How do we construct our representations of the external world?

To represent the world, we must first detect physical energy (a stimulus) from the environment and convert it into neural signals. This is a process called sensation.

When we select, organize, and interpret our sensations, the process is called perception.

The Dark Restaurant

“I went to this restaurant in Berlin…”

The Senses

• Traditional Five:
  – Sight
  – Hearing
  – Touch
  – Smell
  – Taste

• Six others that humans have
  – Nociception (pain)
  – Equilbrioception (balance)
  – Proprioception & Kinesthesia (joint motion and acceleration)
  – Sense of time
  – Thermoception (temperature)
  – Magnetoception (direction)

Bottom-up Processing

Analysis of the stimulus begins with the sense receptors and works up to the level of the brain and mind.

Letter “A” is really a black blotch broken down into features by the brain that we perceive as an “A.”

Top-Down Processing

Information processing guided by higher-level mental processes as we construct perceptions, drawing on our experience and expectations.

TAE CAT
Top-Down or Bottom-Up?

Learned depth cues make this a top down perceptual distortion.

Making Sense of Complexity

Our sensory and perceptual processes work together to help us sort out complex images.

"The Forest Has Eyes," Bev Doolittle

Sensing the World

Senses suit an organism’s needs, enabling survival.

A frog feeds on flying insects so visual acuity must be very sensitive;
a male silkworm moth is sensitive to female sex-attractant odor;
and we as human beings are sensitive to sound frequencies that represent the range of human voice.
Exploring the Senses

- What stimuli cross our threshold for conscious awareness?
- Could we be influenced by stimuli too weak (subliminal) to be perceived?
- Why are we unaware of unchanging stimuli, like a band-aid on our skin?

Psychophysics

A study of the relationship between physical characteristics of stimuli and our psychological experience with them.

<table>
<thead>
<tr>
<th>Physical World</th>
<th>Psychological World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Brightness</td>
</tr>
<tr>
<td>Sound</td>
<td>Volume</td>
</tr>
<tr>
<td>Pressure</td>
<td>Weight</td>
</tr>
<tr>
<td>Sugar</td>
<td>Sweet</td>
</tr>
</tbody>
</table>

22nd October 1850

A relative increase in mental intensity, Fechner realized, might be measured in terms of the relative increase in physical energy required to bring it about.
**Detection**

<table>
<thead>
<tr>
<th>Intensity</th>
<th>No</th>
<th>No</th>
<th>No</th>
<th>Yes</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Observer's Response</strong></td>
<td><strong>Detected</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Tell when you (the observer) detect the light.

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**Thresholds**

**Absolute Threshold:** Minimum stimulation needed for an individual to detect a particular stimulus 50% of the time.

![Graph showing absolute threshold](image)

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**Subliminal Threshold**

**Subliminal Threshold:** When stimuli are below one’s absolute threshold for conscious awareness.

![Graph showing subliminal threshold](image)
Difference Threshold

Difference Threshold: Minimum difference between two stimuli required for detection 50% of the time, also called just noticeable difference (JND).

Weber’s Law

Two stimuli must differ by a constant minimum percentage (rather than a constant amount), to be perceived as different. Weber fraction: \( k = \delta / I \).

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Constant (k)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>8%</td>
</tr>
<tr>
<td>Weight</td>
<td>2%</td>
</tr>
<tr>
<td>Tone</td>
<td>3%</td>
</tr>
</tbody>
</table>

Signal Detection Theory (SDT)

Predicts how and when we detect the presence of a faint stimulus (signal) amid background noise (other stimulation). SDT assumes that there is no single absolute threshold and detection depends on:

- Person’s experience
- Expectations
- Motivation
- Level of fatigue
SDT Matrix

The observer decides whether she hears the tone or not, based on the signal being present or not. This translates into four outcomes.

