260-2017-03-27-sensation

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Prelude

I was fortunate to get to travel to Vienna, Austria last week to present at a conference. While there I saw an amazing exhibit of the artwork of Egon Schiele, someone I learned about in college. There is nothing like seeing works of art in person. It's a fortunate coincidence that we are starting our discussions about sensory processing.

Today's Topics

- Sensory systems

Sensation/Cognition/Action

One way to think about the relationship between the nervous system, the body, and the world is depicted in this diagram. Here, the nervous system is nested in the body, and the body is nested in the world. Sensory information about the world and body enters through one stream; motor information affecting the body and the world exits through a separate stream. For the next several classes, we'll be talking about the incoming sensory stream.

From sensation to action

This figure depicts how information flows through this system in a very simple task: "press the button when it lights up." The task of sensory neuroscientists is to understand how meaningful information enters the nervous system and how it shapes cognition, emotion, and action.

Systems/information processing view

- Input
- Processing
- Memory
- Output

As we started doing when we talked about emotion, we'll take a systems or information processing approach. What's the input, how is it processed, what role might stored information or memory play, and then what is the output?

You vs. Your Smartphone

I find that most of us aren't used to thinking about how our senses work using this framework, so I want to try to use a metaphor…the smartphone. Have you ever thought about how you and your smartphone are alike?

Multisensory processing in a smartphone

- Accelerometer
- Gyroscope
- Magnetometer
- Proximity sensor
- Ambient light sensor
- Barometer

http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885

Like you, your smartphone has multiple sensors that provide it information.

Multisensory processing in a smartphone

- Thermometer
- Mic
- Camera
- Radios (Bluetooth, wifi, cellular, GPS)

http://www.phonearena.com/news/Did-you-know-how-many-different-kinds-of-sensors-go-inside-a-smartphone_id57885

We'll come back to this metaphor when we talk about action planning. For now, we'll switch back to talking about our own nervous systems.

Dimensions of sensory processing

- *Interoceptive*
  - How am I?
- *Exteroceptive*
  - What's in the world, where is it?

Some of your smartphone sensors provide information about the phone's status – its temperature, position/movement, etc. – in our case, we call sensory systems that provide information about internal status *interoceptive*. These contrast with the systems that provide information about what's out there in the world.

Questions for interoception

- Tired or rested?
- Well or ill?
- Hungry or thirsty or sated?
- Stressed vs. coping?
- Emotional state?

What kinds of information do you think your interoceptive systems provide? What kinds of questions do these sensors help the nervous system to answer?

Questions for exteroception

- Who/What is out there?
- Where is it?

Who/what

- Animate/inanimate?
- Conspecific (same species)/non?
- Threat/non?
- Familiar/un?
- Mate/non? or Friend/not?
- Food source/non?

Let's focus on the first question – who or what is out there. What kinds of questions would a useful exteroceptive system provide information about?

Where

- Distance
- Elevation, azimuth
- Coordinate frames
  - Self/ego (left of me)
  - Object (top of object)
  - Allo/world (North of College)
- Where moving?

The other side of exteroception involves spatial information – where are these things and where are they moving?

How

- What kind of response?
  - External
  - Internal
- Approach/avoid/freeze
- Signal/remain silent
- Manipulate

Finally, the cognition/emotion system takes the information from these "what is it" and "where is it" streams and computes some sort of set of output response. The responses can be external, involving movements of the body, or internatl, involving changes in physiological state.

So, each and every moment of your day, your nervous system takes in streams of interoceptive and exteroceptive information and your nervous system computes what to do about it.

More than 5 senses

So, how many sensory channges are there? Well, I hate to say it, but your elementary school teachers were wrong. There are many more than five. Scientists categorize senses not based on the part of the body – the eye, the skin, the ear – but the kind of energy or chemical information they convey. This perspective focuses more on the physics and the chemistry of these channels, and less on anatomy.

How sensory channels differ

- What is the energy/chemical source
- How does the channel inform
  - What is out there

  - Where it’s located

So, from this perspective, we can ask questions about the source of energy or chemical pattern and how each channel informs questions about what’s out there and where it’s located.

Features of sensory signals

- Tonic (sustained) vs. phasic (transient) responses
- Adaptation
  - Decline in sensitivity with sustained stimulation
  - Most sensory systems attuned to change
- Information propagates at different speeds

It turns out that even within sensory channels, there are important differences between sensors. Some provide sustained or tonic information, others provide only transient or phasic information. Some repond vigorously initially, then adapt or show a decline in response, with repeated stimulation. Also, while we aren’t usually aware of it, the signals from our different senses propagate to the CNS at different speeds. We’ll say more about this next time.

