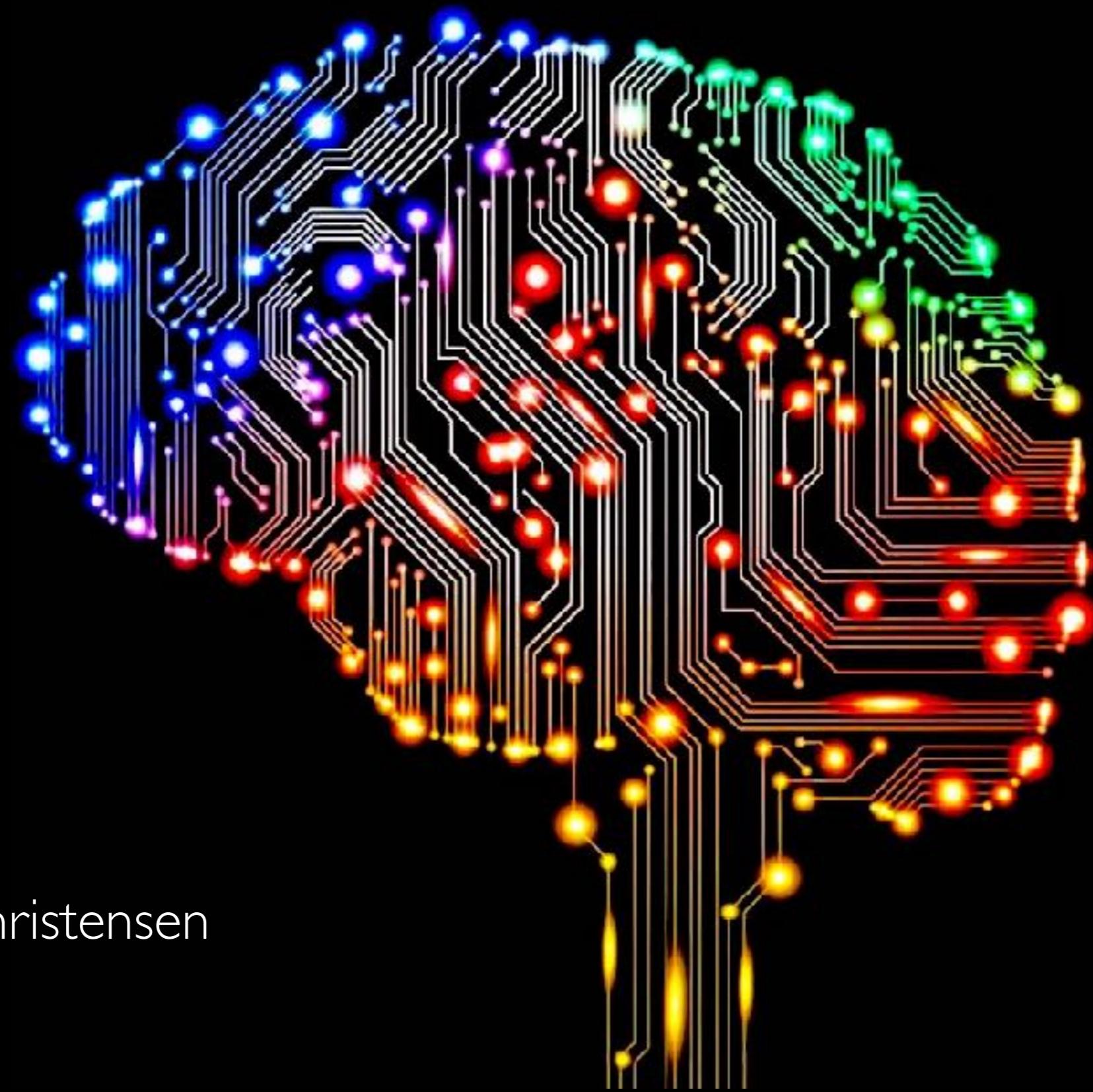


COMPUTATIONAL MODELS OF NEURAL CODING IN VISION AND NEUROSTIMULATION



Elijah Christensen

05.08.20

Stimuli

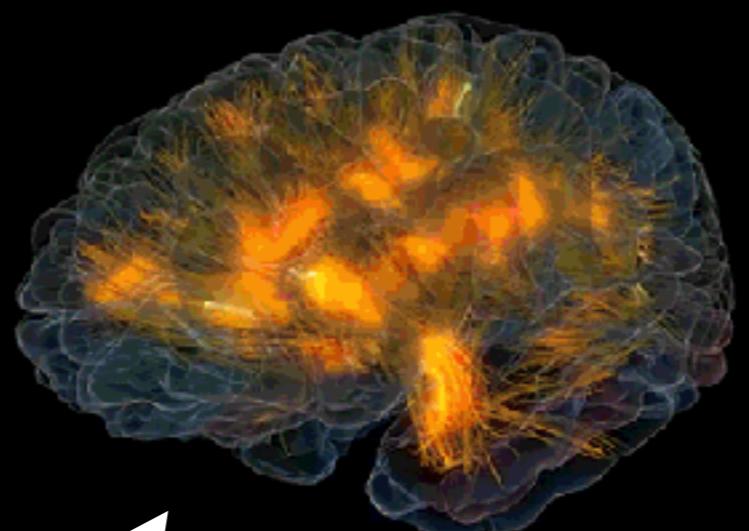
Vision

Hearing

Smell/Taste

Touch

Neural Activity



Encoding
Models

Decoding
Models

States

Mental State

Hunger

Sleep/Wake

Action

Movement

Speech

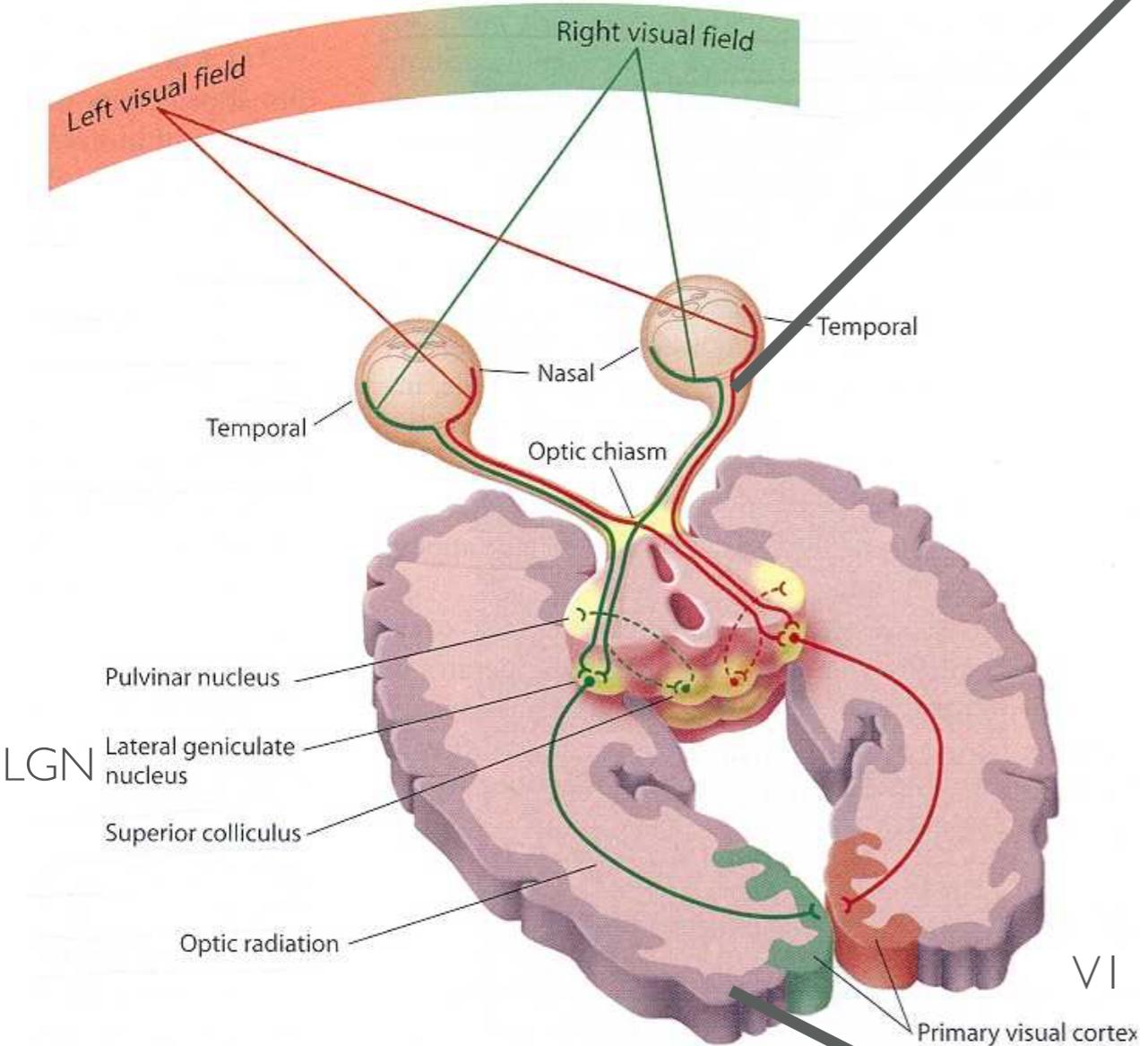
NEURAL INTERFACES IN POP CULTURE



Neo-Neuropixels?

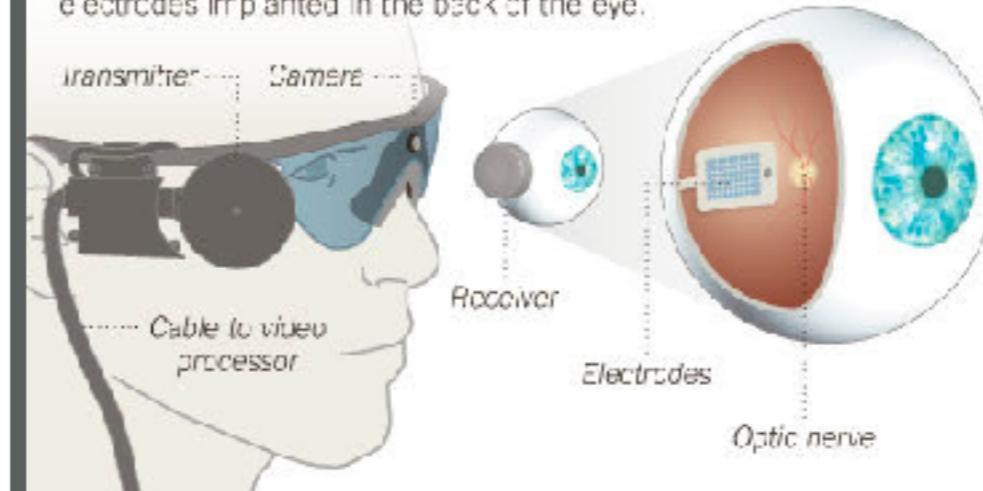


ANATOMY OF VISUAL PROCESSING



Approval for an Artificial Retina

The Food and Drug Administration approved a system that allows people with a severe type of retinal deterioration to see patches of light and dark. Camera images are processed and transferred to electrodes implanted in the back of the eye.

