INF1-CG 2016
Lecture 22

Vision: the higher levels

Richard Shillcock

Today's goals

We will look more at the top end of the process of visual perception and try and find computational principles.

Vision – the story so far …

We have seen that visual perception/cognition is served by many small, slow units (neurons)…

that there is a lot of hierarchical neural architecture …

that there are receptive fields that look like feature detectors, but might not be …

that the visual world gets topographically imported into the brain …

that line-based invariances seem crucial …

and that bottom-up, data-driven processing may be supplemented by top-down information and goals.

Today's readings

Quiroga, R. Q., Kreiman, G., Koch, C., & Fried, I. (2008). Sparse but not 'grandmother-cell' coding in the medial temporal lobe. *Trends in Cognitive Sciences*, *12*(3), 87-91.

Fine-coding and coarse-coding

There are hemispheric styles of processing.

They are not simple dichotomies.

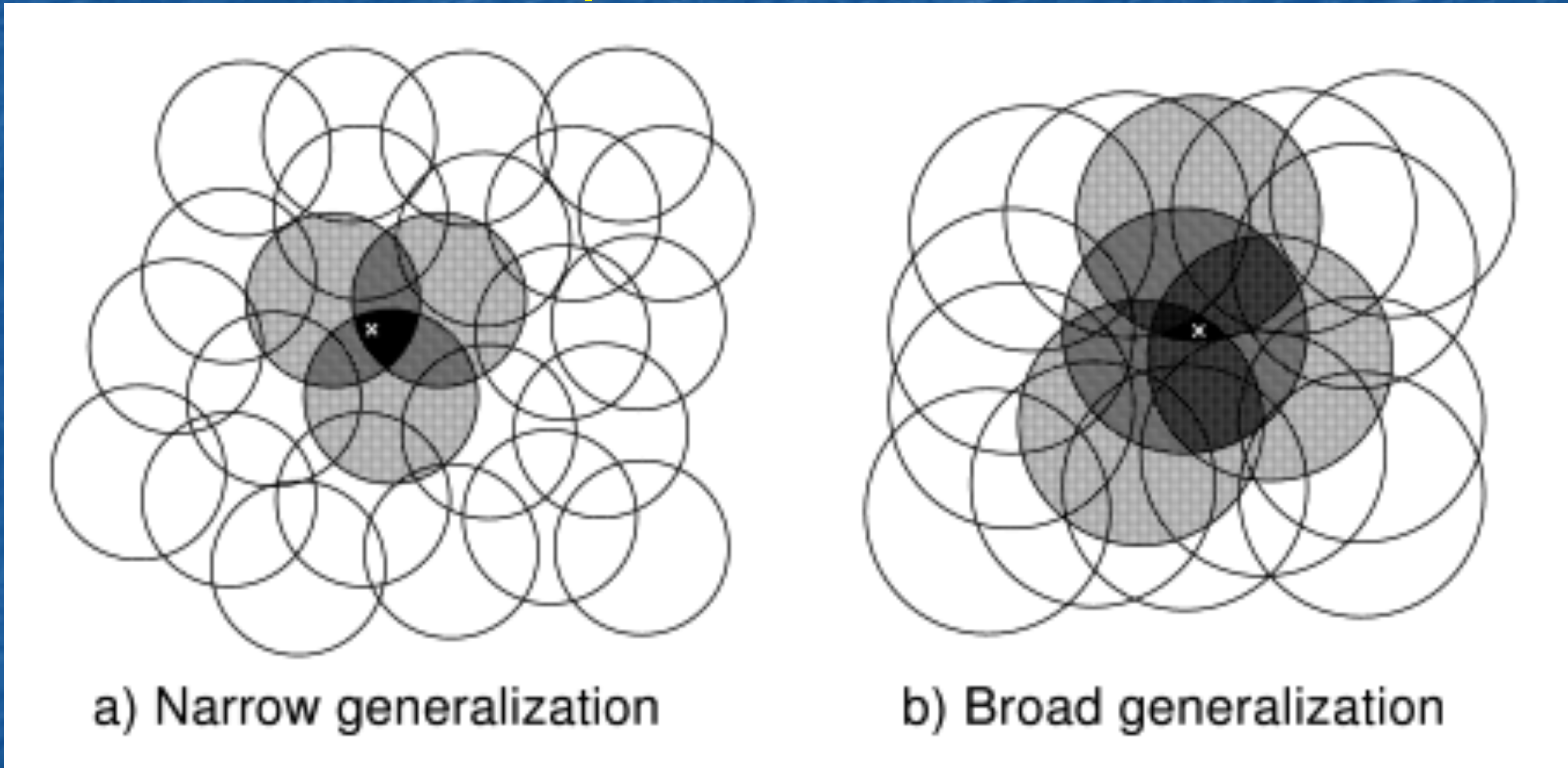
Rather, it is a productive division of labour between different specialisms and between different approaches to the same problem.

Brown and Kosslyn (1993) used a response-time task in which participants responded to a *qualitative* task (is the dot above or below the line?) or a *quantitative* task (is the dot a little way or a long way away from the line?)

LH = qualitative; RH = quantitative …

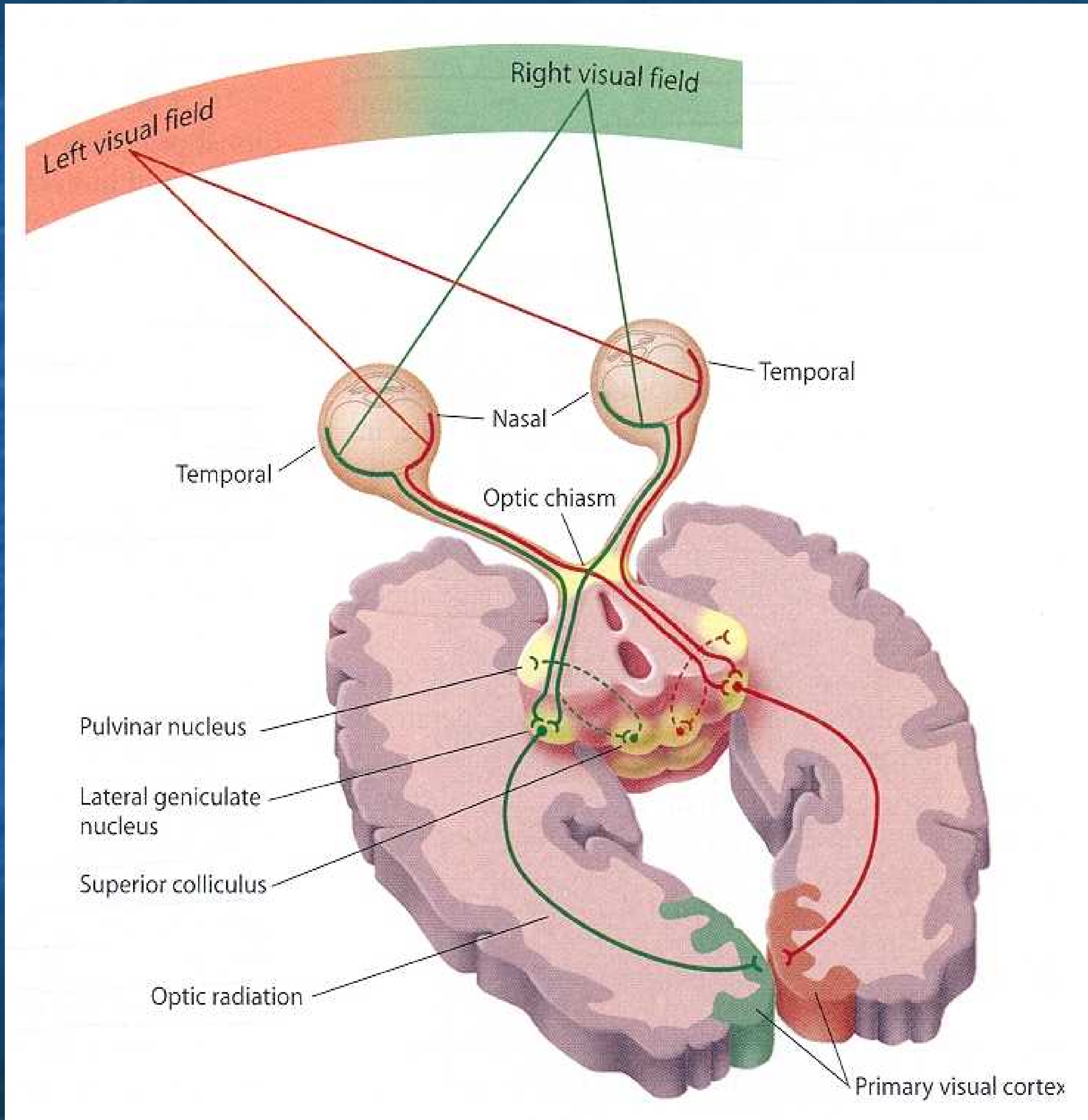
Fine-coding and coarse-coding

Fine-coding and coarse-coding can be conceived of in terms of receptive fields.

