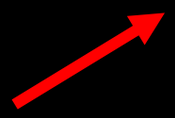
Lecture 24: Attention & Awareness

Outline

O. Review of Big Points from Deep Networks Lecture

I. The crux of Attention: capacity limits and selection



overt vs covert attention

exogenous versus endogenous attention

II. Brain Mechanisms of Attention

Attention modulates neural response in multiple regions, including LGN, V1, FFA, MT, A1, etc.

Source of attentional signals is frontal and parietal lobes

the fronto-parietal attention network (= multiple demand system)

a very domain-general system (unlike FFA, MT, TPJ, etc)

III. Neural correlates of awareness

Binocular rivalry

Attentional blink

Question to Consider

How do you feel about people driving while talking on their cell phones. Is this a good idea?

What if you have a hands-free setup so you don't have to look down at your phone– is that ok?

Why/why not?

The notion of *processing capacity*, or *resources*:

You cannot think about many different things at once.

The "toaster model" of cognition:

when you plug in the toaster the lights dim.

Which mental processes are "on the same circuit"?

Can you listen to music and read at the same time?

Recognize faces and scenes at the same time?

Let's try some simple demos….

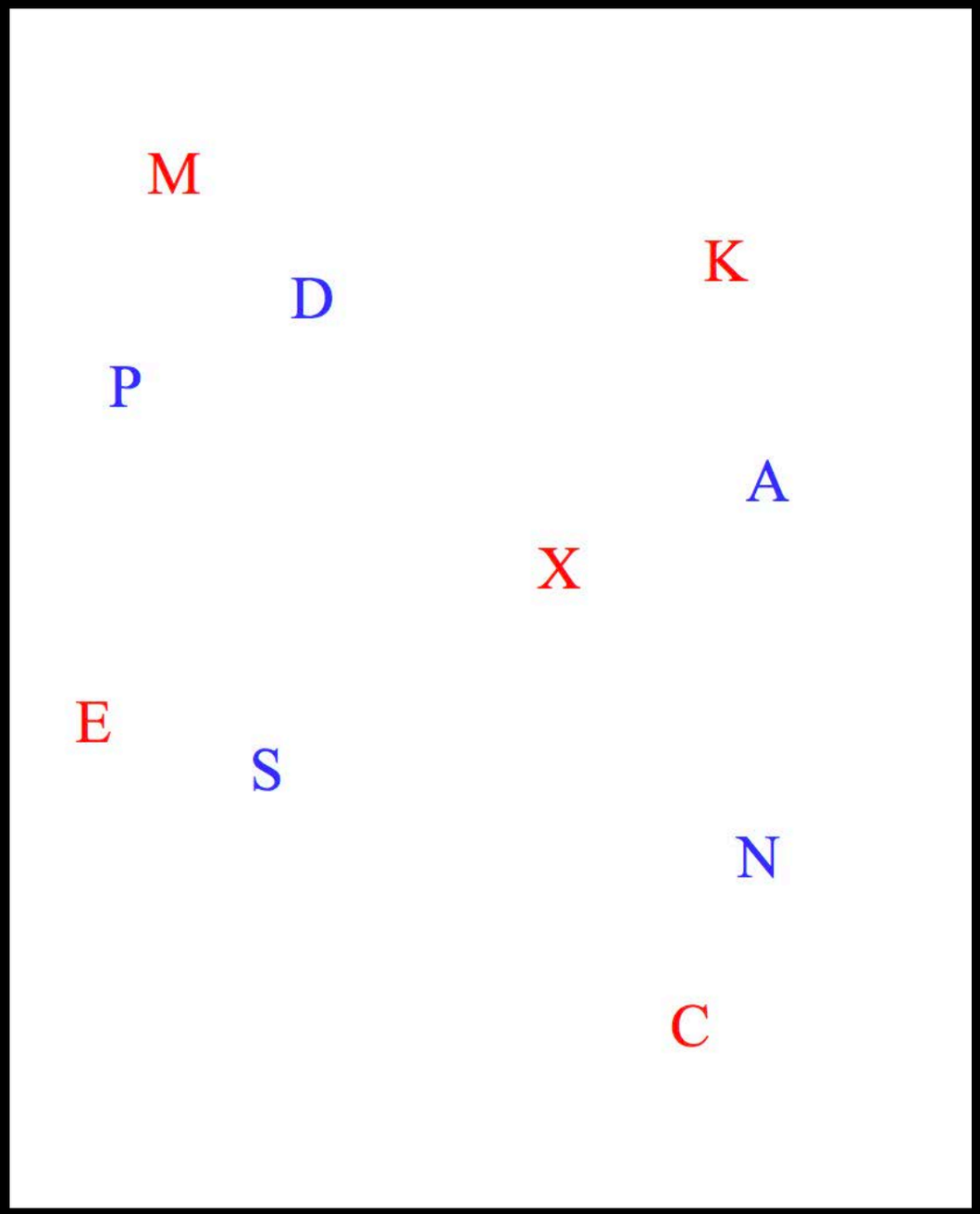
SEE LECTURE VIDEO FOR DEMO

What This Simple Demo Illustrates

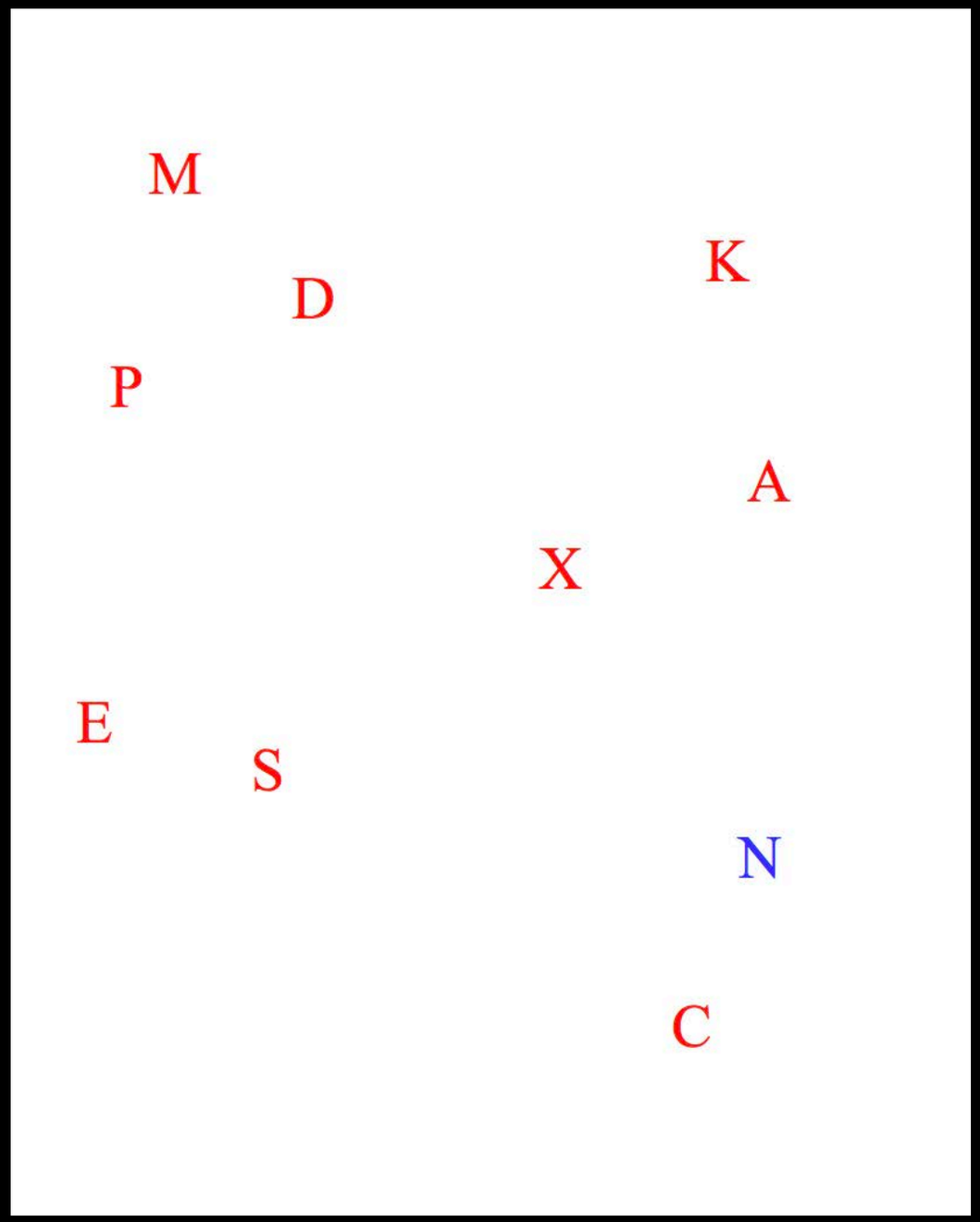
Limited capacity – Only a small amount of information on the retina can be fully processed and used for behavior

Selectivity – We have the ability to filter out unwanted information (e.g., the red letters)…

Probability of reporting "N" is independent of the number of red letters.
Only depends on the number of blue letters.



Display 1



Display 2

Why is our capacity to process visual information limited?

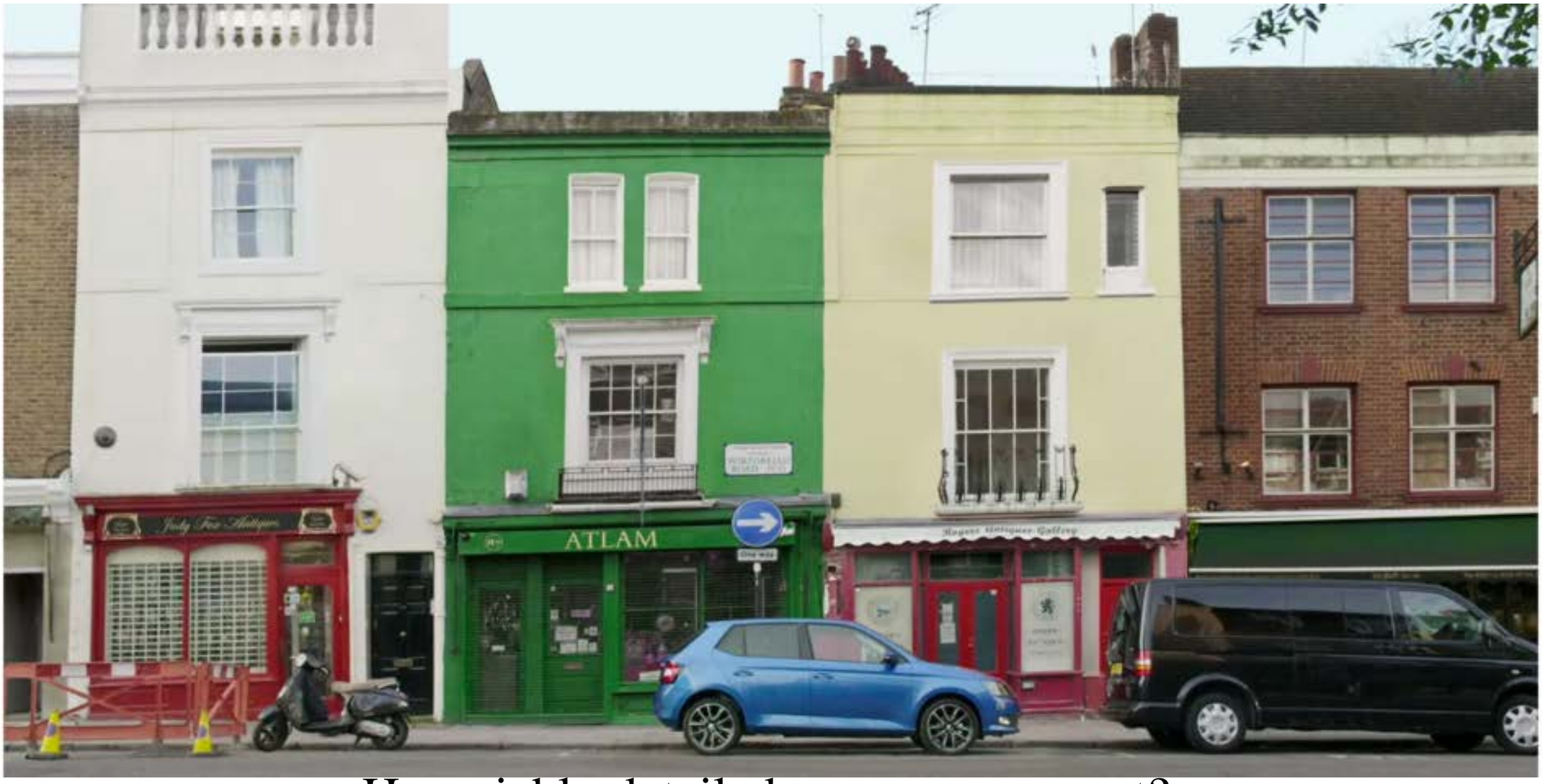
1. Full analysis of everything in the visual field is impossible. (BUT: Given the massively parallel structure of the human visual system, why *can'*t we process everything at once?)

2. We can only direct *action* to one object or portion of the visual field at a time, so having more info might make subsequent processing stages harder.
   Pike fish preys on sticklebacks, catches stickleback faster if there is only one present than if there are five.

More Evidence for Capacity Limits in Perception

There is so much we don’t see, right before our eyes!
For example...

I will show you a pic for a few seconds…



How richly detailed was your percept?

This is a heated topic in field currently.