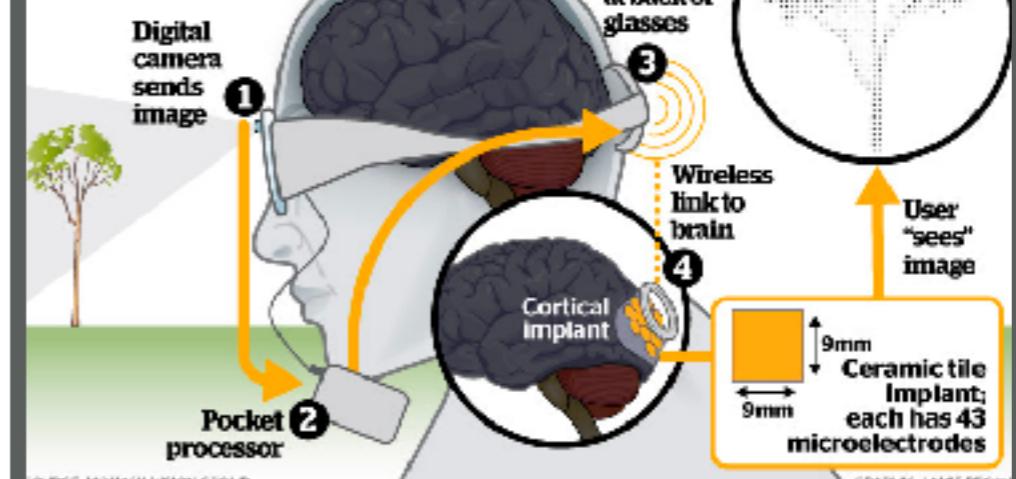


Courtesy Second Sight Medical Products

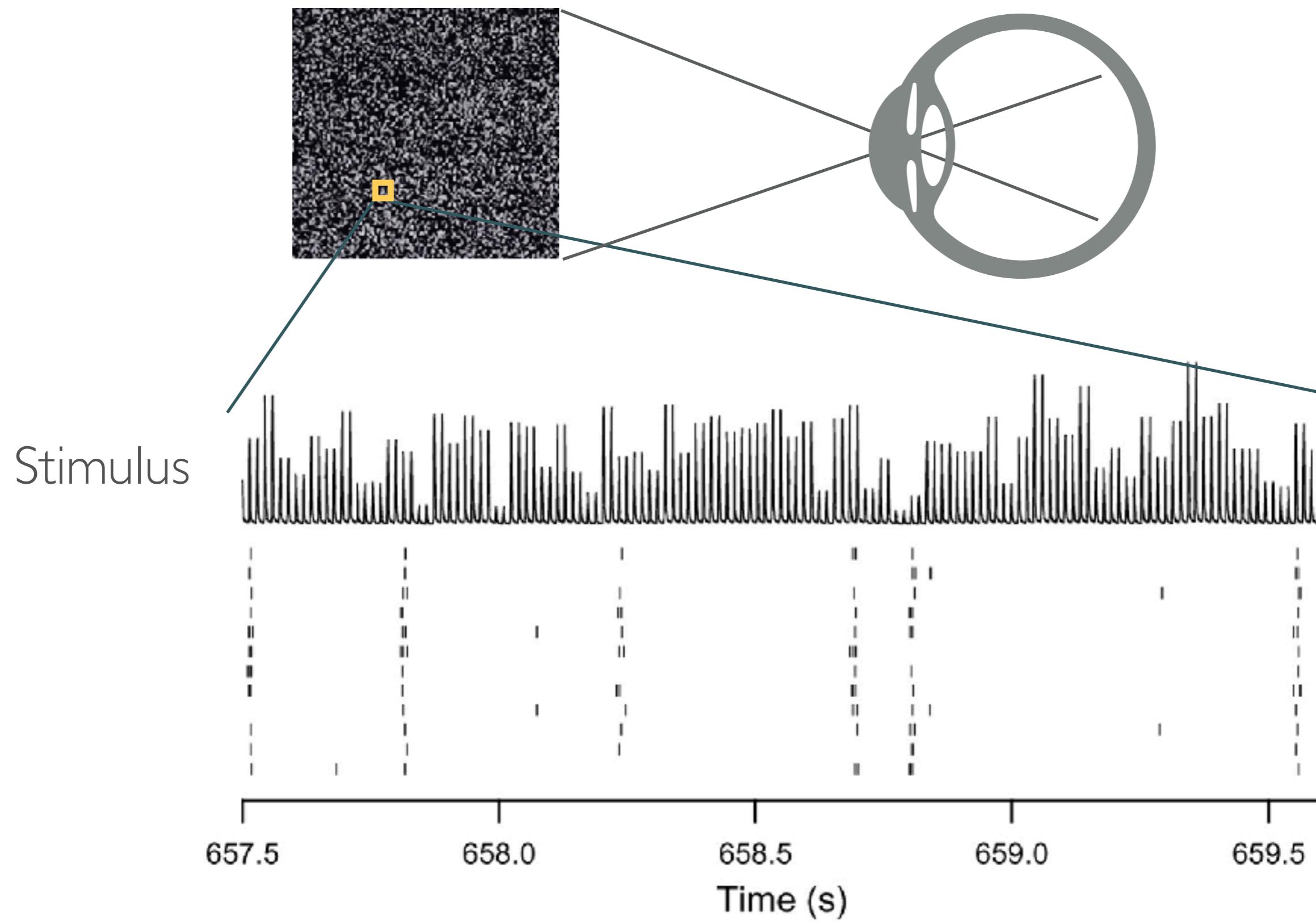
THE NEW YORK TIMES

How it works

Bionic eye that bypasses the eye

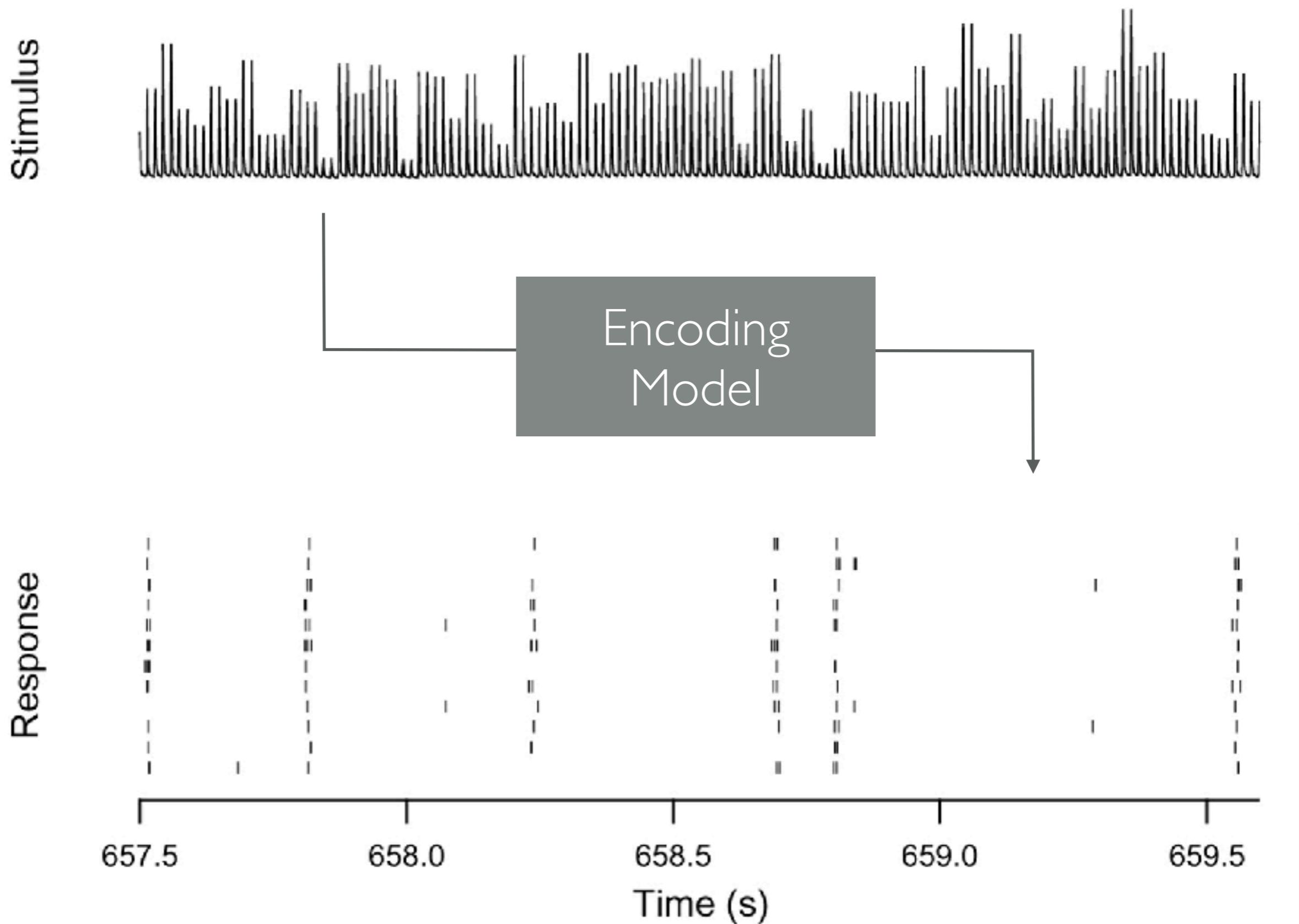


RESPONSE RELIABILITY IN EARLY VISUAL PROCESSING

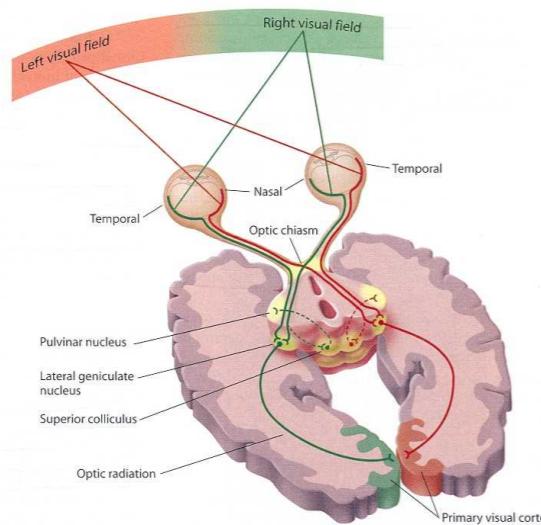
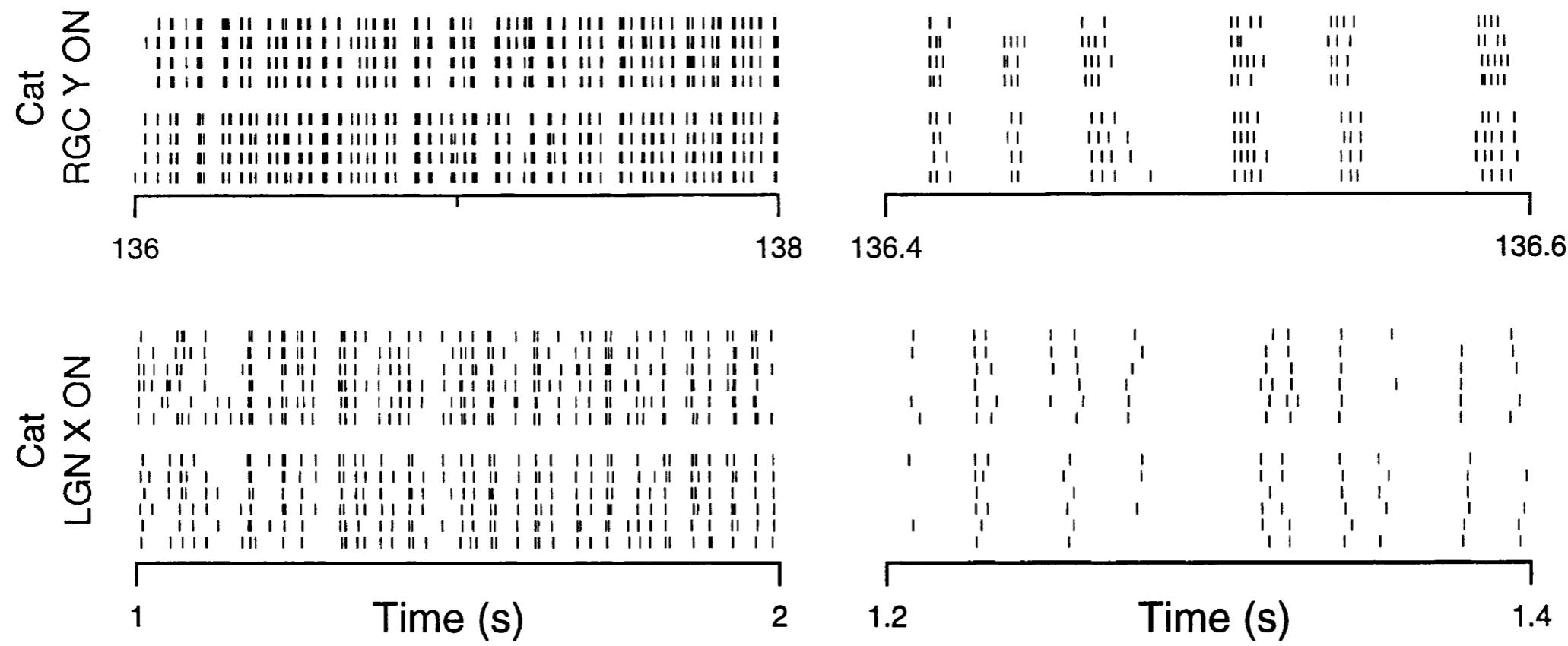


