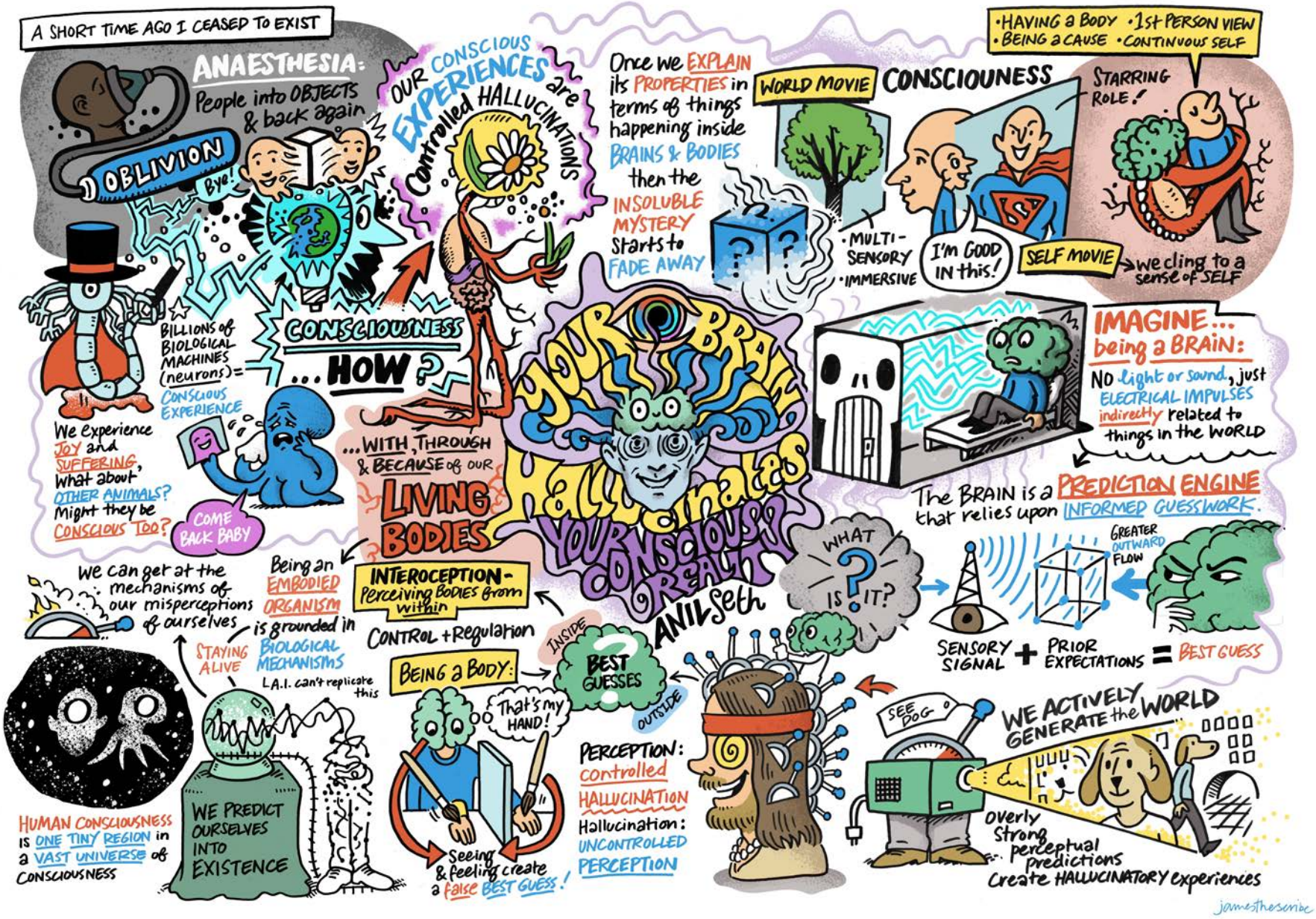
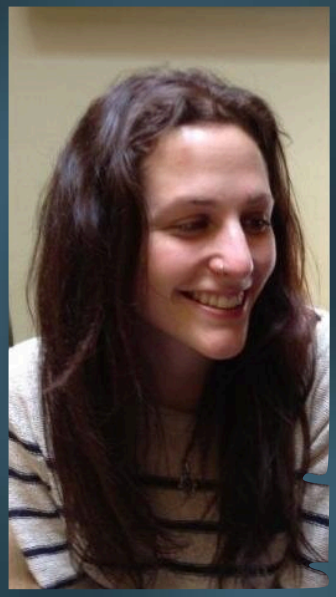



the most unknown
Axel Cleeremans
Netflix (2018), dir. Ian Cheney

The Most Unknown (2018) dir. Ian Cheney

Warrick Roseboom



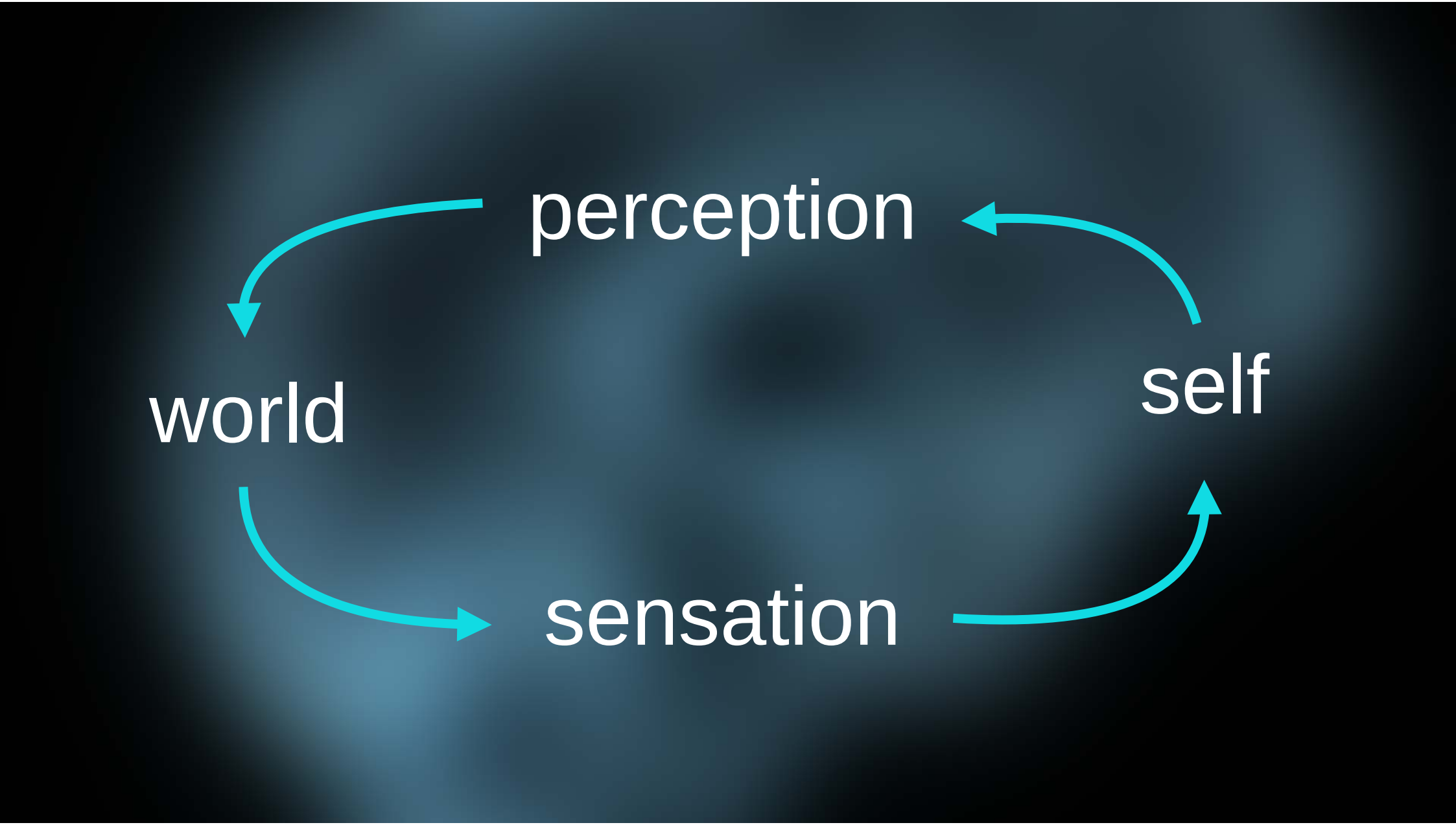
Maxine Sherman

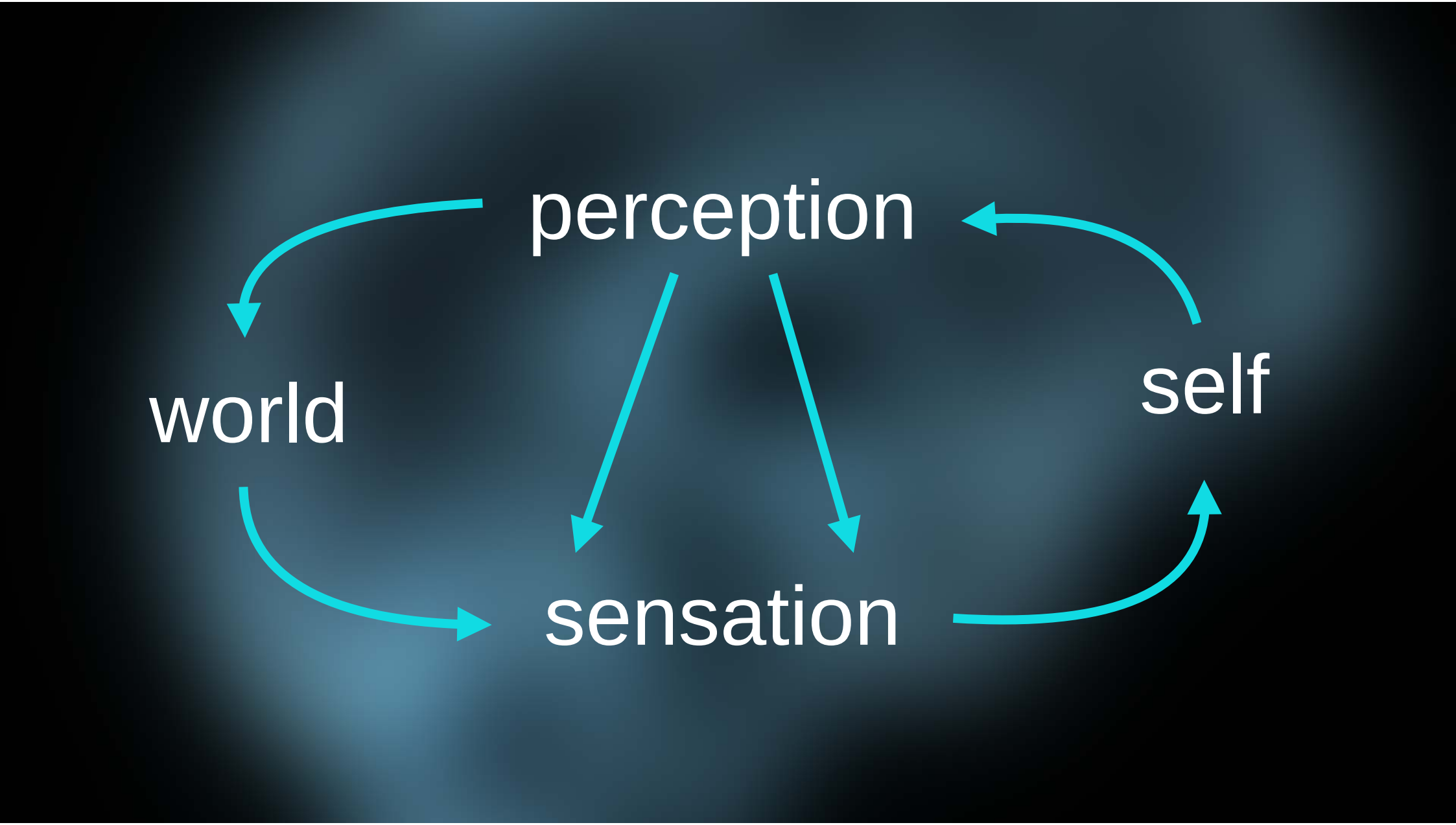
Zafeirios Fountas

Roseboom et al (2019) *Nature Communications*

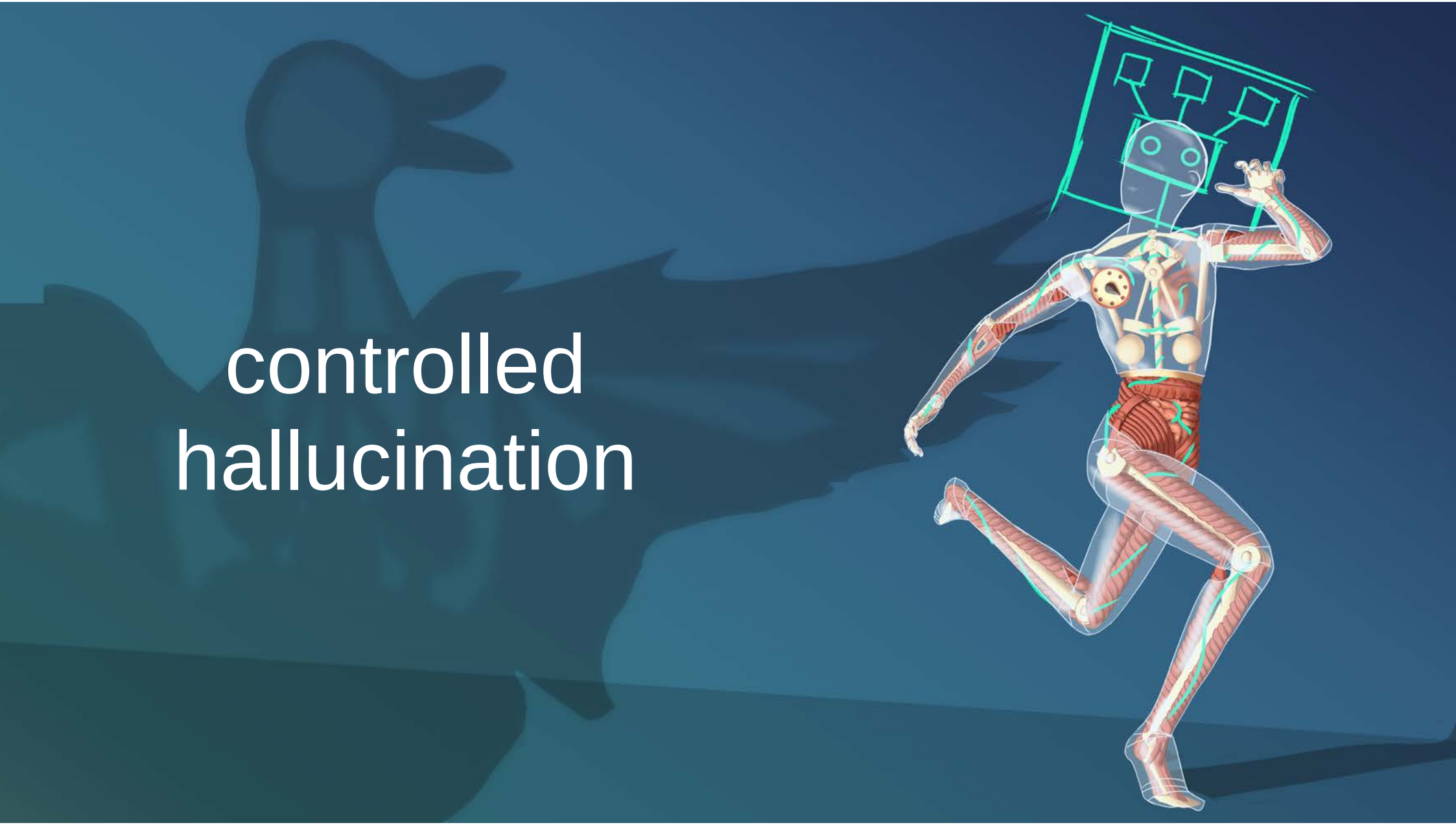
Sherman et al (2022) *BioRXiv*

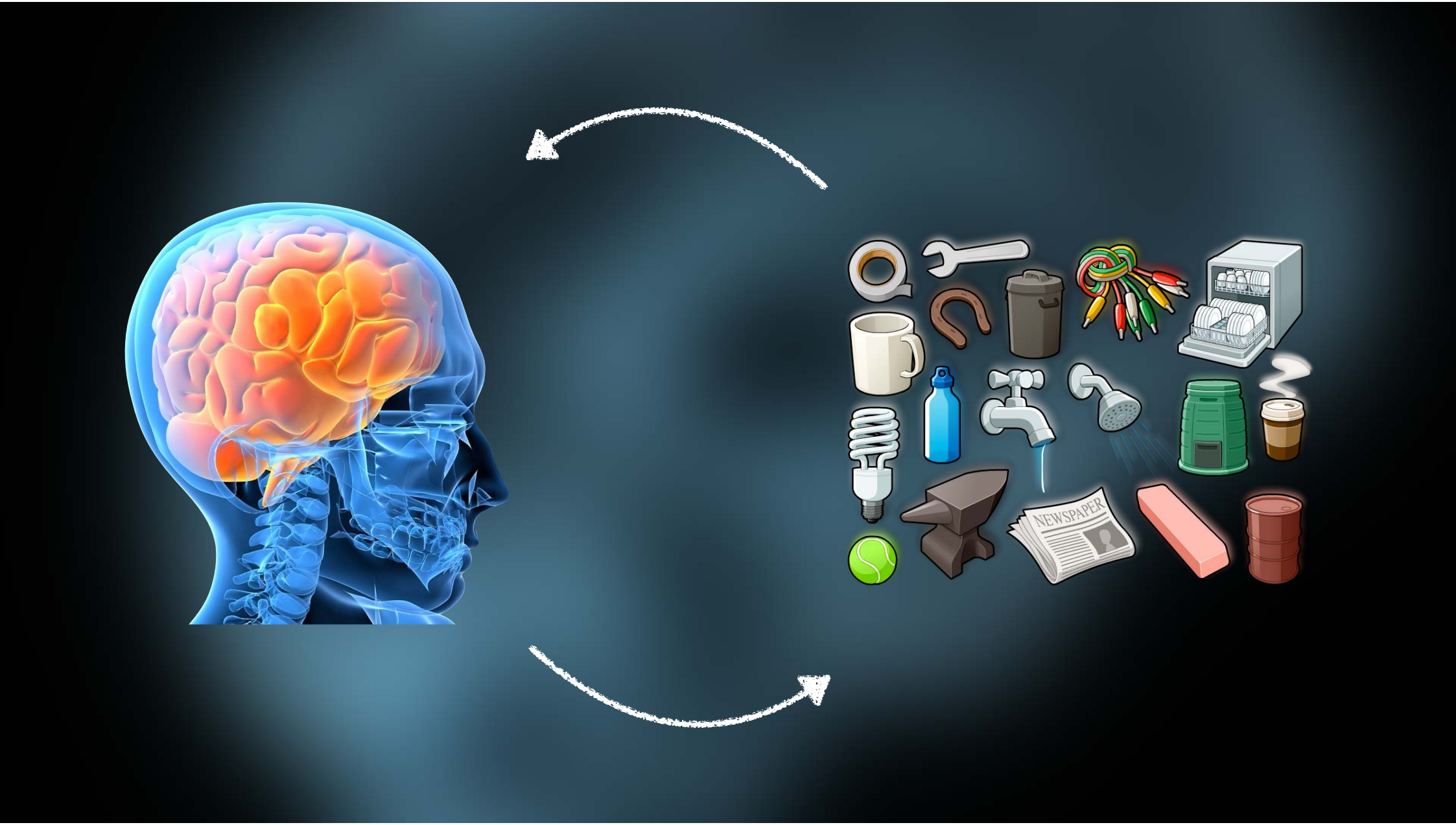
Fountas et al (in press) *Neural Computation*


