaline, and cortisol enter the blood and cause changes. Those changes include increased respiratory rate, blood switches from the digestive system to the muscles and legs to increase strength, raise awareness, sharpen vision, increase impulse speed, reduce pain perception, and activate the immune system [25]. At work, stress helps us to stay focused, excited, and alert. In an emergency, stress can trigger more energy to protect
ourselves. But beyond a certain threshold, stress ceases to be beneficial and causes damage to our health, mood, productivity, relationships, and quality of life [26].

2.4 Perception
Perception is a process when a person feels his/her physical environment. The process is recognizing, compiling, and interpreting sensory information. Perception produces human consciousness that is created from the environment through the five senses that they have, namely the sense of sight (eyes), sense of smell (nose), sense of hearing (ears), sense of taste (tongue), and sense of touch (skin) [27]. The five senses have essential independent functions but mutually influential in shaping the overall perception [28].

In perception formation, there is a phenomenon called the McGurk Effect, which explains that a sense will affect other senses in shaping perception in our brain, especially vision and hearing. Visual effects can strengthen us in perceiving sound, but the opposite can also weaken if the visual and audial are not synchronous [28]. Besides, perception is also influenced by past experiences, expectations, and even assumptions that, together with our senses, shape reality in our minds [29].

This research focuses on how the environment affects a person's stress level based on two senses, namely sighting and hearing. Sighting is the most widely associated perception factor in studies of the relationship between urban greening and human well-being. Meanwhile, studies have shown that hearing has a strong relationship with visual influence on perception [30].

3. Method
This study adopted four stages: literature review, qualitative analysis, computer modeling, and experimentation. The first step was to gather theories about how an environment could be therapeutic for human stress. The application of these theories to the urban oasis design was expected to create an area capable of reducing one's anxiety. The literature study examined two sides: how the environment affected one's emotions, sense, and comfort (restorative theory) and how one felt the environment (perception theory). Scents did not involve in this research though they affect human mood [31].

In the second stage, a qualitative analysis was carried out on the results of the literature review. The result of this stage was a set of urban oasis design guidelines. At this stage, aspects that could help a person experiencing stress reduction in the restorative environment were identified. The compiled theories were used in the next step, namely the stage of computer modeling. This fourth stage was to virtually model an urban oasis. The Unreal Engine 4 software was used to explore its virtual reality technology to design a virtual realistic urban oasis. The virtual urban oasis was then tested on respondents to measure the level of its refreshing effect. Respondents were computer literate people so that computer-related stress could be ignored. The test room used natural air to mimic urban open spaces. At the time of the experiment, the temperature was 28°C - 31°C with humidity 75% - 85%.

Three main tools were used in this research. One computer unit with AMD Ryzen 3600 processor, VGA GTX 1070, and 16GB RAM was used. For Virtual Reality, Oculus Rift S was used, which consisted of two parts, namely the Head Mounted Display (HMD) and two motion controllers (Figure 1). The HMD was equipped with a motion sensor. A motion controller was used to navigate and give the command. The heart rate monitor used Polar H10 (Figure 2). The virtual urban oasis was created using Unreal Engine 4 software based on the design guidelines to develop restorative effects. Computer-generated natural views had been proven to have a stimulating effect (reducing stress levels, increasing
focus, increasing positive feelings and reducing negative emotions, and decreasing empathetic nerve activity) [32]

Figure 1. Oculus Rift S (Source: www.oculus.com)

Figure 2. Polar H10 Heart Rate Sensor, electrocardiogram (ECG). (Source: https://www.polar.com)

Polar H10 is an electrocardiogram (ECG) tool that measures electrical activity in the heart. This tool has electrodes to measure the heart rate accurately. It is used by sticking it to one’s chest. The measurement results were processed directly using the Elite HRV application and were converted to heart rate variables (HRV), which showed the stress levels.

Figure 3. Setting up the virtual urban oasis with Unreal Engine 4. (Source: authors).

4. Findings and Discussion
A virtual reality urban oasis was created using Unreal Engine 4 software (Figure 7). The design of that virtual urban oasis was based on the guidelines derived from references and was qualitatively analyzed. A piece of land of an imaginary city was divided into two parts: the urban area and the urban oasis area. The urban area (stressor) was prepared directly from the Unreal Engine 4 marketplace named Modular Building. It was modified according to sound, lighting, shape, and elements to achieve the desired stressor atmosphere. The urban oasis (the restorative environment) was placed in one corner of the urban area (Figure 4). Respondents explored the urban oasis for five minutes to get used to it and then conducted a heart rate test in those two areas to measure the stress levels difference.
Figure 4. Part of the city was modeled in virtual reality using Unreal Engine 4. (Source: authors)

Figure 5 and Figure 6 show the virtual urban areas. Those figures show images of a city that does not have a park area and only consists of tall buildings. The site will be felt hot during the day and night. This urban scenery was designed to see the people's differences when walking around the buildings and when entering an urban oasis.