Adapted from Keat et al (2001) *Neuron*

RESPONSE RELIABILITY IN EARLY VISUAL PROCESSING

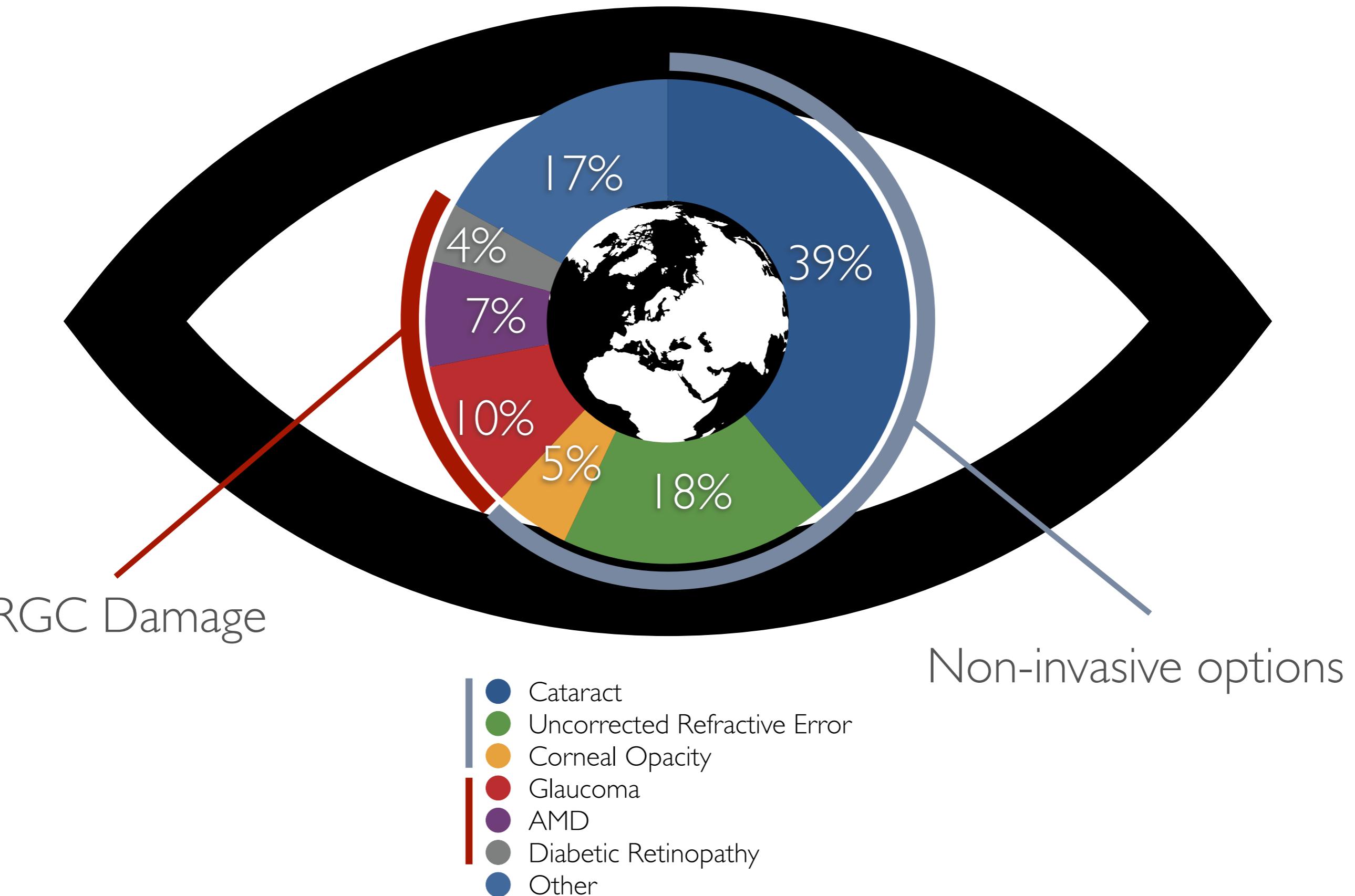


Adapted from Keat et al (2001) *Neuron*

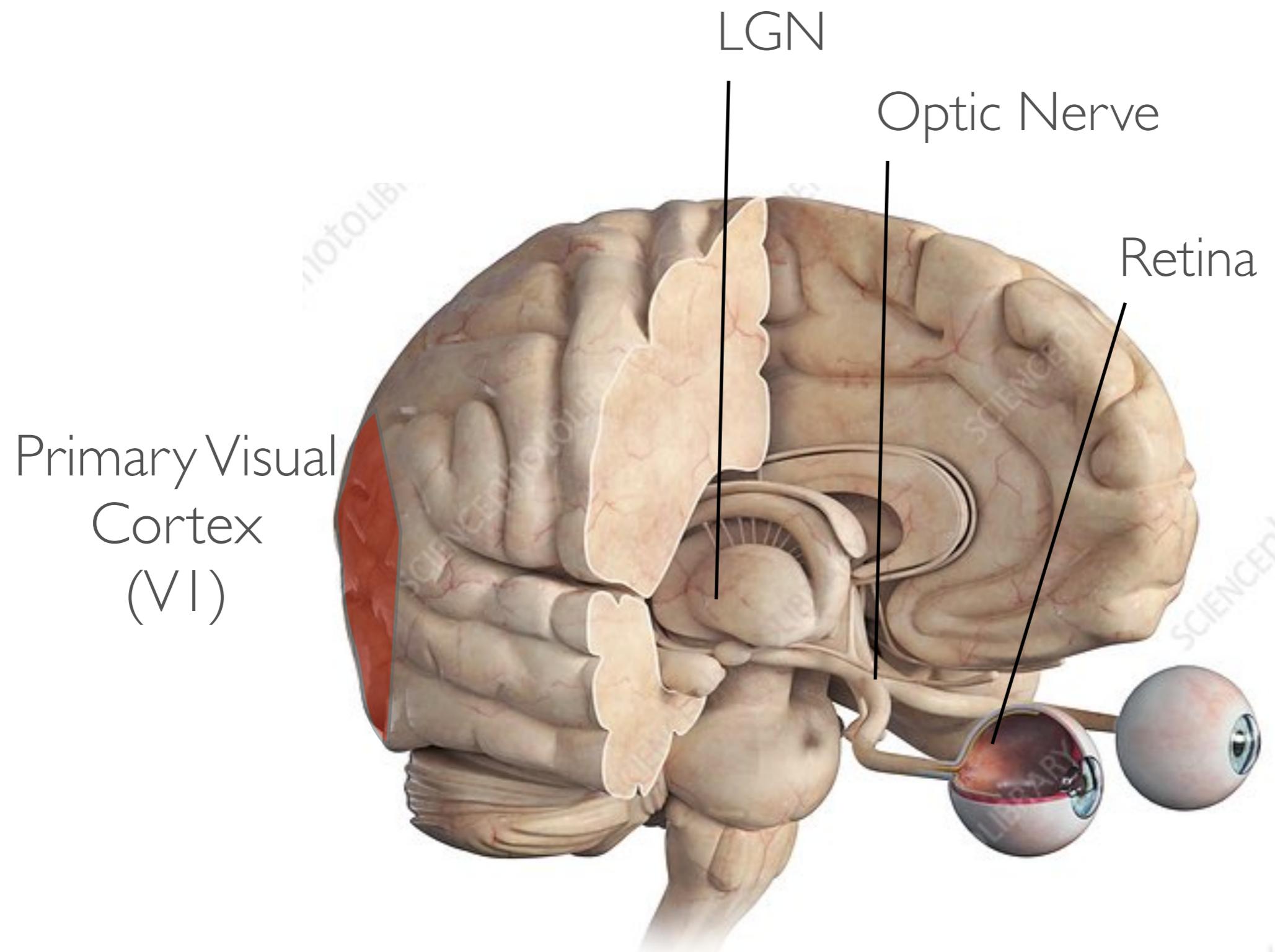


These models do well predicting response properties of retinal and LGN neurons to simplified flicker stimuli but do not do as well with natural images

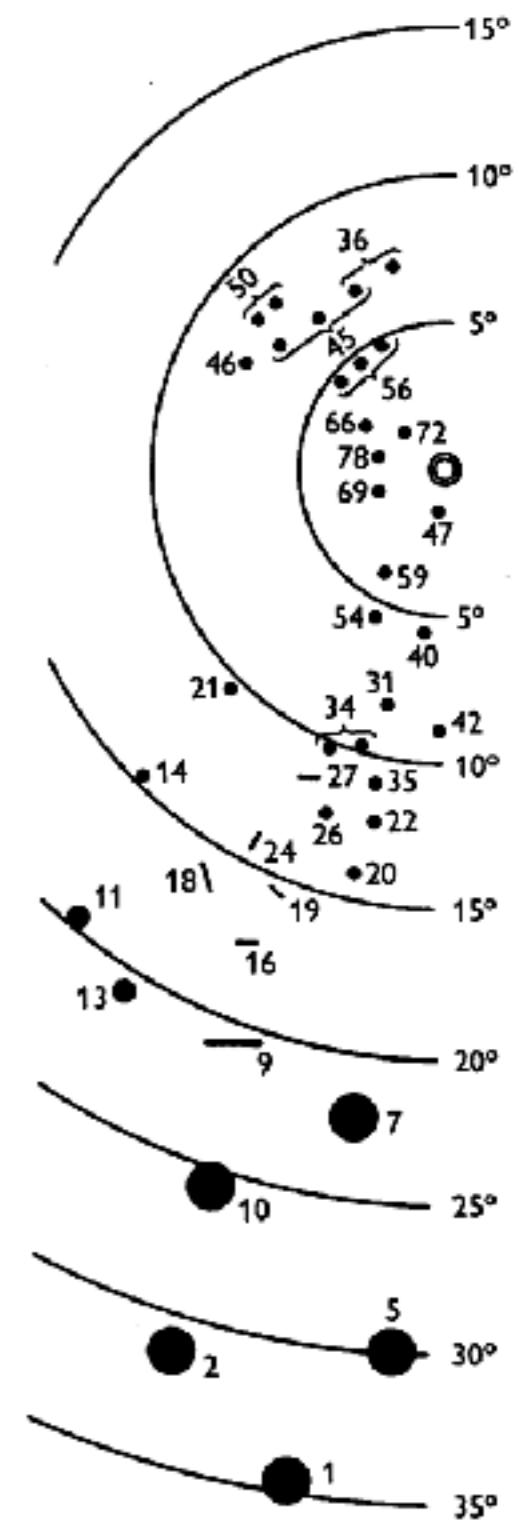
THE USE-CASE OF RETINA BASED IMPLANTS



ANATOMY OF VISUAL PROCESSING



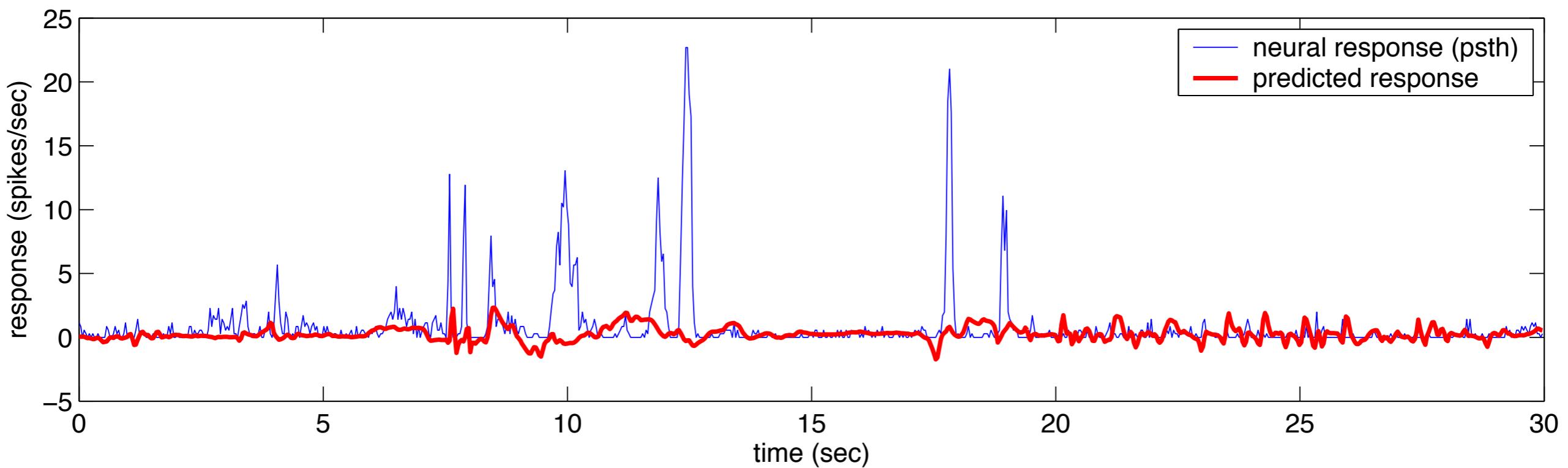
PHOSPHENES / MICROSTIMULATION



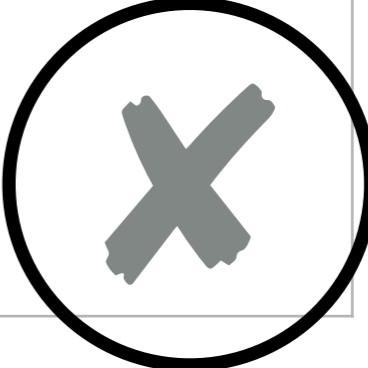
What is the other 85% of V1 doing?

Bruno A. Olshausen
Redwood Neuroscience Institute
and Center for Neuroscience, UC Davis

David J. Field
Department of Psychology
Cornell University



ENCODING MODEL LANDSCAPE

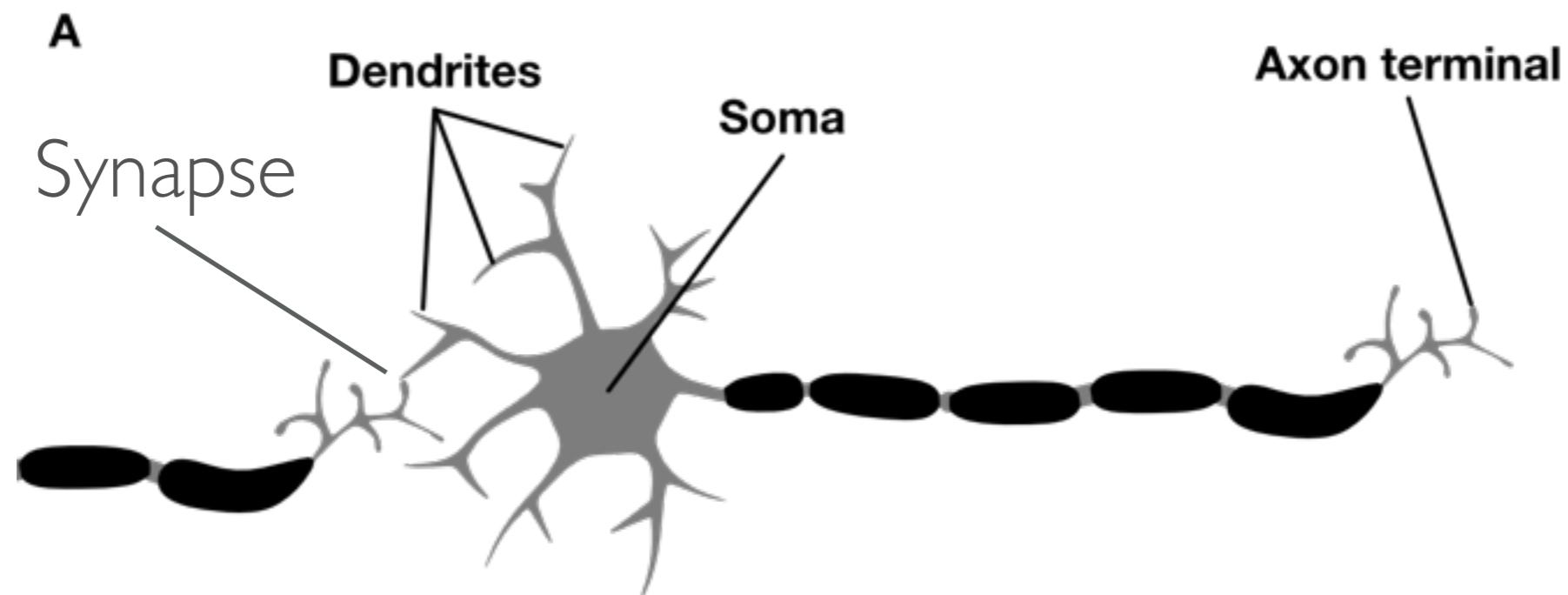
		Stimuli Complexity		
		Full-Field Flicker	White Noise	Natural Images
Encoding Model	Retina	✓	✓	
	LGN	✓	✓	
	VI	✓		

