Enhancing Urban Landscapes with Neuroscience Tools
Lessons from the Human Brain

Text by Agnieszka Anna Olszewska, Paulo Farinha Marques, and Fernando Barbosa
Images by Agnieszka Anna Olszewska
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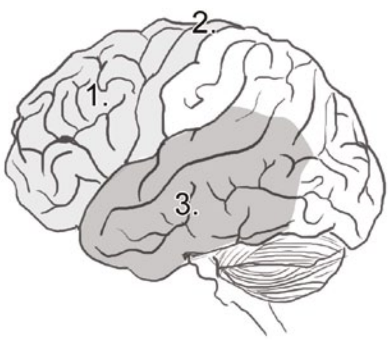

1. Lateral view of the human brain with regions that may be responsible for contemplativeness: (1) frontal lobes, (2) central regions, and (3) temporal lobes.

Since ancient times, people have looked for the best ways of organising their surrounding space. Over 6,000 years ago, numerous principles of *feng shui* were created with the intention of bringing well-being and happiness into people's lives through balance and harmony of space. Thousands of years later, ancient Europe followed this research with the Platonic concept of mimesis (representing good, beauty, and truth) and the Vitruvian Triad (representing *firmitas*, *utilitas*, and *venustas* or "solid", "useful", and "beautiful"), which were sets of requirements for any creation, space, or structure (Tatarkiewicz 1973; Gharibpour 2012).

Since then, not much has changed in the intentions of designers. Nowadays, architects, urbanists, and landscape architects play a strong role in the process of creating urban landscapes. The switch towards a more holistic view over the city structure (which refers to the urban environment as a whole or cityscape) has been remarkable. A very important aspect in their practice is to create spaces that not only function well, but also provide good quality of life and improved well-being for its inhabitants.

Considering the physical aspects in the design of the places we live in can provide many benefits for us, such as a sense of place, security, self-orientation, and identification with the space. However, the development of science and technology has enabled us to find many more benefits of a well-designed space, while also exploring the concept of landscape aesthetics in an unprecedented way. So how can we define the aesthetical value of the landscape? Does it only depend on the eye of the beholder? In addition, how can we measure such vague terms as "beauty" and "aesthetics" using scientific methods to give conclusions in a broadly understood and acceptable manner?

First, the concept of beauty and good coexisting fully depends on our perception. Since the organ that is receiving and processing perceived stimuli is the brain, an outer stimuli assessment should incorporate analyses of brain functioning. The development of the neurosciences has allowed us to explore the brain response to particular visual stimuli in a relatively simple and non-invasive experimental way. Neuroscientific research has resulted in various scales and measures that we can refer to for better understanding of the response mechanisms of individuals towards different design strategies. This article shows that applying neuroscience to architecture, landscape architecture, urban planning, and urban ecology is possible, feasible, and worth serious consideration.

Juggling with Concepts

The concept of beauty has a highly transcendental character; it goes beyond the limits of the material world. Therefore it is difficult to apply it in scientific experimental practice. For the purposes of this research, some combinations of flexible definitions originating from different disciplines had to be made in order to build the necessary bridges between them. This research is based on the possible desired impacts that a beautiful space can have on us.

A beautiful landscape, just like a piece of art, can trigger our attention and make us contemplate. The contemplation of landscape can be defined as attentive watching or an experience of it that might make us ponder and prompt a reflection about our lives within a bigger context of the universe, about the banality of human existence or about a big human family within a circle of life on our planet (Krinke 2005). This continuous state—ultimately leading to relaxation and the elimination of thoughts, non-judgmental focus, and experience of the surrounding space—is more a state of mind than an activity. It can be compared to the trance that each one of us experiences quite often while attentively watching something, for example, television, even if it might bring about negative effects as well (Thurman 1994).