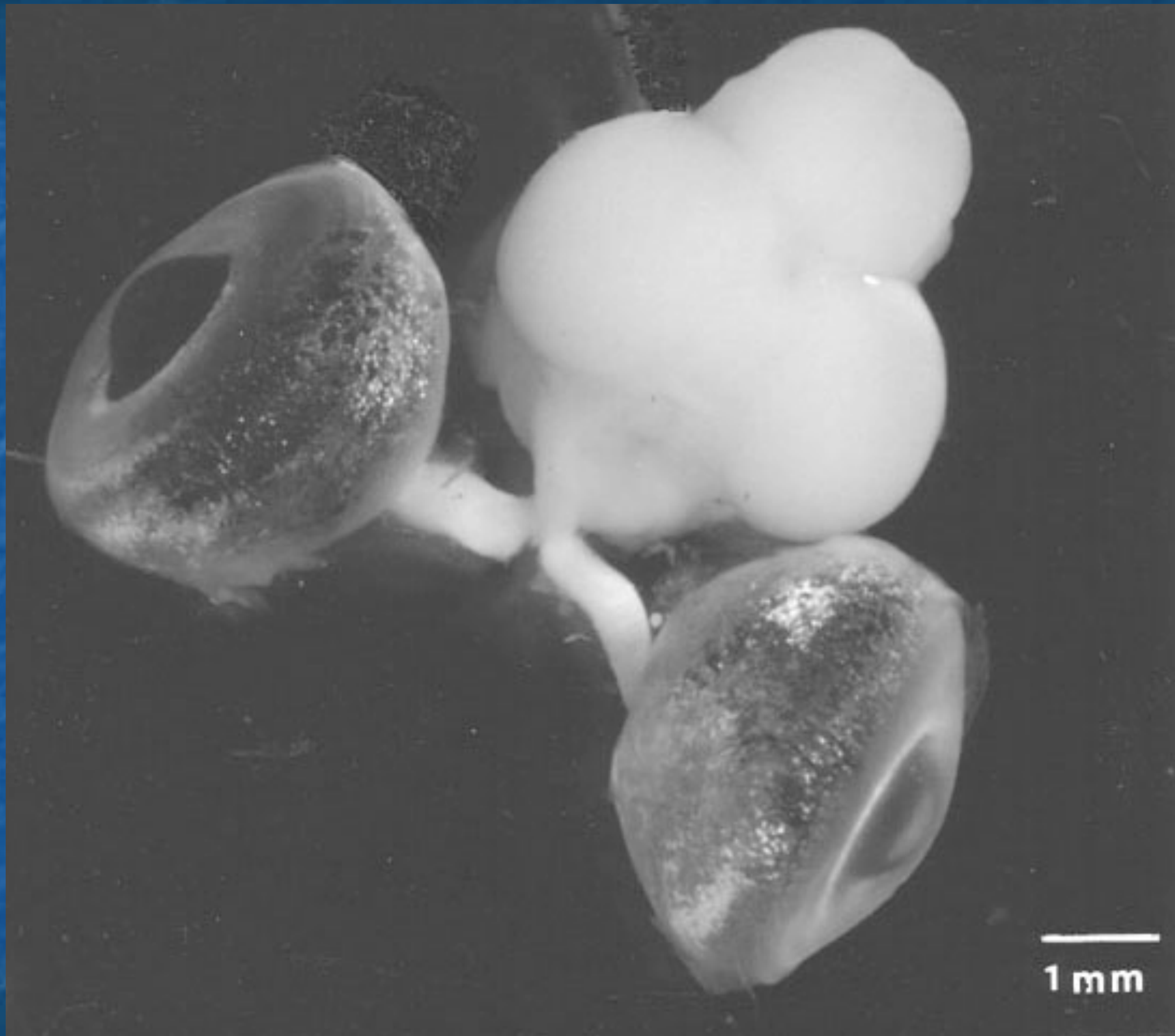


In coarse-coding any one representational unit (e.g. neuron) responds to a broader range of stimuli in the world.

The visual pathways



Lateralization in fish vision



Crossover at the optic chiasm is complete.

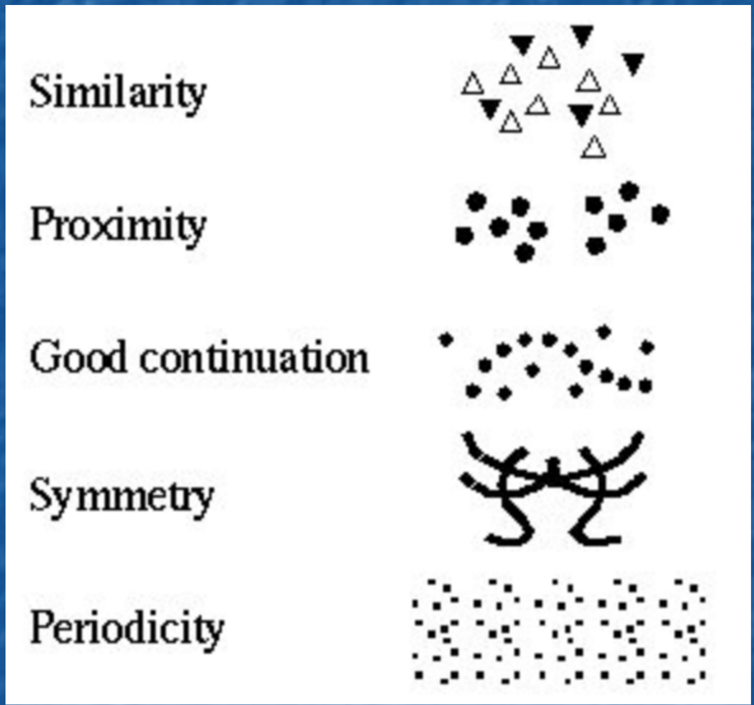
Lateralization in fish vision
Brown, Gardner & Braithwaite (2004)

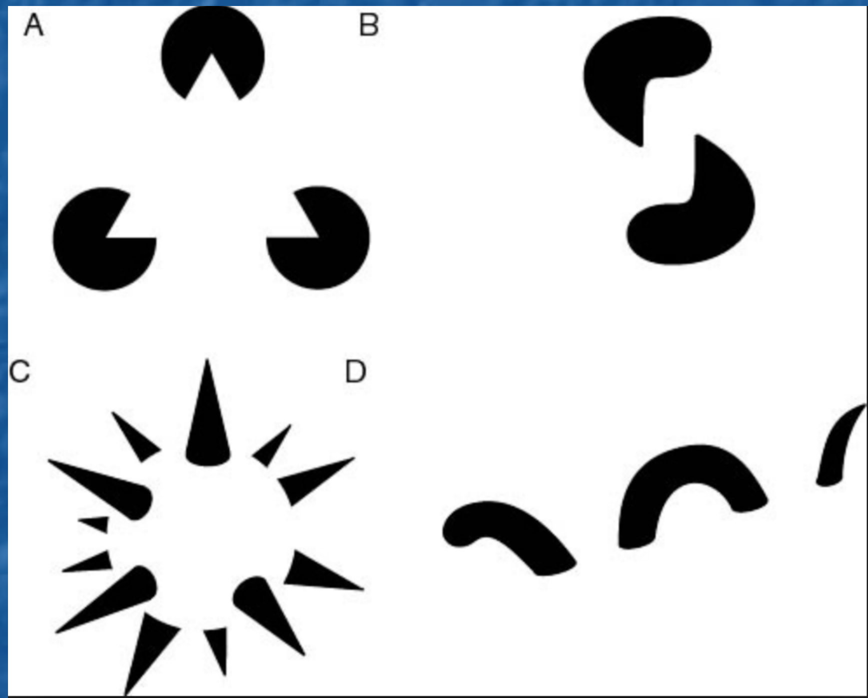
Degree of lateralization is determined by experience of predation.

