Cell PRESS

What is the most interesting part of the brain?

Timothy E.J. Behrens[1,2], Peter Fox[3], Angie Laird[3*], and Stephen M. Smith[1]

[1] Functional MRI of the Brain Centre, University of Oxford, John Radcliffe Hospital, Oxford, OX3 9DU, UK
[2] Wellcome Trust Centre for Neuroimaging, 12 Queen Square, London, WC1N 3BG, UK
[3] Research Imaging Institute, University of Texas Health Science Center, San Antonio, TX 78229, USA

Creative ideas and rigorous analysis are the hallmarks of much impactful science. However, there is an oft-aired suspicion in the neuroscience community that some scientists start with an advantage, simply because of the brain region or behaviour they study. We tested this unstated hypothesis by regressing the journal impact factor against both the pattern of brain activity and the experimental keywords across thousands of brain imaging studies. We found the results to be illuminating.

Most neuroscientists would agree that some brain systems are more 'fashionable' than others. Anecdotally, it might be thought that scientists working in these fashionable fields are more likely to be published in high-impact journals and presumably therefore to attract future funding. However, despite their rigorous approach to their work, scientists are not immune to individual biases in their anecdotes, at least in our experience. Are there really trendy parts of the brain? Or does each scientist falsely believe their own research area to be underrepresented in the top journals, and their friend's recent *Nature* paper to be the result of a passing fad?

The maturity of functional brain imaging allows us to perform a rigorous test of this instinctual feeling. There have now been many thousands of imaging papers published across the journal spectrum. Are some brain regions really overrepresented in this literature? In addition, are papers reporting activation in some brain regions preferentially published in high-impact journals, whereas others are published in low-impact ones? To answer these questions, we examined 7342 functional contrasts published between 1985 and 2008 and documented in the BrainMap database (http://www.brainmap.org) [1,2].

We mapped every activation peak into a local three-dimensional (3D) Gaussian within a brain volume, allowing us to build brain maps incorporating information across all studies [3]. We first examined the spatial distribution of activation frequencies (Figure 1a). Across grey-matter voxels, there were tenfold differences in activation frequency. The champion of the popularity contest was the pre-supplementary motor area (pre-SMA), defeating its nearest contender, the dorsolateral prefrontal cortex, by the considerable margin of 25%. Further lowering the frequency threshold to 'half-a-pre-SMA' revealed a network of brain regions commonly activated in studies of attention and executive function, including the frontal operculum and/or insula, and the intraparietal sulcus. The only intruders on this cognitive panacea were the hand area of primary motor cortex and Broca's area, both in the left hemisphere only.

On examining these popular brain areas, it is tempting to reverse-infer a cognitive bias in functional imaging studies. Such reverse-inference can be dangerous [4] but, in this case, the frequency distribution of experimental keywords in the same database shows it also to be accurate (Figure 1b).

Next, we considered whether there might be any statistical relation between the activity in different regions, and the impact factor of the resulting publication. For the 155 journals in question, we found the Thompson ISI impact factor for the year 2009 (or closest available year). We regressed these impact factors against the presence of activity at each voxel across all studies. We observed a small, but highly significant, negative relation between impact factor and publication date ($r = -0.12$, $P < 5 \times 10^{-26}$). This effect may signal a decline in the collective influence of the technique, or may be an artefact of using 2009 impact factors rather than those at the time of publication. In any event, we therefore controlled for publication date in the regression analysis.

The battle for impact was much more closely fought (Figure 2a). Journal impact factor strongly predicted activity in several different brain areas. With one exception in the primary visual cortex, we suspect these brain regions would largely confirm anecdotal hypotheses. For example, researchers who find activity in a prescribed part of the fusiform gyrus should be confident of having their article selected for publication in a high-impact journal ($Z > 5.7$, $P < 5 \times 10^{-9}$), perhaps due to the role of the region in face processing [5]. Other regions with proposed roles in emotional processing returned similarly stellar performances, including both the ventral and dorsal portions of the rostral medial prefrontal cortex, the anterior insular cortex, the anterior cingulate gyrus, and the amygdala (all $Z > 5$). The recent interest in reward prediction errors might explain impactful peaks in the mid-brain and ventral striatum, areas that exhibited independent significant effects of impact factor, publication date, and their interaction: studies reporting activation in these regions are published in high-impact journals, and are increasing in number (as a proportion of all studies) over time.

Activity in a contrasting set of regions was negatively predicted by impact factor (Figure 2a). Leading the way in ignominy was the secondary somatosensory area ($Z = -4.4$, $P < 5 \times 10^{-6}$), but the supplementary motor area was almost equally disgraced ($Z = -4.25$, $P < 10^{-6}$).

* Present address: Department of Physics, Florida International University, Modesto Maidique Campus, Miani, FL 33199, USA.

