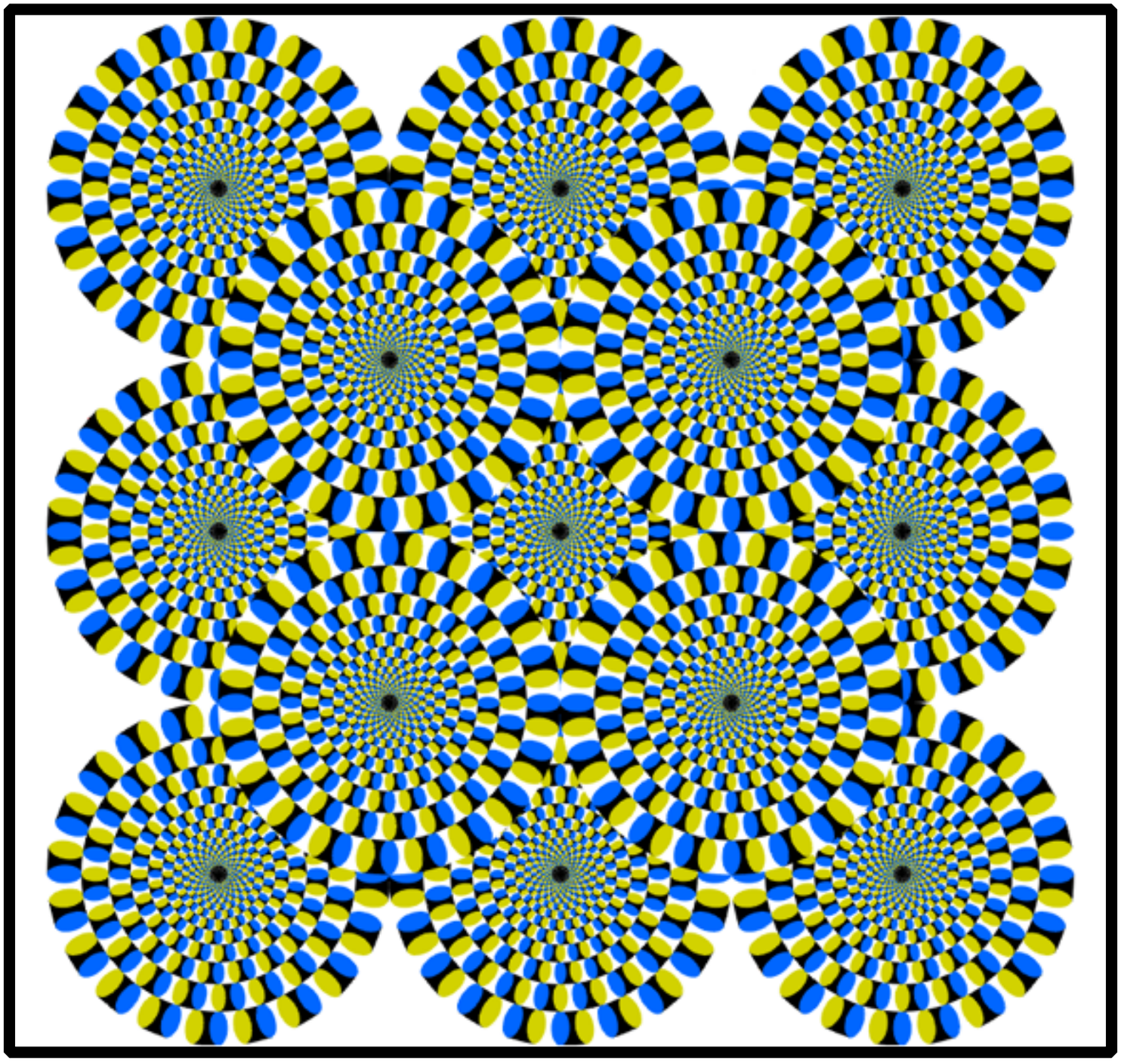
COGS500
Visual Attention



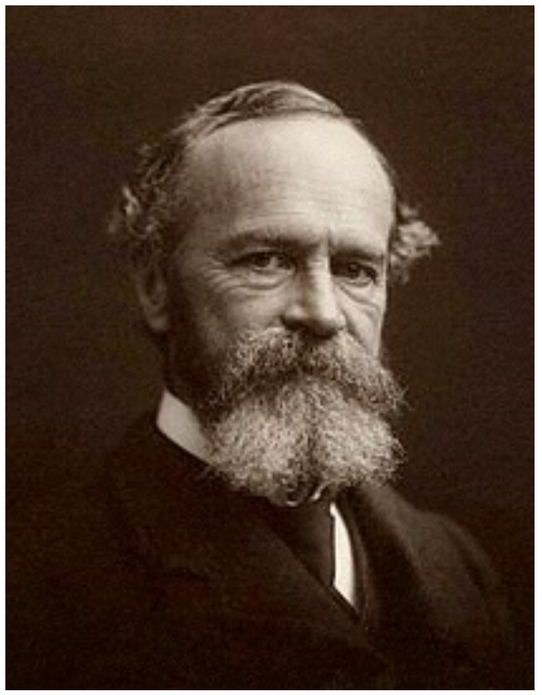
Boun, Nov 2019
İ. Ayhan

What is ‘Attention’?

In the old days:

William James (1890): “Everyone knows what attention is…”

Munsell (1873):“On attention itself it is needless to discourse at length; it’s nature and conditions are familiar to every thoughtful student.”



William James

Harold Pashler, UCSD

Nowadays:

Pashler (1998):

“No one knows what attention is, and there may not be an it there to be known about (although of course there might be).”

Instead of attempting to define attention we study the effects it has on cognitive functions

Attention Induced Blindness

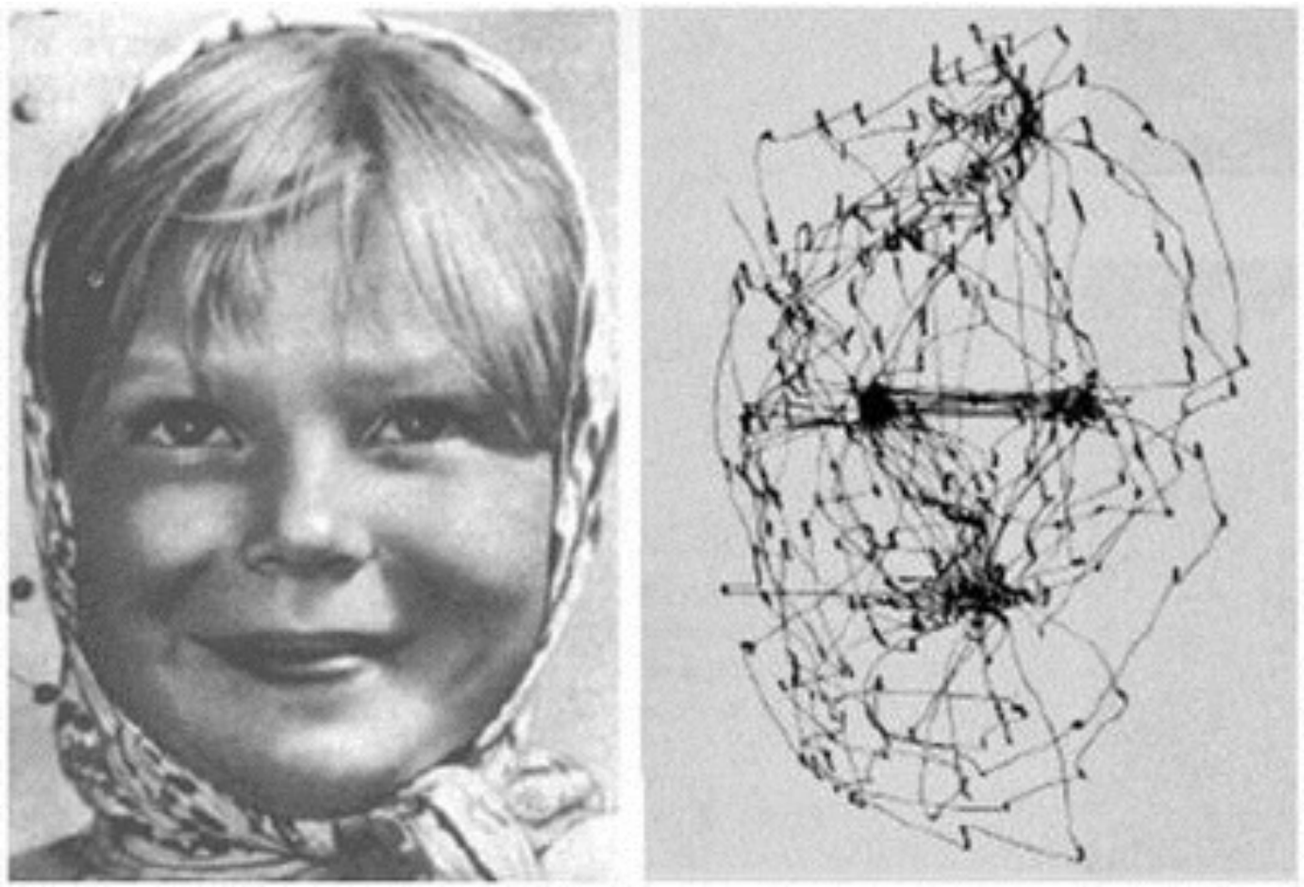
The effects of attention on cognitive functions (e.g. perception, memory)

The role of attention in facilitating perception and any further processing (e.g. action, memory) for relevant stimuli

The role of attention in preventing perception and any further processing (e.g. action, memory) for irrelevant stimuli.

Attention and Eye Movements

- Saccades: quick eye movements from one fixation location to another.
- We make around 3 saccades per second!



Not all parts of a scene are sampled equally

Early eye tracking: 1920-30’s. Developed fastly through 1970’s.

g

What determines where we look?

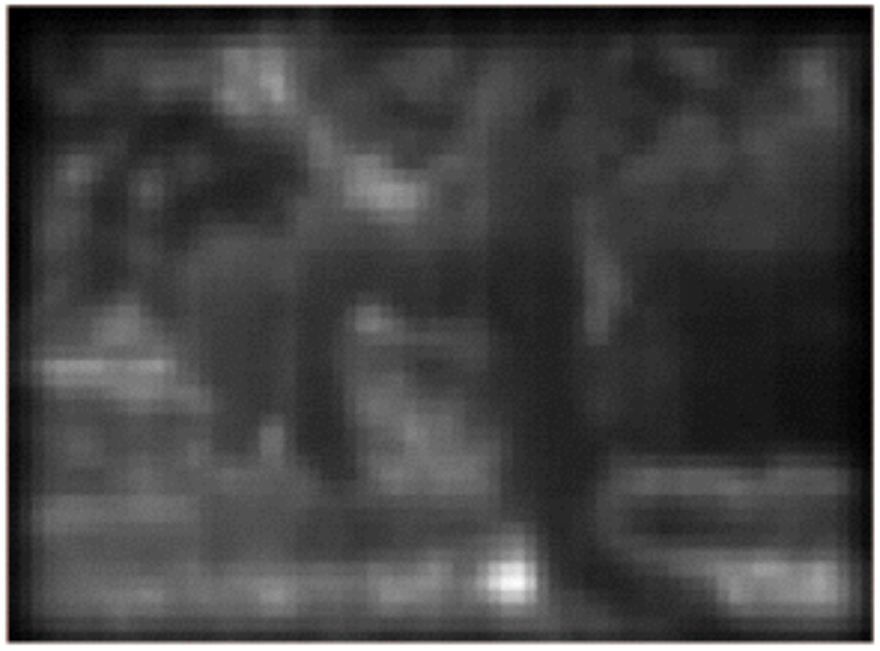
Bottom up factors: Characteristics of the scene:

Stimulus salience - areas of stimuli that attract attention due to their properties:

- Color, contrast, and orientation are relevant properties
- Saliency maps show fixations are related to such properties in the initial scanning process

Visual Image

Salience Map



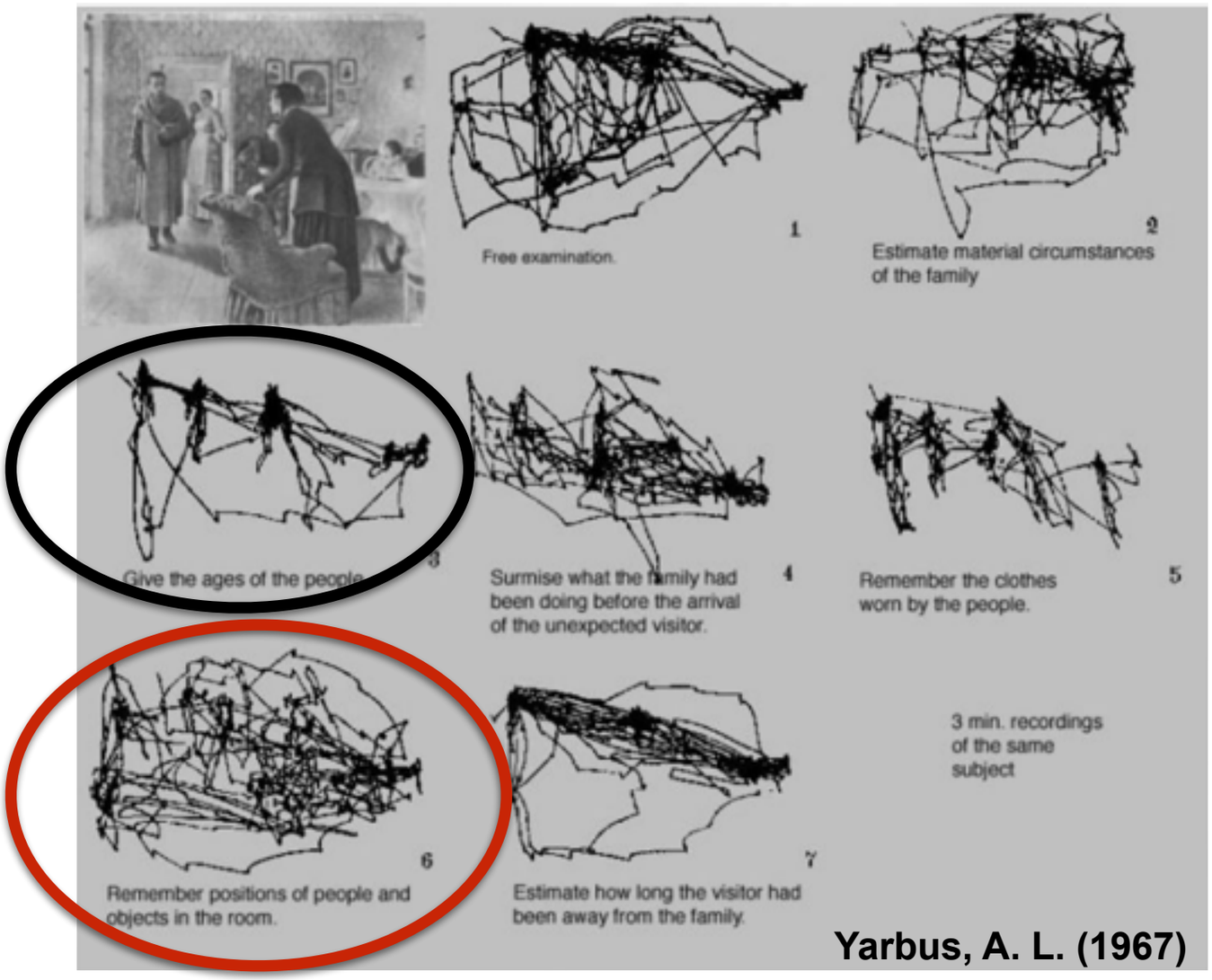
What determines where we look?

