Cognitive Computing

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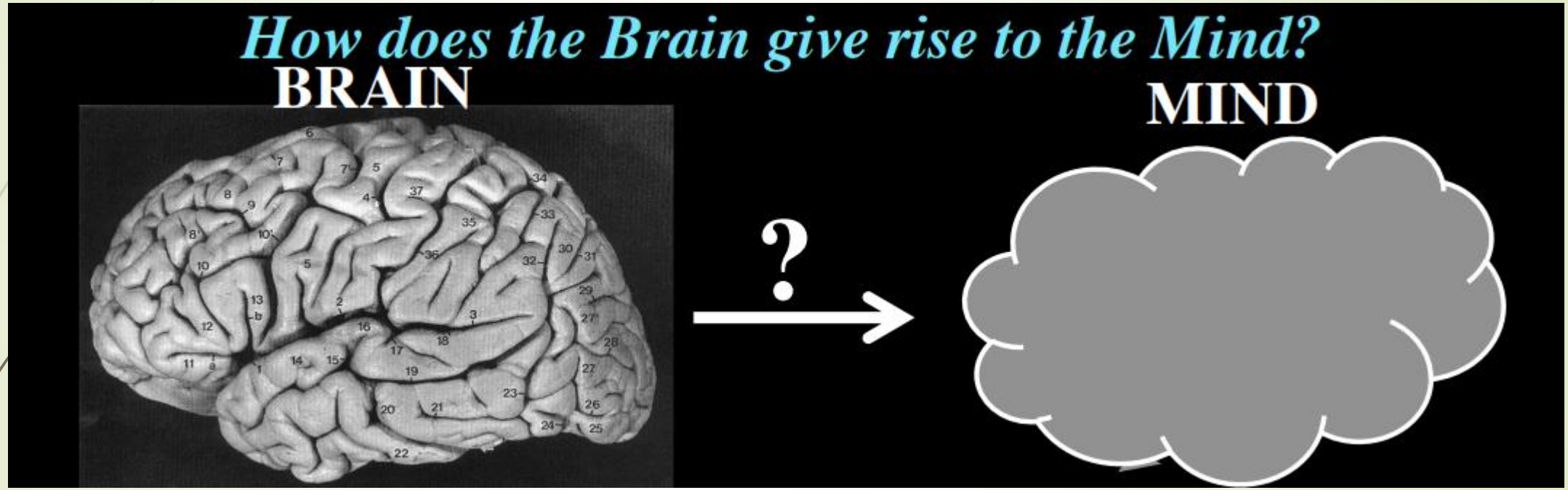
Assistant Professor

IIIT Sri City


How does the Brain give rise to the Mind?
BRAIN
MIND
?

How does the Brain give rise to the Mind?

BRAIN

MIND

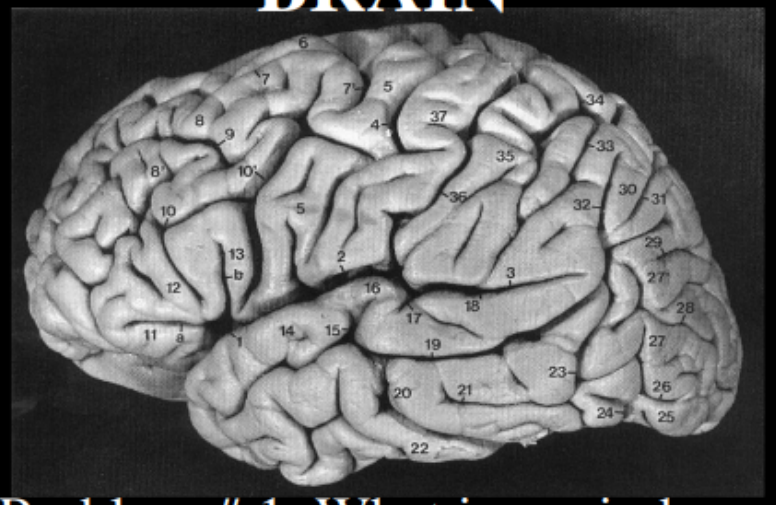
Problem # 1. What is a mind anyway?

Standard working framework:

Mind = a set of *computations* that extract *representations (= percepts/thoughts)*.

How does the Brain give rise to the Mind?

BRAIN



MIND

Problem # 1. What is a mind anyway?

Standard working framework:

Mind = a set of *computations* that extract *representations (= percepts/thoughts)*.

So: Ideally, if we really understood the mind, we would be able to write code that carries out the same computations and extracts the same representations.

Mostly we cannot do this yet, but that is the goal.

How do we get started even trying to think about this?

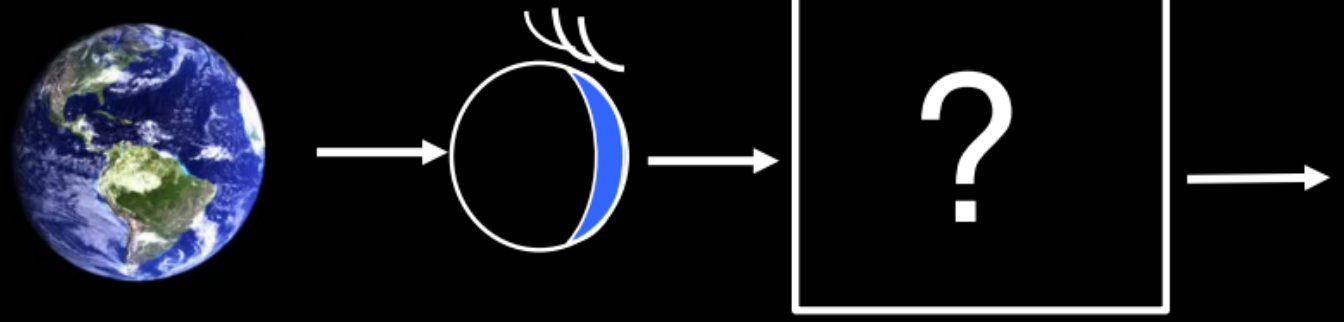
By first thinking about *what is computed and why*.

