ADASS 2009 Sapporo, Japan

Different Displays for Different Brains

How Neurology of Vision Effects the Interpretation of Data

Matthew H. Schneps
Lincoln J. Greenhill
L. Todd Rose

Harvard-Smithsonian Center for Astrophysics

alternate title...

astronomers who read slowly are quick to spot black holes

National Science Foundation

supported by the NSF under grant HRD-0726032

the human interface

- massive data volumes require automated detection algorithms
- yet... all results need to interpreted
- ... capacity for **unanticipated** discoveries are limited by human sensory interface

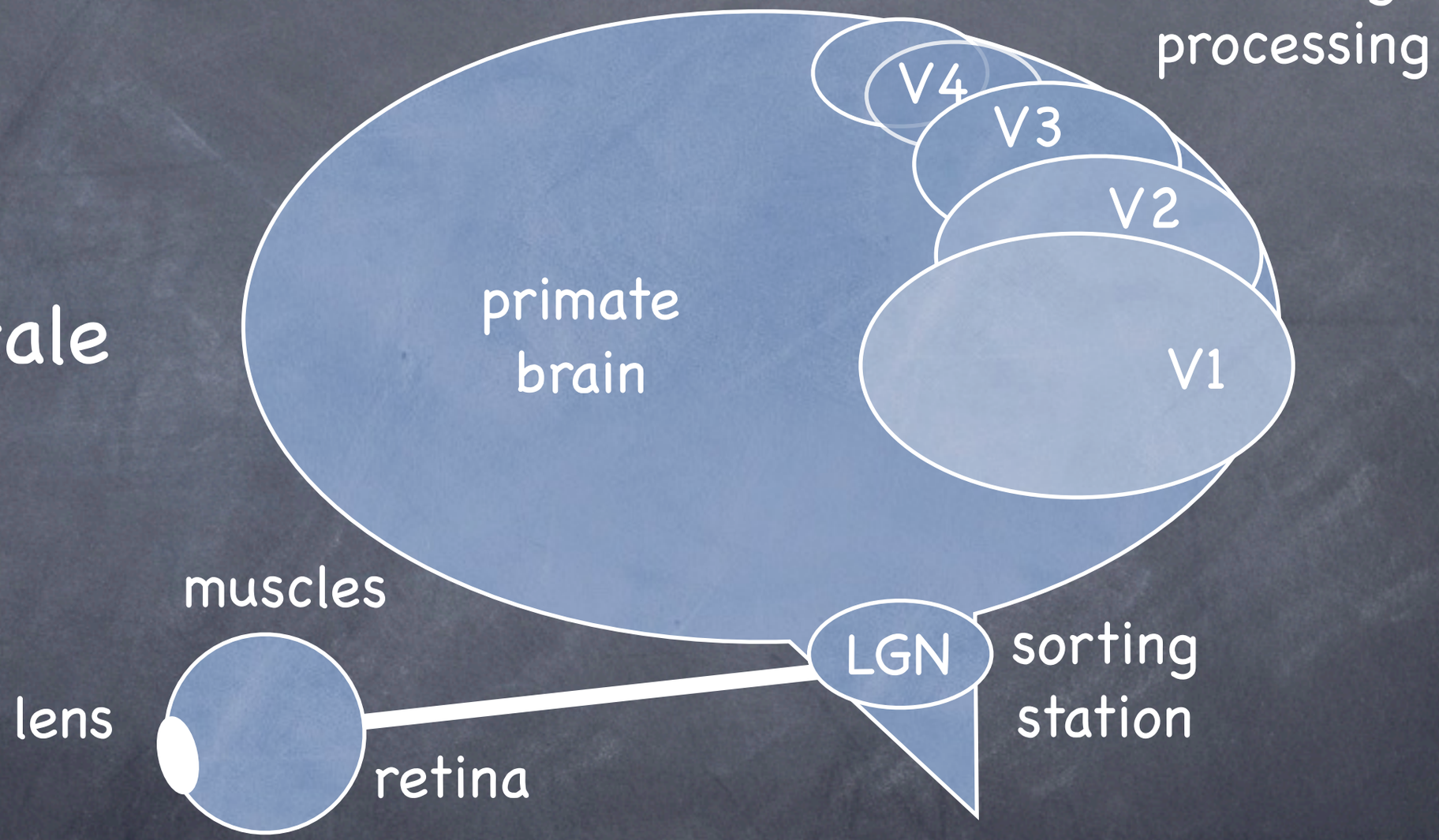
neurology of vision is integral to astronomical data processing

individual differences

individual differences in neurology will cause detection thresholds to vary

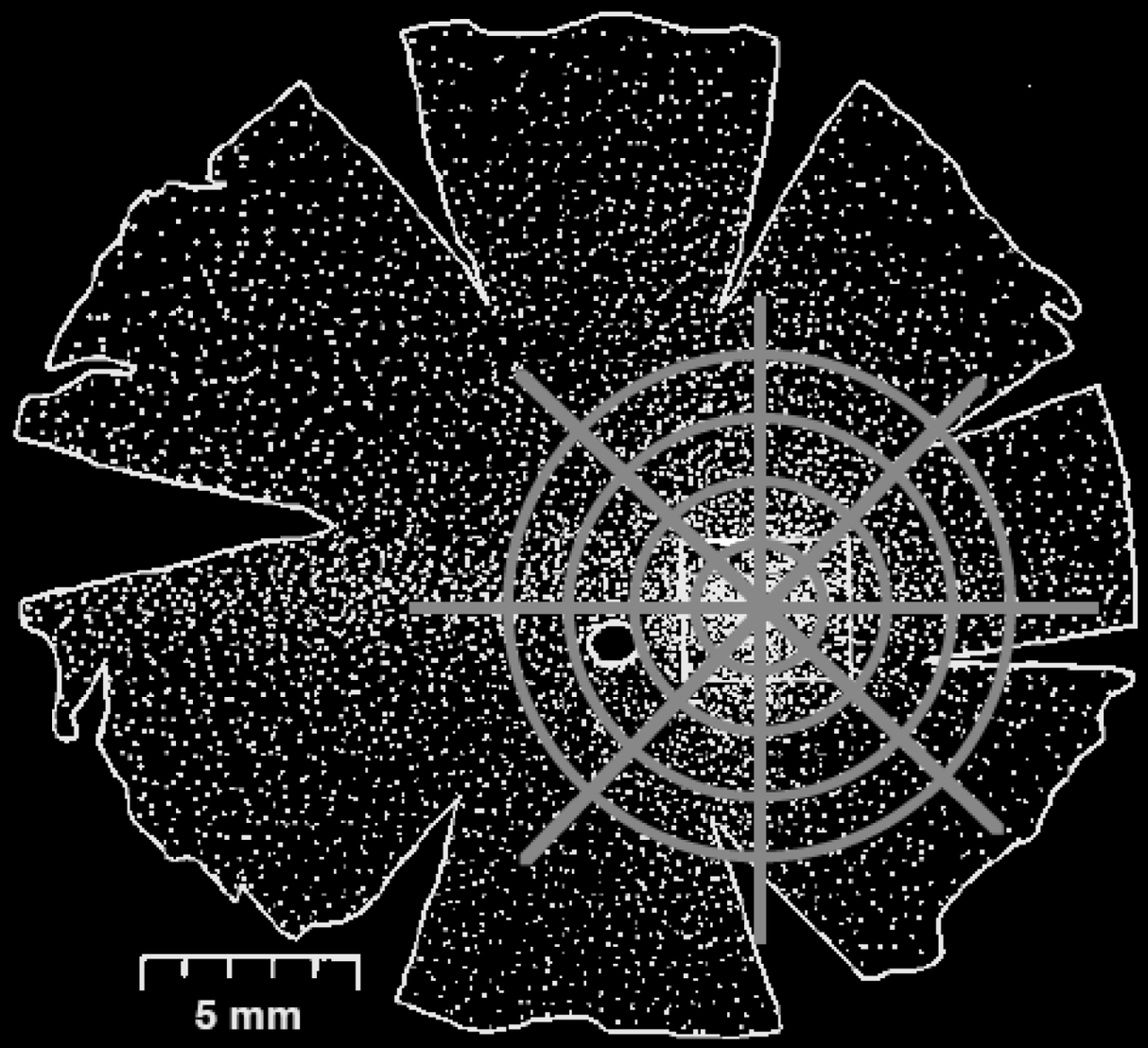
visual abilities vary

not to scale

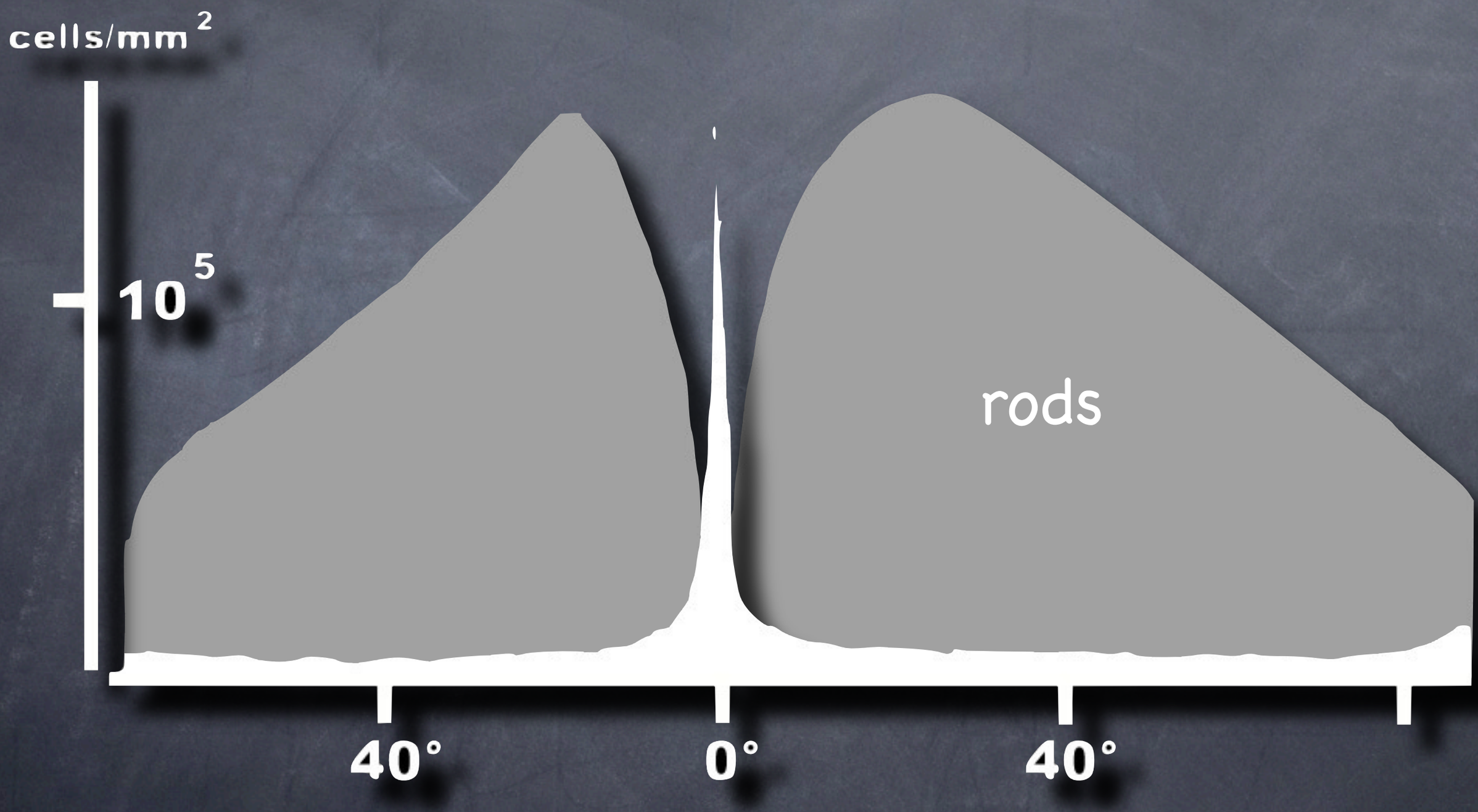


vision is a complex chain

concentric detector



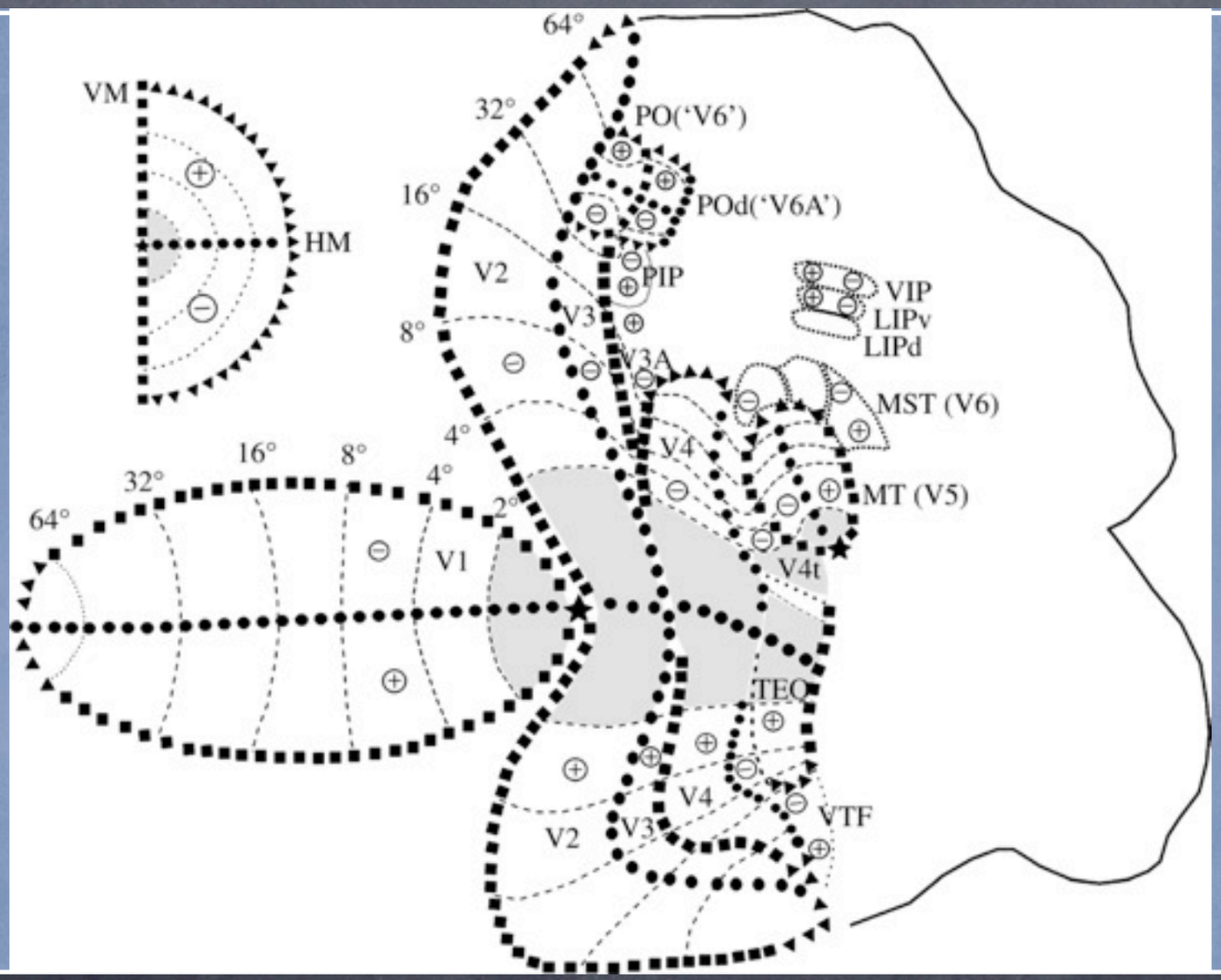
Thibos, L. N. (2002). "V648 Neurophysiology of Vision."