Top down factors:

- Task or goals
- Attention
  - Where to attend (spatial attention)
  - What features to attend to (feature-based attention)

Spatial detail - High spatial frequency-selective system

Global form / Distance relationship Low spatial-frequency selective system



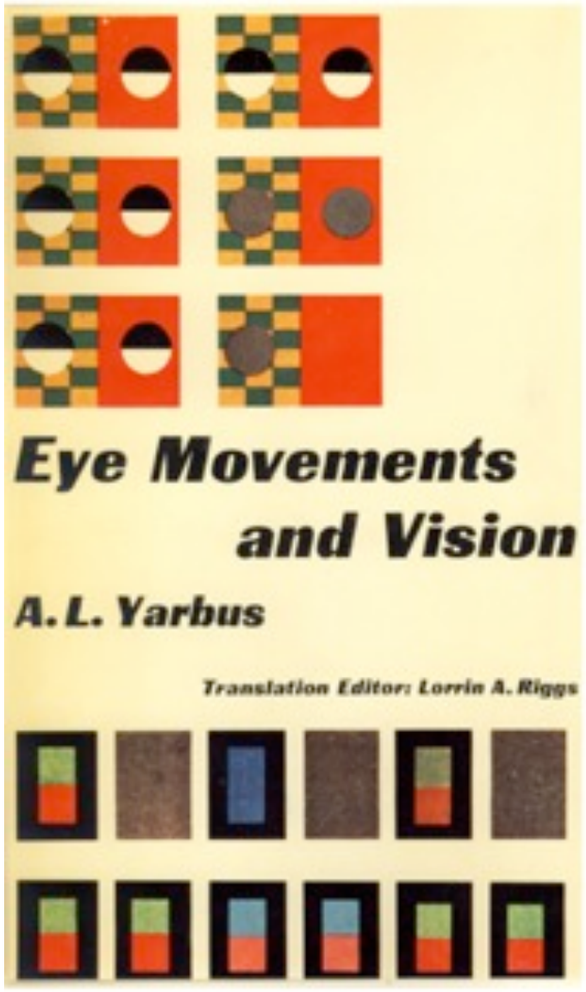
Yarbus, A. L. (1967)

The gaze tends to jump back and forth between the same parts of the scene, for example, the eyes and mouth in the picture of a face.

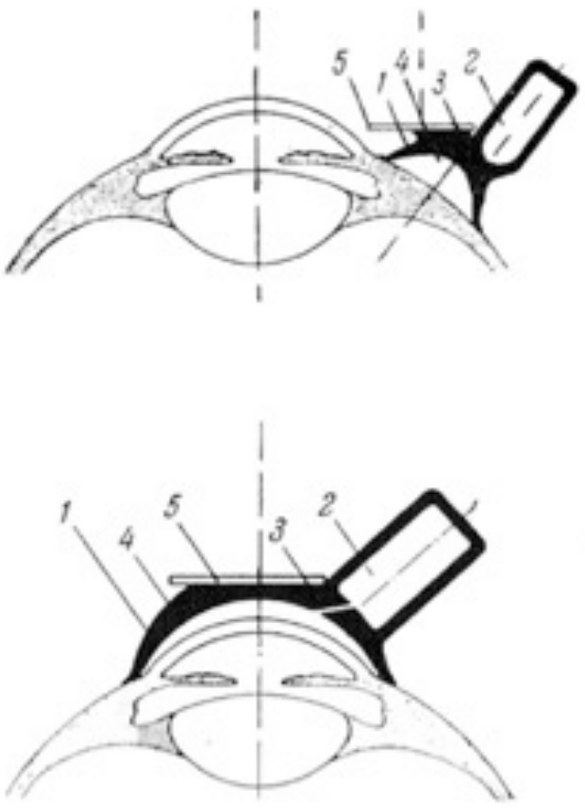
The task has a strong influence on where you attend and look

What determines where we look?

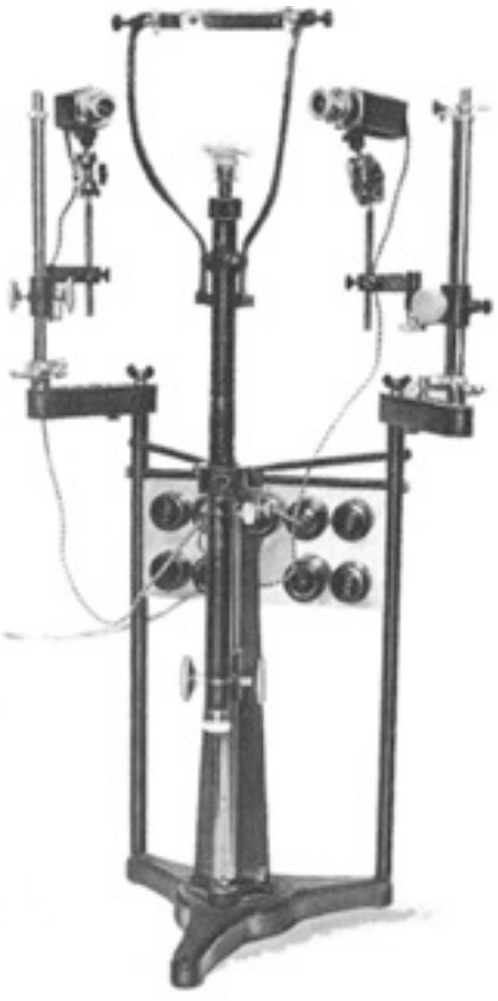
Alfred Yarbus was a Russian psychologist who studied eye movements in the 1950s and 1960s

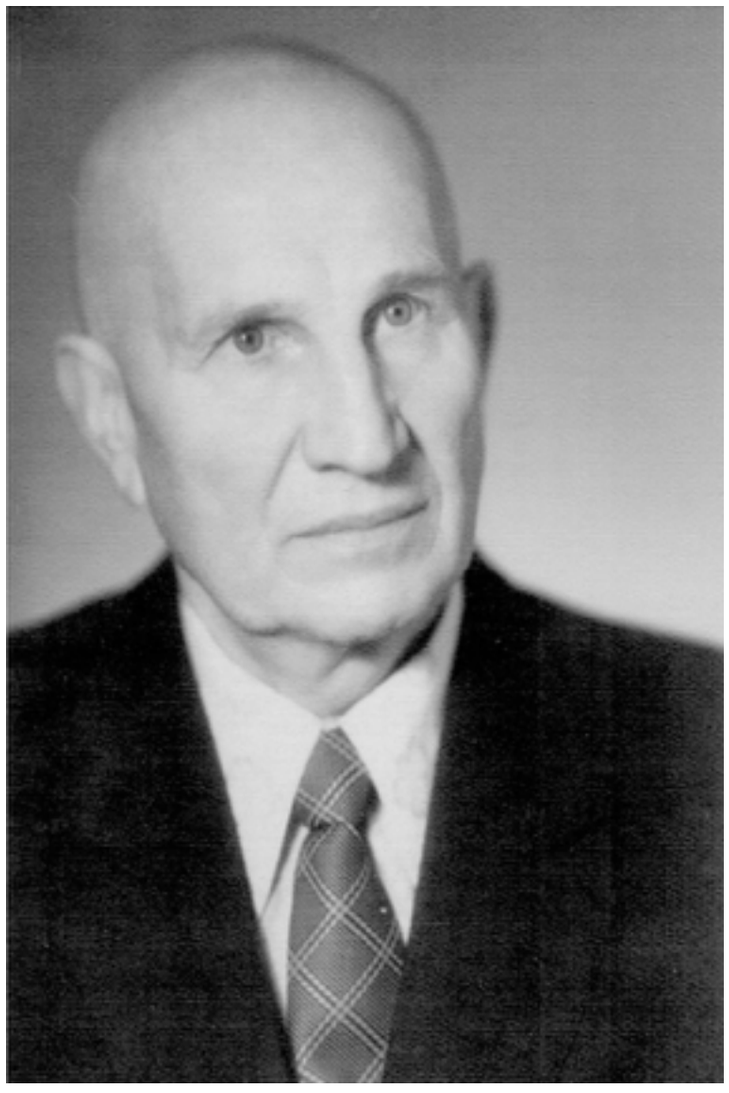


(a)



(b)





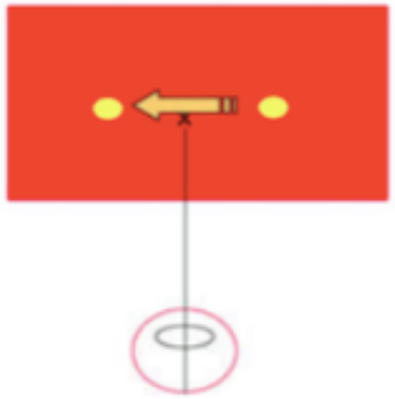
Science in Soviet Russia

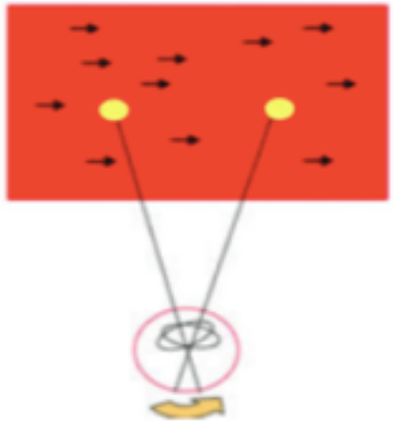
Yarbus also invented a suction cup, which can be attached by suction to the human eye to study visual perceptions in the absence of eye movements, a laboratory condition called retinal stabilization

~ Eye Movements ~

Motion can be sensed in two ways:

1.*retinal movement system* 2. *eye / head movement system*





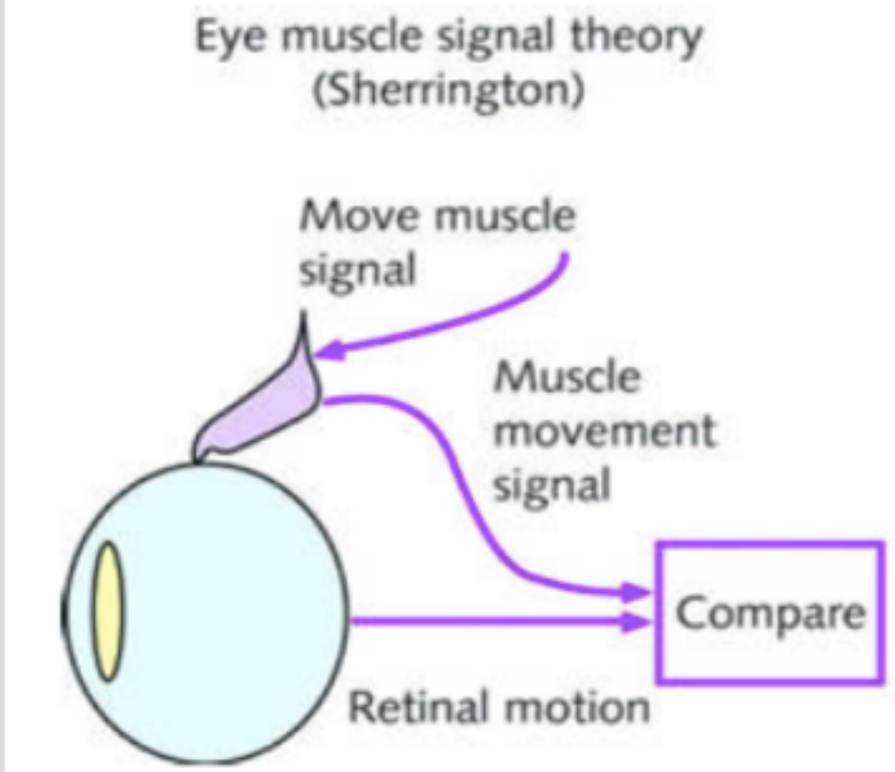
The viewer fixates on a stationary object therefore moves across retina.

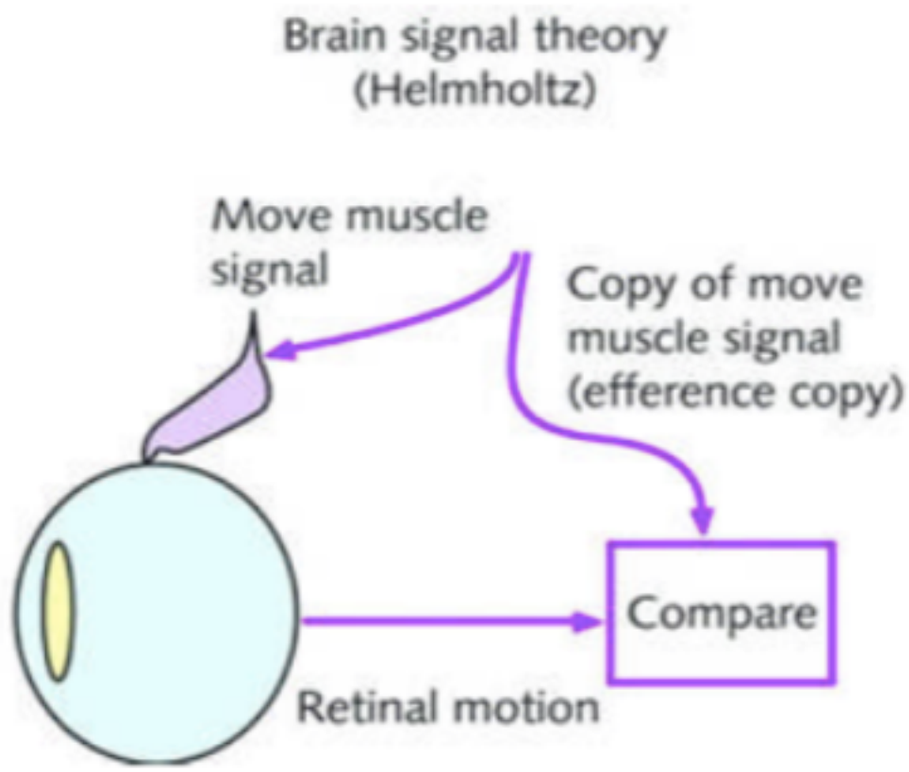
Observer tracks the moving object >> moving object remains stationary on retina >> stationary background moves on the opposite side

Tracking - smooth pursuit eye movements

Sherrington's Theory

Helmholtz' Theory





We monitor the movements of our eye muscles and compare ***retinal image motion*** to ***eye muscle movement***.

The comparison is made with ***the signal from the brain*** that tells the eye muscle to move (***efferent copy*** or ***corollary discharge***) and the retinal image motion.

