ANAT2910

Concepts of Neuroanatomy (Adv) (II)

S2 2018

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ANAT2010 Lecture 13: Pain and perception

Pain and nociception

Sir Charles Scott Sherrington (1857 – 1952) defined **nociceptors as sense organs** that **respond to noxious stimuli**; he defined noxious stimuli as those that either **threaten or actually produce damage.**

Key terms:

- *Nociception:* transmission of electrical signal from the peripheral nociceptor to the CNS
- *Pain:* perception of pain is a product of brain's abstraction and elaboration of nociceptive input

Pain is not simply a sensation – it is defined as an unpleasant sensory and emotional experience i.e. involves **sensory components** (pain "feels" hot, sharp, dull etc.) and **emotional components** (pain is "distressing, exhausting" etc.)

Different types of nociceptors (free nerve endings)

The different sensory qualities of pain may result from activation of different types of nociceptors:

1. **Mechanical nociceptors** – activated by strong stimuli such as pinch and sharp objects that penetrate, squeeze and pinch the skin
   e.g. sharp or pricking pain, via **A-delta fibers** (which are generally quite fast)

2. **Thermal nociceptors –** activated by noxious heat (temp above 45^{o}C), noxious cold (temp below 5^{o}C)
   e.g. hot pain, via A-delta fibers

3. **Polymodal nociceptors –** activated by noxious mechanical stimuli, noxious heat, noxious cold, irritant chemical
   e.g. slow dull during pain or aching pain, via non-myelinated C fibers
   With polymodal nociceptors - associated with muscle pain – persist 1-2 days after stimulus

Nociceptors are located everywhere, in skin, muscle, heart even in cranium in the dura mater.

Acute (short-lasting) pain *is beneficial*

- Homeostatic mechanism – not like vision and audition – more like thirst and hunger e.g. **fight/flight**

    - There are important for survival, protection from damage; the pain is a signal that aims to alter/**drive your behavior** to remove yourself form potential danger.

Different types of pain are associated with different perceptions: skin produces a distinctively different response when compared with pain arising from deeper structures:

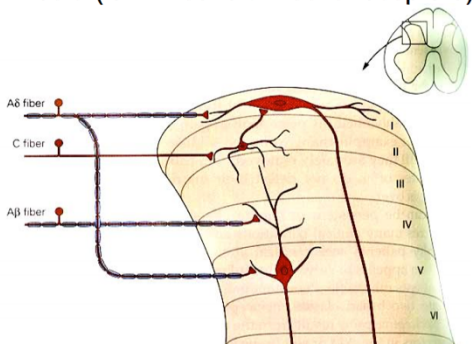
Pain from human skin	*Pain from deeper structures*
brisk movements	quiescence
rise of pulse rate	slowing of the pulse
sense of invigoration	falling of the blood pressure
	sweating
	nausea

Note: it is theorized that pain on the skin is escapable whereas as pain in deeper structure is not.

How does noxious information reach the central nervous system?

Nociceptor afferent input to the spinal cord:

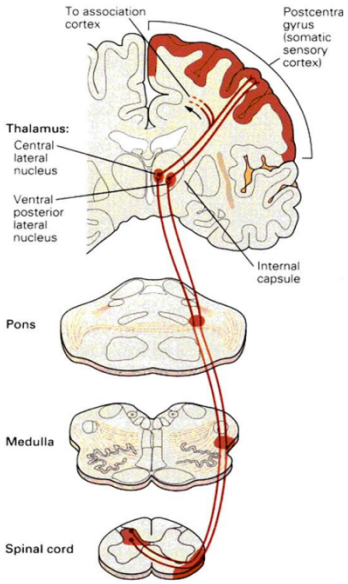
- Projecting neurons in lamina I receive A-delta and C fibers information.
- Neurons in lamina II receive input from C fibers and relay it to other laminae.
- Projecting neurons in lamina V (**wide-dynamic range neurons**) receive A-delta, C and A-beta (low threshold mechanoceptors) fibers information.