Rodieck, R. W. (1998). The first steps in seeing.

separate systems

retinotopic distinctions (center/periphery) maintained throughout the visual cortex

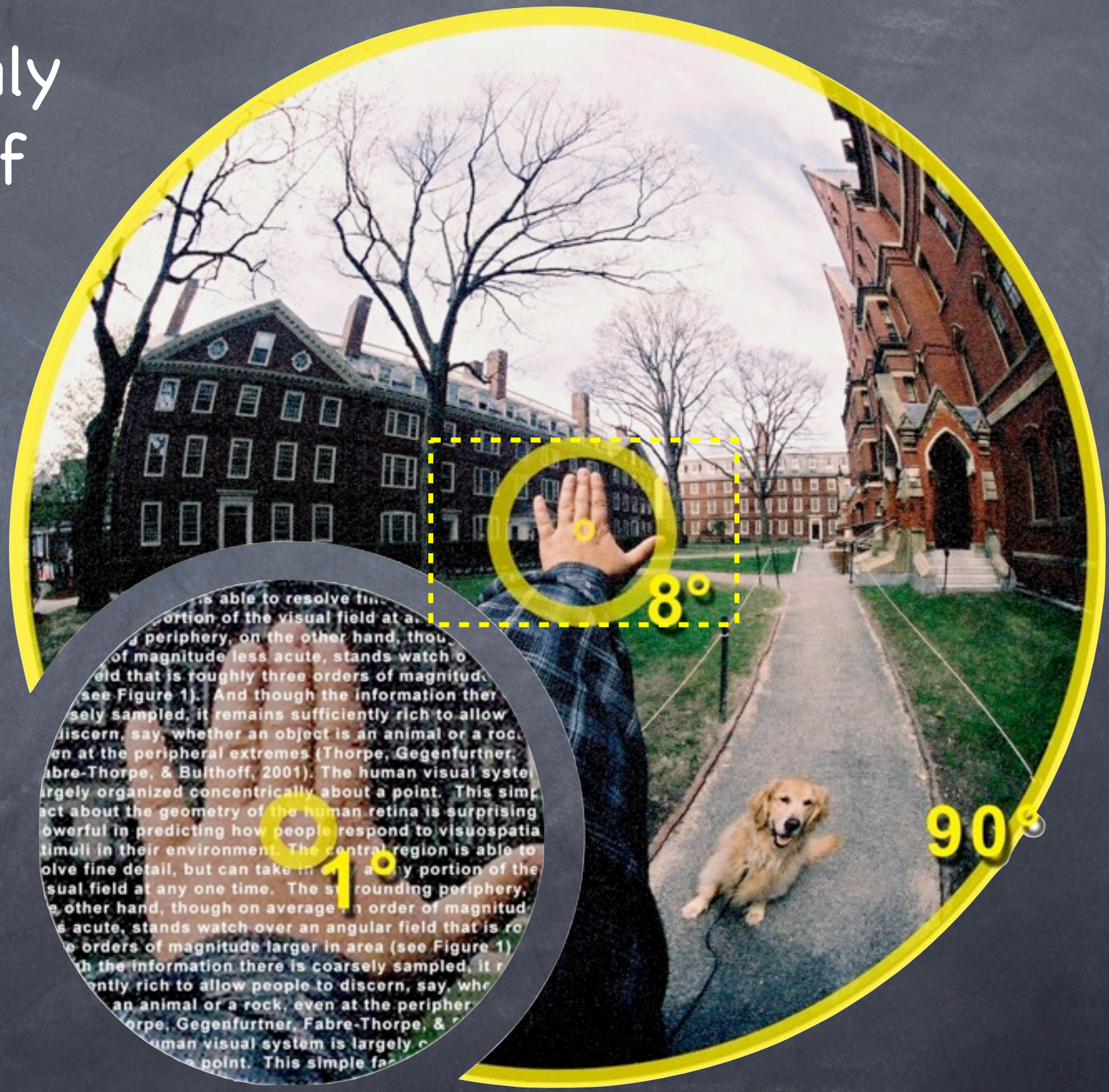


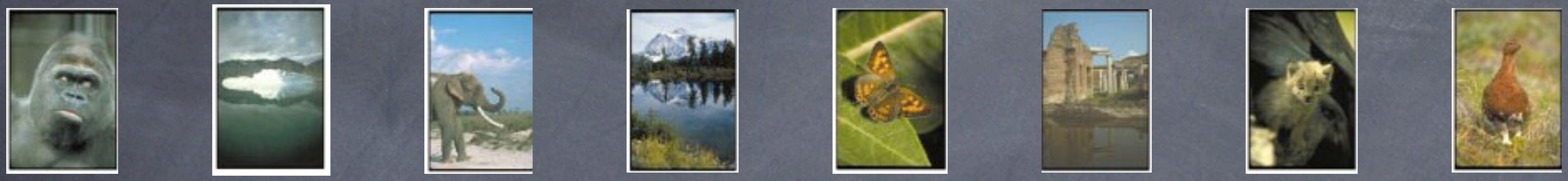
Gattass et al. Cortical visual areas in monkeys: location, topography, connections, columns, plasticity and cortical dynamics. Philos Trans R Soc Lond B Biol Sci (2005) vol. 360 (1456) pp. 709-31

attention = filter+amp

Prof. N. Osaka
noted expert on attention and working memory

reading uses only
a small part of
the available
visual field





28 ms
flash

animal vs rock vs building

better than chance at 70°

Thorpe , et al (2001) "Detection of animals in natural images using far peripheral vision" European Journal of Neuroscience

central
visual field
processes
fine detail

Photo by Dan Duriscoe, U.S. National Park Service.

http://antwrp.gsfc.nasa.gov/apod/ap070508.html

but fine features tell only one aspect of the story...

wide field cameras are valuable as well.

"visual gist"

Photo by Dan Duriscoe, U.S. National Park Service.
http://antwrp.gsfc.nasa.gov/apod/ap070508.html

trans-saccadic perception

holding perception across saccades

Melcher & Colby, 2008, "Trans-saccadic perception" Trends in Cognitive Sciences

hypothesis

- attention reduces peripheral awareness
- reading = attention
- poor reading = poor attention

ergo:

astronomers who read poorly will have
ENHANCED peripheral awareness

peripheral gist

ability to perceive broad trends rapidly with minimal working memory or attention

dyslexia = sensitivity for gist?

hypothesis

do scientists with dyslexia have "talents" for some forms of visual processing?

are there scientists with dyslexia?

(what is dyslexia anyway?)

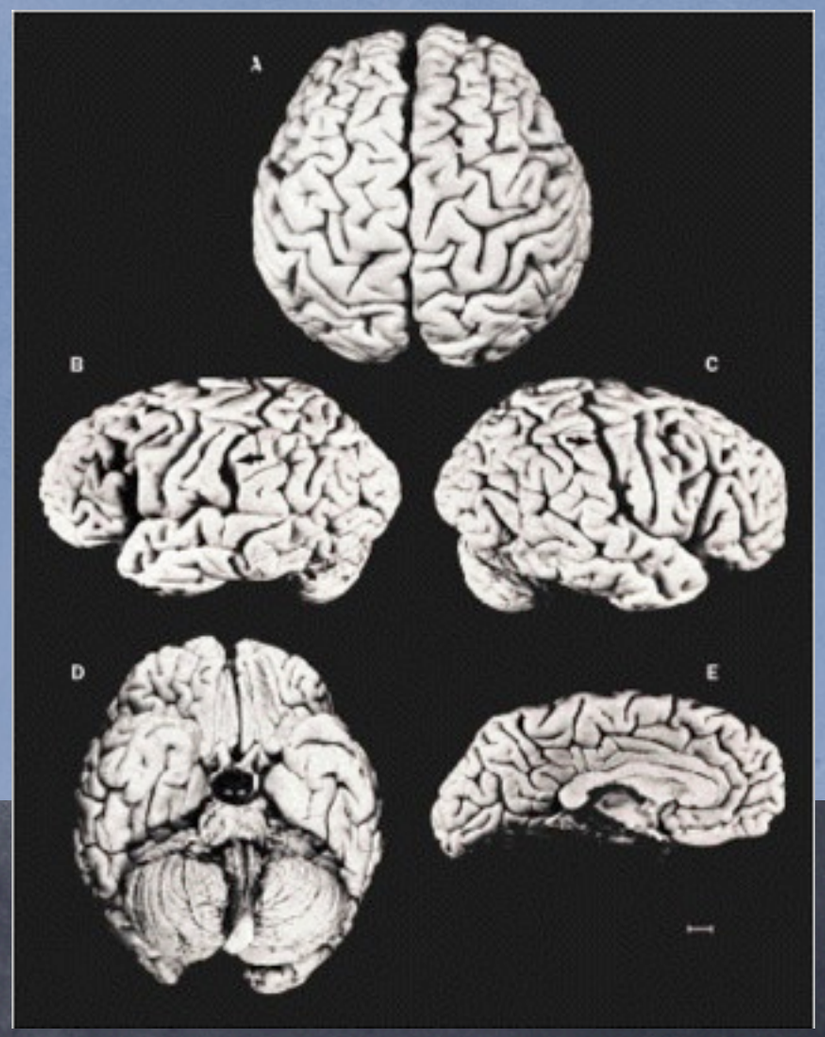
"poor reading" = dyslexia

- struggles reading/writing that are SURPRISING and UNEXPECTED
- dyslexia exists in some form in all languages
- affects 5% - 20% (US/UK)
- neurological
- hereditary
- affects visual attention and working memory

historical scientists with dyslexia?

maxwell

bohr einstein

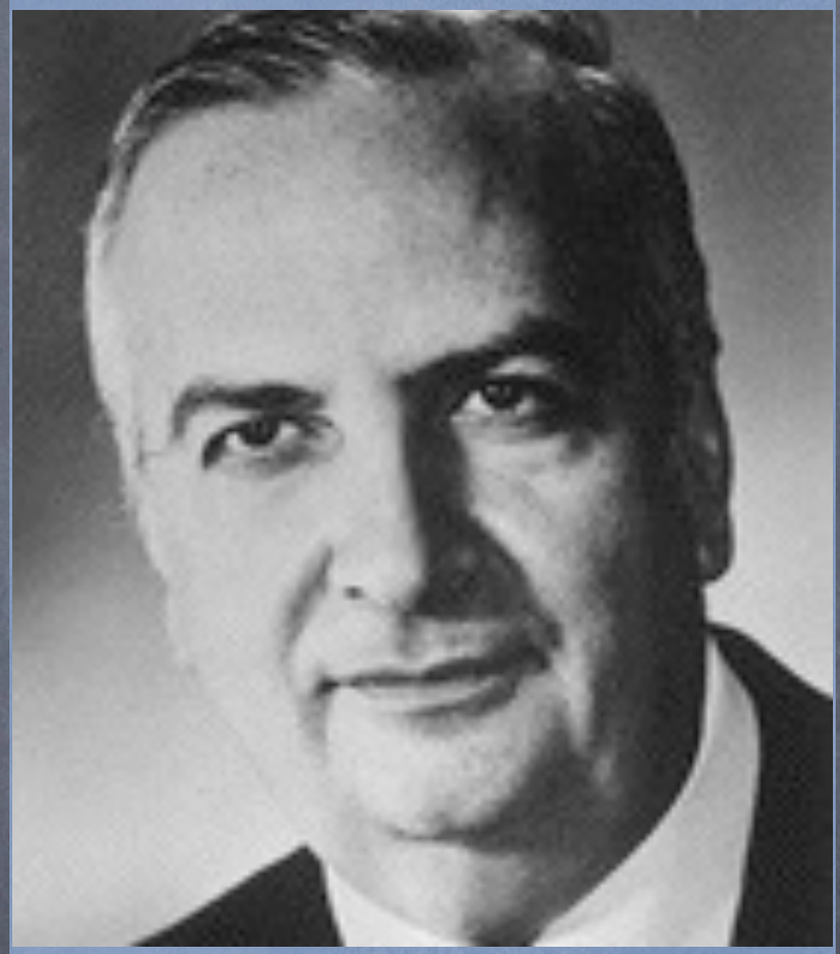


einstein's brain

Witelson, Kigar, Harvey "The exceptional brain of Albert Einstein" Lancet 1999

baruj benaccerraf

nobel prize medicine



FINK, R. P. (2006). *Why Jean and John Couldn't Read – And How They Learned.* . International Reading Association, Newark, Delaware.

incidence among scientists

- difficult to test
- poorly defined
- senior scientists not identified via schools

likely comparable to general population: 10% - 20%

NSF experiment

- open call via AAS used to find likely candidates
- select respondents invited to CfA for testing
- an experimental sample of 15 people was created (and controls)