Sherrington's Theory **Helmholtz' Theory**

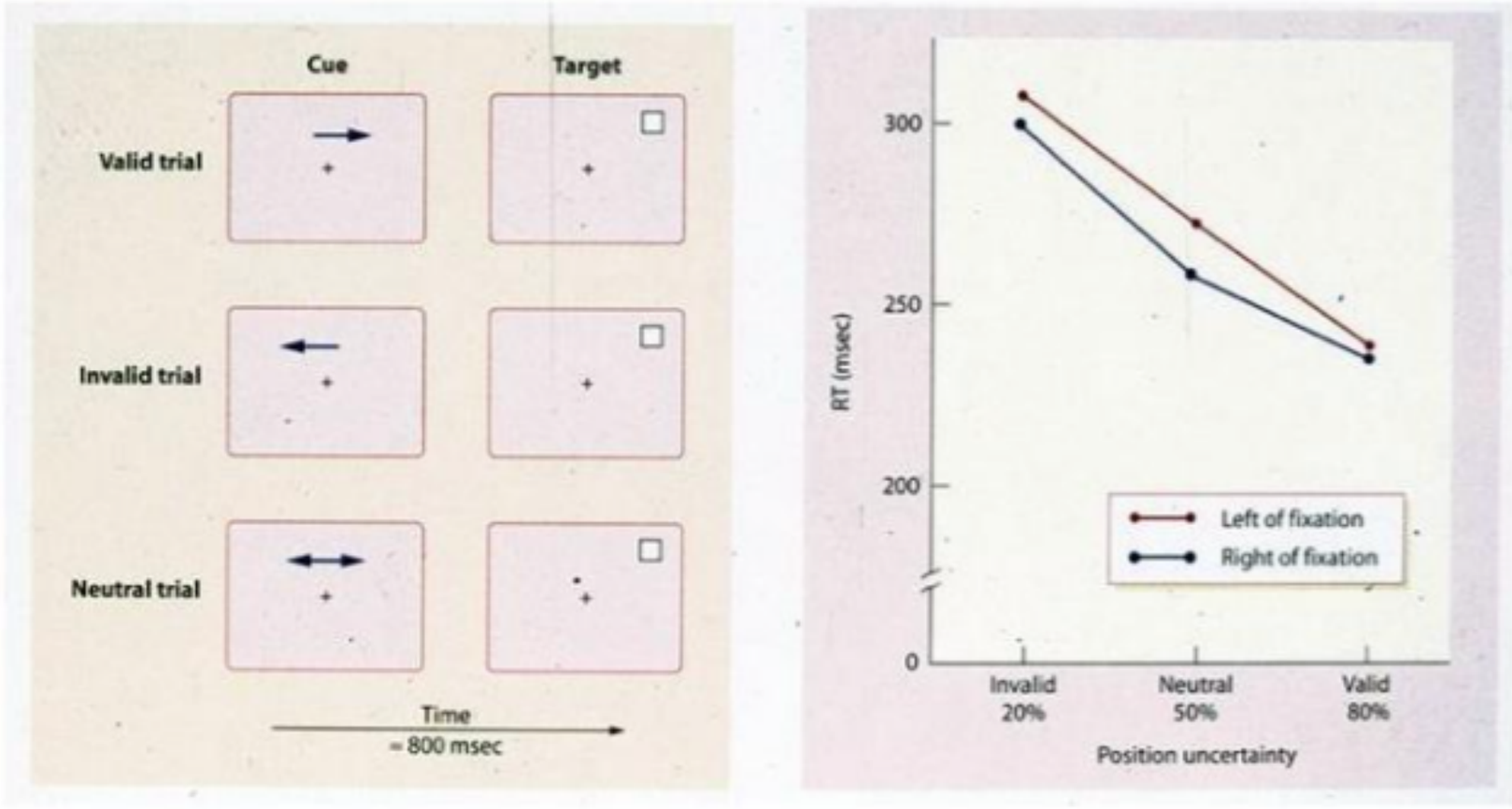
What if we tell our eyes to move but we actually prevent the eyeball from moving?

Helmholtz predicts that the stationary world will appear to move because the eye movement signal is not cancelled by the expected retinal movement. Sherrington predicts no movement because there will be no retinal movement and no eye muscle movement.

the experiment has been done: the world does move (**Stevens et al., 1976**)

- ***Spatial Attention***
- We use spatial attention to highlight everything at a particular location

Covert Attention: a difficult (threshold) visual discrimination task.

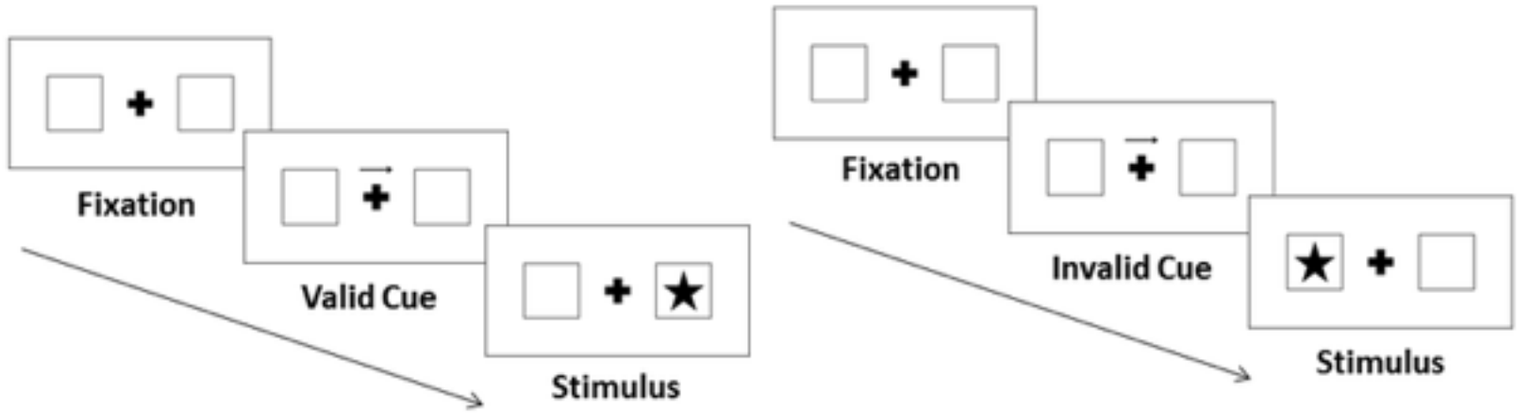


•You can shift spatial attention without eye movements.

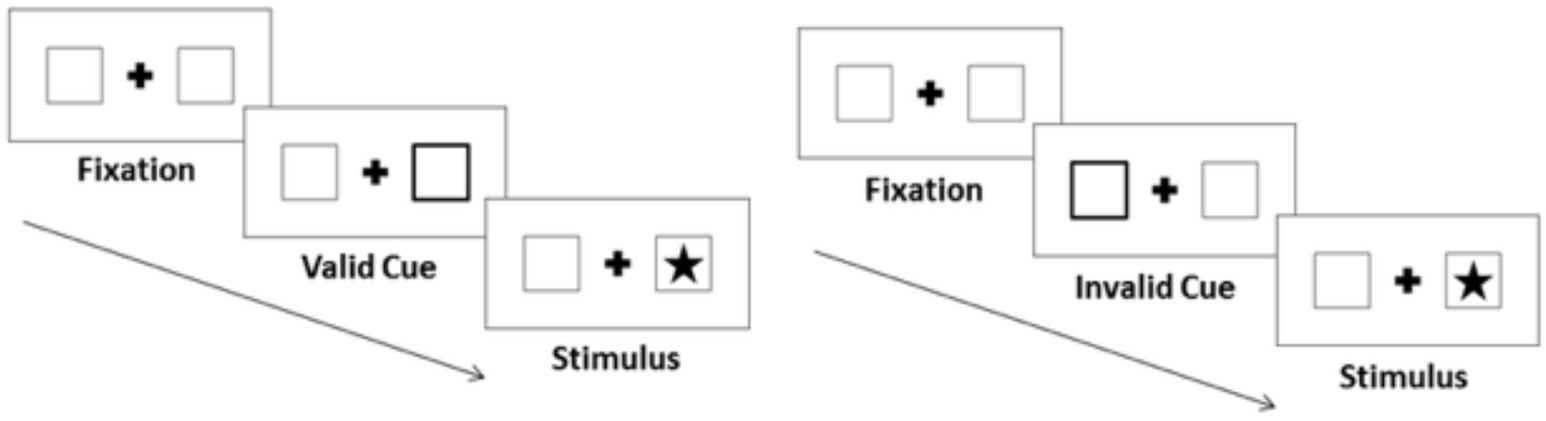
•The shifts can be controlled by the subject's decision to allocate attention (e.g., with instructions, or with a central arrow as a cue) or by automatic attraction (e.g., if something suddenly appears in the periphery of your visual field).

•Performance falls off smoothly with distance when cued to the wrong location.

Endogenous Cues



Exogenous Cues



- An endogenous cue is presented in the center of the screen, usually at the same location as the center of focus. This cue relies on input from the central visual field.

- An exogenous cue is presented outside of the center of focus, usually highlighting the left or right box presented on the screen (peripheral input).

- ***Spatial Attention***

  - Types of covert spatial attention: Endogenous and Exogenous

  - Sustained (endogenous)

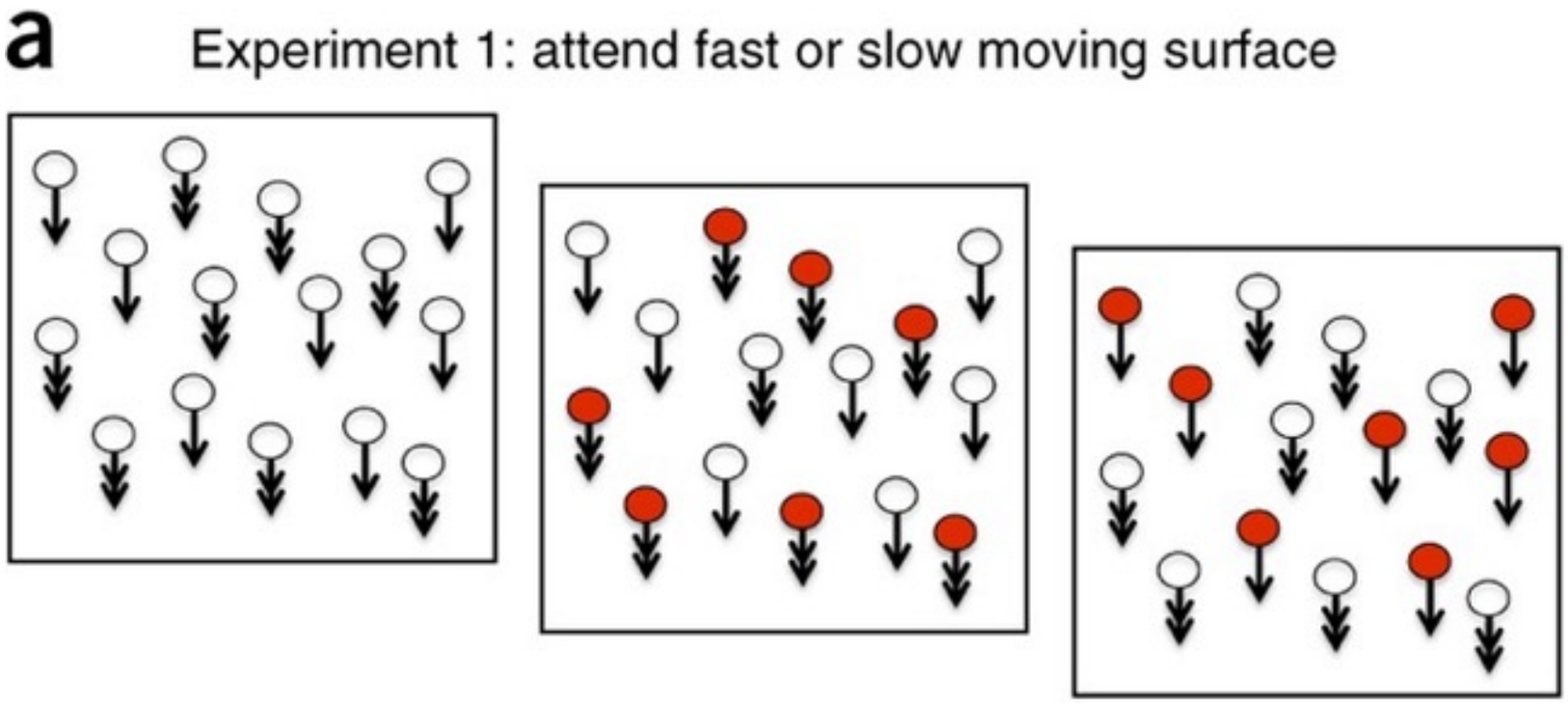
  voluntary, or by instruction in laboratory experiments: “attend left”.
    - willfully monitor information at a given location. Goal oriented.
    - 300 ms,
    - Affects performance only under high noise conditions.
    - Feedback from frontal and parietal areas.

  - transient (exogenous)

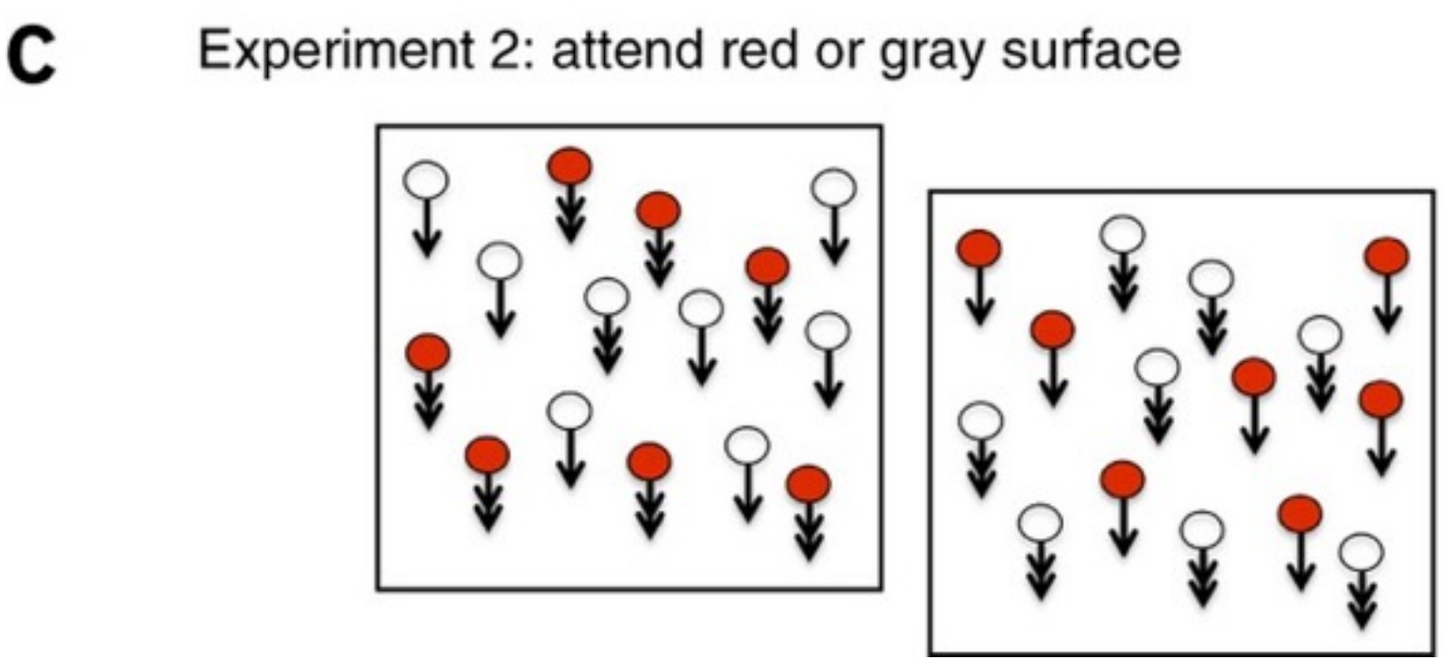
  involuntary, often by a flash, sound or any sudden change.
    - automotaic orienting response to allocation where sudden stimulation has occurred.
    - It raises and decays quickly peaking about 100-120 ms. Faster time course.
    - allowing us to respond to environmental demands and react quickly to stimuli
    - Older in evolution.
    - Can operate under both low and high noise conditions.

Saliency

- ***Feature-Based Attention***
- We use feature-based attention to highlight specific features throughout a scene.