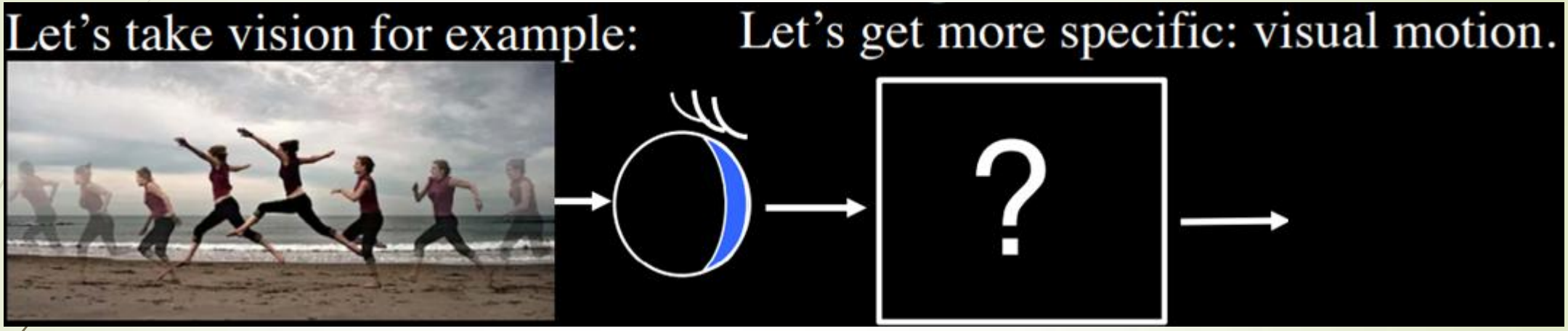
Marr's big insight is that this is the necessary first step, before empirical studies of minds or brains

How does the brain give rise to the mind?

Let's take vision for example:

Let's get more specific: visual motion.

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How does the brain give rise to the mind?

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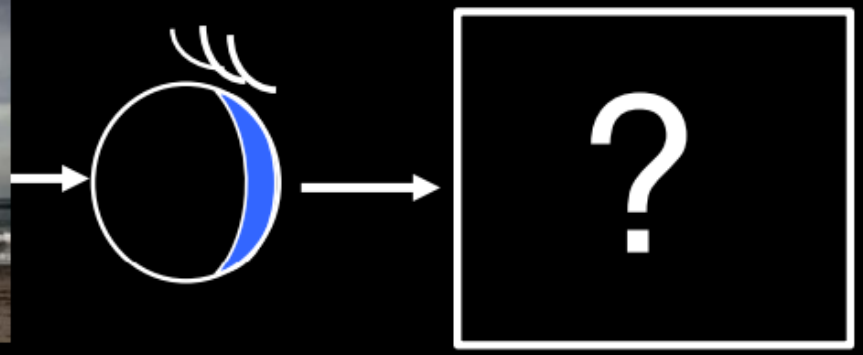

presence of motion?
presence of person?
motion from R to L?
jumping?
health?
mood?

To understand this, we need to know:

What is computed and why?

How does the brain give rise to the mind?

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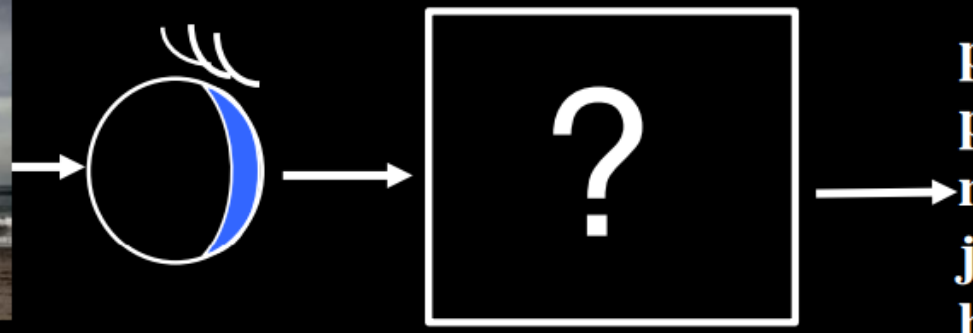

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To understand this, we need to know:

- What is computed and why?
- What are the inputs? What are the outputs?
- What are the computational challenges in getting from inputs to outputs?

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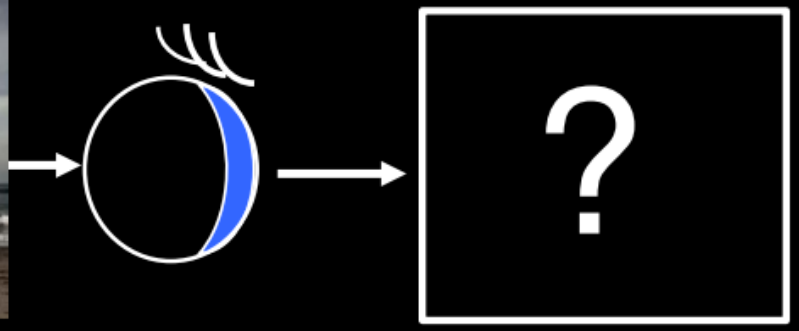

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To understand this, we need to know:

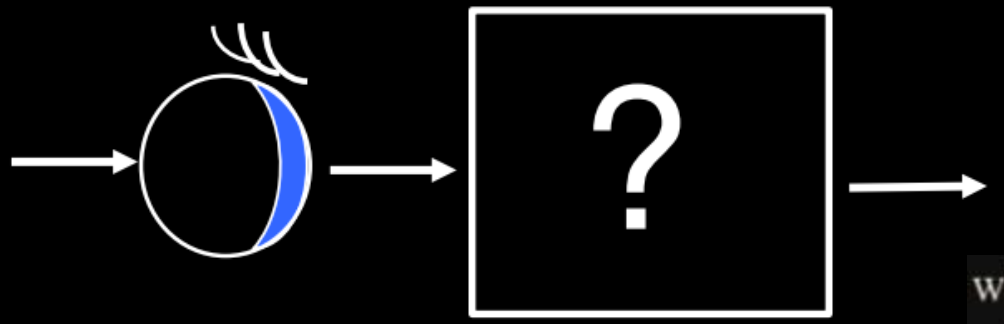
- What is computed and why?
- What are the inputs? What are the outputs?
- What are the computational challenges in getting from inputs to outputs?
- Marr: this is a prerequisite for understanding minds, and hence brains.