Professional Astrophysicists with Dyslexia

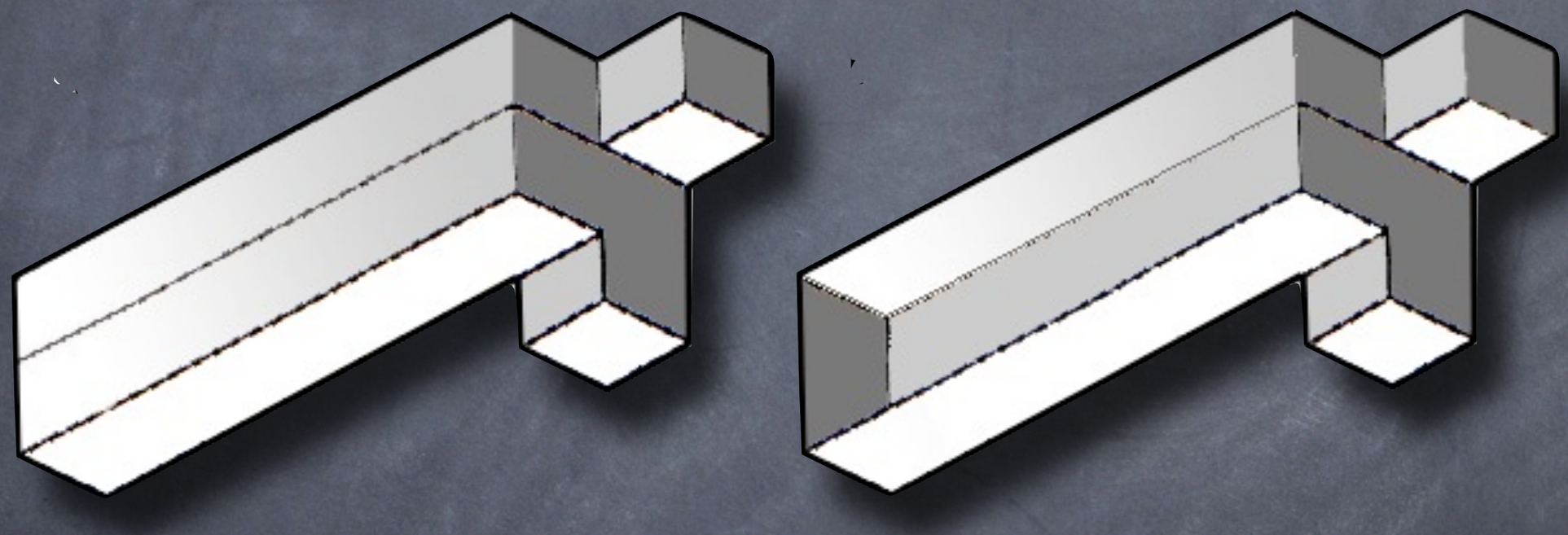
	Non-Dyslexia (n=15)		Dyslexia (n=15)			
Variable	M	(SD)	M	(SD)	t	prob
Age (months)	519.93	(130.18)	526.73	(140.21)	-0.14	0.89
Block Design	64.27	(5.57)	57.93	(7.74)	2.57	0.02
Vocabulary	64.66	(7.14)	59.42	(12.75)	1.38	0.17
Word Reading	78.37	(3.39)	61.73	(6.73)	8.54	0.001
Rapid Naming	10.83	(1.83)	7.97	(2.52)	3.55	0.001
Working Memory	20.26	(3.71)	14.07	(4.06)	4.36	0.001
Alerting	48.39	(22.21)	36.77	(28.54)	1.10	0.29
Orienting	16.71	(12.66)	7.43	(24.40)	1.14	0.27
Conflict	129.97	(33.01)	144.96	(48.57)	-0.87	0.40

7f 8m 5f 10m

visual differences observed

many deficits - but also some advantages (!)

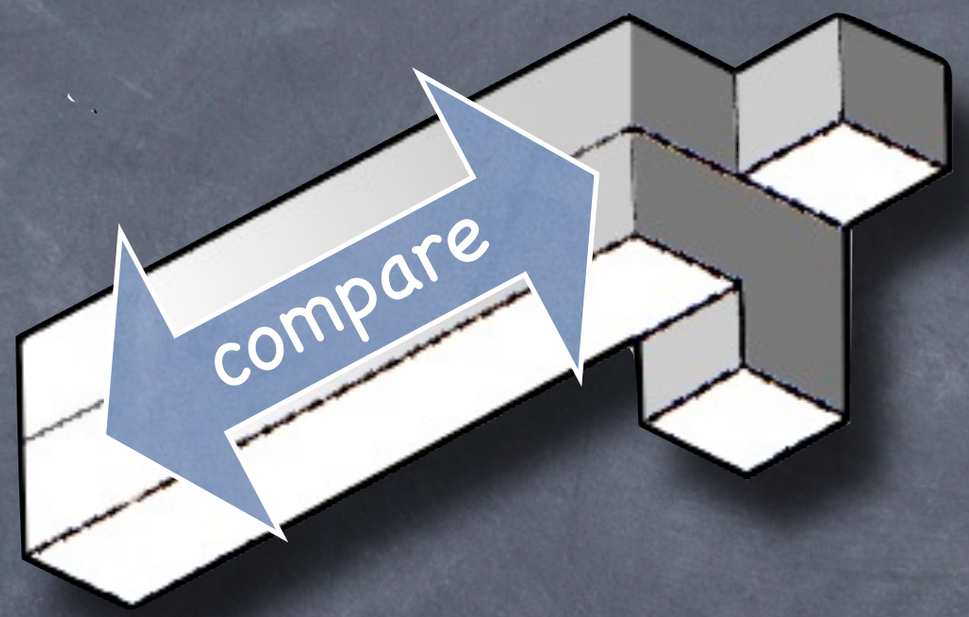
impossible figures



people w/dyslexia are faster at solving these

von Karolyi, Winner, et al. (2003). Brain and Language **85**(3): 427-31.

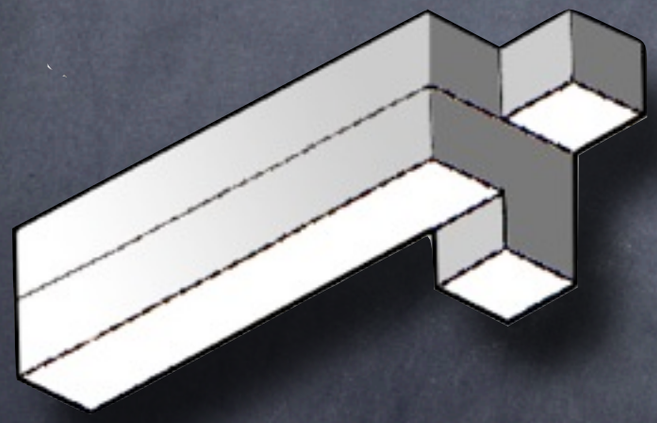
anomaly detection



is a high PCR task

detecting logical anomaly

a skill that is useful in science and math!



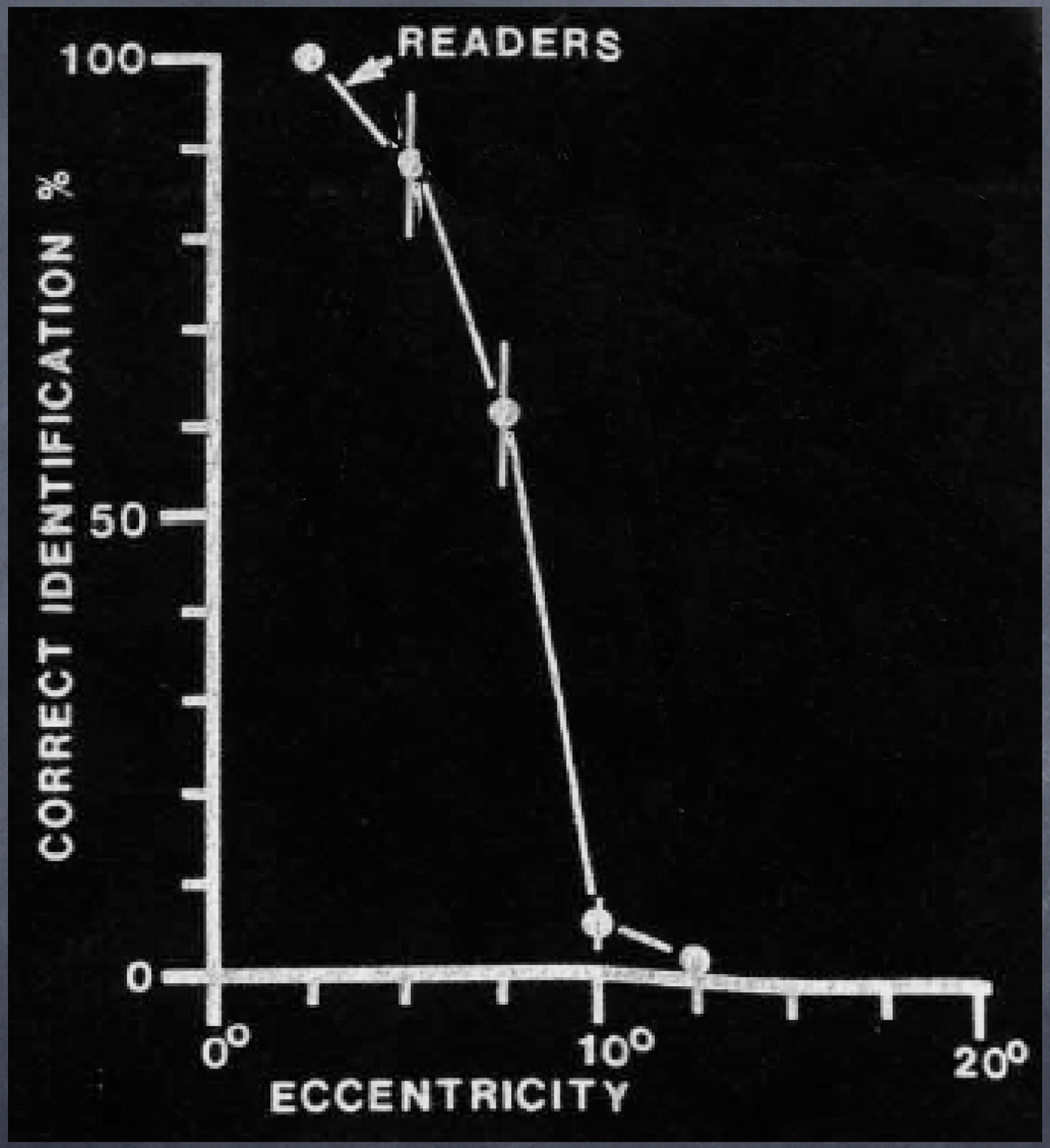
peripheral letter recognition

d ⟷ **w**

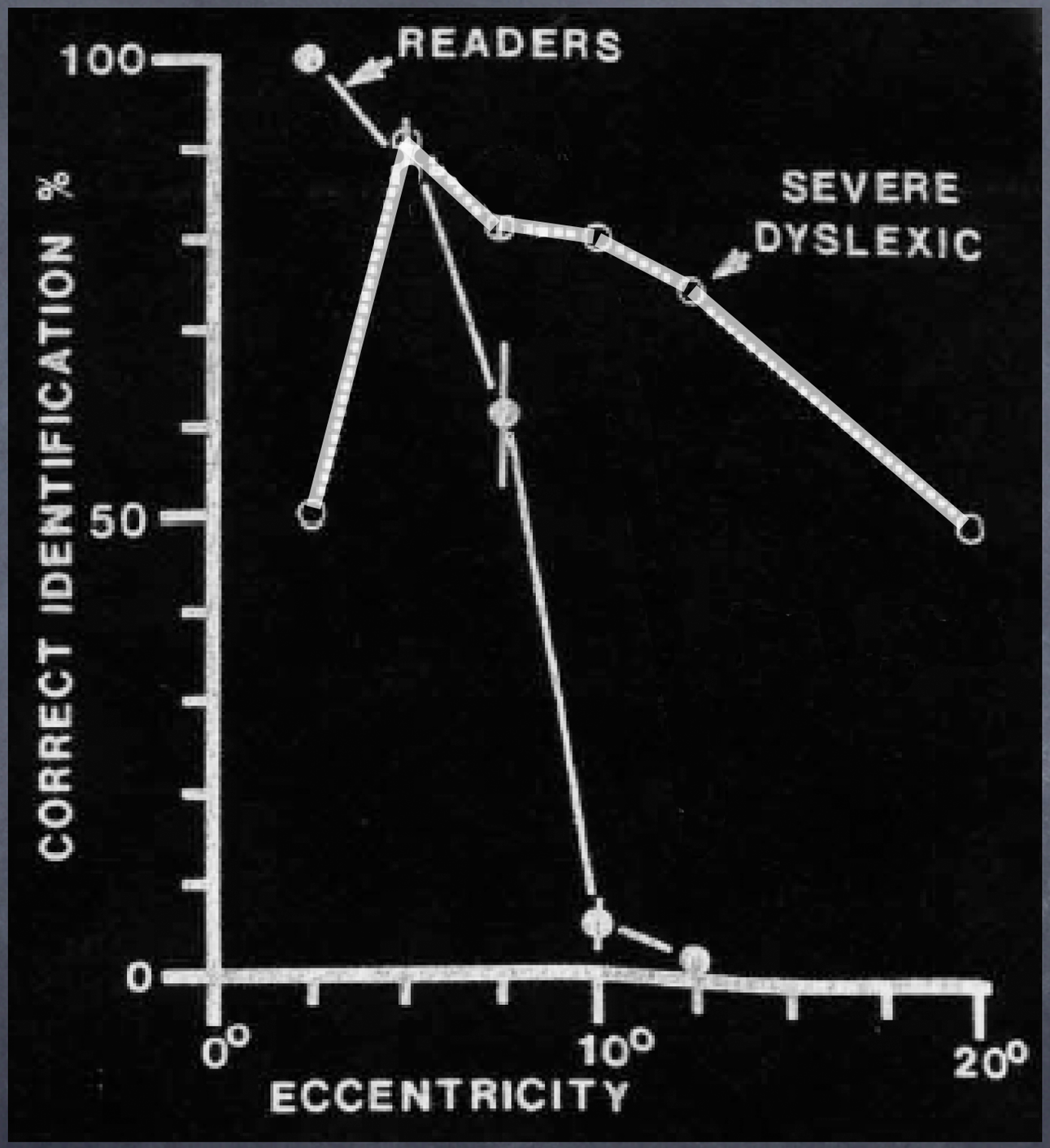
vary eccentricity

very quick flash
~15 ms

Geiger, G. and J. Y. Lettvin (1987). New England Journal of Medicine **316**(20): 1238-1243.

