ASHI636: Advanced Neuroscience Dr. Olav E. Krigolson

Lecture 5: Consciousness



What is consciousness?

Being Awake

Martin Martin Martin B

Theta waves

man man man man

Awake Low-voltage, highfrequency beta waves

Drowsy Alpha waves prominent

Stage 1 sleep Theta waves prominent

Stage 2 sleep Sleep spindles and mixed EEG activity

Slow-wave sleep (stage 3 and stage 4 sleep) Progressively more delta waves (stage 4 shown)

REM sleep Low-voltage, highfrequency waves

The Neural Basis of Sleep

Brain Structures:

- Ascending reticular activating system
- Pons, medulla, thalamus, hypothalamus, limbic system

Neurotransmitters:

- Acetylcholine and serotonin
- Also norepinephrine, dopamine, and GABA



Why Do We Sleep?

Hypothesis 1:

Sleep evolved to conserve organisms' energy
Hypothesis 2:

Immobilization during sleep is adaptive because it reduces danger

Hypothesis 3:

Sleep helps animals to restore energy and other bodily resources

Variations in Consciousness

Levels of <u>AWARENESS</u>: Consciousness is Not All-or-None

- Awake
- Sleep
- Anesthesia
- Coma
- Persistent Vegetative State
- Death



Healthy Brain



Vegetative State



What is consciousness?

Awareness of external events Awareness of internal sensations Awareness of yourself as a unique being having experiences

Awareness of your thoughts about these experiences

The critical element in consciousness is awareness.

What is consciousness?

Awareness of external events (perception)









Frame4: Funny – Non-funny



Cerebellum



Cerebellum

Cerebellum





What is consciousness?

Awareness of internal sensations (sensory, emotion)





fMRI activations during painful stimulus.







HAPPY



SAD

What is consciousness?

Awareness of yourself as a unique being having experiences (memory)









What is consciousness?

Awareness of your thoughts about these experiences



Self Reflection

You name it, there is a distinct pattern of neural activity for it...

The ability to generate all of these "unique" and "human" patterns of activity is consciousness.

Default Mode Network

THE BRAIN IN NEUTRAL

When you switch off, a distinctive network of brain areas not involved in focused attention bursts into action

- Default network
- Areas involved in focused visual attention





Default Mode Network

Two reliable characteristics:

1) shows greater BOLD activity during quiet restfulness (e.g. the resting state) than during active cognition.

Internal Dialogue Hypothesis: the default network forms part of the neural substrates underlying autobiographical memory, social cognition, reflection, awareness



Raichle et al., 2001. A default mode of brain function. PNAS, 98 (2). 676-82.

Default Mode Network

Two reliable characteristics:

2) Activity is suppressed when individuals engage in goal-directed, task specific processing

The default mode network is inherently anti-correlated with task positive networks



Fair & Raichle, 2007 Nature Review Neuroscience

Individual Differences


Alcoholic



Normal Control





P<0.001, uncorrected

Consciousness:





- Consciousness requires
 - Intelligence (ability)
 - Awareness (state)
- Not necessary alive







Consciousness: functional requirements

Intelligence (Memory)
 Central Executive (Badelley)
 Attention and Attention Switching (Badelley)
 Perception (Previous)
 Cognitive Action Control (Next)

Consciousness



Evolution and consciousness

- appearance and evolution of consciousness

Living Bein	ng	Evolutionary traits	Analogous feasibility in machines
	Human Beings	 Fully developed cross-modal representation Sensory capabilities: auditory, taste, touch, vision, etc. Pre-frontal cortex: planning, thought, motivation 	Impossible at present
	Hedgehog (earliest mammals)	 Cross-modal representation Sensory capabilities: auditory, touch, vision (less developed), etc. Small frontal cortex 	Impossible at present
	Birds	 Primitive cross-modal representation Sensory capabilities: auditory, touch, vision, olfactory. Primitive associative memory 	Associative memories