“Trying to understand perception by studying only neurons is like trying to understand bird flight by studying only feathers; it just cannot be done. To understand bird flight, you need to understand aerodynamics, only then can one make sense of the structure of feathers and the shape of wings. Similarly, you can't reach an understanding of why neurons in the visual system behave the way they do, just by studying their anatomy and physiology. “

"The nature of the computations that underlie perception depends more upon the computational problems that have to be solved than upon the particular hardware in which their solutions are implemented. “

Marr, 1982

Computational Theory Level Questions about Color



what do we use color for?
what are the outputs?
let's try to think about this by experiencing what we miss when we do not have color info.....

To understand this, we need to know:

- What is computed and why?
- What are the outputs?
- What are the inputs?
- What are the computational challenges in getting from inputs to outputs?

What is the deal with this goddamned Dress

DEMO

Disambiguating “The Dress”

Rosa Lafer-Sousa

Dept. of Brain and Cognitive Sciences, MIT

Many thanks to **Bevil Conway**, whose initial formulation of The Dress account (WIRED, the Guardian; March 2015) inspired this demo.

And to **Beau Lotto** who provided the Rubik’s cube scenes

Standard story: to find fruit
How many berries?

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How many berries?

And tell if it is ripe:

but there is a problem determining the color of an object…..

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The problem:

We want to determining the color (or R, “reflectance”) of an object.

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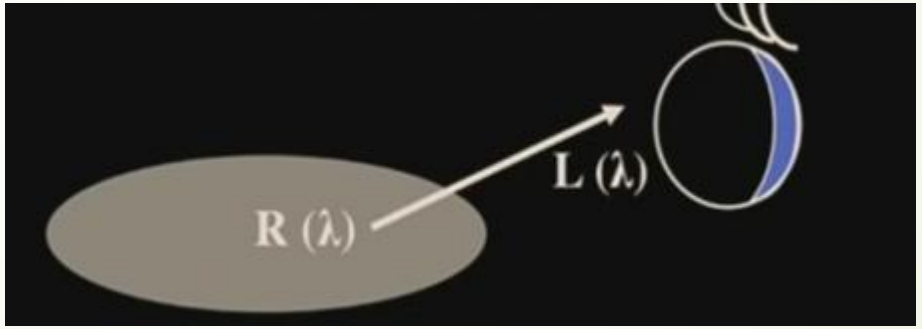

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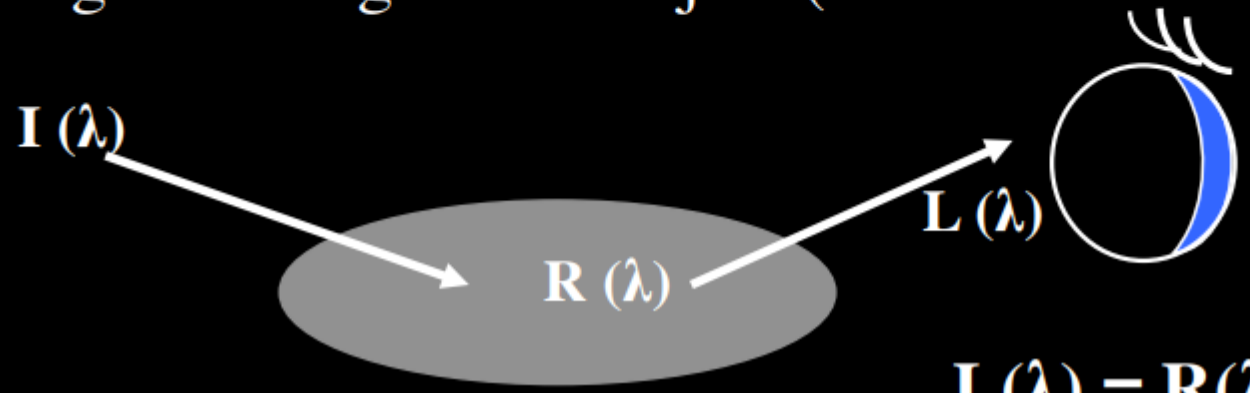
And that light L is a function not only of the object, but
also of the light shining on the object (the ”illuminant” or I):



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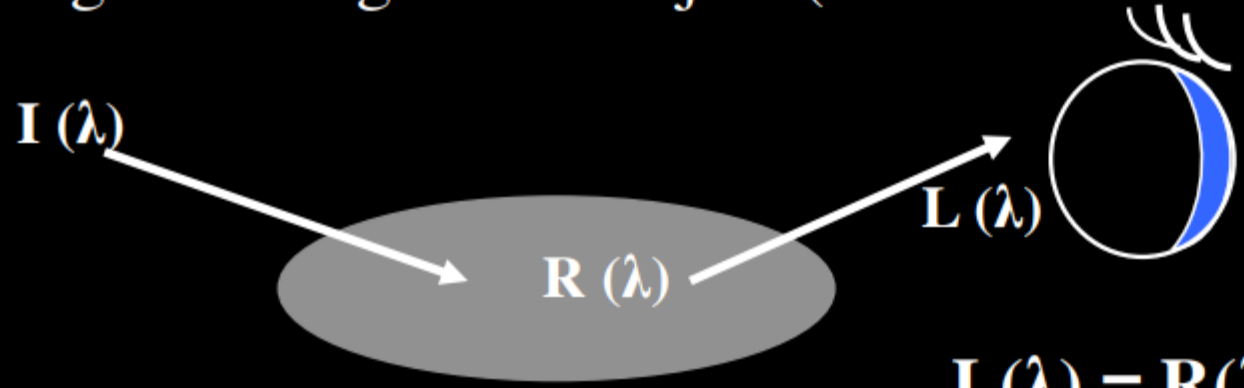