Let's find out more.

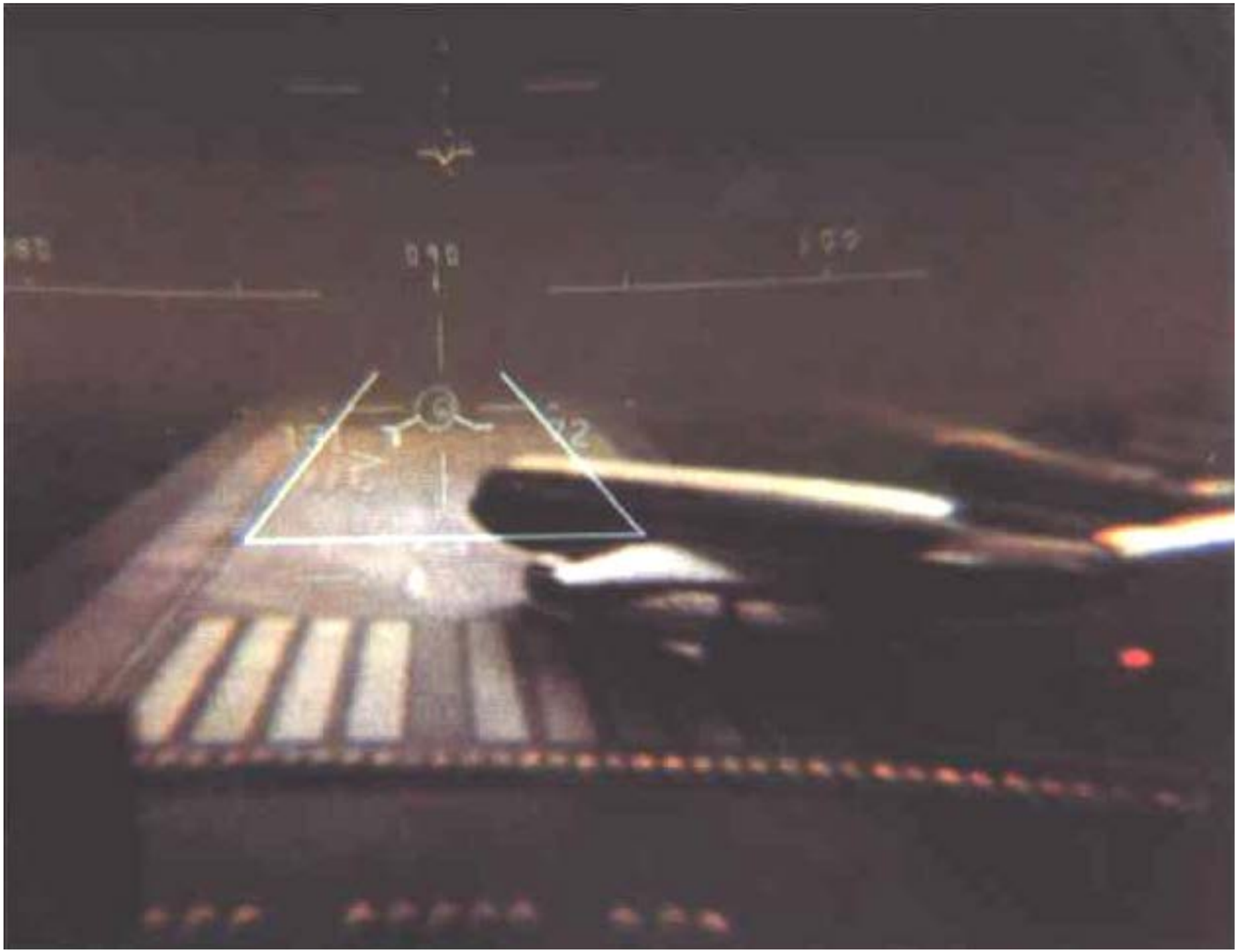
The image will blink multiple times, see if you can spot any changes…

What changed?

Selective attention video: Test Your Awareness: Whodunnit?

Does this kind of thing only happen when it doesn't really matter?

Commercial Airline Pilots fly straight through Plane in Simulator



Plane on simulated runway © Plenum Press/Springer. All rights reserved. This content is excluded from our Creative Commons license. For more information, see https://ocw.mit.edu/fairuse. Haines, R.F. Ch. 17 "A breakdown in simultaneous information processing", in *Presbyopia Research*, 1991.

Commercial airline pilots with thousands of hours of flying experience used a high-quality flight simulator with a head-up display. During one sequence, they came in for a landing under somewhat foggy conditions. They broke through the cloud ceiling and spotted the runway, landing the plane as they usually would. Two of them never saw **the other plane** that was sitting on their runway and landed right through it.

Attention

A filter that lets attended/selected information in but filters unattended information completely out of awareness.

Two key properties of attention that go hand in hand:

- capacity limits - we cant efficiently process everything at once.
- selectivity - so we select a subset of the available information for detailed analysis

Different forms/ways of attending.
An important distinction realized long ago by Helmholtz…..

Helmholtz: Attention is Different from Fixation

" ...our attention is quite independent of the position and accommodation of the eyes, and of any known alteration in these organs, and free to direct itself by a conscious and voluntary effort upon any selected portion of a dark and undifferentiated field of view. This is one of the most important observations for a future theory of attention."

Physiological Optics, circa 1860, quoted in James Principles, pg. 414

Overt versus Covert Visual Attention

• "overt attention" - eye movements - change in retinal *input*
a very powerful selection mechanism because of the fovea.

We make 2-4 eye movements per second, collecting high resolution information from a surprisingly small subset of the visual world at the fovea.

[Recall sharp dropoff in visual acuity in periphery because of:
photoreceptor density (cones denser in fovea)
cortical magnification (more area of V1 devoted to fovea)]

So, eye movements are the MOST powerful way to select.

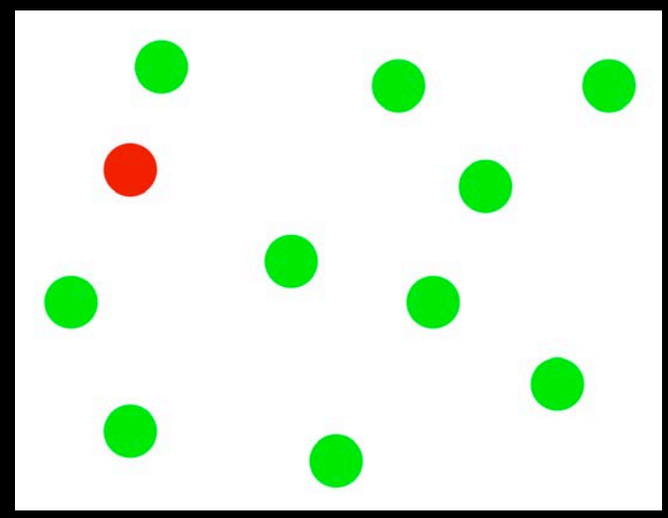
Watch how finely-tuned our sampling of the visual world is…..

Overt versus Covert Visual Attention

• "overt attention" - eye movements - change in retinal *input*
a very powerful selection mechanism because of the fovea

• "covert attention" - no eye movements, only changes in the way the same retinal image is *processed.*
Why bother with covert when you have overt?
other people can see overt, many problems from
elevator eyes, looking at name tag, looking at clock
cannot foveate more than one thing

Distinctions about Visual Attention



- overt versus covert attention

- automatic/stimulus-driven/exogenous attention
  e.g. web pop-ups
  "pop-out" in visual search

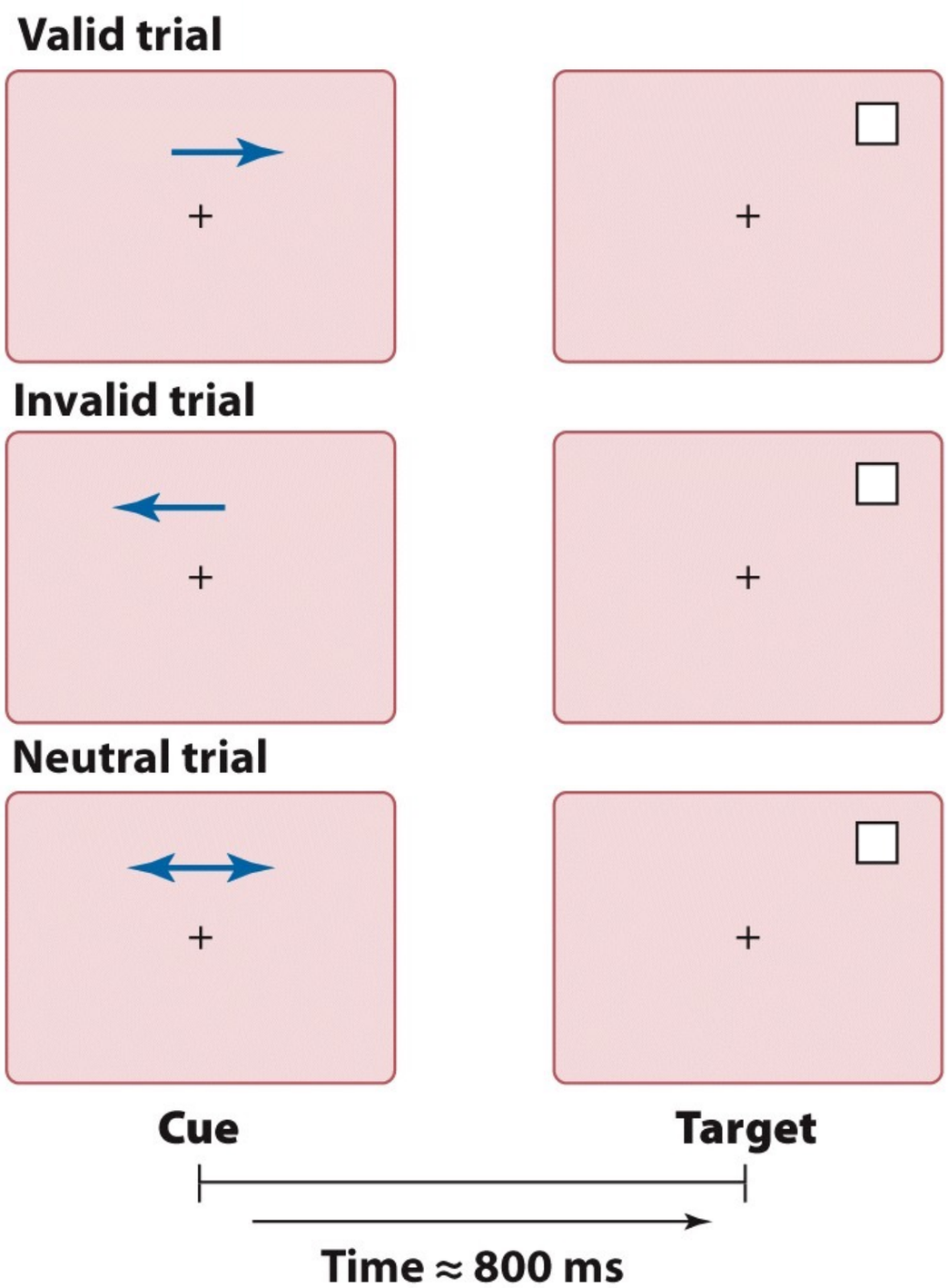
versus controlled/voluntary attention

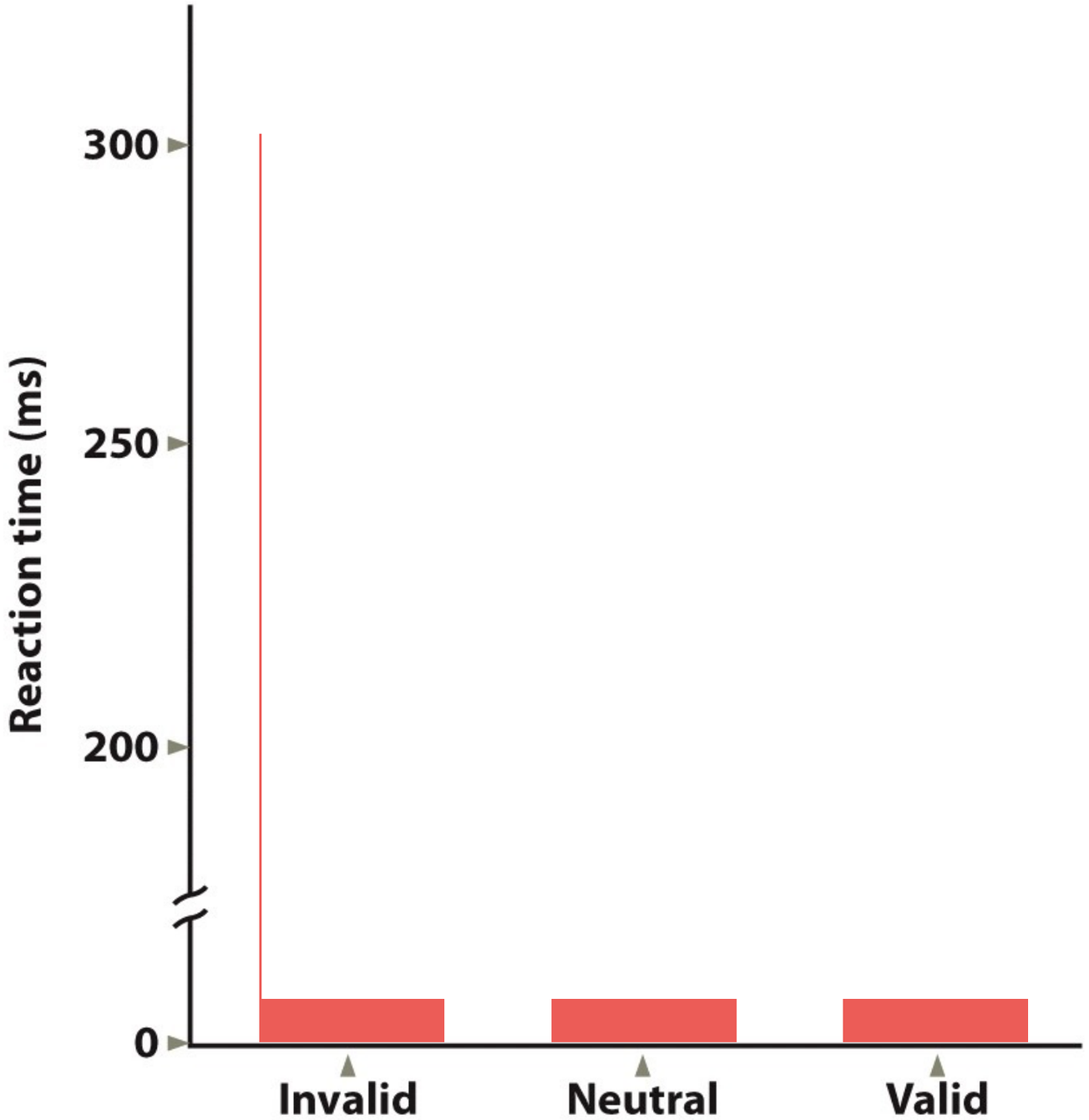
Big idea: your mental life is not (totally) controlled by the information coming in through your senses, you can chose what to pay attention to (thankfully)!

e.g. deciding to focus on something else when you are hungry or reading an article despite annoying web pop-ups

or, using a cue to determine where to attend….