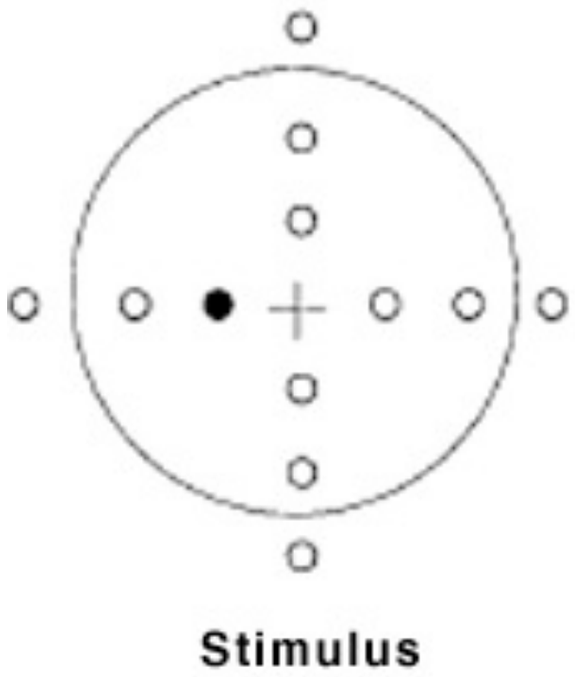


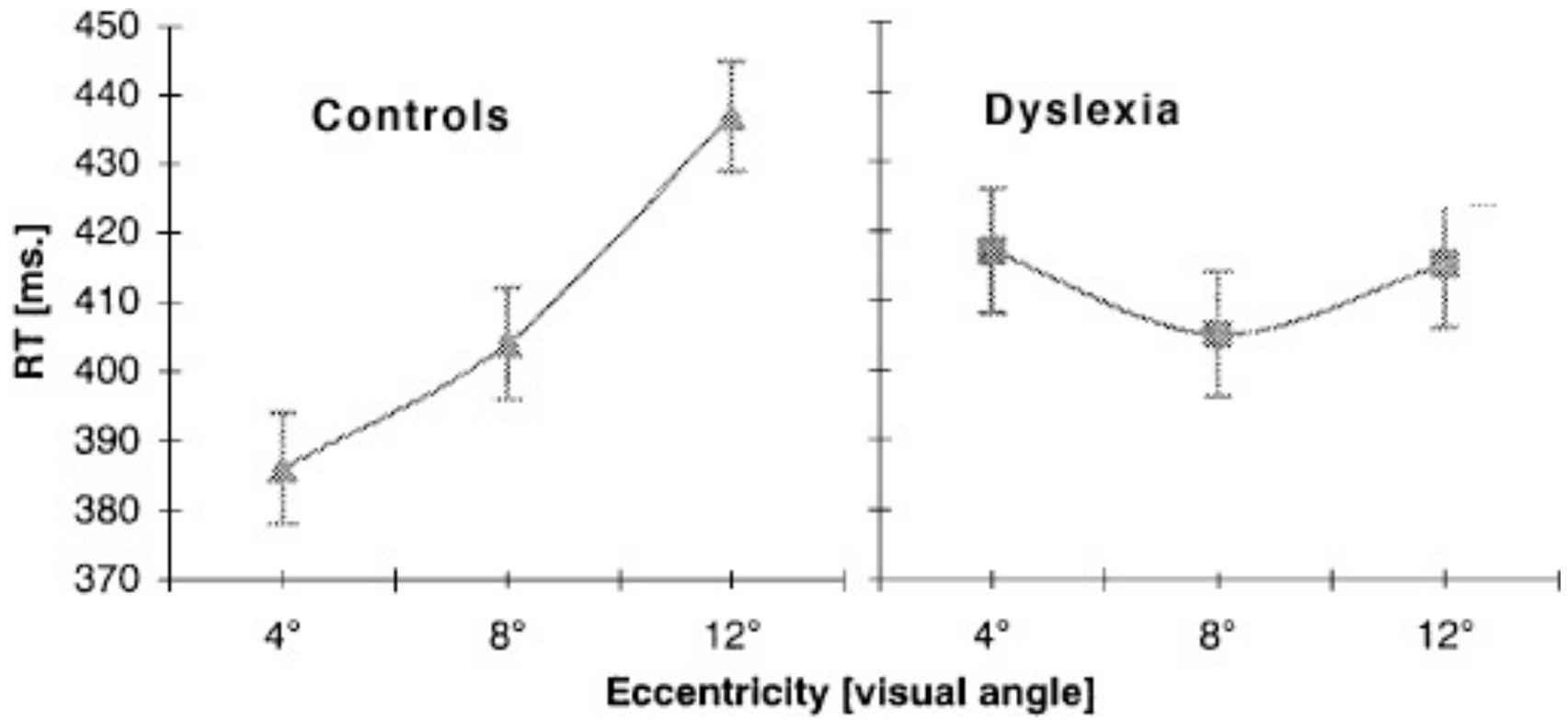
Geiger, G. and J. Y. Lettvin (1987). New England Journal of Medicine **316**(20): 1238-1243.



Geiger, G. and J. Y. Lettvin (1987). New England Journal of Medicine **316**(20): 1238-1243.

sensitivity to rapid flash



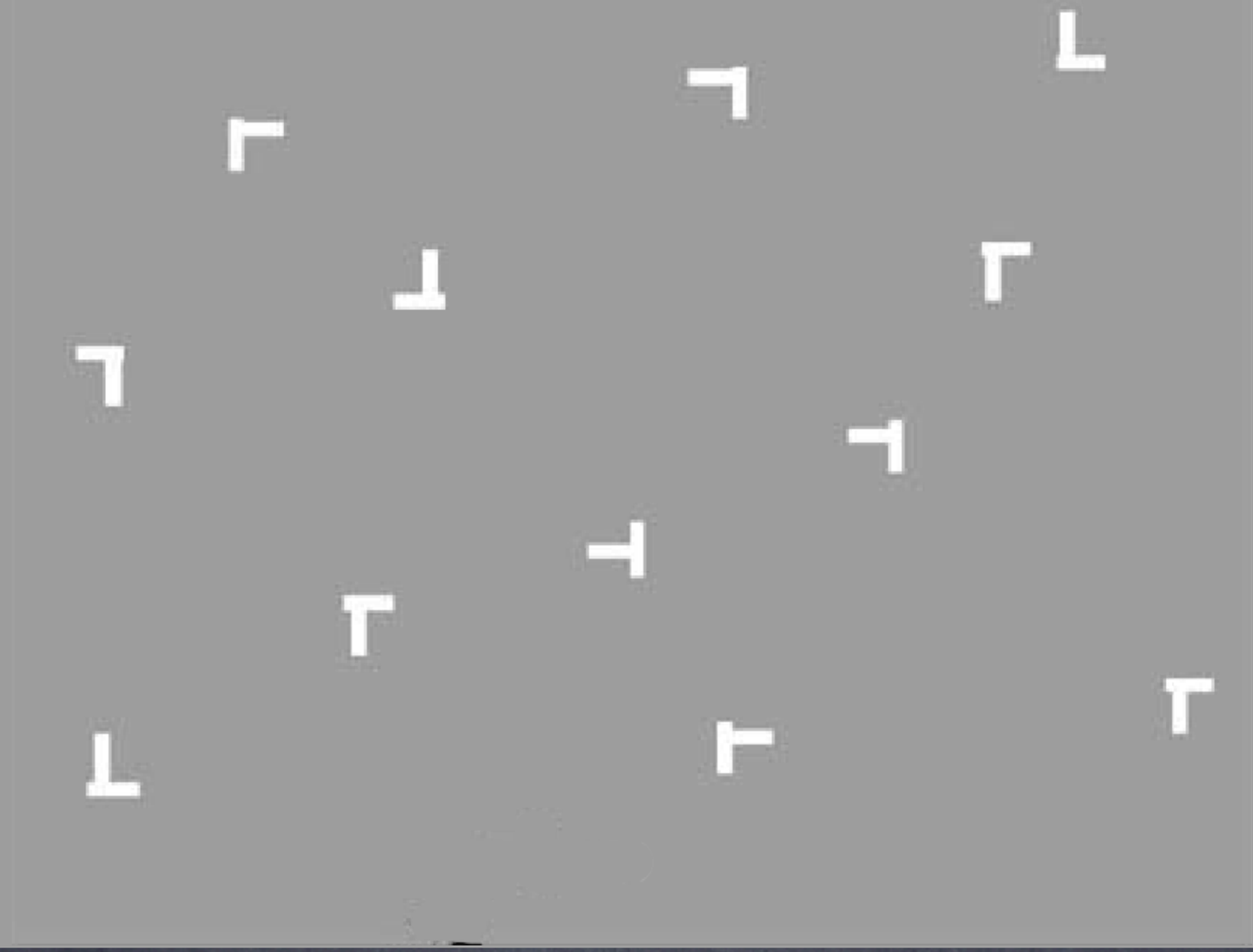


Facoetti, A., P. Paganoni, et al. (2000).Experimental Brain Research **132**(4): 531-538.

messy offices

spatial memory for object locations

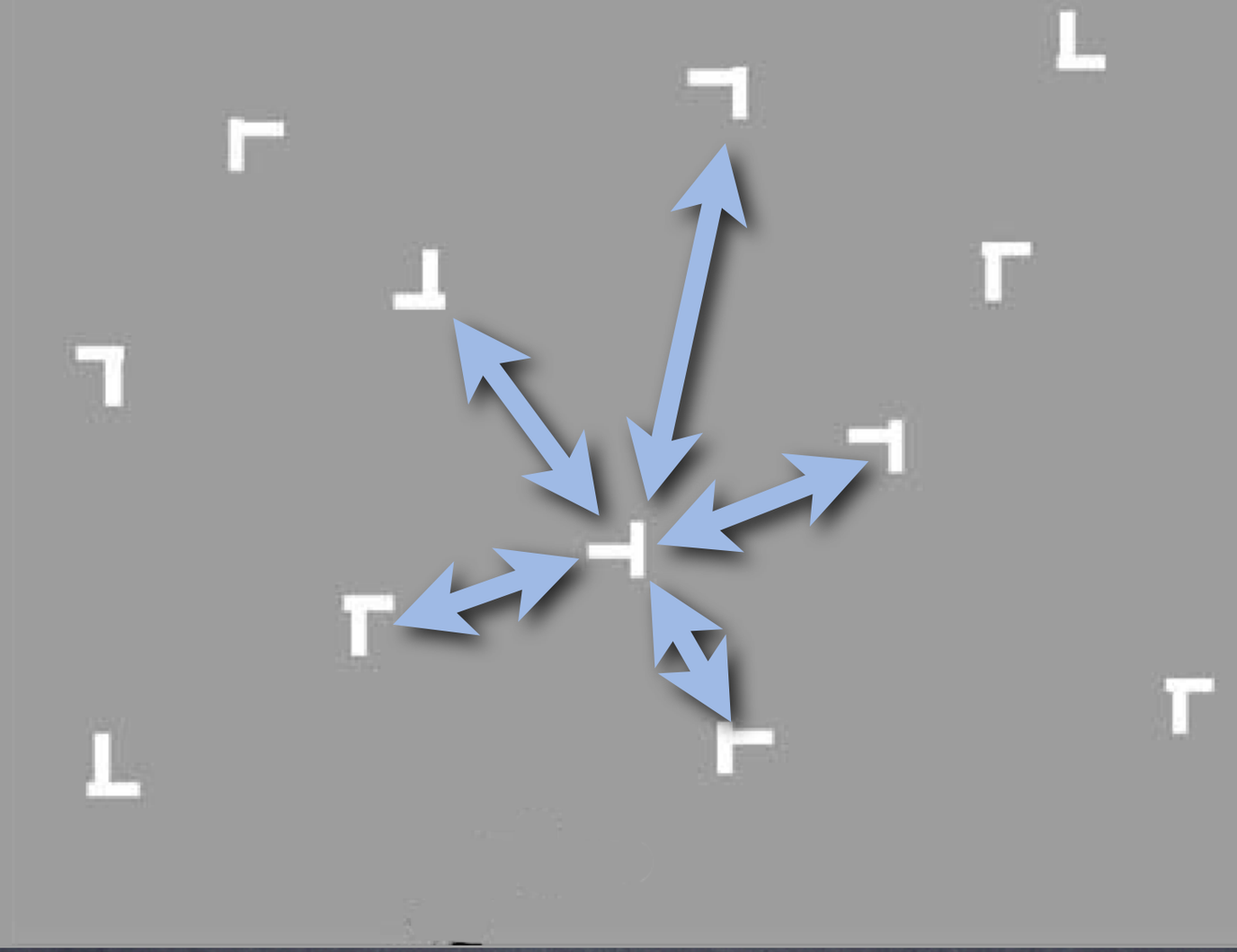
spatial learning



contextual cueing

Chun, M. M. and Y. Jiang (1998). Cognitive Psychology **36**(1): 28-71.

spatial learning



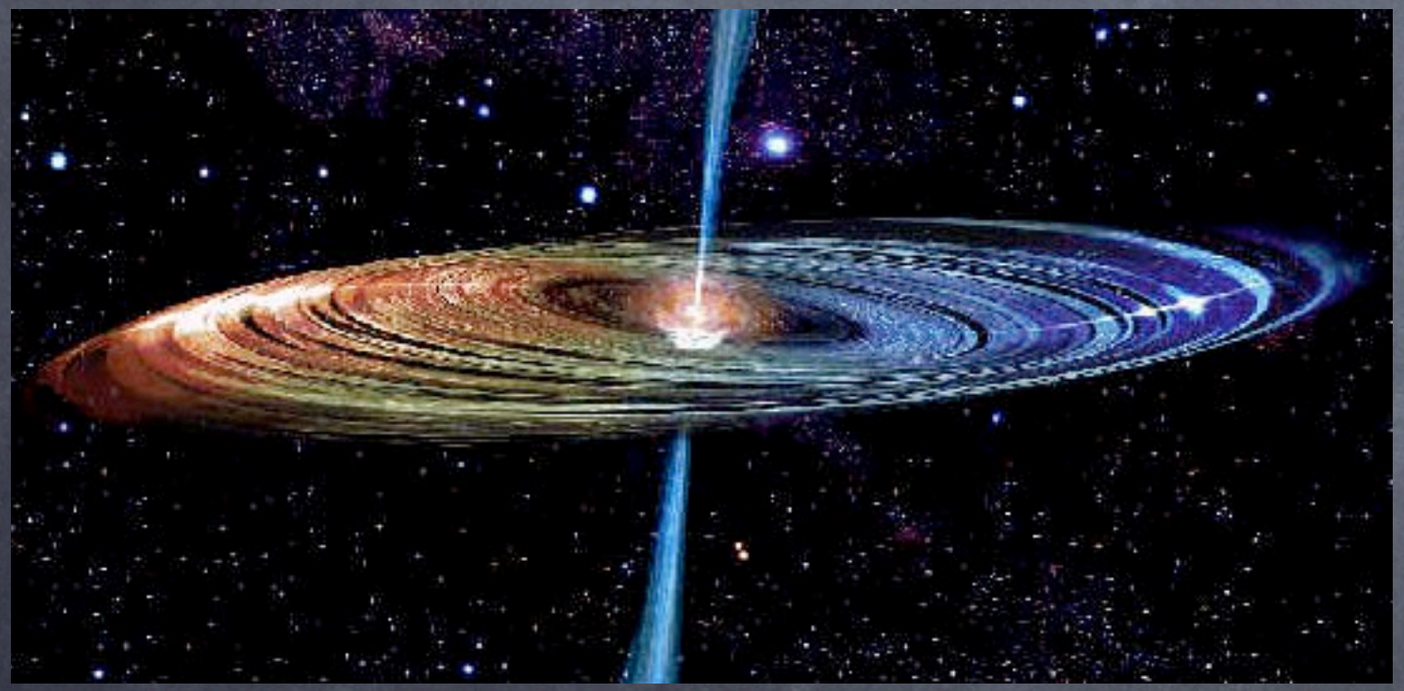
better accomplished using peripheral comparison