perception
world
self
sensation


perception
world
self
sensation

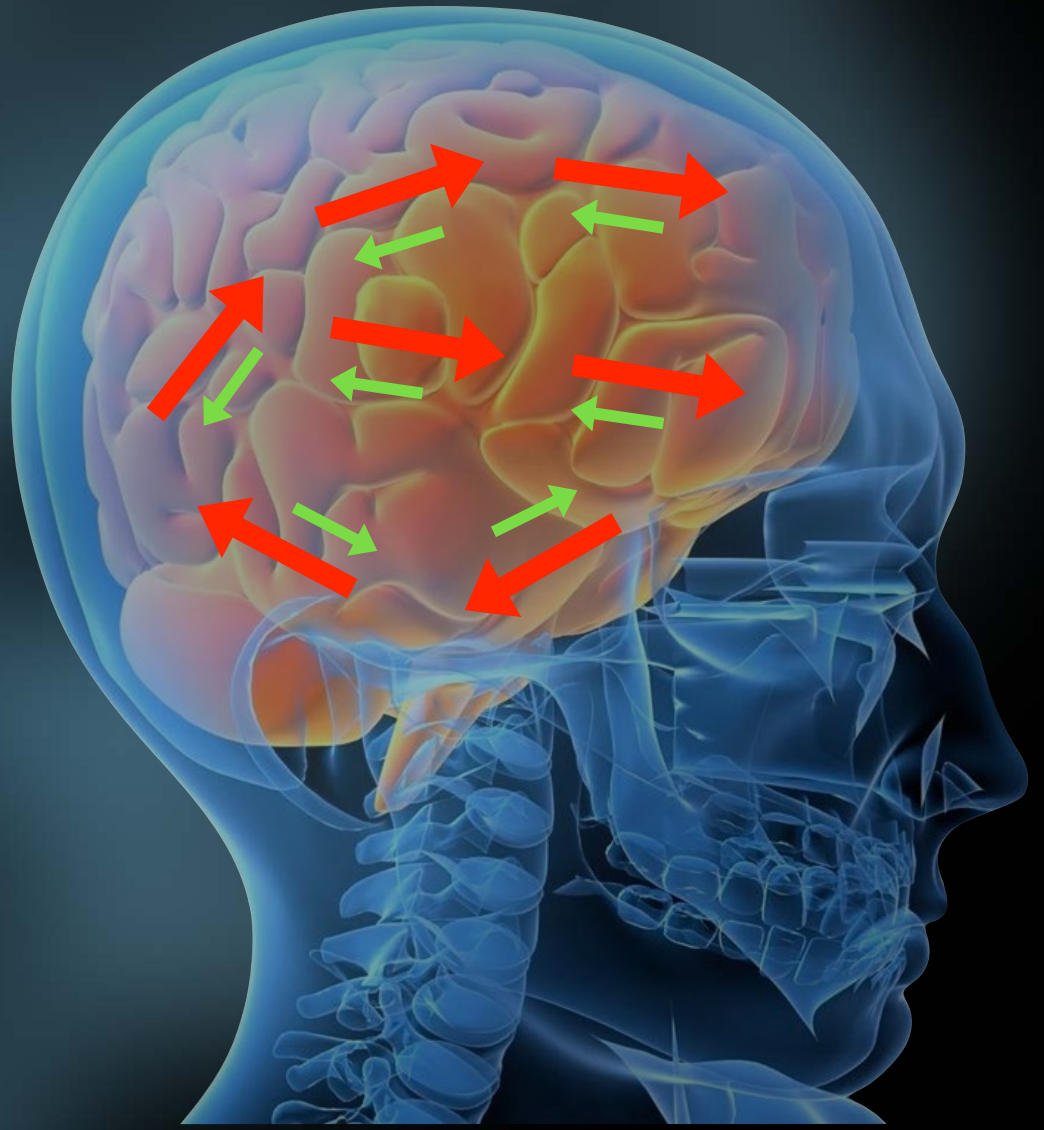
controlled
hallucination

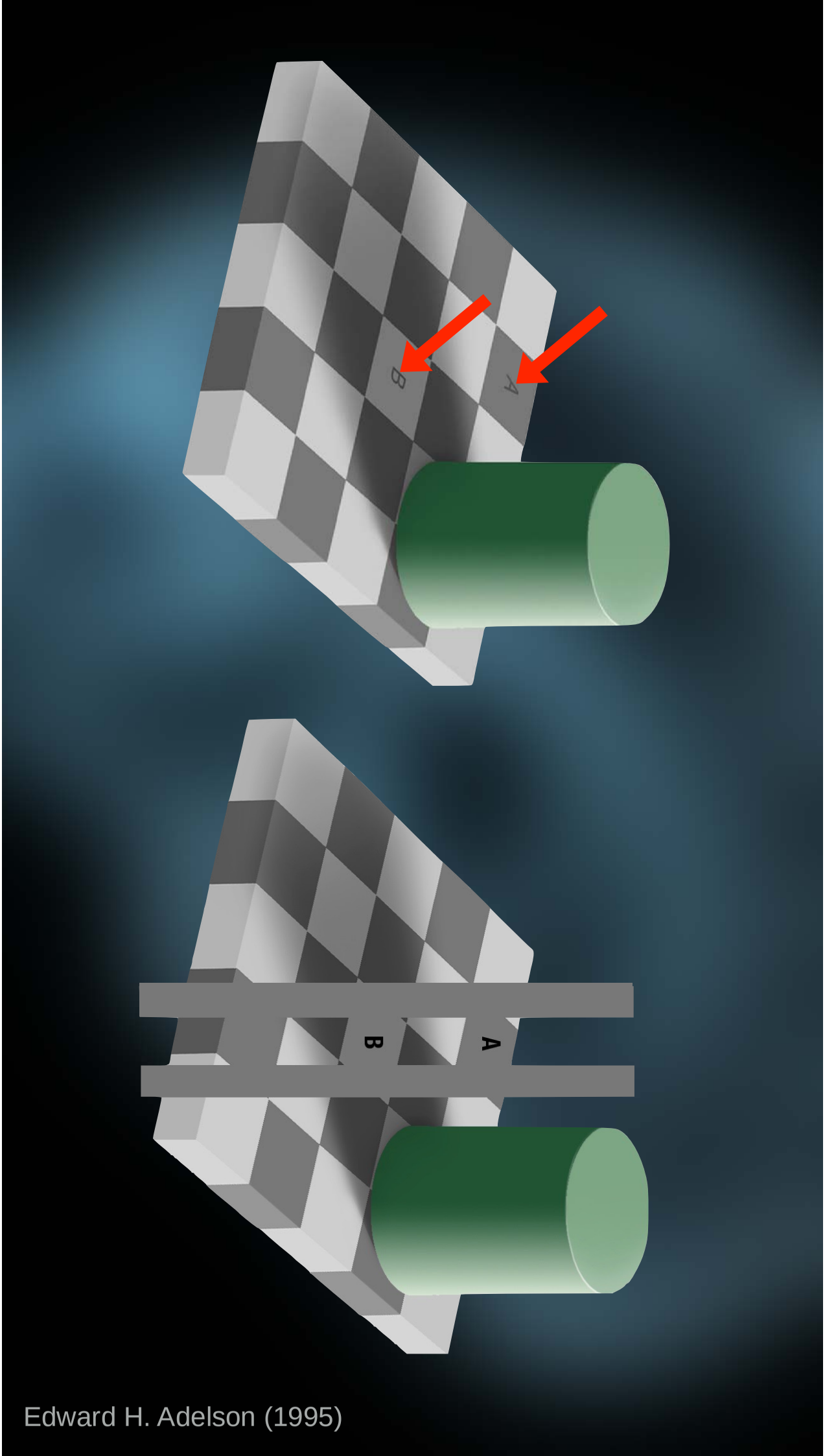



NEWSPAPER

predictive processing

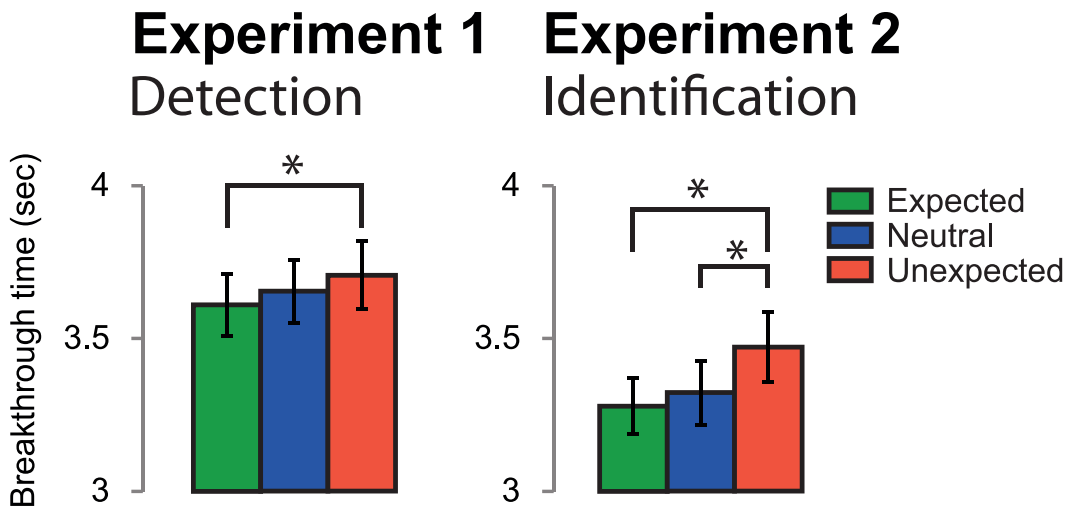
- perceptual content is conveyed by top-down predictions
- bottom-up ‘sensory’ signals convey prediction errors



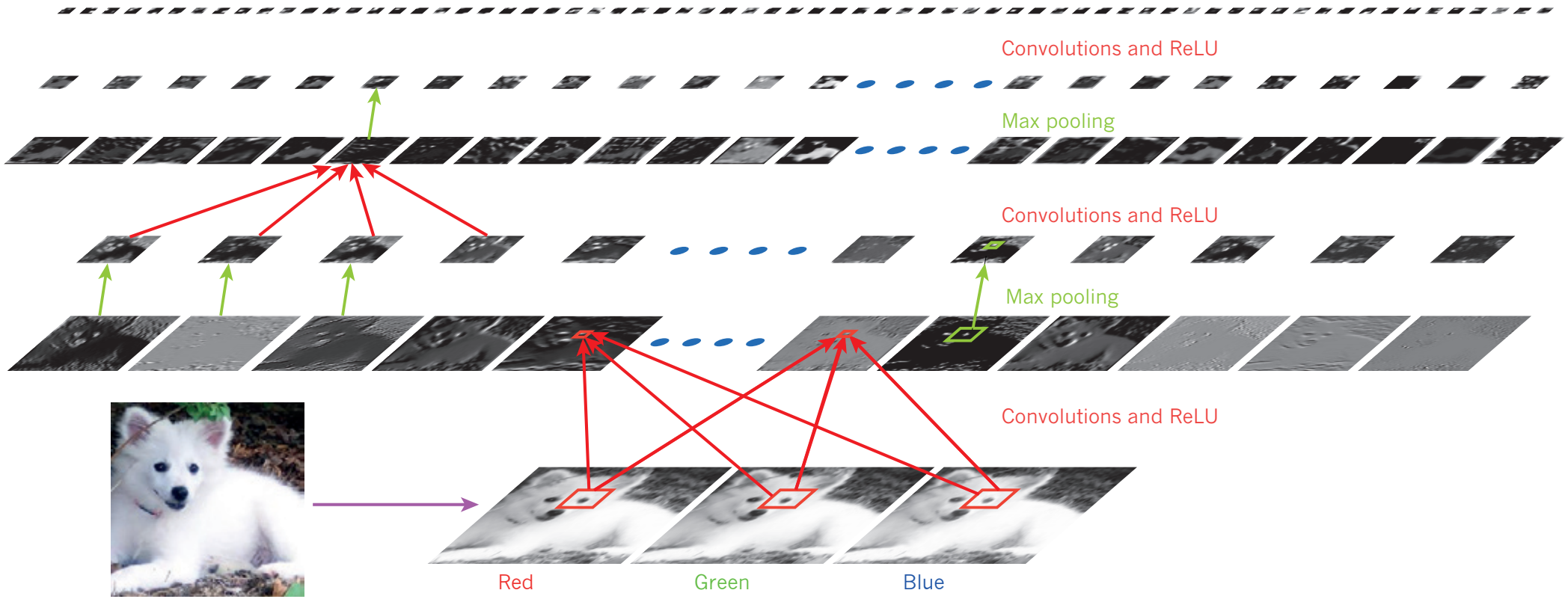


Edward H. Adelson (1995)

perceiving the expected



Pinto et al (2015) *Journal of Vision*



Le Cun et al (2015) *Nature*

Suzuki et al (2017) *Scientific Reports*

hallucination:
uncontrolled perception

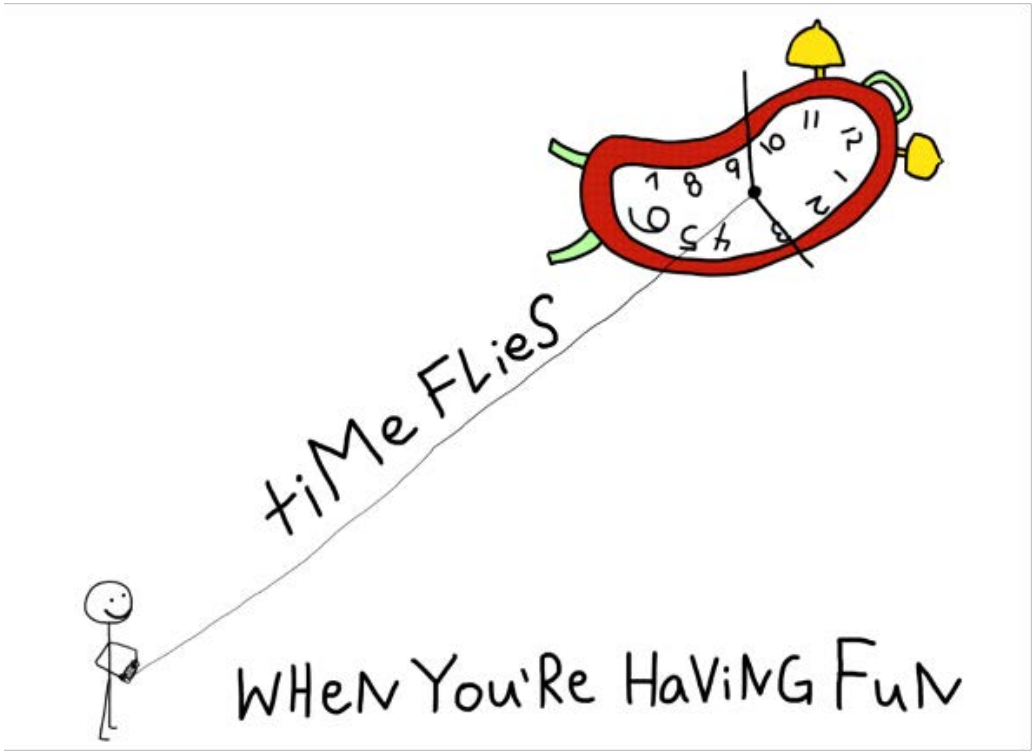
perception:
controlled hallucination


taste
sense of reality
smell
duration
colour
time
sound
objecthood
self

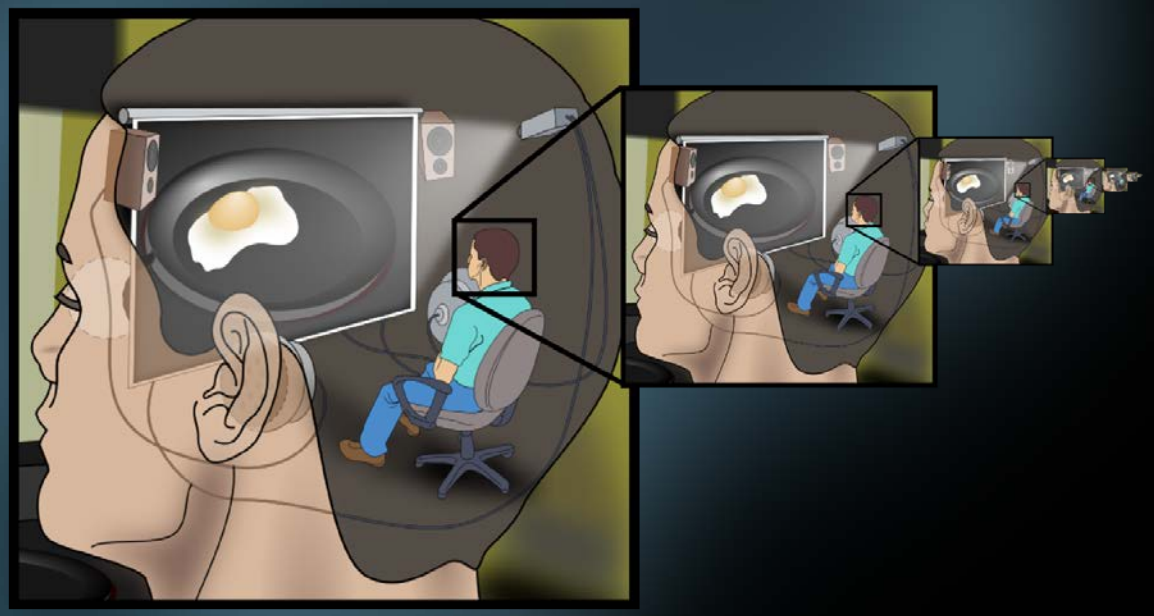

taste
sense of reality
smell
duration
colour
time
sound
objecthood
self

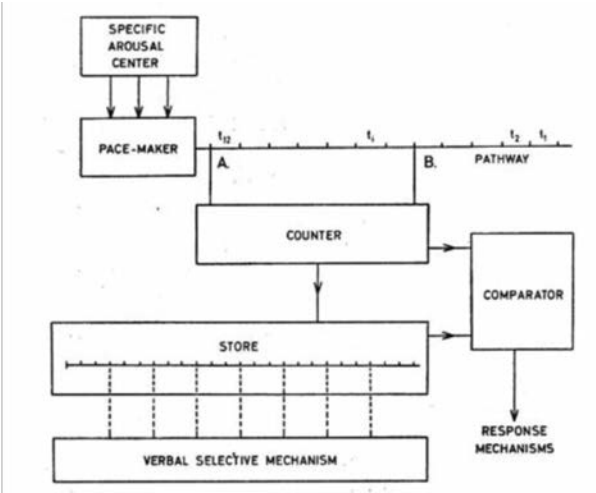

time perception

PERFORMANCE ANXIETY

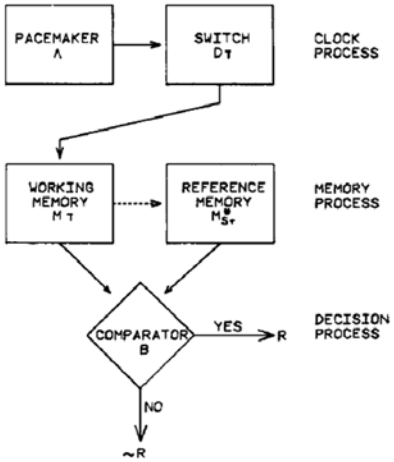


clocks in the head?