Exogenous Attention Improves Processing Speed and Accuracy





Slide Adapted from Michael Cohen

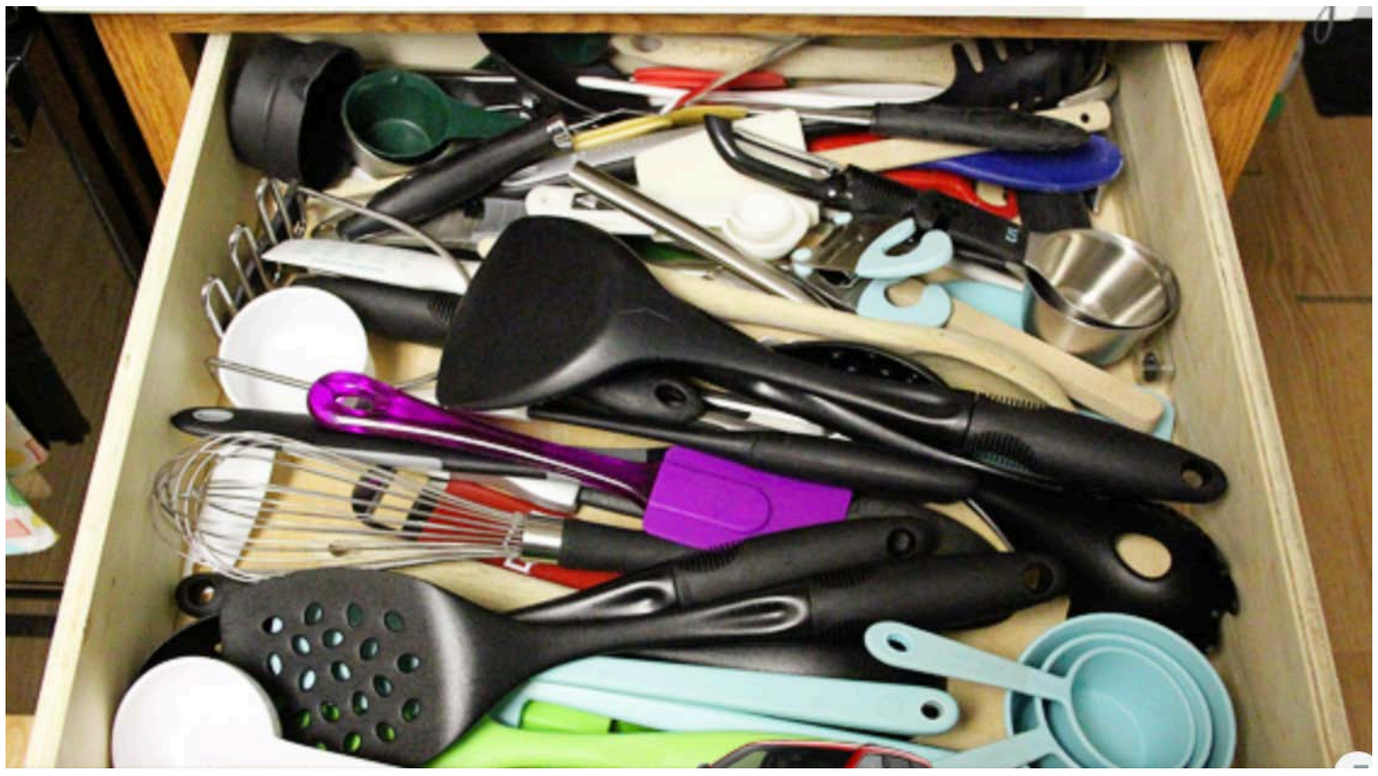
Different Kinds of Attention

How does all this work in the brain?

1. Overt (eye movements) versus covert (no eye movements).

2. Exogenous (or stimulus-driven, or bottom-up) attention
   "pop-out"
   vs endogenous (or internally driven or top-down) attention

3. Spatial attention (previous example)
   versus feature-based attention, e.g.



find the black vegetable peeler

find the purple rubber spatula

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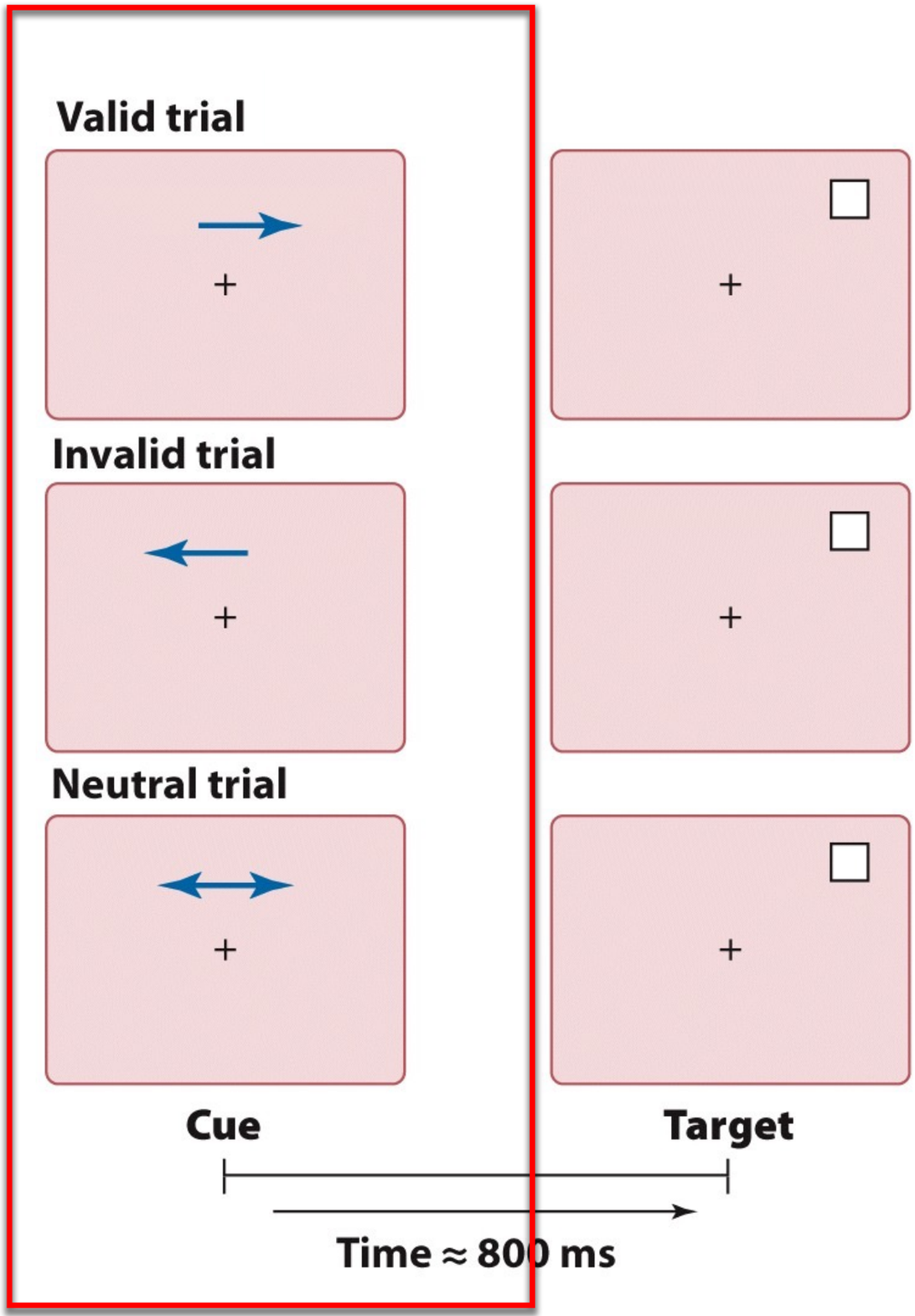
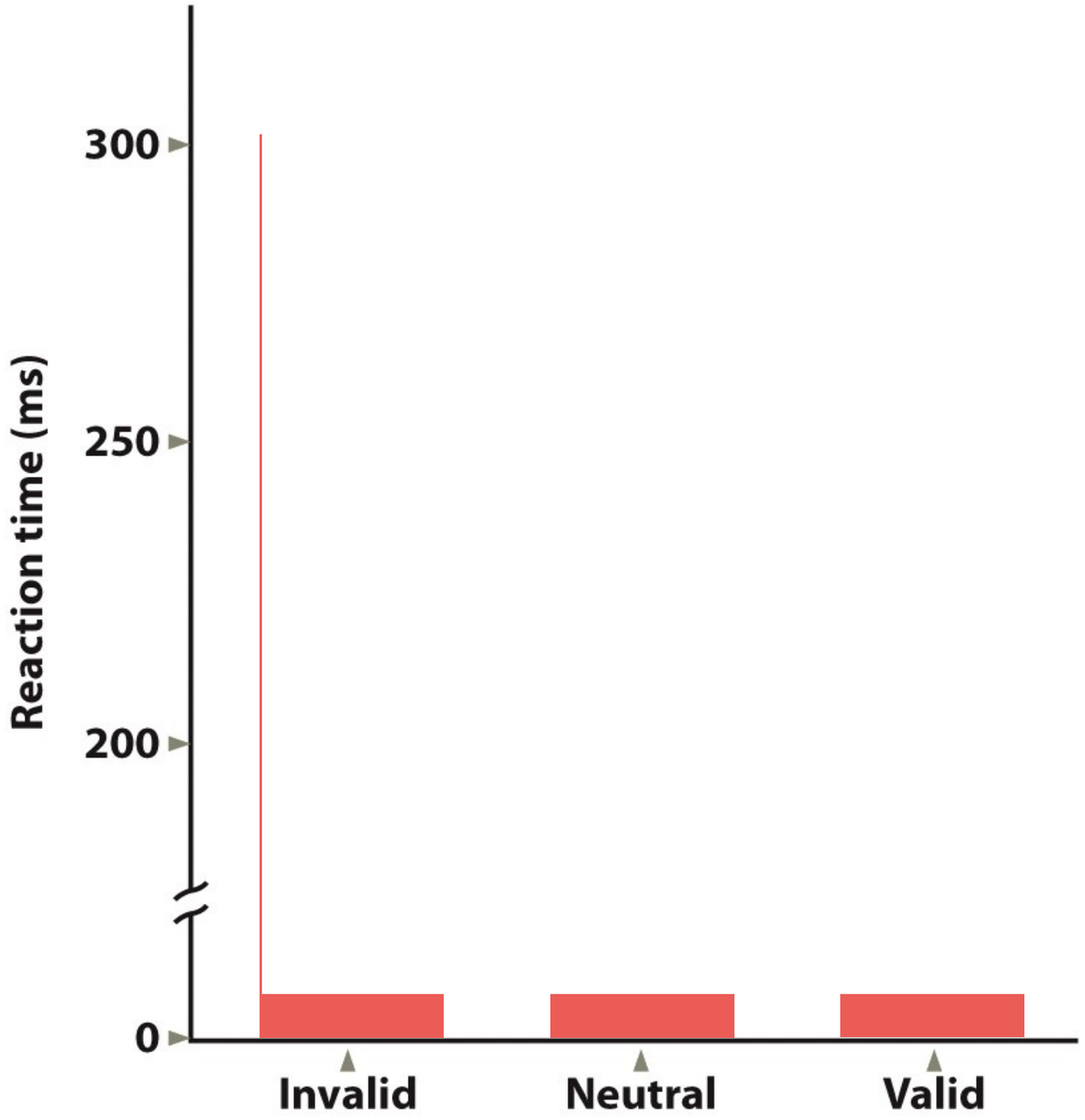
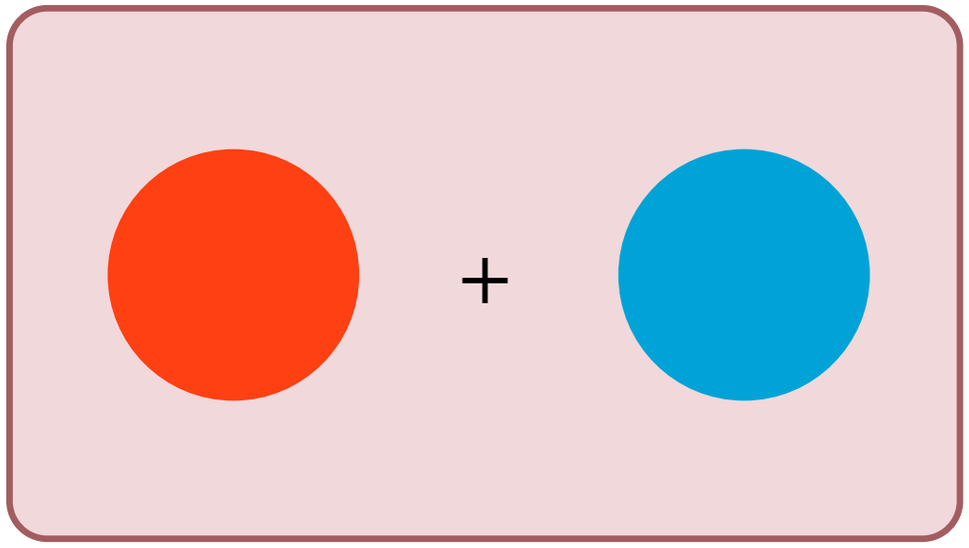
What happens after the cue, but before the stimulus?