Unlike channel surfing, the contemplation of a beautiful landscape stills the mind and gives a sense of well-being, which contributes to psychological, intellectual, and spiritual development, while stimulating creativity and stress reduction mechanisms (Kaplan and Kaplan 1989). The concept of contemplation originates

2. View over the lake at Porto City Park.

from artistic disciplines and has much more to do with Far Eastern philosophies and practices, such as meditation, than the experimental scientific world. Nevertheless, psychology has developed methods and tools of generating quantifiable data that adequately describes the functioning of the human brain. In the area of so-called positive psychology, there is a concept, inherited from Buddhist tradition, known as *mindfulness*. The conceptual model used in this research is based on the assumption that what psychologists call mindfulness and what artists call contemplation actually has the same influence on our brain activity.

Buddhists describe mindfulness as a step towards enlightenment through transcendental meditation. It simply focuses on awareness of one's self in the present moment and attentiveness towards the perceived stimuli without judgement, but instead with a positive open attitude towards it. The findings have shown a strong link between mindfulness and mental health improvement, stress defence anxiety, and depressive states reduction (Kabat-Zinn 1982; Shapiro, Schwartz, and Bonner 1998). They have also shown strong links with "learning and memory processes, emotion regulation, self-referential processing, and perspective taking" (Baer 2003, 125). Mindfulness can be experienced on a daily basis in people whose sensitivity, self-awareness, openness and comprehension of the world is greater; it can also be trained and enhanced by trainings and retreats.

Brain Structure and Functioning in Relation to Outdoor Space Experience

The human brain is the organ that serves as a centre of the nervous system. Its surface is covered by the cerebral cortex (the largest part), which is estimated to contain 15 to 33 billion neurons in a typical human (Pelvig et al. 2008). Each neuron is able to produce and transmit electrical impulses, called neural potentials, by the diffusion of calcium, sodium, and potassium ions across the cell membranes. During different activities and exposure to different stimuli, different parts of a person's brain are activated. The activity of the brain regions can be analysed as electromagnetic waves with different frequencies and amplitudes. The four most important brainwave bands distinguished are delta (less than 3 hertz), theta (3.5 to 7.5 hertz), alpha (8 to 13 hertz), and beta (greater than 13 hertz) (Niedermeyer and Lopes da Silva 1993).

Neural potentials have become a base for developing a method called electroencephalography (EEG), which uses special machinery, usually in a laboratory-based environment, to monitor and record raw electrical signals from the brain. The first EEG machine was developed during the early twentieth century, and it has continuously been improved, including the tools needed to

3. Aerial view of Porto City Park (Photo: Porto City Council).

4. Long-distance view in Porto City Park.

5. Autumn view at Porto City Park (Photo: Sidónio Pardal).

6. EEG data acquisition with a wireless mobile device.

process, analyse, and interpret the data. The big advantages of contemporary EEG machines are that they are non-invasive, easy to use, mobile, and wireless, while at the same time reliable. Together with the development of neuropsychophysiology, the knowledge about EEG activity in different brain regions and its association with various mental states has increased. There are a number of brain regions and processes already studied that can be associated with the state of mindfulness and with the perception of positive outer stimuli.

The areas of the cortex of the human brain that spatial designers might find interesting are the prefrontal lobes, central regions, and temporal lobes (See Fig. 1). According to researchers, mindfulness occurs together with increased alpha and theta power in the left hemisphere (left-sided alpha asymmetry) (Davidson et al. 2003). This is a state associated with relaxation and positive affect. A general increase of alpha and theta power in the frontal and central regions is associated with meditative states, recovering, and stress reduction functions (Aftanas and Golocheikine 2002; Lagopoulos et al. 2009). Increased beta power in the temporal lobes indexes visual attention (Wróbel 2000), corresponding with focused attention, attention control, and the experience of interesting scenery.

Finding similar brainwave patterns in people exposed to different landscapes can bring about interesting conclusions about specific human responses to different designs while helping to discover the healing potential of those spaces. For example, beta temporal asymmetry has been proven to correlate with improved visual attention, as such stimuli with a potential to induce increased beta asymmetry in temporal regions can help people with attention disorders, such as Attention Deficit Hyperactivity Disorder (Hale et al. 2010). Moreover, brain activity related to mindfulness, when practised regularly, leads to stress reduction and the alleviation of cardiovascular disorders, among many other benefits (Grossman et al. 2004).