OUR APPROACH

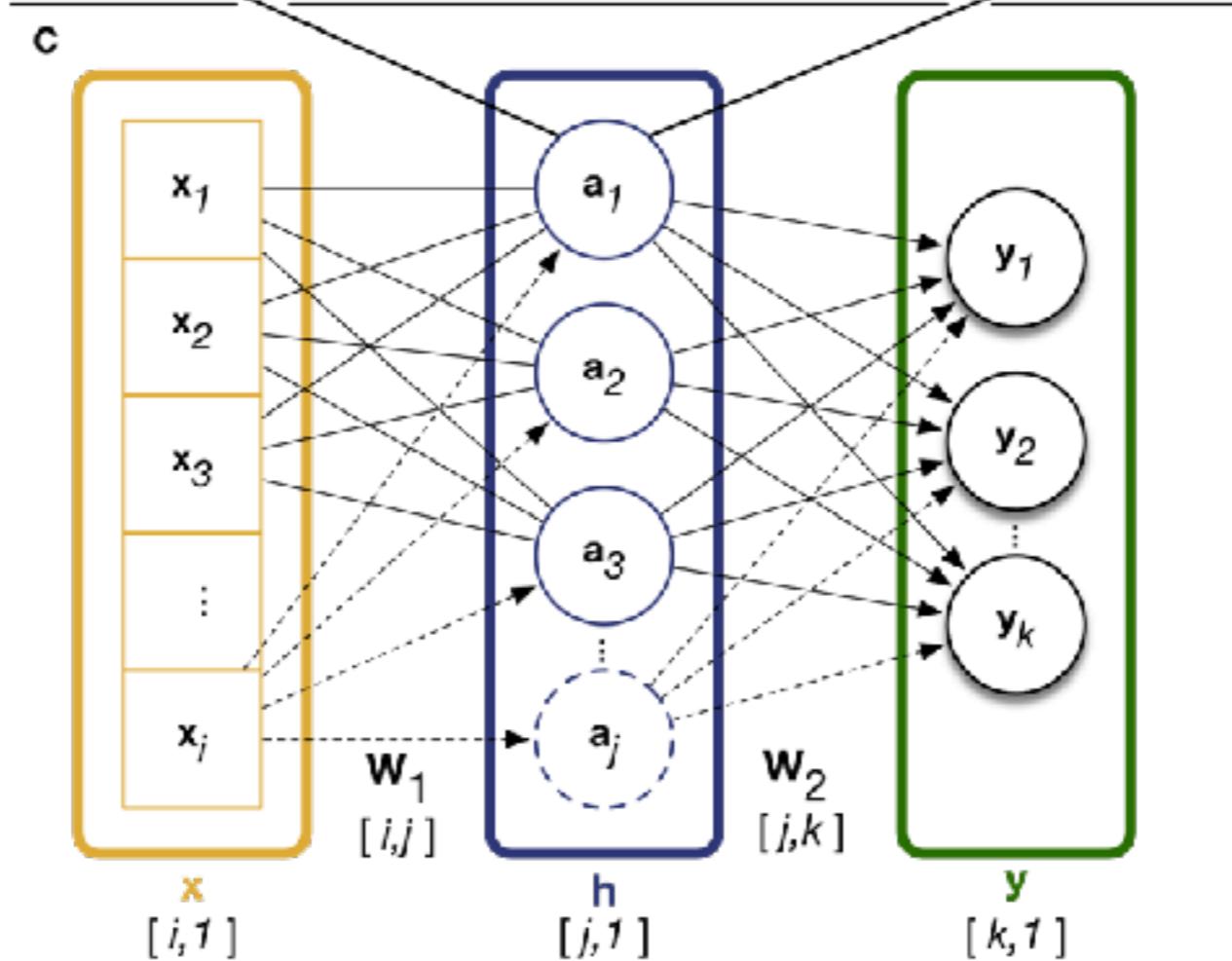
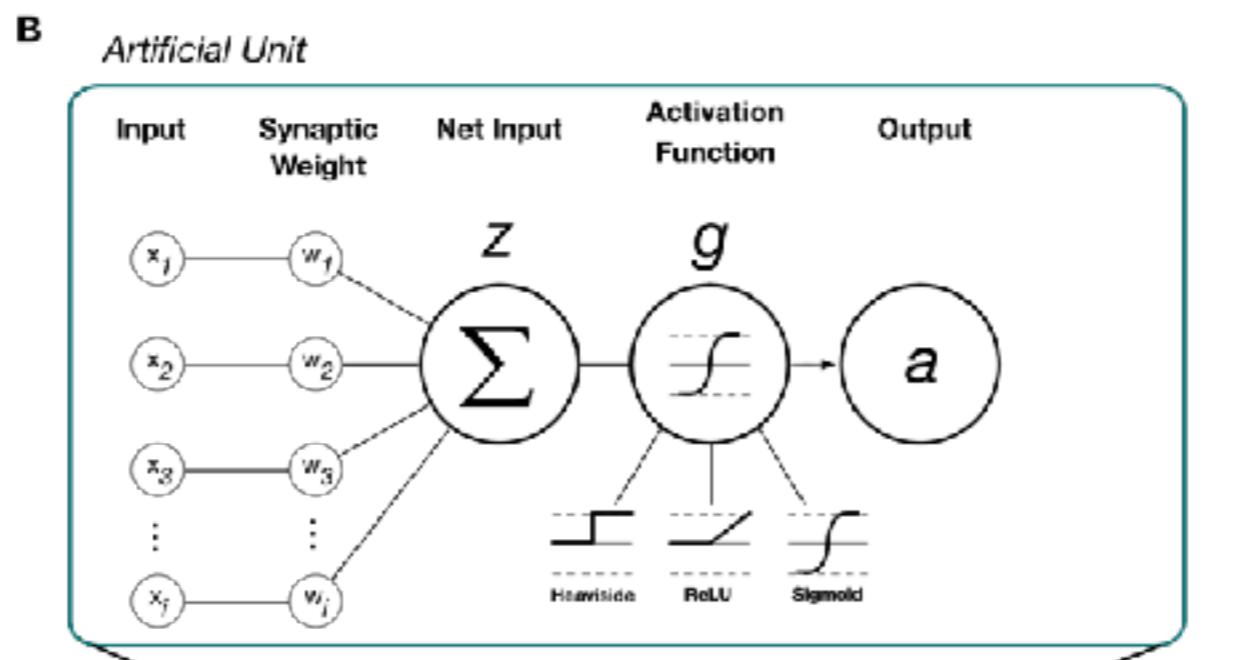
A



NEUROANATOMY AND NEURAL NETWORKS



NEUROANATOMY AND NEURAL NETWORKS



ANN'S ARE UNIVERSAL FUNCTION APPROXIMATORS

Neural Networks, Vol. 2, pp. 359–366, 1989
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0893-6080/89 \$3.00 + .00
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ORIGINAL CONTRIBUTION

Multilayer Feedforward Networks are Universal Approximators

KURT HORNICK

Tecnnische Universität Wien

MAXWELL STINCHCOMBE AND HALBERT WHITE

University of California, San Diego

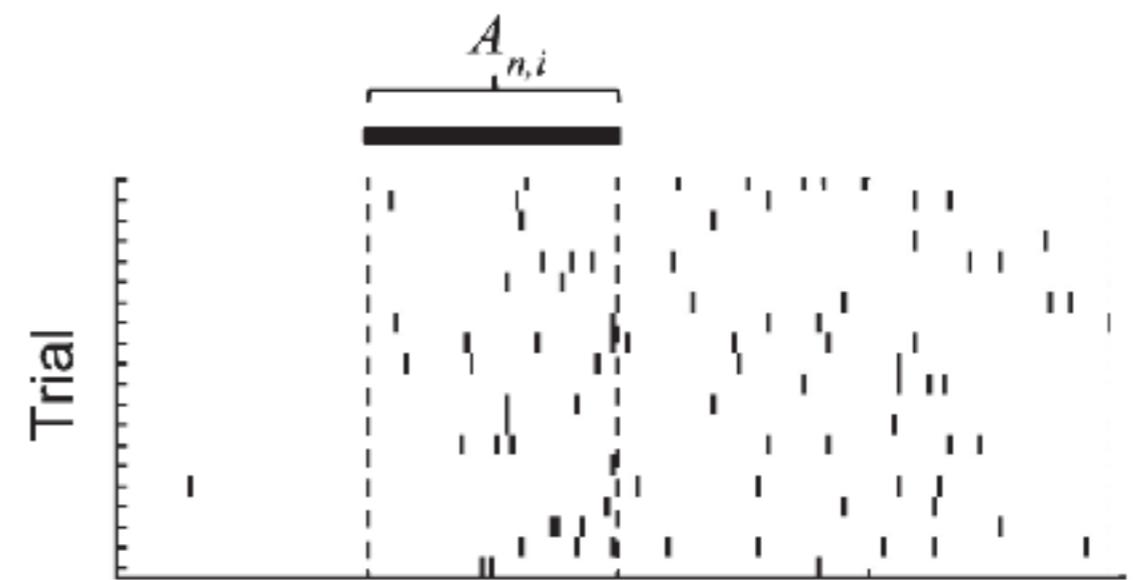
(Received 16 September 1988; revised and accepted 9 March 1989)

Abstract—This paper rigorously establishes that standard multilayer feedforward networks with as few as one hidden layer using arbitrary squashing functions are capable of approximating any Borel measurable function from one finite dimensional space to another to any desired degree of accuracy, provided sufficiently many hidden units are available. In this sense, multilayer feedforward networks are a class of universal approximators.

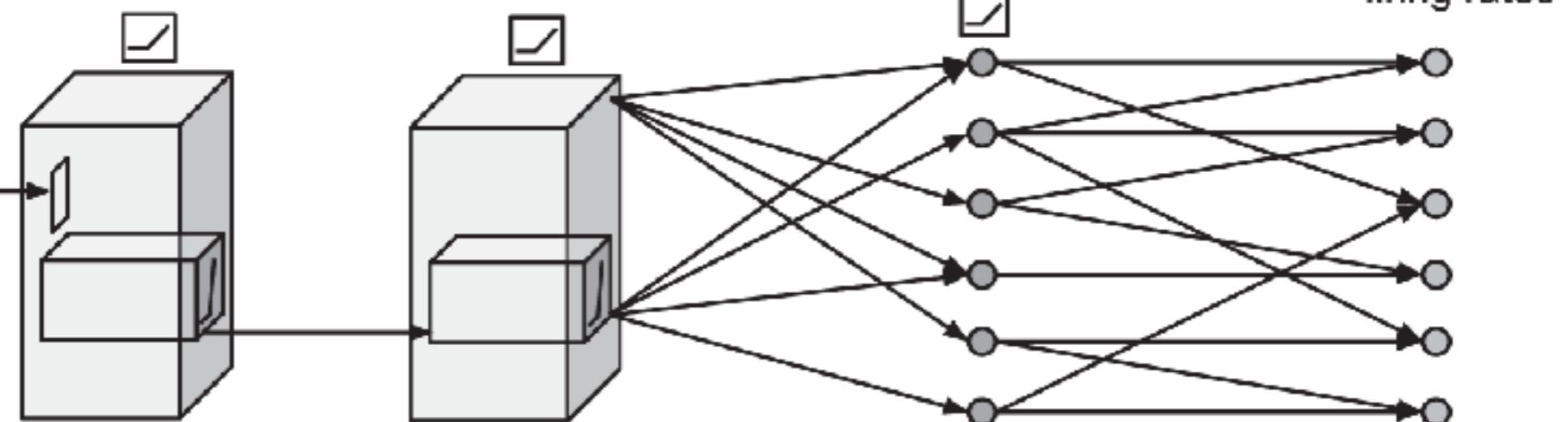
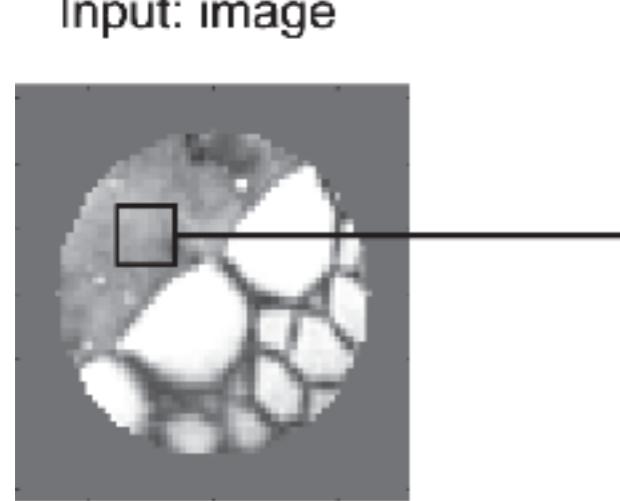
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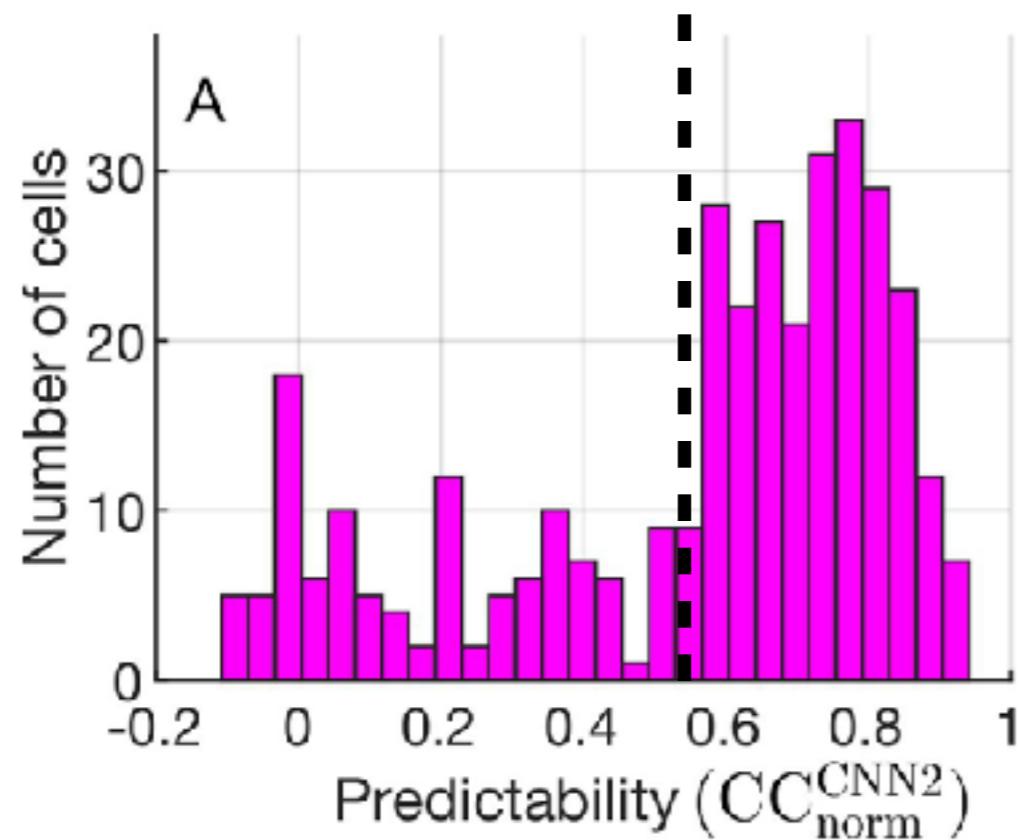
C



