Landscape and Urban Planning 172 (2018) 25–28

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Comment

Comment on "Using functional Magnetic Resonance Imaging (fMRI) to analyze brain region activity when viewing landscapes"

Adam C. Roberts[a,b,c], George I. Christopoulos[a,b,*]

[a] Culture Science Institute, Nanyang Business School, Nanyang Technological University, Singapore
[b] Decision, Environmental and Organizational Neuroscience Lab, Nanyang Business School, Nanyang Technological University, Singapore
[c] Civil and Environmental Engineering, Nanyang Technological University, Singapore

ARTICLE INFO

Keywords:
fMRI
Brain imaging
Neuroscience
Landscape research
Human health and well-being
Methods

ABSTRACT

Modern neuroscience methods, such as functional Magnetic Resonance Imaging (fMRI), offer the unparalleled opportunity to monitor the human brain *in vivo* − a revolution that has had a tremendous impact on many disciplines (economics, culture, health). Thus, the paper by Tang et al. (2017) is an exciting epistemological step introducing this technology and the possibilities for those studying the health effects of landscapes. Yet, as in similar interdisciplinary efforts there are always risks: questions are very general or results are misinterpreted. The present commentary aims, using examples and a simple but rigorous language, to help the audience of *Landscape and Urban Planning* understand the basic principles of fMRI and neuroscience methods We end up with a call to landscape researchers and others studying how environments can affect people's mental health and well-being to boldly be involved in this exciting interdisciplinary effort to help neuroscientists understand how the brain works.

1. Introduction

In their paper, Tang et al. (2017) pose a seemingly simple, but very substantial, question: are there any differences in (i) attitudes towards, and (ii) biological, stress-related responses to, different types of landscapes? They examine the first aspect using self-reports (questionnaires) and the latter by employing functional Magnetic Resonance Imaging (fMRI)–an established method that can record *in vivo* brain-activity-related responses to external stimuli. The study nicely adopts a theoretical framework aiming to understand whether images of non-urban environments have a restorative (stress-reducing) effect when compared to urban images. In terms of brain imaging, their main finding is that four brain areas have differential responses when non-urban environments are shown to the participants.

This paper is an important step forward for the growing number of landscape researchers, environmental psychologists, public health researchers, and others concerned with understanding the effects that landscape (nature, greenspace) has on human mental health and well-being. In preparation for future applications of fMRI to this work, we would like to take the opportunity to emphasize some methodological, theoretical and practical issues that could help towards a better use of this technology. We are highly motivated by the epistemological precedent of similar interdisciplinary efforts: a typical example is the recently established field of neuroeconomics (Bossaerts & Murawski, 2015), where the introduction of neuroscience tools and theories to economics and decision making has helped not only in the development of a brand-new discipline but, importantly, in a deeper understanding of brain mechanisms (thus helping neuroscience) and economics (thus improving the science of economics). Yet, this and other such interdisciplinary efforts in education (Ansari, De Smedt, & Grabner, 2012), neuro-marketing (Fugate, 2007; Hubert & Kenning, 2008), cultural studies (Chiao, 2009), law and political science (Westen, Blagov, Harenski, Kilts, & Hamann, 2006), and neuroaesthetics (Chatterjee & Vartanian, 2014) have faced significant criticisms, especially during the first steps. The major reason was that the neuroscientific methods were not properly understood. In particular, (i) the limitations of the technology were not appreciated, thus creating high expectations; (ii) the other disciplines tried to fit/confirm their theories to the method, without integrating or understanding *how* the brain functions–i.e. without integrating neuroscience theories. Conversely, (iii) the advantages of the technology–mainly, its ability to test mechanisms–were downplayed because of the complexity of analysing the fMRI signal beyond simple comparisons. The aim of this Commentary is to help guide future studies employing fMRI technology to understand people's response to landscapes or other environmental parameters to avoid these practical and epistemological pitfalls.

* Corresponding author at: S3-B2B-64, 50 Nanyang Avenue, 639798, Singapore.
E-mail addresses: aroberts@ntu.edu.sg (A.C. Roberts), cgeorgios@ntu.edu.sg, georchris7@gmail.com (G.I. Christopoulos).

https://doi.org/10.1016/j.landurbplan.2017.12.006
Received 23 June 2017; Received in revised form 20 December 2017; Accepted 20 December 2017

2. Methodological, practical and theoretical considerations

First, some disclaimers: A thorough presentation of the fMRI methodology is beyond the scope of this commentary. We here assume a simplified experimental design that only examines the visual presentation of individual pictures, in line with the Tang et al. study. This simplified view does not take into account all possible uses of fMRI and the examples we use below are rather generalised. We also attempt to reduce the use of technical jargon and complex terms.

We also note that the most critical problem–interpreting results–appears last in the list below. But it is essential to understand the other issues before reaching this important topic.