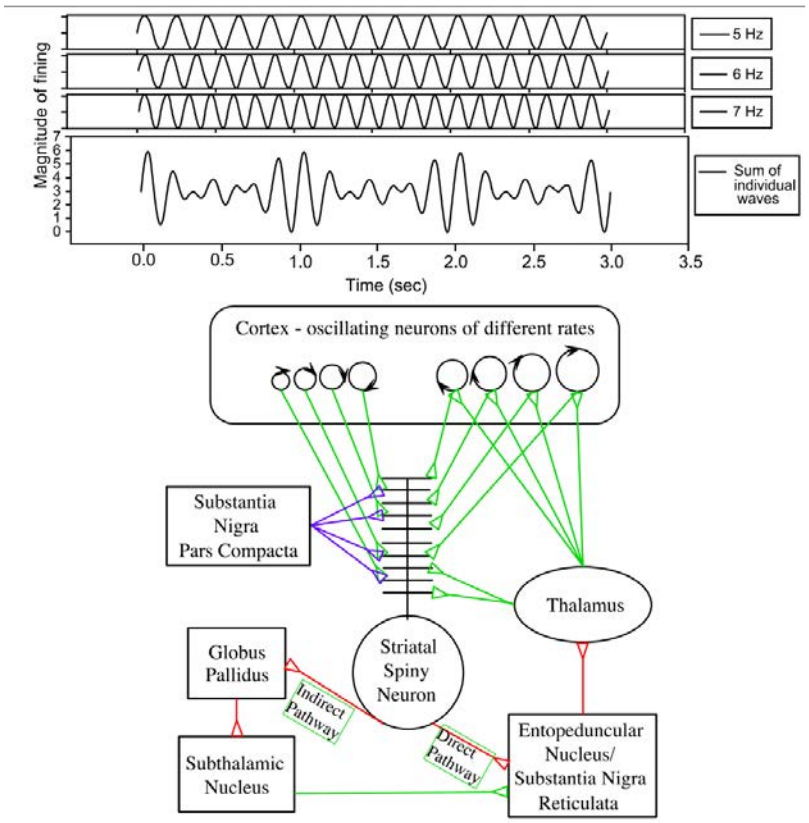




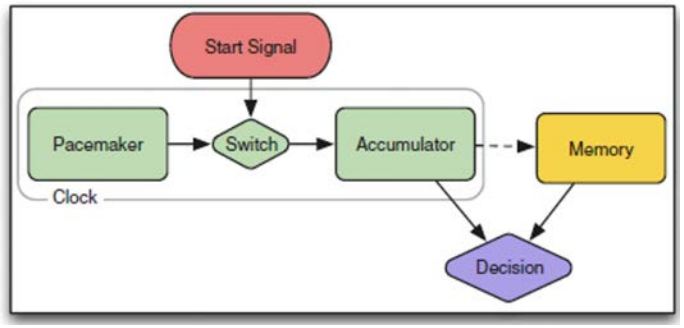
Treisman (1963)



Gibbon et al (1984)



Mattell & Meck (2004)



van Rijn et al (2014)

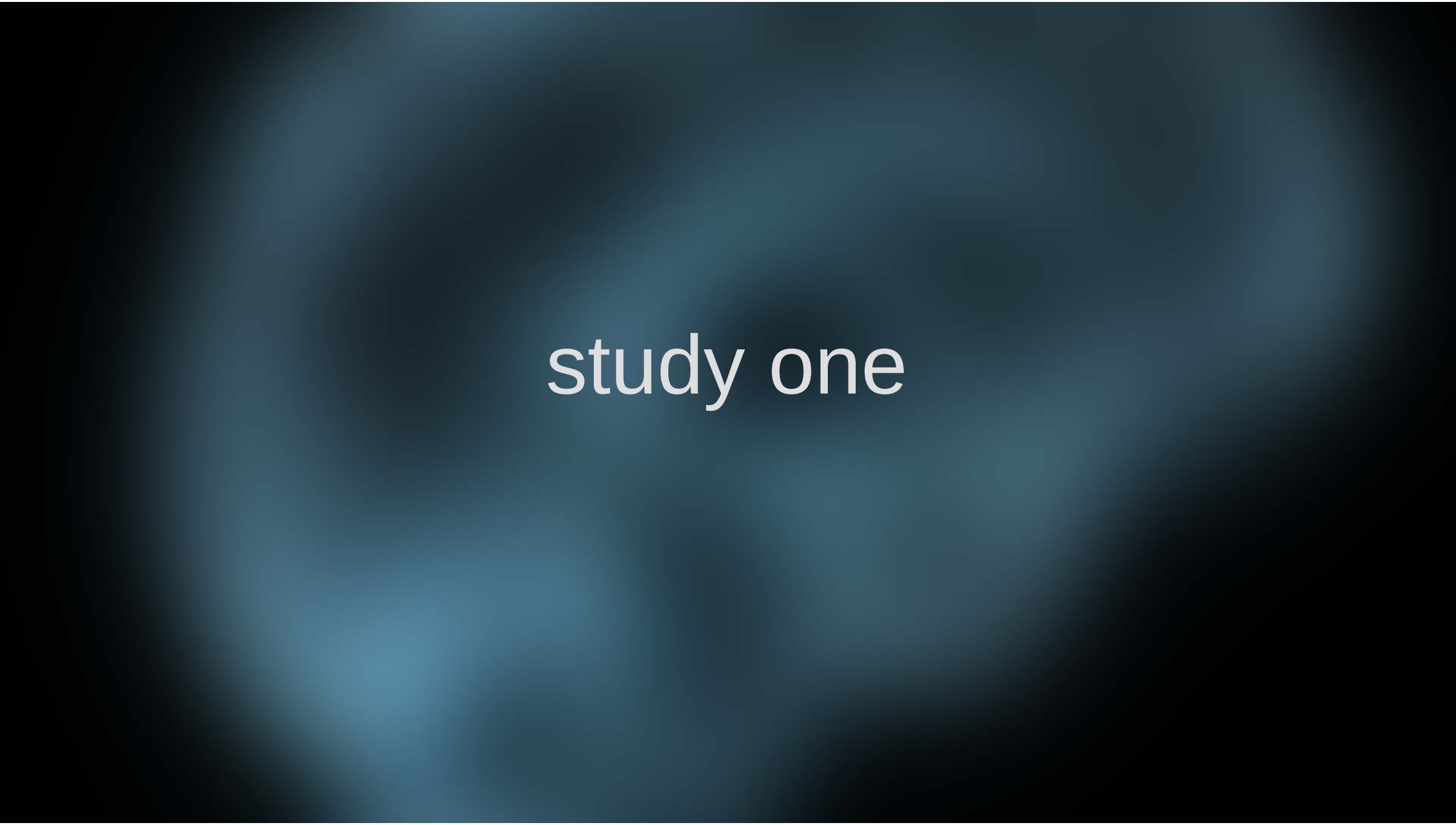
time perception

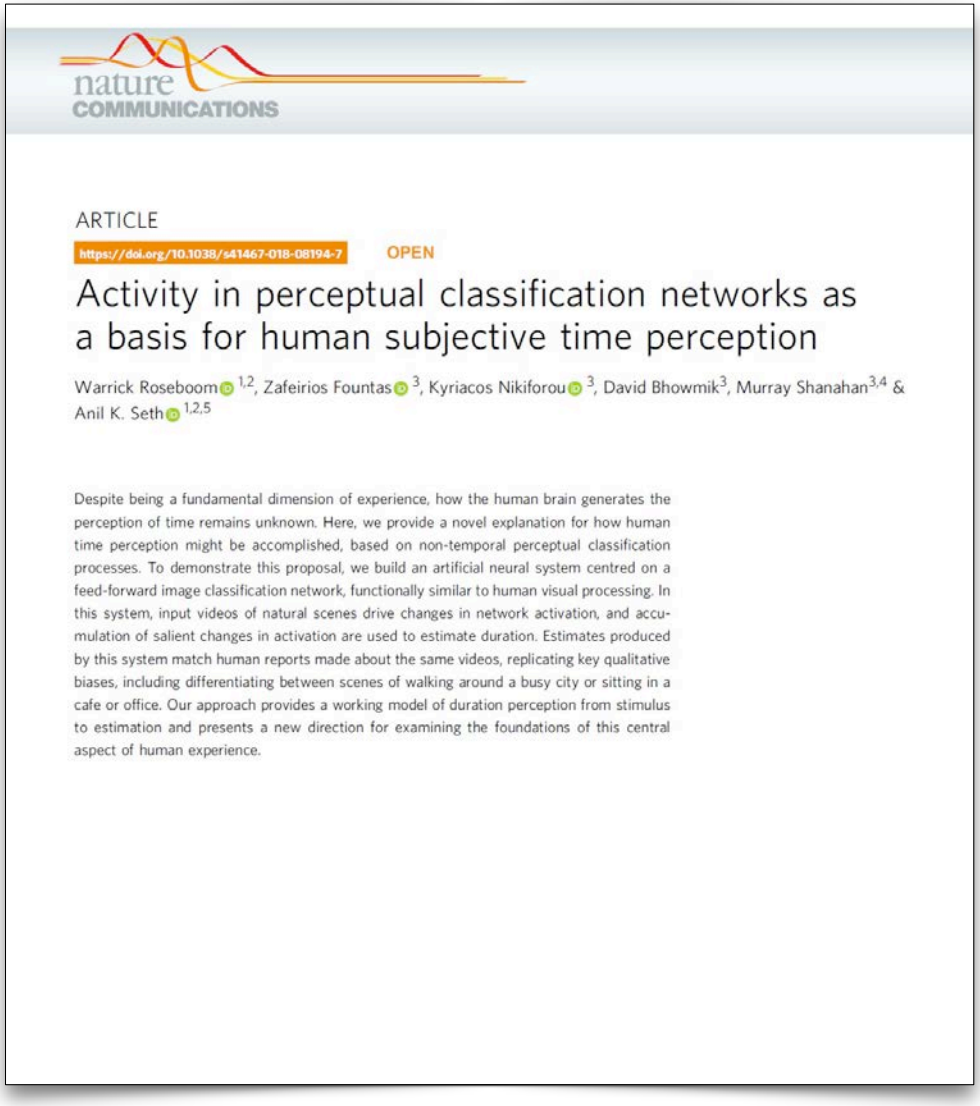
- proposal: subjective duration is based on accumulated salient perceptual change across multiple levels of processing
- not merely changes in low-level stimulus properties

Roseboom et al (2019) *Nature Communications*

Sherman et al (2022) *BioRXiv*

Fountas et al (in press) *Neural Computation*


study one



nature COMMUNICATIONS

ARTICLE

https://doi.org/10.1038/s41467-018-08194-7 OPEN

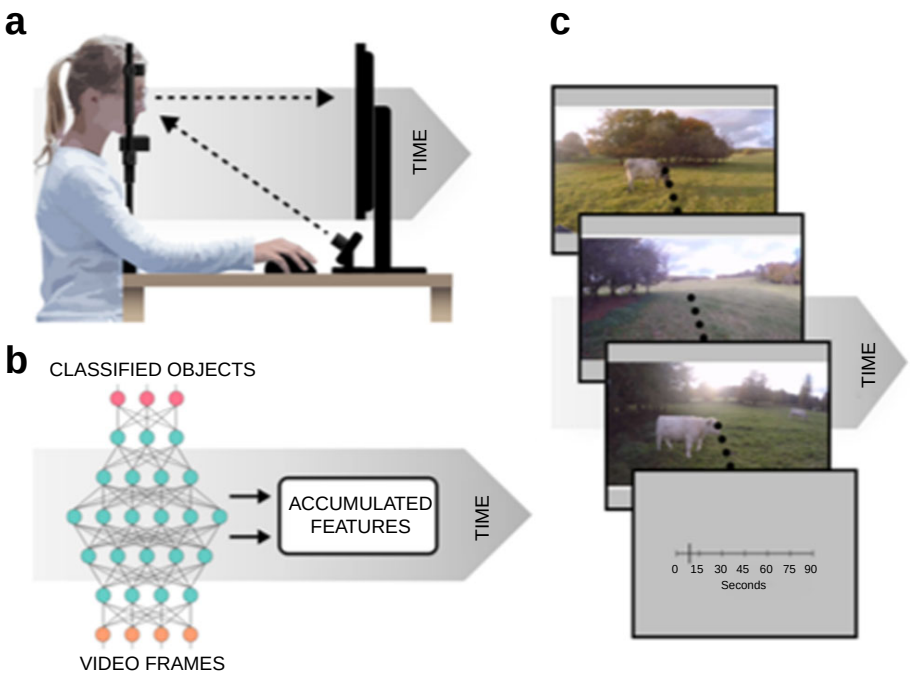
Activity in perceptual classification networks as a basis for human subjective time perception

Warrick Roseboom[1,2], Zafeirios Fountas[3], Kyriacos Nikiforou[3], David Bhowmik[3], Murray Shanahan[3,4] & Anil K. Seth[1,2,5]

Despite being a fundamental dimension of experience, how the human brain generates the perception of time remains unknown. Here, we provide a novel explanation for how human time perception might be accomplished, based on non-temporal perceptual classification processes. To demonstrate this proposal, we build an artificial neural system centred on a feed-forward image classification network, functionally similar to human visual processing. In this system, input videos of natural scenes drive changes in network activation, and accumulation of salient changes in activation are used to estimate duration. Estimates produced by this system match human reports made about the same videos, replicating key qualitative biases, including differentiating between scenes of walking around a busy city or sitting in a cafe or office. Our approach provides a working model of duration perception from stimulus to estimation and presents a new direction for examining the foundations of this central aspect of human experience.