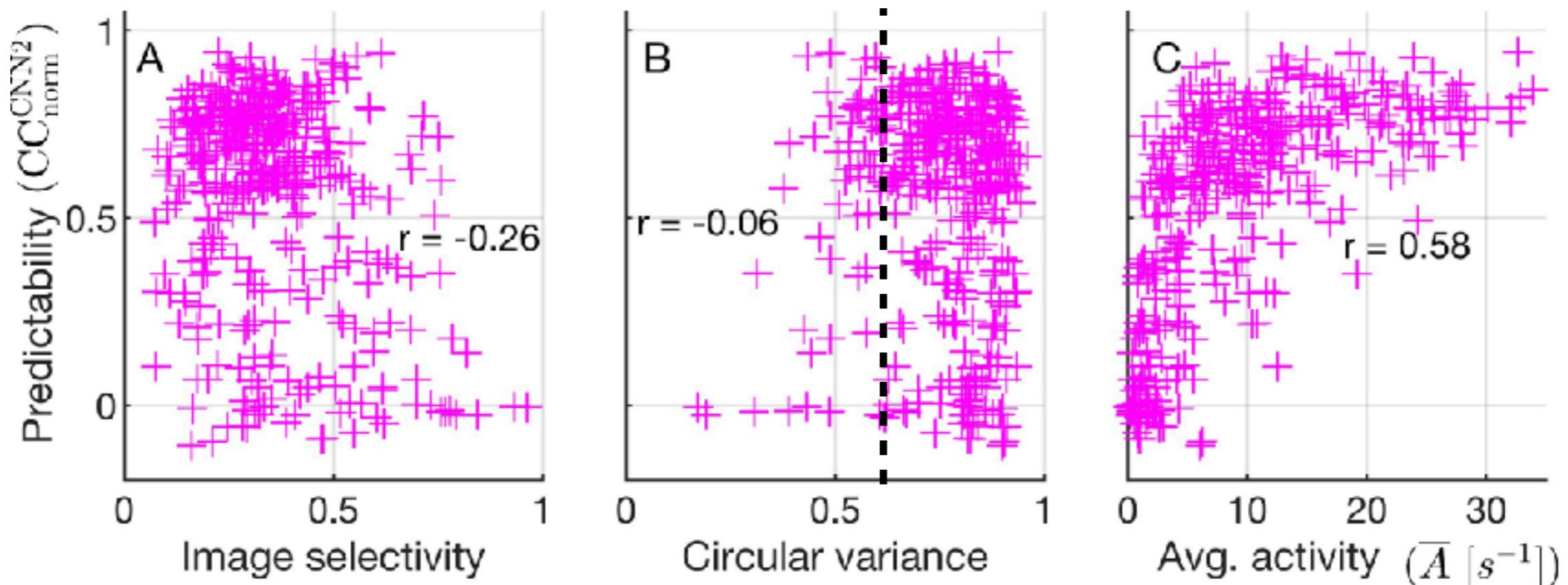
Input: image



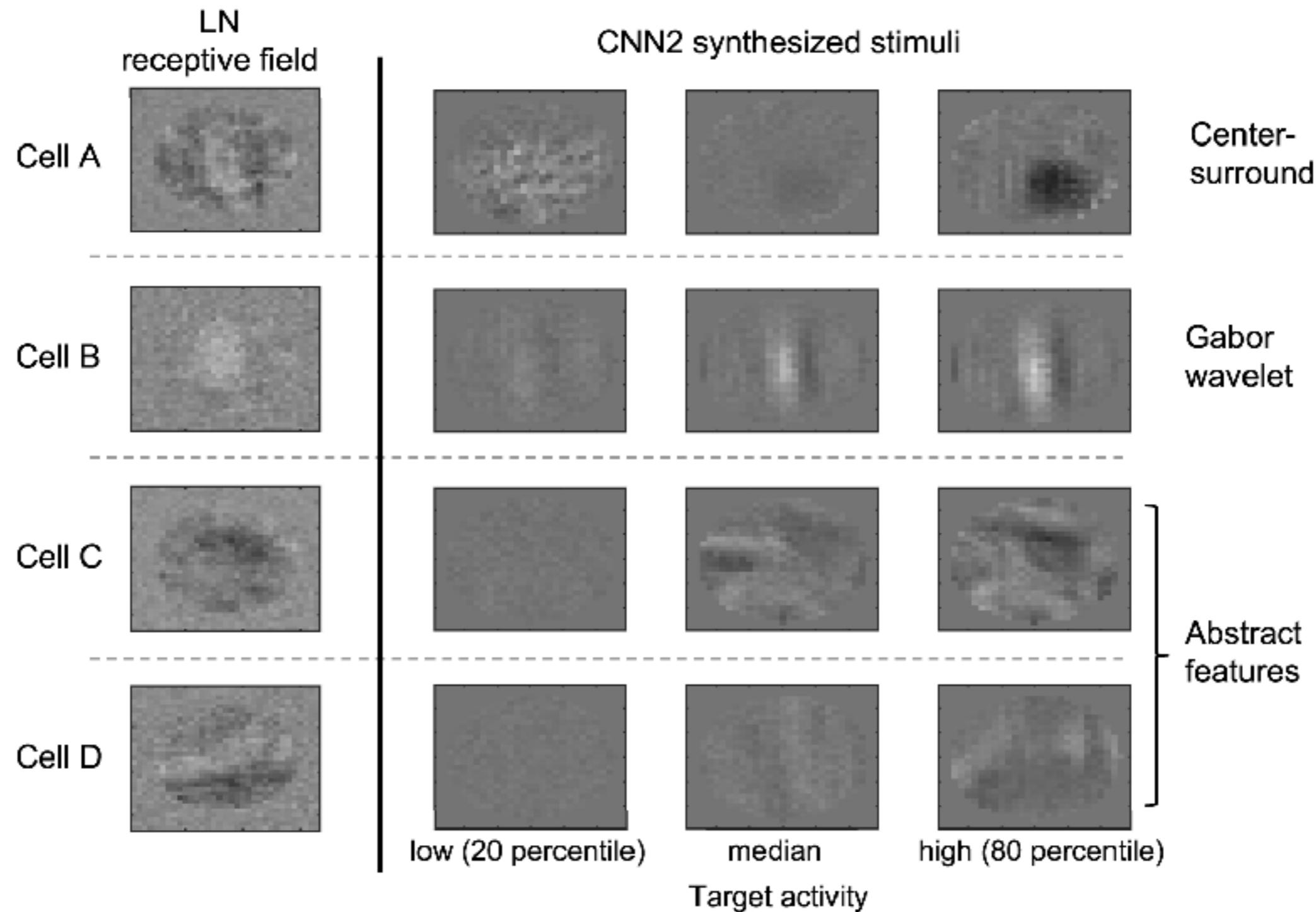
ANN'S ACHIEVE HIGH PREDICTABILITY ACROSS ALL NEURONS



ANN'S ACHIEVE HIGH PREDICTABILITY ACROSS ALL NEURONS



REVEAL NOVEL FEATURES OF NEURAL CODE



SUMMARY

- ANN's make good VI predictors
- Important role in the future of visual neural interfaces

Stimuli

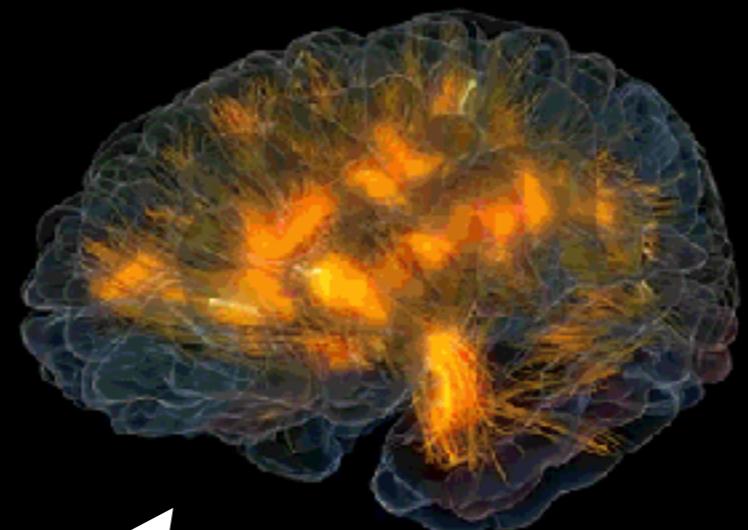
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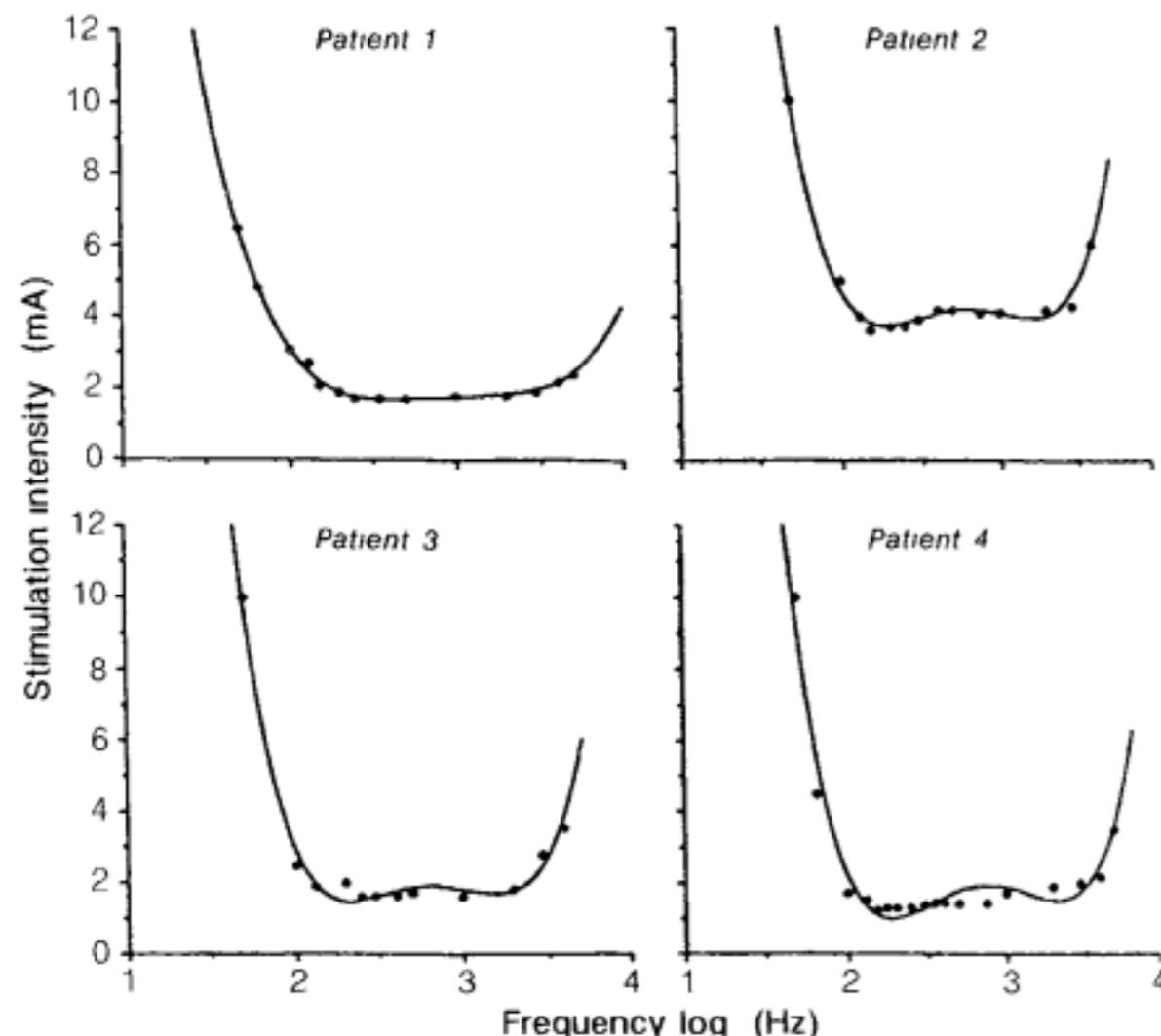
Sleep/Wake

Action

Movement

Speech

Long-term suppression of tremor by chronic stimulation of the ventral intermediate thalamic nucleus