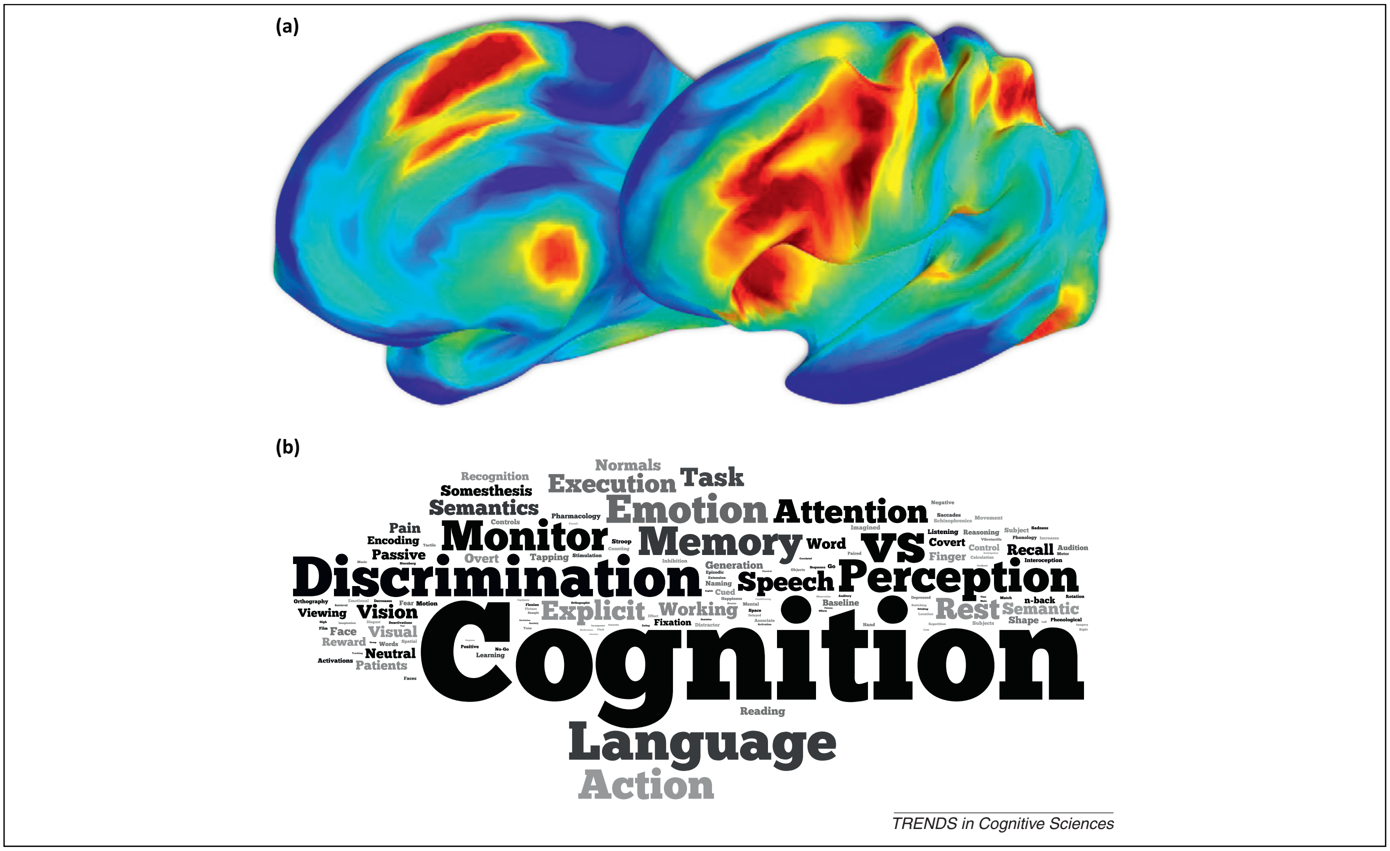

Figure 1. **(a)** Distributions of activation frequency across the brain. Popular voxels are portrayed in red; unpopular ones in blue. **(b)** Frequency distribution of keywords describing experimental domains, paradigms, and functional contrasts. The size of each word is proportional to its frequency in the BrainMap database. Graphics reproduced with permission from http://www.wordle.net.

Researchers unfortunate enough to find activity in these regions can expect to be published in a journal with approximately half the impact of their most celebrated colleagues (mean impact factors of approximately 5 compared with approximately 9). At a slightly lower threshold, low impact voxels almost perfectly map out the entirety of the motor somatosensory strip, and include several prominent peaks in the intraparietal sulcus.

Differences in impact between different brain regions were paralleled in an analysis of the experimental keywords associated with each study in the database (Figure 2b). Words from similar domains had similar relations with impact factor. We leave it to the reader to examine Figure 2b and decide which set of words was positively correlated with impact factor, and which exhibited a negative correlation.

