Urban Environments, Stress and Its Biomarkers

How do built and natural environments impact human neurophysiology?

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Theoretical Background

Urbanisation has been associated with mental disorders and poor health, common pathological outcomes of stress[1-3]. Stress is a response to stimulating factors, the European Environment Agency defines urban stress as a state of bodily and mental tension associated with urban living [4]. We can measure urban stress using cardiorespiratory or neurophysiological methods and observe changes in its biomarkers, for instance, in blood pressure, heart rate, amygdala activity or cortisol levels.

With urbanisation continuing, it is paramount to understand what exact environmental parameters stimulate urban stress. A contributing factor might be the underlying geometry of urban spaces, since it generates different metabolic demands for the visual cortex[6;7]. However, a link between the physical low-level environmental geometry and stress pathways is yet to be established.

Urban Geometry as a Stressor

The built environment is made of repetitive Euclidean patterns with high contrast energy. Such geometry is demanding for metabolism as it generates a haemodynamic response in the visual cortex and induces visual discomfort.[5; 6]

The natural environment is formed of non-Euclidean fractal patterns our visual system can process efficiently as they require activation of only a small subset of neurons at any given time (so-called *sparse neuronal coding*).[5; 7]

Aim

The overall aim is to establish how exposure to different urban environments and their attributes affects neurophysiological biomarkers of stress.

Objectives

1. Measure the effect of exposure to built and natural environments on stress and its biomarkers.

2. Quantify natural and built scenes by their low-level visual parameters (fractal dimension and contrast energy).

3. Examine if low-level parameters of urban and natural environments contribute to changes in a stress response.

4. Derive a composite score that reflects stress response and adaptation to parameters of the urban environment.

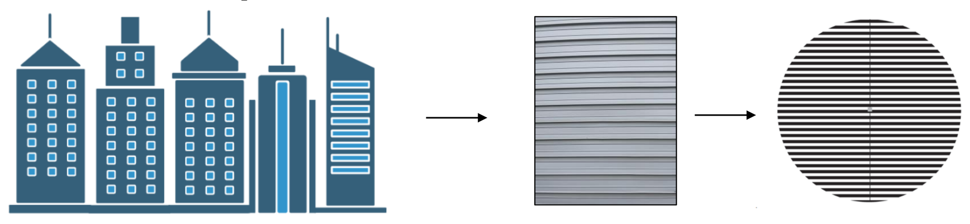
Hypotheses

The built environment will induce stress, natural environments will reduce stress. This will be reflected by changes in alpha activity of the frontal cortex, beta activity of the parietal lobe, haemodynamic response of the visual cortex, amygdala activity, eye fixation, heart rate variability, skin conductance response and cortisol levels.

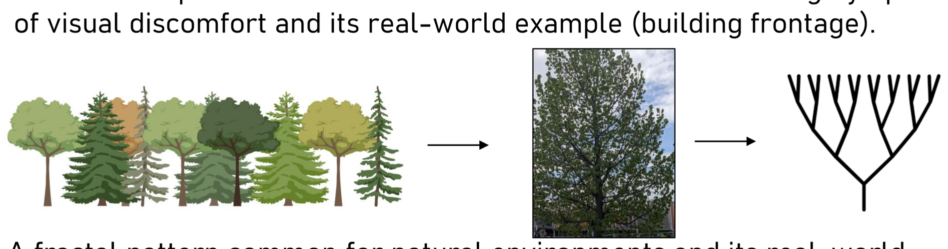
Low-level visual parameters of built and natural scenes will be associated with observed neurophysiological responses.

Stress Pathways and the Assumed Role of Urban Geometry

1 Urban geometry as an underlying visual factor of urban exposure.

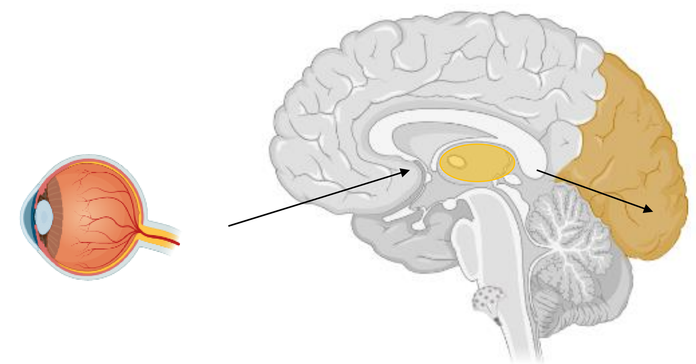


A Euclidean pattern common for urban environments eliciting symptoms of visual discomfort and its real-world example (building frontage).



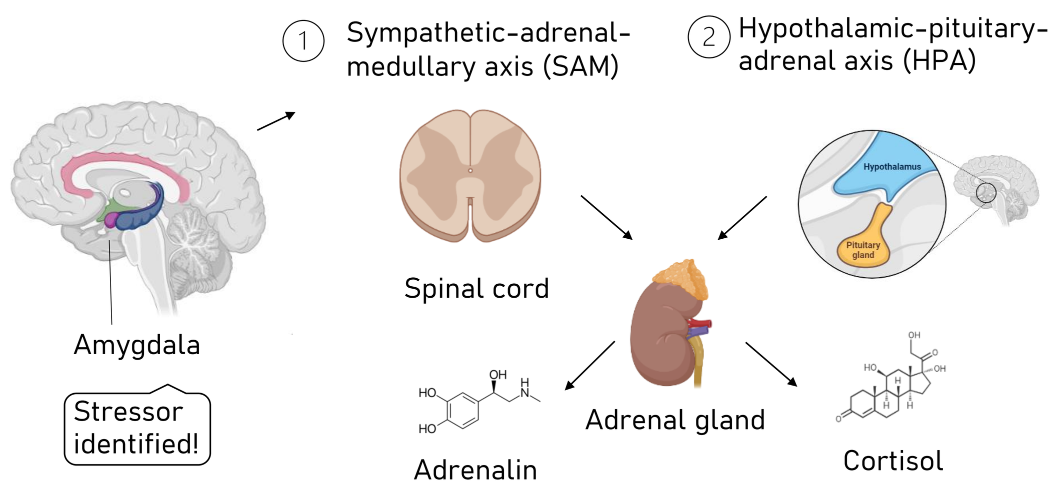
A fractal pattern common for natural environments and its real-world example (tree).