Common principles

- Sensors detect repeating signals
  - In space (textures)
  - In time

Despite these differences in energy/chemical type and responses over time within channels, there are striking similarities in the way sensory channels work. For example, many systems have ways of detecting signals that repeat in space or time.

Spatial frequency/contrast sensitivity

http://fourier.eng.hmc.edu/e180/lectures/figures/csf_image.gif

In vision, we find that most patterns can be decomposed into mixtures of “spatial frequencies” or variations in lightness and darkness. We’ll learn more about this when we talk about visual processing.

Frequencies in sound

http://hearinghealthmatters.org/waynesworld/files/2012/06/Fourier-Analysis.gif

Similarly, as many of you may know, sounds are made up of mixtures of frequencies that the brain unmixes to make sense of the acoustic world.

Common principles

- Compare (>1) sensor for each channel
  - Eyes
  - Ears
  - Nostrils
  - Skin surface

Another common principle we see across sensory systems is the use of two sensors for the same channel. This allows the nervous system to compare the inputs from both.

Why is the snake's tongue forked?

http://indianapublicmedia.org/amomentofscience/files/2010/06/tongue_111.jpg

A fun example of this is the snake's forked tongue. Snakes "smell or taste" with their tongues. Anyone want to speculate what information they get from the two parts?

Common principles

- Sensory neurons have "receptive fields"
  - Area on sensory surface that when stimulated changes neuron's firing

Another commonality among sensory systems is that many can be thought of as "surfaces", and cells within these surfaces respond only to stimulation in particular parts and with particular properties. The combination of the location on the sensory surface and the properties that stimulate a cell is called the cell's *receptive field*.

Tactile receptive field

So, a somatosensory neuron's receptive field is the area on the skin that it responds to.

Visual receptive field

https://classconnection.s3.amazonaws.com/594/flashcards/1450594/png/untitled_picture51356035996428.png

And a visual neuron's receptive field is the part of the retina the cell responds to.

Common Principles

- Topographic maps

The arrangement of sensory neurons across a sensory surface usually follows some sort of pattern. This often results in "maps" of different parts of the sensory surface that can be found all the way up the processing chain to the brain. In fact, the brain contains lots of different types of maps.

Tonotopic (frequency) maps in auditory cortex

http://www.his.kanazawa-it.ac.jp/~tomi/public/MEGLab/Auditory/tonotopy.gif

In the auditory cortex, there is a map of cells that respond to different sound frequencies.

Retinotopic maps in visual cortex

http://jov.arvojournals.org/data/Journals/JOV/933499/jov-3-10-1-fig001.jpeg

In the visual cortex, there is a topographic map of the retina called a retinotopic map. Here, the map is being measured using fMRI. It turns out that the size of these maps differs by a factor of 2 among different adults.

Common principles

- Non-uniform sensitivity

Another common principle is that of non-uniform sensitivity.

Two-point touch thresholds

http://jov.arvojournals.org/data/Journals/JOV/933499/jov-3-10-1-fig001.jpeg

For example, your ability to detect small spatial differences in skin stimulation varies considerably across the body, lowest on the back of your calf, and highest on your fingertips.

Acuity variations across visual field

https://upload.wikimedia.org/wikipedia/commons/thumb/2/27/AcuityHumanEye.svg/270px-AcuityHumanEye.svg.png

We don't often notice it, but our visual acuity falls off rapidly away from the center of our visual field.

Hearing threshold varies across frequency

http://www.hearforever.org/userfiles/image/tools_to_learn/SS4_Hearing_Sensitivity.jpg

And, some animals hear frequencies we just can't, and vice versa.

Hierarchical processing

There is a common hierarchy of processing among sensory signals. Most originate in the periphery, project through sense-specific regions of the thalamus, and then go to sensory-specific regions of the cerebral cortex.

Parallel processing

But there is also a lot of parallel processing going on even among sensory systems.

Parallel processing

For example, when you hold a hot coffee cup, there are separate channels providing information about the cup's temperature, whether it is painfully hot or not, the cup's texture, and weight.

How does the brain put these separate pieces into a coherent whole? That's a great question, and we'll start to answer next time.

Next time...

- Somatosensation