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ORIGINS OF PAIN AND BEYOND

MAKING STIMULUS COMPLEXITY - BEYOND THE BORDER

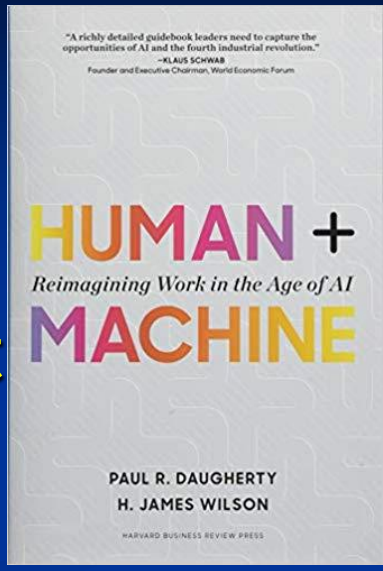
Dejan M. Nešić, MD, PhD, Associate professor

Institute of Medical physiology, School of Medicine, University of Belgrade

SENSORY SYSTEMS

All sensory pathways begin with a stimulus, which acts on sensory receptors, which convert the stimulus in neural signals, which are transmitted by sensory neurons to the brain, where they are integrated.

SENSING IN THE HUMAN



- Information i/o …
  - visual, auditory, haptic, movement
- Information stored in memory
  - sensory, short-term, long-term
- Information processed and applied
  - reasoning, problem solving, skill, error
- Emotion influences human capabilities
- Each person is different

SENSATION & PERCEPTION PROCESSES

1

Stimulus

Example: A green light emits physical properties in the form of photons (light waves).

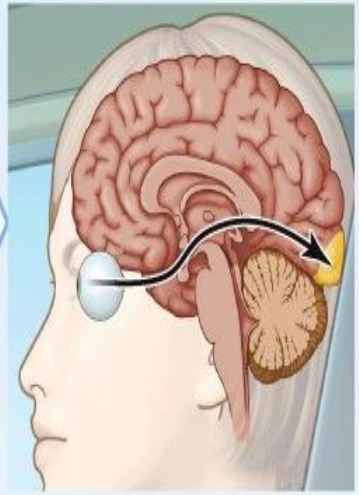
2

Sensation

Sensory receptors in the driver's eyes detect this stimulus.

3

Sensory Coding



The stimulus is transduced (translated into chemical and electrical signals that are transmitted to the brain).

4

Perception

The driver's brain processes the neural signals and constructs a representation of a green light ahead. The brain interprets the representation of the light as a sign to continue driving.