2 Visual processing of urban stimuli.

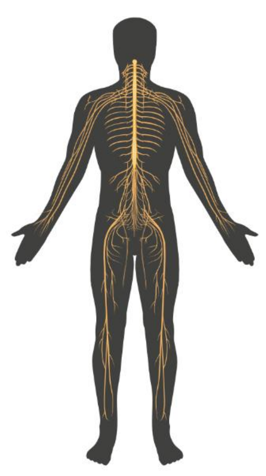


Visual input reaches the thalamus and the primary visual cortex in the occipital lobe.

3 Stress-response pathways following an exposure to a stressor.



4 Stress response.



Cortisol and adrenalin activate a fight or flight response. We can observe this as changes in biomarkers such as the variables below:

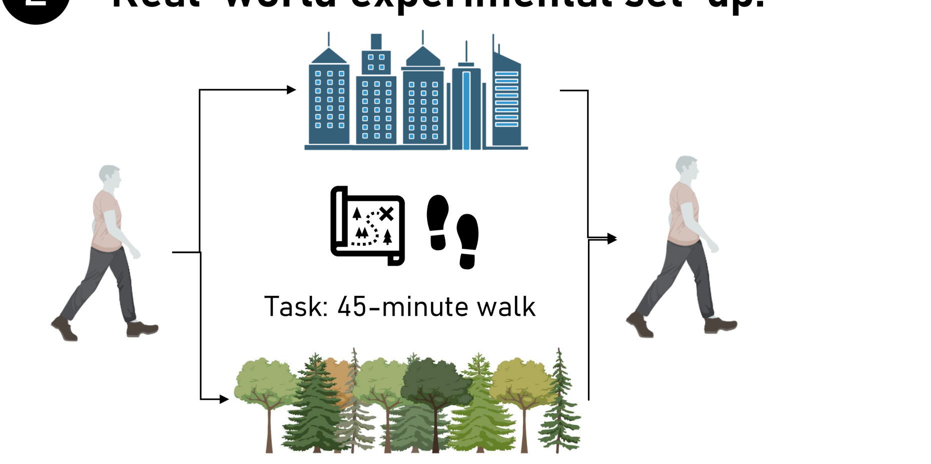
- *heart rate*
- *skin conductance response*
- *respiration*
- *blood pressure*
- *breathing*

Methodology

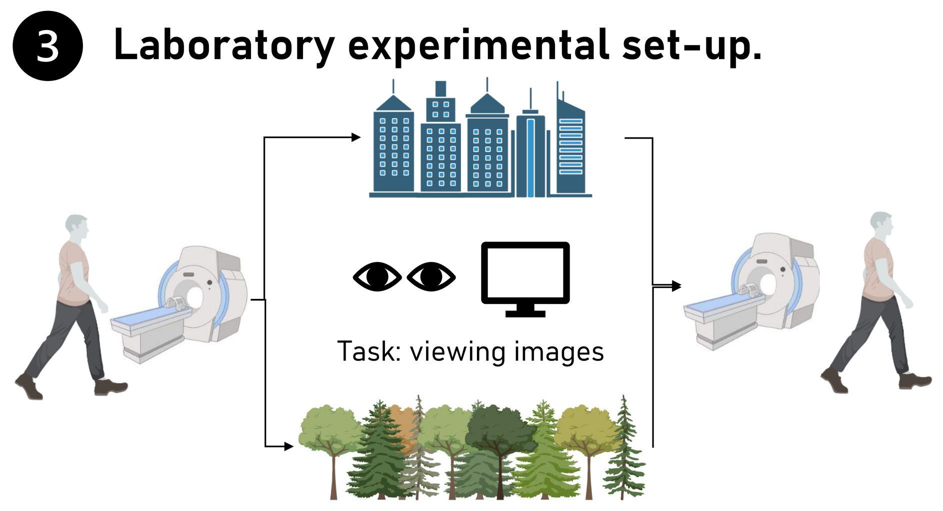
1 Recording of walking routes and image decomposition.

Flow chart for quantifying the geometry of built and natural environments using an algorithm from Penacchio and Wilkins (2015) [8].

2 Real-world experimental set-up.



3 Laboratory experimental set-up.



4 Methods.

1. Mobile EEG / fMRI
2. Salivary cortisol
3. Heart rate variability
4. Skin conductivity

Combination of experiments in real-world and laboratory settings follows a proposed framework to achieve ecological validity. [9]

5 Data analysis.

- functional data analysis
- generalized linear models
- convulational neural networks

Expected Outcomes

Findings could reveal optimal geometry for stress reduction. In collaboration with an industry partner, this could result into the development of a stress-reducing graphical pattern for urban infrastructure (e.g. building frontages or noise barriers).

Establishing how exposure to different urban environments and their attributes affects neurophysiological biomarkers of stress can improve evidence-based design and, in turn, contribute to more liveable, high-quality and healthier urban environments.

References

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