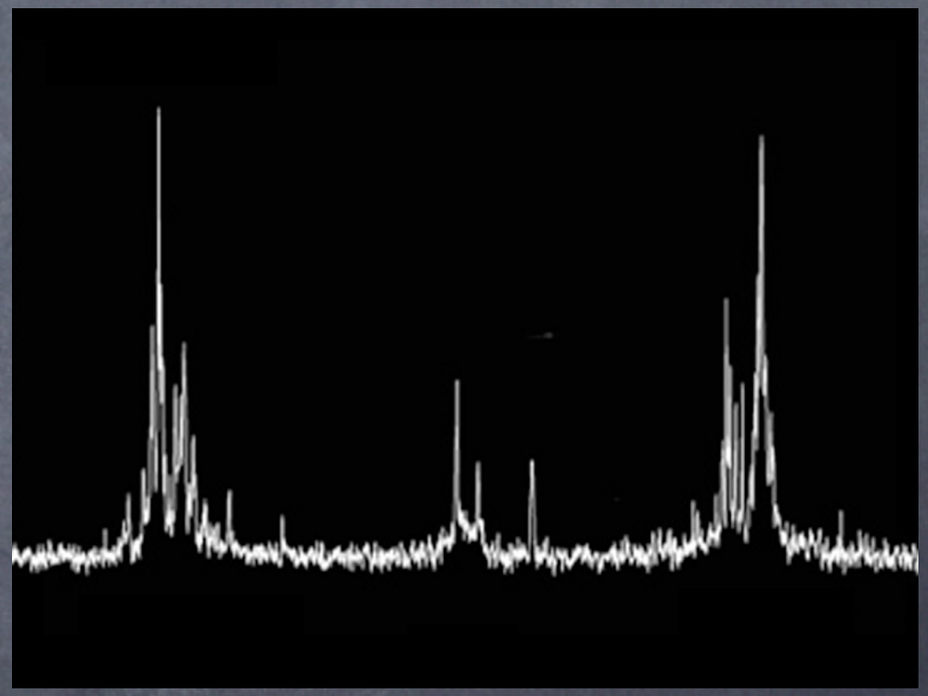
Brady, T. F. and M. M. Chun (2005). Journal of Vision **5**(8): 860-860.

a test of the hypothesis

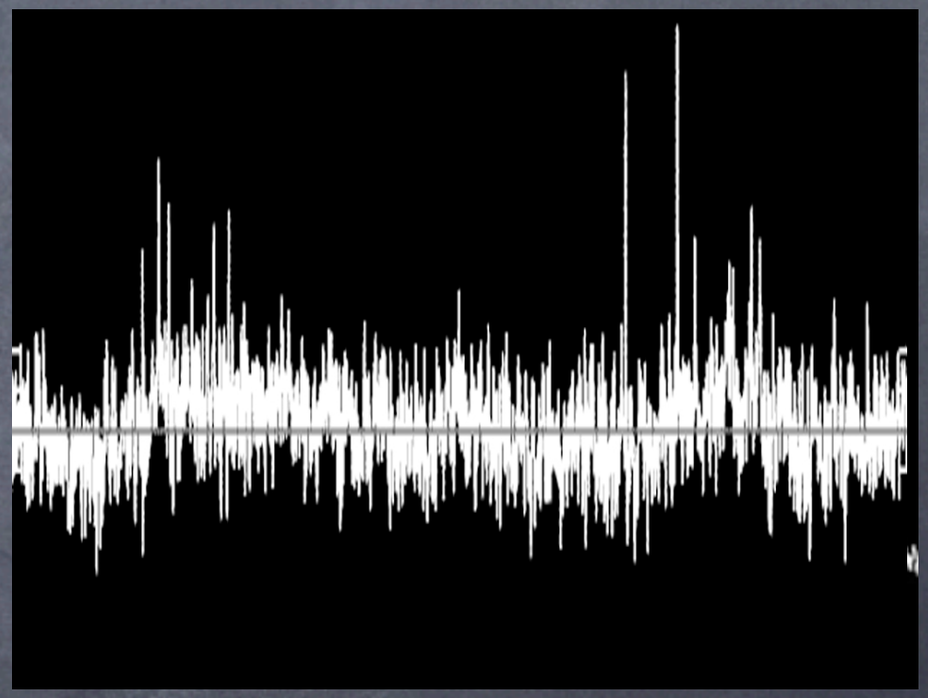
are astrophysicists with dyslexia better at finding black holes?

black hole detection





black hole detection

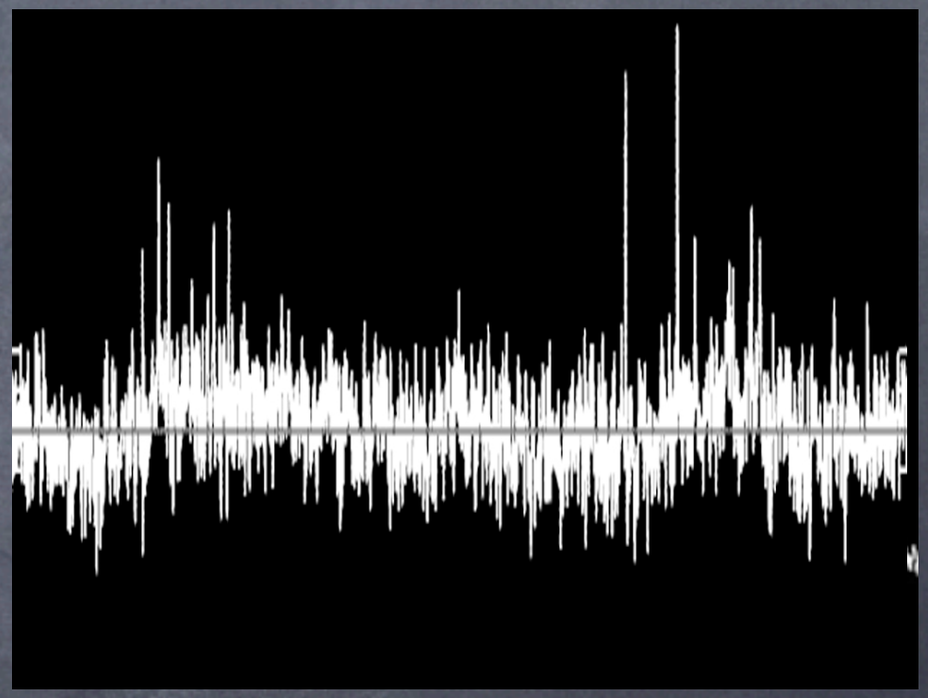


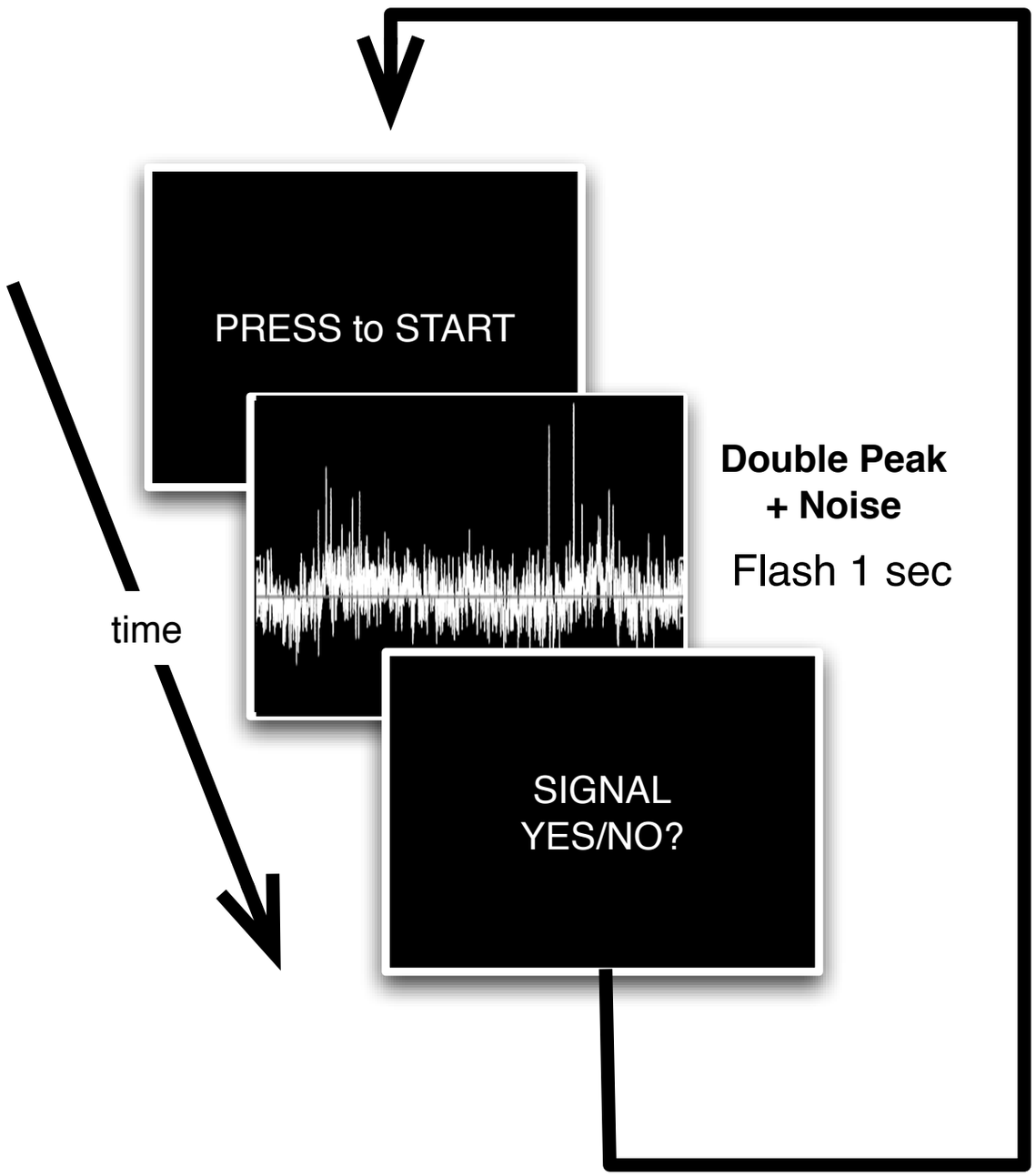
do scientists with dyslexia have lower thresholds for detection?

hypothesis

based on prior studies

black hole detection





repeat
increase noise until
detection-threshold reached

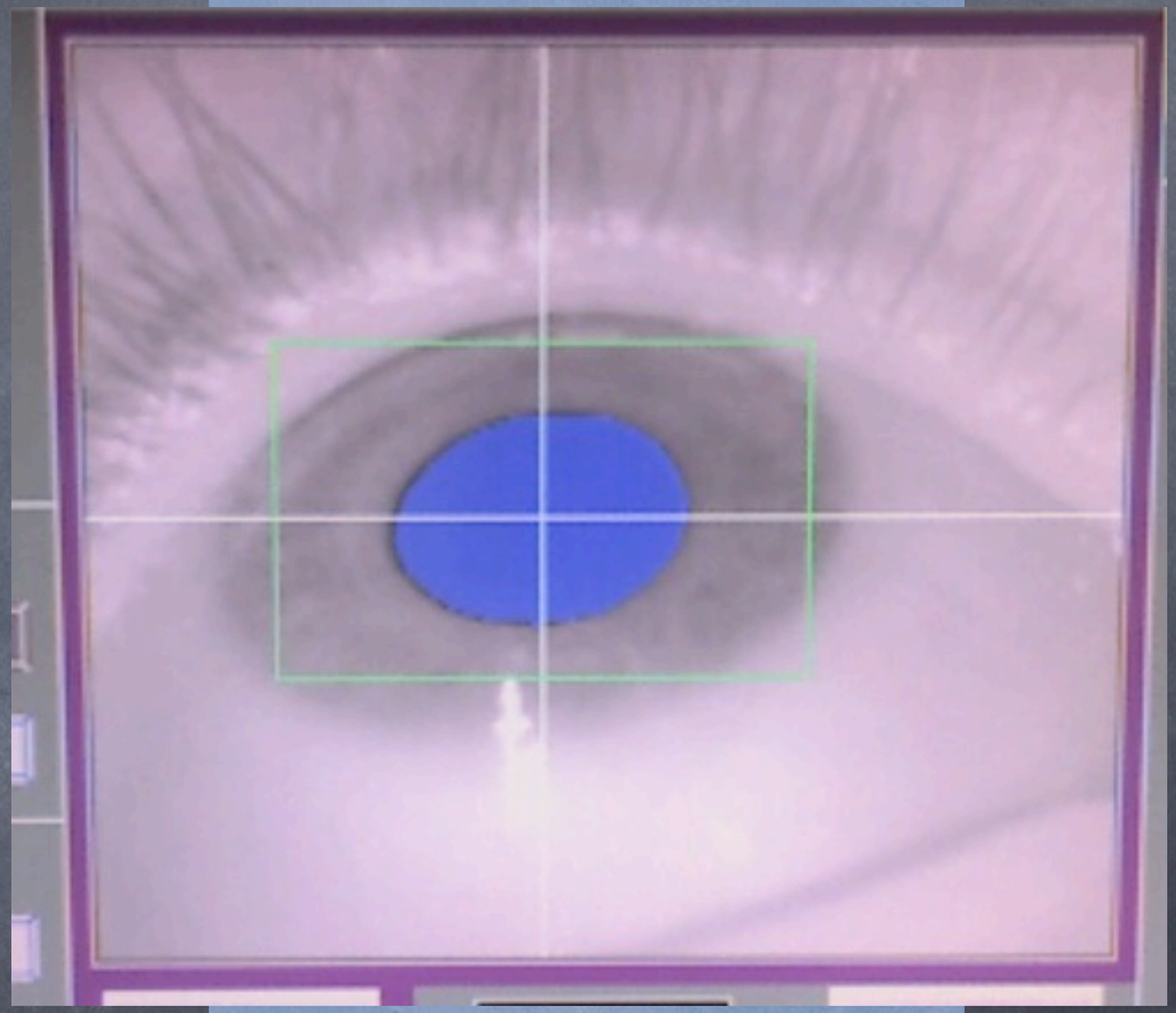
black hole detection task

astrophysicists with dyslexia show peripheral bias in black holes!