Chance alignments, *not* invariances

Invariances, probably *not* chance

The idea of invariances shares a lot with *Gestalt principles* (Koffka, 1935):





Gestalt principles are generalisations about the effects of "good forms" in vision.

Vision is a hard problem

Does a computer have to know that telephones don’t usually float in space?

Vision is a hard problem

When we try to proceduralize visual recognition – to model it computationally – we understand all of the assumptions made along the way. Do humans have hands that are the same size?

“World knowledge”

Douglas Lenat,
“14 lb cheeseburger”,
controversial Cyc Project.

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(#$isa #$BillClinton #$UnitedStatesPresident)
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(#$genls #$Tree-ThePlant #$Plant)
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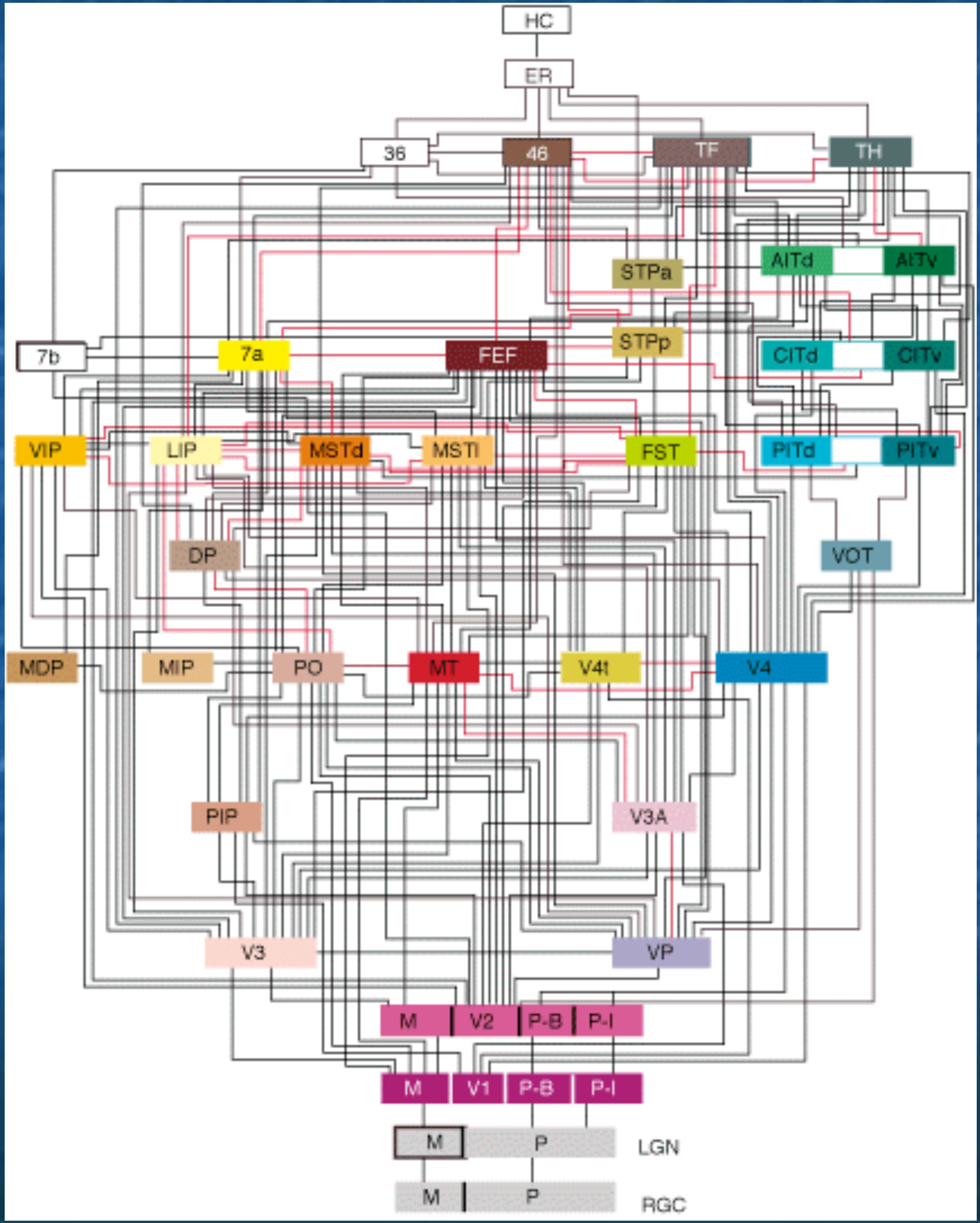
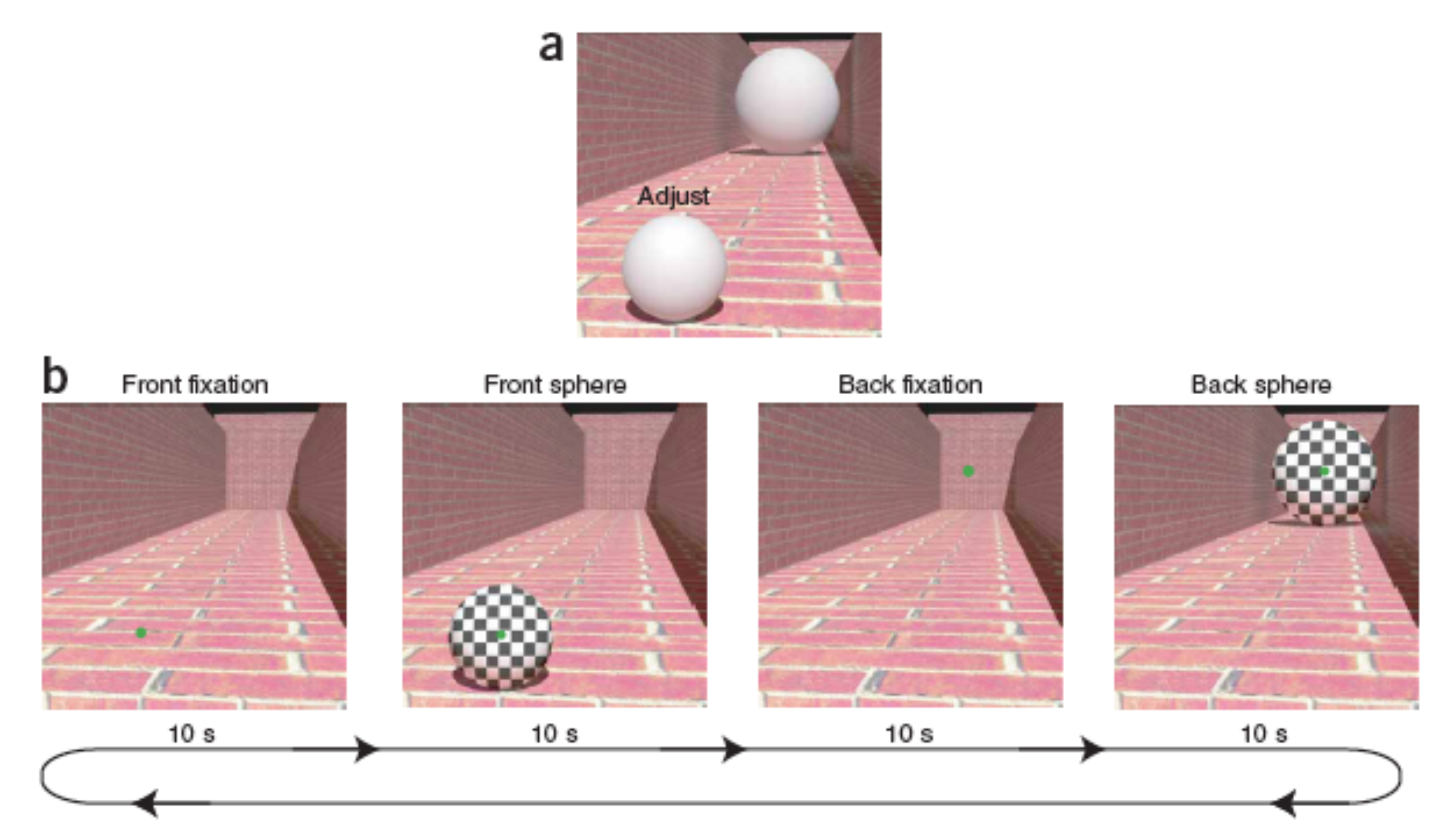
How do we represent and use “world knowledge” (*cf.* Lenat & Guha, 1989)?