Vision

Two stages in vision

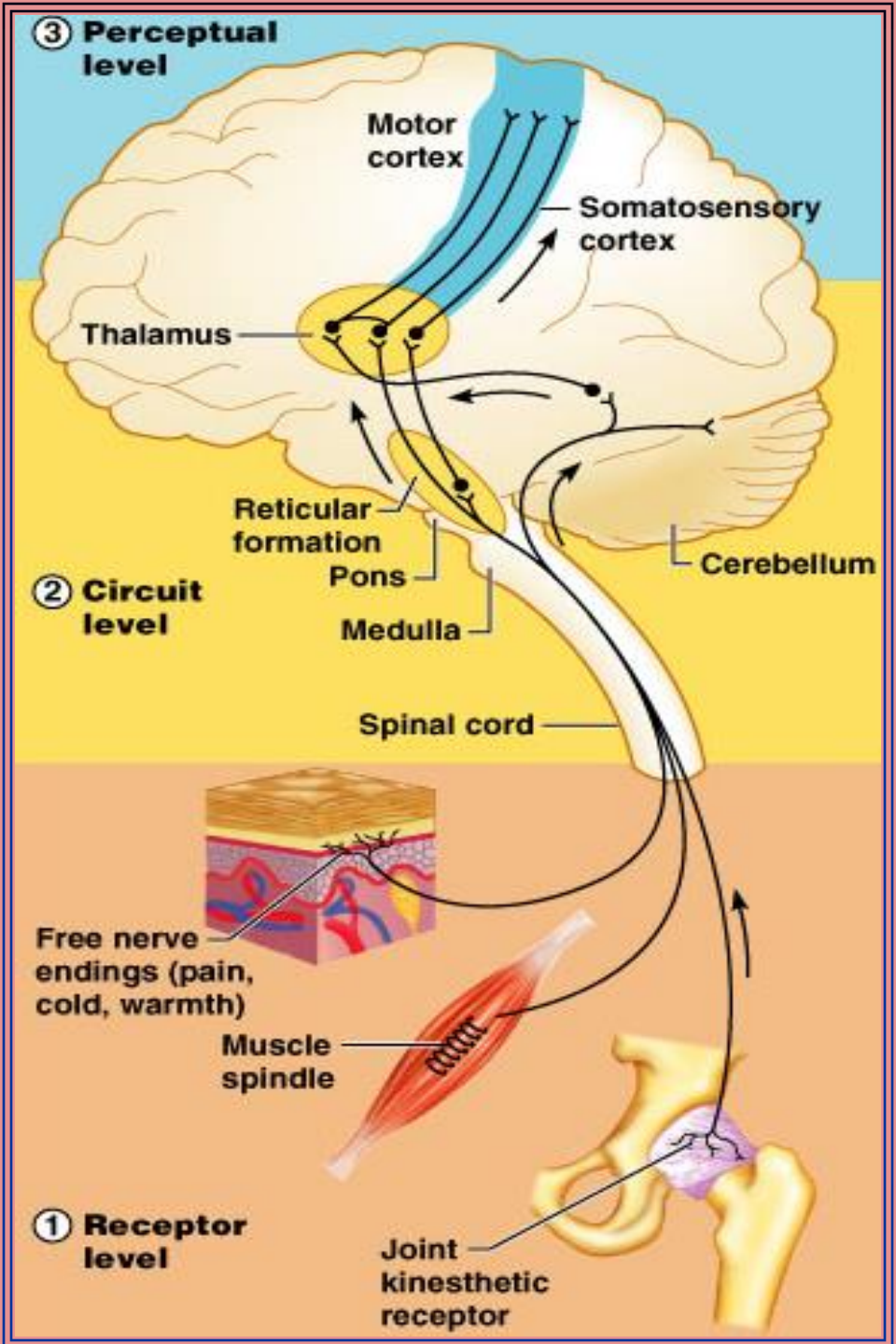
- physical reception of stimulus
- processing and interpretation of stimulus

THE EYE - PHYSICAL RECEPTION

- mechanism for receiving light and transforming it into electrical energy
- light reflects from objects
- images are focused upside - down on retina
- retina contains rods for low light vision and cones for colour vision
- ganglion cells (brain!) detect pattern and movement

THE RIDDLE OF SEPARATE SENSATIONS

- **Sense receptors**
  - **Specialized cells that convert physical energy in the environment or the body to electrical energy that can be transmitted as nerve impulses to the brain**



SENSATION TO PERCEPTION

3 main levels of neural processing are:

- Receptor level
- Circuit level
- Perceptual level

SENSORY RECEPTORS

Function as:

- **receivers – specialized to respond to changes in environment (external and internal), and**
- **transducers – convert different types of energy (adequate stimuli) to action potential (e.g.**

stimulus → graded potential → action potential→ CNS → effector

Classification of sensory receptors:

- **type of stimulus they detect**
- **body location**
- **structural complexity**