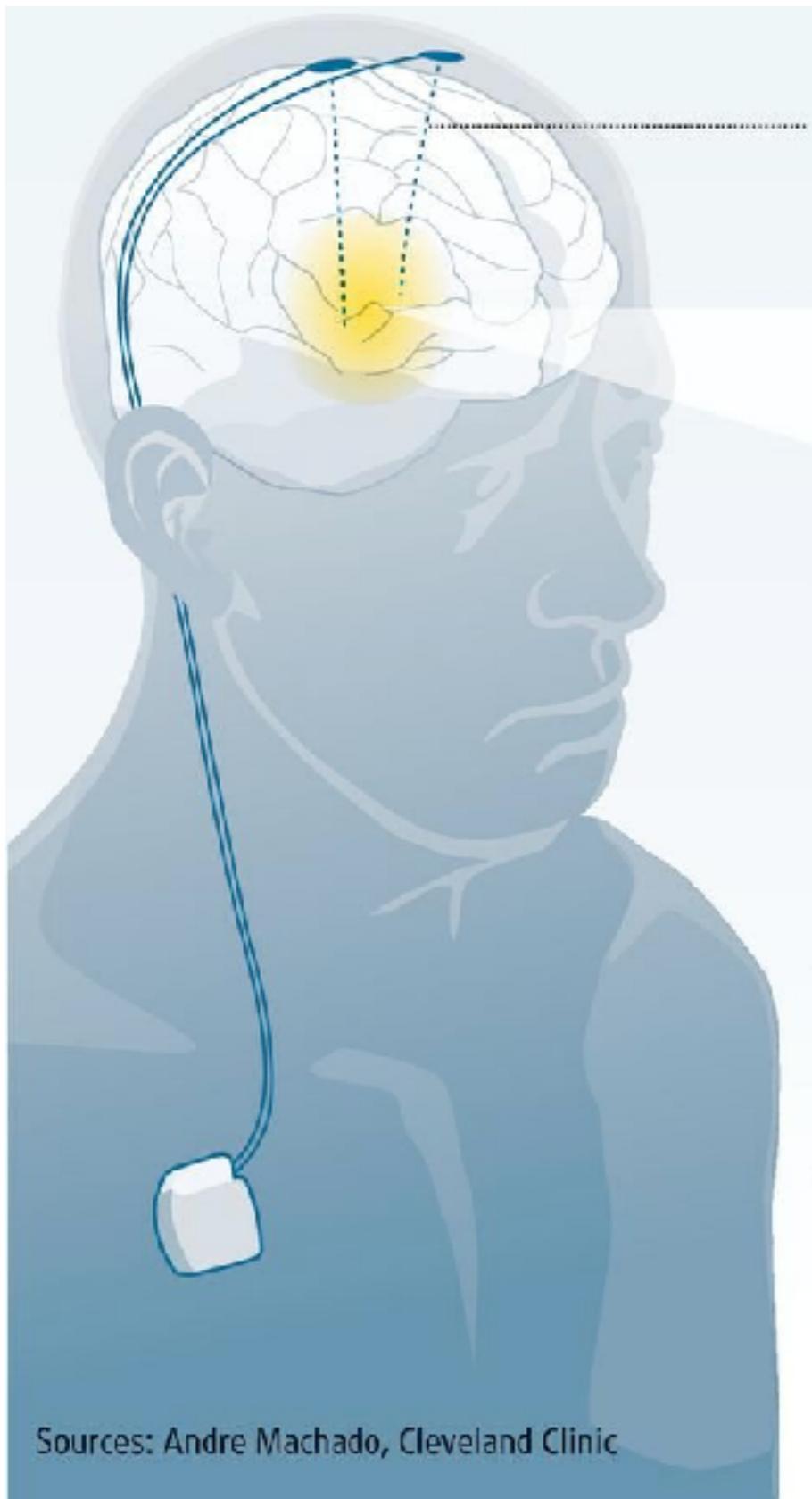


Relation between electrical stimulation frequency and intensity necessary to abolish tremor in four individual patients.

Uses (FDA Approval)

- Chronic Pain (1989)
- ET (1997)
- PD (2002)
- Primary Dystonia (2003)
- OCD (2009)
- Tourette Syndrome
- Refractory Depression
- Epilepsy
- Cluster Headache
- Huntington's Disease
- Obesity
- Addiction

DEEP BRAIN STIMULATION



How it works

Thin coated wires carry an electrical current from battery-powered implant to electrodes in the brain.

Area targeted in PD:

Subthalamic Nucleus (STN)

Uses (FDA Approval)

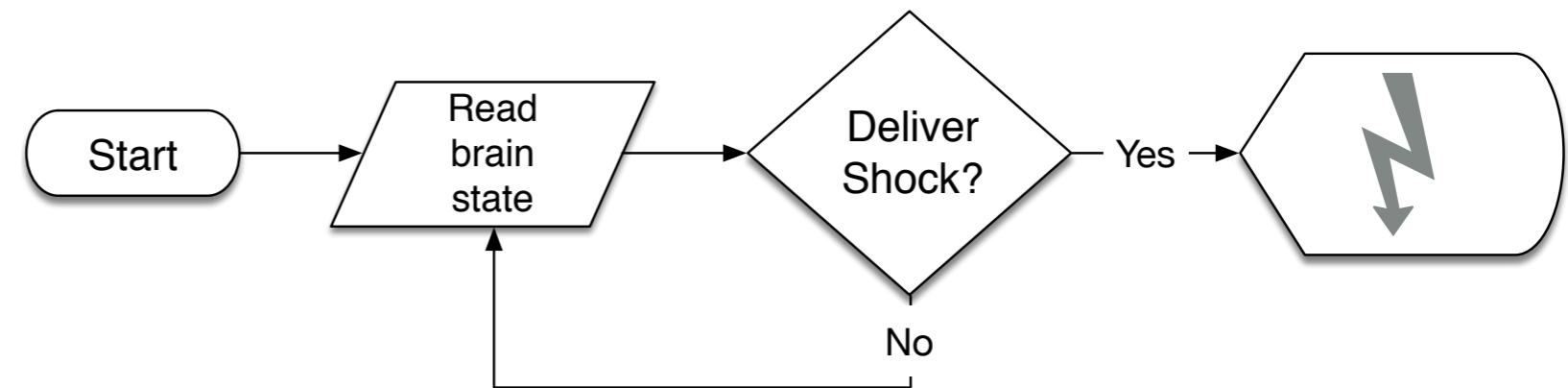
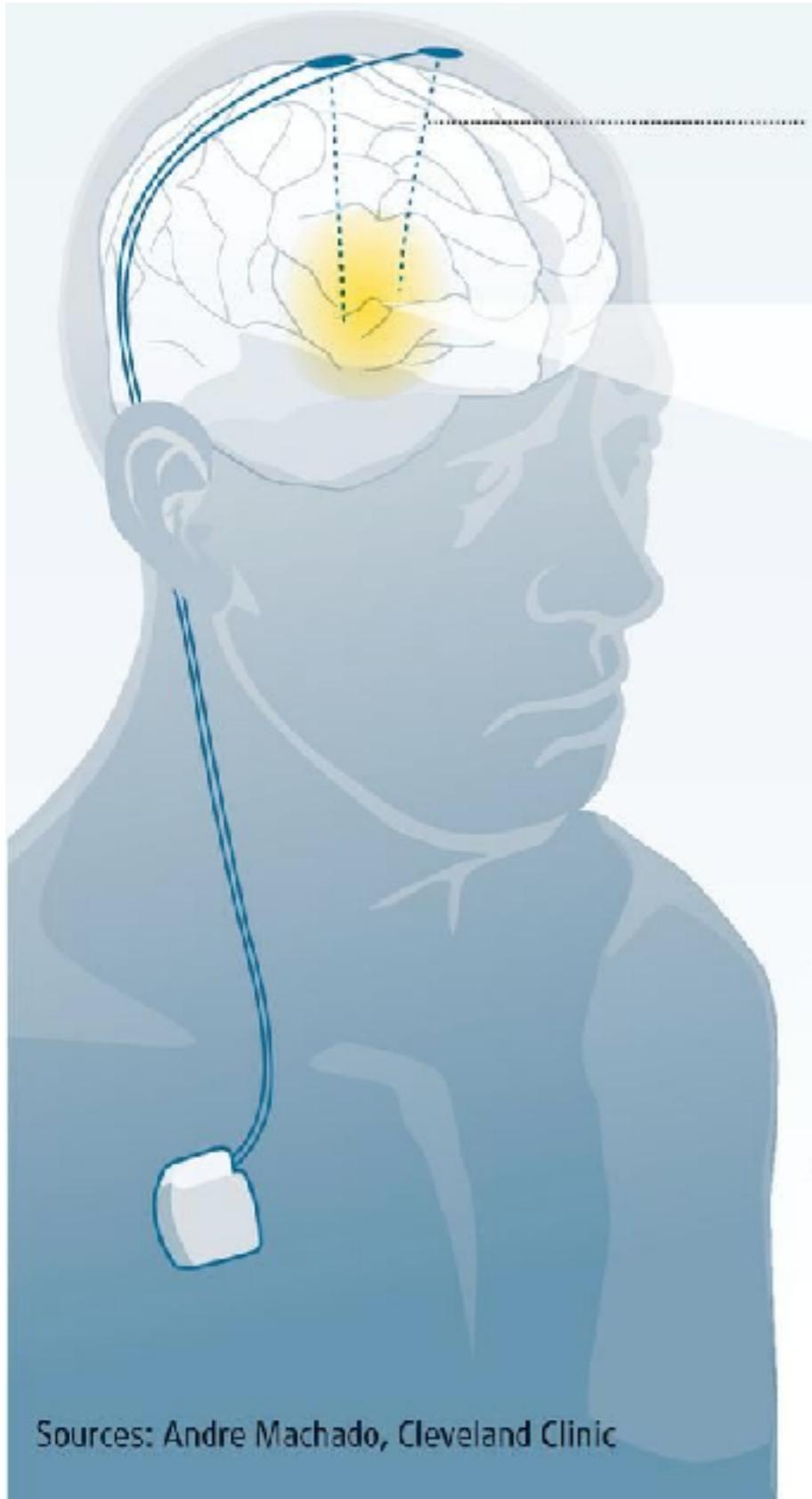
- Chronic Pain (1989)
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Sources: Andre Machado, Cleveland Clinic

Chen et al. (2013) Interventional Neurology

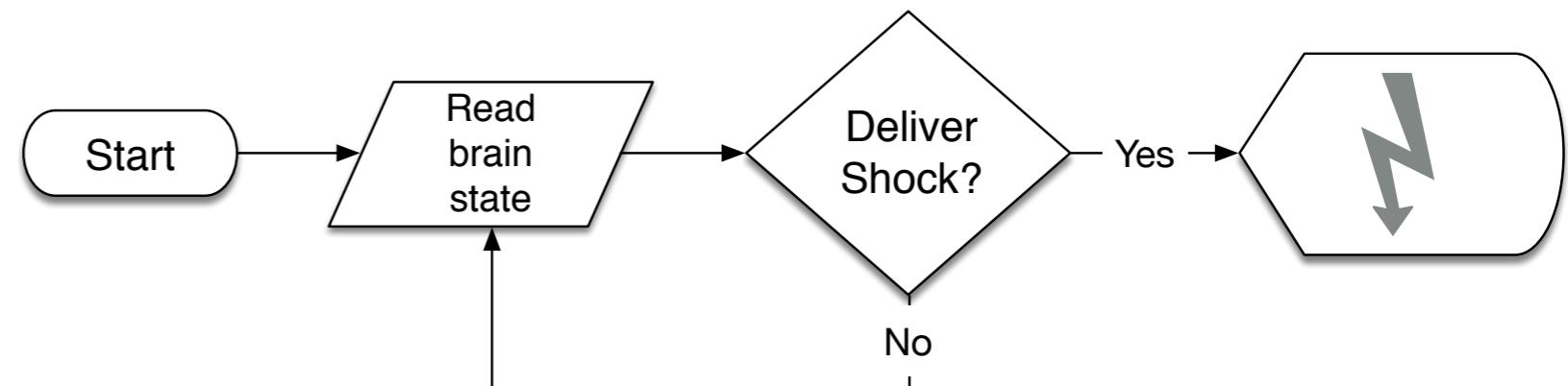
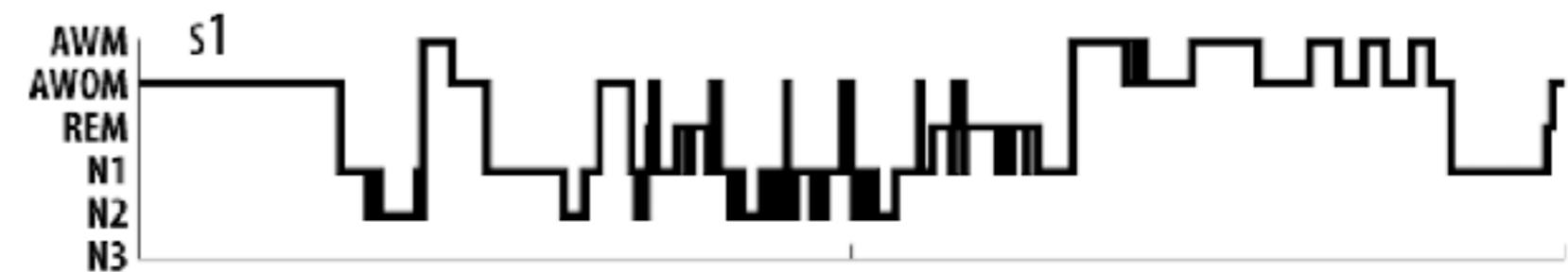
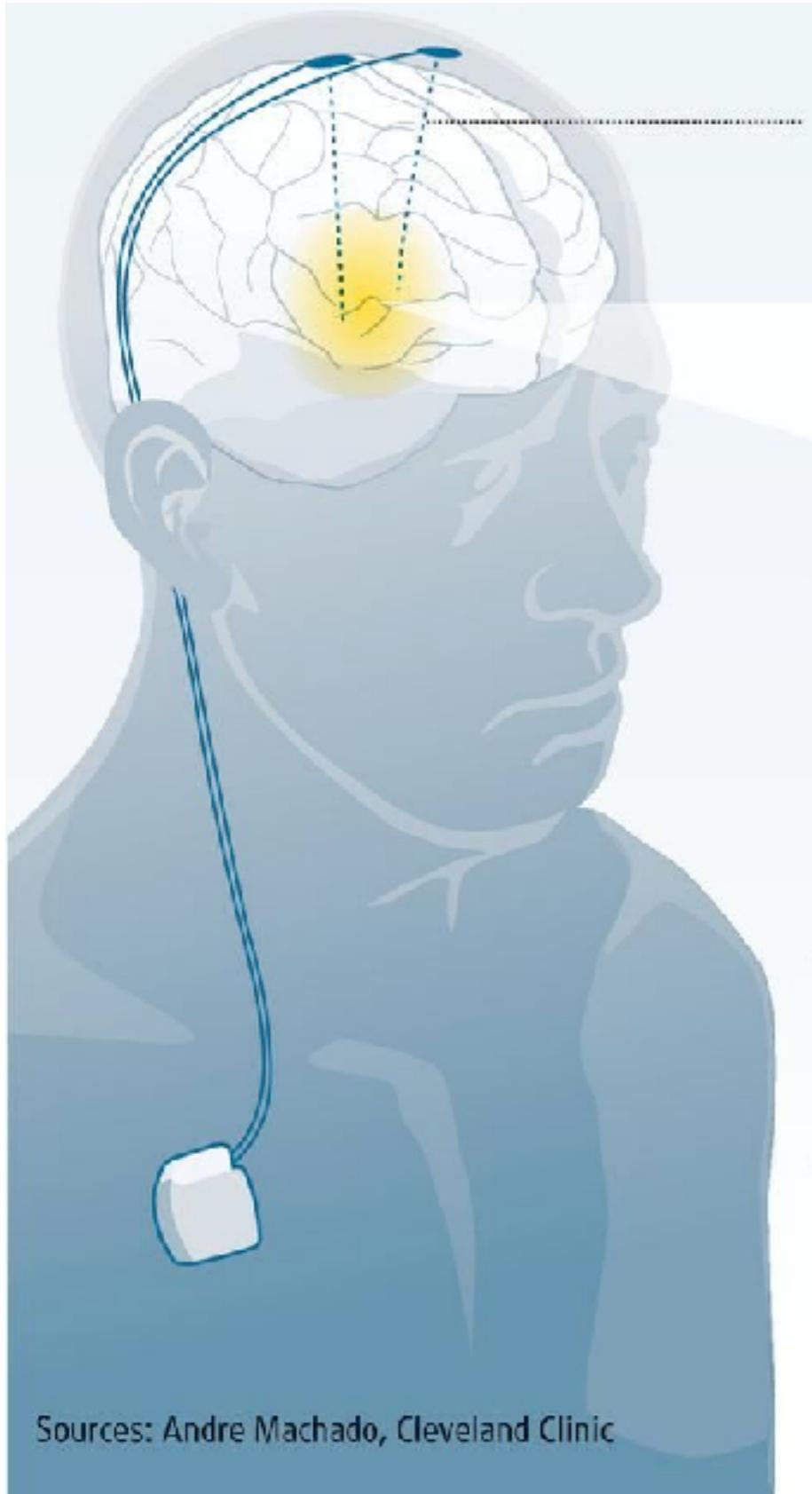
Electrical stimulation will presumably have to be continued indefinitely; therefore, the pulse generator will have to be replaced regularly.