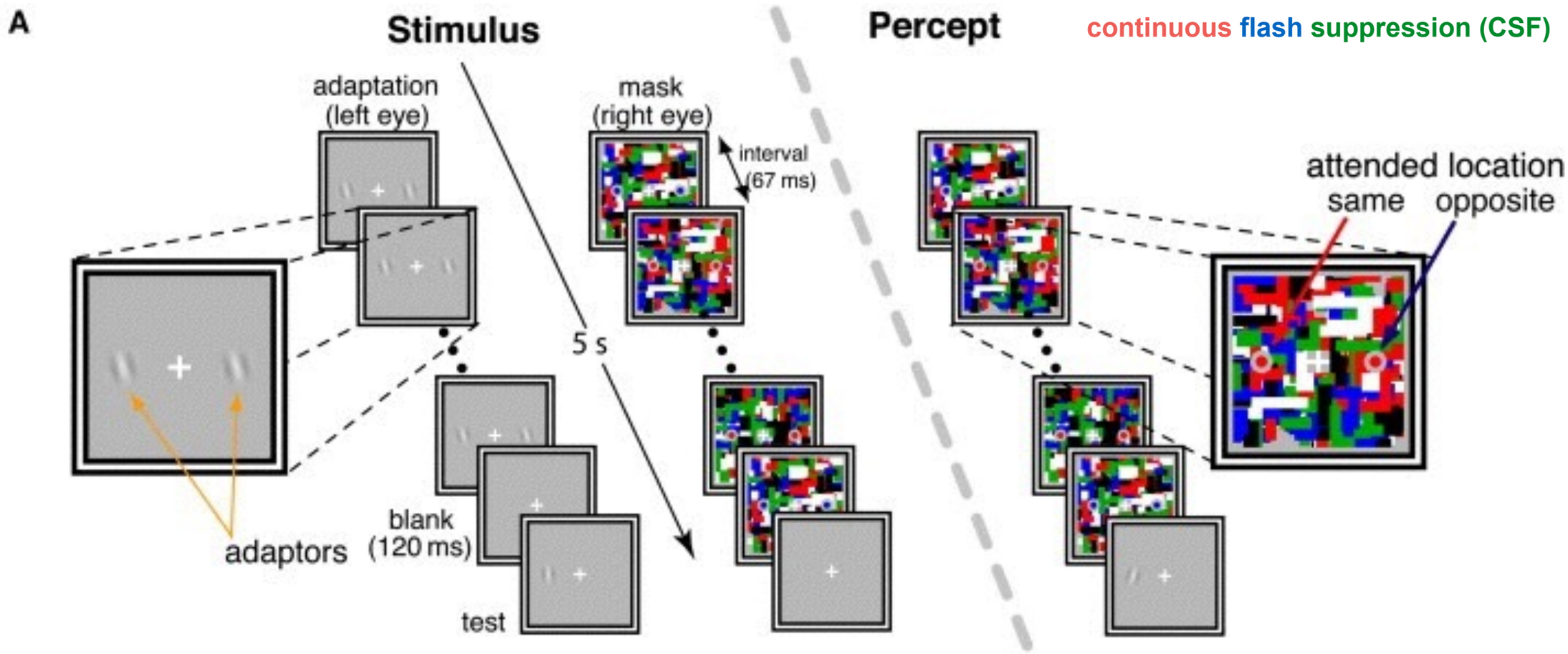


- i.e. speed or colour



- ***The Dissociation Between Visual Attention and Awareness***

Kanai, R., Tsuchiya, N. & Verstraten, F. (2006). The scope and limits of top-down attention in unconscious visual processing. *Current Biology*, 16 (23), pp 2332–2336.



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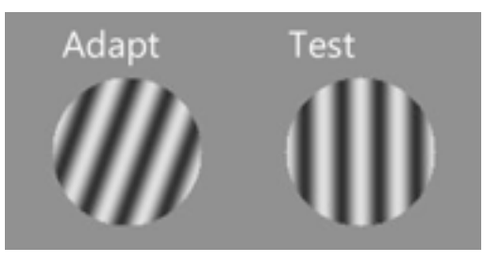

Tilt aftereffect

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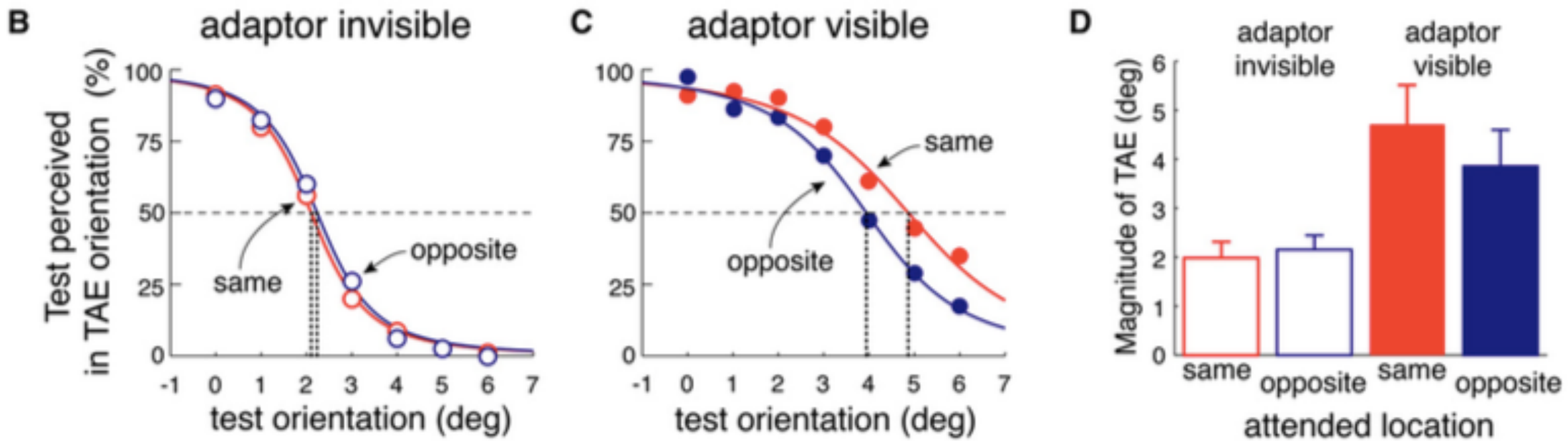

Positive values indicate a slight tilt to rightwards direction after having adapted to rightwards tilt

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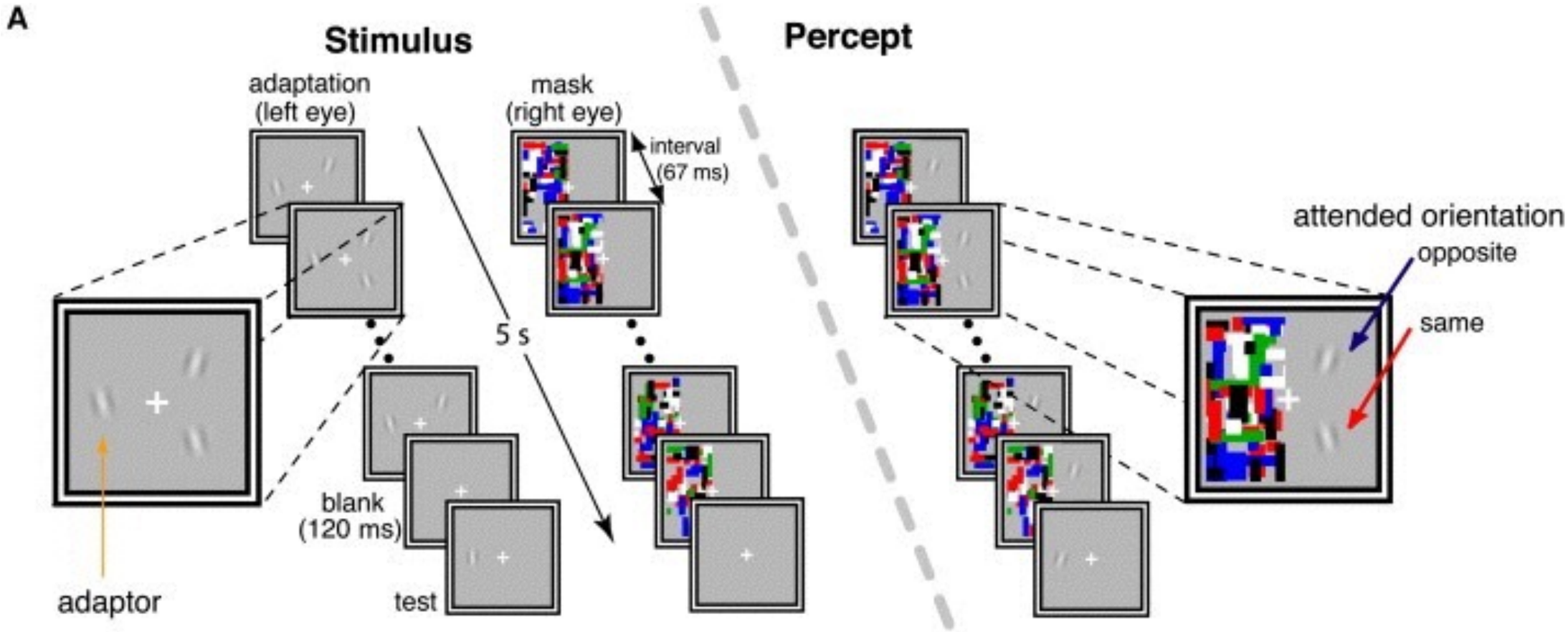

feature-based attention can modulate the processing of invisible stimuli.

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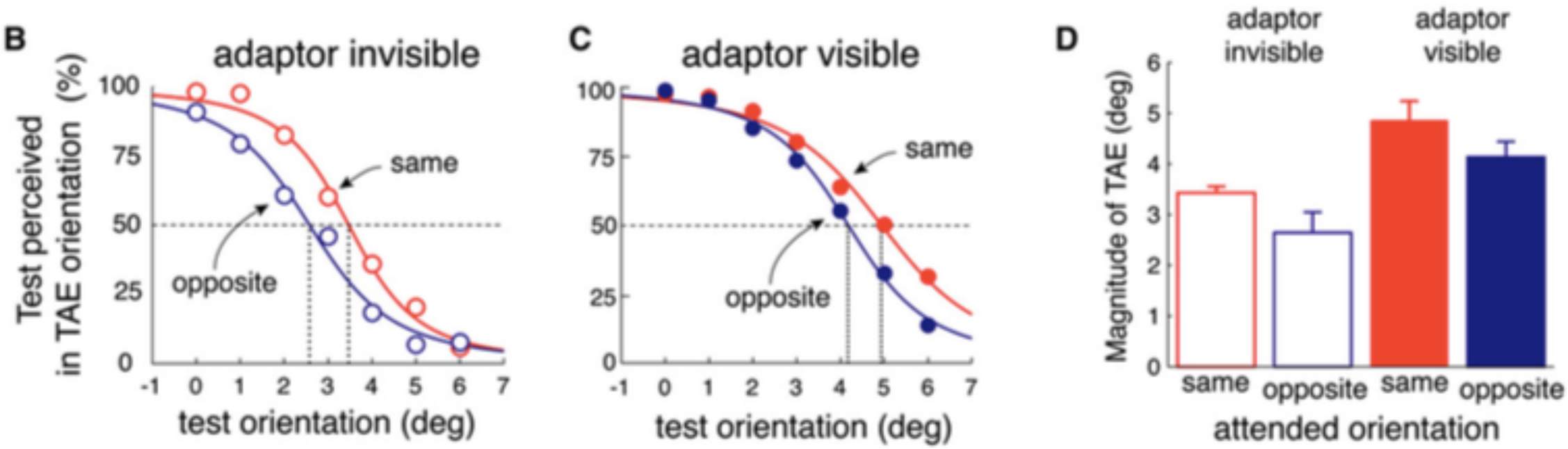

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Koch, K. & Tsuchiya, N. (2006). Attention and consciousness: two distict brain processes. *Trends in Cognitive Sciences*, 11 (1), pp 16 – 22

Opinion TRENDS in Cognitive Sciences Vol.11 No.1

Attention and consciousness: two distinct brain processes

Christof Koch[1] and Naotsugu Tsuchiya[2]

[1] Division of Biology 216–76, California Institute of Technology, Pasadena, CA 91125, USA
[2] Division of the Humanities and Social Sciences, 228–77, California Institute of Technology, Pasadena, CA 91125, USA

Table 1. A fourfold classification of conscious and unconscious percepts and behaviors[a]

	Might not give rise to consciousness	Gives rise to consciousness
Top-down attention is not required	Formation of afterimages Rapid vision (<120 ms) Zombie behaviors	Pop-out in search Iconic memory Gist Animal and gender detection in dual tasks Partial reportability
Top-down attention is required	Priming Adaptation Visual search Thoughts	Working memory Detection and discrimination of unexpected and unfamiliar stimuli Full reportability

- ***The Dissociation Between Visual Attention and Awareness***

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Full text provided by www.sciencedirect.com ScienceDirect

Attention and consciousness: two distinct brain processes

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Top-down attention is required	Priming
	Adaptation
	Visual search
	Thoughts

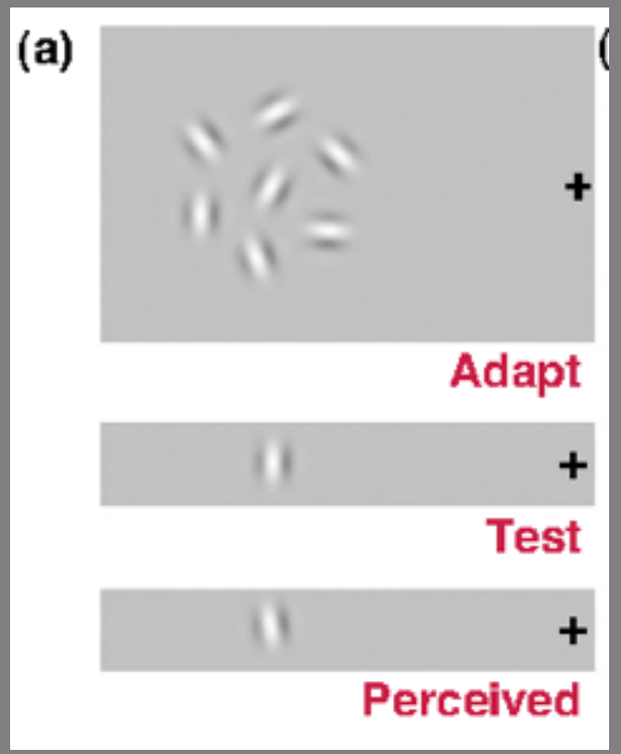
Adaptation: In lateral masking (visual crowding), the orientation of a peripherally presented grating is hidden from conscious sight but remains sufficiently potent to induce an orientation- dependent aftereffect

Priming: priming has been elicited for invisible words (suppressed by a combination of forward and backward masking), but only if the subject was attending to the invisible prime–target pair (specific temporal window)

Adaptation: feature-based attention can spread to invisible stimuli (the previous study we discussed)

Visual Search: when searching for an object in a cluttered scene (e.g. keys in a messy room), attention is paid to an *invisible* object and its associated features. This research shows that attentional selection does not necessarily engender conscious sensation.

