So, what brain areas are specific for pain perception?

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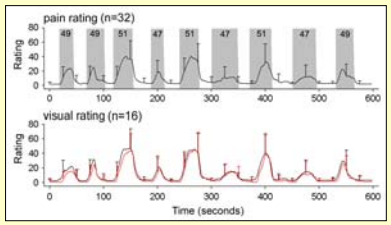
INTRODUCTION

Psychological theories and recent imaging data allude to a common central mechanism governing our abilities to discriminate and judge intensities of stimuli impinging on the senses. Within this framework, we examine similarities and differences in brain activity for magnitude rating in a painful and neutral visual rating task using fMRI. We also determine the correlation of various brain areas with subjective intensity ratings and identify cortical functional networks underlying both tasks. These convergent approaches aid us in identifying a cortical network underlying magnitude estimation in both tasks, and distinguishing between brain regions that specifically provide nociceptive information in contradistinction from magnitude evaluation.

METHODS

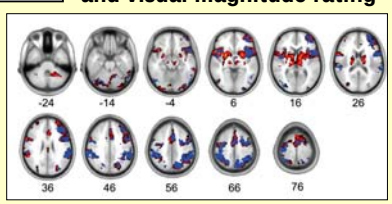
- 16 healthy subjects participated in this study and were trained to use the finger-span device to rate magnitude of either their pain, or that of a moving bar.
- In the scanner each volunteer performed 2 thermal pain and one visual rating scans (panel 1)
- The signals for pain and visual scans were used to search for the BOLD signal using a GLM model (FSL software; fmrib, Smith et al. 2001). Group average maps for the 2 rating tasks, in addition to their contrast and conjunction are shown in panel 2.
- Percent BOLD change was extracted by computing deviation from the mean for voxels within the ROI and averaging the 9 stimuli repetitions for each trial type (Panel 3).
- Functional networks were produced by extracting the BOLD time course from a seed region then computing correlation coefficient between the time course and the time courses from all other brain voxels (panel 4)
- Information flow within the network was analyzed using partial directed coherence (PDC)

1 On-line thermal pain and visual magnitude ratings

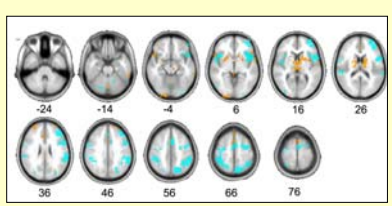


Average subjective pain ratings for painful thermal heat applied to the back. Grey areas delineate epochs of thermal stimulation. Bottom panel shows average rating for the visual task. The black trace is the input and it is obtained from the subject's pain ratings. The red trace corresponds to the subjects rating (output).

2 Brain activity for thermal pain and visual magnitude rating



Random-effects analysis for magnitude rating of pain (red) and visual (blue) Brain areas that are commonly activated include mid ACC and right DLPFC areas in addition to bilateral insular, secondary somatosensory, and posterior parietal regions. Bilateral thalamus and basal ganglia were only active during pain



The conjunction map is shown in blue and represents voxels that were significantly activated by the pain and visual rating tasks. Areas that are activated include bilateral insula , S2, posterior parietal in addition to mACC right DLPFC and SMA. Contrast was performed using a pair t-test. Brain regions that were significantly more active for pain rating are shown in yellow and include bilateral thalamus and basal ganglia in addition to the most anterior part to insula and mACC.

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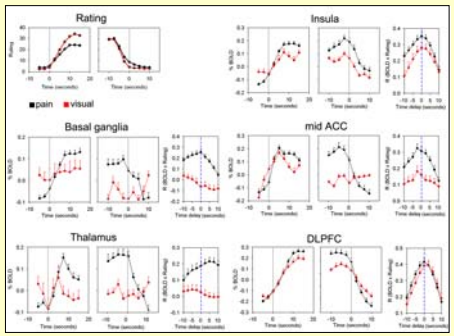
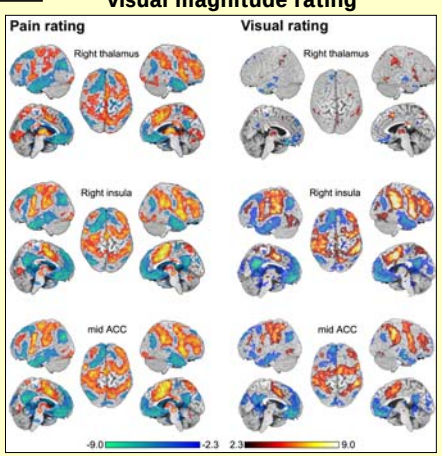
3 Time course for BOLD during thermal pain and visual rating