2.1. What are "brain images"? How are the images generated?

The colored brain images usually presented in fMRI studies are not arbitrary graphic representations; in fact they represent a formal statistical analysis of a biological response–the so-called blood-oxygenated level-dependent response (BOLD) which has been shown to be indicative of neuronal activity (Logothetis & Wandell, 2004). At their most basic form, brain images generated by fMRI analyses are commonly a contrast between at least two conditions. For Tang et al., the contrast was the brain responses when presenting a set of images of urban spaces vs. the brain responses when presenting a set of images of natural landscapes. This is rather important: the brain responses are always in relation to another brain state–they are not, at least directly, answering general questions such as "what happens in the brain". Of course, as it is the case with behavioural statistics, modern neuroscience has moved on beyond simple contrasts analyses (see below).

2.2. What type of stimuli should be presented? Do we need controls?

The point above means that we should carefully select the conditions we contrast. When examining landscapes, a natural environment could be inherently greener than an urban environment–so here the question is this: Is the brain response identified selective to the green color (that could also lead to restorative responses)? Or, is it something more in the natural environment (ordered complexity? Shapes? Space?) that brings up the restorative (or other brain) responses? Do note that this is crucial for indoor and urban design, as if we could find which property of nature is restorative, then we could design targeted interventions.

It should be understood that the brain (and, by extension, the fMRI signal) "picks up" first and foremost "low-level" properties of the stimuli–and these are exactly the visual properties of the image. So, if one contrasts a "white" face to a "black" face with the aim of identifying an area that is related to race detection, it is very possible that responses from visual areas will emerge. Yet, these responses should not be classified as responses to race per se–they could very well be (and most likely are) responses to white vs. black color. In other words, a contrast "black" face > "white" face will identify brain areas that are responsive to the black color as well as responsive to black faces.

What could be a solution? One solution is to include a control condition where one compares the low level properties of the stimuli–in our example a scrambled black face vs. a scrambled white face (notice here that important aspects such as eyes should not be visible). Such images were generated by Tang et al. (2017) and used as baseline images. These images can be used in a typical factorial design (2 × 2) where color (black or white) and race ("black" or "white") are the main factors. Yet, additional analyses are then needed, such as exclusive masking (i.e. where one asks for areas sensitive to one contrast ("race") while removing areas sensitive to another contrast ("color") to help further isolate effects.

2.3. How many stimuli are needed?

This is an important and related methodological issue. For reasons immediately explained below, we need to present many different instances of the same category in the very same experiment and participant. Thus, it is preferable to include many different images of urban, forest, water, etc. environments. The first reason stems from point (2): it might be that if you select only one stimulus, then this image certainly has some special properties that could drive the results. Going back to the faces example, if you used only one "black" and only one "white" face, it might be that the two faces differ in other dimensions –for instance, the specific white face has a very wide forehead or a mole and this could attract attention, but *not because the face is white*. Thus, by including many faces (or many stimuli generally), we could avoid such effects and reduce undesirable variance.

The second reason is that the fMRI signal is noisy and we thus need many measurements to get a better signal. Here we should note that there are two types of design: a "blocked" design (adopted by Tang et al.) where stimuli from the same category are presented for a long time, before switching to another block, where another category is presented; or an "event-related" design, where on each trial an image (say urban) is presented briefly (maximum 4–5 s) followed by a brief relaxation period before moving to the next trial–which could be of another type (say green). Both designs have advantages and disadvantages, but the event-related design is nowadays preferred as it is psychologically more versatile and can collect more responses and serve more complex experimental designs.

2.4. Engaging participants

The most challenging issue is to ensure that participants are actually viewing the images. "Passive viewing" has many problems as participants might just not pay attention–some even close their eyes or engage in excessive mind wandering. To prevent such unwanted responses one could (i) ask participants to rate the images (ii) position an arrow on the image and ask participants to indicate its direction or even (iii) subliminally present the stimuli (< 50–100 milliseconds) for testing subconscious responses (Yap, Christopoulos, & Hong, 2017).

2.5. The "so what?" question; targeting specific functions/mechanisms, employing established paradigms and using neuroscience theories; and the problem of reverse inference

This is, for us, the most important issue. Non-neuroscientists usually try to seek general responses–for instance "what happens to the brain" when "consumers select a product"; "people navigate an environment"; "make an investment decision"; "experience urban scenery" etc. The problem becomes apparent when one gets the results and finds that "area X is activated". This is an outcome that is very difficult to interpret, as typically a brain area is responsible for more than one functions. Therefore, it would be invalid to believe (unless, as explained below, one has a better design) that because (for instance) the amygdala is activated when people see urban spaces, they thus feel more threatened. This is the problem of the so-called "reverse inference" (Poldrack, 2006), where one inductively reasons that because a specific brain response is observed, then a cognitive/emotional process (which is usually not directly tested) is happening.

So what is a better approach? Reverse inferences are common even in mainstream neuroscience, but should be used as the basis for future research and not as a conclusion of the existing study. A solution is to use experimental tasks that target specific functions and reliably activate specific brain areas. For instance: if the hypothesis is that natural scenes are more relaxing compared to urban scenes, then a better way would be to engage participants in a stressful task (showing threatening images). These images will reliably activate areas (say amygdala) associated with fear or threat. Then the *a priori* hypothesis could be that