Recurrence in the visual system

Felleman & Van Essen (1991)

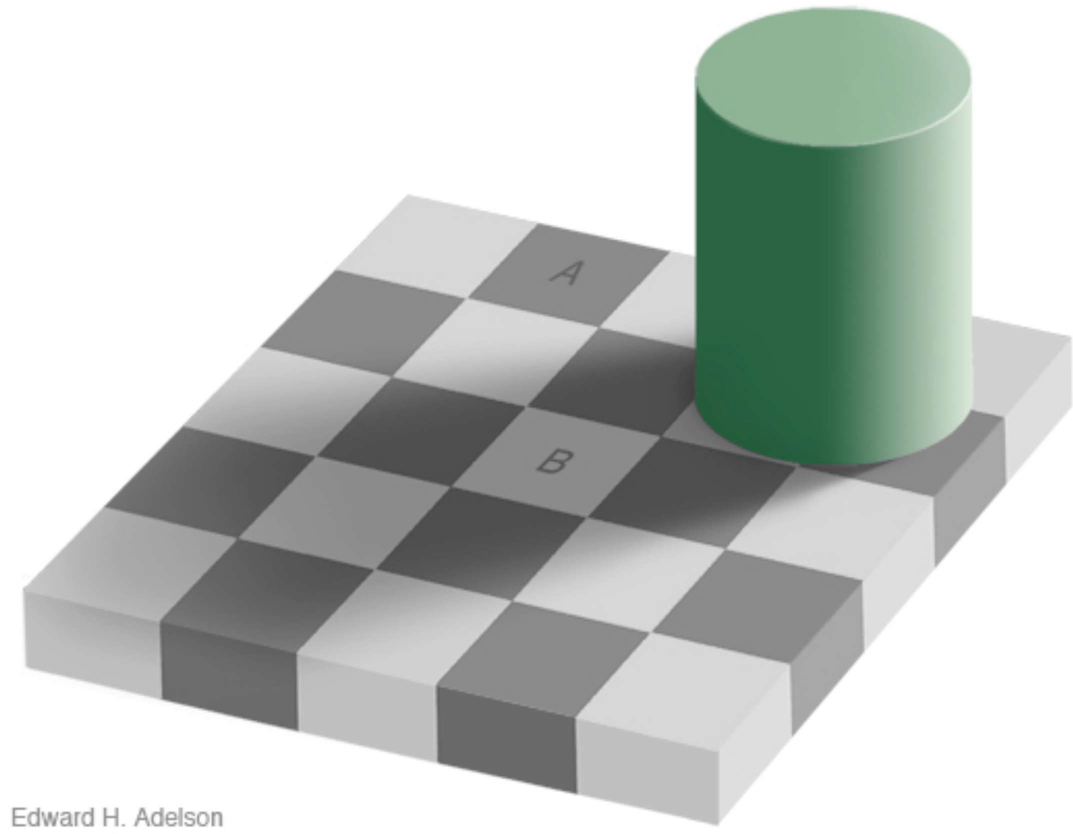


Topographic mapping and V1



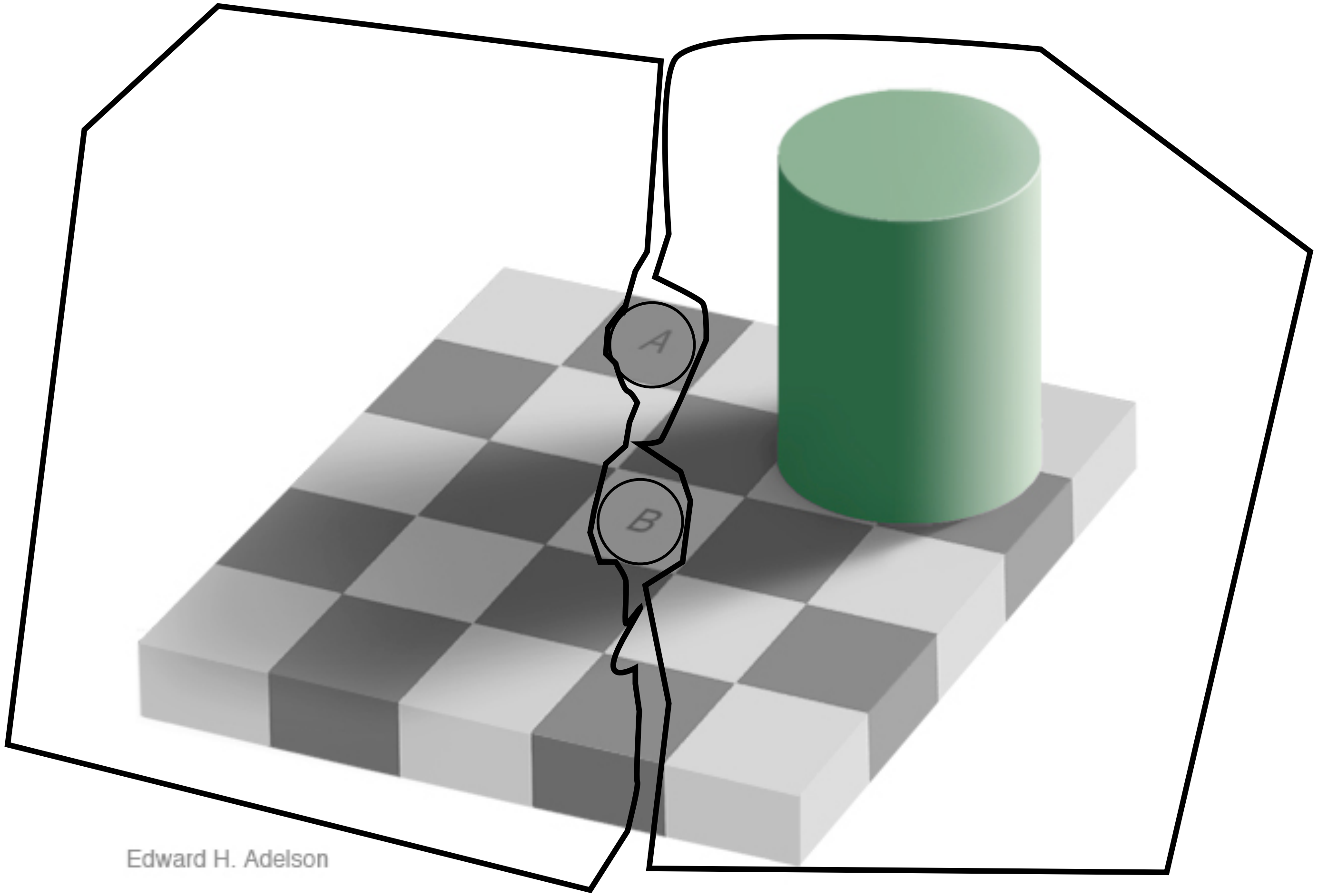
Topographic mapping in V1 is affected by real-world understanding of size (Murray et al., 2006).