<table>
<thead>
<tr>
<th>Decision</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>Hit</td>
<td>Miss</td>
</tr>
<tr>
<td>Absent</td>
<td>False Alarm</td>
<td>Correct Rejection</td>
</tr>
</tbody>
</table>

The observer decides whether she hears the tone or not, based on the signal being present or not. This translates into four outcomes.

Sensory Adaptation

Diminished sensitivity as a consequence of constant stimulation.

Put a band aid on your arm and after awhile you don’t sense it.

Now you see, now you don’t
Sense of Touch

The sense of touch is a mix of four distinct skin senses—pressure, warmth, cold, and pain.

Skin Senses

Only pressure has identifiable receptors. All other skin sensations are variations of pressure, warmth, cold, and pain.
Touch Sensation/Perception

• The intense tickling sensation that makes you laugh uncontrollably...
  – Only happens when someone else tickles you
  – You cannot tickle yourself and get this response (Blakemore, et al., 2000)
• Why?

Taste

Traditionally, taste sensations consisted of sweet, salty, sour, and bitter tastes. Recently, receptors for a fifth taste have been discovered called “Umami”.

Sensory Interaction

When one sense affects another sense, sensory interaction takes place. So, the taste of strawberry interacts with its smell and its texture on the tongue to produce flavor.
Taste

*Scientific American Frontiers: Tasters and Super-tasters*

Smell

Like taste, smell is a chemical sense. Odorants enter the nasal cavity to stimulate 5 million receptors to sense smell. Unlike taste, there are many different forms of smell.

Age, Gender, and Smell

Ability to identify smell peaks during early adulthood, but steadily declines after that. Women are better at detecting odors than men.
Smell and Memories

The brain region for smell (in red) is closely connected with the brain regions involved with memory (limbic system). That is why strong memories are made through the sense of smell.

Example of Sensory Interaction
Audition/Vision

Count the Fs:
FINISHED FILES ARE THE RESULTS OF YEARS OF SCIENTIFIC STUDY COMBINED WITH THE EXPERIENCE OF YEARS.

Pheromones, Odor, and Sweaty T-Shirts

• http://www.pbs.org/wgbh/evolution/library/01/6/l_016_08.html
Vision

Transduction

In sensation, the transformation of stimulus energy into neural impulses.

Phototransduction: Conversion of light energy into neural impulses that the brain can understand.

The Stimulus Input: Light Energy
Light Characteristics

- Wavelength (hue/color)
- Intensity (brightness)
- Saturation (purity)

Wavelength (Hue)

Hue (color) is the dimension of color determined by the wavelength of the light.

Wavelength is the distance from the peak of one wave to the peak of the next.

Different wavelengths of light result in different colors.
Intensity (Brightness)

**Intensity**
Amount of energy in a wave determined by the amplitude. It is related to perceived brightness.

Blue color with varying levels of intensity. As intensity increases or decreases, blue color looks more “washed out” or “darkened.”

Purity (Saturation)

Monochromatic light added to green and red makes them less saturated.
The Eye

Parts of the eye

1. **Cornea**: Transparent tissue where light enters the eye.
2. **Iris**: Muscle that expands and contracts to change the size of the opening (pupil) for light.
3. **Lens**: Focuses the light rays on the retina.
4. **Retina**: Contains sensory receptors that process visual information and sends it to the brain.
The Lens

**Lens:** Transparent structure behind the pupil that changes shape to focus images on the retina.

**Accommodation:** The process by which the eye’s lens changes shape to help focus near or far objects on the retina.

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The Lens

**Nearsightedness:** A condition in which nearby objects are seen more clearly than distant objects.

**Farsightedness:** A condition in which faraway objects are seen more clearly than near objects.

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Retina

**Retina:** The light-sensitive inner surface of the eye, containing receptor rods and cones in addition to layers of other neurons (bipolar, ganglion cells) that process visual information.
Optic Nerve, Blind Spot & Fovea

**Optic Nerve:** Carries neural impulses from the eye to the brain. **Blind Spot:** Point where the optic nerve leaves the eye because there are no receptor cells located there. This creates a blind spot. **Fovea:** Central point in the retina around which the eye’s cones cluster.