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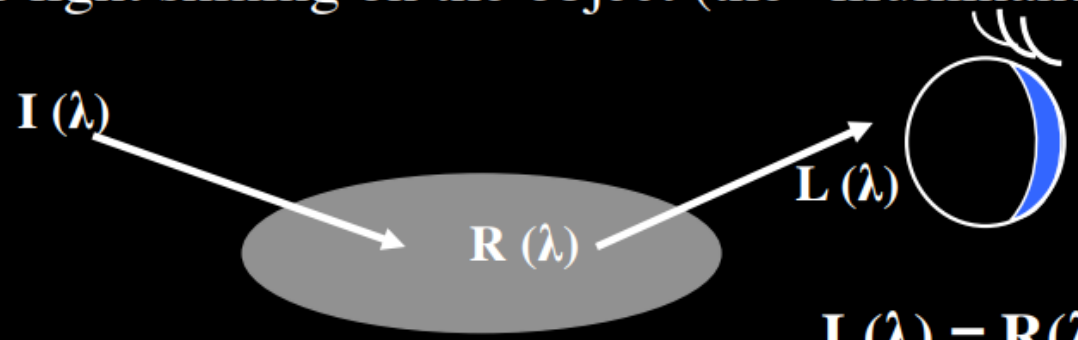


$$L(\lambda) = R(\lambda) \times I(\lambda)$$

Given L, what is R?

Uh-oh.

Like: A x B = 48, please solve for A and B.

This is an "ill-posed" or "underdetermined" problem.

We do not have enough information to uniquely solve this.

Marr's Levels of Analysis applied to Color Vision

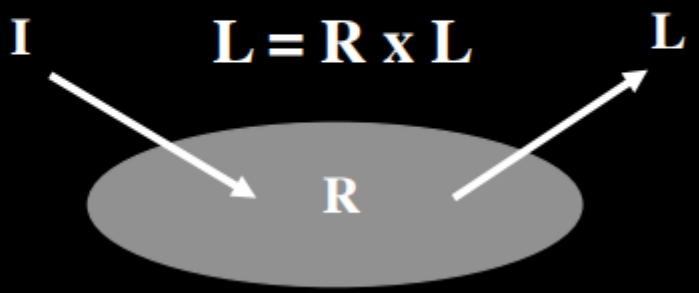
I. Computational theory

what information is extracted and why?

R, useful for characterizing objects

what cues are available?

only L!



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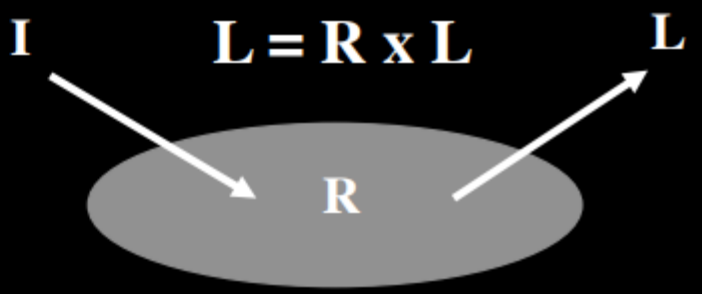
Yes! because I is unknown

what regularities in the world constrain the inference?

what other sources of information might constrain I?

all of this with no data about mind or brain or machines!

just thinking, with a little optics, physics, ecology



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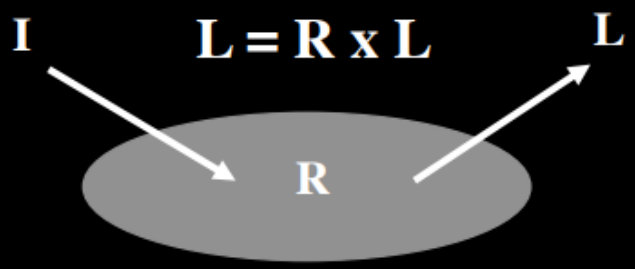

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one way: psychophysics! just asking people what they see for example….

II. Algorithm/representation

how does the system do what it does, i.e.

can we write the code to do this?

what assumptions, computations representations?

how would we find out?

As soon as you can tell, shout out the answer:
What color is the car?


The light coming from each of the cars is the same: GREY!

- The algorithm running your head is trying to figure out what is the color of car, is trying to solve ill-posed problem.
- And it is using other information than just the illumination of light coming from the object.
- It uses information from rest of the object.
- It is making inferences about L, the luminace, light hitting the object

The light coming from each of the cars is the same: GREY!

The key: What color is the illuminant? (i.e. the color of the light shining on the car)

- What your visual system did is look quickly and figure out the color of incident light L.
- And solve ill-posed problem for solving for R, the color of car.

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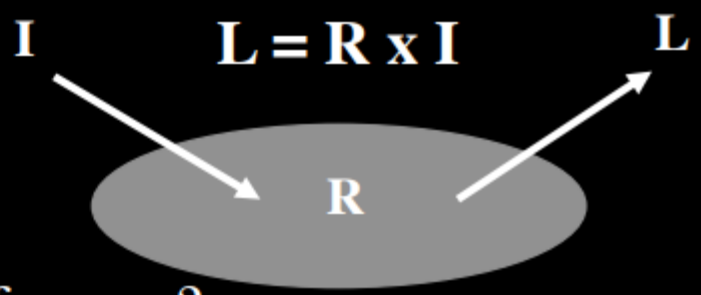

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Behavior, or psychophysics, (including illusions) can reveal the assumptions the human perceptual system uses to constrain ill-posed problems.

In this case, assumptions we made about I to enable us to infer R from L.