Perceptual constancy



The viewer adjusts perceived luminance in the light of experience (Adelson, 1999)

Perceptual constancy



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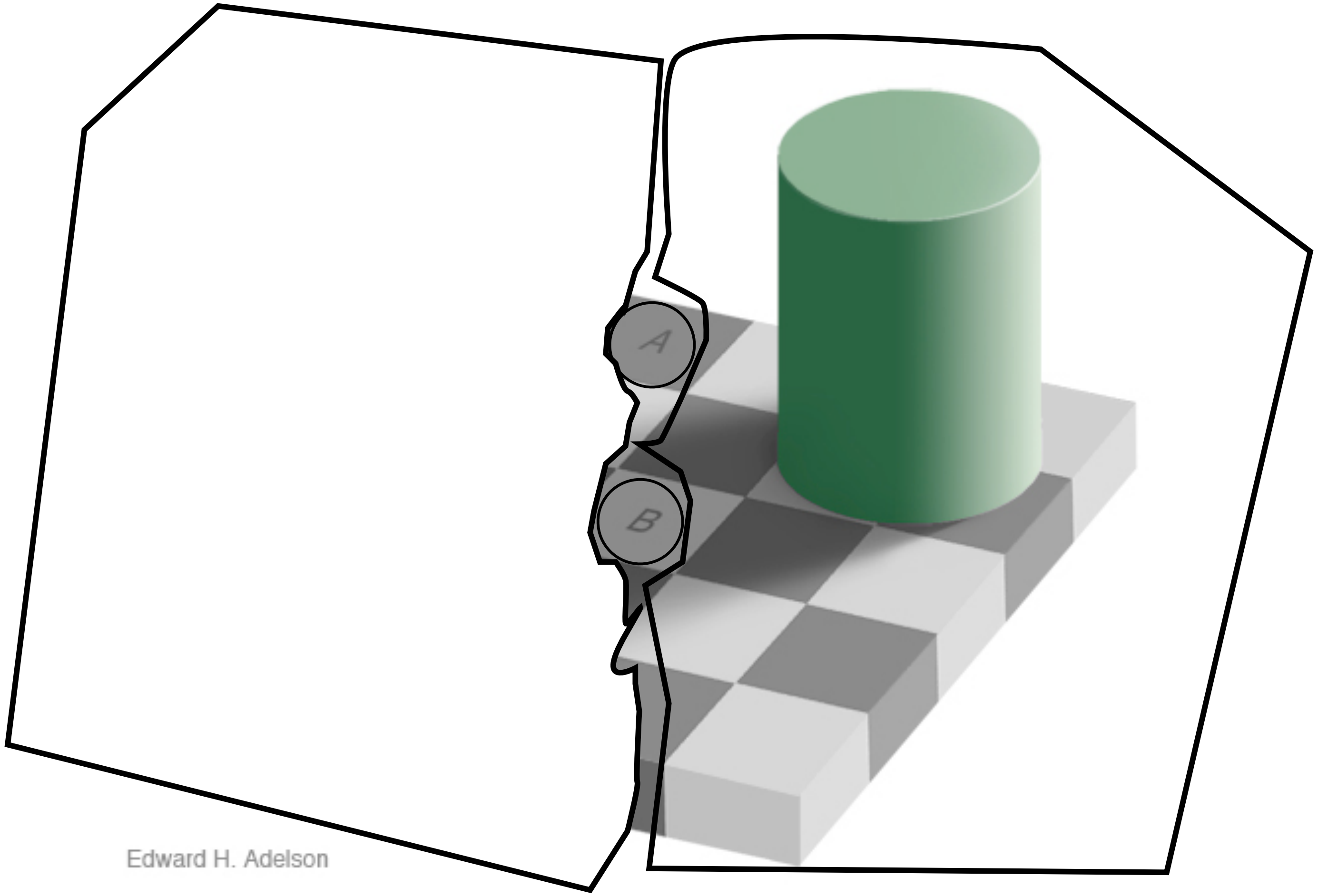

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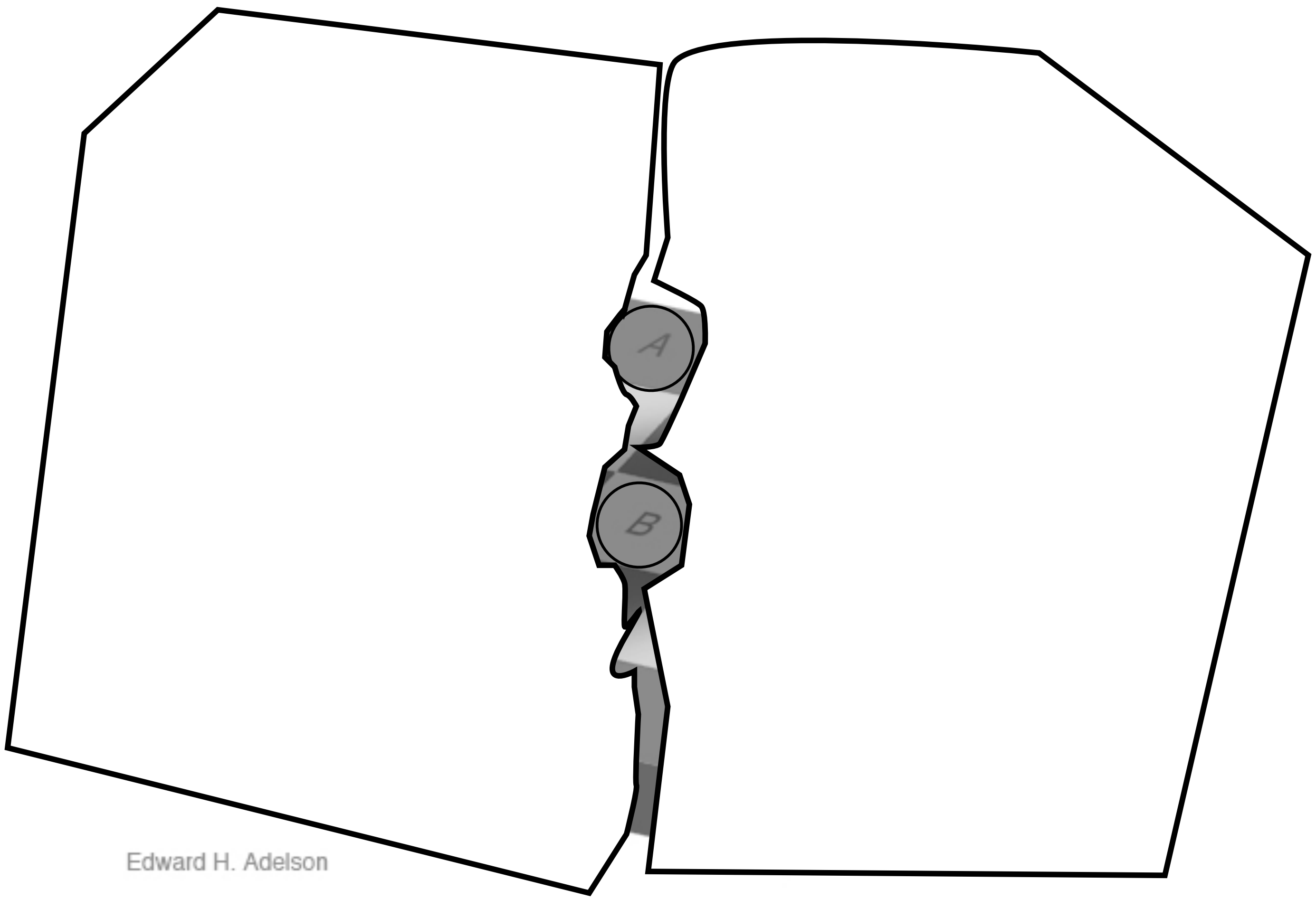

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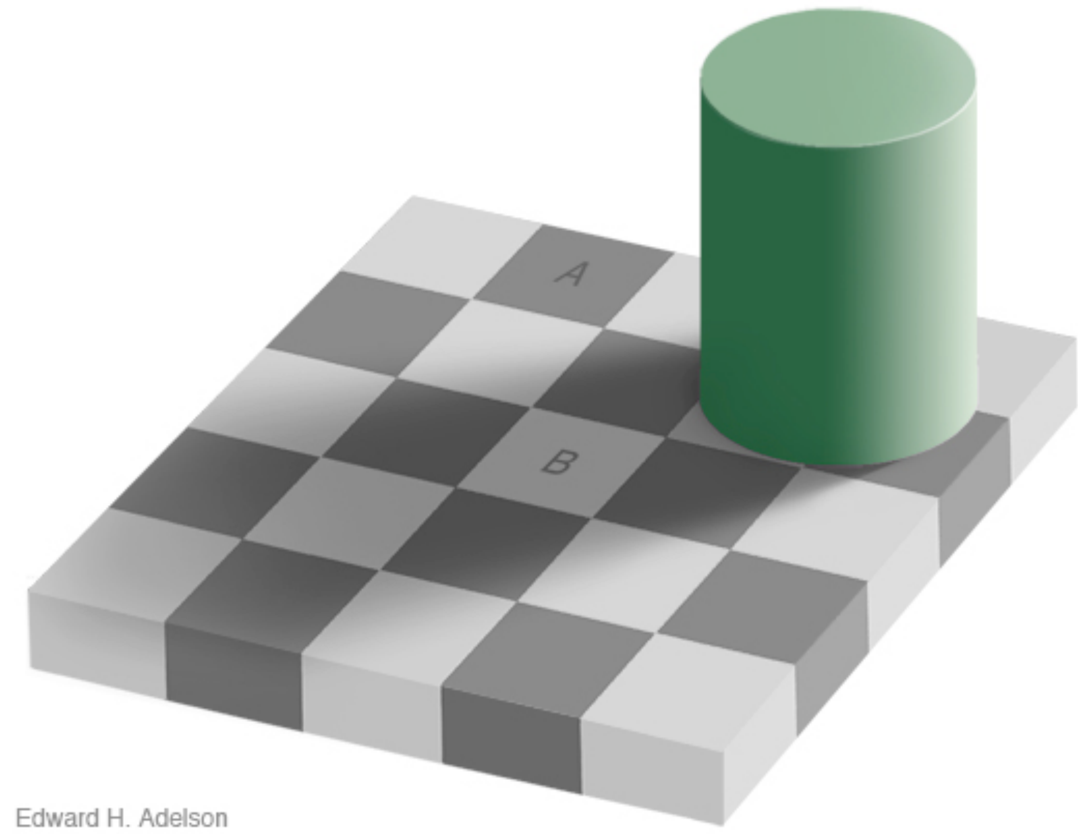