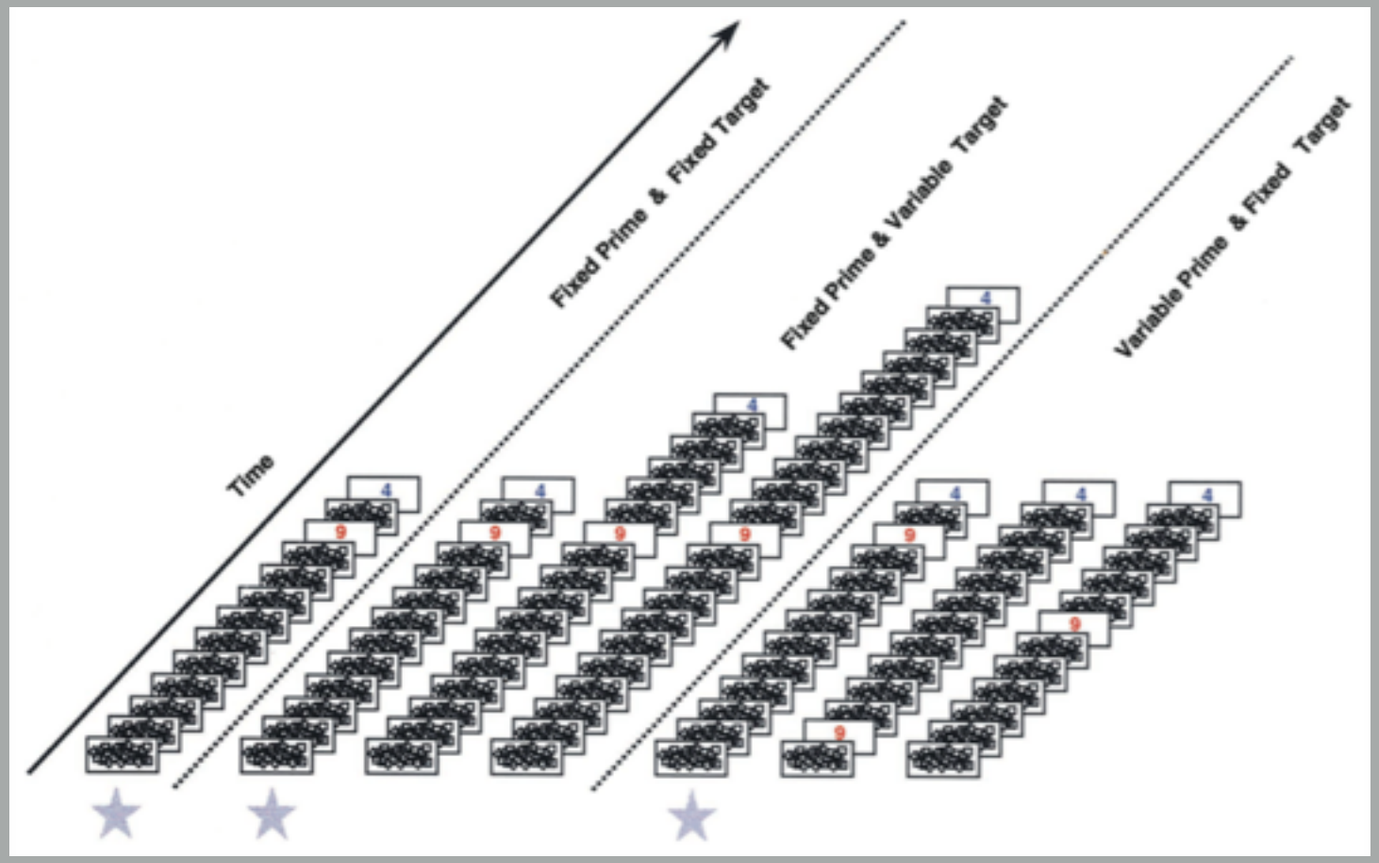
- ***The Dissociation Between Visual Attention and Awareness***



Visual Crowding: priming has been elicited for invisible words (suppressed by a combination of forward and backward masking), but only if the subject was attending to the invisible prime–target pair (specific temporal window)

VISUAL spatial resolution is limited by factors ranging from optics to neuronal filters in the visual cortex[1,2], but it is not known to what extent it is also limited by the resolving power of attention. To investigate this, we studied adaptation to lines of specific orientation, a process that occurs in primary visual cortex[3]. When a single grating is presented in the periphery of the visual field, human observers are aware of its orientation, but when it is flanked by other similar gratings ('crowding'), its orientation becomes impossible to discern[4,5]. Nevertheless, we show that orientation-specific adaptation is not affected by crowding, implying that spatial resolution is limited by an attentional filter acting beyond the primary visual cortex. Consistent with this, we find that attentional resolution is greater in the lower than in the upper visual field, whereas there is no corresponding asymmetry in the primary visual cortex. We suggest that the attentional filter acts in one or more higher visual cortical areas to restrict the availability of visual information to conscious awareness[6].

- ***The Dissociation Between Visual Attention and Awareness***



Priming: priming has been elicited for invisible words (suppressed by a combination of forward and backward masking), but only if the subject was attending to the invisible prime–target pair (specific temporal window)

Subjects were told that they would see a target number between 1 and 9, excluding 5, and that they would have to com- pare it with a fixed standard of 5, pressing the right button for targets larger than 5 and the left button for targets smaller than 5. Unbeknownst to them, another number, surrounded by geometric masks that made it invisible, was presented for 29 ms immediately before the target.

- ***The Dissociation Between Visual Attention and Awareness***

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Attention and consciousness: two distinct brain processes

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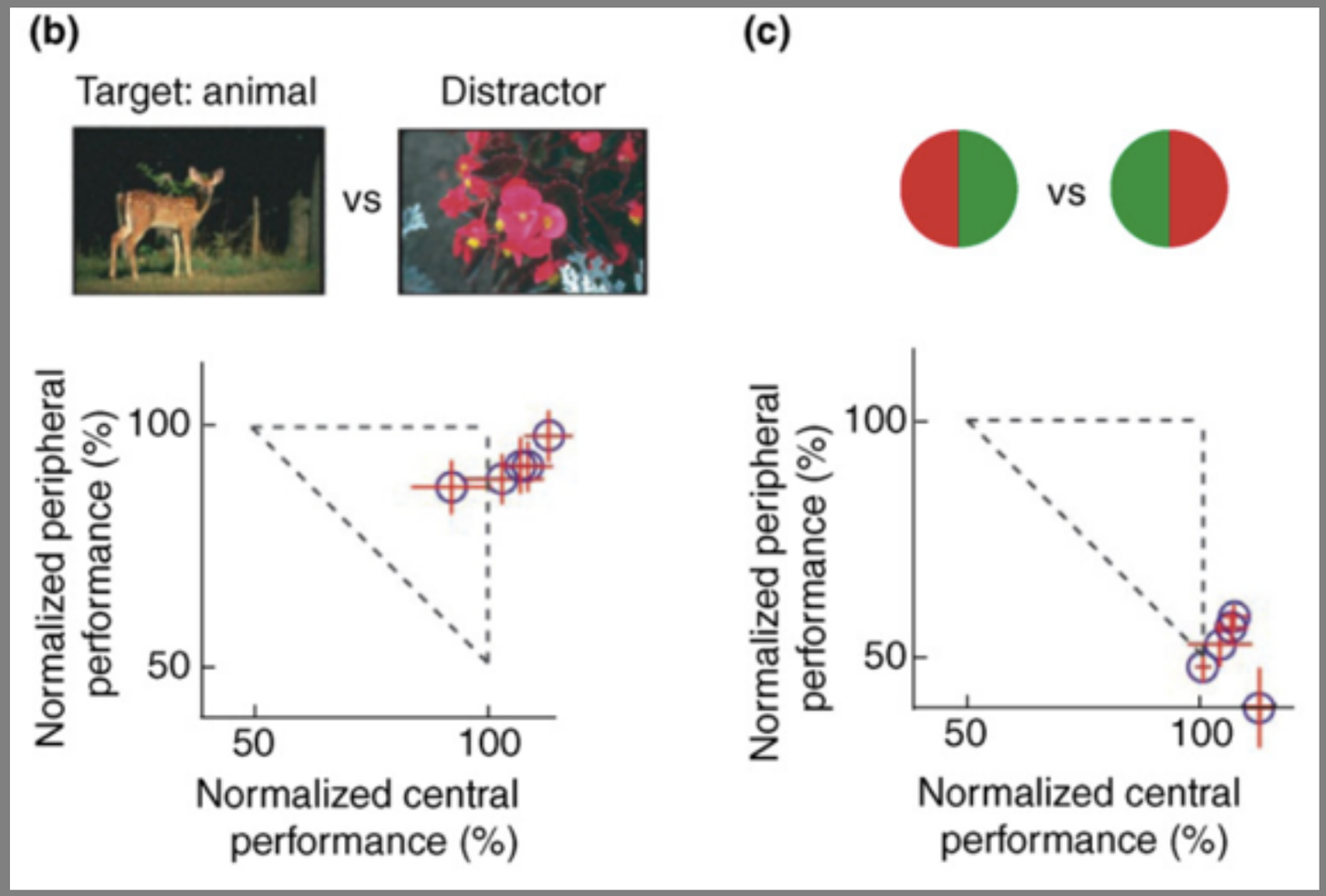
Top-down attention is not required	Gives rise to consciousness
	Pop-out in search
	Iconic memory
	Gist
	Animal and gender detection in dual tasks
	Partial reportability

Gist: when a photograph was briefly flashed unexpectedly onto a screen, subjects could accurately report a summary of the photograph. In a mere 30 ms presentation time, the gist of a scene can be apprehended.

Animal & gender detection in dual tasks: With focal attention busy at the center, subjects can determine whether a scene contains an animal (or a vehicle) but are unable to distinguish between a red–green and a green–red disk >> And they are not guessing: they can be confident of their discrimination choices and 'see', albeit often indistinctly, the peripheral stimuli.

Pop-out in search: Saliency

- ***The Dissociation Between Visual Attention and Awareness***



Animal & gender detection in dual tasks: With focal attention busy at the center, subjects can determine whether a scene contains an animal (or a vehicle) but are unable to distinguish between a red–green and a green–red disk >> And they are not guessing: they can be confident of their discrimination choices and 'see', albeit often indistinctly, the peripheral stimuli.

- ***Zombie Behaviours***

Action without Awareness

Blindsight: brain damage to V1 in one hemisphere leaves the subjects totally blind (no visual awareness) in large parts of the contralateral visual hemifield.

Blindsight was first described in patients with gunshot wounds to the striate cortex, who move their eyes towards or point at small visual stimuli which they claimed they were unable to “see”

non-visual awareness of a visual stimulus has been described by subject GY as "The nearest I ever get, and it is not a fair comparison, is waving your hand in front of your eyes when they are closed. You are kind of aware that something happened but you don't quite see it."

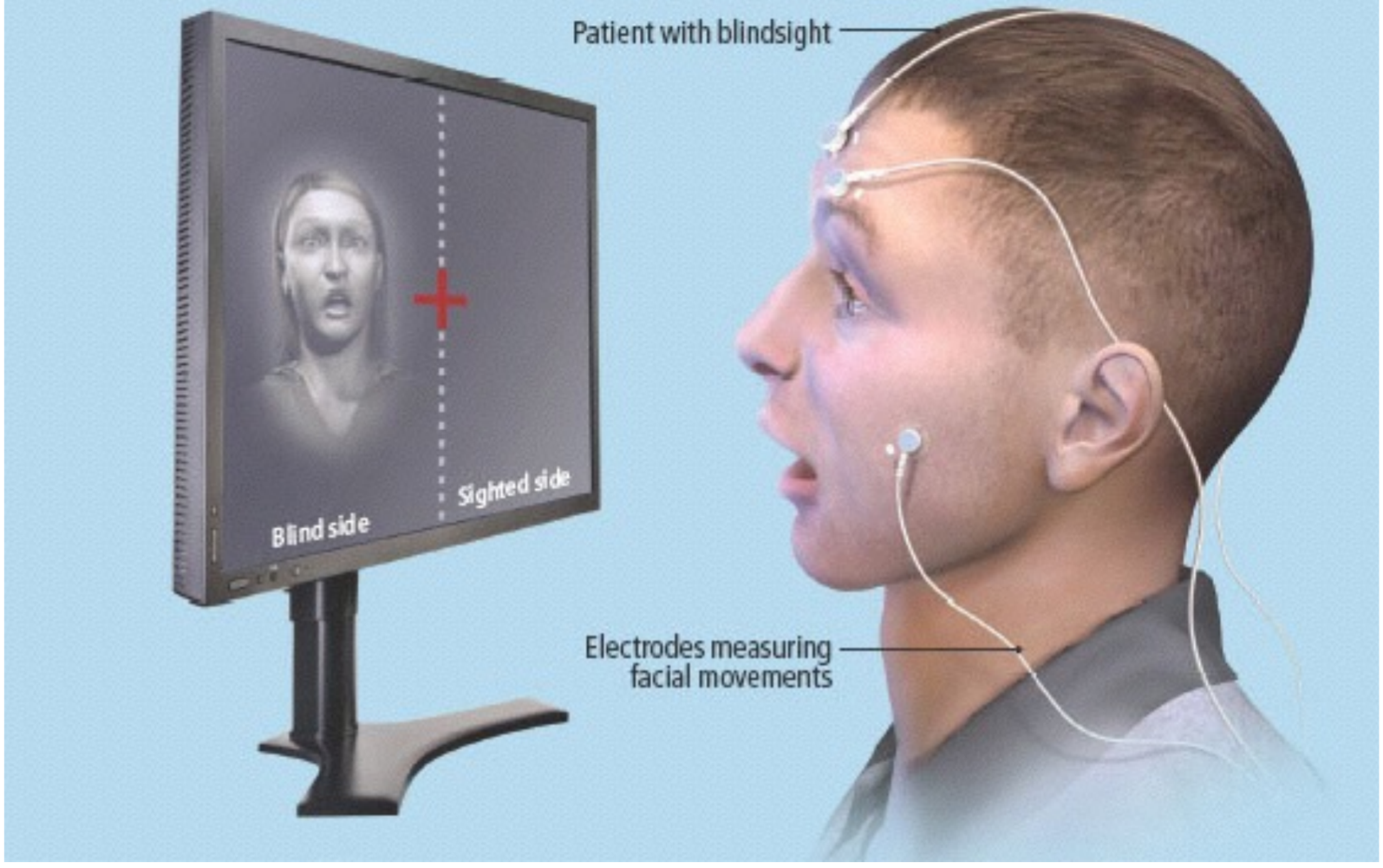
[EXPERIMENTS]

Investigating Blindsight

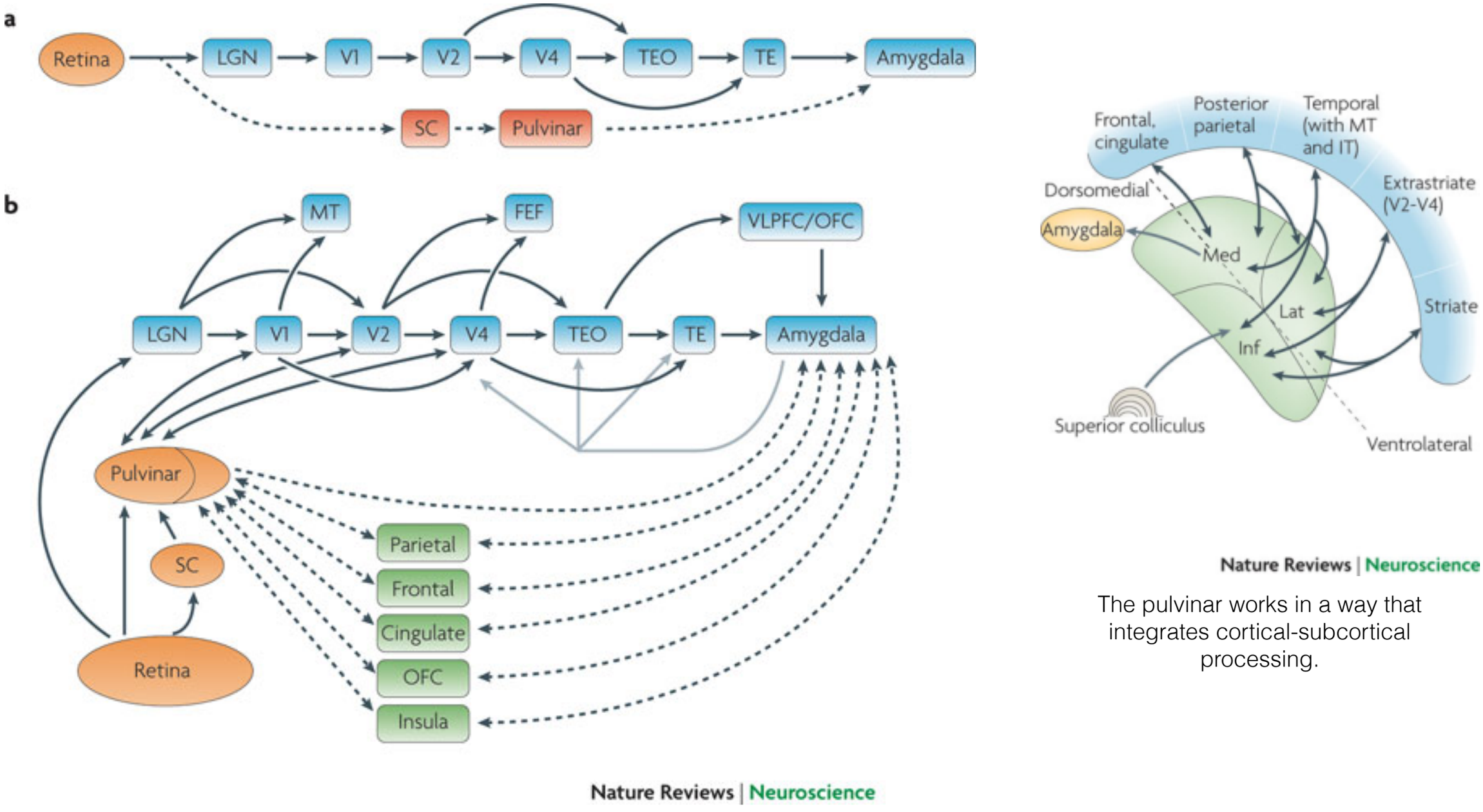
Because total cortical blindness like patient TN's is rare, studies of blindsight often use patients blind on one side of their visual field. The patient stares at a fixed point while images are presented on each side. The subject may be asked to "guess" what is on the blind side or to press a button on seeing items on the sighted side. Equipment may monitor brain activity and measure involuntary responses such as tiny facial movements and pupil dilation.