STIMULUS AND RESPONSE

Stimulus

An external environmental trigger

Response

An internal reaction to the stimulus

Huges D., Bioinspiration & Biomimetics 2019,

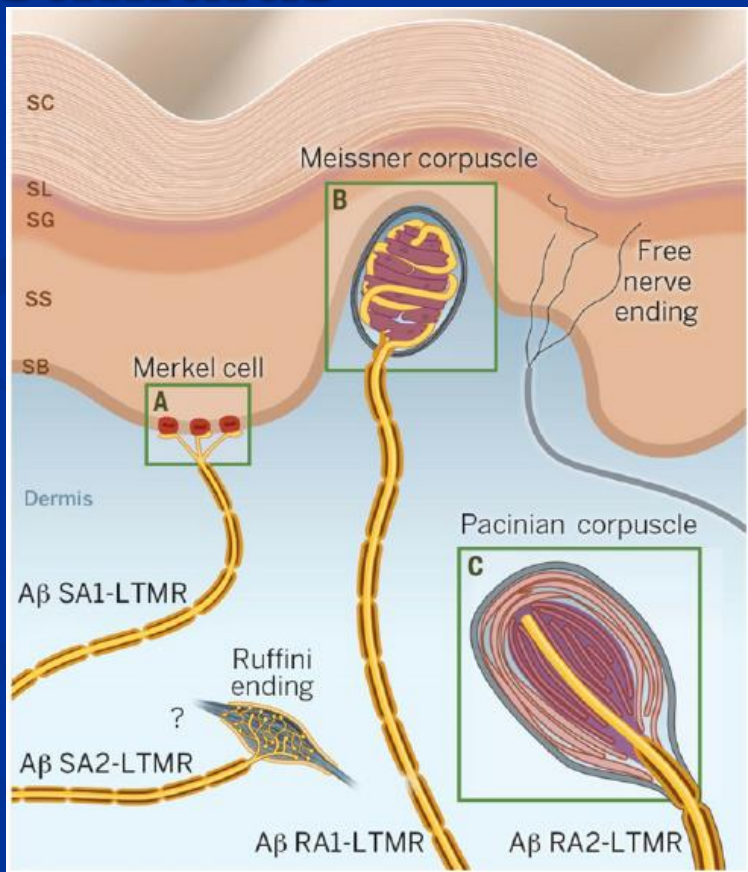


Table 3.-1. Classification of cutaneous mechanoreceptors according to rate of adaption (headings above the columns) and adequate stimulus (at the bases of the columns)

	ADAPTATION TO CONSTANT PRESSURE STIMULUS		
	Slow	Moderately rapid	Very rapid
Hairless skin:	Merkel's disk	Meissner corpuscle	Pacinian corpuscle
Hairy skin:	Tactile disks, Ruffini endings	Hair-follicle receptor	Pacinian corpuscle
	Intensity detector	Velocity detector	Acceleration detector
	CLASSIFICATION BY ADEQUATE STIMULUS		

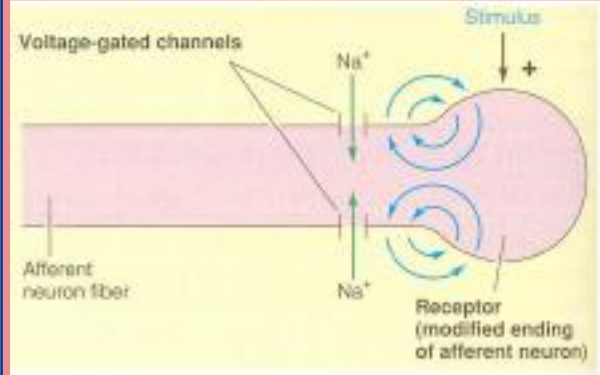
Rapidly adapting Re's = Phasic Re's or Movement Re's

Slowly adapting Re's = Tonic Re's (can transmit information for many hours) - Chemo-baroreceptors, muscle spindles, Golgi tendon organ……..

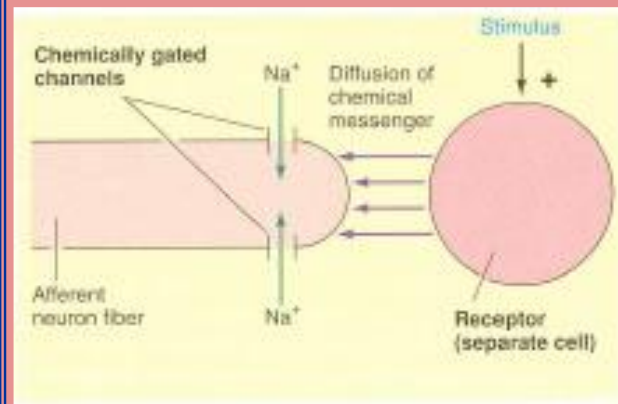
PAIN Re's never adapt completely !