Note: synapses *outer lamina* of the dorsal horn

Ascending Pathways

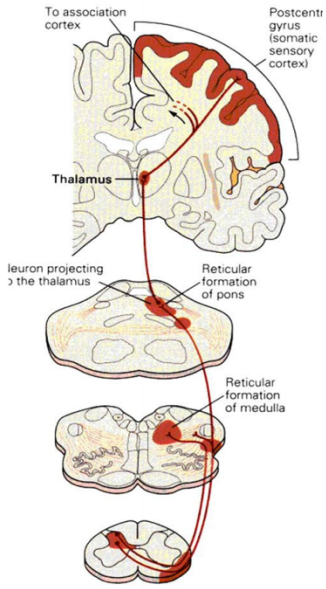
Spinothalamic



Pain location, intensity, sensory quality, affective component

Ascending Pathways

Spinoreticular

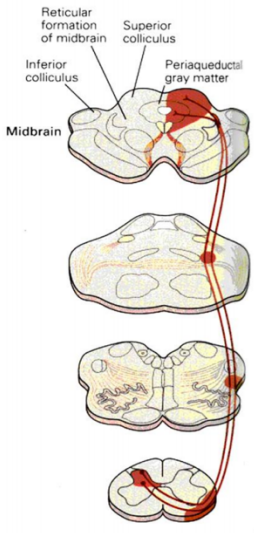


Arousal?

Note: **reticular formation** of the pons sets the general arousal of the brain – increase or decrease sensory input/vigilance to the environment.

Ascending Pathways

Spinomesencephalic



Defensive behaviours

Note: Periaqueductal gray matter responsible for defensive behavior e.g. flight or fight

How do we know where noxious information is processed in the CNS?

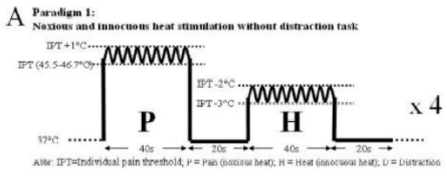
- Animal studies – tract tracing, neural activation (c-fos, electrophysiology, autoradiography) immunohistochemistry

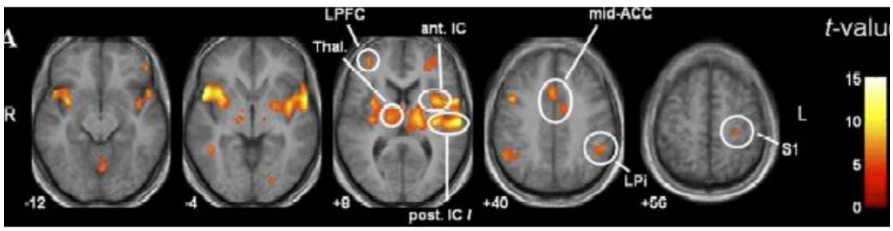
- Human studies – lesions, EEG, brain imaging (PET, fMRI)

e.g. looking at the changing brain activity between noxious and non-noxious stimulus

Human brain imaging studies:

Heat Pain





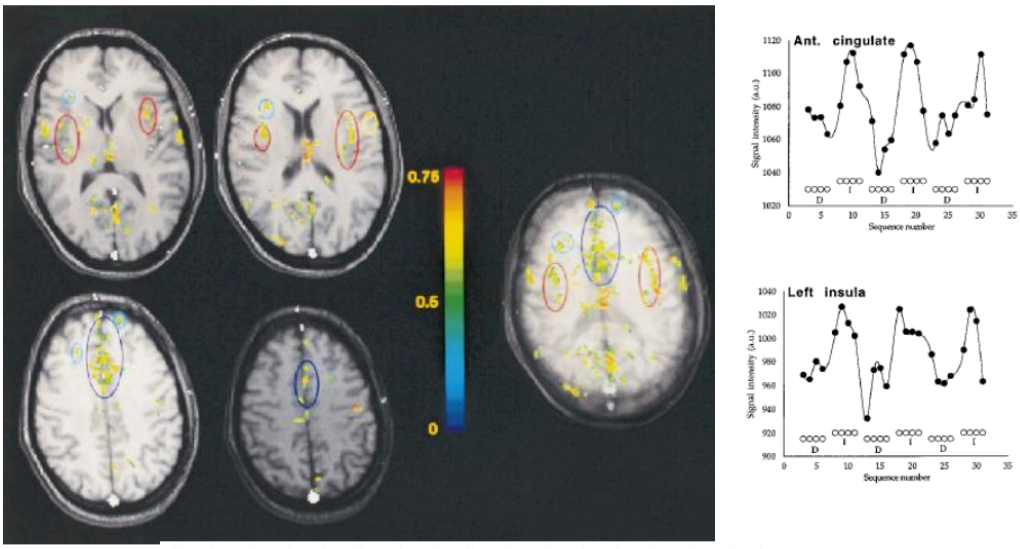
Distraction modulates connectivity of the cingulo-frontal cortex and the midbrain during pain—an fMRI analysis