▼ DOES BLINDSIGHT SEE EMOTIONS?

Patients shown images on their blind side of people expressing emotions correctly guessed the emotion most of the time. Facial muscles used in smiling and frowning reacted in ways that matched the kind of emotion in the unseen image (*below, exaggerated*). Thus, the emotions were recognized without involving conscious sight. The effect worked with images of faceless bodies as well as faces, implying that patients were recognizing an emotion and not merely mimicking a facial expression unconsciously.



Without V1, how did these signals get to the dorsal pathway?
There's a second pathway to the dorsal stream that bypasses V1!
Retina – Superior Colliculus - Pulvinar



The pulvinar works in a way that integrates cortical-subcortical processing.

Behavioral studies have shown that the SC is not needed for object recognition, but plays a critical role in the ability to direct behaviors toward specific objects >> *gaze shifts*

Lesions of the pulvinar can result in neglect syndromes and attentional deficits

- ***Change Blindness***

- Attention, eye movements, and memory allow you to ‘paint’ a coherent scene in your mind.

BUT

with an assumption that the outer world remains stable.

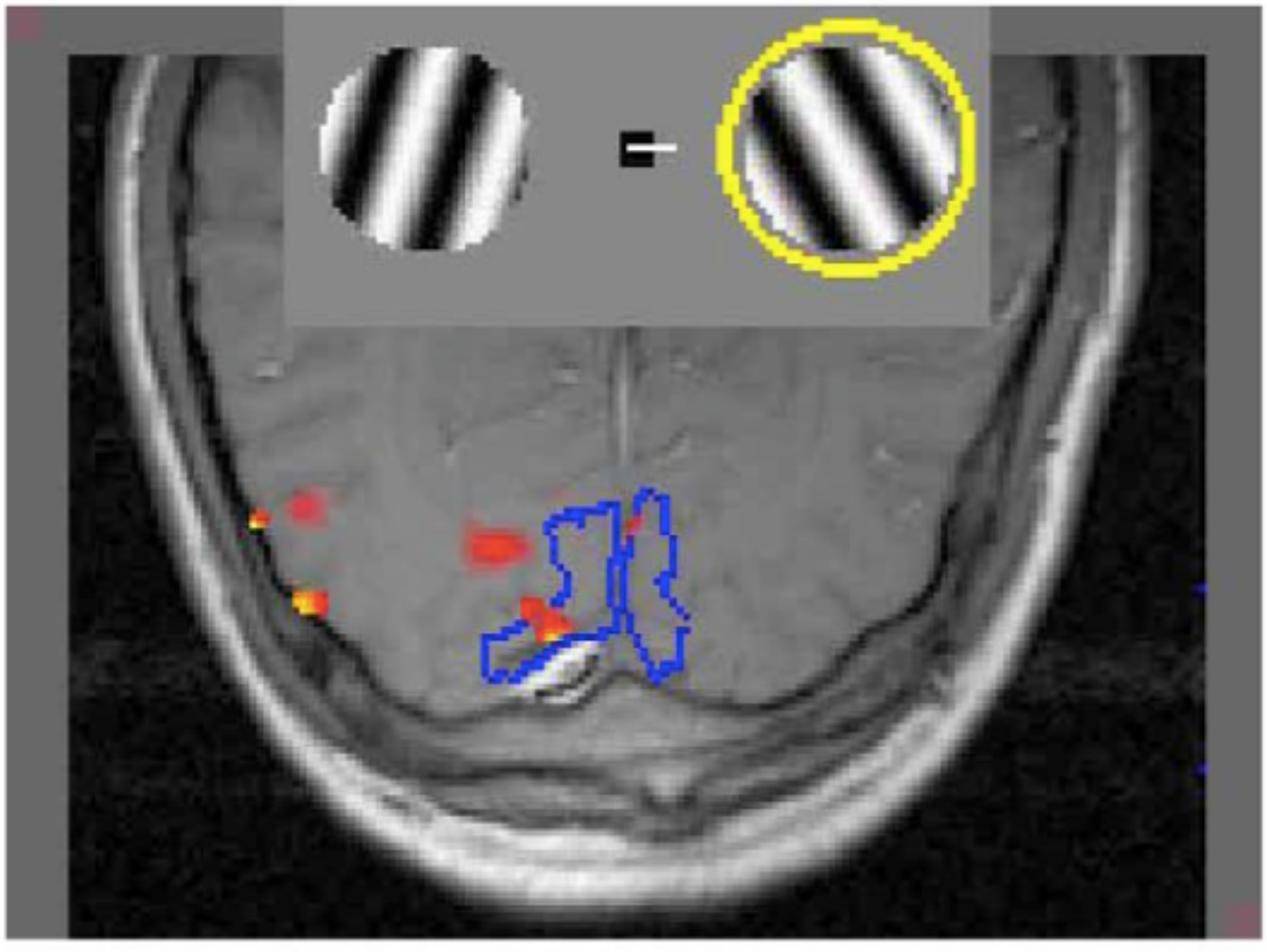
- ***Flicker Induced Change Blindness***

- Observers are shown a picture with and without a missing element in an alternating fashion with a blank screen

- Results show that the pictures had to alternate a number of times before the change was detected

Attentional Modulation of V1 Brain Activity

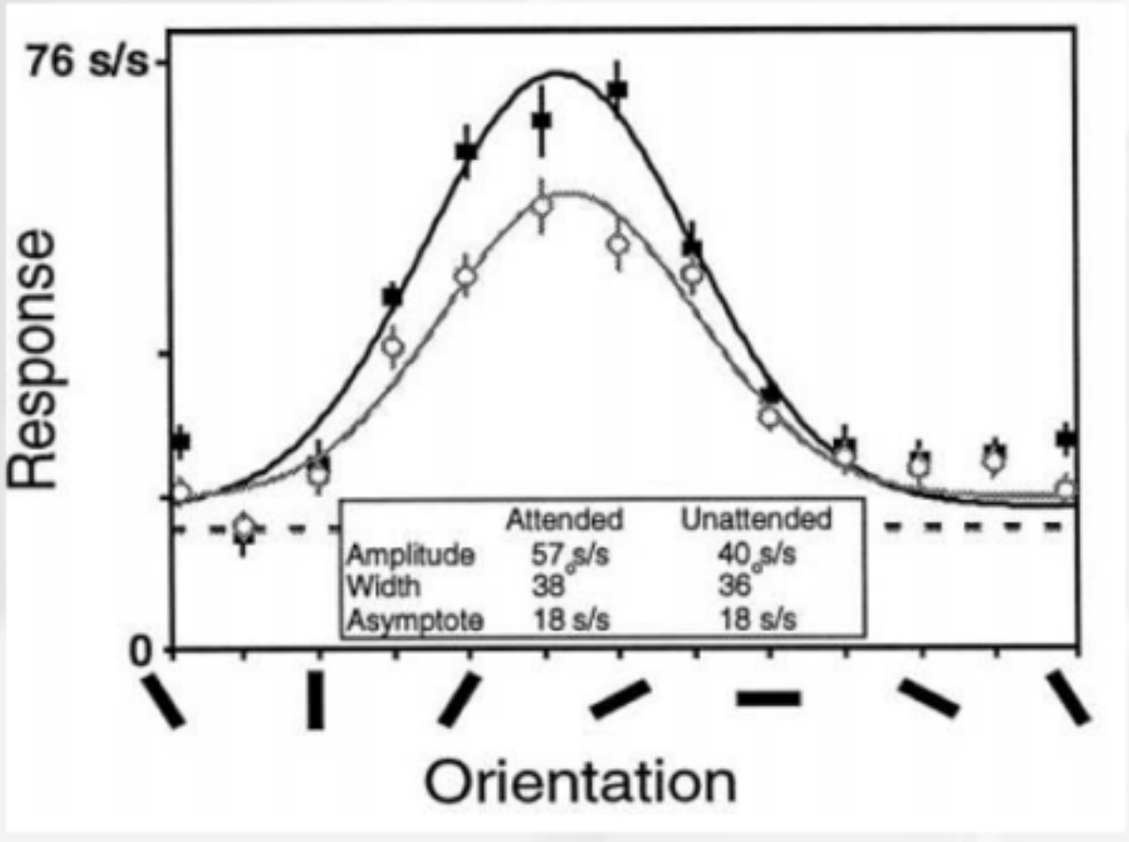
http://www.cns.nyu.edu/~david/courses/perception/lecturenotes/attention/attention.html



fMRI responses in V1 are increased by spatial attention

How does **spatial attention** affect neuronal responses in the visual cortex?

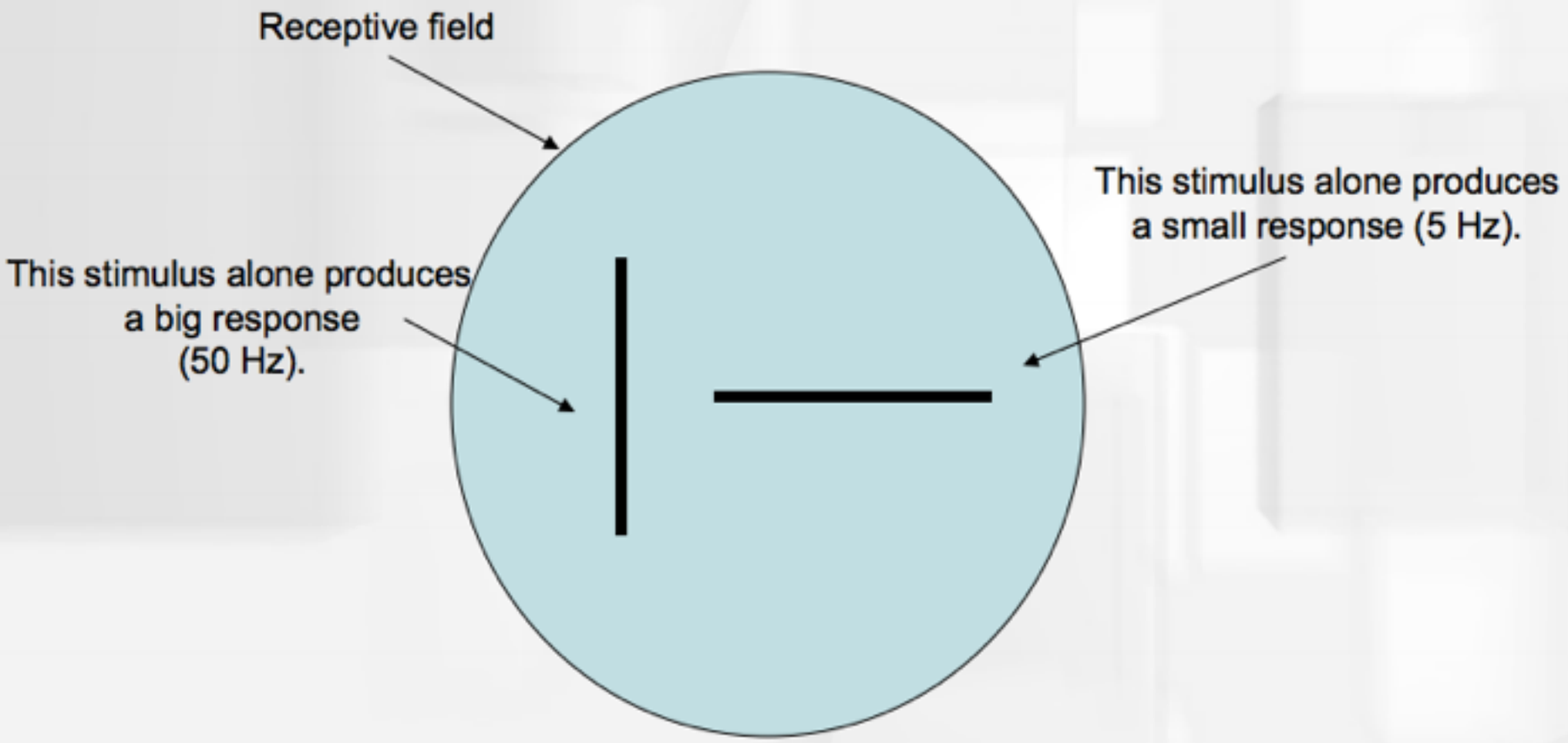
Electrophysiological experiment: have monkeys attend or ignore a stimulus in the receptive field of a neuron.



Electrophysiological responses (spikes) increase with spatial attention in macaque V1 (and area V4) without changing the shape of the orientation tuning

How does **feature-based attention** affect neuronal responses in the visual cortex?