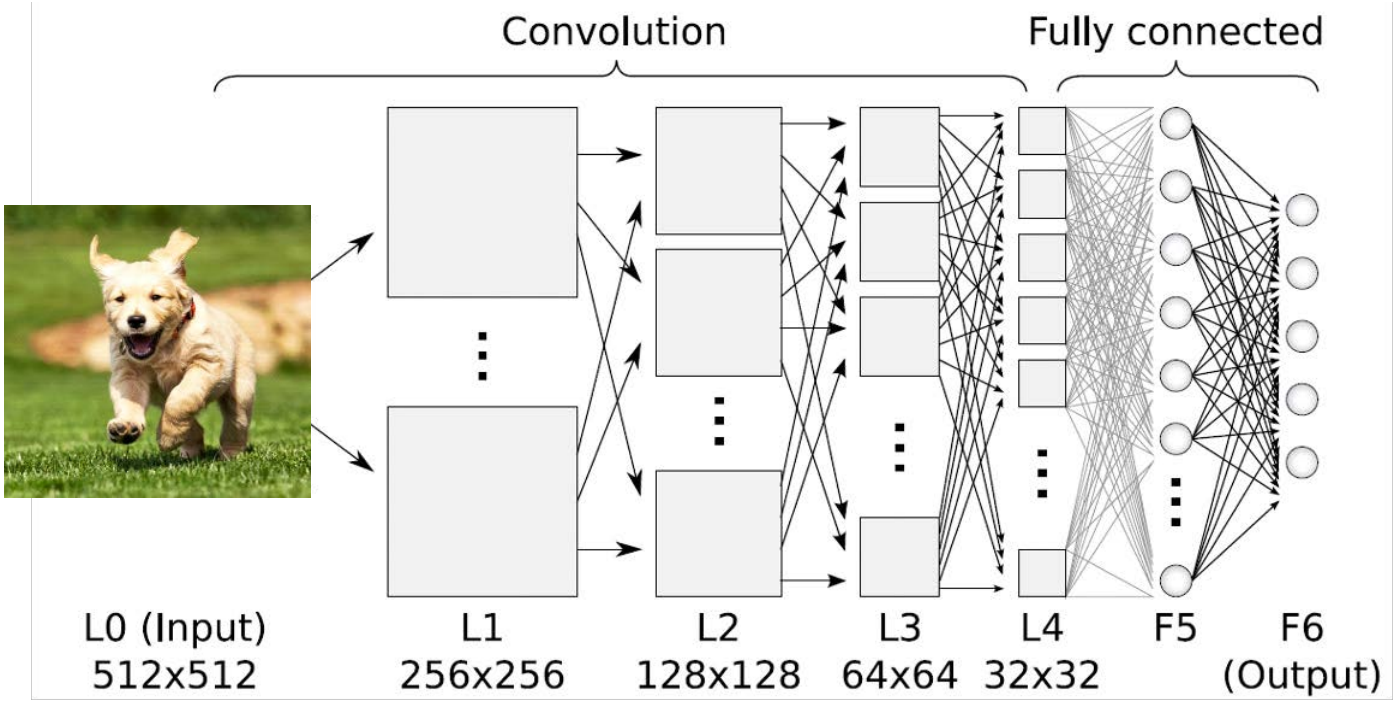
Roseboom W., Fountas, Z., Nikiforou, K., Bhowmilk, D., Shanahan, M., & Seth, A.K. (2019) *Nature Communications*

paradigm



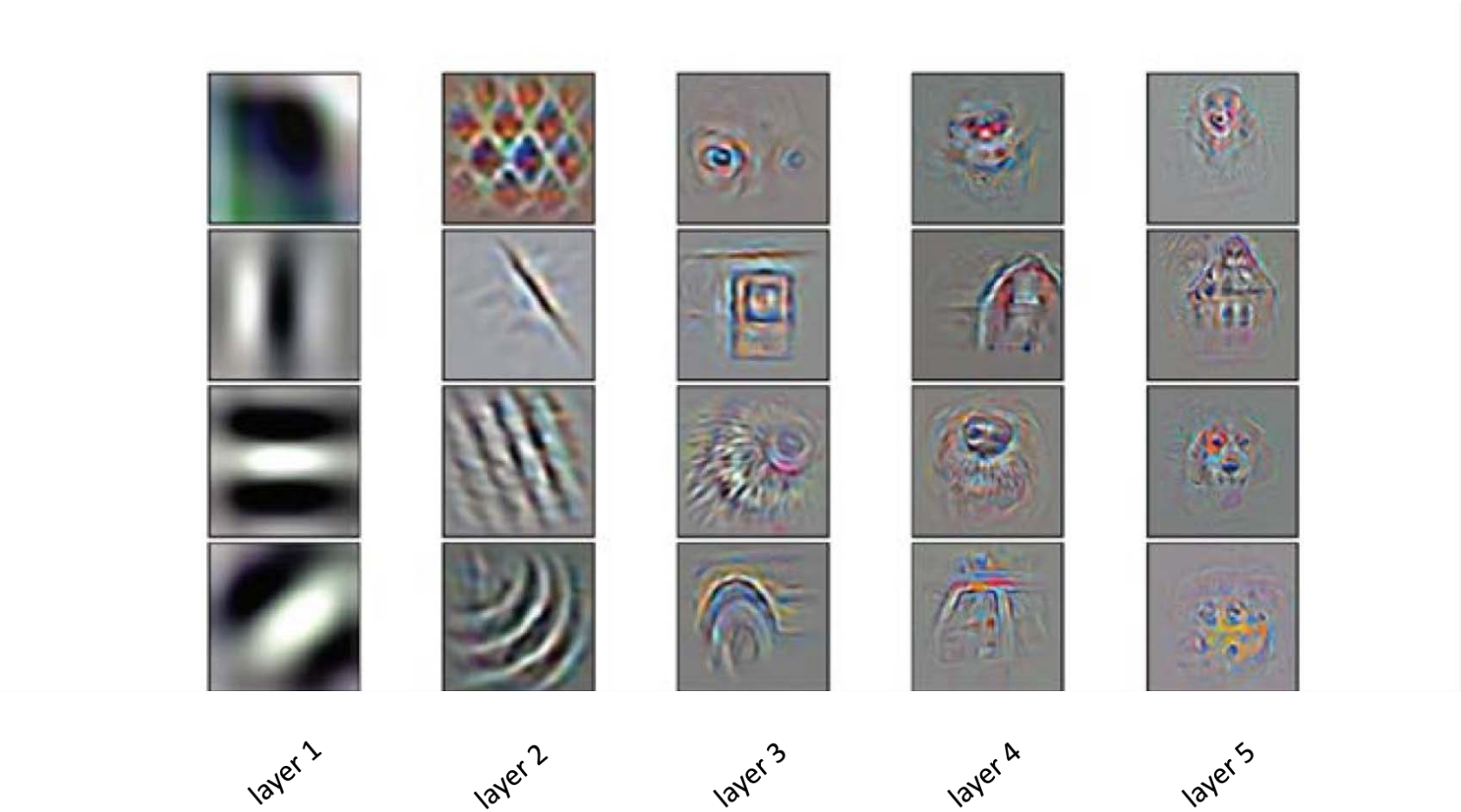
Roseboom et al (2019) *Nat Comms*

image classification



Le Cun et al (2015) *Nature*

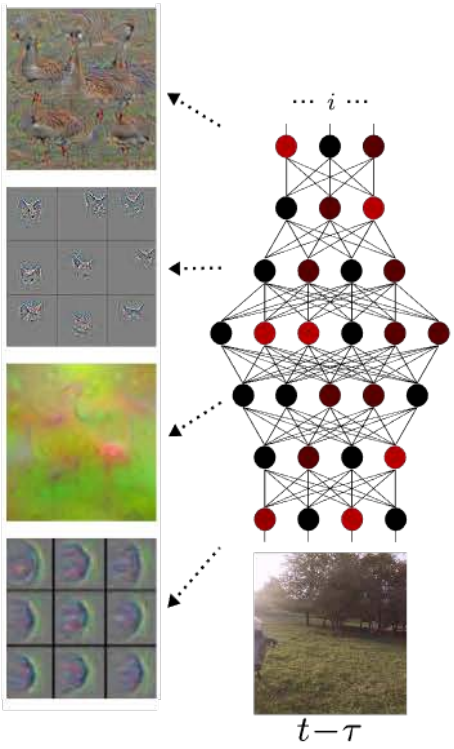
DCNN ‘receptive fields’



Kriegeskorte (2015)

Guclu & van Green (2015)

computational model



Roseboom et al (2019) *Nat Comms*

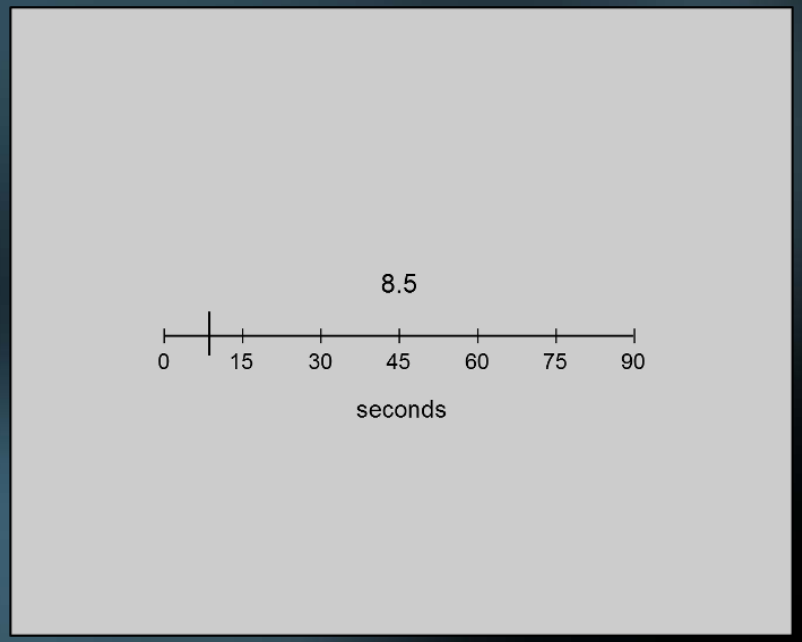

Roseboom et al (2019) *Nat Comms*


Roseboom et al (2019) *Nat Comms*


Roseboom et al (2019) *Nat Comms*

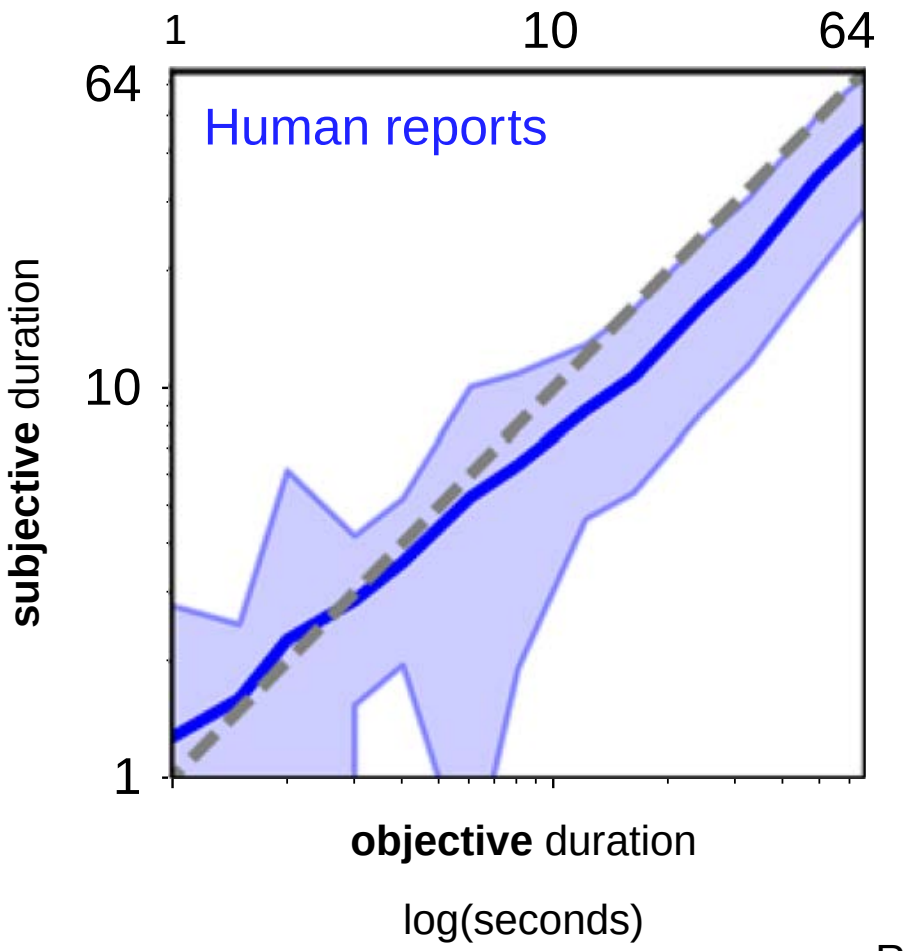
human experiment

- videos of (objective duration) 1-64 sec
- 4290 trials ~= 55 hours of data
- each participant completed up to 1 hour of trials
- eye tracking also measured



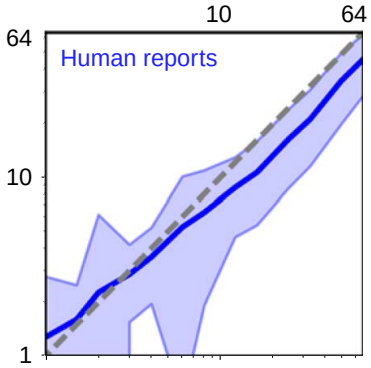
Roseboom et al (2019) *Nature Communications*