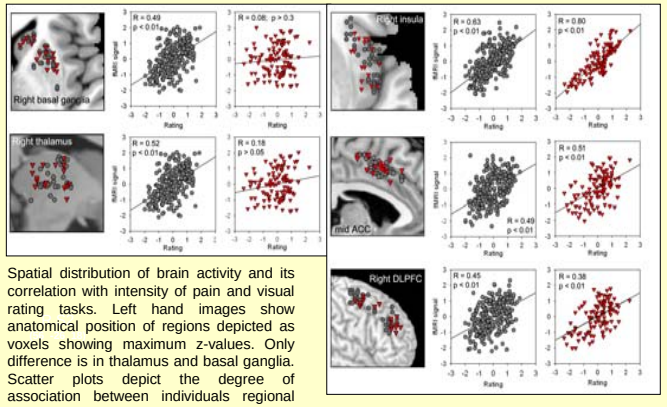
BOLD responses for pain (red) and visual (black) rating tasks. Presented are average BOLD for periods of increased rating (left) and decreased rating (middle), and the cross-correlation between ratings and BOLD at different time delays (right). Most significant difference in BOLD trends between visual and pain tasks are in the thalamus and basal ganglia. Bilateral insula and DLPFC show no difference between the two tasks and exhibit highest cross-correlation with subjective ratings

4 Functional networks for pain and visual magnitude rating



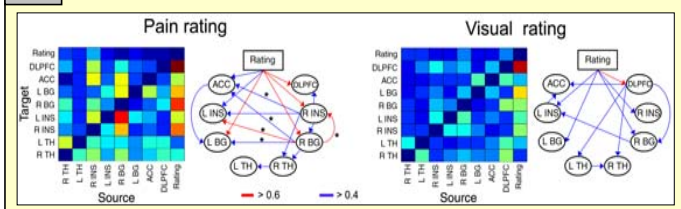
Population z-score maps showing correlated (red) and anticorrelated (blue) networks with 3 seed regions. All seed correlation maps for pain are strikingly similar, indicating that BOLD fluctuations are correlated within two intrinsically defined networks. The same functional networks were observed during the visual task when the seed region was placed in either the insula or mACC, but not the thalamus.

5 Brain activity vs thermal pain and visual rating



Spatial distribution of brain activity and its correlation with intensity of pain and visual rating tasks. Left hand images show anatomical position of regions depicted as voxels showing maximum z-values. Only difference is in thalamus and basal ganglia. Scatter plots depict the degree of association between individuals regional signal and magnitude ratings for pain (black) and visual (red), shown in standardized units

6 Partial directed coherence (PDC)



PDC for 8 brain regions and pain/visual ratings. Left panels show proportion of subjects exhibiting a given causal link . Right diagrams show resultant network (thresholded at >0.4, blue, and >0.6, red). Both pain and visual rating exhibit strong causality to cortical areas. A fisher exact test was performed to calculate significant connectivity differences between visual and pain ratings (*). The main difference is restricted to bilateral basal ganglia

CONCLUSION

- Multiple cortical areas constituting the 'pain matrix' (including insula, mACC, S2 and DLPFC) are also involved in rating and encoding the magnitude of a neutral stimulus.
- The only brain regions that seem specific for nociception appear to be the thalamus and basal ganglia.
- Changes in BOLD in the cortex during pain fall within a general network observed for attention and resting state. However, information flow within this network seems task specific.