Brain Plasticity and Consciousness

Review from Last Class

• PNS vs CNS
  – CNS: brain and spinal cord
  – PNS: autonomic vs skeletal (somatic)
• CNS:
  – Subcortical structures
  – Cortex
    • Localization of function
    • Split brain

Review

• Neurons
  – Dendrites
  – Cell body (soma)
  – Axon
• Action Potentials
  – Resting potential
  – Depolarization, hyperpolarization
  – Myelin
  – Synapses
  – Neurotransmitters, agonists, antagonists
• Techniques for studying the brain
Brain Wiring

- Plasticity
- Critical periods
- Rewiring
Somatosensory Homunculus

Homunculus (little man)
• shows the relative size of the somatosensory representation devoted to various body parts
• Do you notice a relationship between the size of the representation and the sensitivity?

Are brain maps fixed or plastic?

Prior to the 1980s, scientists assumed that brain maps were hard-wired and unchangeable. Do the maps actually depend on experience?

More Experience → Larger representation

• Merzenich & colleagues had monkey use index finger to obtain food
• Representation of that fingertip grew with experience

Elbert et al., 1995

Musicians who play string instruments
– show larger brain responses to stimulation of the digits and a larger cortical representation for the thumb and pinky finger
– show stronger responses if they learned the instrument at an early age
Phantom Limb

- amputees report rich and vivid perceptions of touch to the amputated limb
- stimulation to remaining parts of the body can be perceived in the missing limb

Normal Subject

Hand

"You touched my arm"

Face

"You touched my hand"

"You touched my face"

Phantom Limb Subject

Hand

Face

"You touched my arm"
Phantom Limb Subject

"You touched my hand"

"You touched my face"

How did it get that way?
Minimize cortical distances (axon lengths) between areas that are activated together

Ramachandran’s theory

"An engineer in Florida reported a heightening of sensation in his phantom (left) lower limb during orgasm and that his experience actually spread all the way down into the [phantom] foot instead of remaining confined to the genitals, so that the orgasm was much bigger than it used to be."

-- Ramachandran, 1993
Biological Rhythms and Sleep

Biological Rhythms

- Circadian rhythms
  - ~1 day
  - circ = about + dia = day ("about a day")
  - e.g., sleep, temperature
- Infradian rhythms
  - occur less than once/day, < 1 year
  - e.g., menstruation, egg-laying in fish
  - Circannual rhythms
    - ~1 year
    - e.g., migration, hibernation
- Ultradian rhythms
  - occur more than once/day
  - e.g., heartbeat, respiration, cycles within sleep

Circadian Rhythms
What happens when there is no natural light?

Identifying endogenous circadian rhythms:

Michel Siffre, 1972—chronobiologist
- lived in a Texas cave for 6 months with no natural light
- "you live following your mind... it's all your brain, your functions. It's black -- you have not the alternance of day and night. The cave where I was is a semitropical cave, you know, no sound, no nothing... darkness completely."
- recorded sleep, biological functions,
- days lengthened (~25 hr clock) so his day #151 was really day #179

Why was Siffre’s day longer than 24 hours?

- How do you know when to sleep?
- How does the body use light to sense the time of day?
- What do you think happened to Siffre’s sleep cycle once he left the cave?

How does the body know what time it is?

- aside from the “primary visual pathway” (retina → thalamus → occipital lobe), other pathways from the retina go to other areas
  - suprachiasmatic nucleus (SCN) in the hypothalamus
  - SCN = master pacemaker
  - SCN → pineal gland
**Pineal Gland**

- Was Rene right? Is it the seat of the soul???
- Sadly, no. It's just an endocrine (hormone) gland
- secretes melatonin at night (with little secreted during the day)
  - melatonin taken 1-2 hours before bed may help induce sleep
  - some people use it to treat jet lag
  - Mixed results

**Desynchronized Cycles**

- cave-dwellers and others deprived of natural light often show cycles slightly different from 24 hours
- shift on normal clock
- for most people, the natural rhythm is ~25 hours (slightly longer than a real day)

**Internal desynchronization: Jet Lag**

- flying westbound - time is earlier there so you have to stay up later
- flying eastbound - time is later there so you have to go to bed earlier
  - most people find this much harder
  - baseball teams that fly east win fewer games than those that fly west (37% vs. 44%)
Jetlag-- video clip

Other Sleep Disruptions

Switch to daylight savings time
• lose an hour of sleep in April → 7% more traffic accidents
• No effect in the fall
• “blue Mondays”

Shift work
• more accidents happen after employees have undergone shift changes
• accidents due to human error are most likely to happen in the middle of the night (Three Mile Island, 1979; Chernobyl, 1986; Exxon Valdez, 1989) or with sleep-deprived employees or decision makers (Space Shuttle Challenger, 1986).

Measuring your alertness:
Keep hourly record of alertness using 5 point scale on two days, one week apart
1. Extremely alert and efficient
2. Alert and efficient
3. Moderately alert
4. Drowsy
5. Sleepy
Sleep Deprivation

• become really tired, esp. 2:00 - 6:00 a.m.
• can cause lapses in attention and memory
• microsleeps
  – fall asleep for a few seconds or a minute
  – eyelids droop and you become less responsive to stimuli
  – people are often unaware that they blanked out
  – can be fatal when driving
  – driving tired can be worse than driving drunk
  – after being awake 18 hours, your performance is comparable to a blood alcohol level of 0.05% (~ 3 drinks in one hour for a 150 lb male)

How can we measure sleep?