Test your Blind Spot

Use your textbook. Close your left eye, and fixate your right eye on the black dot. Move the page towards your eye and away from your eye. At some point the car on the right will disappear due to a blind spot.

Photoreceptors

<table>
<thead>
<tr>
<th>RECEPTORS IN THE HUMAN EYE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cones</td>
</tr>
<tr>
<td>Number</td>
</tr>
<tr>
<td>Location in retina</td>
</tr>
<tr>
<td>Sensitivity in dim light</td>
</tr>
<tr>
<td>Color sensitive?</td>
</tr>
<tr>
<td>Detail sensitive?</td>
</tr>
</tbody>
</table>
Bipolar & Ganglion Cells

Bipolar cells receive messages from photoreceptors and transmit them to ganglion cells, which are for the optic nerve.

Visual Information Processing

Optic nerves connect to the thalamus in the middle of the brain, and the thalamus connects to the visual cortex.

Ganglion & Thalamic Cells

Retinal ganglion cells and thalamic neurons break down visual stimuli into small components and have receptive fields with center-surround organization.
Feature Detection
Nerve cells in the visual cortex respond to specific features, such as edges, angles, and movement.

Shape Detection
Specific combinations of temporal lobe activity occur as people look at shoes, faces, chairs and houses.

Theories of Color Vision
Trichromatic theory: Based on behavioral experiments, Helmholtz suggested that the retina should contain three receptors that are sensitive to red, blue and green colors.
Subtraction of Colors

If three primary colors (pigments) are mixed, subtraction of all wavelengths occurs and the color black is the result.

 Addition of Colors

If three primary colors (lights) are mixed, the wavelengths are added and the color white is the result.

Photoreceptors: Trichromatic Theory

MacNichol, Wald and Brown (1967) measured directly the absorption spectra of visual pigments of single cones obtained from the retinas of humans.
Opponent Process Theory

Hering proposed that we process four primary colors combined in pairs of red-green, blue-yellow, and black-white.

Color Blindness

Genetic disorder in which people are blind to green or red colors. This supports the Trichromatic theory.

Opponent Colors

Gaze at the middle of the flag for about 30 Seconds. When it disappears, stare at the dot and report whether or not you see Britain's flag.
Perception in Brain

Our perceptions are a combination of sensory (bottom-up) and cognitive (top-down) processes.

Visual Information Processing

Processing of several aspects of the stimulus simultaneously is called parallel processing. The brain divides a visual scene into subdivisions such as color, depth, form and movement etc.

From Sensation to Recognition
Color Constancy

Color of an object remains the same under different illuminations. However, when context changes the color of an object may look different.

Change Blindness

- Phenomenon that occurs when a person viewing a visual scene apparently fails to detect large changes in the scene.
- The change typically has to coincide with some visual disruption (saccade: eye movement) or a brief obscuration of the observed scene or image.
- Memory (short term) may be involved.


Visual Illusions

http://www.michaelbach.de/ot/

More on this in next lecture....
Audition

The Stimulus Input: Sound Waves

Sound waves are composed of compression and rarefaction of air molecules.

*Acoustical transduction*: Conversion of sound waves into neural impulses in the hair cells of the inner ear.

Sound Characteristics

- Frequency (pitch)
- Intensity (loudness)
- Quality (timbre)
Frequency (Pitch)

Frequency (pitch): The dimension of frequency determined by the wavelength of sound.

Wavelength: The distance from the peak of one wave to the peak of the next.

Intensity (Loudness)

Intensity (Loudness): Amount of energy in a wave, determined by the amplitude, relates to the perceived loudness.