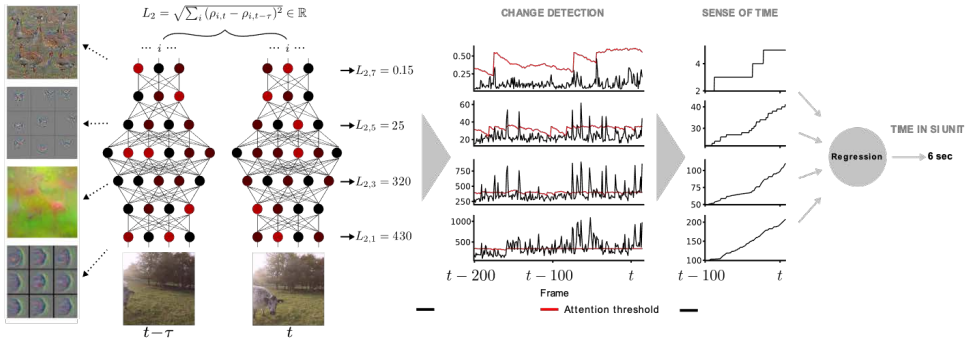
human experiment



Roseboom et al (2019) *Nature Communications*

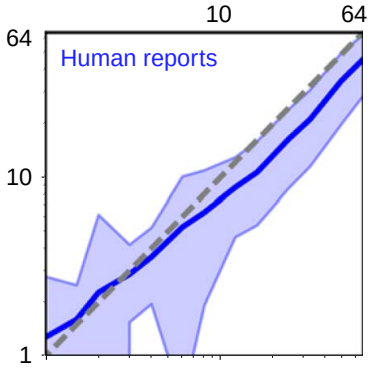
computational model

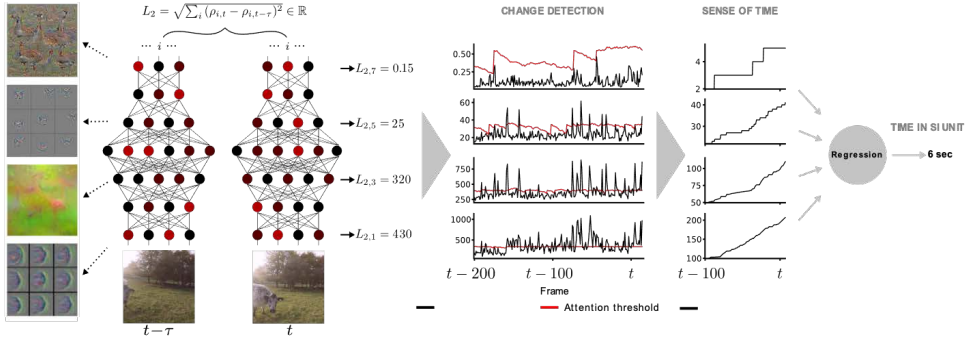


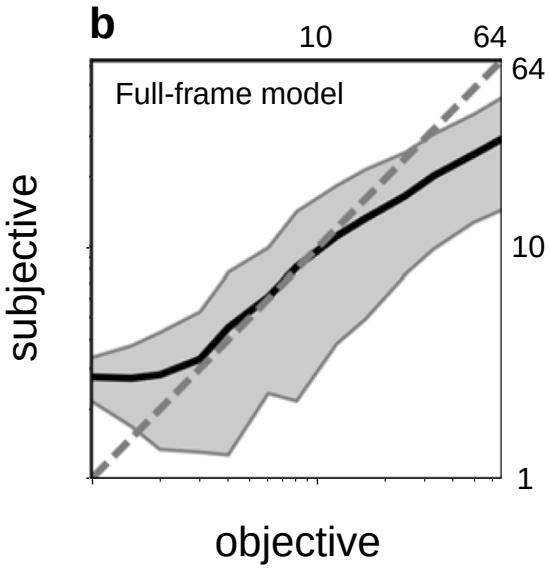


Roseboom et al (2019) *Nature Communications*

computational model

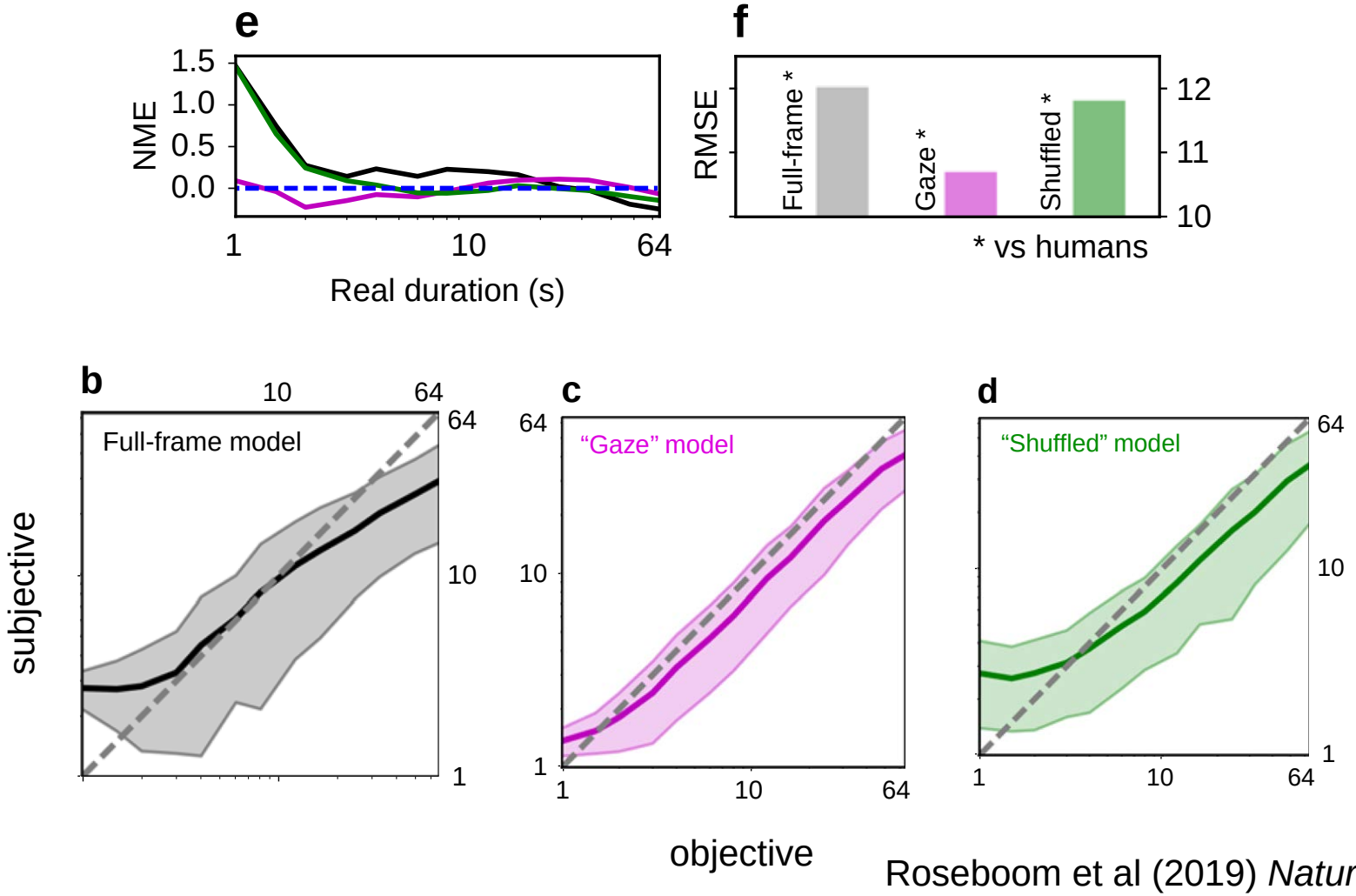






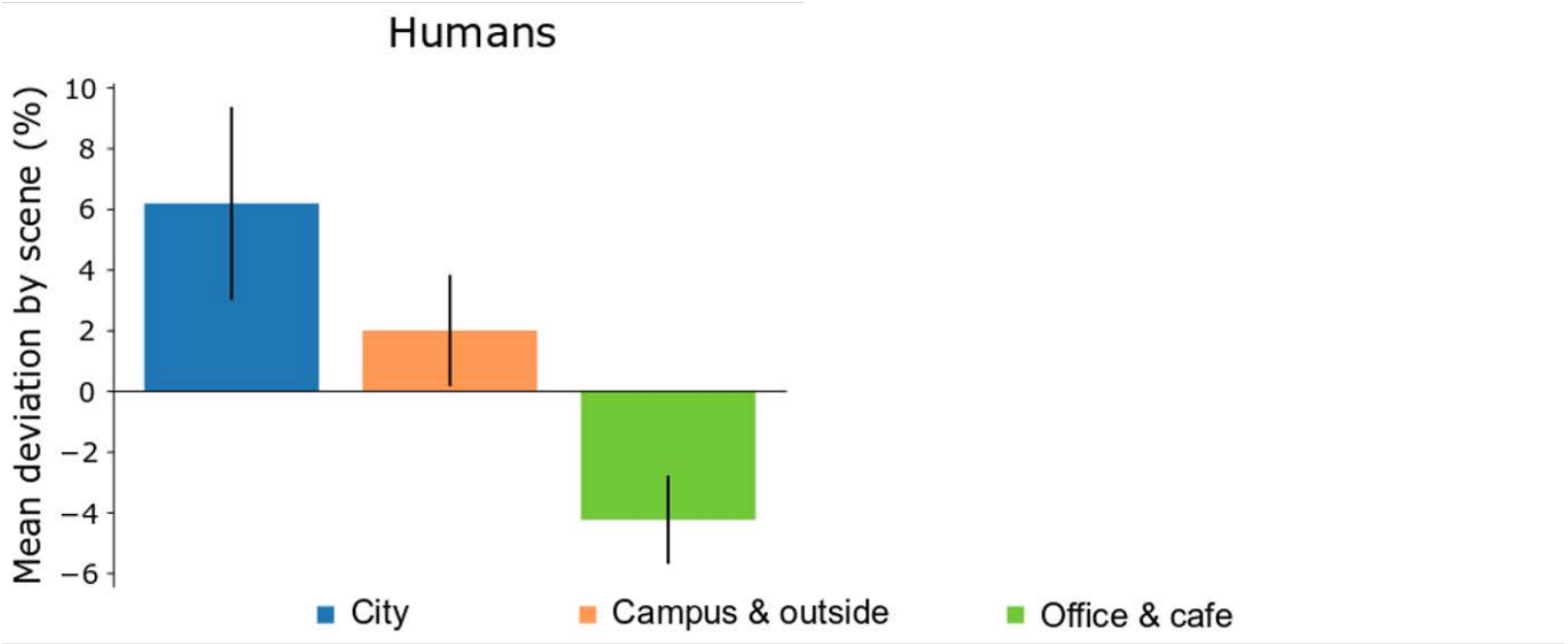
Roseboom et al (2019) *Nature Communications*

computational model

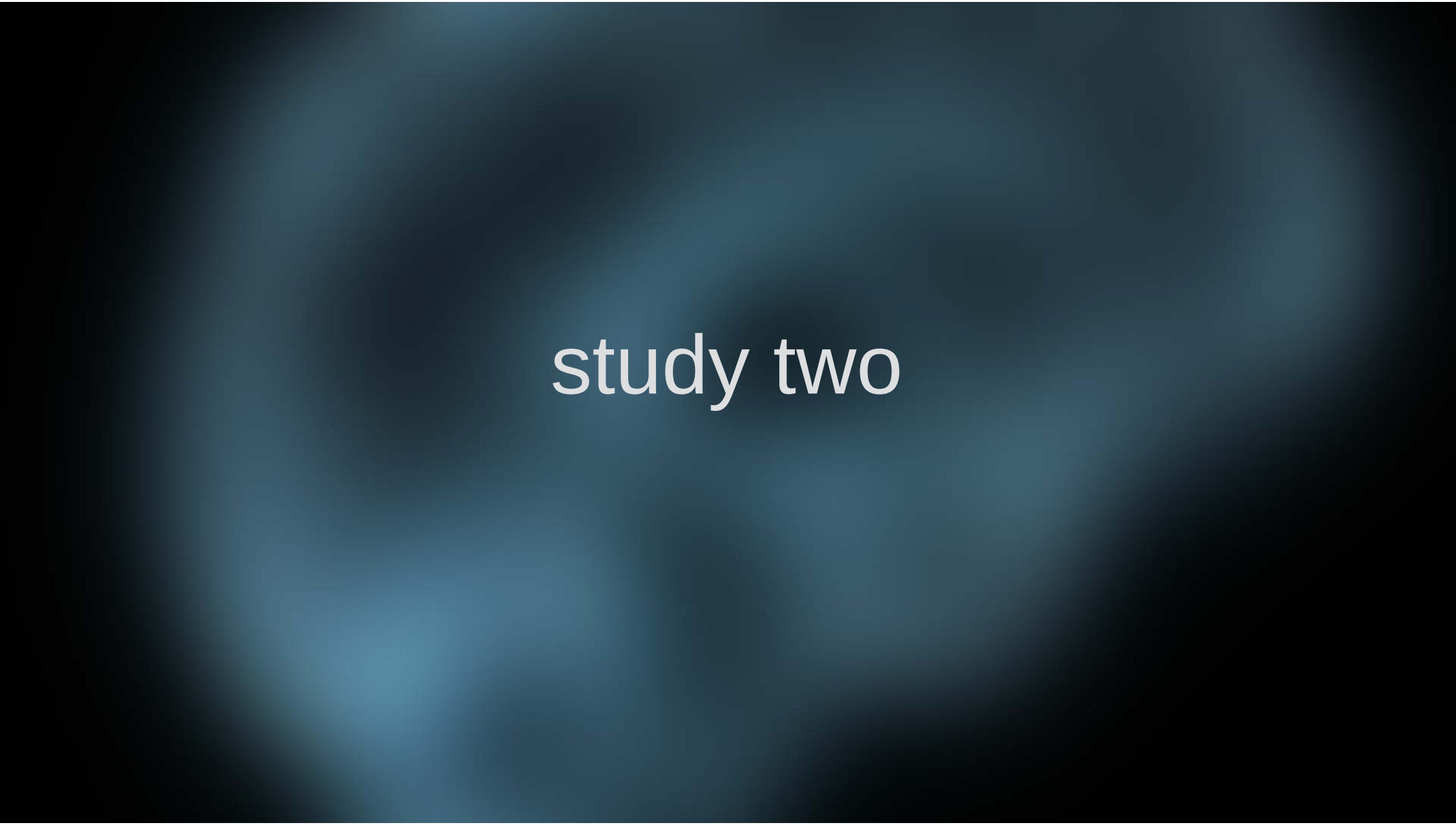


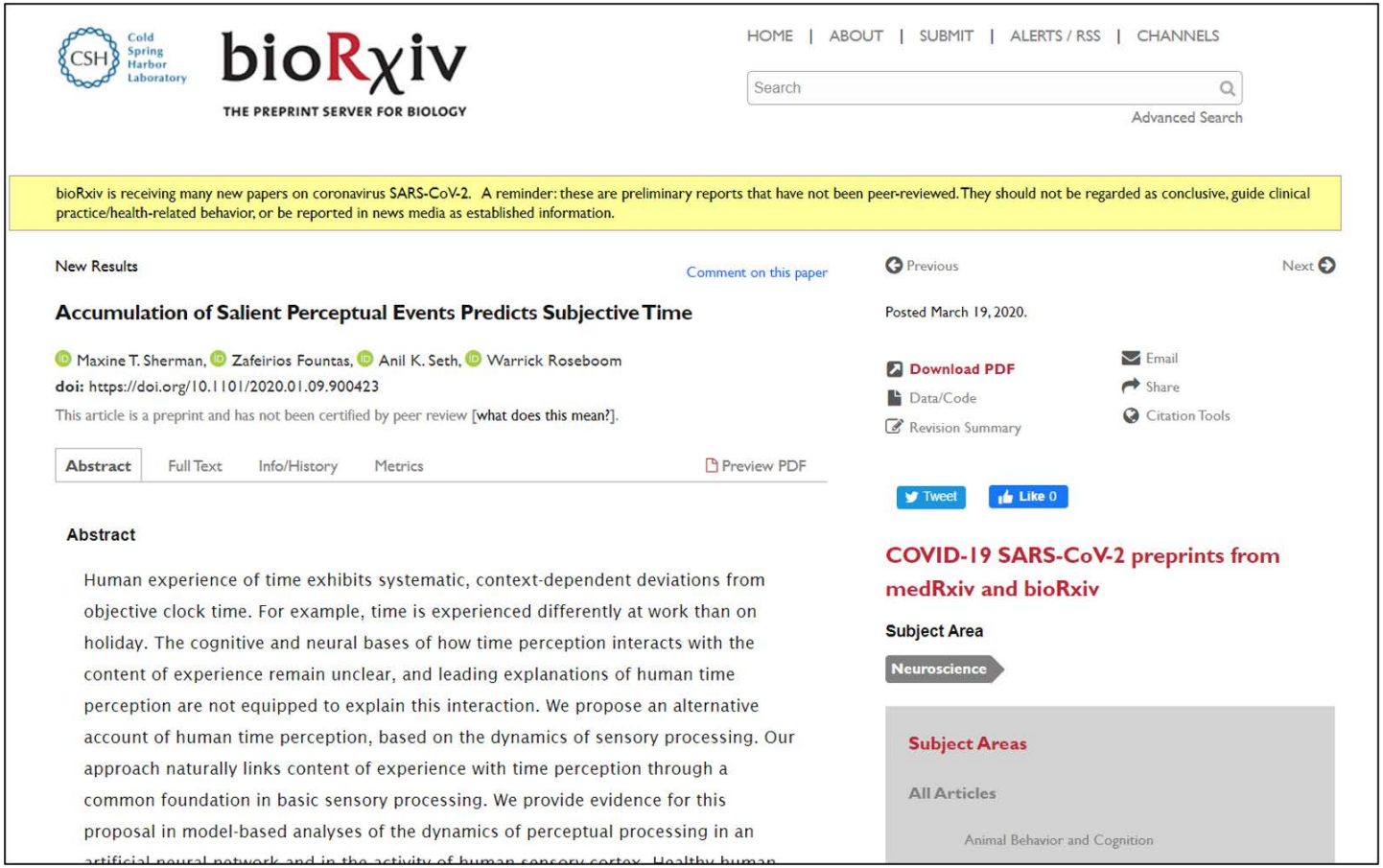
Roseboom et al (2019) *Nature Communications*

effect of context



Roseboom et al (2019) *Nature Communications*


study two



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New Results

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Accumulation of Salient Perceptual Events Predicts Subjective Time

Posted March 19, 2020.

Maxine T. Sherman, Zafeirios Fountas, Anil K. Seth, Warrick Roseboom

doi: https://doi.org/10.1101/2020.01.09.900423

This article is a preprint and has not been certified by peer review [what does this mean?].

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Abstract

Human experience of time exhibits systematic, context-dependent deviations from objective clock time. For example, time is experienced differently at work than on holiday. The cognitive and neural bases of how time perception interacts with the content of experience remain unclear, and leading explanations of human time perception are not equipped to explain this interaction. We propose an alternative account of human time perception, based on the dynamics of sensory processing. Our approach naturally links content of experience with time perception through a common foundation in basic sensory processing. We provide evidence for this proposal in model-based analyses of the dynamics of perceptual processing in an artificial neural network and in the activity of human sensory cortex. Healthy human

COVID-19 SARS-CoV-2 preprints from medRxiv and bioRxiv

Subject Area

Neuroscience

Subject Areas

All Articles

Animal Behavior and Cognition

Maxine Sherman

Sherman, M., Fountas, Z., Seth, A.K., & Roseboom, W. (submitted)

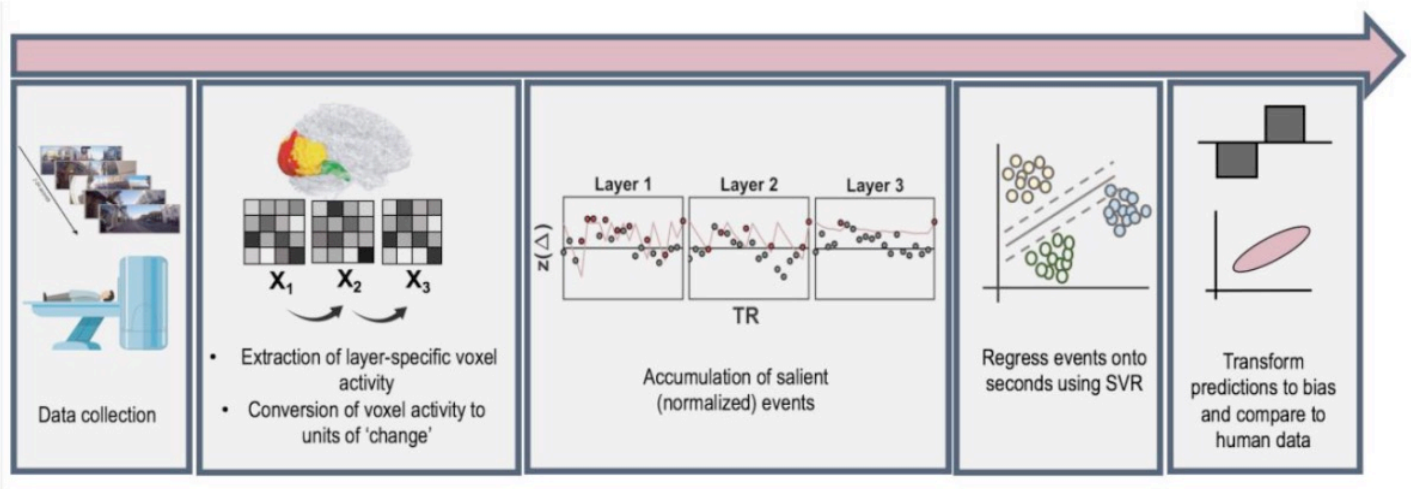
imaging experiment

- videos of (objective duration) 8-24 sec
- city scenes and office scenes
- 40 participants
- record estimated duration and calculate scene-wise bias

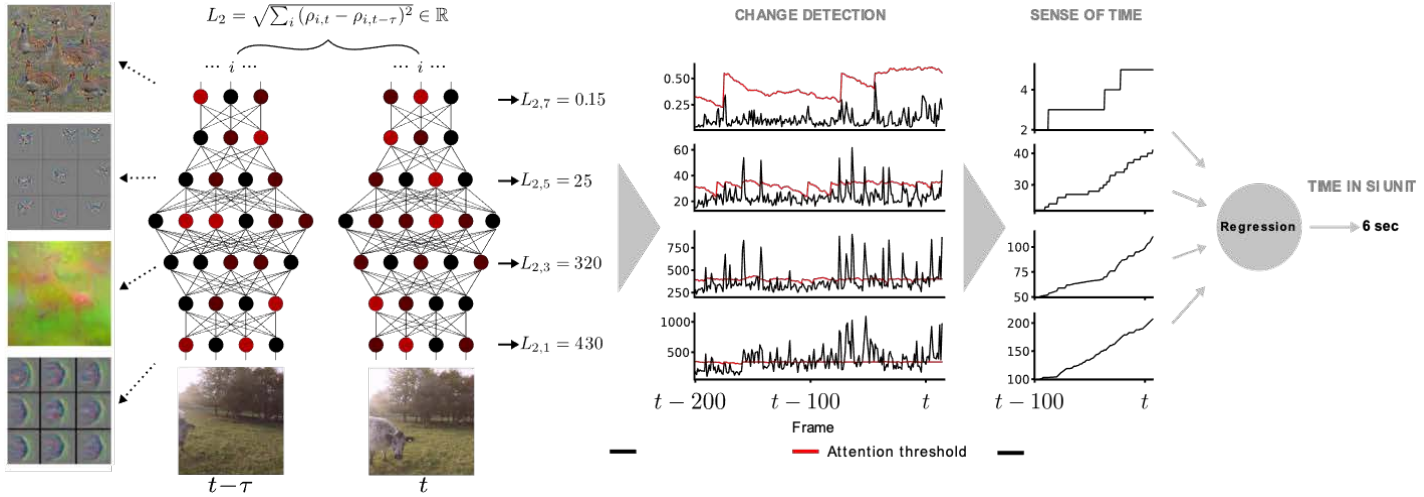
Sherman et al (submitted)