schneps, rose, greenhill, pomplun (2010) in preparation

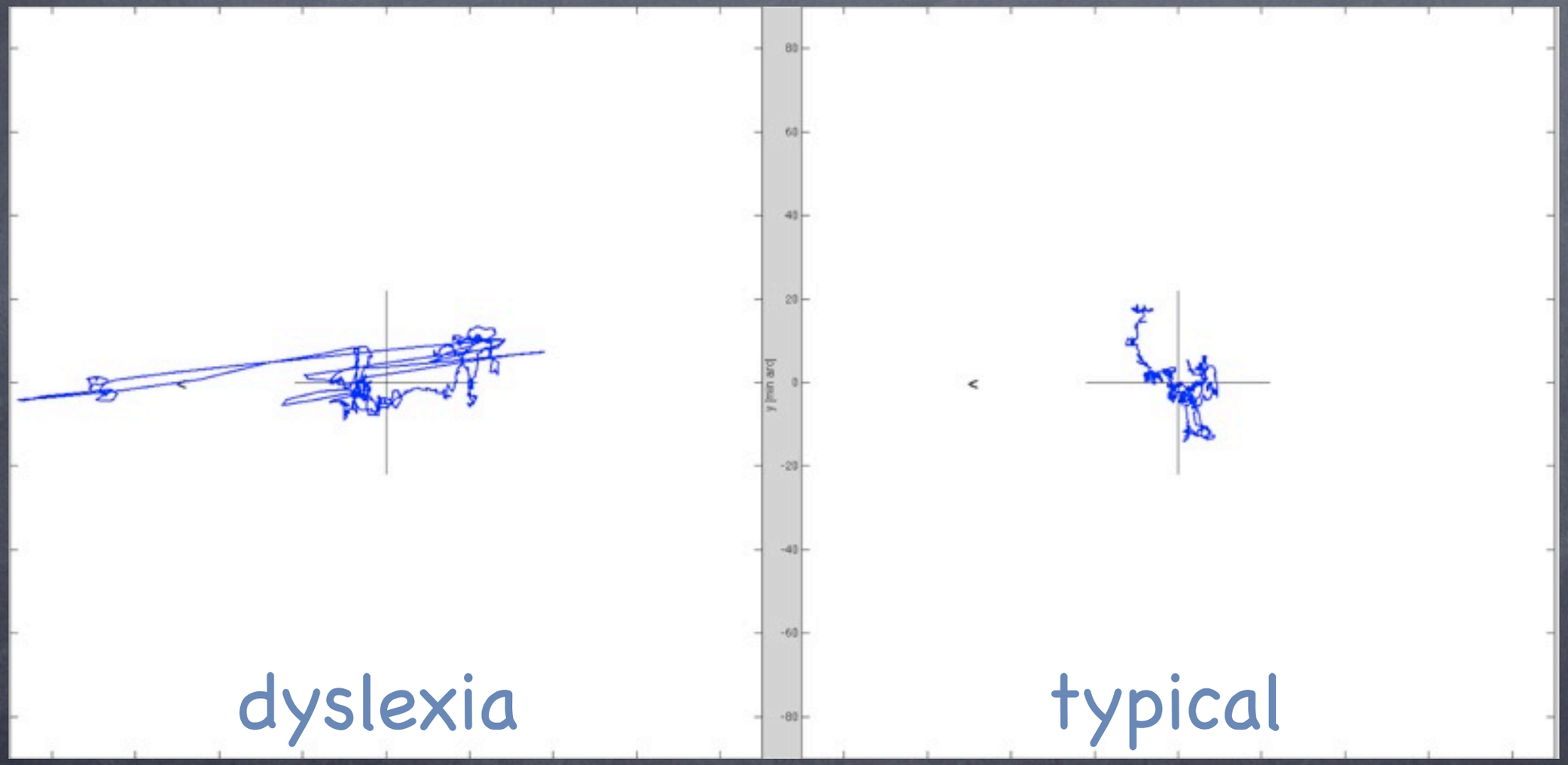
eye tracking

image processing
traces gaze direction
at 1000 Hz = 1 ms timing



nerve conduction = 10 ms
first stage vision = 60 ms
frontal lobe involvement = 200 ms

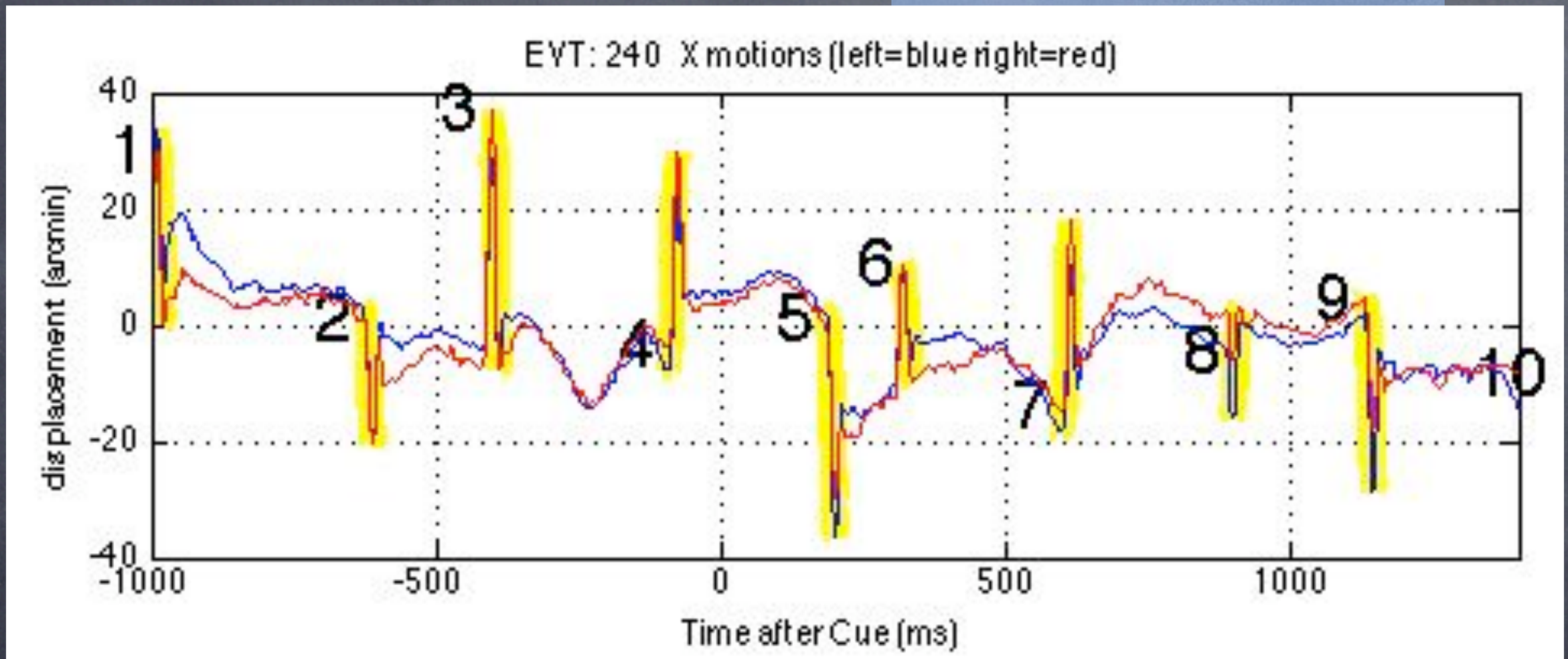
eye motions



poor fixation, atypical motions

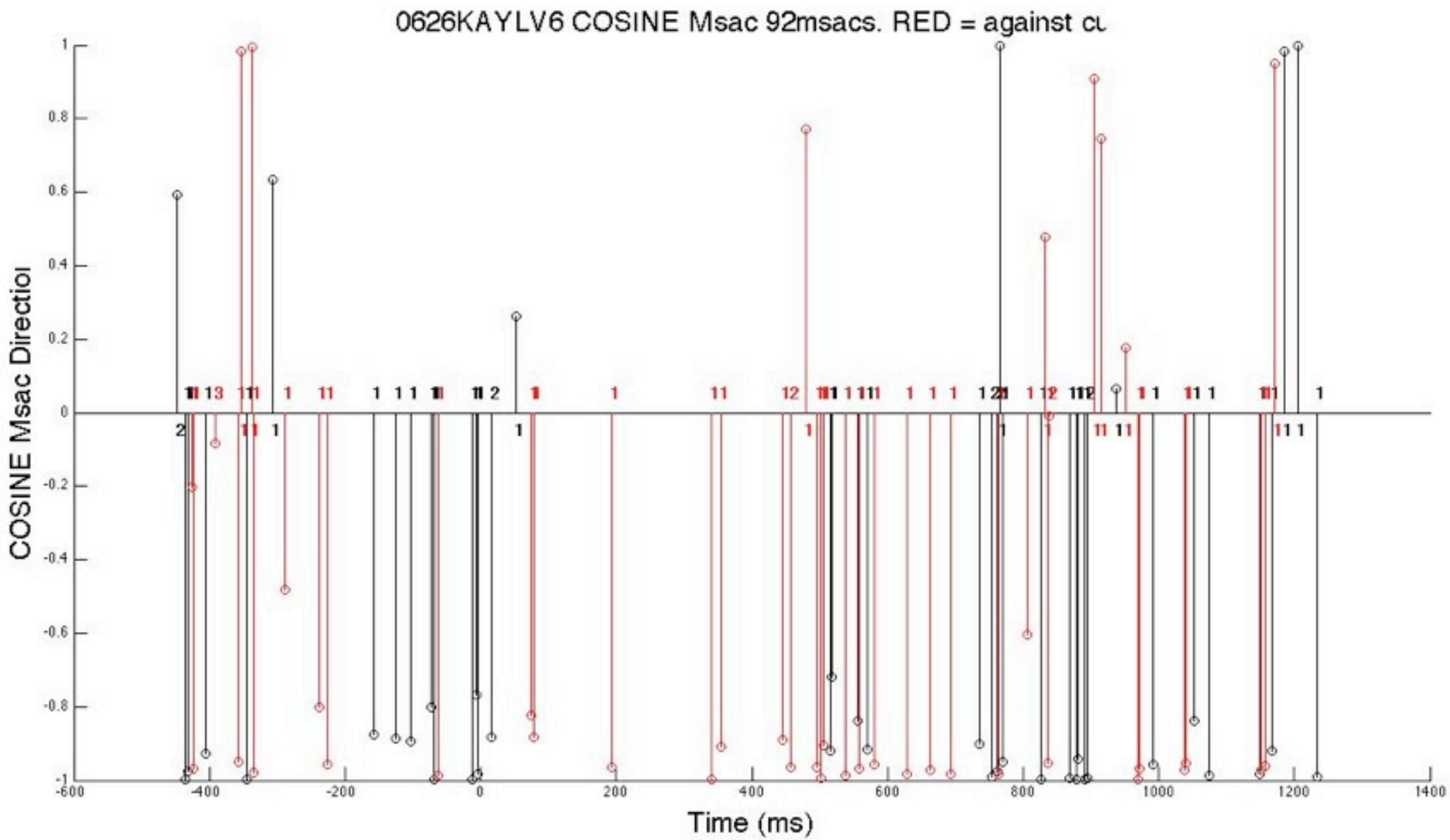
Schneps,M.H. and Rose, L.T. (2008) prepublication results

microsaccades

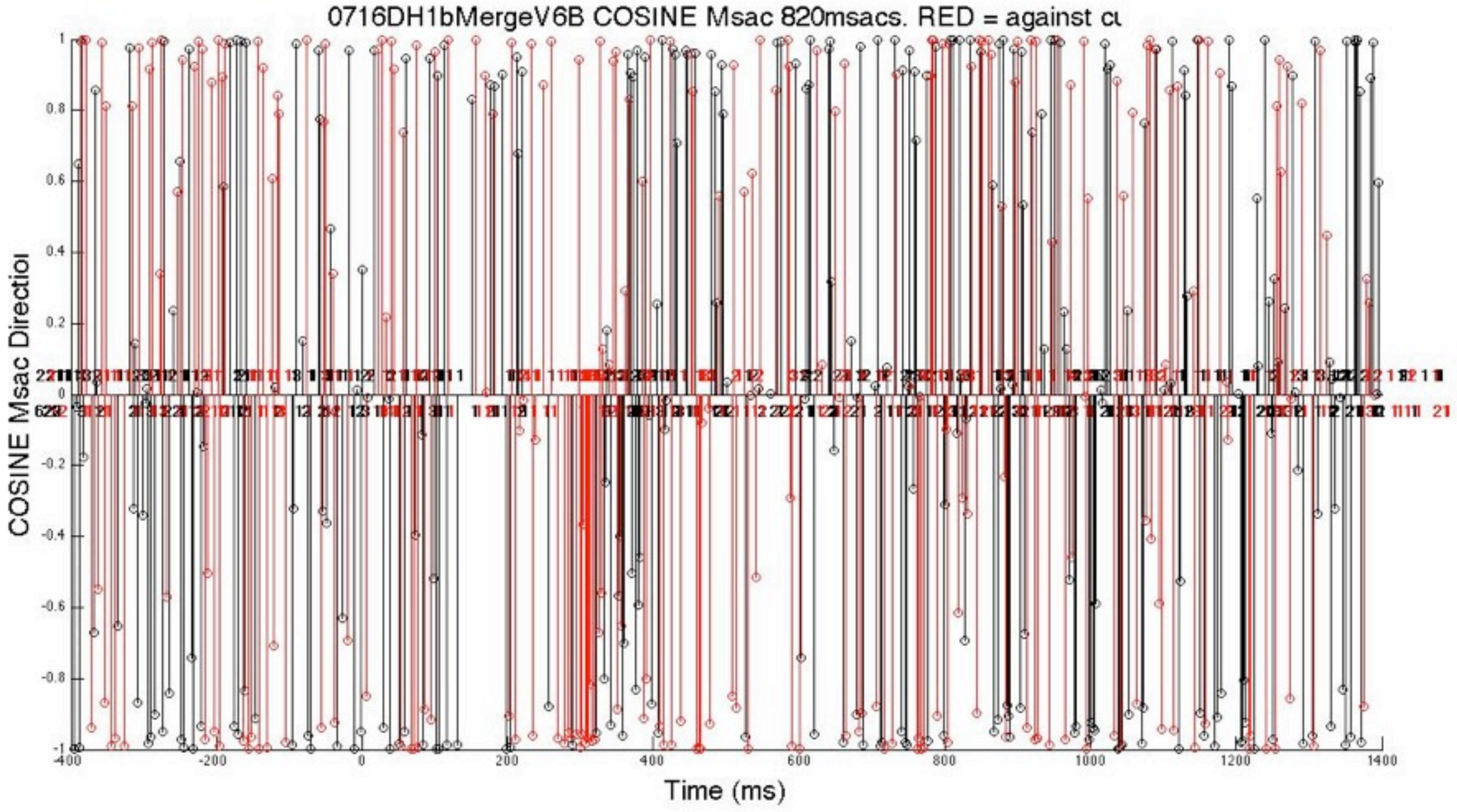


thought to play a role in perception: e.g. troxler fading, oddball, illusory motion