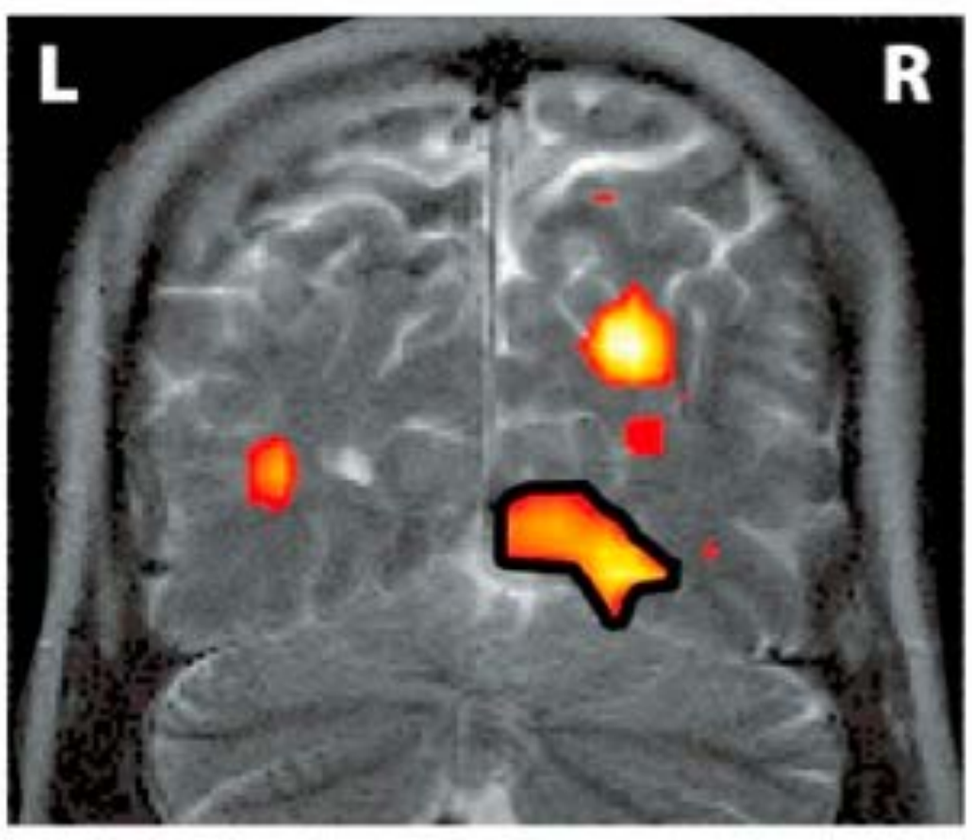


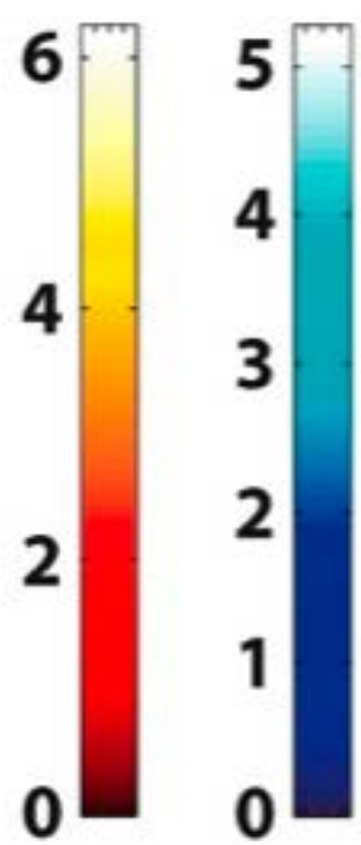


Retinotopic cortex (V1/V2)