neuroimaging study

imaging

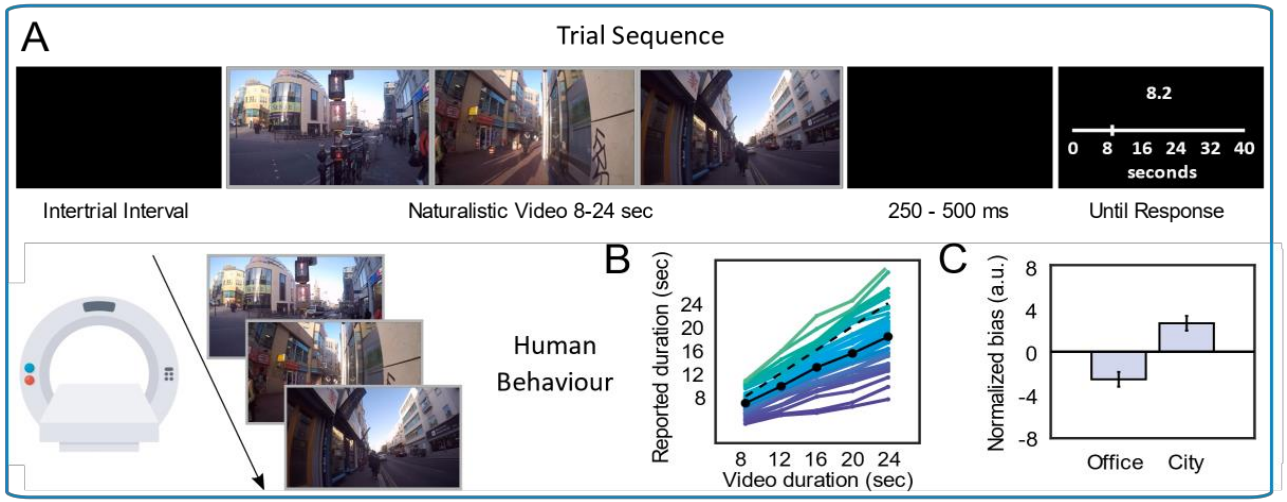


model

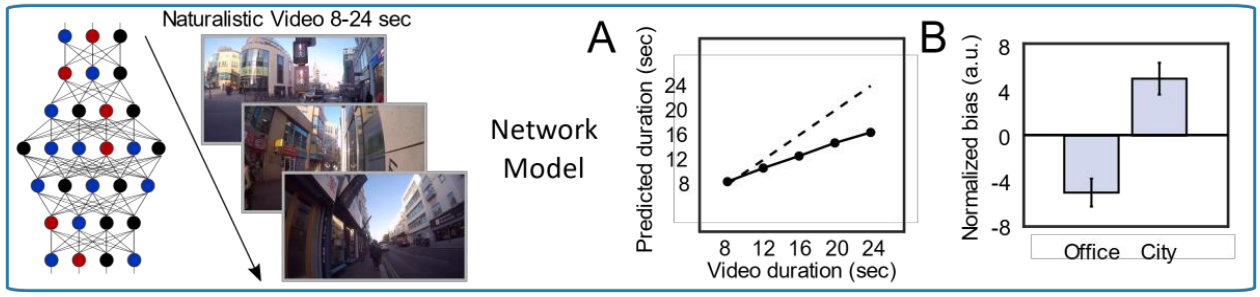


Sherman et al (submitted)

behavioural results



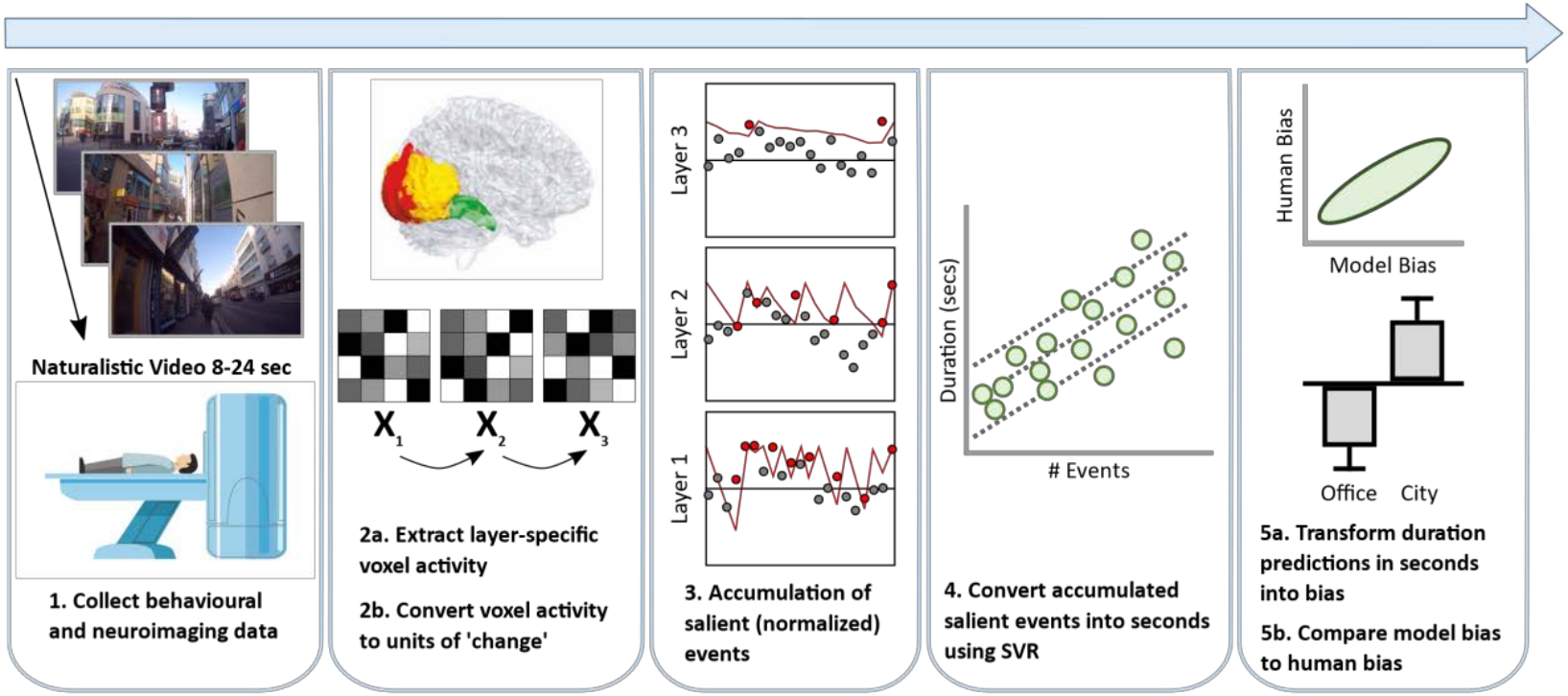
A. Naturalistic videos and ratings scale, presented while subjects were scanned using fMRI.
B. Participant-wise relationship between real and estimated duration, w/ mean and (dashed) line-of-unity.
C. Relative over/under-estimation for office vs city scenes (+/- SEM)

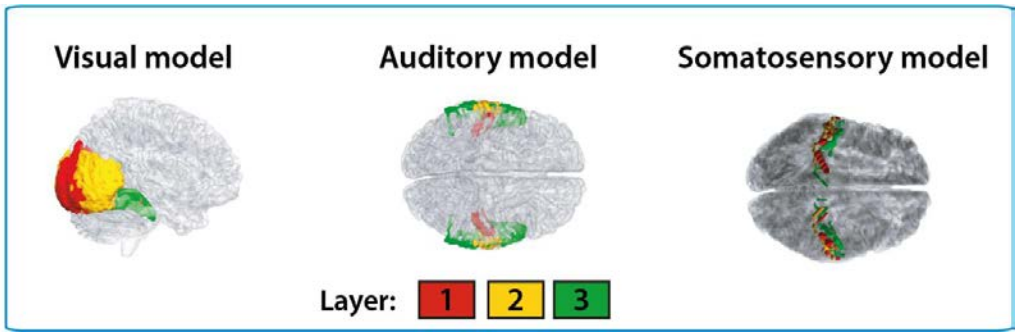


A. Relationship between real and model-estimate duration (with line-of-unity).
C. Relative over/under-estimation for office vs city scenes, for model

Sherman et al (submitted)

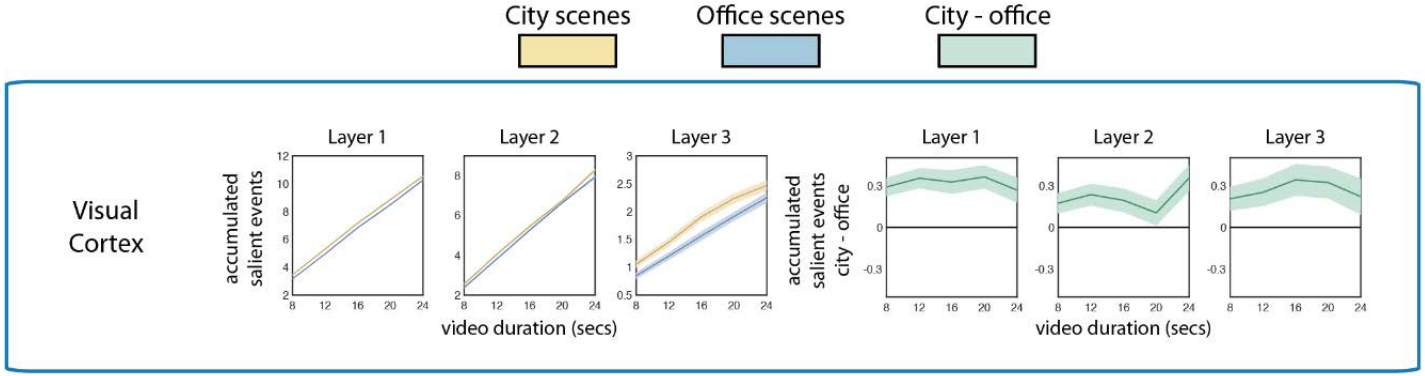
model-based fMRI





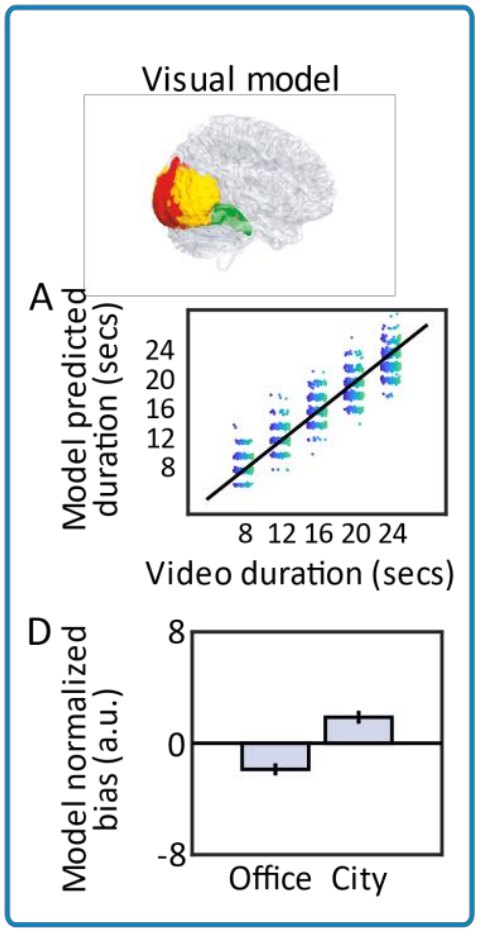
Sherman et al (submitted)

model-based fMRI

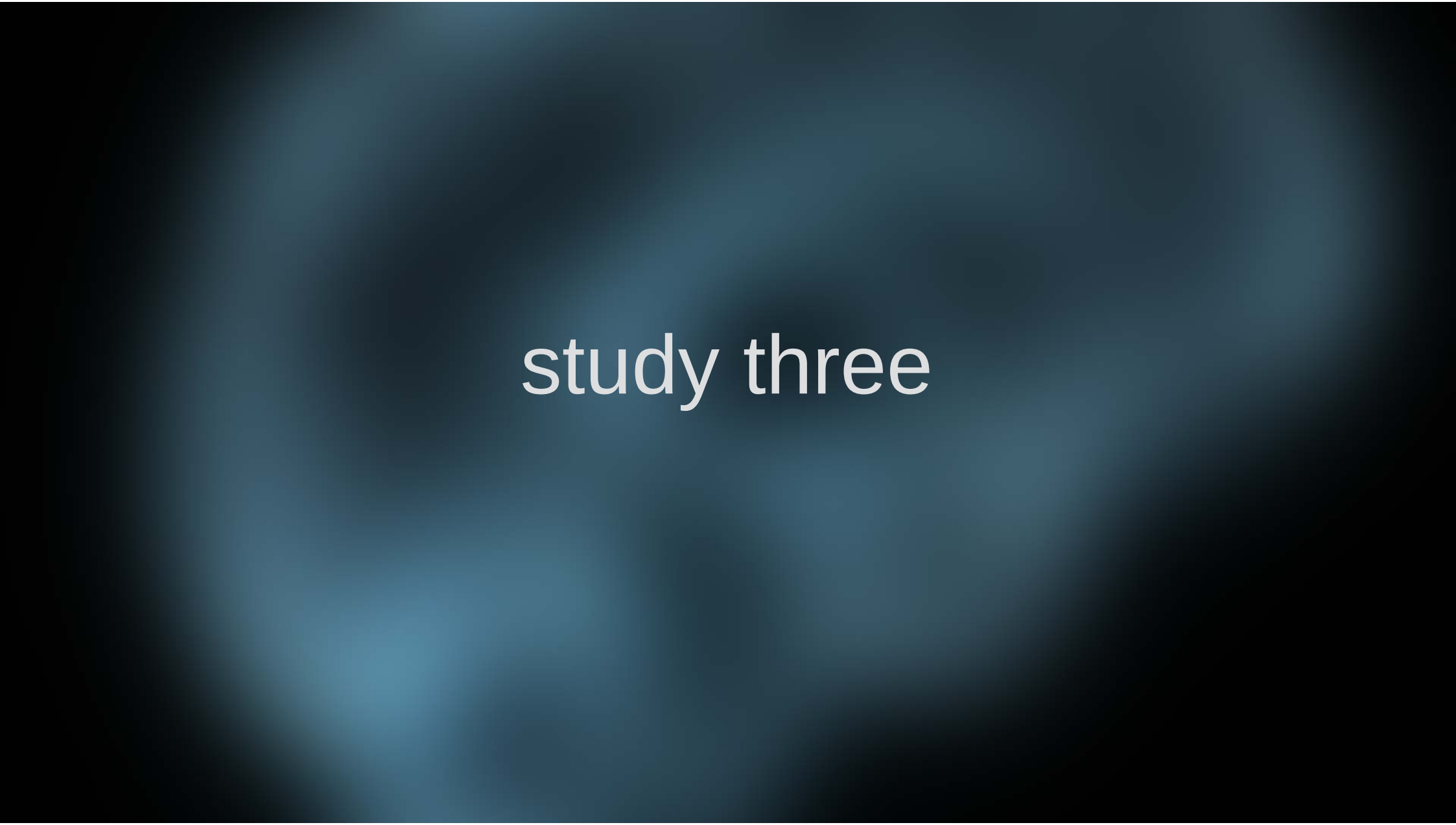


Sherman et al (submitted)

model-based fMRI



Sherman et al (submitted)


study three

A predictive processing model of episodic memory and time perception

Zafeirios Fountas[1,2], Anastasia Sylaidi[3], Kyriacos Nikiforou[4], Anil K. Seth[5,6], Murray Shanahan[4], and Warrick Roseboom[5]

[1] *Emotech Labs, London, UK*

[2] *Wellcome Centre for Human Neuroimaging, Institute of Neurology, University College London, London, UK*

[3] *Spike AI Research Labs, London, UK*

[4] *Department of Computing, Imperial College London, London, UK*

[5] *Department of Informatics and Sackler Centre for Consciousness Science, University of Sussex, Sussex, UK*

[6] *Canadian Institute for Advanced Research (CIFAR) Program on Brain, Mind, and Consciousness, Toronto, Ontario, Canada*

March 28, 2022

Abstract

Human perception and experience of time is strongly influenced by ongoing stimulation, memory of past experiences, and required task context. When paying attention to time, time experience seems to expand; when distracted, it seems to contract. When considering time based on memory, the experience may be different than in the moment, exemplified by sayings like "time flies when you're having fun". Experience of time also depends on the content of perceptual experience – rapidly changing or complex perceptual scenes seem longer in duration than less dynamic ones. The complexity of interactions between

Zafeirios Fountas

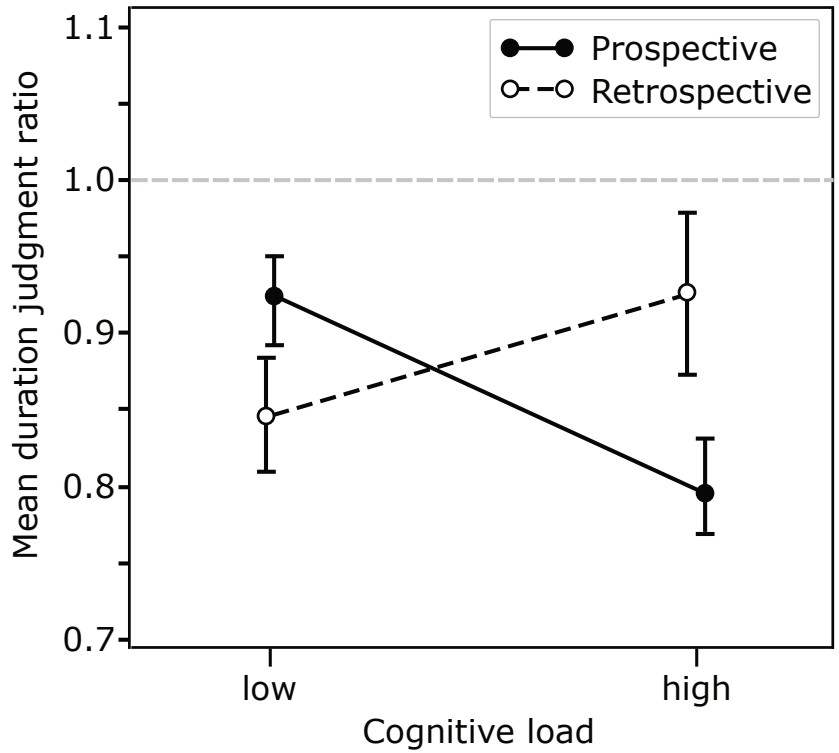
Fountas, Z., Sylaidi, A., Nikforou, K., Seth, A.K., Shanahan, M., & Roseboom, W. (in press) *Neural Computation*

time and memory

- computational model integrating hierarchical predictive coding, short-term plasticity, spatio-temporal attention, and episodic memory formation and recall
- behavioural (online) experiment with ~13,000 participants
- test whether model can replicate influences of
  (i) cognitive load
  (ii) scene type
  (iii) prospective vs retrospective judgement

