Consider a machine that can pass the general Turing tests for vision (i.e., that can answer ANY question about ANY image and those answers are indistinguishable from human answers).

Would that machine have “visual consciousness”, like you and me? Please type your answer in the chat box.
Visual Object Recognition
Computational Models and Neurophysiological Mechanisms
Neurobiology 230. Harvard College/GSAS 78454

Class 1 [09/02/2020]. Introduction to Vision
Class 2 [09/14/2020]. Natural image statistics and the retina
Class 3 [09/21/2020]. The Phenomenology of Vision
Class 4 [09/28/2020]. Learning from Lesions
Class 5 [10/05/2020]. Primary Visual Cortex
October 12th: University Holiday
Class 6 [10/19/2020]. Adventures into terra incognita
Class 7 [10/26/2020]. From the Highest Echelons of Visual Processing to Cognition
Class 8 [11/02/2020]. First Steps into in silico vision
Class 9 [11/09/2020]. Teaching Computers how to see
Class 10 [11/16/2020]. Computer Vision


FINAL EXAM, PAPER DUE 12/14/2020. No extensions.
The Turing test for vision

How far are the ladies with a red garment?

Are there people riding bikes?

Are there any dogs?

How many people are there?

What color are the signs?

What is the man with the black hat doing?
Towards the neural correlates of consciousness
Hidden in plain sight: a pragmatic definition of consciousness

https://www.youtube.com/watch?v=IGQmdoK_ZfY
Hidden in plain sight: a pragmatic definition of consciousness

Resnik et al 1997
Hidden in plain sight: a pragmatic definition of consciousness
How can a physical system give rise to consciousness?

How can consciousness be explained in terms of neurons and their interactions?

How can a physical system have qualia?

Why are humans conscious and not just a bunch of zombies?

Do other animals also have consciousness? How did consciousness evolve?
A (non-exhaustive) list of possible answers

• “Religious” answers. E.g. “… consciousness requires a non-physical soul…” (Plato; The bible; Descartes (modern form of dualism: res extensa and res cogitans); Aristotle, Thomas Aquinas, Karl Popper, Sigmund Freud, John Eccles)

• Science cannot understand consciousness (the “mysterian” approach)

• There is no such thing as consciousness. It’s just an illusion. (e.g. Dennett)

• We need new (as yet undiscovered) laws to explain consciousness (e.g. Roger Penrose)

• Consciousness requires behavior (and language) (e.g. Cotterill)

• Consciousness is an epiphenomenon
Some basic working assumptions

We are conscious (it is not an illusion or an epiphenomenon)
Some other animals are also conscious
We start with simple questions that we can try to study rigorously
We start with vision. Hopefully, we will be able to extrapolate some of what we learn from vision to other sensations (e.g. pain, smell, self-awareness)
We need an explicit representation
Only parts of the brain will correlate with the contents of consciousness. We search the neuronal correlates of consciousness (NCC)

We leave out many interesting topics for now: Dreams, Lucid dreaming, Out of body experiences, Hallucinations, Meditation, Sleep walking, Hypnosis, Self awareness. Qualia, Feelings

A minimal\(^1\) set of neuronal events and mechanisms jointly sufficient\(^2\) for a specific conscious percept\(^3\)

1 “Minimal”: A solution such as “the whole healthy human brain can experience consciousness” is not very informative.

2 “Sufficient”: We are not looking for “enabling” factors such as the heart or the cholinergic systems arising in the brainstem

3 “Specific conscious percept”: e.g. seeing a face (as opposed to being conscious/unconscious)
"Zombie modes": not all brain activity leads to consciousness

Rapid, transient, stereotyped and unconscious responses

In a zombie mode the main flow of information is feed-forward

Zombie modes are very fast and useful

The NCC representation must be *explicit*

Explicit: A single layer of neurons can deliver the answer.

An explicit representation is necessary but not sufficient.
We are not aware of the entire visual field

We have the illusion that we “see” the whole visual field.
   But: inattentional blindness illusion!

Attention filters information¹.