ADAPTIVE NEUROSTIMULATION REQUIRES INSIGHT INTO BRAIN STATE



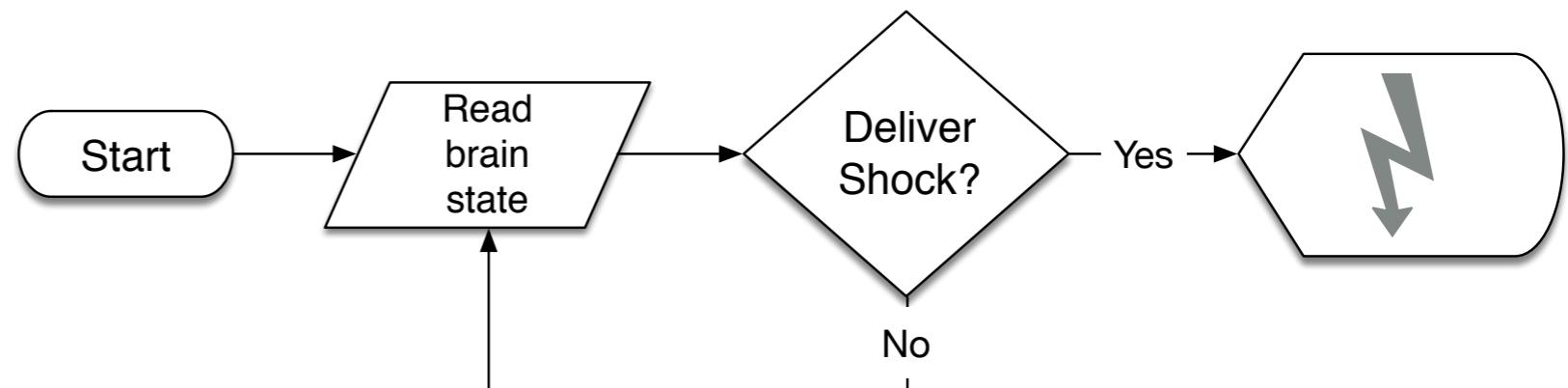
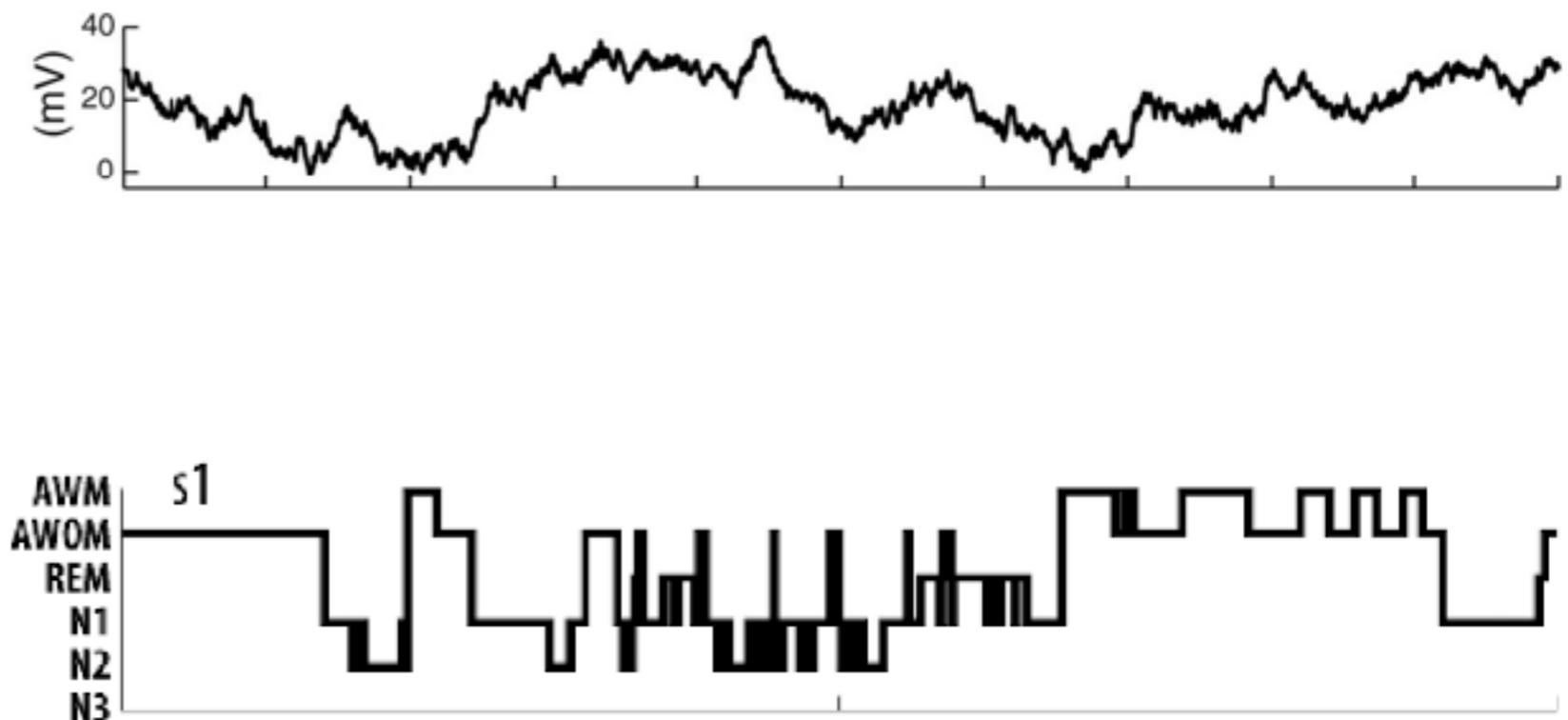
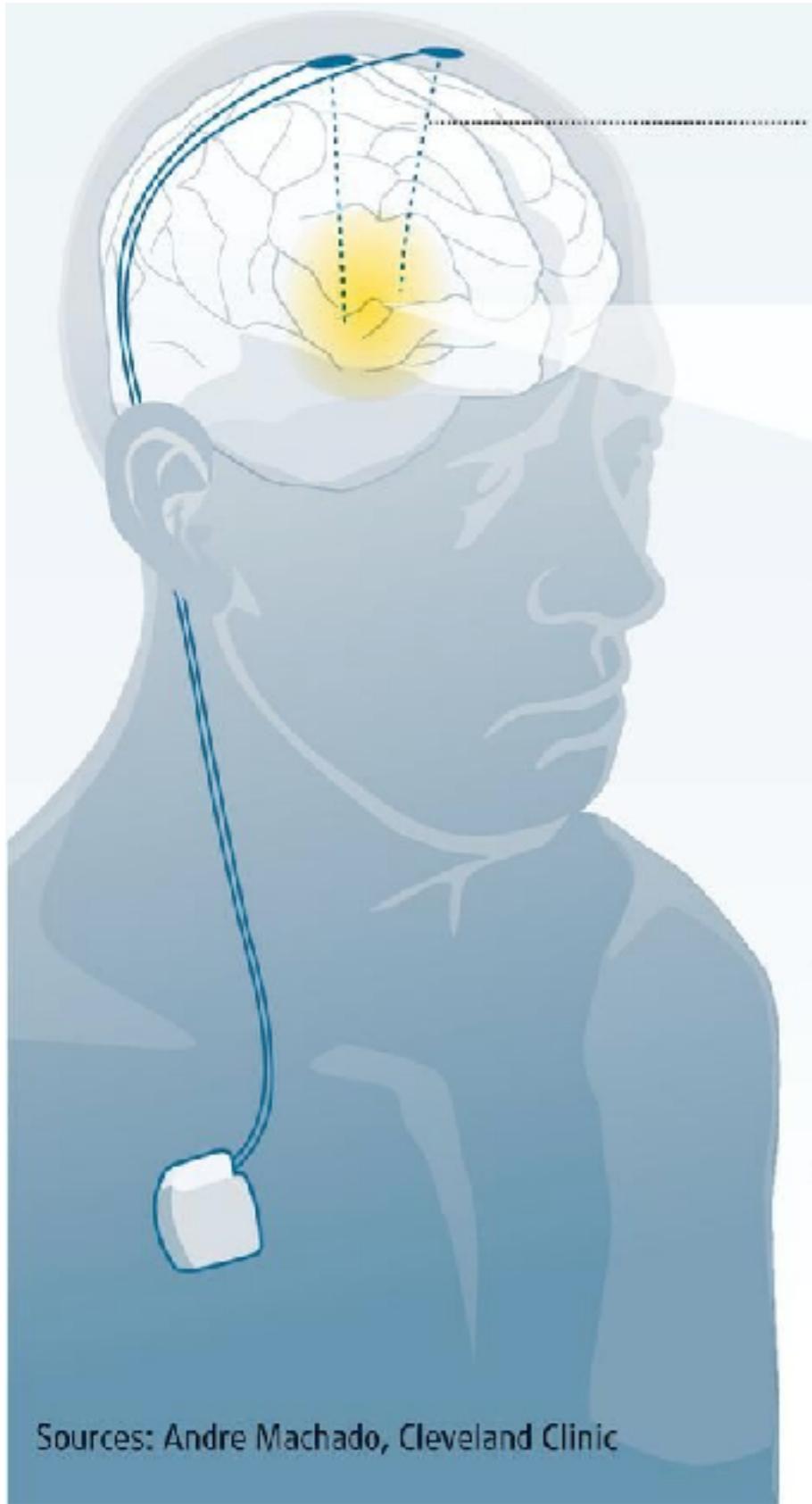
Sources: Andre Machado, Cleveland Clinic