The viewer adjusts perceived luminance in the light of experience (Adelson, 1999). There are also constancies of shape, size, colour, *etc.*

Coping with slowness of neurons

Neurons are slow. Vision cannot work by a lot of sequential computations.

One response is "population coding", in which whole populations fire at once and encode something particular. There is no shortage of neurons.

Another response is using top-down knowledge-driven processing.

Mathematical perspectives on perception

Similar ideas have surfaced and resurfaced within Cognitive Science, from Helmholtz (1860) to Neisser's (1967) "analysis by synthesis" to Dayan et al.'s "Helmholtz Machine" to Grush's (2004) emulation to Friston et al.'s "predictive coding" and "the free energy principle".

They are driven by advances in mathematics and in neuroscience.

Mathematical perspectives on perception

They all have in common the idea that the individual's brain *generates* an internal model of the external cause and the bodily reaction and makes *predictions* about what will happen next.

Successful prediction *is* perception.

There is a critical role for the *error* between the incoming signal and the prediction.

Reducing that error is successful perception/cognition.

"A critique of pure vision"
Churchland, Ramachandran & Sejnowski (1994)

They criticize the standard view of "pure vision", abstracted away from movement.

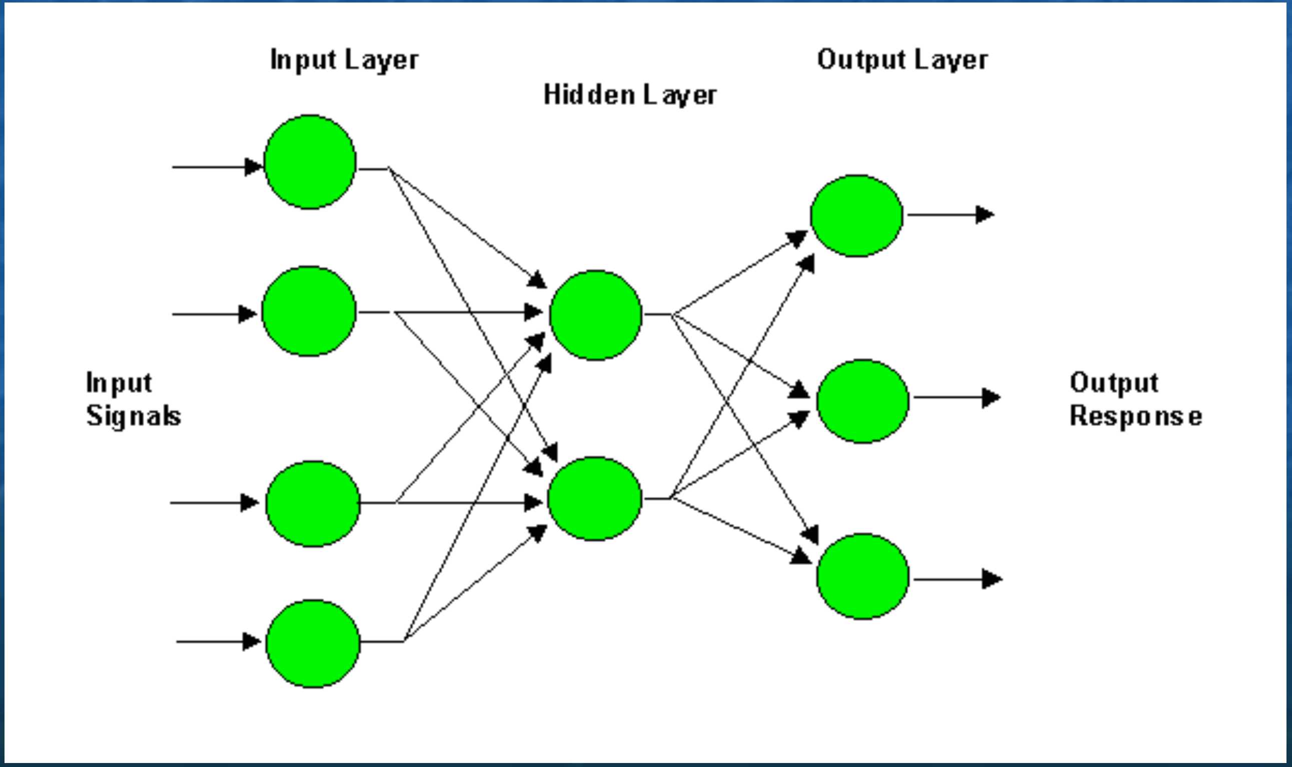
"no obvious replacement term for "hierarchy" suggests itself, and a new set of concepts adequate to describing interactive systems is needed" (p. 27).

They suggest an alternative *heterarchical*, interactive view – "interactive vision".

The "grandmother cell"

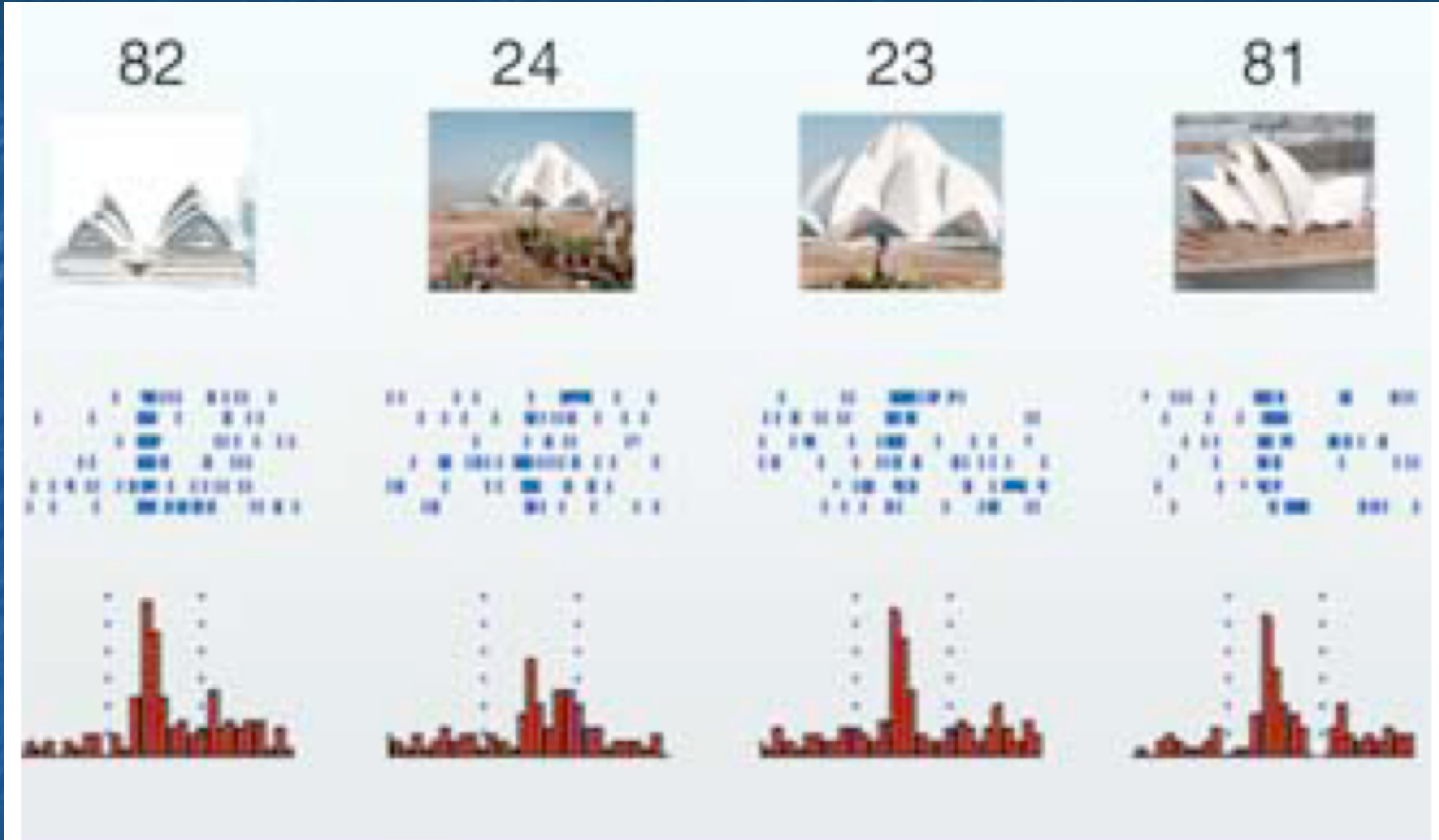
Lashley's (1950) "Mass Action Principle" regarding learning: learning is *distributed* – as "engrams".