Loudness of Sound

<table>
<thead>
<tr>
<th>Decibels</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Threshold of hearing</td>
</tr>
<tr>
<td>20</td>
<td>Whisper</td>
</tr>
<tr>
<td>30</td>
<td>Normal conversation</td>
</tr>
<tr>
<td>40</td>
<td>Typical room</td>
</tr>
<tr>
<td>65</td>
<td>Loud thunder</td>
</tr>
<tr>
<td>110</td>
<td>Jet plane at 50 feet</td>
</tr>
<tr>
<td>120</td>
<td>Rock hard (amplified at close range)</td>
</tr>
<tr>
<td>125</td>
<td>Loudest sound a person can tolerate</td>
</tr>
</tbody>
</table>

120dB

70dB
Quality (Timbre)

Quality (Timbre): Characteristics of sound from a zither and a guitar allows the ear to distinguish between the two.

Overtones

Overtones: Makes the distinction among musical instruments possible.

The Ear

Visual diagrams and images related to the ear's anatomy and function.
The Ear

**Outer Ear:** Pinna. Collects sounds.

**Middle Ear:** Chamber between eardrum and cochlea containing three tiny bones (hammer, anvil, stirrup) that concentrate the vibrations of the eardrum on the cochlea’s oval window.

**Inner Ear:** Innermost part of the ear, containing the cochlea, semicircular canals, and vestibular sacs.

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Cochlea

**Cochlea:** Coiled, bony, fluid-filled tube in the inner ear that transforms sound vibrations to auditory signals.

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Theories of Audition

**Place Theory** suggests that sound frequencies stimulate the basilar membrane at specific places resulting in perceived pitch.
Theories of Audition

**Frequency Theory** states that the rate of nerve impulses traveling up the auditory nerve matches the frequency of a tone, thus enabling us to sense its pitch.

<table>
<thead>
<tr>
<th>Sound Frequency</th>
<th>Auditory Nerve Action Potentials</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 Hz</td>
<td></td>
</tr>
</tbody>
</table>

Can not explain high frequencies

Localization of Sounds

Because we have two ears, sounds that reach one ear faster than the other ear cause us to localize the sound.

Localization of Sound

1. Intensity differences
2. Time differences

Time differences as small as $1/100,000$ of a second can cause us to localize sound. The head acts as a “shadow” or partial sound barrier.
Hearing Loss

Conduction Hearing Loss: Hearing loss caused by damage to the mechanical system that conducts sound waves to the cochlea.

Sensorineural Hearing Loss: Hearing loss caused by damage to the cochlea’s receptor cells or to the auditory nerve, also called nerve deafness.

Hearing Deficits

Older people tend to hear low frequencies well but suffer hearing loss when listening for high frequencies.

![Graph showing hearing loss](attachment:hearing_deficits_graph.png)

- **Amplitude (Intensity)** required for perception relative to 20-29-year-old group
- **Frequency of tone in waves per second**
- **Lox** → **High**
- **More intense** → **Less intense**

**Categories:**
- Low
- Medium-Low
- Medium
- Medium-High
- High

**Groups:**
- 20-29 years old
- 30-39 years old
- 40-49 years old
- 50-59 years old
- 60 years old and up

**Breaking News:** Indian judge recommends that 10-declared American missionaries be released.
Deaf Culture

Cochlear implants are electronic devices that enable the brain to hear sounds.

Pain

Pain tells the body that something has gone wrong. Usually pain results from damage to the skin and other tissues. A rare disease exists in which the afflicted person feels no pain.

Biopsychosocial Influences

Biological Influences
- activity in a thalamic relay
- area of thalamus
- activity in thalamus
- area of brain
- thalamic projections

Psychological Influences
- attention to pain
- learning of pain
- expectation of pain

Social and cultural Influences
- sense of others
- empathy for others' pain
- cultural expectations

Personal experience of pain
Gate-Control Theory

Melzak and Wall (1965, 1983) proposed that our spinal cord contains neurological “gates” that either block pain or allow it to be sensed.

Pain Control

Pain can be controlled by a number of therapies including, drugs, surgery, acupuncture, exercise, hypnosis, and even thought distraction.

Body Position and Movement

The sense of our body parts’ position and movement is called kinesthesia. The vestibular sense monitors the head (and body’s) position.