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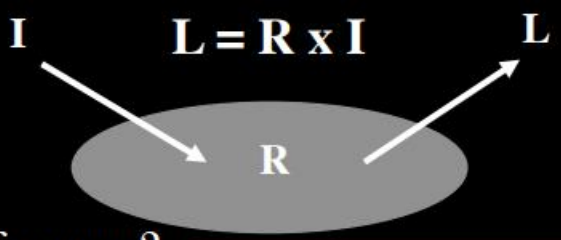

II. Algorithm/representation

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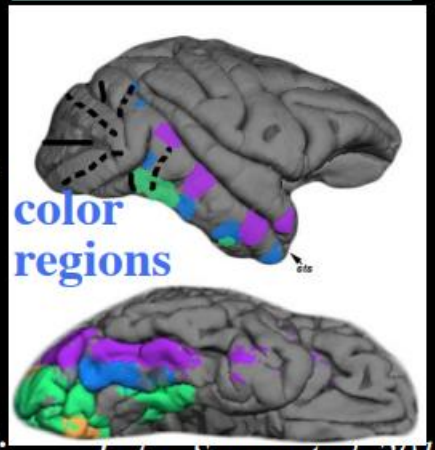
III. Hardware implementation

how is the system physically realized
in neurons & brains



Big Point:
Need many levels of analysis to understand minds & brains.

Later-Sousa et al. 2016

Face Perception: Who Cares?

What do we need face perception for?

From the case of Jacob Hodes' freshman year at Swarthmore...

Face perception

- In his hometown, he was with same group of kids, all the way from 1st to higher secondary.
- He can not able to recognize faces.
- He was little, his mom gives cues about kids. That helps to remember person.
- So he developed clues about who is who.
- When he went college, all new people there.
- No proper face recognition.
- Study shows large population (around 2%) is like that.

Other race effect

- Fact that they look same if you have less experience looking at that group of people.

Face Perception is Important Because

Faces are enormously informative stimuli:

- they convey information about a person's:
  identity, age, sex, mood, race, direction of attention
  maybe aspects of personality (e.g., is this person trustworthy?)

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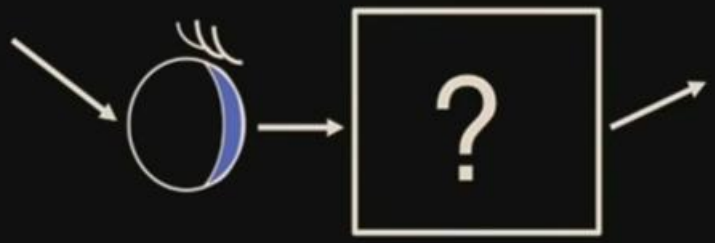
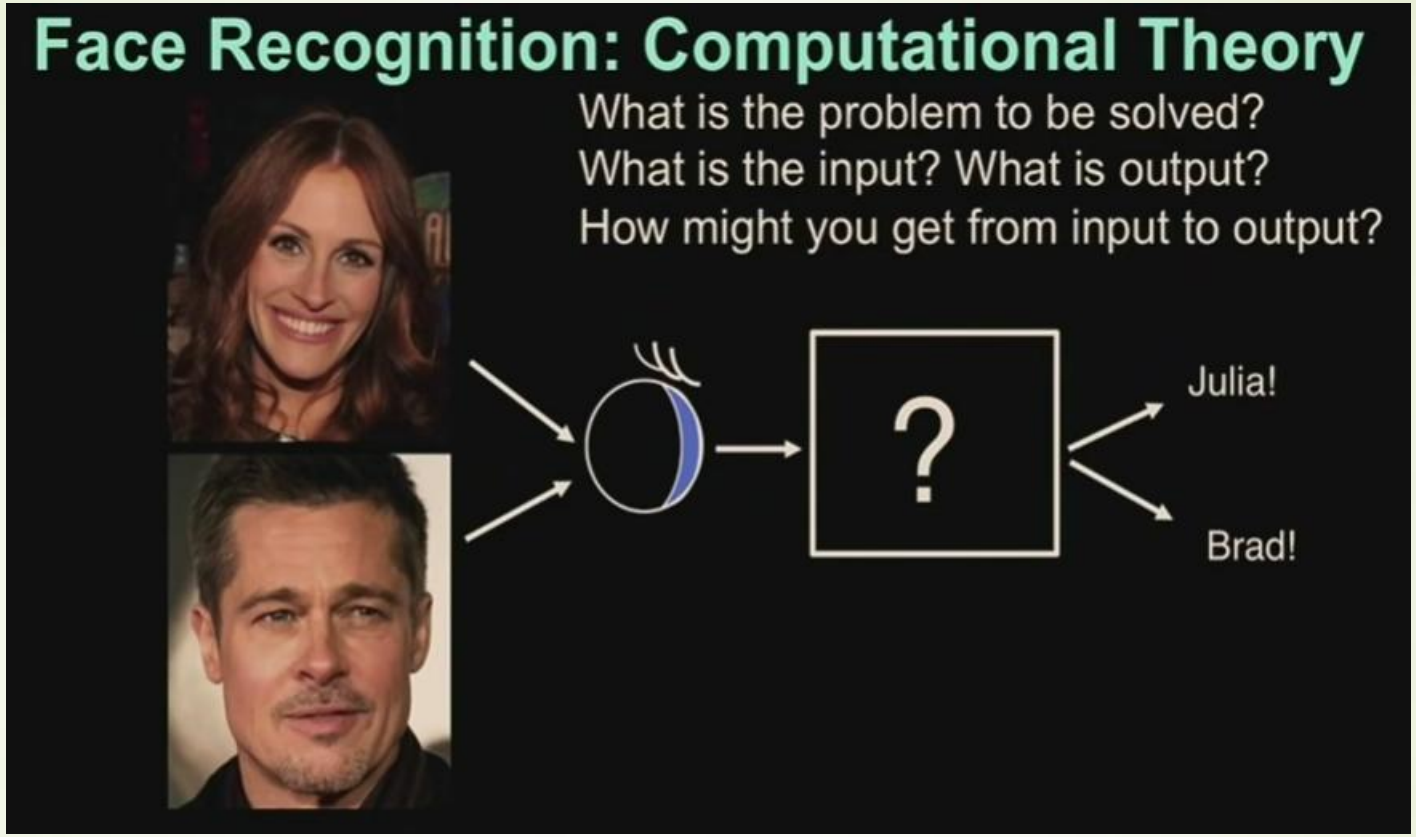
Faces are among the stimuli we look at most frequently in daily life

Face perception abilities were probably important to our ancestors' survival

Face Recognition: Computational Theory

What is the problem to be solved?
What is the input? What is output?
How might you get from input to output?