	LAYERS OF THE LANDSCAPE	LANDFORM	VEGETATION	COLOR & LIGHT	COMPATIBILITY	ARCHETYPAL ELEMENTS	CHARACTER OF PEACE AND SILENCE
6 5	far distance view (400m or more), layers greatly enhance the visual quality	undulating lanform, natural lines	high diversity of species, plants seem native; seasonally changing vegetation	natural, broken or warm colors AND visibility of light and shade	physical and visual relations are worked out AND explicit spatial order, harmony, balance between *natural* and *created*	strongly influence the overall perception	explicit, in contrast to the urban environment; invites to rest and relax AND gives sense of solitude
4 3	layers moderately enhance the overall visual quality	landform is not very significant to the setting OR hard to say	moderate diversity of vegetation, moderate changes across the seasons	moderate amount of contrasting colors, moderate amount of light and shade	physical and visual relations are not clear OR some elements disturbing the harmony and balance	are present but not important for the overall perception	moderate, AND/OR moderate sense of solitude AND/OR less contrast with urban environment
2 1	layers do not enhance the overall visual quality OR no layers	flat or rugged landform	low diversity of vegetation, minority of native species; no seasonal changes	lots of vivid, contrasting colors, light and shade are not visible	physical and visual relations are not worked out well or not at all OR chaos / lack of harmony	no archetypal elements	no character of peace and silence, busy, no conrast with the urban environment

7. Contemplative landscapes evaluation chart based on seven key elements with a 1 to 6 point scale.

How Landscape Design Can Affect the Human Brain

Case Example: The City Park of Porto, Portugal

Some, if not all, existing parks and gardens were designed in order to provide a contemplative, soothing, and restorative experience to their visitors. Landscape architects know how to design spaces with specific neuropsychological effects by applying a specific programme to each proposal. Whether based on their creativity or copying successful solutions or historic models, it has always been an intuitive approach. Is it then possible to reinforce intuition-based design with evidence-based design?

The City Park of Porto (*Parque da Cidade do Porto*), in northern Portugal, is an example of a park designed for contemplation and entertainment (See Fig. 3). The 83-hectare green space facing the Atlantic Ocean was inaugurated in 1993 and serves as one of the most important green areas and major tourist attractions of the city. The landscape architect of the project, Sidónio Pardal, describes his creation:

> The Park's landscape is an end in itself and expresses its essence. It doesn't attempt to imitate nature and has no other purpose than direct use as a public urban space for recreation activities and contemplation... (Pardal 2006, 27)

The large size of the park and excellent local conditions enabled the use of very strong contemplative design strategies and the application of main archetypal elements in the design, such as:

1 Long-distance views, with the possibility of viewing further than 400 metres away and in the three planes of fore-, middle-, and background, offer comfort. The comfort of long vistas was proven as one of the most important qualities that has positive effects on our restorative and contemplative experience (Smardon, Palmer, and Felleman 1986). Long views are also good for our ocular accommodation (Bates 2011).

2 The coastline of the Atlantic Ocean and a valley corridor are two structural archetypal elements. According to C.G. Jung's dream analysis, the ocean and valley are important symbols existing in the collective unconscious and significantly influence mind recovery (Jung 1964).

3 The water basins, with a still water mirror reflecting the sky, stimulate us to look up to the sky and direct our attention to its vastness (Hermann 2005, 65).

4 The areas in the park with a high density of tall trees, which give shade and cool shelter on hot sunny days, and shaded narrow, windy paths through greenery increase a sense of solitude. Those paths lead to radical openings of views and large clearings with long vistas (See Fig. 2, 4 and 5).

In Search of Contemplative Settings

The City Park of Porto is one of the multiple designed spaces that can possibly induce the brainwaves associated with mindfulness in visitors. The set of design strategies concerning the composition of the setting, openings, and closings of park views or designed elements is limited and can be repeated everywhere around the world. Therefore, it would be useful to categorise the landscapes by their specific settings and not simply by park. We have come up with a questionnaire that organises contemplative characteristics into seven key elements and will allow architects and designers to evaluate the *contemplativeness* of a landscape setting (See Fig. 7).