Michael Valet[a,*], Till Sprenger[a], Henning Boecker[a,b], Frode Willoch[b], Ernst Rummeny[c], Bastian Conrad[a], Peter Erhard[a,b,c], Thomas R. Tolle[a]

Pain 109 (2004) 399–408

Visceral Pain

Rectal pain was induced by inflating a latex balloon catheter that had been inserted into the rectum.



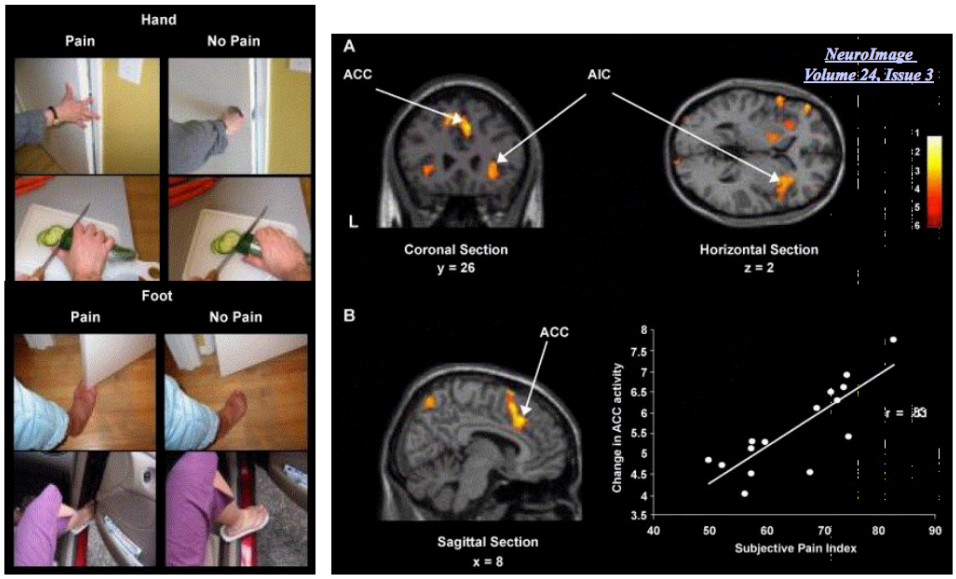
Central Processing of Rectal Pain: A Functional MR Imaging Study

Note: although we can track somatotopic map does not mean its involved in perception of stimulus localization.

Where are emotional components of pain processed?

- If the cingulate cortex is lesioned – personality altered
- Insular – alters emotional processing

How do we perceive the pain of others? A window into the neural processes involved in empathy



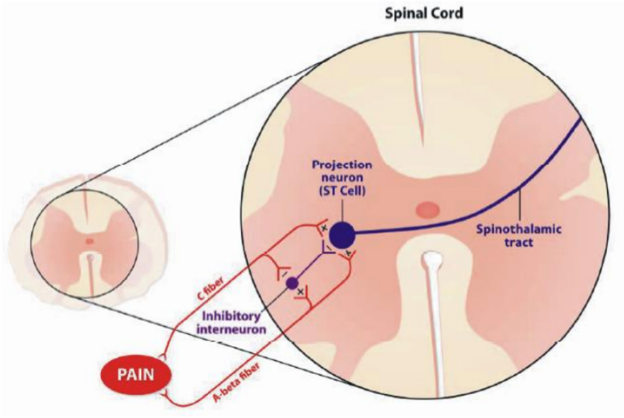
Note: the problem is that seeing someone in pain also activates the same areas of the brain as if you were in pain e.g. cingulate and insula

Pain perception can be modulated:

- Pain reflexes and behavioral responses can be altered or suppressed if not appropriate (step on nail near/on edge of step, burn hands while holding a baby). Pain can be suppressed if not needed for survival.
- Pain perception can be modulated by all kinds of factors – including behavioral states (stress, sex), cognitive states (hypnosis) and mental states ("trance"), social norms and drugs.