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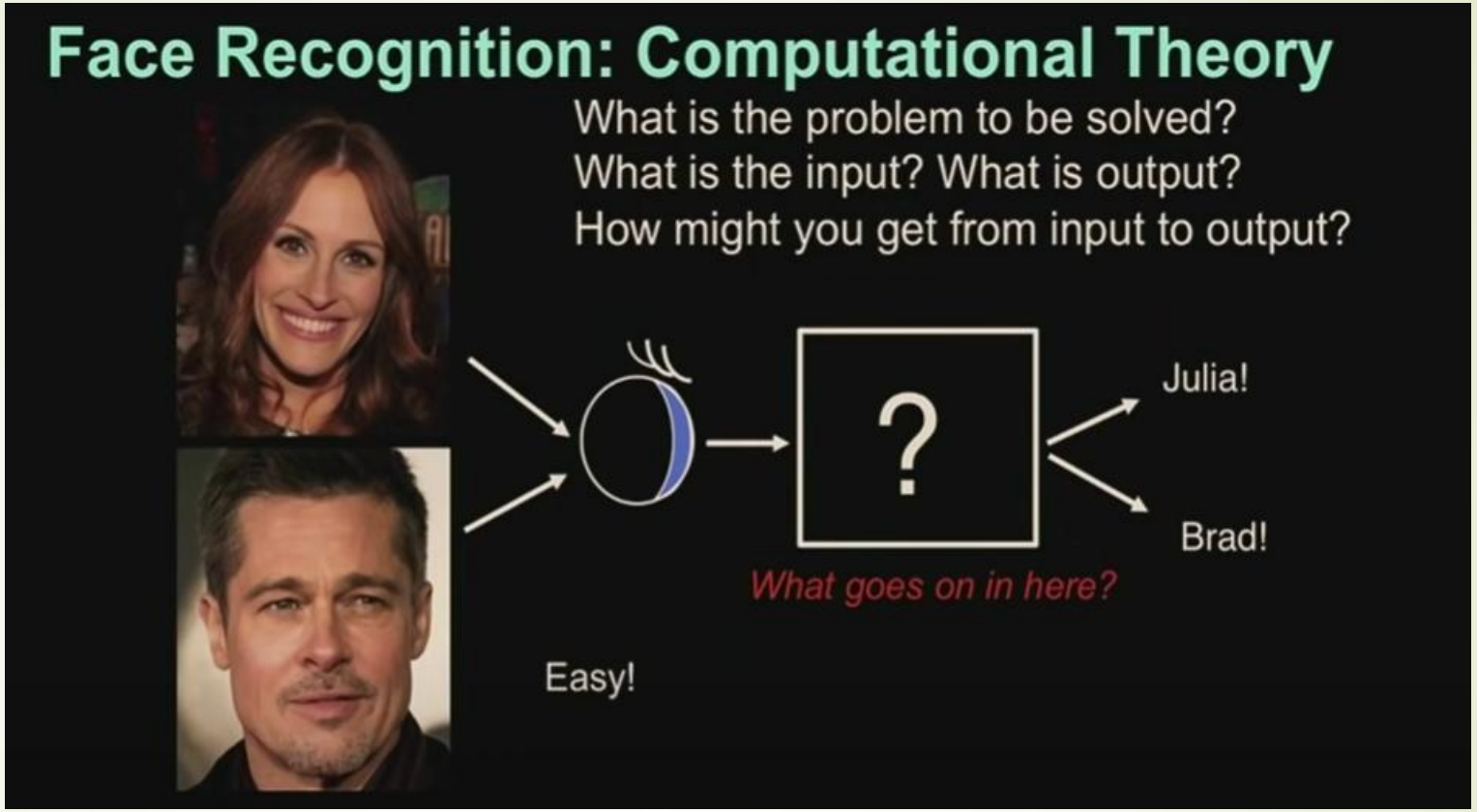