Earlier in the course, we have seen connectionist models involving this principle.



How to recognize Jennifer Anniston

How to recognize Jennifer Anniston

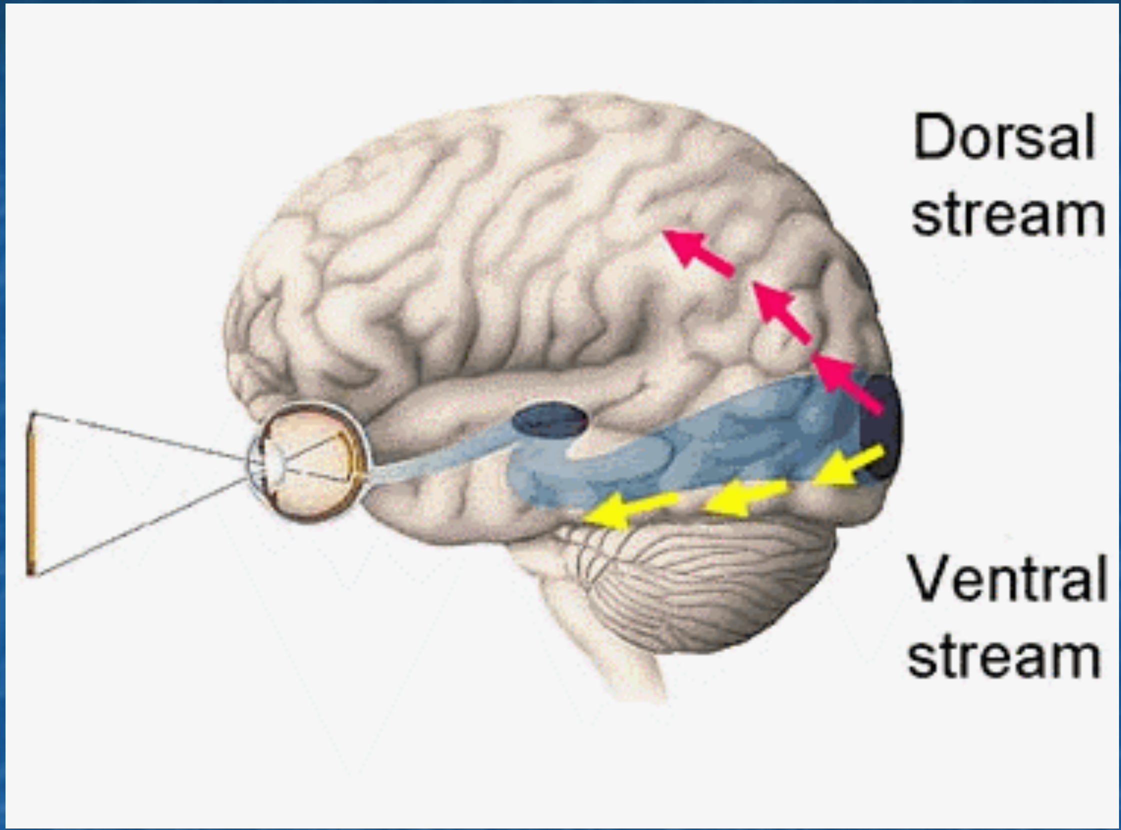


What does it mean to have such *sparse* response characteristics?

The case of DF

A *dissociation* can occur, between preserved and impaired functions.

This can be a clue to the functional architecture of cognition.



DF has bilateral, ventral stream brain damage from CO poisoning (Goodale & Milner, 2004). The dorsal stream is intact.

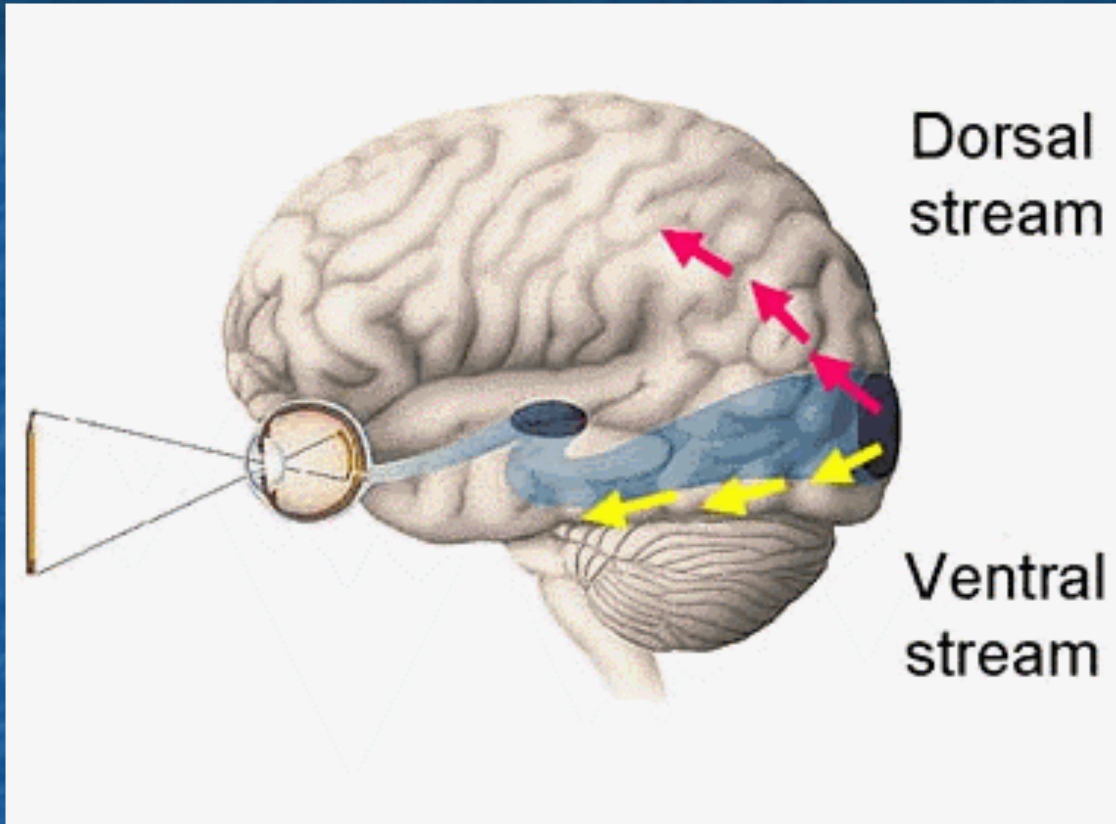
The case of DF

DF cannot identify figure from ground, visually segment objects or identify lines and edges.

But her grasping of objects is good.

(This is the opposite of *optic ataxia*.)