Consciousness may generally require attention
   But consciousness may happen in the absence of attention²

Two mechanisms for attention: bottom-up (saliency) and top-down (cognitive)

¹Desimone and Duncan (1995). Annual Review of Neuroscience
²Li et al. (2002) Proc Natl Acad Sci USA
More demos

Filling in
http://smc.neuralcorrelate.com/illusions-and-demos/dy

Change blindness
http://nivea.psycho.univ-paris5.fr/CBMovies/FarmsFlickerMovie.gif
https://www.youtube.com/watch?v=FWSxSQsspiQ

Selective attention and basketball passes
http://www.youtube.com/watch?v=vJG698U2Mvo
https://www.youtube.com/watch?v=IGQmdoK_ZfY

Person swapping experiments
http://www.youtube.com/watch?v=ElLnNalL4xY

Change blindness in a movie
http://www.youtube.com/watch?v=ubNF9QNEQLA
A framework to define the NCC (Crick and Koch)

1. The nonconscious *Homunculus*
2. A lot can be done in *zombie mode*
3. The NCC involve coalitions of neurons
4. An *explicit* representation is needed
5. Higher levels first
6. The NCC require strong driving projections
7. Consciousness comes in snapshots
8. Attention and binding
9. The NCC may involve specific firing patterns
10. Penumbra, meaning and qualia

Crick and Koch 2003
Experimental paradigms to examine the neural correlates of visual consciousness

Difficulty: where/how/when to search for the neural correlates?
Experimental paradigms to examine the neural correlates of visual consciousness
Bistable percepts example: ambiguous structure from motion

Neurons in area MT following the percept

Bistable percepts

Monocular rivalry (weaker)

Binocular rivalry (stronger)

Different stimuli are presented to the right and left eyes

The input is constant

Perception alternates between one percept and the other

What are the neuronal changes responsible for the perceptual alternation?

Helmholtz haploscope

Right eye

Left eye

perception
Binocular rivalry: competition between percepts (as opposed to competition between eyes)

Binocular rivalry can be studied in both humans and monkeys.


Neurons in inferior temporal cortex follow the percept

Sheinberg and Logothetis 1997; Leopold and Logothetis 1999
Neurons in inferior temporal cortex follow the percept

Sheinberg and Logothetis 1997
Leopold and Logothetis 1999
Neurons in the human medial temporal lobe follow the percept

There is an increase along the visual hierarchy in the proportion of neurons that correlate with the subjective percept.

- Binocular Rivalry/Flash Suppression – “one-to-many” between stimulus and percept. Allow us to manipulate the percept.

- Neuronal evidence from monkeys shows that neurons in early areas (LGN, V1) show little or no percept effect.

- Neurons in later areas (IT, MTL) predominantly follow the percept.

- Candidates for the NCC?

- These studies showed correlations. What we will need in the future is causation.
What would constitute evidence that we understand the NCC?

The possibility to:

(a) Model and predict neuronal responses given a perceptual state
(b) Accurately predict perceptual state given neuronal activity
(c) Induce a specific perceptual state by selective electrical stimulation
(d) Inactivate or repress a perceptual state
Integrated Information Theory -- Axioms

Intrinsic existence, Composition, Information, Integration, Exclusion

Giulio Tononi (2015), Scholarpedia, 10(1):4164.
Integrated Information Theory – Postulates illustration

Giulio Tononi (2015), Scholarpedia, 10(1):4164.
Central identity: an experience as a maximally irreducible conceptual structure

Giulio Tononi (2015), Scholarpedia, 10(1):4164.
Outlandish competition seeks the brain sources of consciousness

http://klab.tch.harvard.edu/press/2019/Outlandish%20competition%20seeks%20the%20brain%E2%80%99s%20source%20of%20consciousness%20%20Science%20%20AAAS.pdf

Adversarial collaboration

Preregistered experiments

Data sharing
Summary

- Consciousness has been discussed for millennia. Now, it is a central scientific question in Neuroscience.

- Experimental efforts have focused on searching for minimal and jointly sufficient neuronal correlates of consciousness, the NCC.

- During binocular rivalry, neuronal responses in the highest parts of visual cortex correlate with the dynamical changes in the contents of consciousness.

- A full description of the NCC would require a quantitative computational model that can predict neuronal responses given the perceptual state, and that can also predict the perceptual state given the neuronal responses. Activating or suppressing the NCC should elicit or silence specific perceptual states.

- Integrated information theory (IIT) is the first quantitative theoretical framework that aims to explain how consciousness emerges from a dynamical system with interconnected parts.
Further reading


Original articles cited in class
Resnik, R.A., O'Regan, J.K., and Clark, J.J. (1997). To see or not to see: the need for attention to perceive changes in scenes. Psychological Science 8, 368-373.
Sheinberg and Logothetis 1997
Leopold and Logothetis 1999
Tsuchiya and Koch
Li et al. (2002) Proc Natl Acad Sci USA