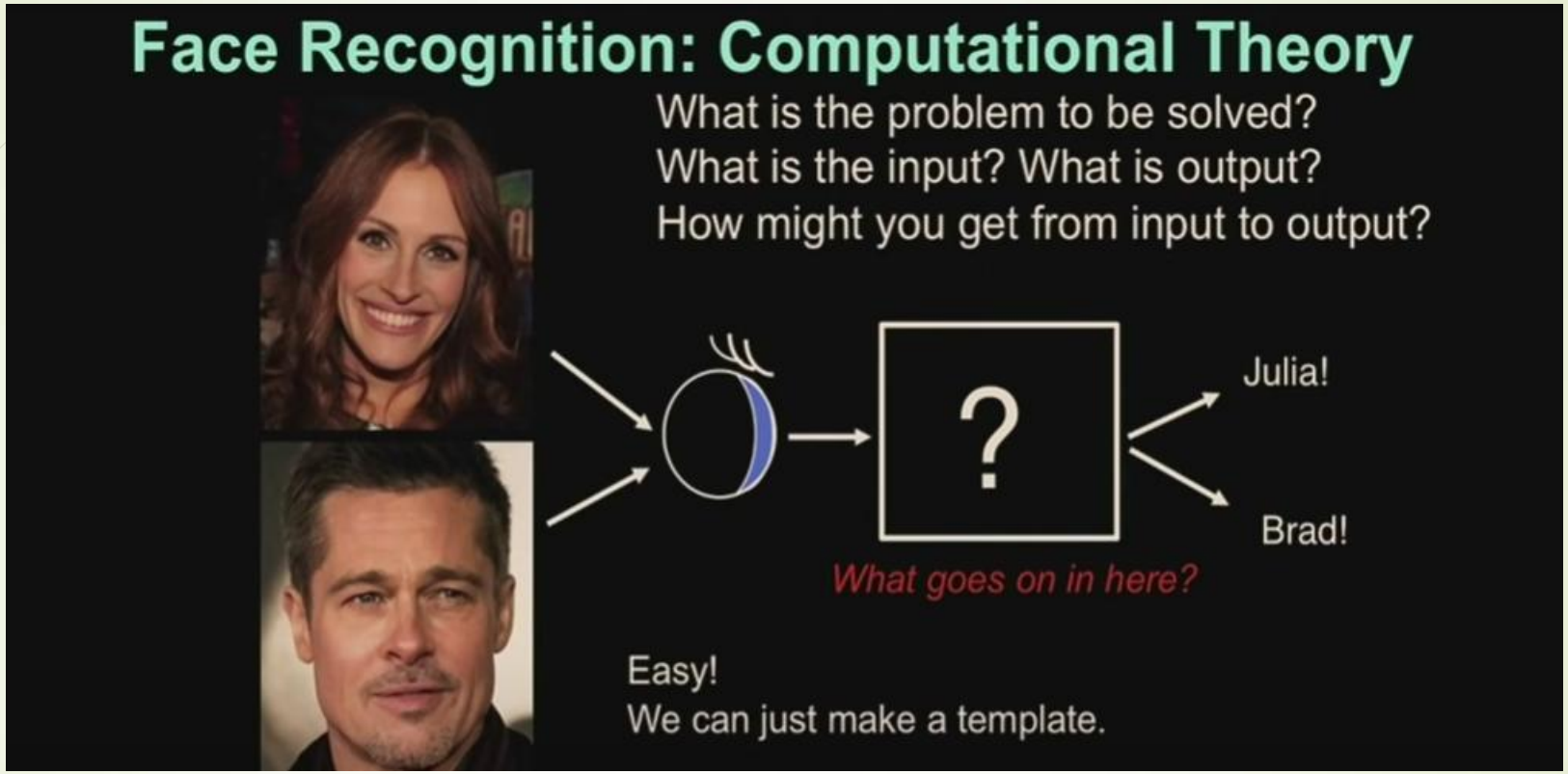
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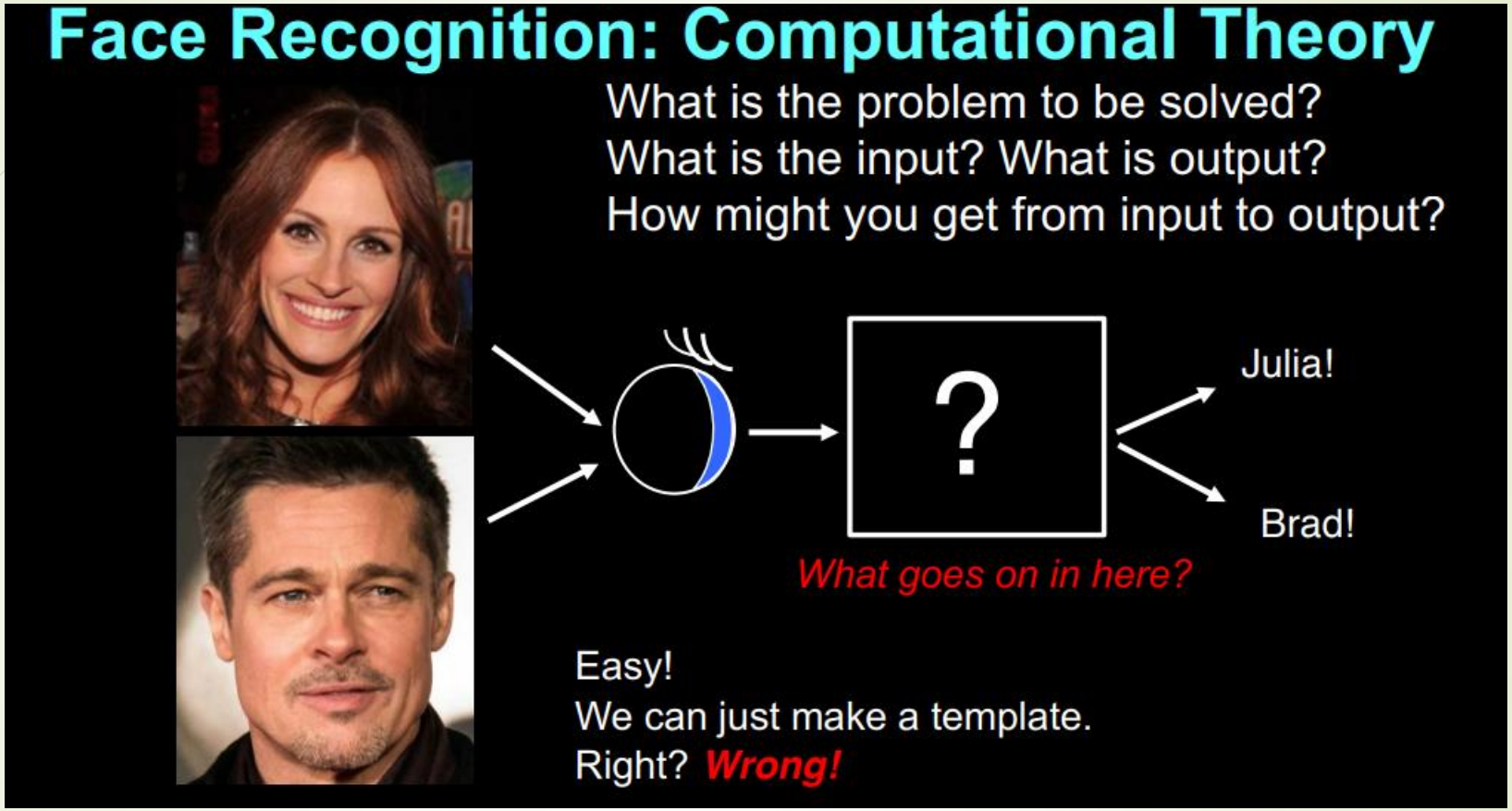
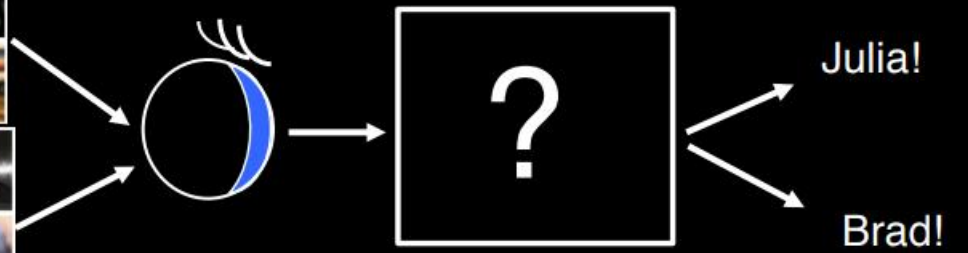
What goes on in here?
Easy!
We can just make a template.