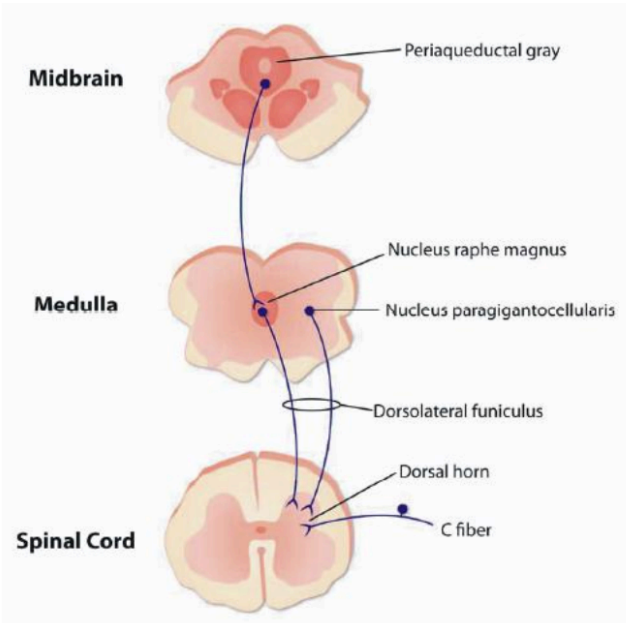
e.g. perceive pain differently if in the presence of male vs female.
You can activate nociceptors and not perceive pain and the converse is also true, you cannot activate nociceptors and still perceive pain.

- Melzack and Wall gate control theory



Note: Non-noxious somatosensory input can actually inhibit noxious somatosensory input – at the level of the dorsal horn, most terminate.

- Endogenous analgesia



Chronic pain

- Pain lasting at least 3 months
- Has no benefit i.e. dysfunction – significant impact on sufferer's life

Note: pain results from changes in brain activity – which **may or may not** result from a change in nociceptor activity.

For example – phantom pain, post stroke pain, SCI pain

Types of chronic pain:

1. **Nociceptive chronic pain –** results from constant activation of nociceptors
   e.g. arthritis, temporomandibular disorder
   Note: if the anesthetize the nociceptor, you can probably get rid of that pain.

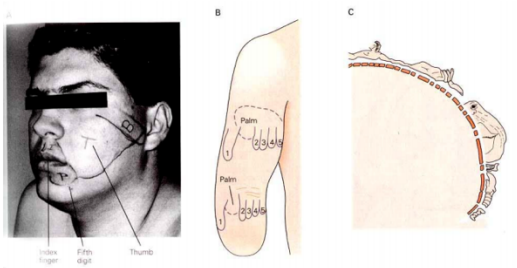
2. **Neuropathic chronic pain –** results from damage to the nervous system
   e.g. post-stroke pain, phantom limb pain, lower back pain, trigeminal neuralgia, post-herpetic pain.

Chronic pain following complete spinal cord injury

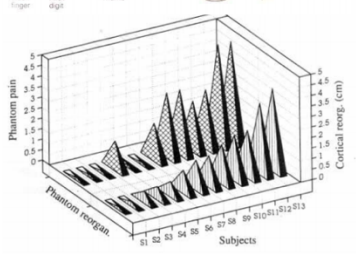
In 1978 Melzack and Loeser wrote about a patient who had below level pain following a spinal cord injury:

"One was explored through a laminectomy and then had his cauda equina decompressed after which a sympathetic novocain block, a lumbar sympathectomy, a posterior rhizotomy and finally a cordotomy were performed without affording any relief of his pain . . . ."

S1 cortical reorganization and phantom limb pain



Phantom Pain intensity as a function of Cortical Reorganization.



Phantom-limb pain as a perceptual correlate of cortical reorganization following arm amputation

H. Flor*, T. Elbert†, S. Knecht‡, C. Wienbruch‡, C. Pantev‡, N. Birbaumer§, W. Larbig§ & E. Taub‖

Note: rewiring of the brain – plasticity

Can we trick the brain into reducing pain?

Mirror therapy was first described by Dr.V.S. Ramachandran

<u>Mirror box therapy:</u>

- subject thinks they have 2 hands!
- results in a decrease in phantom limb pain