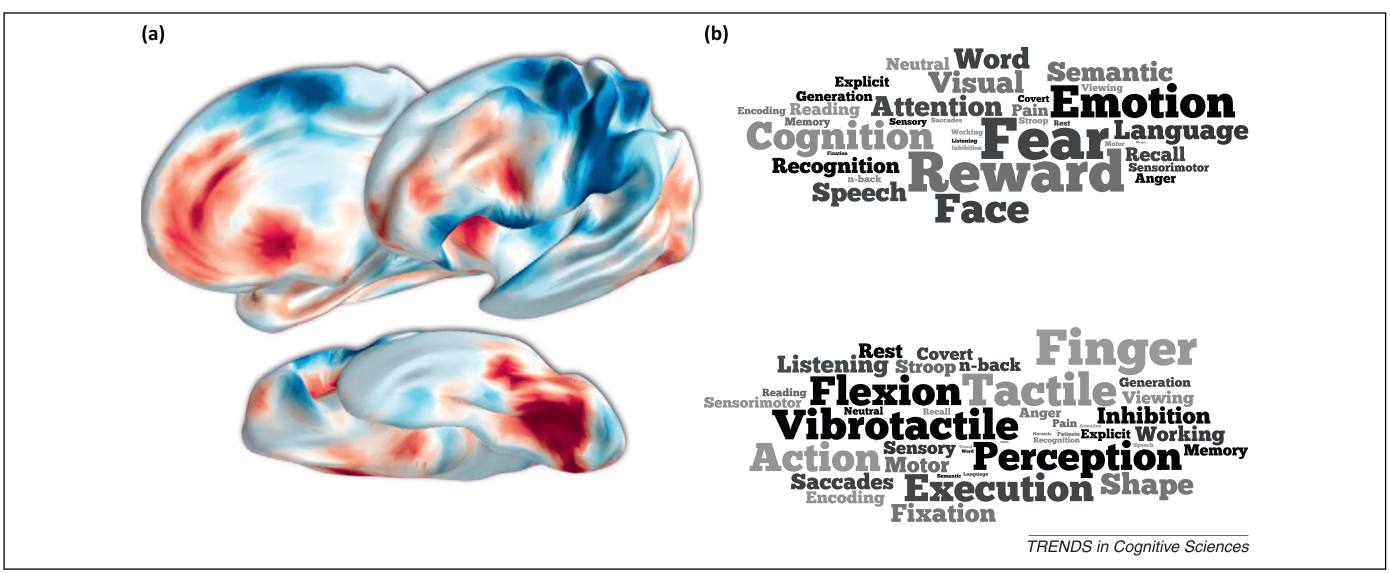

Figure 2. **(a)** Brain regions that correlate positively (red) and negatively (blue) with journal impact factor. Only voxels activated in more than 30 studies are considered in the analysis. **(b)** Relation between experimental keyword and impact factor. In one of these two word clouds, large words have positive correlations with impact factor. In the other, large words exhibit negative correlations. Which word cloud is which? Graphics reproduced with permission from http://www.wordle.net.

There are of course a host of possible explanations for such strong regional biases in neural popularity, and many of these have no Machiavellian implications. For example, is it more likely that researchers will diligently report their most basic contrasts in journals with less punitive word limits? Less mundanely, are the most popular human brain experiments precisely those that are hardest to investigate with animal models? Whatever the underlying reasons, we hope that the current results will provide fodder for spirited coffee-time debates and gratifying inter-lab jealousy. We wish for you all an activation at (−32,12,4) in your next study.

Acknowledgements
We would like to thank Karla Miller for sleeping late one morning, leaving Tim and Steve a bit bored; and Saad Jbabdi for making the brains look pretty. The BrainMap database was supported by NIMH grants R01-MH074457 and R01-MH084812.

References
1 Fox, P.T. *et al.* (2005) BrainMap taxonomy of experimental design: description and evaluation. *Hum. Brain. Mapp.* 25, 185–198
2 Laird, A.R. *et al.* (2005) BrainMap: the social evolution of a human brain mapping database. *Neuroinformatics* 3, 65–78
3 Smith, S.M. *et al.* (2009) Correspondence of the brain's functional architecture during activation and rest. *Proc. Natl. Acad. Sci. U.S.A.* 106, 13040–13045
4 Poldrack, R.A. (2006) Can cognitive processes be inferred from neuroimaging data? *Trends Cogn. Sci.* 10, 59–63
5 Kanwisher, N. *et al.* (1997) The fusiform face area: a module in human extrastriate cortex specialized for face perception. *J. Neurosci.* 17, 4302–4311

1364-6613/$ – see front matter
http://dx.doi.org/10.1016/j.tics.2012.10.010 Trends in Cognitive Sciences, January 2013, Vol. 17, No. 1