Fountas et al (in press) *Neural Computation*

prospective vs retrospective time



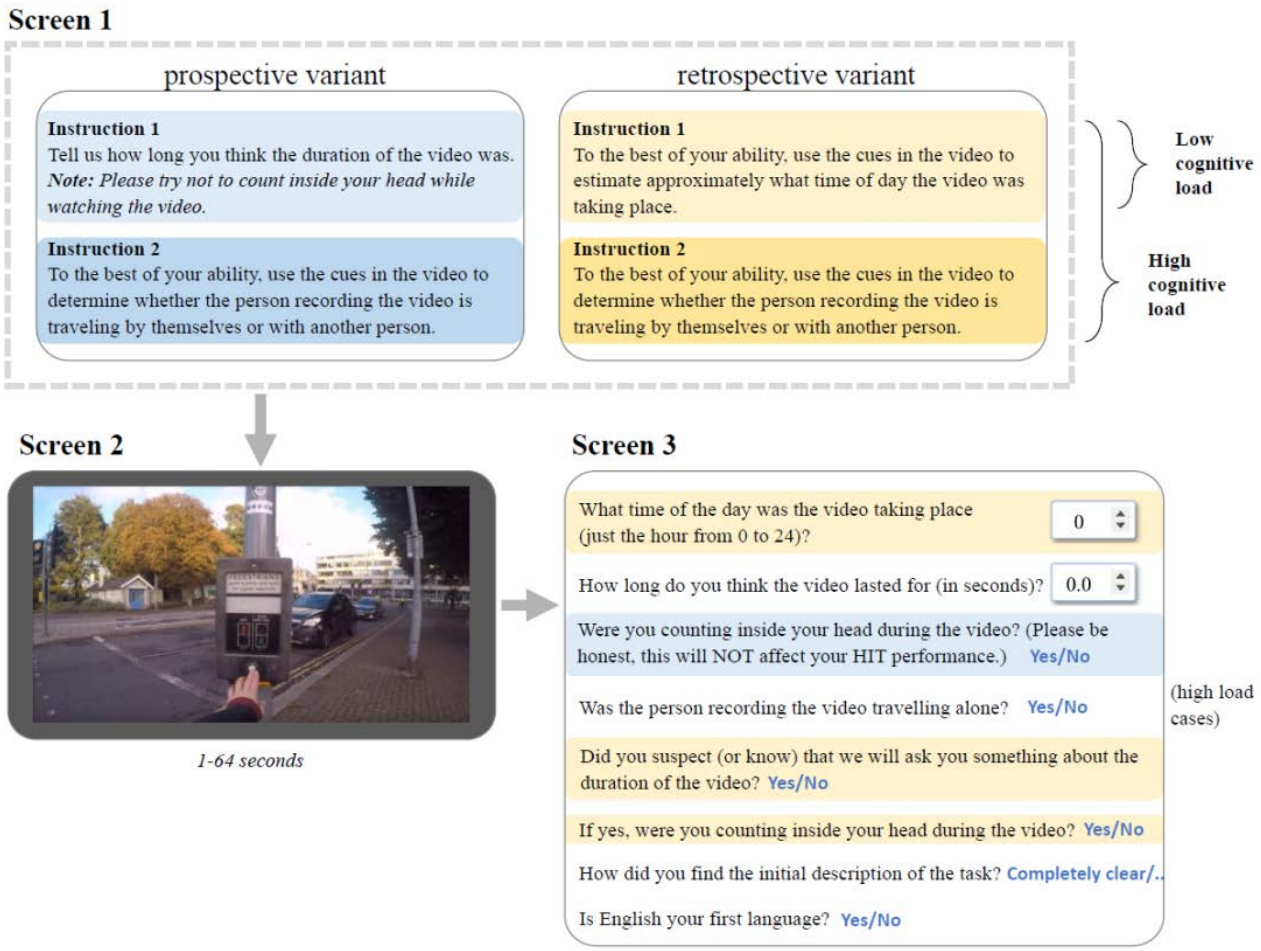
High cognitive load *decreases* apparent duration for *prospective* estimates …

…. but *increases* apparent duration for *retrospective* estimates

Block et al (2010) *Acta Psychologica*

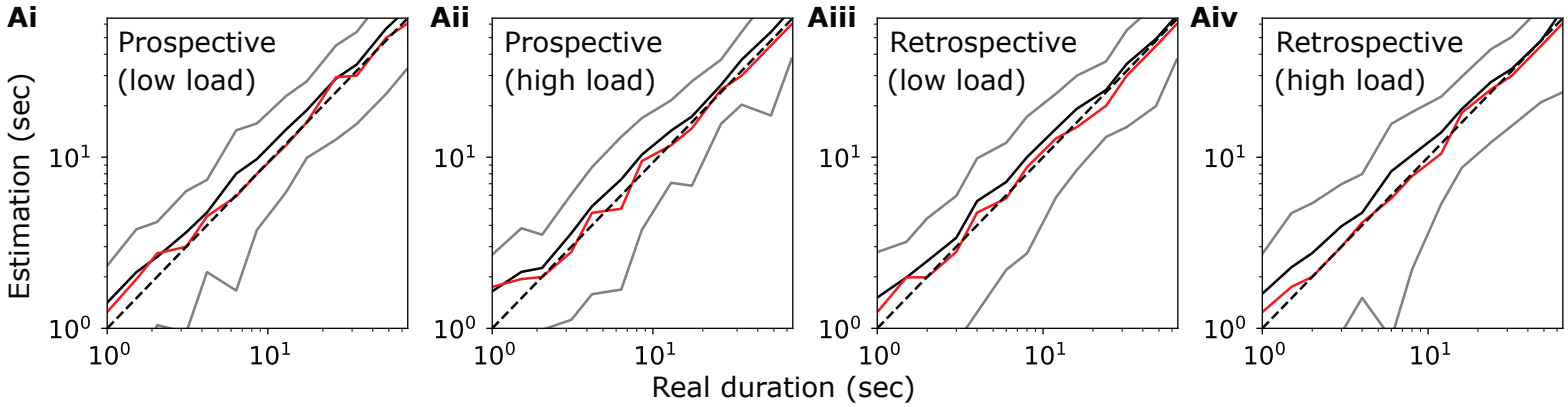
behavioural study

- ~13,000 participants, each performing one trial
- prospective vs retrospective
- high vs low cognitive load
- quiet vs busy scenes
- estimate duration



Fountas et al (in press) *Neural Computation*

behavioural study



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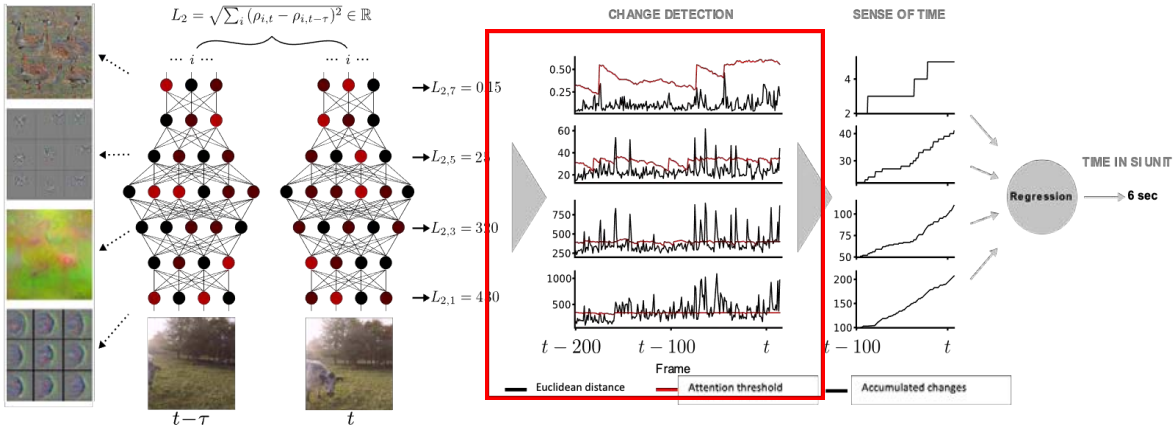
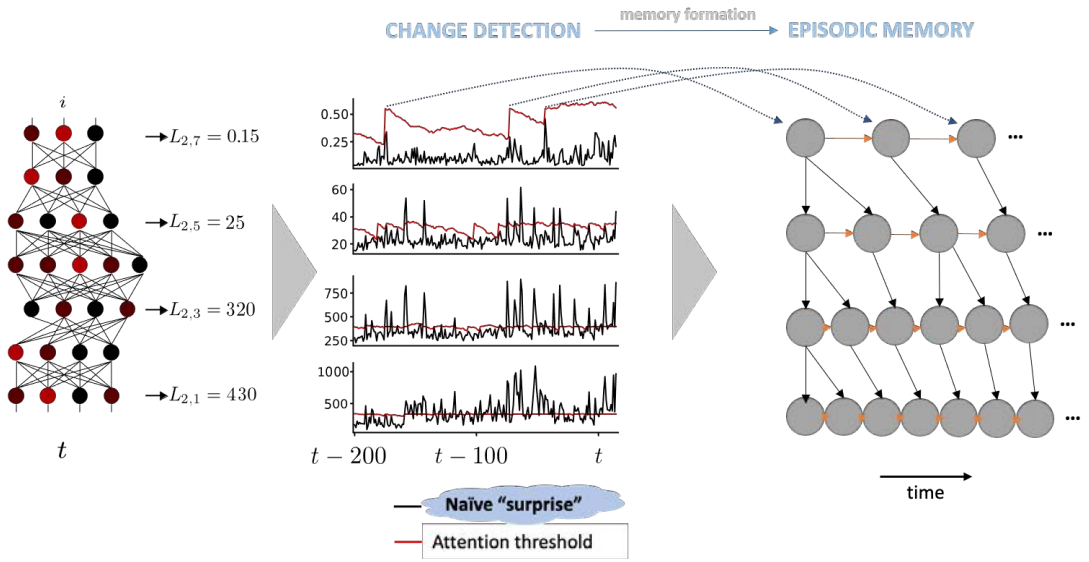
computational model: memory formation





- use salient changes to trigger (hierarchical) episodic memory formation
- replace Euclidean distance with Bayesian prediction error

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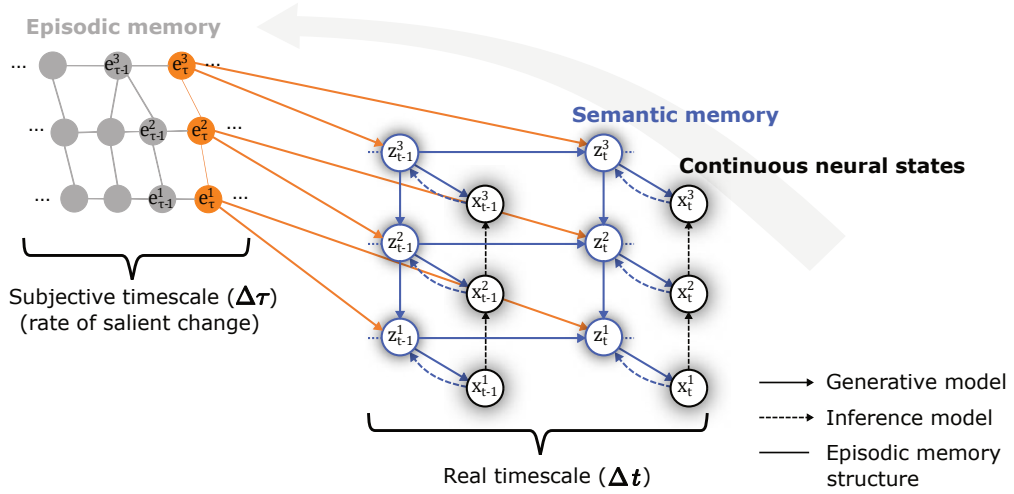
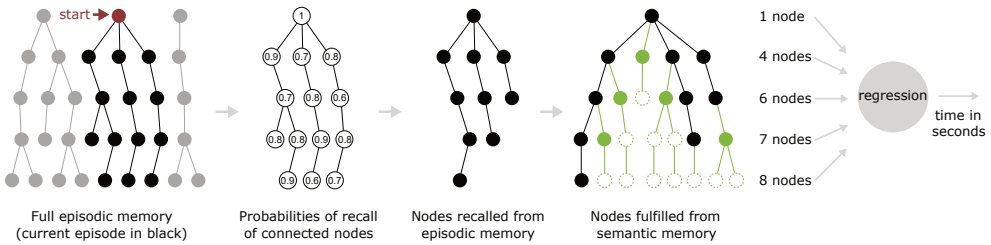
computational model: recall





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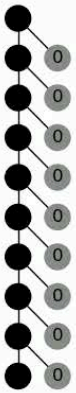
computational model: demo




Experience in layer 0

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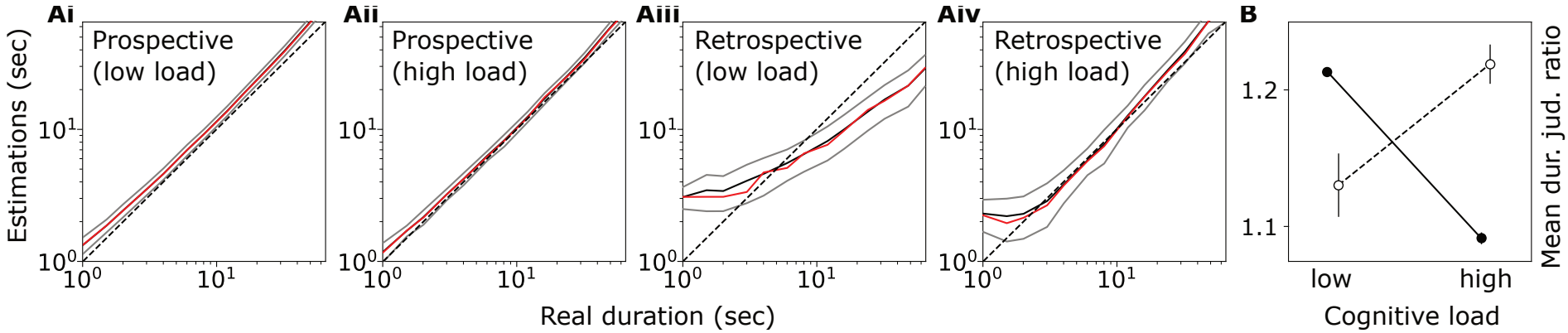
computational model: results



Fountas et al (in press) *Neural Computation*

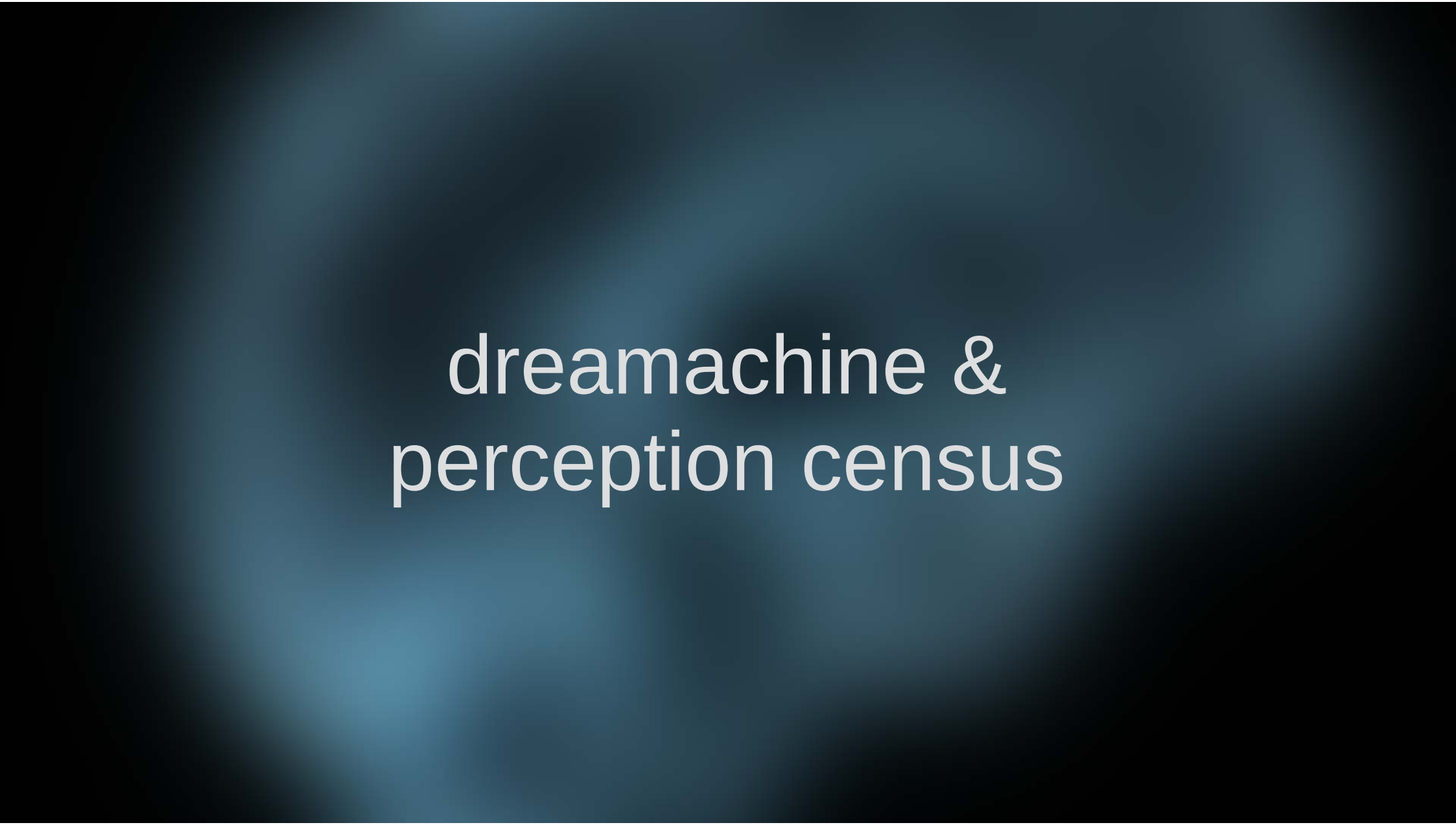
summary

- study 1: accumulated salient perceptual change provides a sufficient basis for human duration estimation
- study 2: this applies to the brain too, in a modality specific way
- study 3: extension of model to include episodic memory formation, to account for prospective vs retrospective judgements