The case of DF



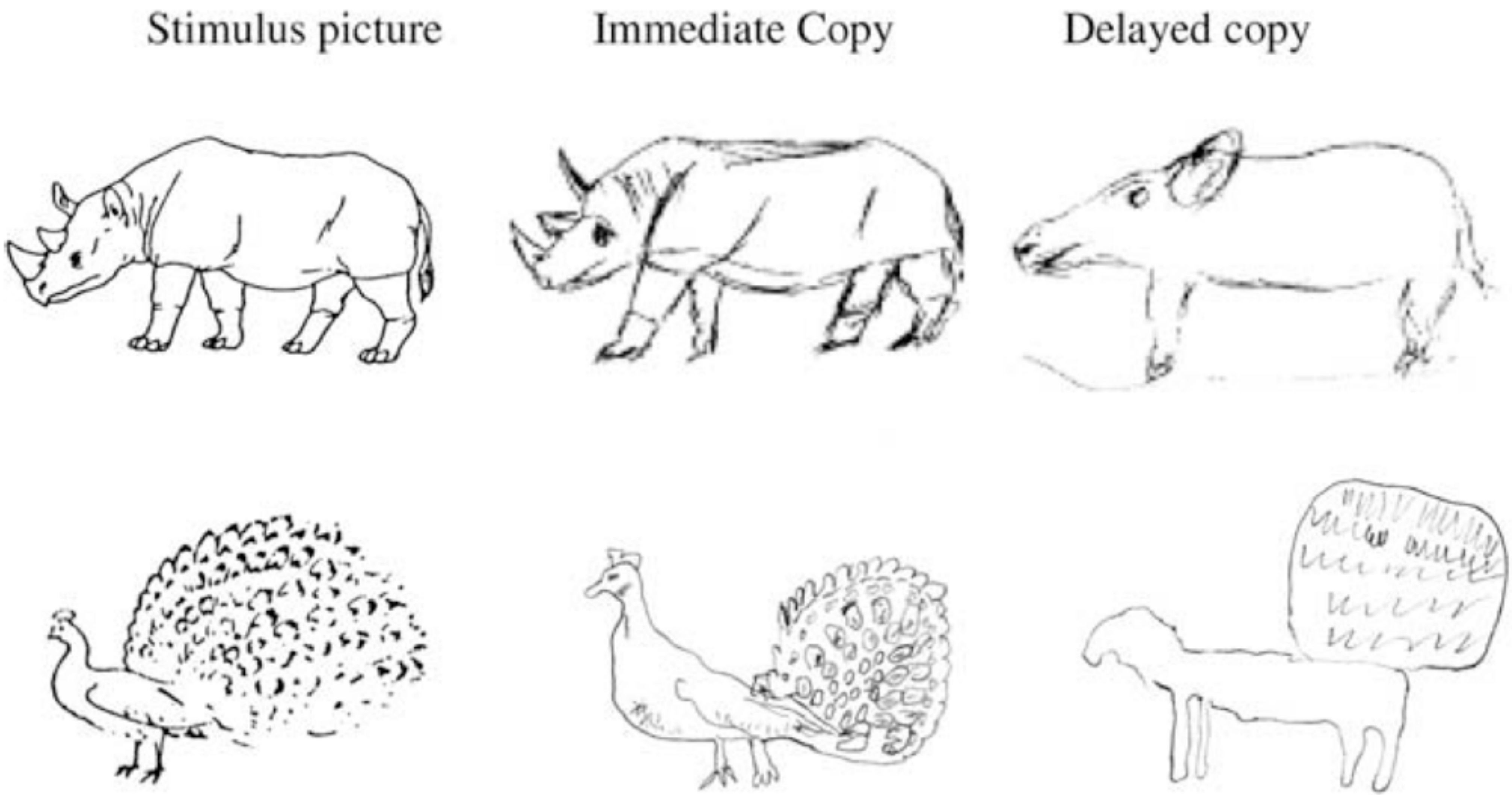
The dorsal stream has been characterised as "where" and as "perception for action". But there is interaction between the two streams and the debate continues with regard to grasping *affordances* (*cf.* Mon-Williams & Bingham, 2011).

Affordances
Gibson (1977)

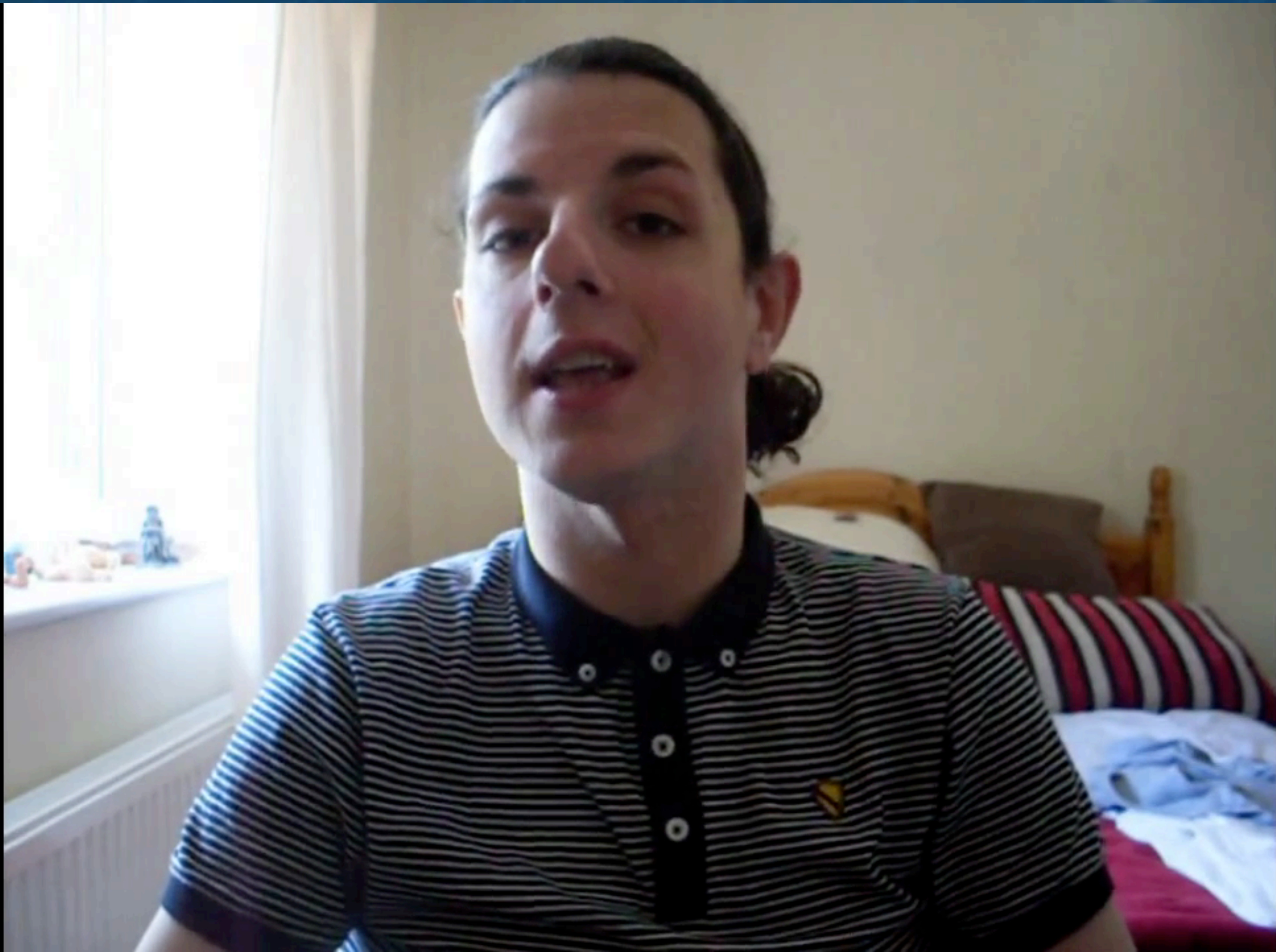
A jug invites being picked up by its handle.

Amodal representations

Lambon-Ralph, Matthew & Patterson (2008)



Simultagnosia



Challenges

To test computational principles in real implementations.

To identify processing preferences and specialisms in particular brain architectures.

To engage therapeutically with visual impairment.

To keep pinning the mathematical advances down to the philosophical distinctions.

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http://www.youtube.com/watch?v=3ur7WjPprss