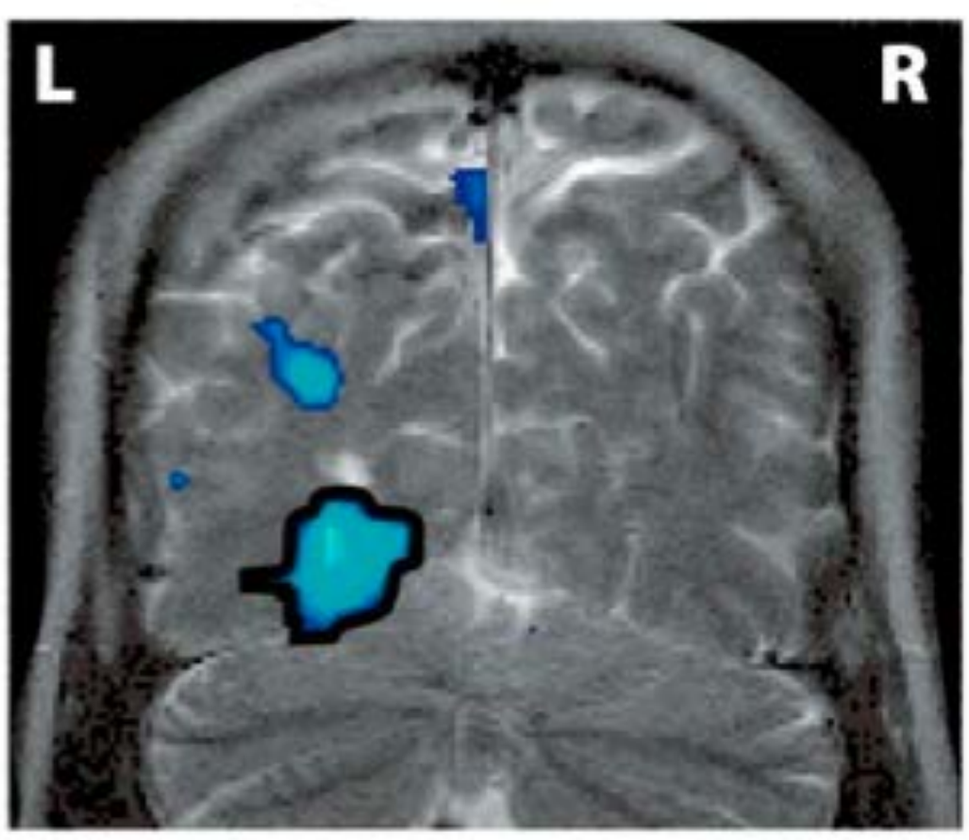


Att. left > Att. right

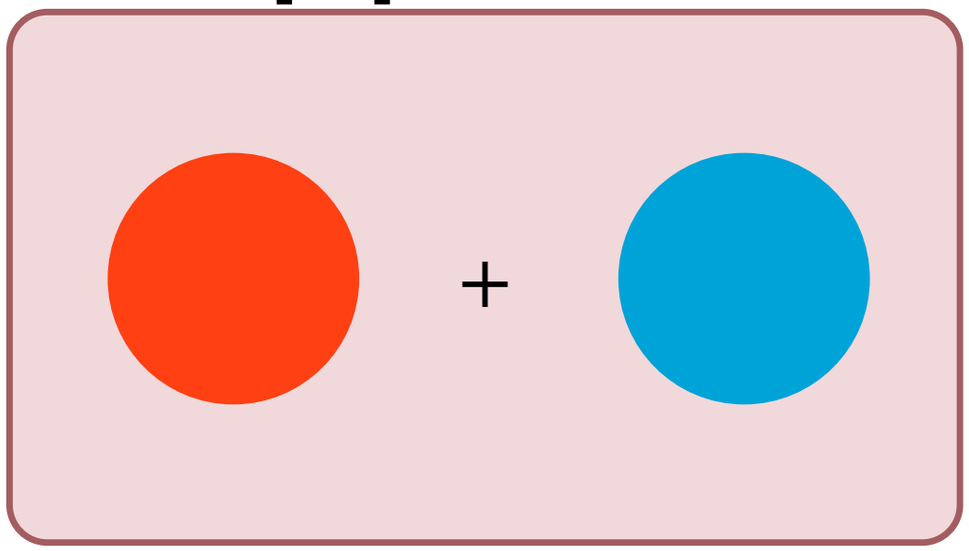


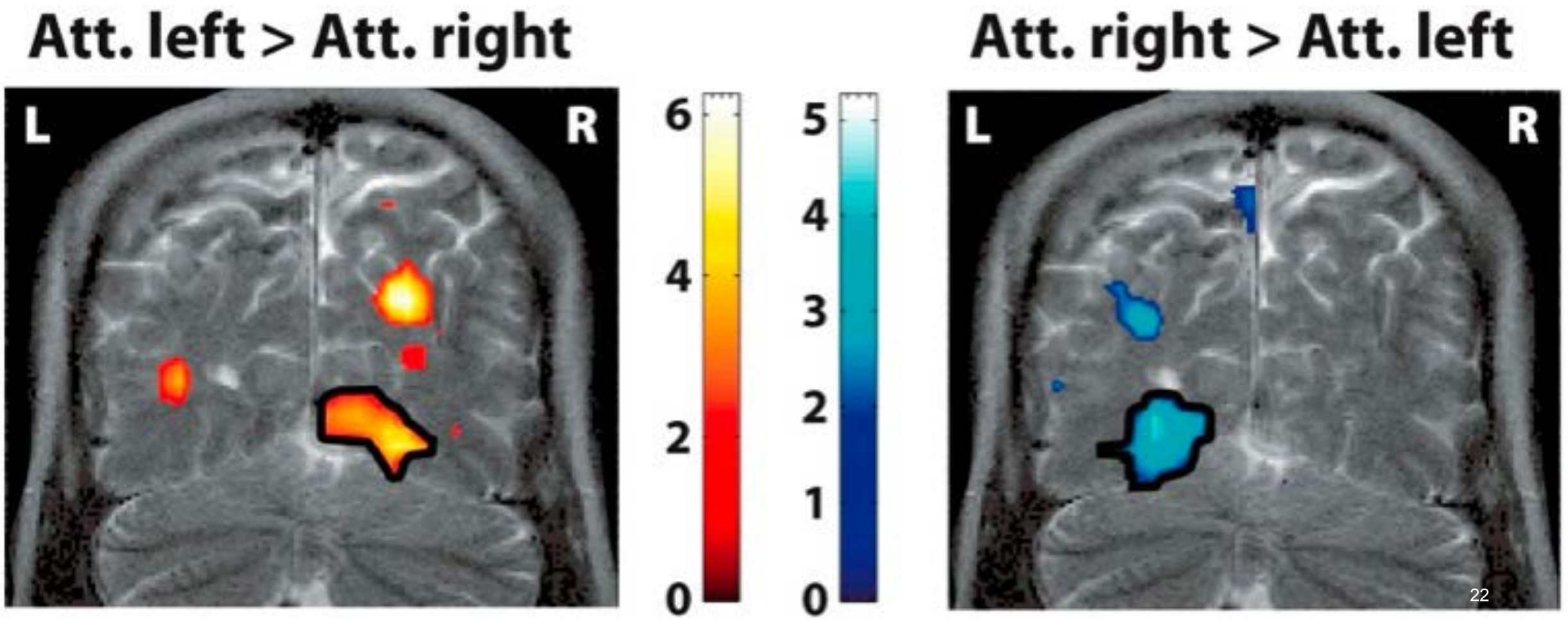


Att. right > Att. left

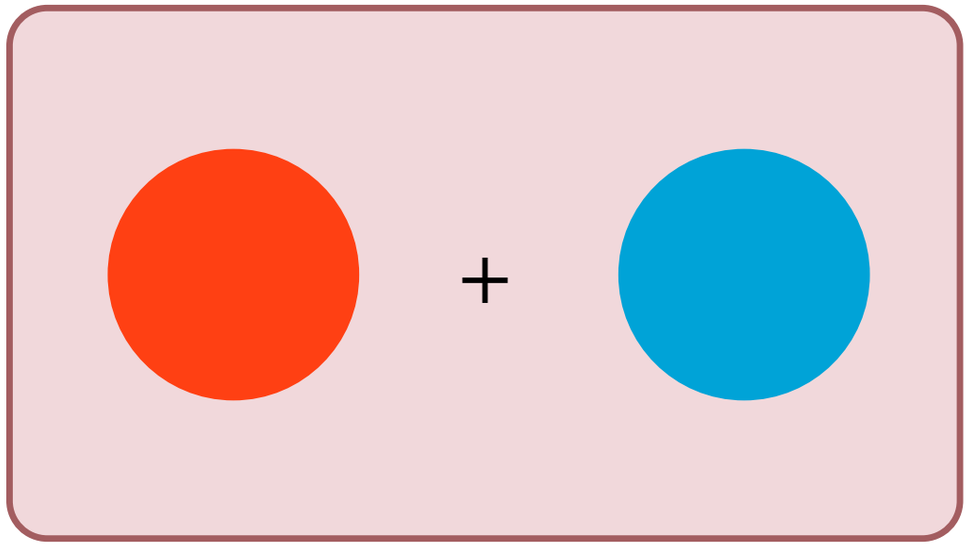


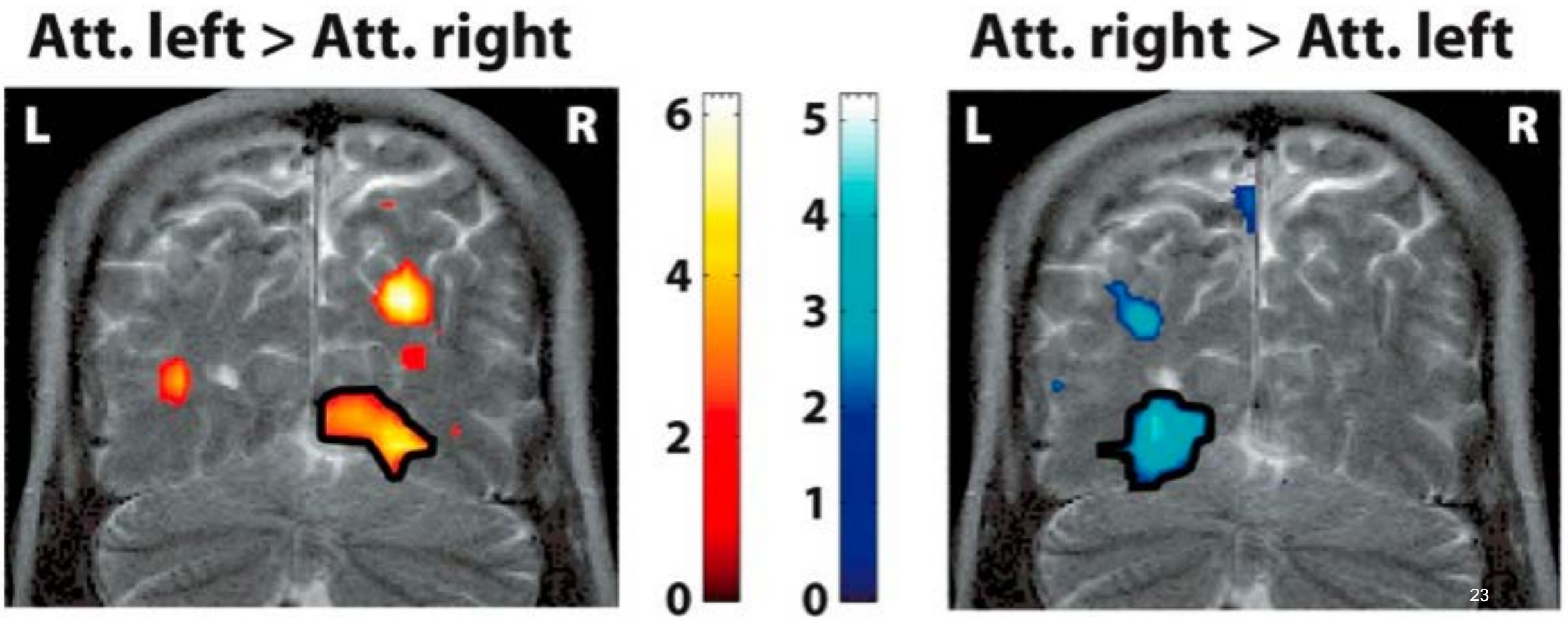
BEFORE a stimulus appears





Priming the brain

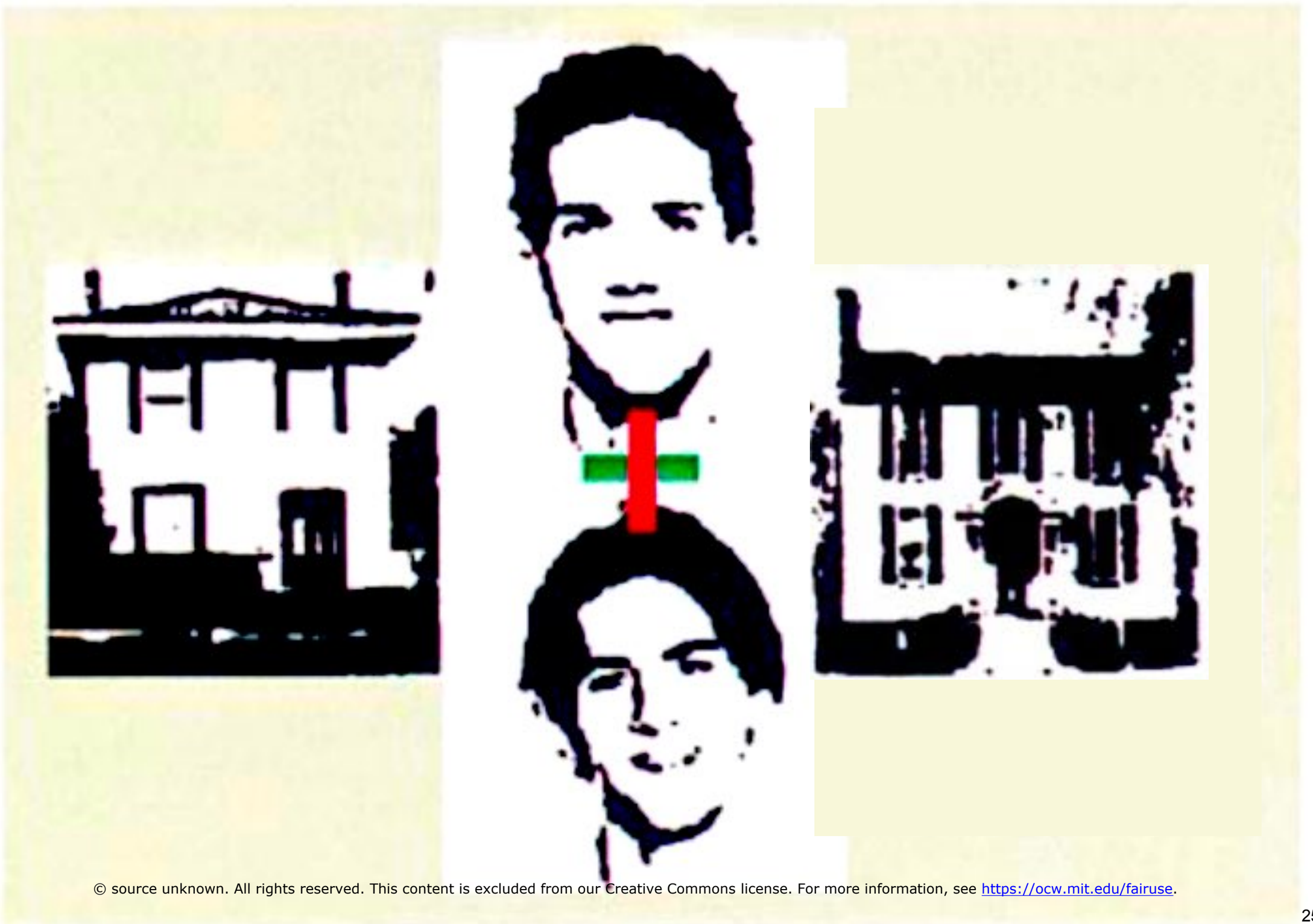




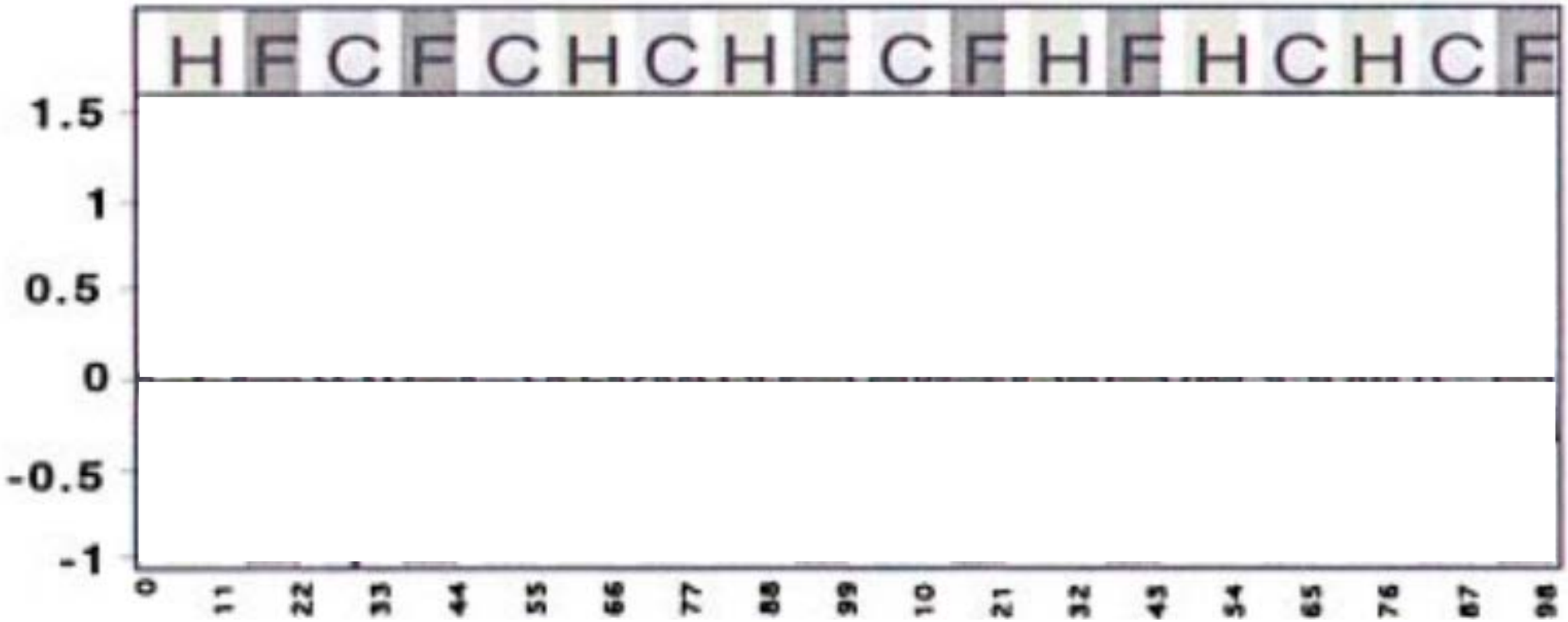
Attention can also increase the strength of a signal related to a stimulus that IS present.

How might we use fMRI to test whether attention can affect the neural response to a face?