Roseboom et al (2019) *Nature Communications*

Sherman et al (2022) *BioRXiv*

Fountas et al (in press) *Neural Computation*


dreamachine &
perception census

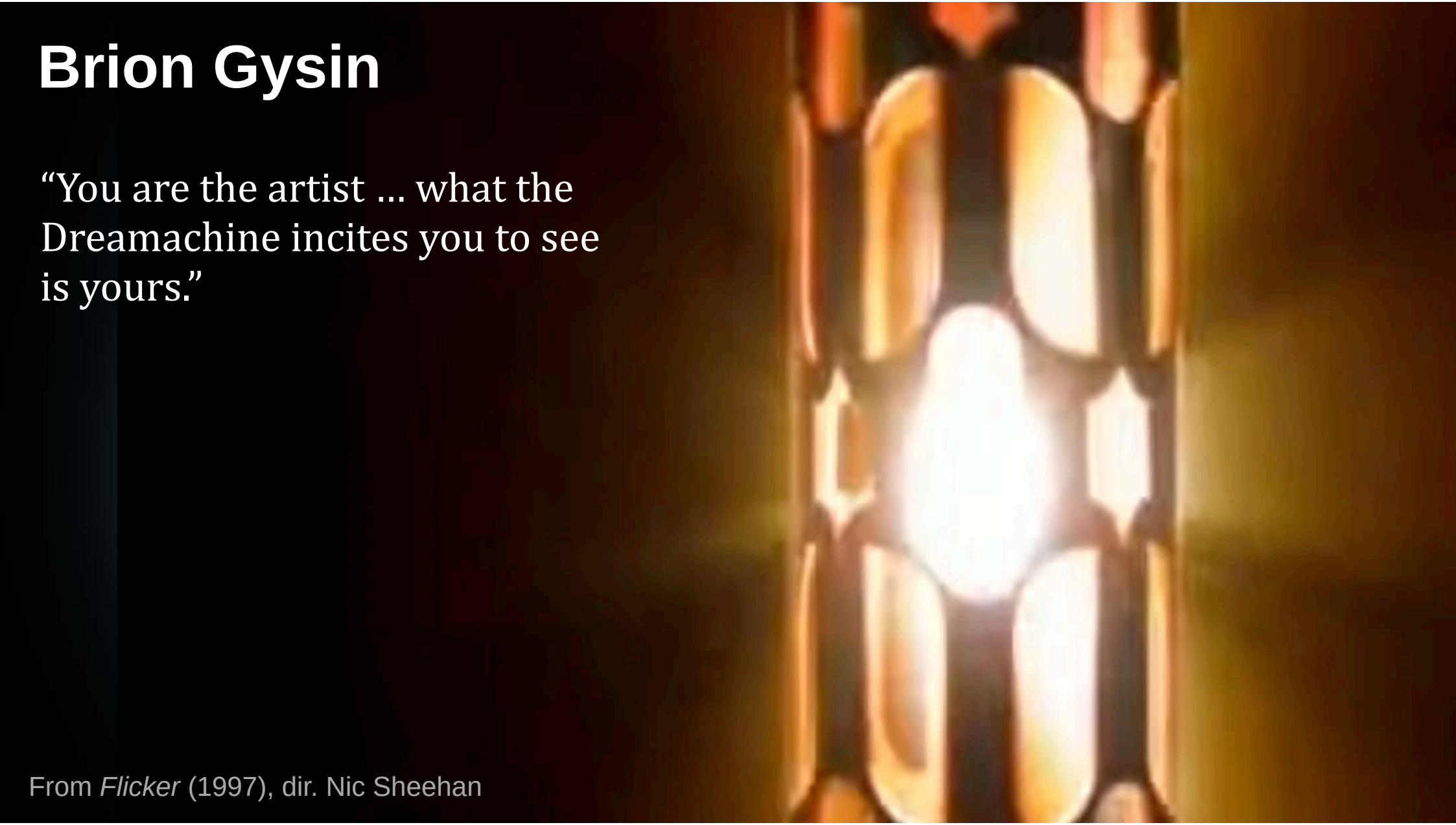
dreamachine

dreamachine Presented by COLLECTIVE ACT

UNBOXED
CREATIVITY IN THE UK

Brion Gysin

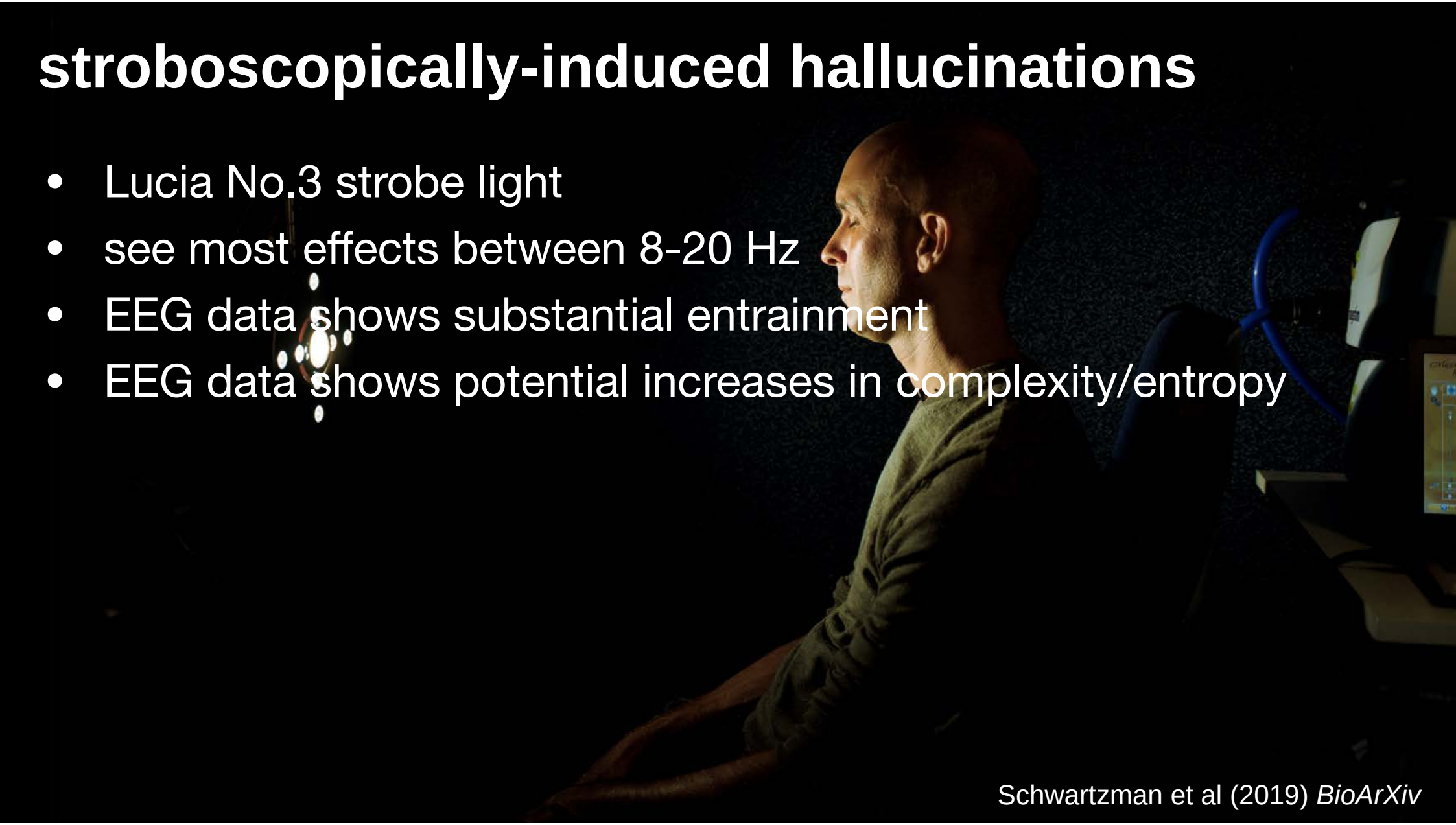
“You are the artist … what the Dreamachine incites you to see is yours.”



From *Flicker* (1997), dir. Nic Sheehan

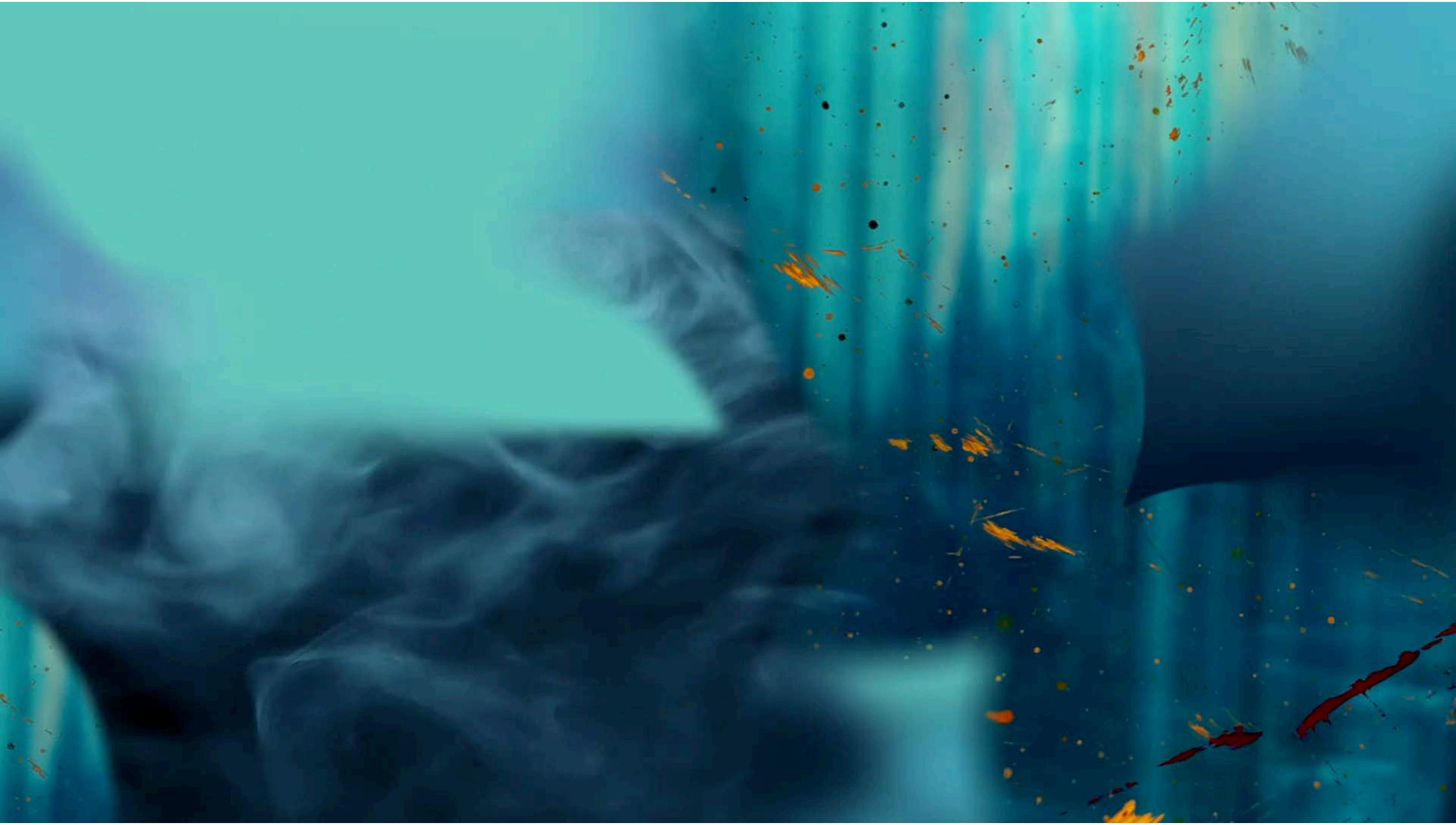
stroboscopically-induced hallucinations

- Lucia No.3 strobe light
- see most effects between 8-20 Hz
- EEG data shows substantial entrainment
- EEG data shows potential increases in complexity/entropy



Schwartzman et al (2019) *BioArXiv*


dreamachine
About | Experience | Discover | Schools

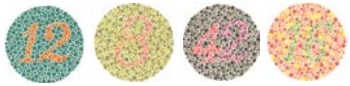


perception census

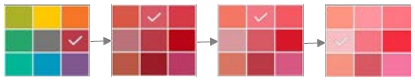
vi = visual impairments
hi = hearing impairments
ni = no impairments

1. Colour perception – hi & ni

Ishihara test – report what number is presented



Favourite colour – pick preferred colour



2. Imagery – vi, hi, ni

Imagery snapshot – self-report of imagery vividness

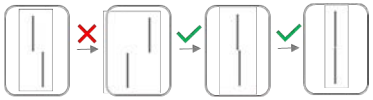
How vivid is your mental imagery?
1-10 scale: no mind's eye to as vivid as real perception

How vivid is your auditory imagery?
1-10 scale: no mind's ear to as vivid as real perception

3. Classic Psychophysics – hi, ni

Visual size illusions – adjust size of the orange objects

Vernier acuity – report misalignment of the top line



4. Anomalous perception

vi

White Christmas task – report if you can hear WC

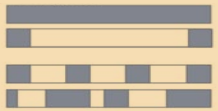
hi & ni

VEARs – report experience of sound

5. Time perception

vi

Sound duration estimation



hi & ni

Video duration estimation

6. Information sampling – hi, ni

Event segmentation task

7. Phenomenological control – vi, ni

Suggestibility primer
Participants will be asked to use their imagination to create a certain experience. After that, participants will rate the report on their experience.

8. Synaesthesia – mostly for ni, some for vi & hi

Synaesthesia quiz – explain synaesthesia is and outline different forms and ask people which, if any, th

Do letters have colours?

Do letters have personalities?

9. Beliefs about consciousness

2 items from the beliefs about consciousness survey

Baykova et al (in progress)

summary

- study 1: accumulated salient perceptual change provides a sufficient basis for human duration estimation
- study 2: this applies to the brain too, in a modality specific way
- study 3: extension of model to include episodic memory formation, to account for prospective vs retrospective judgements
- dreamachine: a large-scale art-science project, and survey of perceptual diversity

Roseboom et al (2019) *Nature Communications*

Sherman et al (2022) *BioRXiv*

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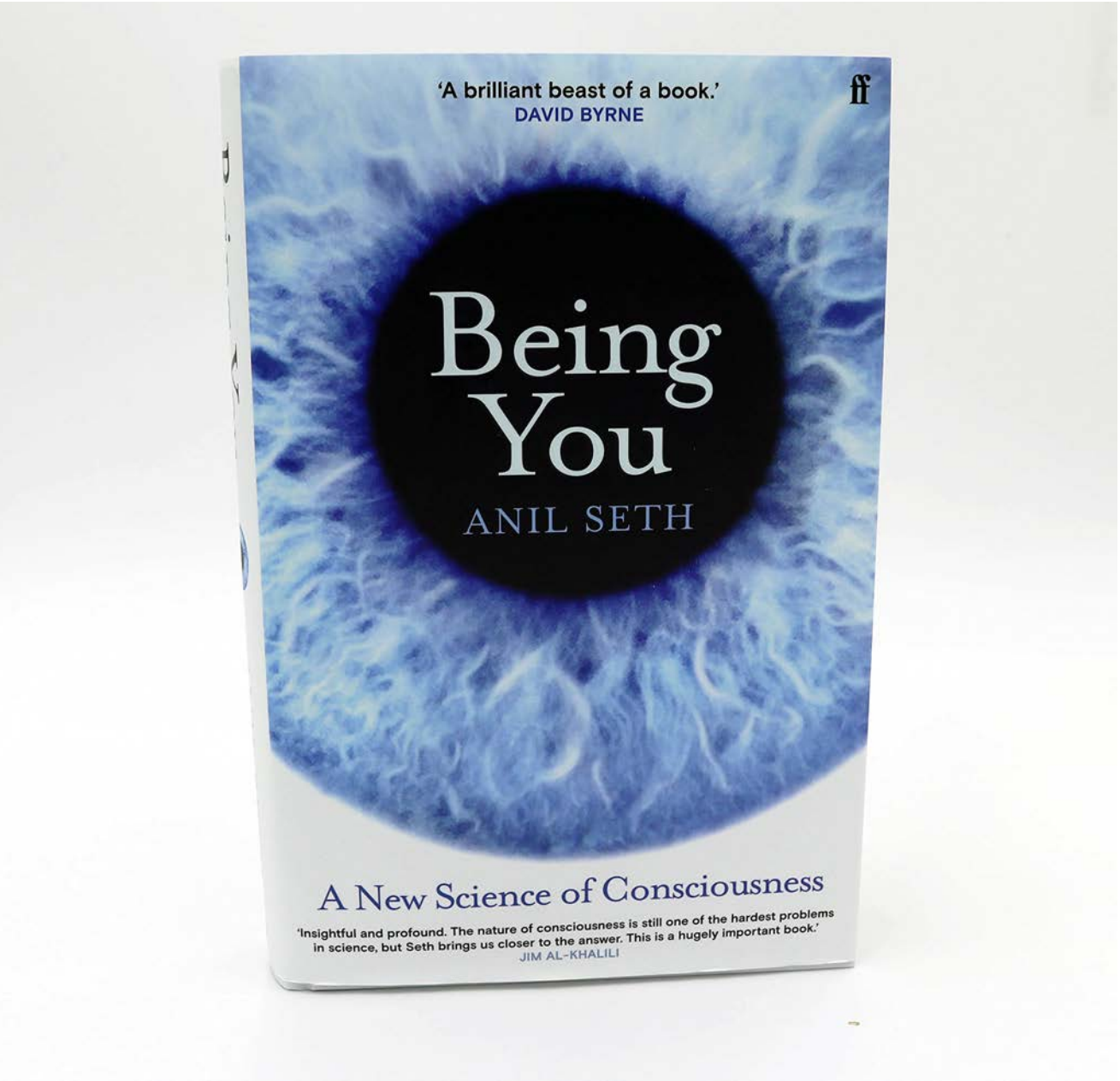

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