These key elements, and the characteristics that comprise them, are based on a literature review of contemplative landscape design as well as the visual quality assessment model (VRM), which is well known and recognised in scenic landscape research. The contemplative value of a landscape setting may be operationalised by the following features (each feature being scored on a six-point rating scale):

1. Landscape layers (the more layers, the better the contemplation score)
2. Landform (a smooth undulating landform achieves the highest contemplation score)
3. Vegetation (high biodiversity and native and seasonally changing vegetation score higher on contemplation)
4. Light and colour (calm, non-contrasting colors, shaded observation points, and visibility of shade movements along the daily cycle score higher)
5. Compatibility (the more harmonic, balanced, and consistent the design, the higher the contemplation score)
6. Archetypal elements (the presence of archetypal elements, for example, a large old tree, makes the landscape score higher)
7. Character of peace and silence (the more peaceful and calm the space, the higher the setting scores on contemplation)

Moreover, the questionnaire and its seven items (or key elements) were tested by applying it in the evaluation of 40 different landscape photographs by 10 experts. The psychometric analyses showed high reliability coefficients (Cronbach's Alpha = .798, Guttmann Split-Half = .854, Inter-rater reliability ICC2 = .814) and a high Pearson's correlation coefficient (mean = .779; item 1: .61, item 2: .34, item 3: .44, item 4: .45, item 5: .84, item 6: .56, item 7: .90) between the seven mentioned items and experts' judgement on how contemplative landscapes were on a scale of 1 to 6, which confirms the validity of the questionnaire as an instrument for measuring the contemplativeness of landscape settings (Webb, Shavelson, and Haertel 2006; Zumbo 2006).

Any landscape setting can be evaluated for its contemplativeness using the questionnaire based on the above-mentioned items. For example, the mean contemplativeness score of the setting presented in Figure 4 was 4.7 points on the six-point scale, which puts this landscape in a relatively high rank. After generating the results, we can analyse them by relating the score to the archetypal element of "water-mirror" and visibility of the foreground and background, among other design strategies.

Taking Landscapes to a Neuroscience Lab

Laboratory experiments are focused on producing at least two sets of brain data for individuals observing high and low contemplative landscapes, which after statistical analyses may or may not show different brain responses. We are currently conducting this kind of research, displaying the most contemplative pictures (selected out of the 40) and the least contemplative ones (as scored in the previously mentioned expert evaluation) to a group of subjects, while recording their EEG signals in order to analyse the changes in brain activity that can be associated with those sets of landscapes (See Fig. 6).

Pre-processing of the acquired data involves filtering the raw signal, rejecting possible artefacts, and aggregating the signals of all subjects into one study. Then, the power spectra for each region of the brain (from each electrode) and for each brainwave pattern (alpha, beta, delta, or theta) may be extracted, always in comparison to the resting state (baseline). Subsequently, statistical methods are applied, such as repeated measure analysis of variance, in order to test for statistically significant differences between the two sets of data. Statistical differences between the two sets of data mean that each set of landscapes—high versus low contemplativeness—induces different patterns of brain activity across all subjects. Finally, some general explanatory effort can be made in order to interpret the findings, namely relating them with known patterns of brain activity in mindfulness.

Conclusions

This article demonstrates one possible way of combining the insights of art with the developments of neuroscience. Reflection on the universal understanding of a well-designed space and the purpose of landscape architecture in the contemporary world can lead to quantifiable data confirming that certain types of settings have a specific influence on people's brains in comparison to others. Yet it is a long and difficult path, especially since adequate knowledge in the areas of neuroscience is currently not consistent enough. Researchers that decide to merge landscape architecture with neuroscience might take some missteps or come up with inconclusive evidence and contradictory results.

Nonetheless, building the bridges between art and science, two seemingly distant disciplines, is definitely worth the effort. The growing interest in the area of evidence-based design draws the attention of urban decision makers towards innovative interdisciplinary approaches. It is very important to raise awareness of such possibilities and create opportunities to design living spaces (regardless of their scale) in collaboration with scientific approaches. This could, in effect, redefine the practice of landscape architects, urban planners, and architects, aligning their design decisions with positive evidence, reassessing the impacts that the space we live in might have on us and creating new valuable living spaces. CG

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