microsac. typical

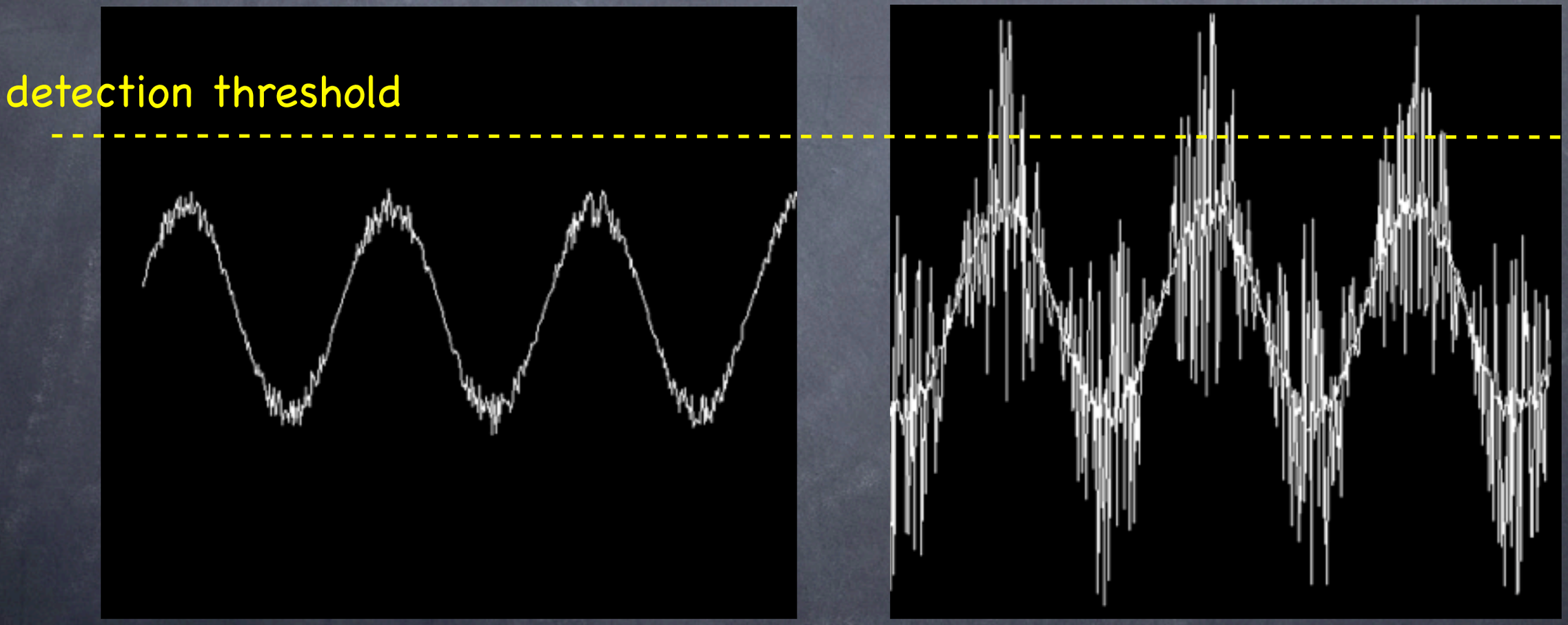


msacs dyslexia/ADHD



stochastic resonance

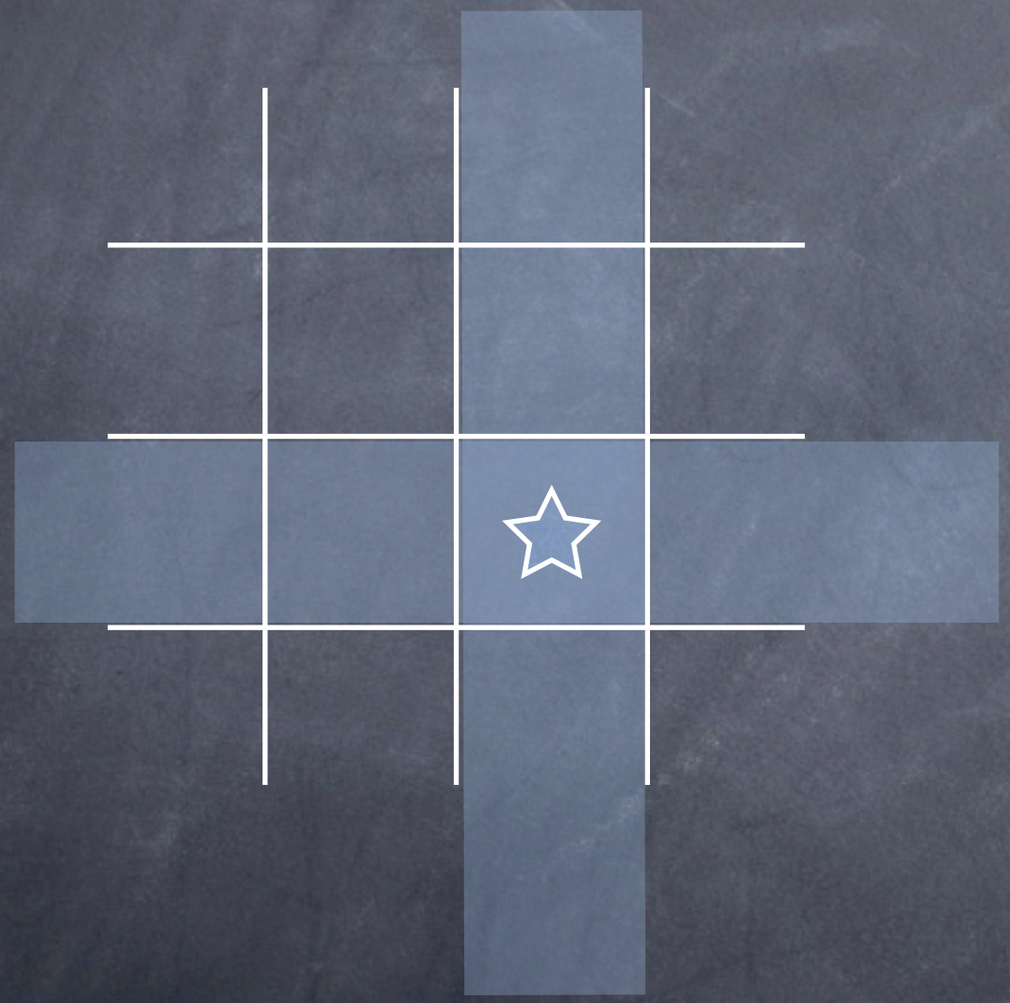
noise helps detect subthreshold signals



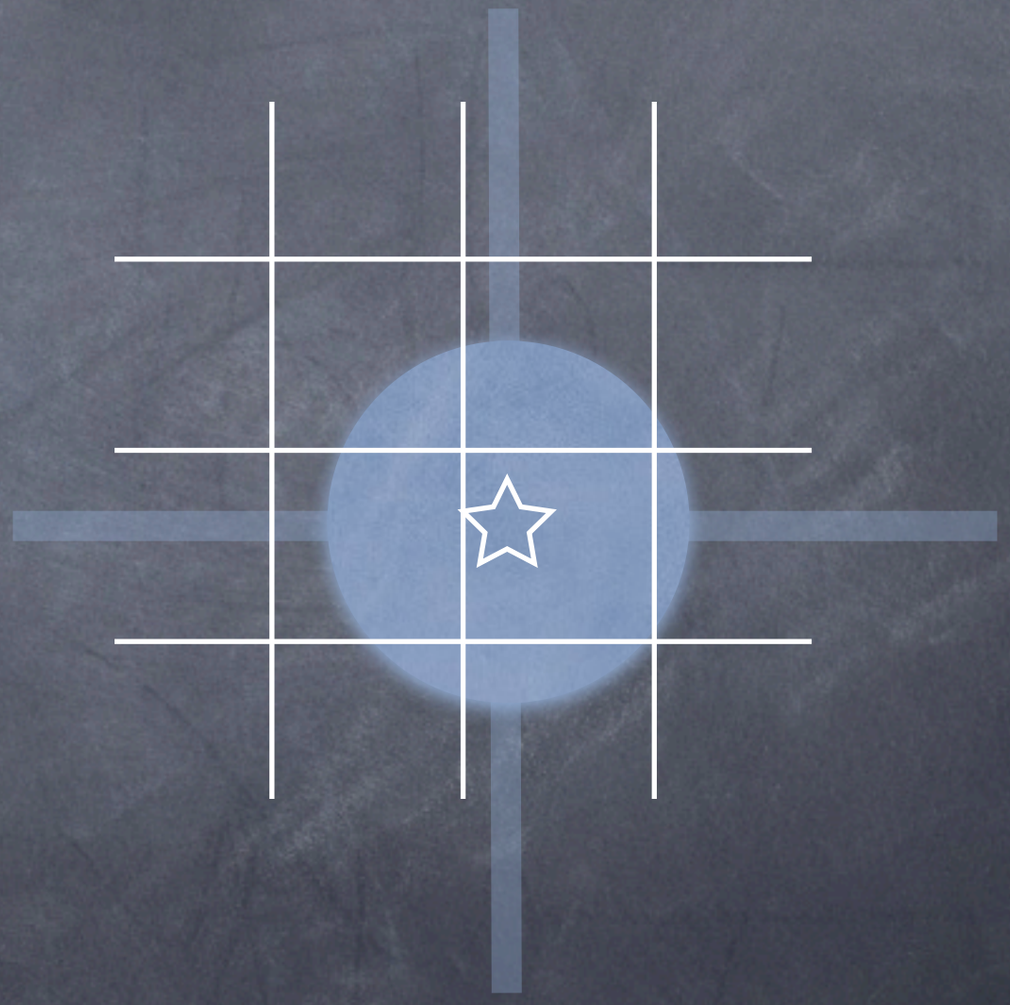
adding noise (e.g. movement) improves localization and sensitivity

Hennig, M. & Worgotter, F. (2004). *Advances in Neural Information Processing Systems* **16**.

