

Review article

Brodmann area 10: Collating, integrating and high level processing of nociception and pain

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ARTICLE INFO

Article history:

Received 30 June 2017

Received in revised form 16 November 2017

Accepted 28 November 2017

Available online 2 December 2017

Keywords:

Brodmann area 10

Frontal pole

Pain

Nociception

Anatomical connection

Functional imaging

ABSTRACT

Multiple frontal cortical brain regions have emerged as being important in pain processing, whether it be integrative, sensory, cognitive, or emotional. One such region, Brodmann Area 10 (BA 10), is the largest frontal brain region that has been shown to be involved in a wide variety of functions including risk and decision making, odor evaluation, reward and conflict, pain, and working memory. BA 10, also known as the anterior prefrontal cortex, frontopolar prefrontal cortex or rostral prefrontal cortex, is comprised of at least two cytoarchitectonic sub-regions, medial and lateral. To date, the explicit role of BA 10 in the processing of pain hasn't been fully elucidated. In this paper, we first review the anatomical pathways and functional connectivity of BA 10. Numerous functional imaging studies of experimental or clinical pain have also reported brain activations and/or deactivations in BA 10 in response to painful events. The evidence suggests that BA 10 may play a critical role in the collation, integration and high-level processing of nociception and pain, but also reveals possible functional distinctions between the subregions of BA 10 in this process.

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Abbreviations: ACC, anterior cingulate cortex; AI, anterior insula; AN, attentional network; BA, Brodmann area; BOLD, blood oxygenation level dependent; CNS, central nervous system; DLPFC, dorsolateral prefrontal cortex; DMN, default mode network; DTI, diffusion tensor imaging; ECN, executive control network; EEG, electroencephalography; fMRI, functional magnetic resonance imaging; FP, frontal pole; FPM, medial frontal pole; FPL, lateral frontal pole; FPO, orbital frontal pole; GM, gray matter; ICN, intrinsic connectivity network; IL, intralaminar (thalamic nucleus); IPa, deep cortical structure in the rostral segment of the superior temporal sulcus; IPL, inferior parietal lobule; MD, mediodorsal (thalamic nucleus); MNI, montreal neurological institute; mPFC, medial prefrontal cortex; NIRS, near infrared spectroscopy; OFC, orbitofrontal cortex; paAlt, lateral parakoniocortex; PAG, periaqueductal gray; PCC, posterior cingulate cortex; PET, positron emission tomography; PFC, prefrontal cortex; PMA, premotor area; SI, primary somatosensory cortex; SII, secondary somatosensory cortex; SMA, supplementary motor area; SMN, sensorimotor network; SN, salience network; SSN, substantia nigra; TAA, architectonic subdivision of the superior temporal sulcus; TPO, polysensory region of the superior temporal sulcus; Ts1, superior temporal area 1; Ts2, superior temporal area 2; Ts3, superior temporal area 3; VA, ventral anterior (thalamic nucleus); VBM, voxel-based morphometry; VTA, ventral tegmental area.

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<https://doi.org/10.1016/j.pneurobio.2017.11.004>

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1. Background

Multiple frontal cortical brain regions have emerged as being important during pain experience (Apkarian et al., 2005; Kucyi and Davis, 2015; Neugebauer et al., 2009; Tracey and Mantyh, 2007). Pain is a complex phenomenon that includes sensory, emotion, cognition and integration across those dimensions. The involvement of high-order cortical areas, including the frontal regions, is therefore not surprising. Previous studies regarding cortical processing of pain have primarily focused on the “traditional” nociceptive pathways such as the insula and the anterior cingulate cortex (ACC), revealing multidimensional roles of these areas from sensory encoding to affective processing (Brooks and Tracey, 2007; Coghill et al., 1999; Davis et al., 2005; Derbyshire et al., 1997; Fuchs

et al., 2014; Gu et al., 2013; Price, 2000; Shackman et al., 2011; Starr et al., 2009). The contribution of specific frontal regions to pain experience, on the other hand, is still ill defined at the current stage. One such region is the frontal pole (FP) – specifically within Brodmann areas 10 (BA 10) located in the anterior medial frontal cortex. This region is located inferior to Brodmann area 9 (BA 9, superior frontal cortex) and superior to Brodmann area 11 (BA 11, the anterior extension of orbitofrontal cortex). BA 10 (Fig. 1), also known as the anterior prefrontal cortex, frontopolar prefrontal cortex or rostral prefrontal cortex, is a supramodal cortex that is involved in a wide variety of functions including risk and decision making, odor evaluation, reward and conflict, pain, and working memory (Burgess et al., 2007a; Gilbert et al., 2006b; Ramnani and Owen, 2004). While there may be differences between the right

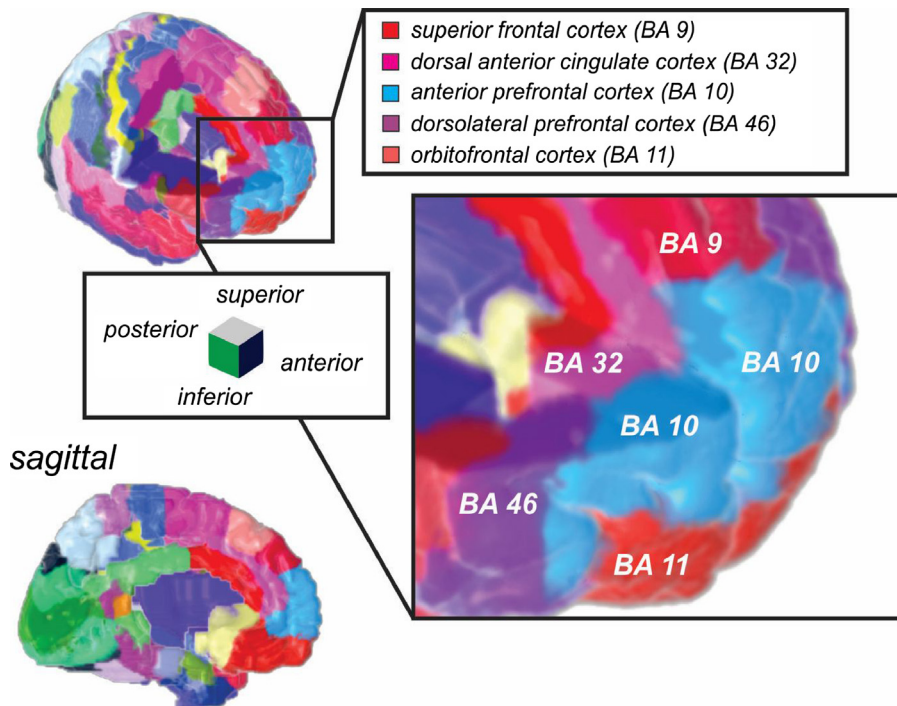


Fig. 1. Depiction of Brodmann Area 10.

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