Same-diff Task on face, color, or house
Stimuli on screen don't change

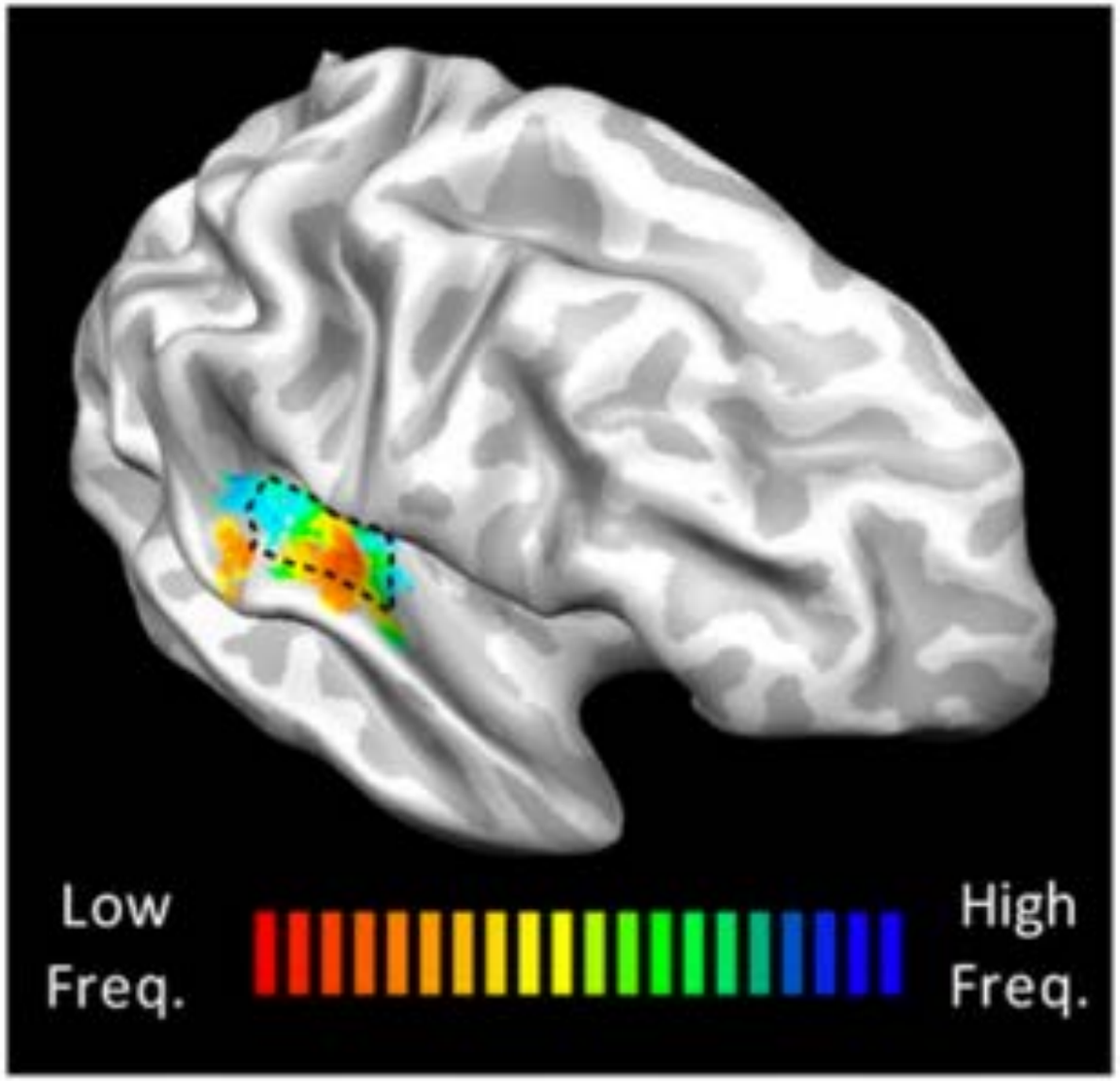


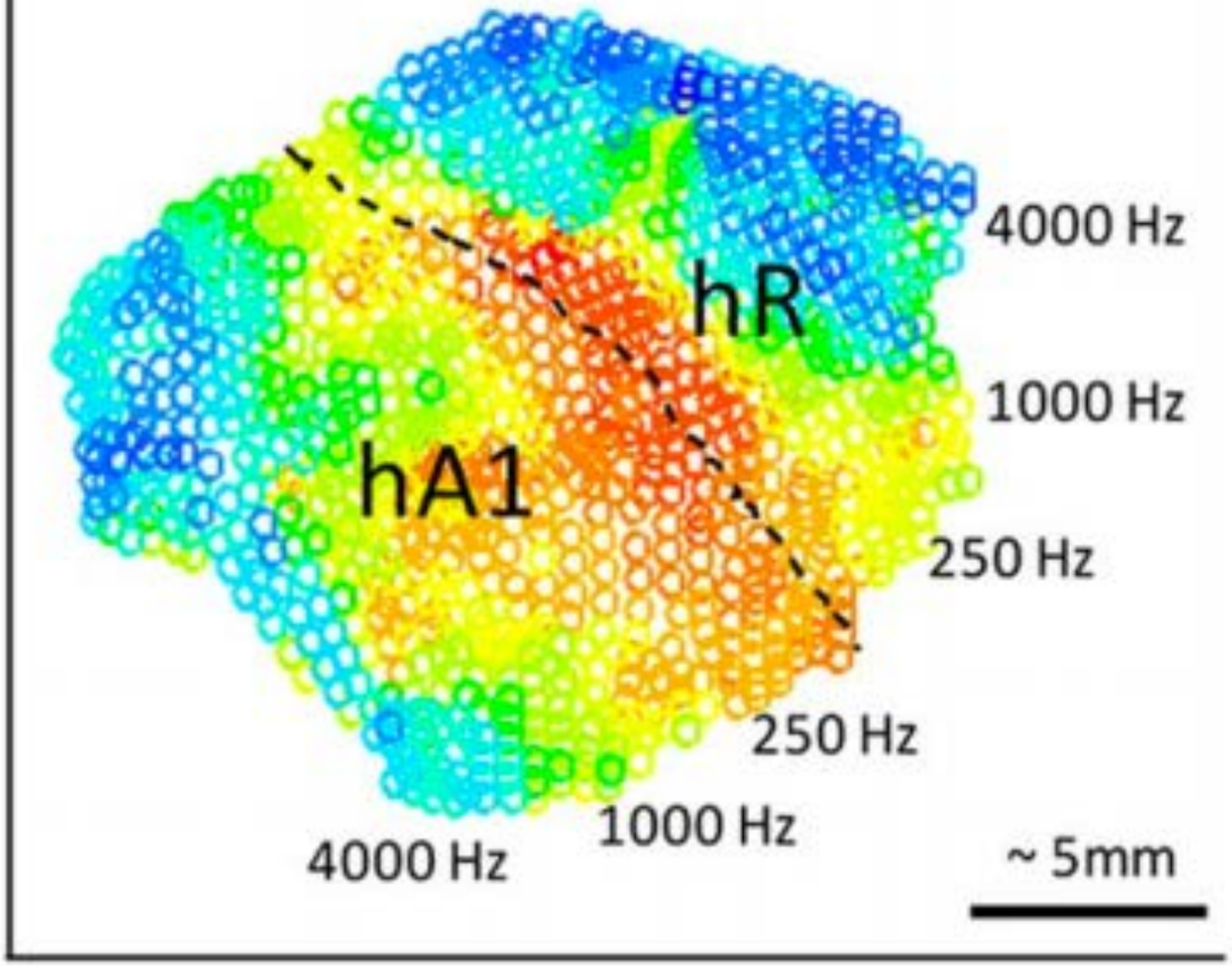
FFA response

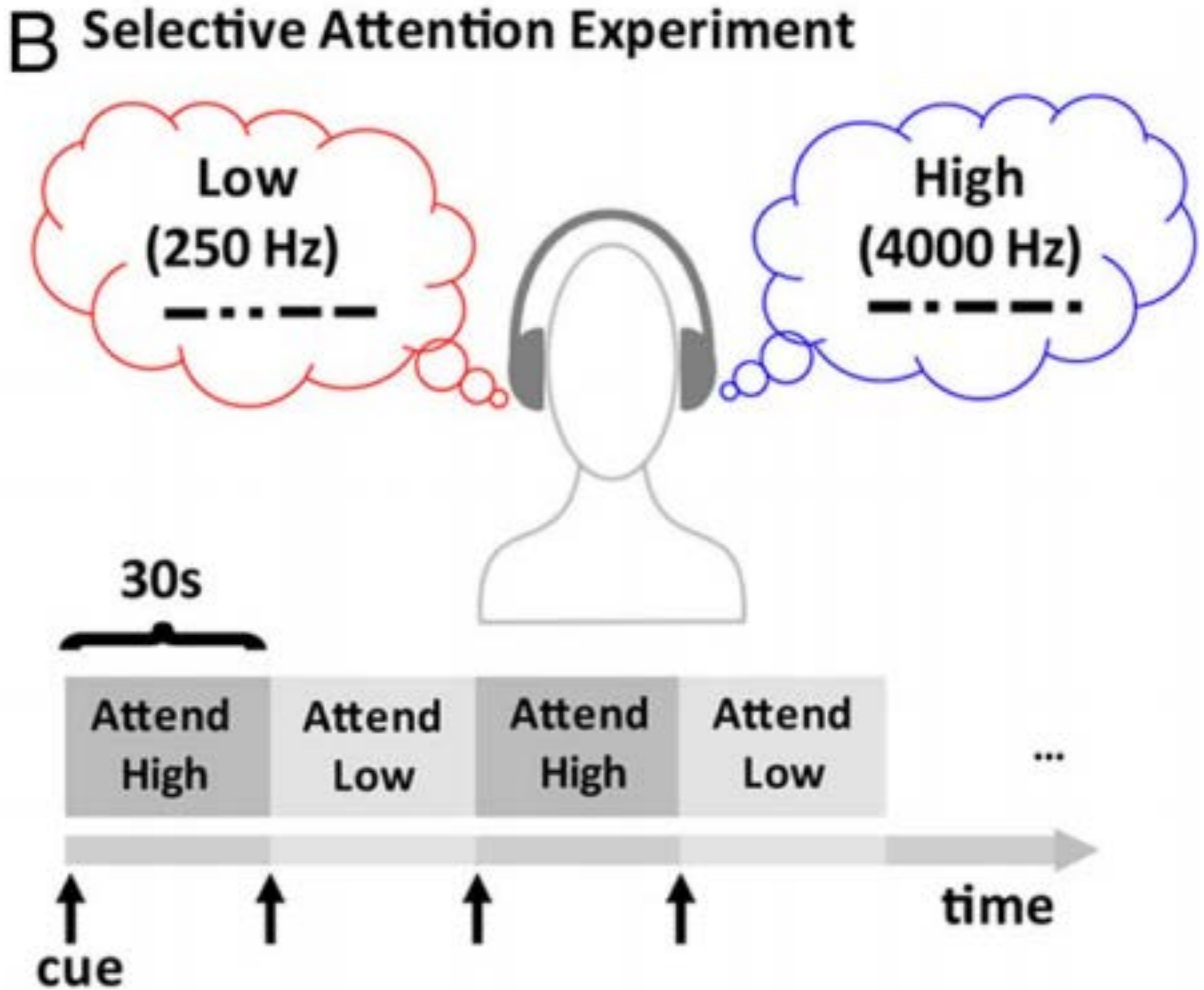


This is a pure attentional effect;
the stimuli are identical in all conditions.
Similar attentional modulation is seen in MT, PPA, EBA, and retinotopic cortex including V1.
Attentional modulation is even seen in the LGN!
Other modalities? [skip if no time]

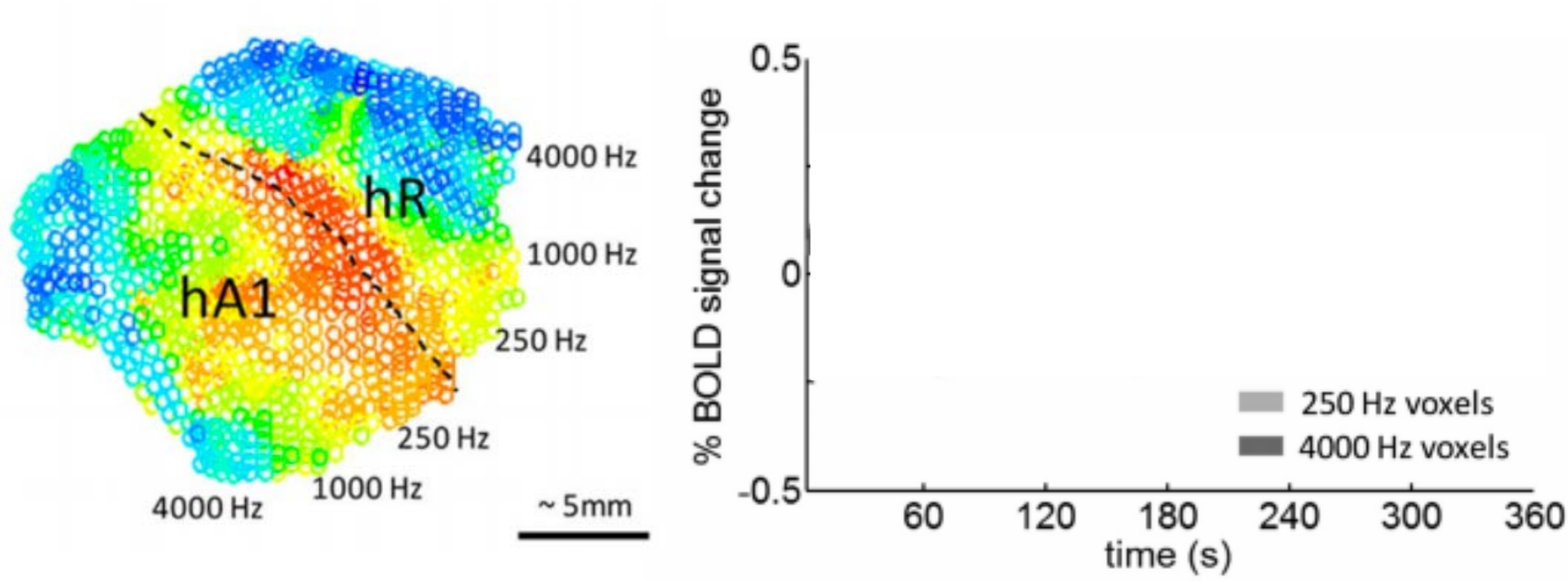
A Tonotopic Mapping







What pattern of results would we predict in auditory cortex?



So, responses in LGN, V1, A1, FFA, MT, etc. are all modulated by attention.

What is the *source* of attentional signals in the brain?

A set of frontal and parietal regions…….