Electrophysiological experiment: present two stimuli in the receptive field of a V4 neuron

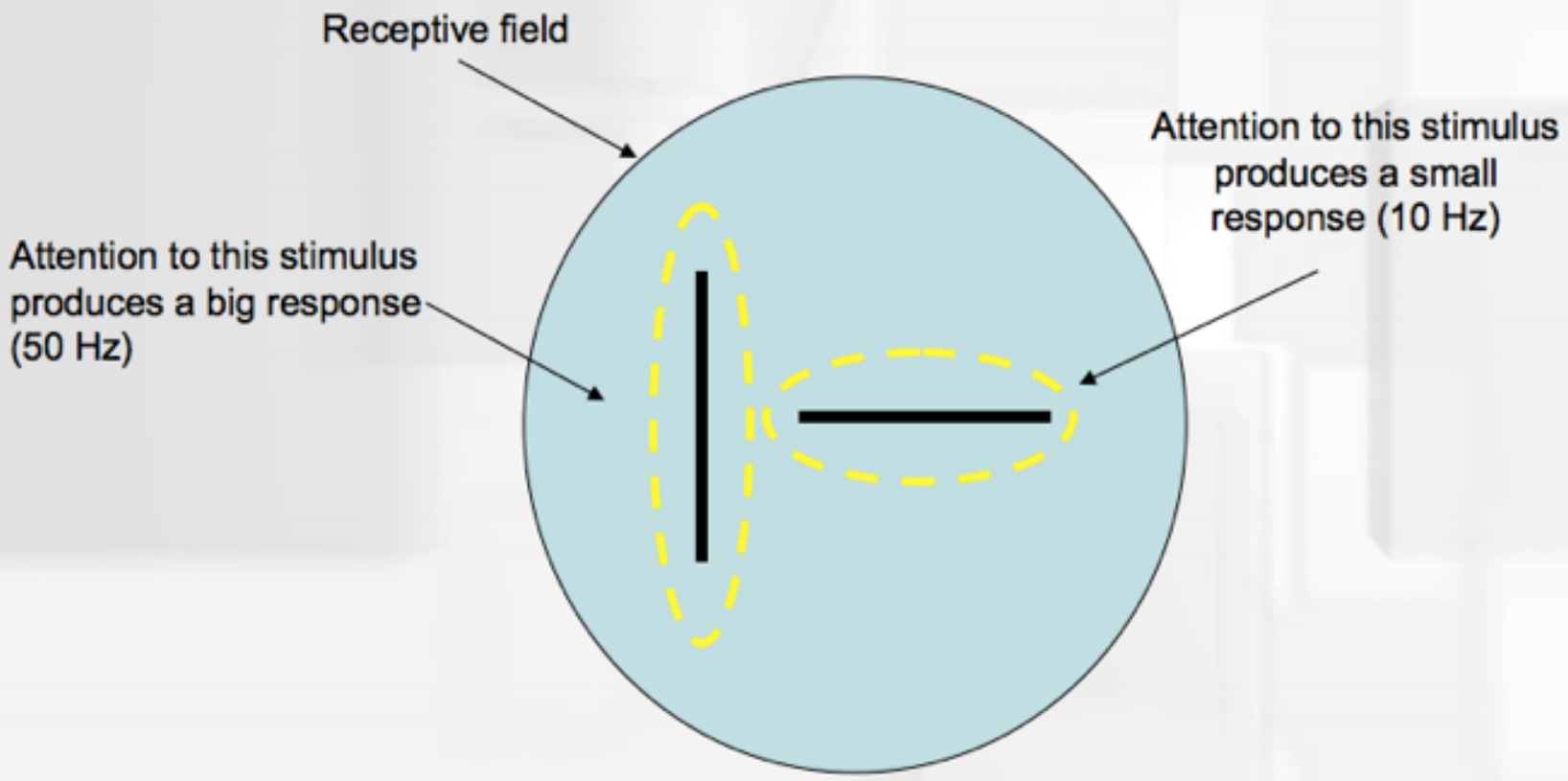


Presented together, the stimuli produce an intermediate response (20 Hz).

Moran and Desimone, 1995

How does **feature-based attention** affect neuronal responses in the visual cortex?

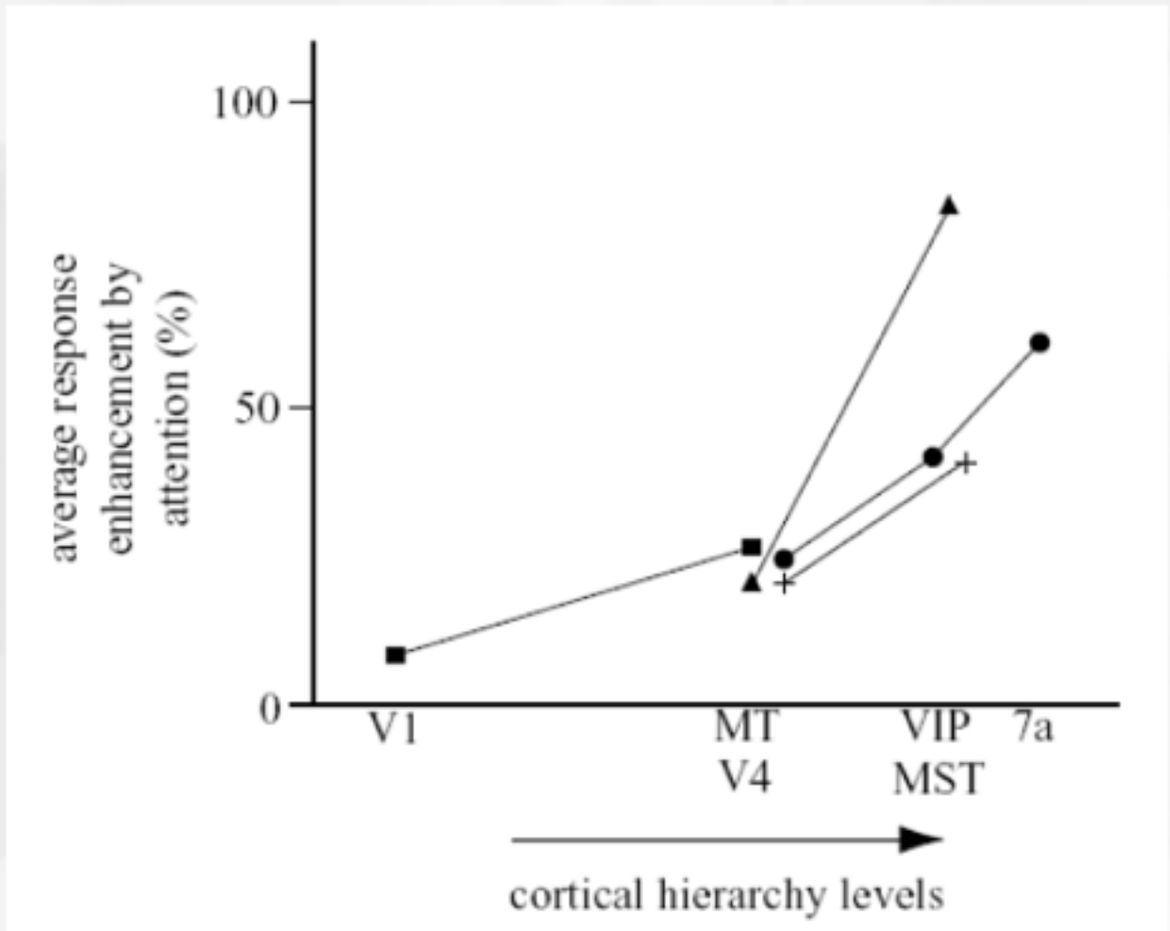
Electrophysiological experiment: now have monkeys attend to one of the two stimuli.



Applying feature-based attention (to orientation) is like removing the unattended stimulus from the receptive field.

Moran and Desimone, 1995

Effects of attention increase along the hierarchy of visual areas

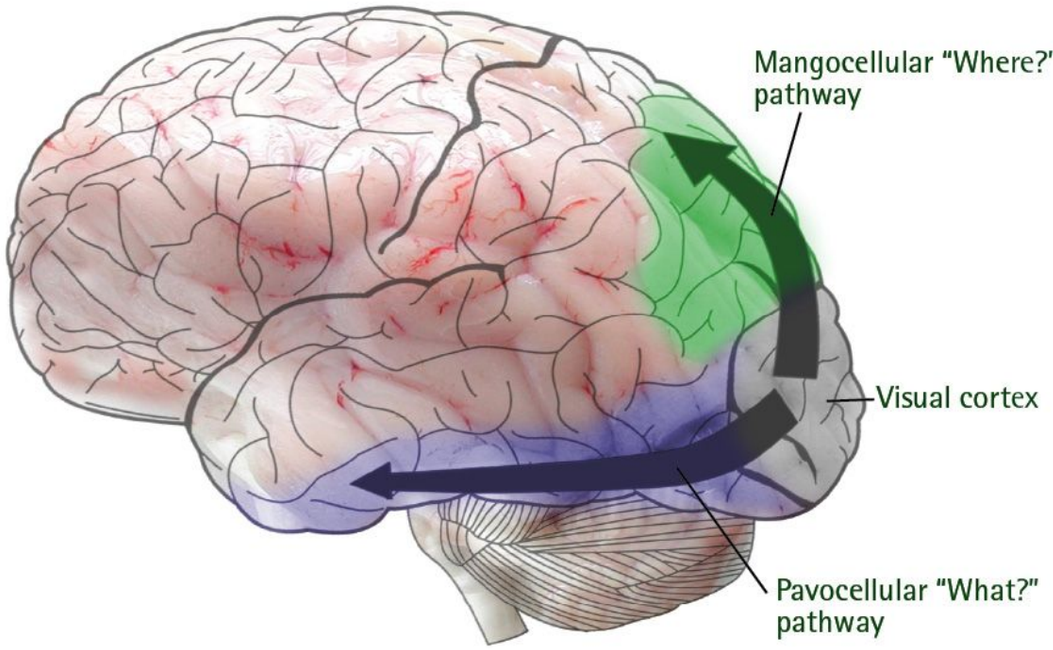


General rule:

Responses in early visual (LGN, V1) areas depend on the visual stimulus.
Responses in higher areas (V4, MT, Parietal) reflect what you actually experience.

Temporal Attention

What are the mechanisms register time at the neuronal level?

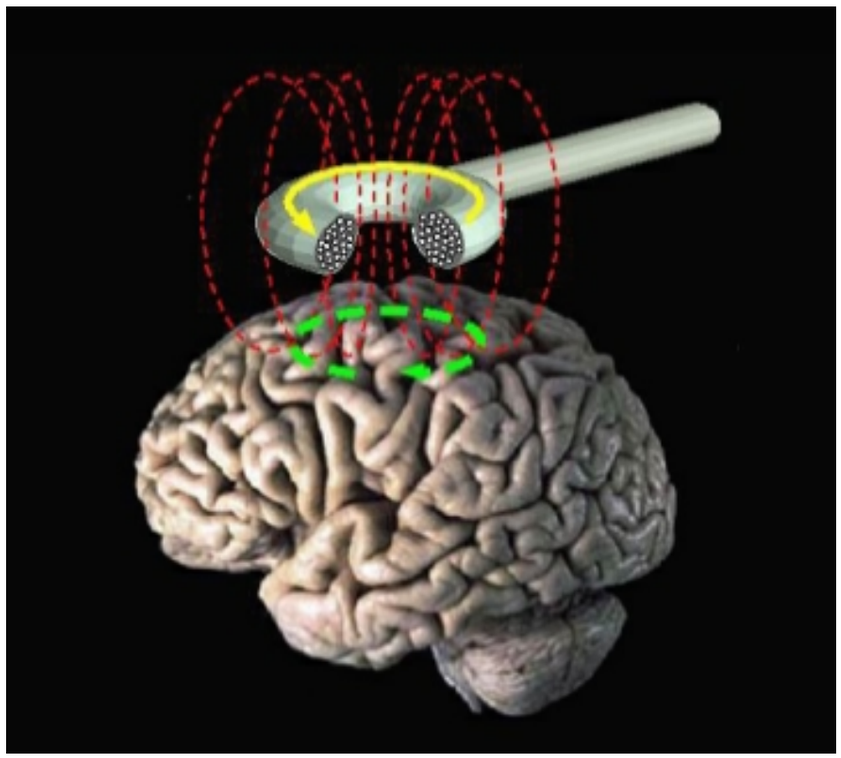


- What pathway: how we identify objects
- Where pathway: how we locate those objects
- When pathway: how we compute *when* visual events occur

Introduction

- There is **enormous range of neural functions**, from the microsecond delays of auditory processing to the measure of the seasons
- Some suggest an **internal clock model**: common neuronal mechanism for all timing operations, from visual to speech perception to timing a wide range of motor tasks
- Others suggest that timing is distributed among **different neural structures** ranging from microseconds processing to millisecond
- There are two broad classes of temporal analysis at these longer scales:
  - **metric** – the judgment of duration or interval between events
  - **ordinal** – the judgment of order of events in a series (in this experiment)

Transcranial magnetic stimulation (TMS)



- In this experiment they used TMS to show temporal attention is lateralised via disrupting the **electrical impulses** produced in right parietal lobe. (proposed as when pathway)

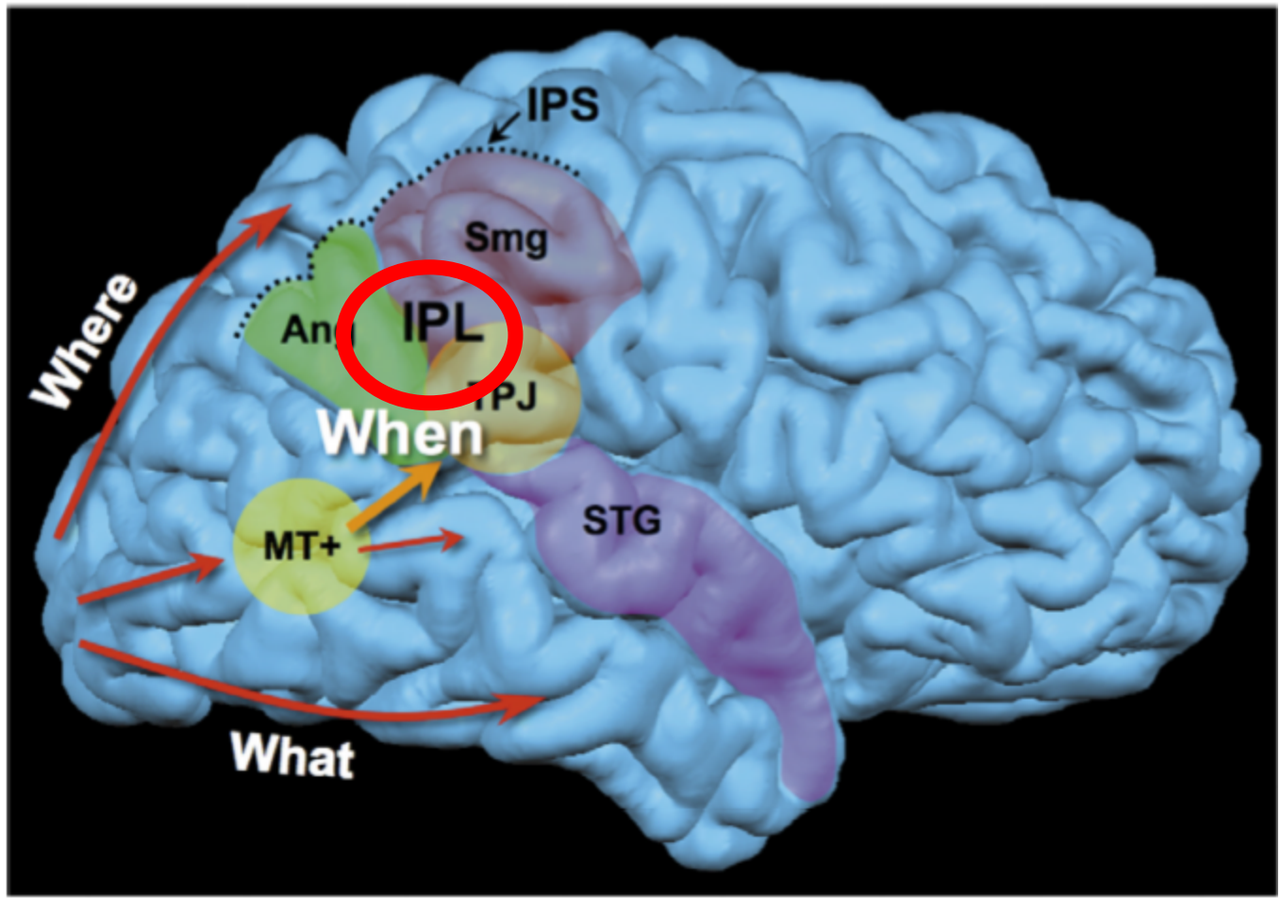
Patients with lesion:

- They not only used TMS, they also used patients with **lesion**.
- **Parietal control** over spatial attention is strongly **contralateral**, whereas

the control of the **right parietal cortex** over temporal attention is **bilateral: So different mechanisms?**

- The difference between **bilateral** and **contralateral** effects is then **diagnostic** of the contributions of spatial and temporal attention in tasks where both are involved

The processing of the temporal dimension



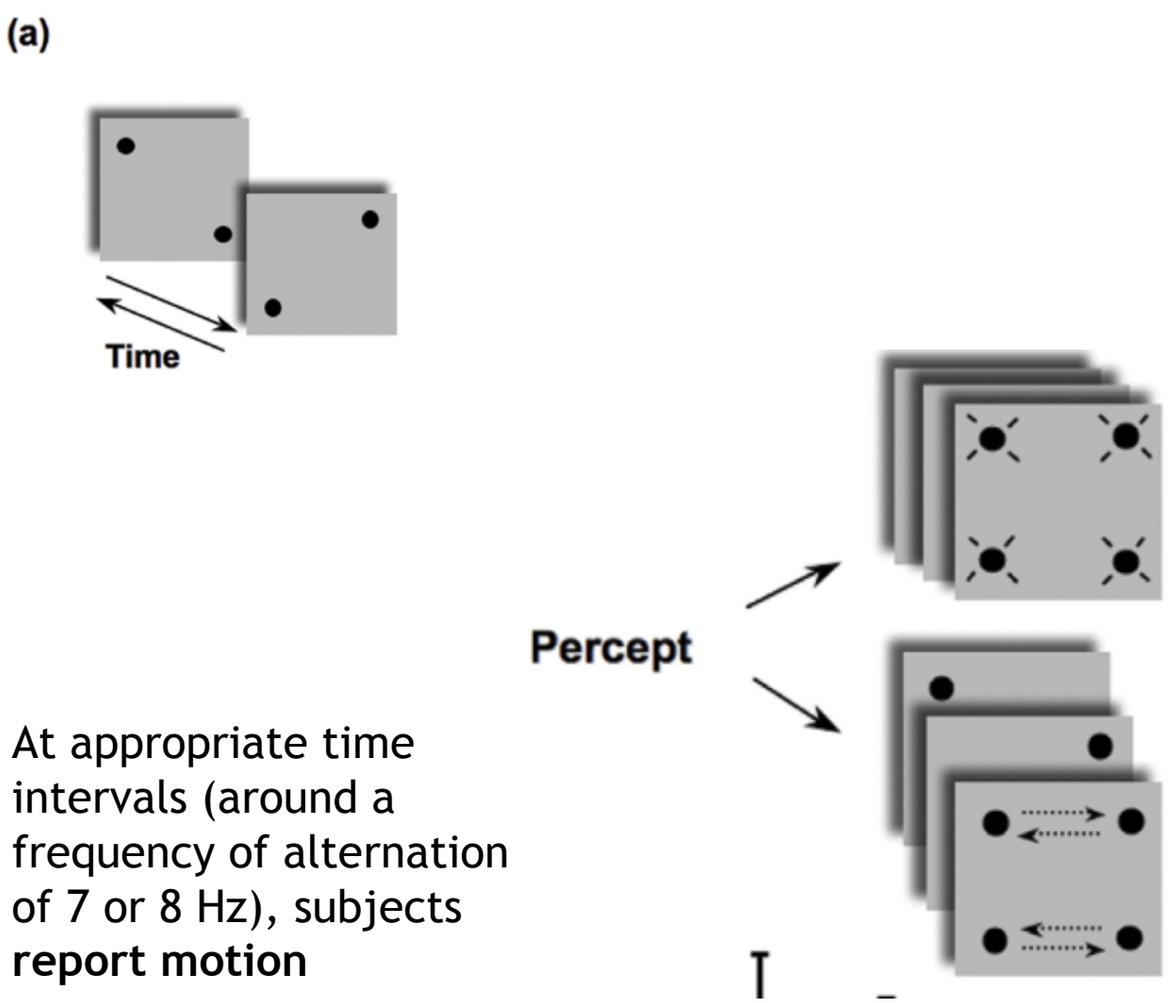
Inferior Parietal Lobe:

- has a major role in detecting visual events at **unexpected locations**
- studies on patients who have **lesions in the right IPL** suggest a specific role for this area of the brain in perceptual abilities that require the **analysis of time**

IPL: Its principal functions are related to perceptual-motor coordination (e.g., directing eye movements and reaching) and visual attention, which allows for visually-guided pointing, grasping, and object manipulation that can produce a desired effect.

Apparent Motion

Apparent motion task: Two frames with two dots each are alternated at a variable frequency



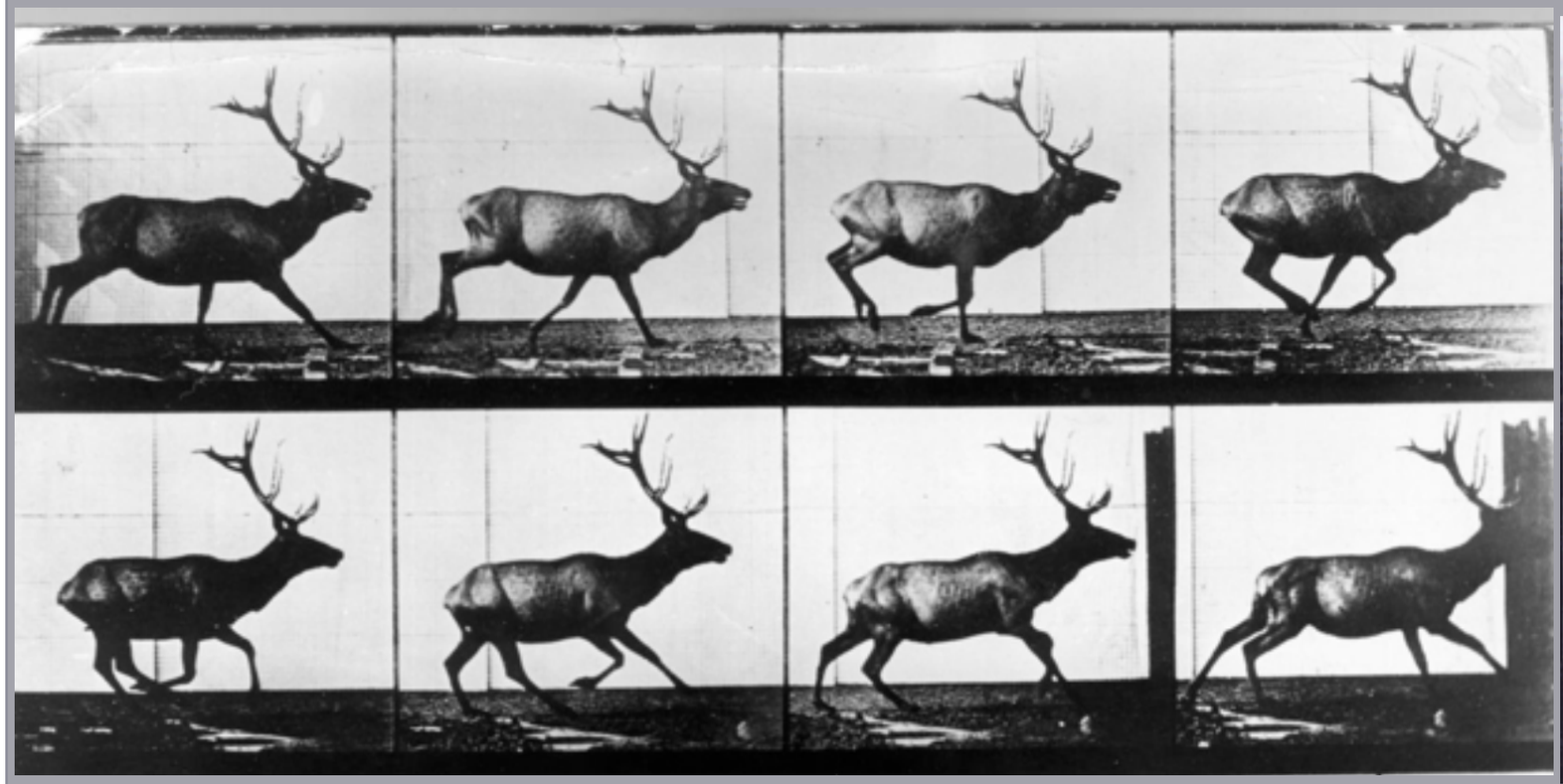
When the interval between the frames is very short (at high frequency, >10 Hz), subjects can perceive only flickering dots and no motion is reported

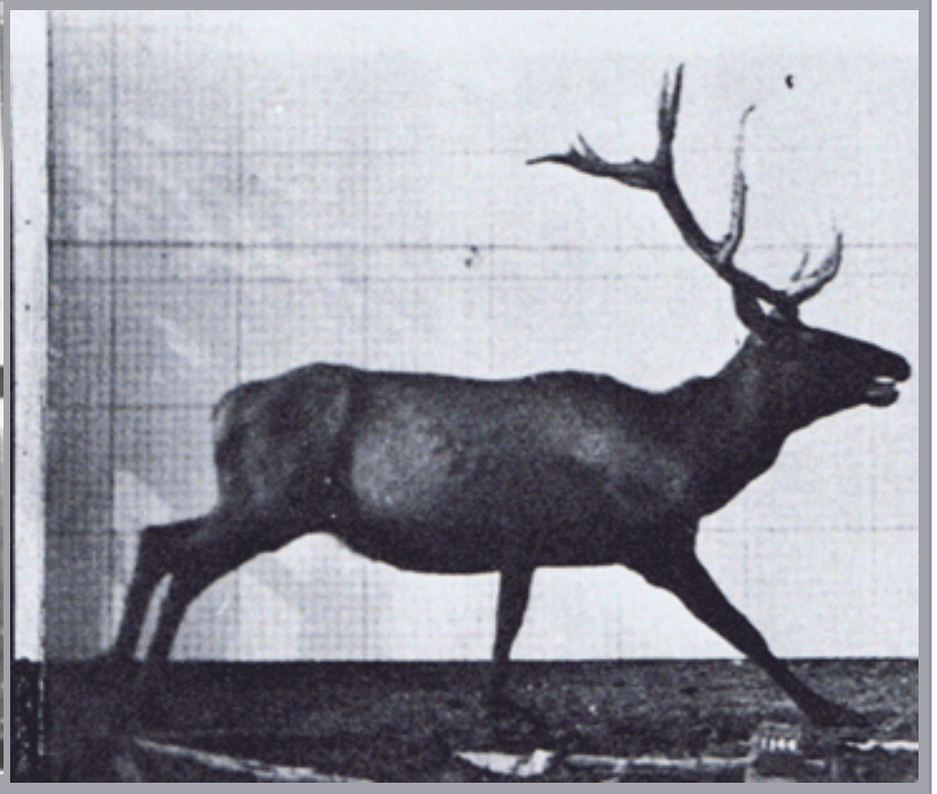
At appropriate time intervals (around a frequency of alternation of 7 or 8 Hz), subjects **report motion**

Apparent Motion

Eadweard Muybridge, 19th century

English photographer important for his pioneering work in photographic studies of motion, and early work in motion-picture projection

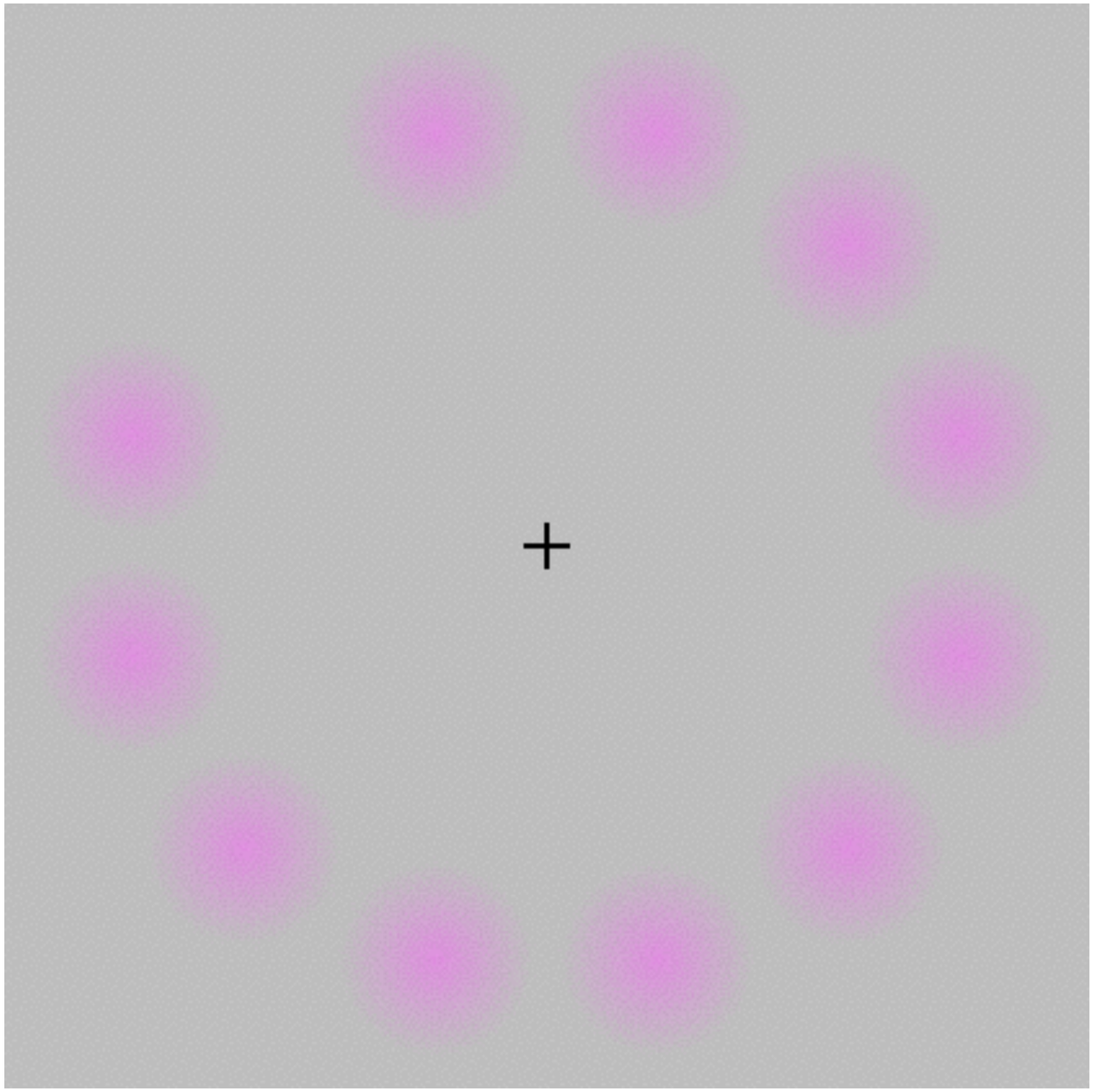




He invented **zoopraksiskop** device accepted as the first projector device.

Today, films are composed of 24 snapshots per second.

i.e. High-Level Motion System (Lilac Chaser Illusion)



The right parietal lobe and bilateral control of transient attention

- Attentional mechanisms are involved in the **perception of apparent motion**
- Both spatial and temporal properties determine the **perception of apparent motion** and this enables us to:
  - ask whether visual **spatial and timing functions** are sub-served by the same **high-level neuronal substrates**
  - or whether they are **distinct** functions in the brain
- Spatial deficits following parietal damage are typically lateralized but other deficits, **specifically temporal ones, have been found to be non-lateralized (bilateral)**