- If we are storing template, we need to store lot of them.

The Problem of Face Recognition



Easy!
We can just make a template.
Right? ***Wrong!***

The same person (or thing) casts infinitely many different images as it changes in position, distance/size, viewpoint, lighting, expression, hair….

Yet we still recognize individuals across these changes. How is this possible?

memorize lots of templates?

extract an “invariant” representation? (e.g. close eyes?)

The Problem of Visual (Face) Recognition

Machine face recognition didn't work very well, until recently.
So we did not have working computational models for how face recognition *might* work until a few years ago...

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[PDF] **Deep face recognition.**

OM **Parkhi**, A **Vedaldi**, A **Zisserman** - bmvc, **2015** - cis.csuohio.edu

The goal of this paper is face recognition–from either a single photograph or from a set of faces tracked in a video. Recent progress in this area has been due to two factors:(i) end to end learning for the task using a convolutional neural network (CNN), and (ii) the availability of very large scale training datasets. We make two contributions: first, we show how a very large scale dataset (2.6 M images, over 2.6 K people) can be assembled by a combination of automation and human in the loop, and discuss the trade off between data purity and time; …

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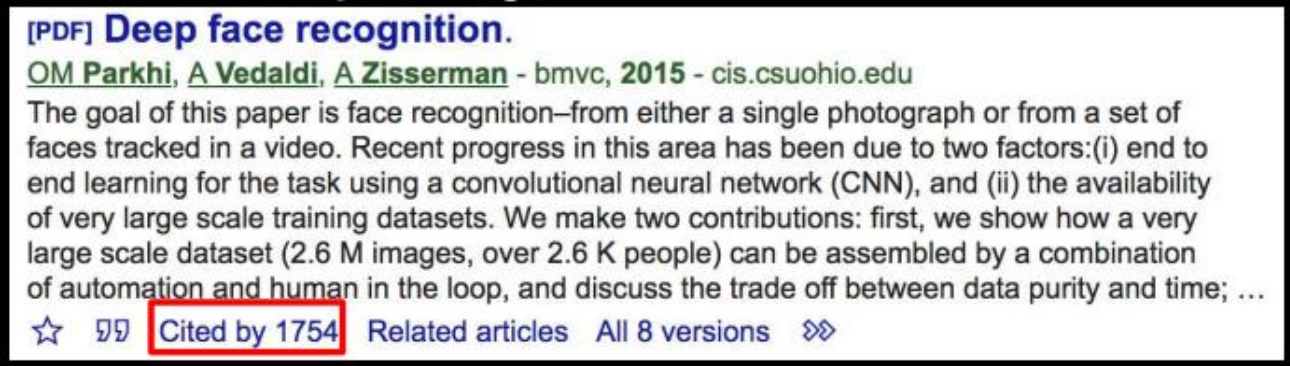
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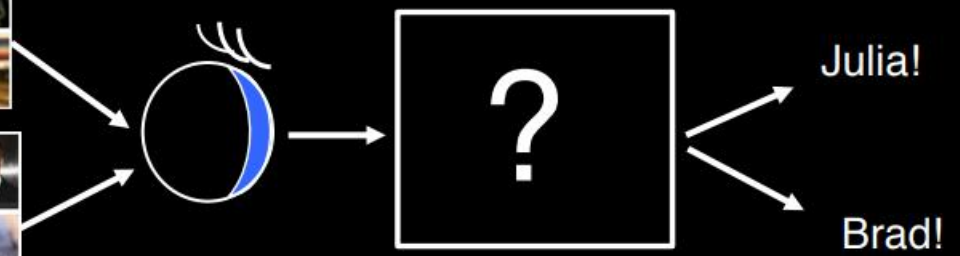
So, it is a possible model of how face recognition might work in humans.
That is progress.
But: It is not clear exactly how VGG-face itself works.
Or whether human face recognition works in a similar way.
So, what do we know about how face recognition works in humans?

How does Face Recognition Work in Humans?



What goes on in here?

We recognize individuals across these changes. How is this possible?

memorize lots of templates? << This should *not work for unfamiliar faces.*

extract an "invariant" representation? << This should work for unfamiliar faces.

Which story is right for humans?

Key test: can we tell if two different photos are of the same person *if we do not know that person?*

Can we Match Different Photos of the Same Unfamiliar Person?

Jenkins et al, Cognition, 2011

1. Collected photos off the web of Dutch politicians, will multiple images of each.
   Asked subjects to sort them into different piles of the same identity.
   Let's try it……..

How many different people are here?

Courtesy Elsevier, Inc., https://www.sciencedirect.com. Used with permission.

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1. Collected photos off the web of Dutch politicians, will multiple images of each. Asked subjects to sort them into different piles of the same identity.
   How many think there are over ten different people? under 10? over 5? under 5?

- **You can not match photos of a same person if you do not know the person**