SENSORY TRANSDUCTION

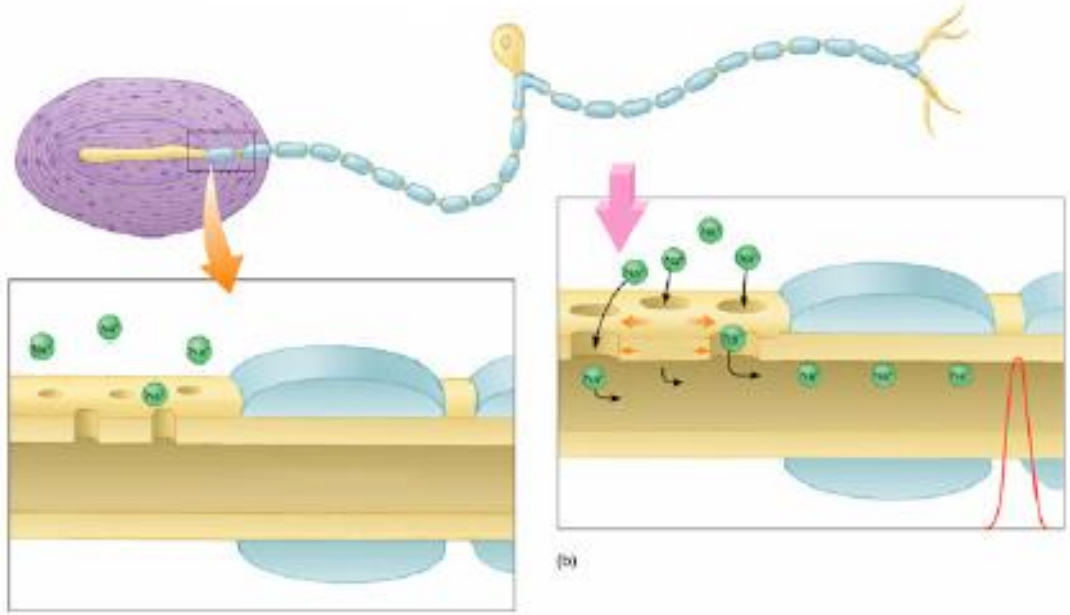
Sensory transduction converts stimuli into graded potentials. Such changes in receptor membrane potential are known as the **receptor potential** and the **generator potential**.



somatic sense receptors



special sense receptors



In most cases, channel opening results in net influx of Na^+ into the receptor, causing a **depolarization** of the membrane.

SENSORY REPRESENTATIONS

To create an accurate neural representation of sensory stimuli, the brain must distinguish four stimulus properties:

- **Stimulus modality – labeled line coding;**
- **Stimulus location – receptive field, input convergence, topographical maps, lateral inhibition;**
- **Stimulus intensity – population & frequency coding**
- **Stimulus duration – best reflect changes in stimulation**

STIMULUS MODALITY

Law of Specific Nerve Energies (Muller's Law)

The specificity of a receptor for a particular type of stimulus is called the law of specific nerve energies.

Sensation characteristic of each sensory neuron is that produced by its normal or adequate stimulus.

Adequate stimulus: requires least amount of energy to activate a receptor.

Regardless of how a sensory neuron is stimulated, only one sensory modality will be perceived.

DOCTRINE OF SPECIFIC NERVE ENERGIES

- Different sensory modalities exist because signals received by the sense organs stimulate different nerve pathways leading to different areas of the brain.
- Synthesia
  - A condition in which stimulation of one sense also evokes another.