The “Fronto-Parietal Attention Network”

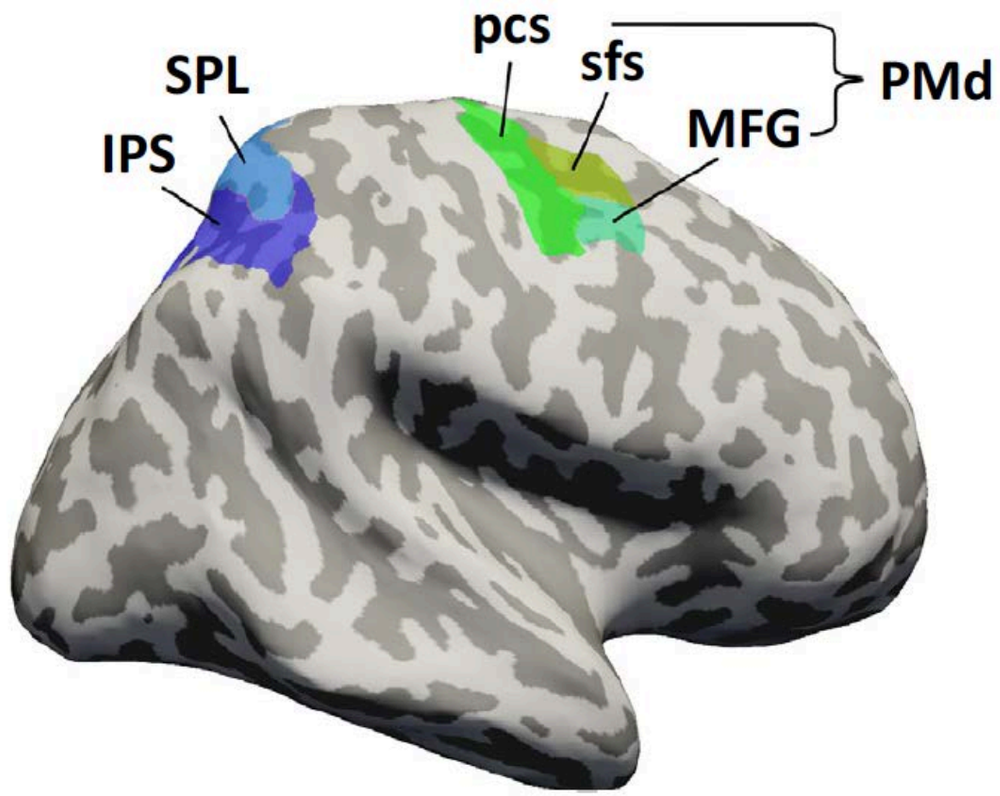
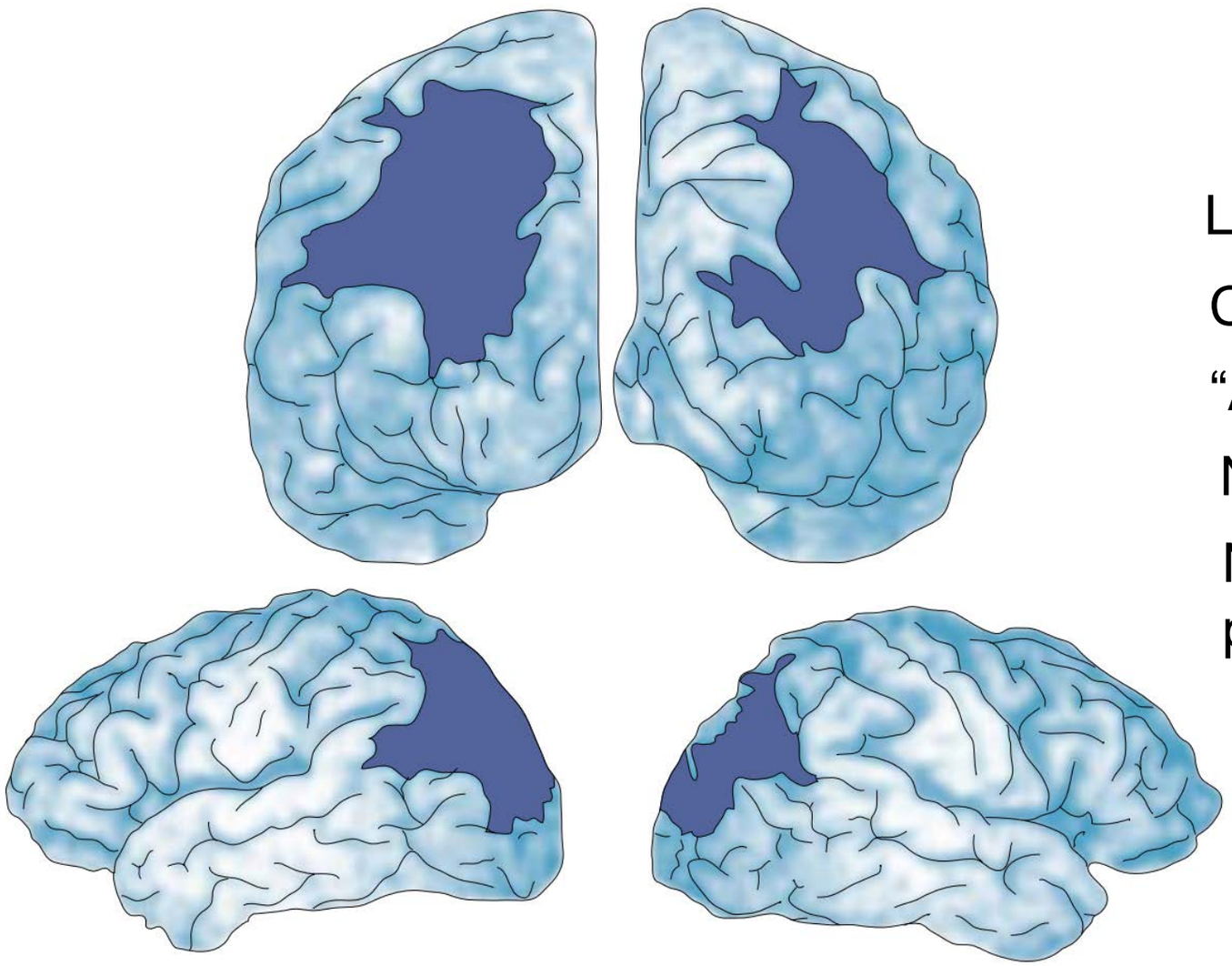


Figure courtesy Elsevier, Inc., https://www.sciencedirect.com. Used with permission. Source: R Ptak, A Schnider, & J Fellrath. *Trends in Cognitive Sciences*, August 2017, Vol. 21, No. 8. http://dx.doi.org/10.1016/j.tics.2017.05.002

These parietal and frontal regions that are active during:
i) shifting of attention, and attentionally-demanding tasks
ii) Mostly the same as th network engaged by nearly any difficult task (hence “multiple demand”).
~The opposite of domain-specific regions: *domain general!*

When this system is damaged bilaterally, get deficits in shifting attention and in perceptual awareness…

Balint's syndrome



Lose the ability to attend to multiple locations.

Can only report seeing one object at a time.

"Attentional tunnel vision"

Never voluntarily move their eyes

Normal acuity, depth, motion, and object perception

All this indicates a role of these parietal regions in shifting attention.

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III. Neural correlates of awareness
- Binocular rivalry
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How do we Uncouple Perceptual *Awareness* from just *Perception*

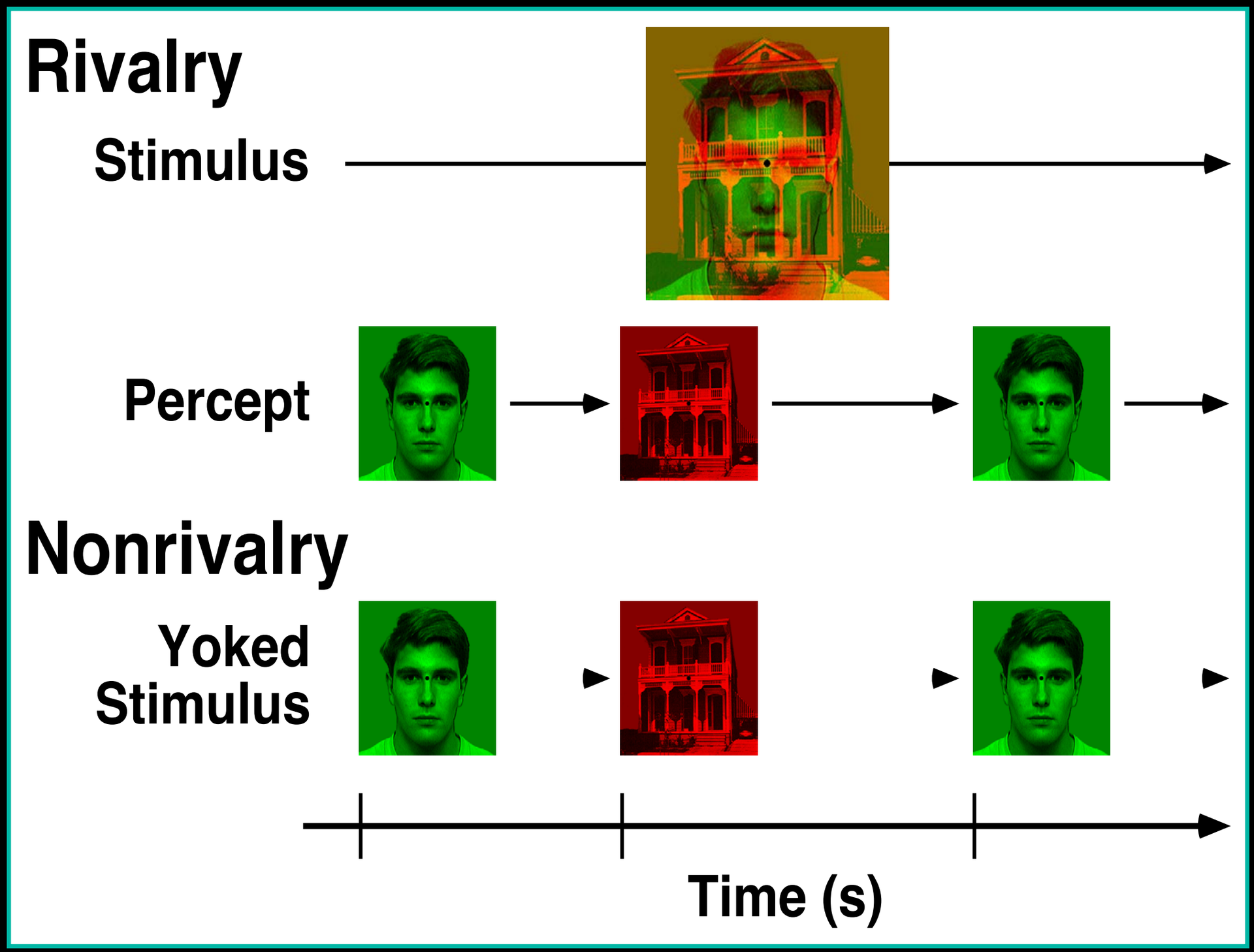
Attention is one way:

Same stimulus > different awareness

Here is another…..

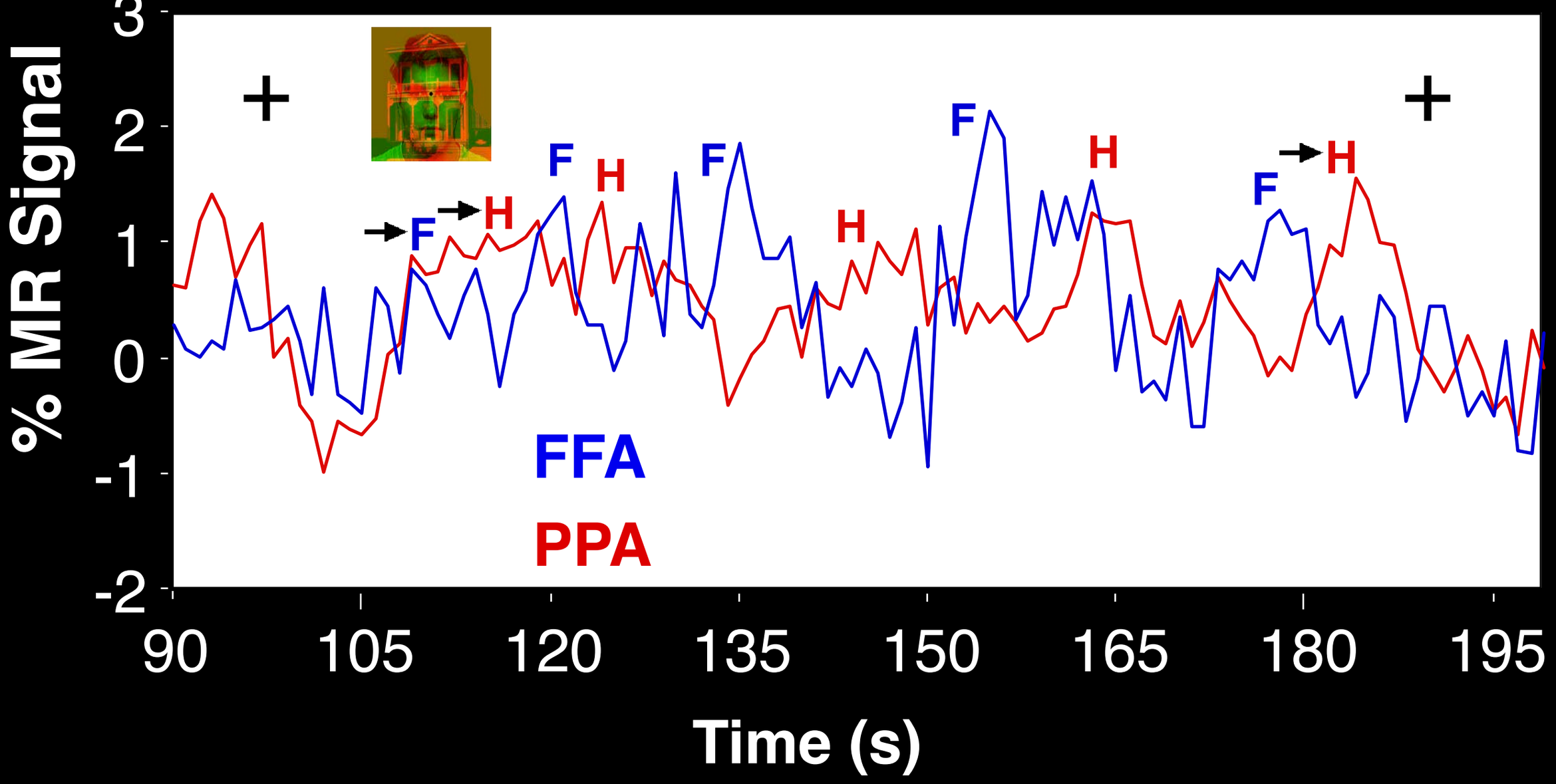
Courtesy Elsevier, Inc., https://www.sciencedirect.com. Used with permission.