Figure 5. A human’s eye view of the urban area. (Source: authors)

Figure 6. A bird's eye view of urban areas. (Source: authors)

Figure 7 shows a quiet urban oasis part. The urban oasis was located two meters lower than the pedestrian so that noise from the city environment can be reduced to around 38dB. Under normal
circumstances, urban noise ranges from 60 to 80dB. A 38dB reduction (from 80dB) makes the urban oasis noise level 42dB. That is relatively quiet. Trees were selected from dense tropical trees with lush and light leaves to create a dynamic shadow effect and have a maximum cooling effect when the city's air temperature is high. Another consequence is the tropical trees can provide wind pressure in the urban oasis area. It makes the heat stress in the area lower than the surrounding area so that pedestrians in the urban oasis area do not feel the urban heat. The leaves will rustle when blown by the wind and have a calming effect. The urban oasis’s colors are dominated by natural colors such as green leaves and brown wood.

Figure 7. The urban oasis was placed on land subsidence to reduce noise from the urban environment. This reduction reduced noise up to 38dB. Trees with bushy leaves were chosen to provide dynamic shadowing effects and natural sounds. (Source: authors)

Figure 8 Mini waterfalls and fishponds are intended to help urban oasis visitors finding contemplative objects to divert the mind from stressful office works. The waterfall creates the calming sound of water. Water sprinkles from the waterfall give a cool sensation. Water with lower temperatures helps to cool the environment. A pond shaded by trees generates a cooling effect on urban areas and prevents heating the atmosphere at night due to heat absorption during the day.

Figure 8. Waterfalls and ponds give a cool impression. (Source: authors)
The virtual reality of urban oasis’s features included grass, trees, water that move or sway, falling leaves, small animals such as birds [33], flowers [34], fish, and dragonflies. There were also environmental sounds like the sound of the wind, water, birds chirping, and the faintly sound of urban traffic.

The HR and HRV measurement used a POLAR H10 tool. Data processing used EliteHRV software version 4.5 (mobile iOS). HR and HRV measurements were taken twice from the three respondents; each measure lasted for 60 seconds. The first measurement was made in the first five minutes after the respondent explored the urban area and the first five minutes after exploring the urban oasis. Measurements were taken from respondents under normal circumstances (not being sick nor after finishing heavy activities).

Naturally, human has a heart rate that varies between beats, called heart rate variability (HRV). When a person experiences stress, the sympathetic nerve activates the fight or flight response in the body to respond to the surrounding conditions by releasing some chemicals such as adrenaline, noradrenaline, and cortisol. These substances enter the blood and cause several changes, one of which is characterized by an increase in the heart rate (HR) [25]. The higher the level of one’s HR, the smaller his/her HRV. That phenomenon can be used as an indicator of measuring human's stress levels. Among the measurement methods available (in terms of accuracy and without interruption), the HRV method ranks highest in measuring stress levels [35].

Figure 9 and Table 2 show the three respondents' HRV measurements after exploring the virtual urban area and urban oasis using the Oculus Rift S virtual reality headset. The three respondents indicated an average increase of 8% (from 50bpm to 58bpm) in HRV. In other words, the urban oasis design had a stress recovery level of 8%.

![Figure 9. HR and HRV records of the three respondents. (Source: authors)](image)

| Table 2. Result of heart monitoring (Source: authors) |
|-----------------------------------------------|
| Urban area | Urban oasis area |
|-------------------|-------------------|
| Respondent 1 | 53 | 65 |
| Respondent 2 | 59 | 63 |
| Respondent 3 | 39 | 47 |
| Mean | 50 | 58 |

The three respondents' test results showed an average HR reduction by 11% (from an average of 82 bpm to 73 bpm). Meanwhile, the rate of HRV increased by 8% (from 50bpm to 58bpm), which showed the recovery stress levels of 8%.

5. Conclusions
A decrease in heart rate (HR), followed by an increase in heart rate variability (HRV), indicates stress restoration. In general, everyone can experience the restoration of stress naturally, but the environment
can improve the speed and effectiveness of the restoration. The experiment results indicate that the stress level in an urban oasis was lower than that in other urban areas.

Overall, the research found that:

- Urban oasis lowers the urban stress level and can be used as a therapeutic (stimulating) environment.
- Heart Rate and Heart Rate Variability can be used to measure urban stress levels.
- Virtual Reality technology can be utilized to measure an urban oasis design’s healing potentials before it is built.

This research is the first step in finding a better urban oasis design for warm-humid tropical urban areas to reduce stress levels. This study only formulates a general urban oasis design guideline. A further detailed and in-depth analysis of each stress-inducing element, involving more respondents, are needed. A better understanding of the therapeutic role of urban oasis design elements to the human mind is essential before building a real urban oasis, including its application in warm and humid climates. However, considering that a quiet environment is beneficial for reducing urban stress if visitors crowd the urban oasis, the calming effect is no longer practical.

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