Stage 1

Stimuli from one or more of the five senses are sent to the brain

Stage 2

The brain deciphers the stimulus as either a threat or a non-threat

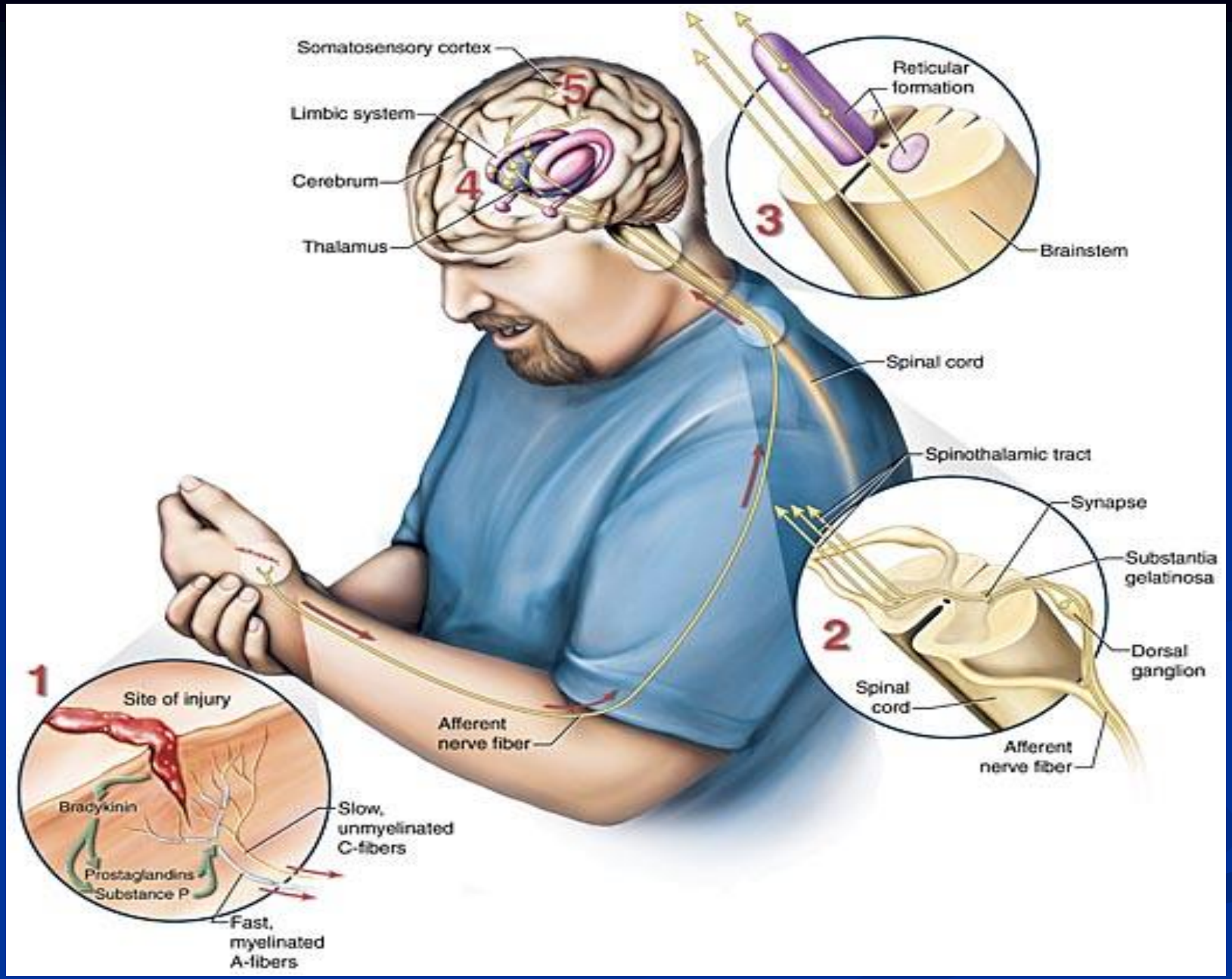
Stage 3

The body stays activated or aroused until the threat is over

Stage 4

The body returns to homeostasis, a stage of physiological calmness, once the threat is gone


PAIN
Muscle Tension
Pressure on Nerves
Reduced Circulation
Muscle Shortening
Restricted Movement
Trigger Points
Irritating Wastes
STRESS



LEVELS OF PAIN TRANSMITION

NEUROMATRIX THEORY OF PAIN

- Theory that the matrix of neurons in the brain is capable of generating pain (and other sensations) in the absence of signals from sensory nerves.

NEURAL CIRCUITS

Neurons are interconnected with one another to form circuits, much as electronic components are wired together to form a functional circuit.

"Pain Matrix"

- **Anterior cingulate cortex (ACC)**

(Response selection, motor suppression, attention, affect)

- **Insular cortex (IC) or Insula**

(sensory integrative (T, P, taste, vestibular), visceral sensory, visceral morot, limbic integration)

- **Thalamus**

major source of nociceptive input

- **Somatosensory cortex (SS I, SS II)**

(S I - sensory discriminative in general, alt. stim localization

S II - sensory integrative (touch, pain, visual), spatially directed attention)

- **Prefrontal Cortex**

(Affect, emotion, memory)

Moseley GL. *Man Ther.* 2016;

"Pain Matrix"

The pain matrix mainly consists of the thalamus (Th), the amygdala (Amyg), the insula cortex (Insula), the supplementary motor area (SMA), the posterior parietal cortex (PPC), the prefrontal cortex (PFC), the cingulate cortex (ACC), the periaqueductal grey (PAG), the basal ganglia and cerebellar cortex (not shown) and the primary (S1) and secondary (S2, not shown) sensory cortex

Moseley GL. *Man Ther.* 2016;

IS THIS ALL THE WAY THAT WE SAYING ?

Sensory-discriminative aspects of pain perception are often thought to be independently and specifically represented in S1 and S2, constituting the so-called "lateral pain system" or "somatosensory node", while affective aspects of pain perception would be represented in medial brain structures such as the ACC, constituting the "medial pain system" or "affective node"

Neuroimage. 2018 May 15;172:562-574

THE CORTICAL PAIN MATRIX AS A SERIES OF OVERLAPPING SYSTEMS. The primary matrix provides the location information to the pain stimulus, while the secondary matrix focuses attention (or not) on the pain. These operate in parallel, simultaneously. The third matrix integrates the signal from the first two, and then begins to generate a behavioral response.

Pain Manag. 2015;5(4):297-317.