Electroencephalogram (EEG)
  – measures voltage difference between any two points on the scalp (usually with many pairs of electrodes compared)
  – different states \( \rightarrow \) different waveforms

What do the waves mean?

• In many cases, scientists aren’t completely sure, but specific wave forms are reliably associated with specific states
• each electrode sums the output of many, many neurons
• Analogy: like holding a microphone over a football stadium and trying to figure out what the group sounds are telling you
What do the waves mean?

- When each neuron is “doing its own thing”, the pattern looks like irregular high frequency noise (in our stadium analogy, imagine all the spectators chatting to their neighbors randomly).
- When the neurons are doing things in synchrony, the pattern looks like regular low frequency noise (in our stadium analogy, imagine all the spectators cheering or booing simultaneously).

Sleep Waves

- different waves characterize different stages
  - Alpha waves
  - awake, REM sleep
    - irregular high frequency waves indicate unsynchronized activity
  - middle stages
    - weird blips—sleep spindles
  - deep sleep
    - low frequency waves (e.g., delta waves in Stage 4) indicate synchronized activity

Rapid Eye Movement (REM) Sleep

- eyes move rapidly under closed eyelids
- when awoken from REM sleep, subjects are most likely to report that they were dreaming (though in non-REM sleep, subjects may report “sleep thoughts”)
- lose muscle tone → “paralyzed” (but can move during non-REM sleep, tossing and turning)
Progression through the stages

Things to note:
- Progress from Stage 1 to 4 then back up and into REM
- First REM period after ~90 minutes (if not sleep-deprived) and ~every 90 minutes thereafter
- Spend more time in deep stages in early evening, more time in light stages towards morning
  - REM periods typically get longer as evening progresses

Why do we sleep?
- Isn’t sleep just a waste of time? Why bother?
- No one knows for sure, but there are some interesting ideas floating around

1. Restoration Theory
   - Your body needs to rest and recover
   - Runners sleep more after a marathon
   - Regular exercise can help sleep

2. Preservation Theory
   - Why risk being killed if you can only get food in the day?

Brain Structures Involved in Sleep

- **Reticular Activating System (RAS)**
  - Stimulation → awakelike EEG waves
  - Damage → coma, sleeplike EEG waves

- **Pons (“bridge”)**
  - Damage to pons can reduce or abolish REM sleep
  - Has connections to other brain areas to activate cortex, start eye movements and block movements during REM
What do dreams mean?: Four Theories

1) The Interpretation of Dreams (1900)
   - dreams are a meaningful output of the subconscious mind
   - manifest content: the dream as the dreamer remembers it
   - latent content: what the dream symbolizes that is disguised to protect the dreamer

   Sigmund Freud

<table>
<thead>
<tr>
<th>Manifest Content</th>
<th>Latent Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>A trip</td>
<td>Death</td>
</tr>
<tr>
<td>A long and quiet</td>
<td>Your mother and father</td>
</tr>
<tr>
<td>Clothing, train</td>
<td>Having normal stresses</td>
</tr>
<tr>
<td>Rocks or trees</td>
<td>Terror</td>
</tr>
<tr>
<td>Smoke</td>
<td>Pure</td>
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</tbody>
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What do dreams mean?: Four Theories

2) Problem-focused approach
   - Reflect ongoing conscious preoccupations of waking life
   - Problem-solving—predictable dream patterns for people in grief or in a depression

   ![Blocks]

What do dreams mean?: Four Theories

3) By-product of mental housekeeping
   - Strengthening synaptic connections
   - REM sleep associated with consolidation of learning and memory
     - They help us learn
   - Hippocampal activity during REM sleep in rats resembles real activity during maze learning

   ![Hippocampus]
Dreaming May Help You Remember

- REM sleep may help you consolidate memories (i.e., encode them from short term to long term memory)
- Sleep helps you learn (Karni et al., 1994)
  - trained subjects on a hard visual task
  - subjects with normal night’s sleep performed well the next day
  - subjects who had been awakened during non-REM periods performed well the next day
  - subjects who had been awakened during REM sleep performed poorly the next day
- Even naps may help (Mednick et al., 2002)
  - trained subjects on a hard visual task for a long time
  - as training wore on, subjects who did not nap got worse
  - subjects who took a nap maintained good performance
    - a 1-hour nap was better than a 30-minute nap

What do dreams mean?: Four Theories

4) Activation Synthesis Hypothesis
- neural stimulation from the pons activates other brain areas that are involved in waking consciousness
- the sleeping mind tries to make sense of random neural firing by weaving a story
  - during REM, frontal lobes are deactivated (dreams lack logical planning and thinking) and limbic system is activated (dreams often have emotional content, esp. negative emotions)
- dreams are side effects of random neural activity

J. Allan Hobson (contemporary sleep expert)

Infants dream a lot!

- perhaps this indicates that dreaming is crucial for developing brain pathways?
Sleep video clip

Test #1
• 100 MC questions, 120 mins
• BRING A PENCIL