Evolution and consciousness – absence of consciousness

Living Being		Evolutionary traits	Analogous feasibility in machines		
	Reptiles*	Olfactory systemPrimitive vision	Computer vision (emerging)		
	Hagfish (early vertebrate)	Primitive olfactory systemPrimitive nervous system	Artificial neural networks		
	Lower level animals (hydra, sponge, etc.)	Sensory motor unitsPoint to point nervous system	Mechanical or electronic control systems		
* inconclusive\consciousness in transition					

Emergence of Consciousness



Week	Human Fetus brain development
6	Cortical cells come at the correct position
20	Cortical region is insulated with myelin sheath
25	Development of local connections between neurons
30	Fetus' brain generates electrical wave patterns



Emergence of Consciousness

Brain is self-organizing and sparse



Human Brain at Birth





6 Years Old

14 Years Old

Synaptic Density over the Lifespan



Conclusion : Consciousness emerges gradually

Are animals conscious?





But what about other animals?

Choice and Free Will









But why like something in the first place?

Sensation

and...

Individual Differences - hardwired and learned

But why change our minds from day to day...



lce Cream

What is value at a neural level?



And what makes a connection stronger?

But why change our minds from day to day...



Moral Judgment

Cognitive Areas: Lateral PFC ACC

Emotional Areas: Medial PFC PCC Amygdala



Nature Reviews | Neuroscience

Moral Judgement

You are a waiter. You overhear one of your customers say that he is about to go to jail and that in his last forty-eight hours of freedom he plans to infect as many people as possible with HIV. You know him well enough to know that he is telling the truth and that he has access to many potential victims.

You happen to know that he has a very strong allergy to poppy seeds. If he eats even one he will go into convulsions and have to be hospitalized for at least forty-eight hours.

Would you cause this man to have a serious allergy attack in order to prevent him from spreading HIV?





VMPC LESION, BDC CONTROL, NC NORMAL





So what motivates us?

Utilitarianism, but why?

Preservation

Back to decision making...

What is the model?

- 1. Exploit
- 2. Explore

So, you have a fairly good idea of what your favorite food is... why is that?

Lot's of opportunity to explore, solid assessment of values. And your random night when you don't eat your favorite food? Exploration again.

But why is the divorce rate 50%?

How hard is it to calculate the accurate value of a potential mate?

And why seek a divorce? You perceive greater value is attainable.

Geniuses and Savants: Individuality and Regional Specialization





Temporal Cortex and Language

Language involves retrival of information from many brain areas.


Temporal Cortex and Mathematics



"What is one hundred minus seven?"

"Ummmm.... ninety six"

"Is the number you get when you subtract seven from one hundred bigger or smaller than one hundred?"

"Smaller"

Epilepsy

Symptoms:

Erratic firing pattern of neural activity An "electric storm"

Cause: Not clear

Why is it important to us?

People who experience temporal lobe epilepsy report "religious sensations"

"It pales completely beside the divine light I have seen"

Why?

1) These people are actually experiencing God

Why?

2) Over activity in the limbic system results in a strong emotional salience for everything – this is experienced as a "religious experience"

Why?

3) Is there specialized neural circuitry in the brain for religion?



Dr. Michael Persinger, and the "God Helmet"

Before we get back to religious sensation, lets consider geniuses and savants...



Srinivasa Ramanujan

Larger Brains?

Einstein's Brain = NORMAL









Stephen Wiltshire

Savant Theory

1. Savant skills develop from existing or dormant cognitive functions such as memory.

Savant Theory

2. Pathological states in the brain lead to development of prodigious skills. Reciprocal inhibitory interaction among adjacent or distant cortical regions - especially that of the prefrontal cortex and the posterior regions of the brain.

Savant Theory

3. The underconnectivity theory emphasizes the disruption of long-range connectivity and the relative intact or even more enhanced local connectivity in the autistic brain.



The Autistic Brain

THINKING ACROSS THE SPECTRUM

TEMPLE GRANDIN



So back to the "God Spot"...

Comparison of Baseline to Prayer



Summary

Consciousness emerges from patterns of neural activity – there is no "black box" or "soul" – at least from a neuroscience perspective ©