dithering

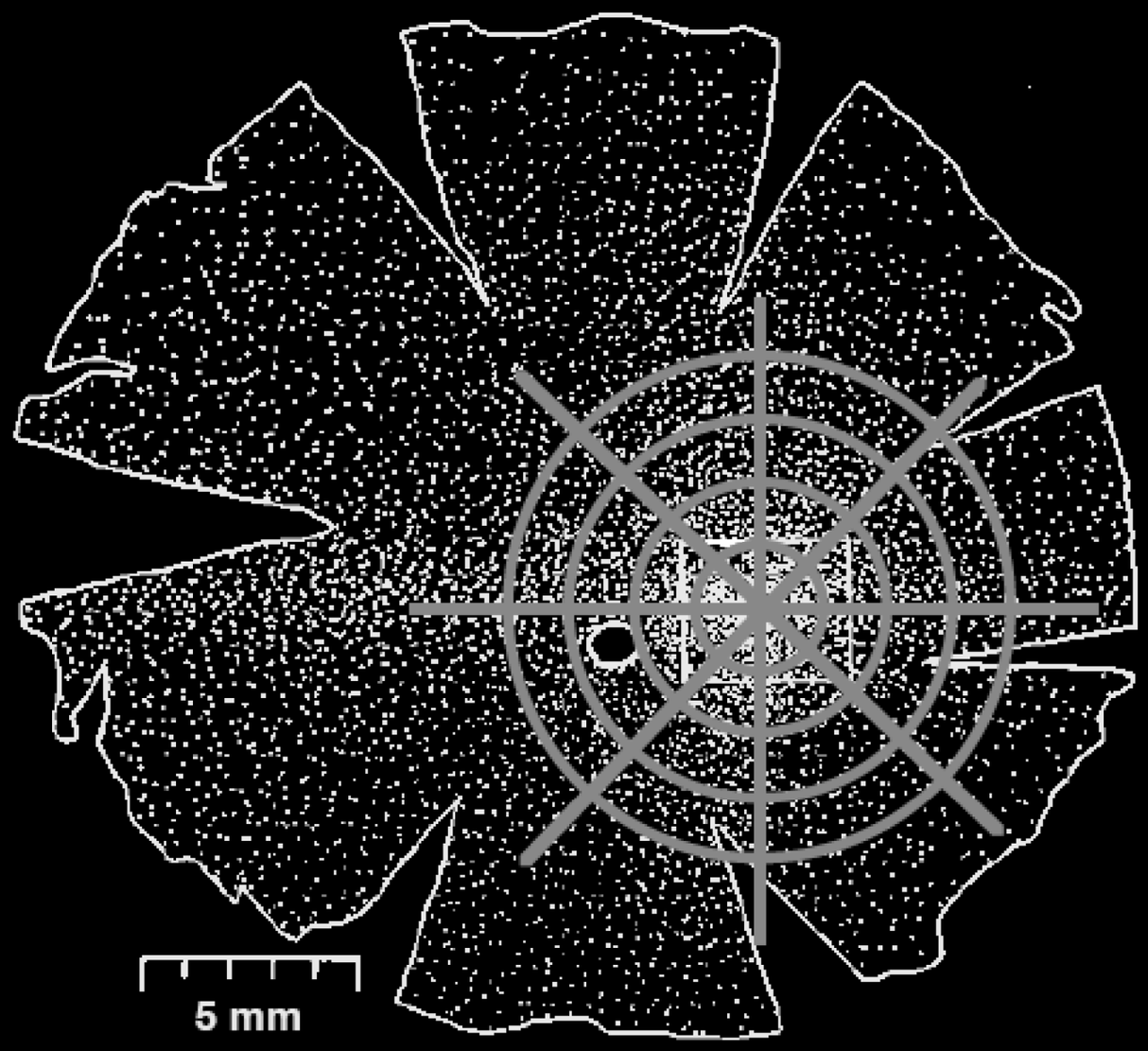


quantized



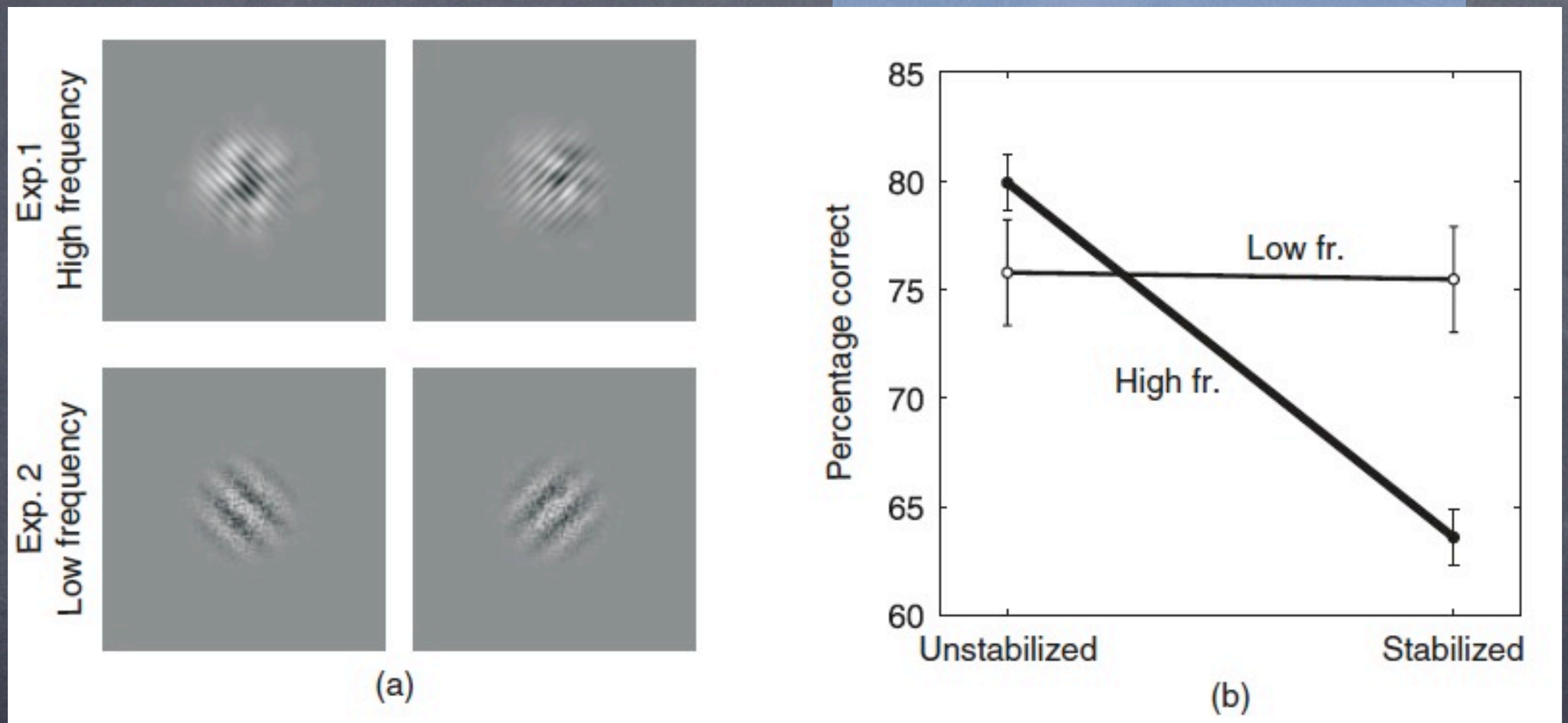
vibration added

primate retina



Thibos, L. N. (2002). "V648 Neurophysiology of Vision."

M. Rucci et al (BU) stabilized images



ability to discriminate high frequencies diminishes when eye motions are stabilized

Rucci, M (2008) "Fixational eye movements, natural image statistics,and fine spatial vision" Network: Computation in Neural Systems

analogy to mpeg

most information in moving scenes is stable, redundant, and highly-correlated

image compression

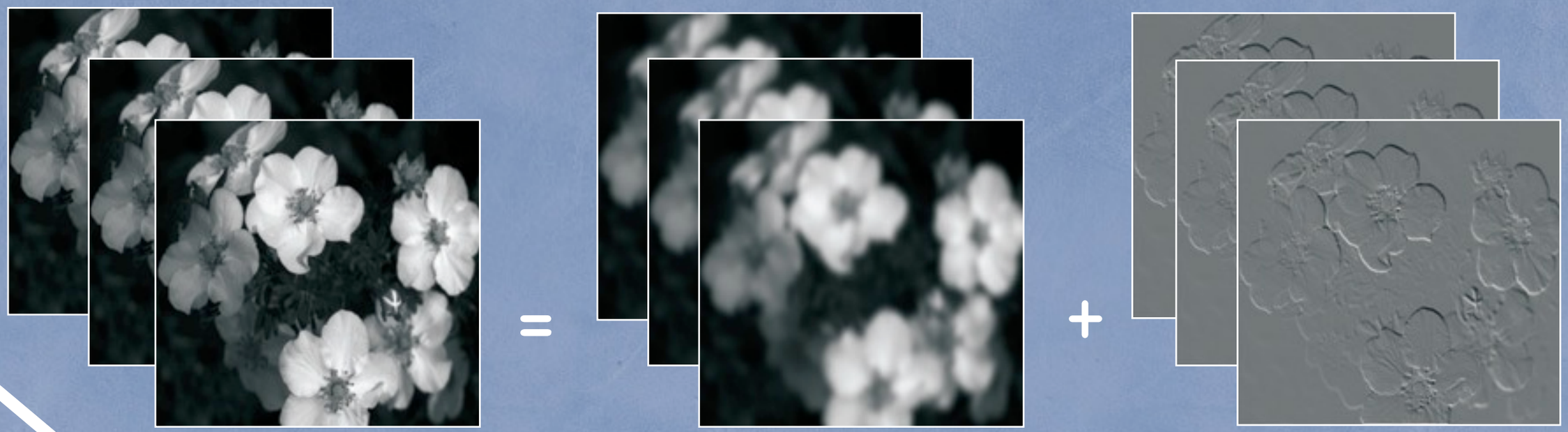
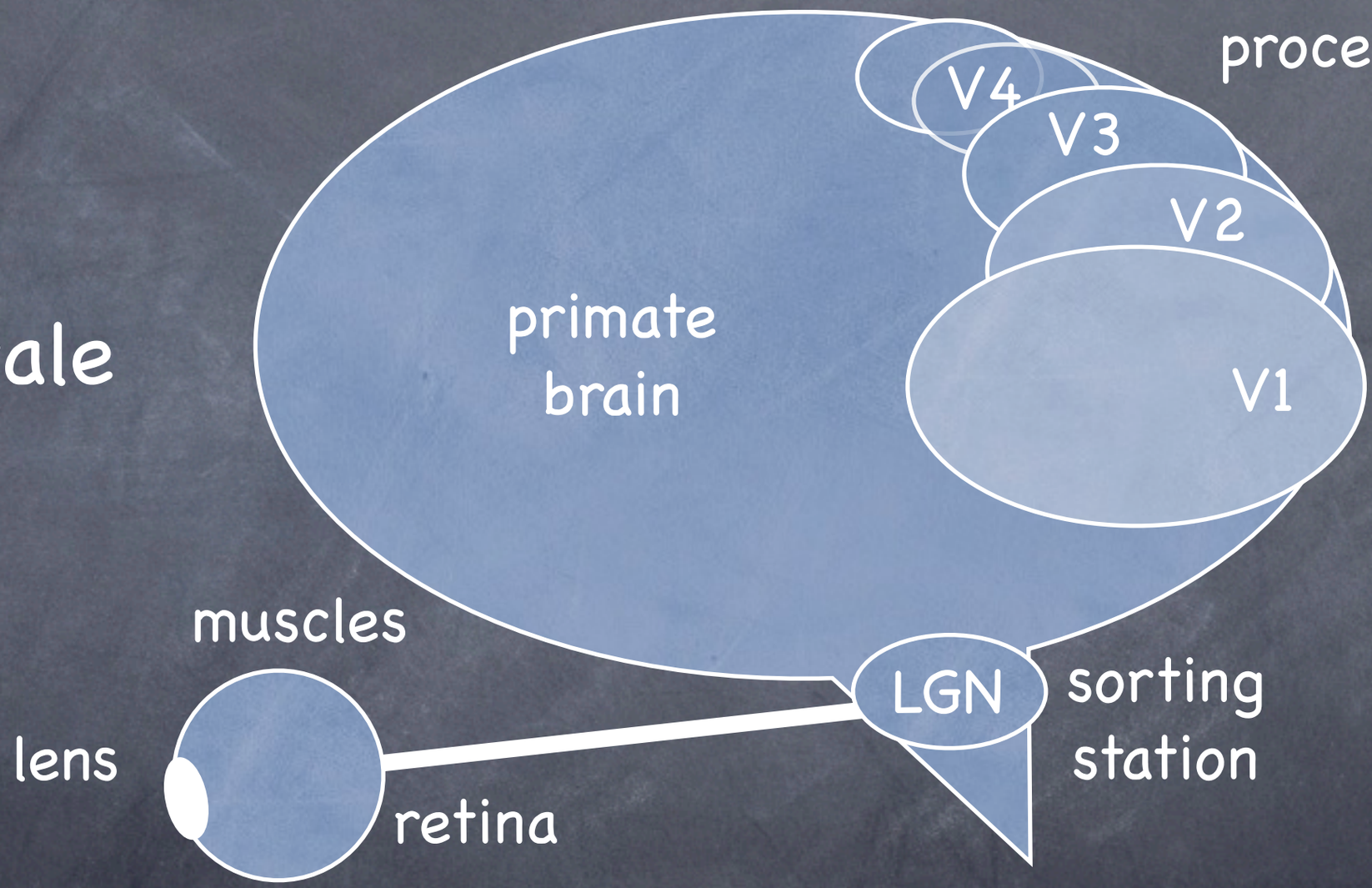


image = stable base + changes (derivatives)

Rucci, M (2008) "Fixational eye movements, natural image statistics,and fine spatial vision" Network: Computation in Neural Systems

other mechanisms



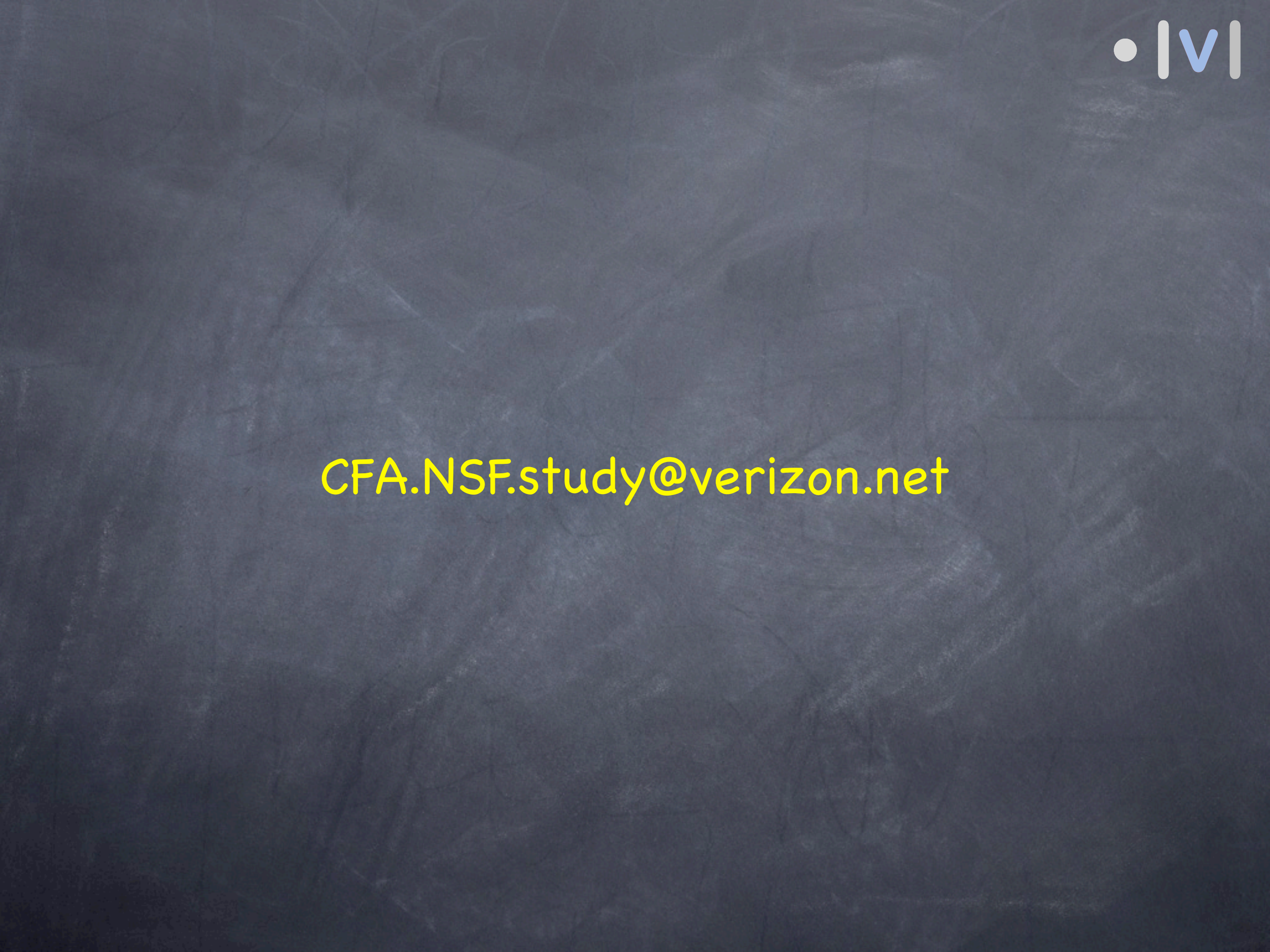
vision is a complex chain

implications of neurology for data analysis

1. **Individuals Vary** in Abilities for Visual Cognition (especially at thresholds where discoveries are first made)

2. **Peripheral Information** Can Be Important; more so for some people than others

optimal display designs respect biological diversity


CFA.NSF.study@verizon.net

Dr. Matthew H. Schneps

Dr. L. Todd Rose

Dr. Lincoln Greenhill

Amanda Heffner-Wong

CFA.NSF.study@verizon.net

Harvard-Smithsonian
Center for Astrophysics

Dr. Marc Pomplun — University of Massachusetts

Dr. Susana Martinez-Condé — Barrow Neurological Institute

National Science Foundation

supported by the NSF under
grant HRD-0726032

Smithsonian Institution