ADAPTIVE NEUROSTIMULATION REQUIRES INSIGHT INTO BRAIN STATE



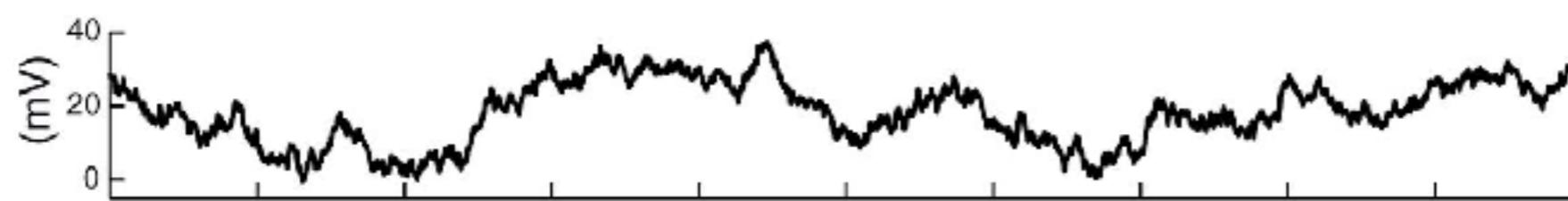
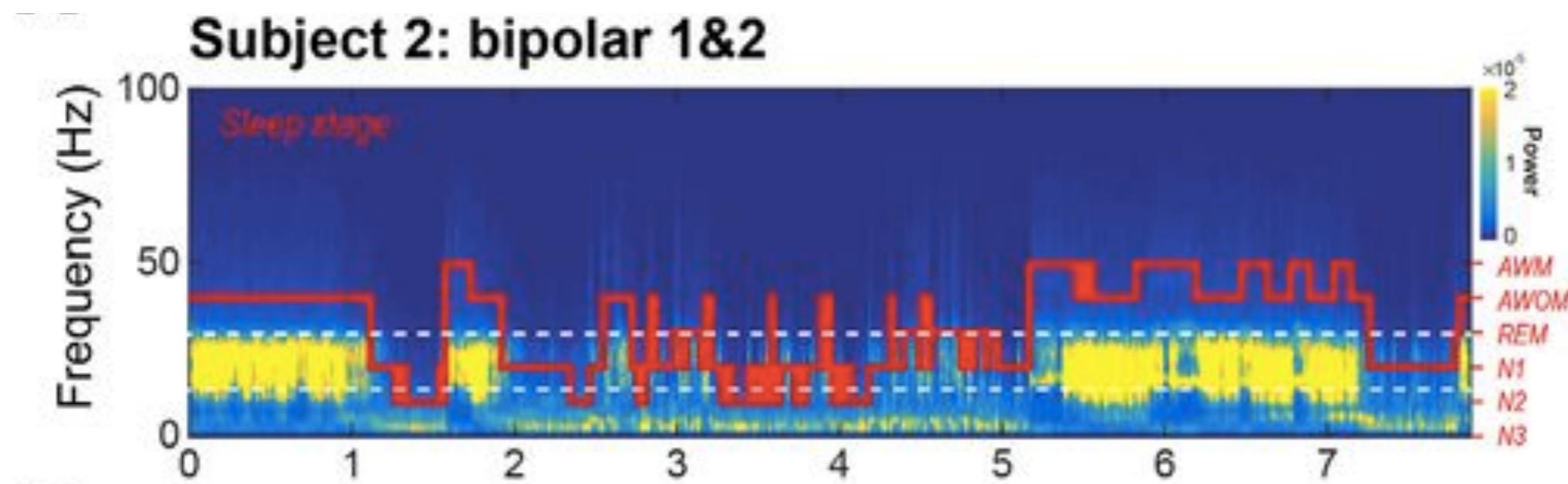
Sources: Andre Machado, Cleveland Clinic

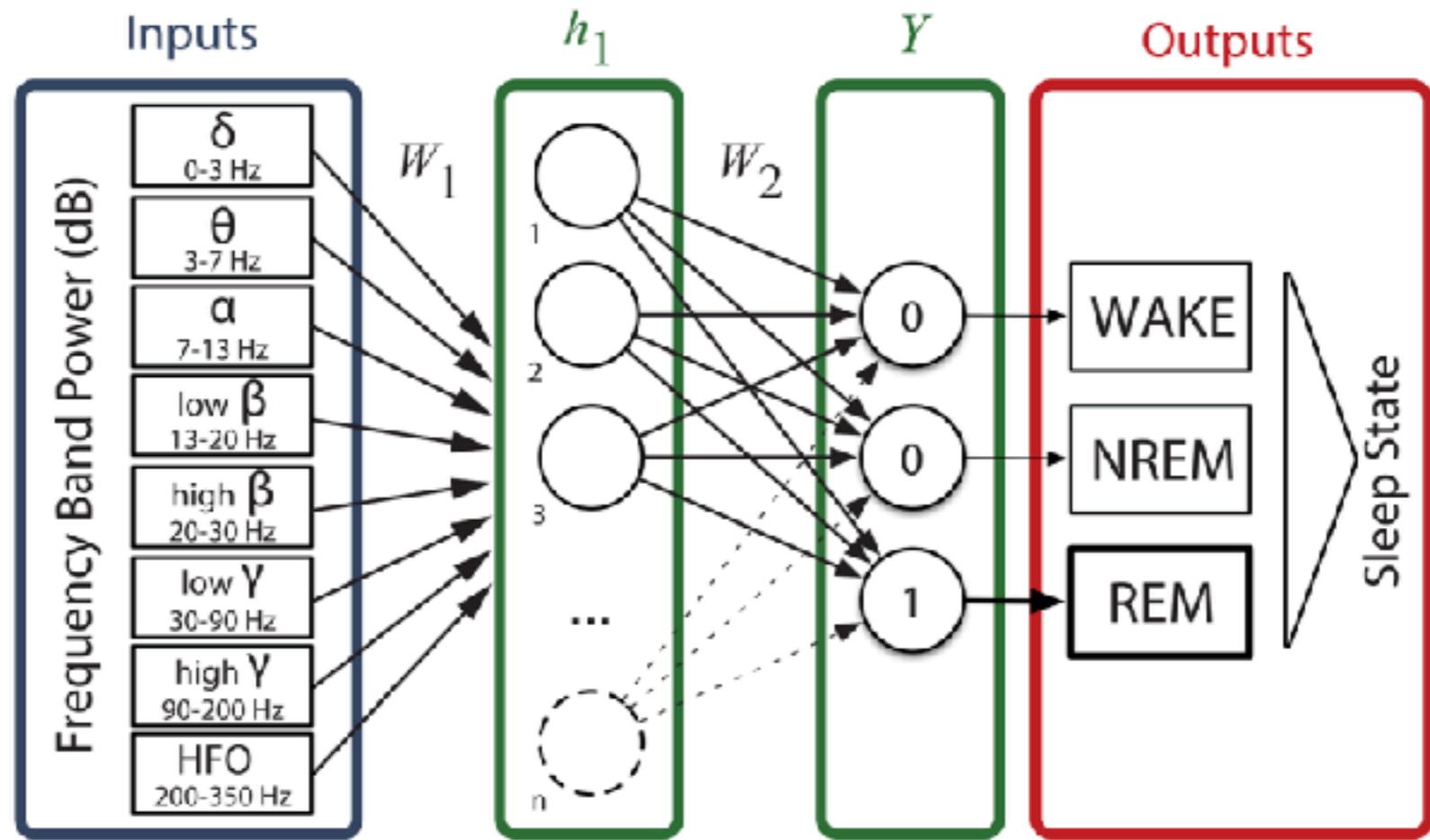
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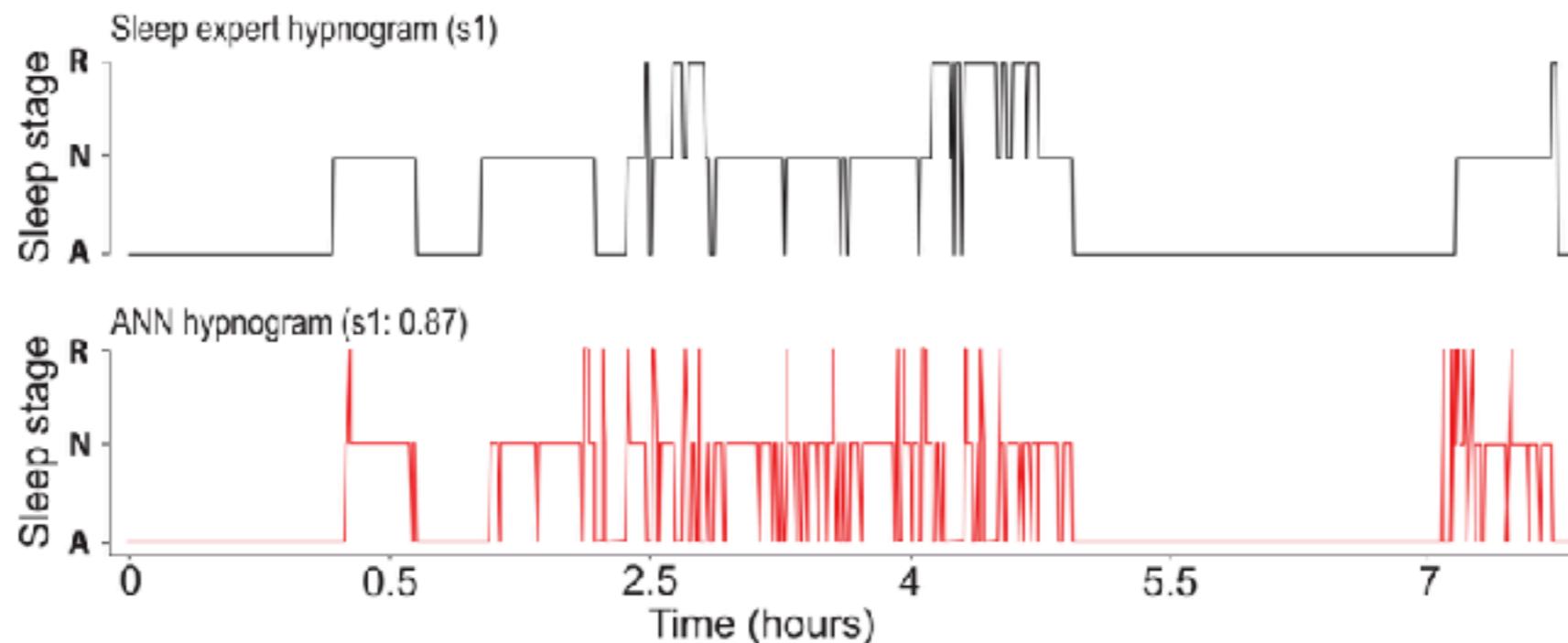
Sources: Andre Machado, Cleveland Clinic

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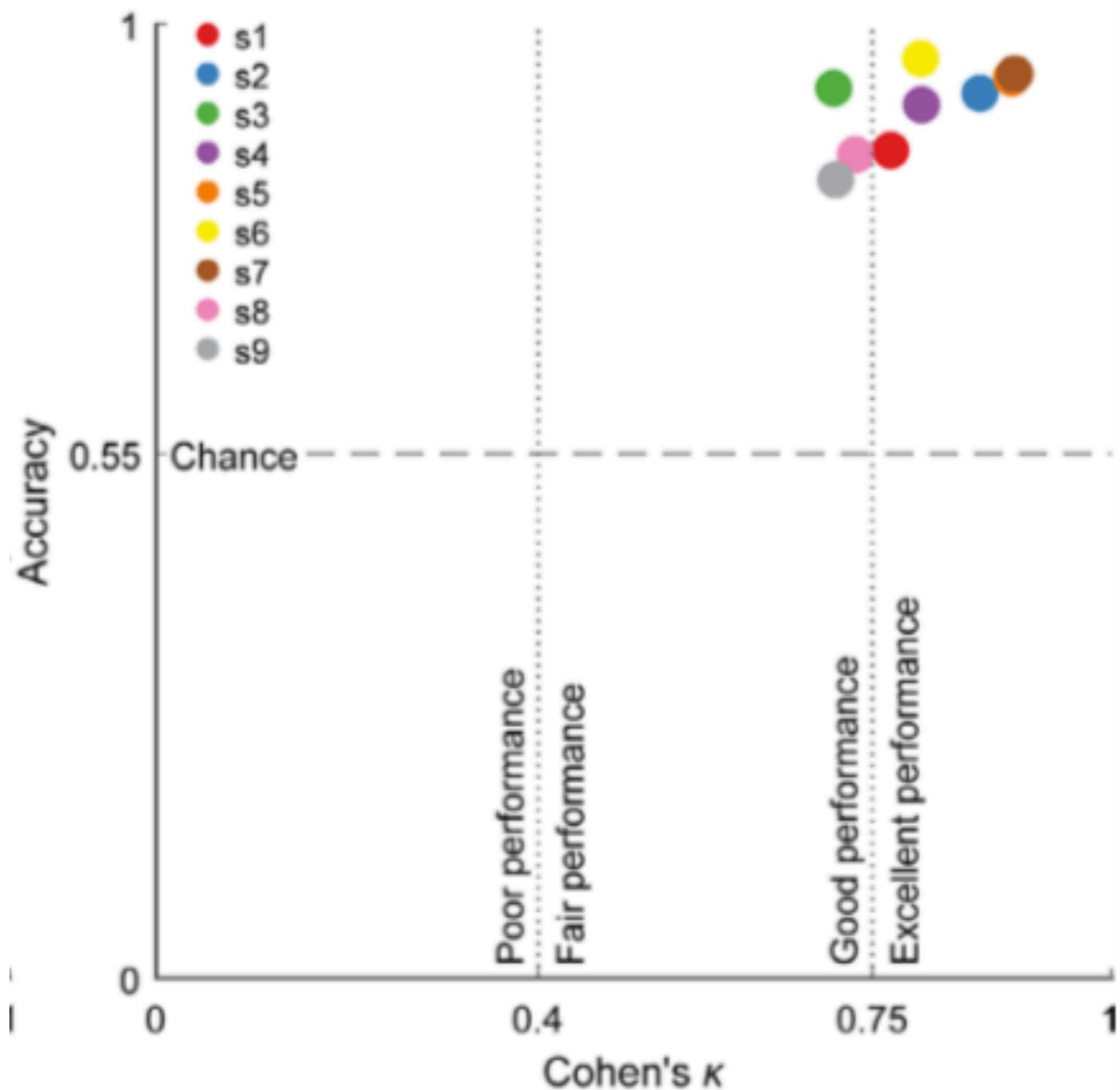




C Hypnogram prediction



(b) Model performance (LOGO)



FUTURE DIRECTIONS

THE GAP BETWEEN SCIENCE AND FICTION IS STILL WIDE