Binocular Rivalry and Visual Awareness



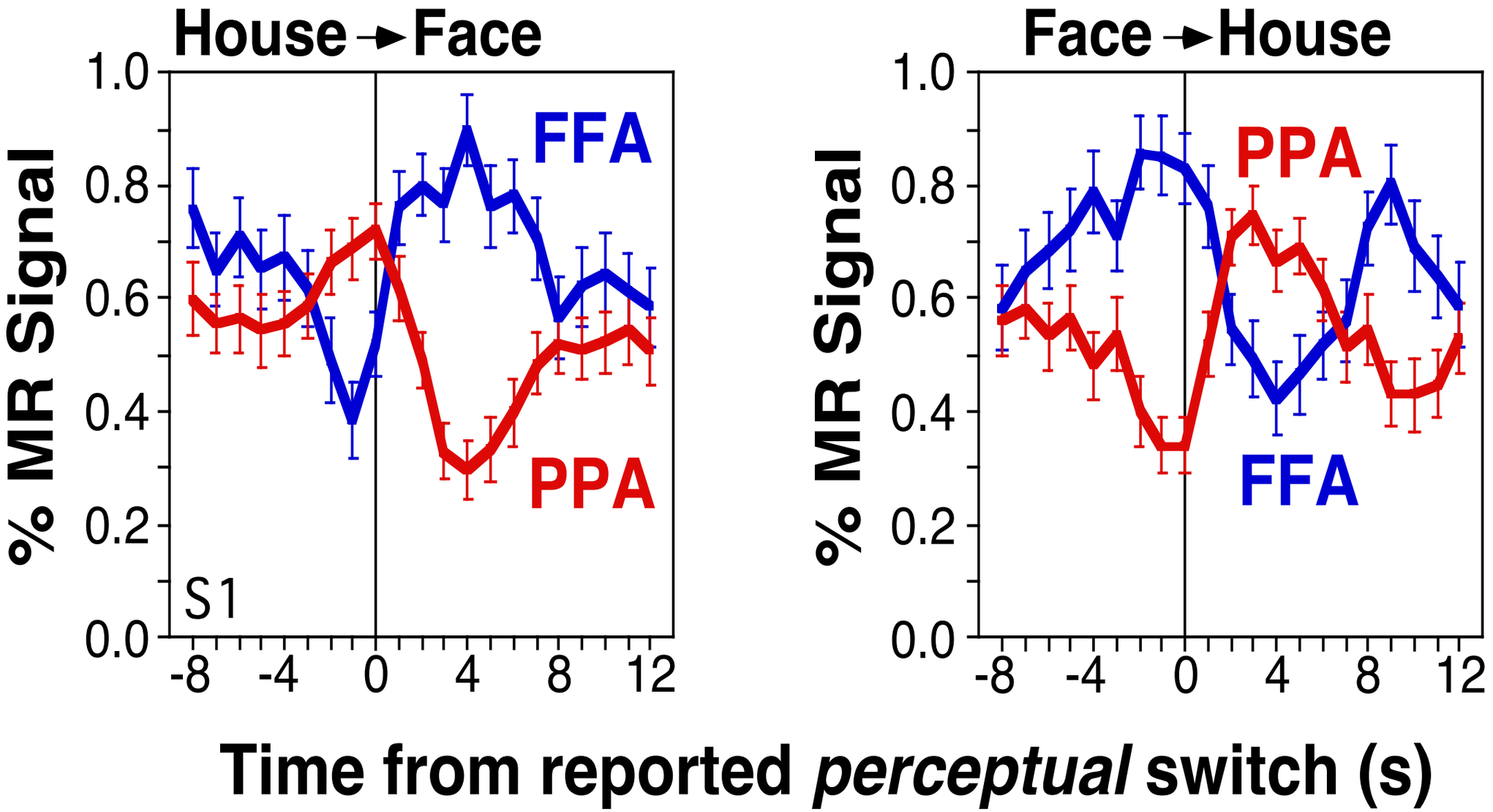
Tong, Nakayama, Vaughan & Kanwisher (1998)

Response in FFA and PPA



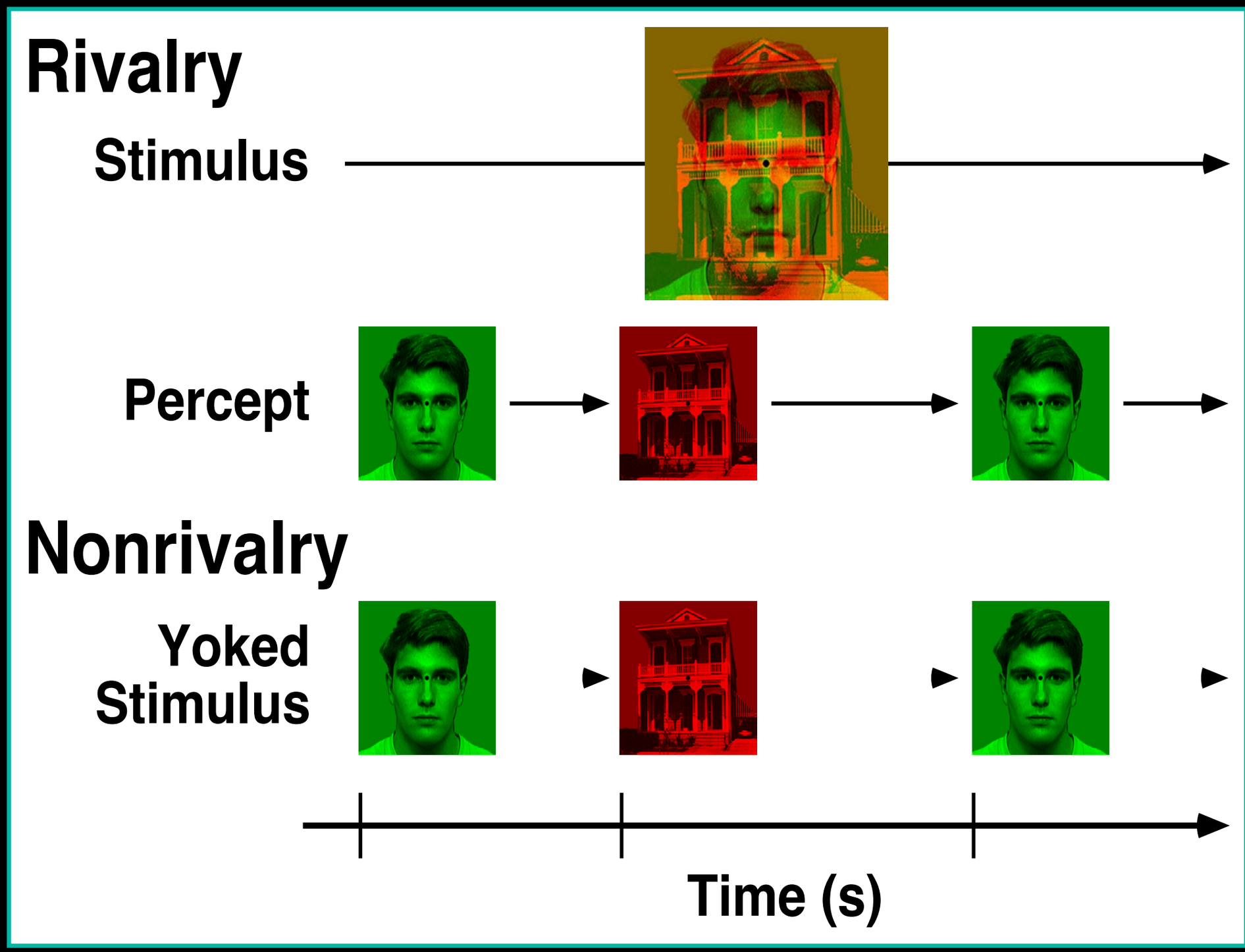
Tong, Nakayama, Vaughan & Kanwisher (1998)

Rivalry



Tong, Nakayama, Vaughan & Kanwisher (1998)

Binocular Rivalry and Visual Awareness



Tong, Nakayama, Vaughan & Kanwisher (1998)

How do we Uncouple Perceptual *Awareness* from just *Perception*

Response of FFA and PPA reflects not the stimulus landing on the retina, but the state of awareness of the subject!

Is there any neural evidence for perceptual representation without awareness?

Maybe……

Demo: I will flash up a very rapid series of digits, that may have one or more letters in it.

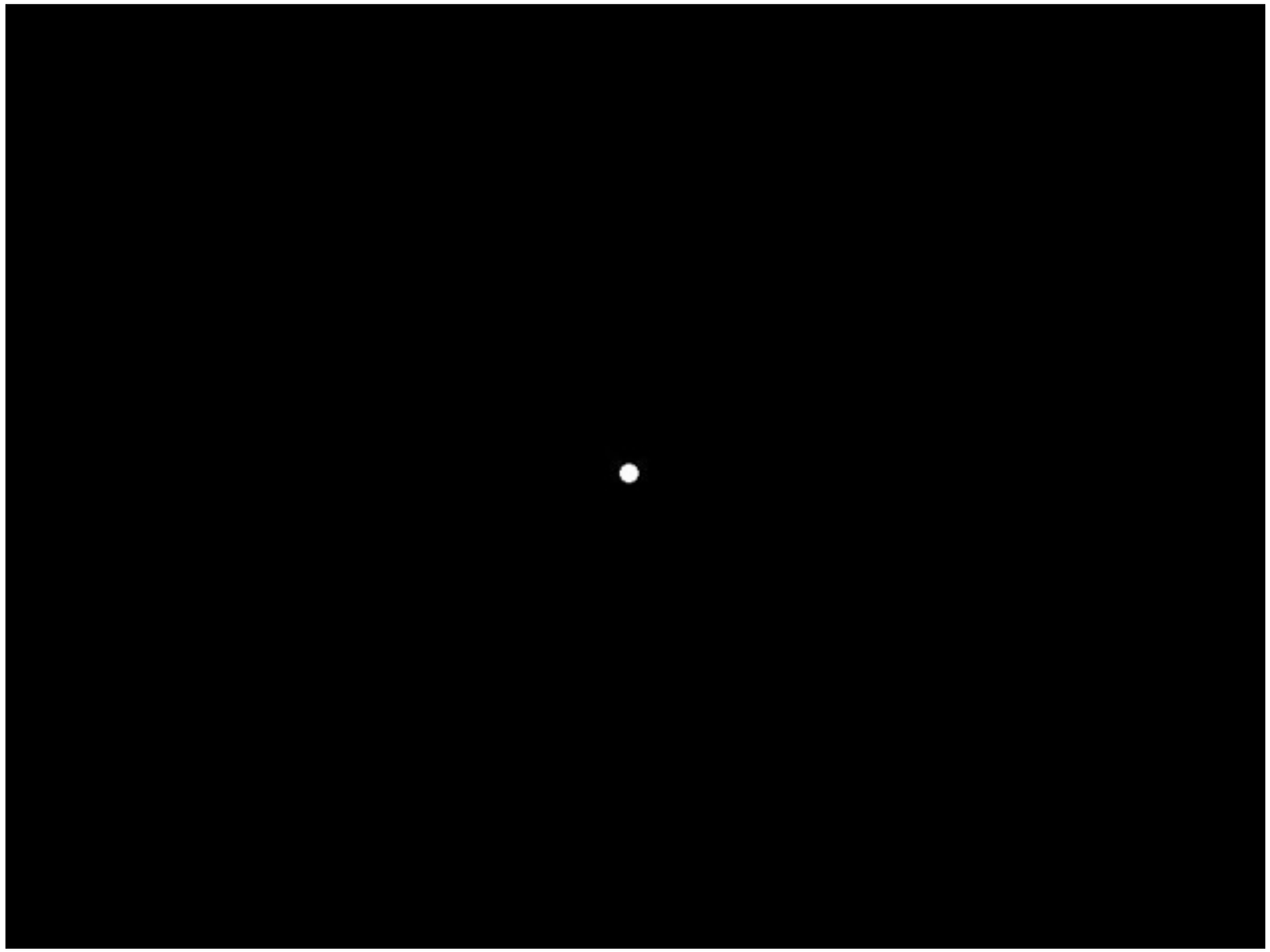
Your task is to try to see the letters.

Find a place to write it/them down at the end.

Here we go…….

OK, write down any letter/s you saw.
Let’s do another one.
Ready?

There were two letters in each sequence.
But was only 1 digit between the A and P in first sequence.
There were 3 digits between the X and H in second sequence



OK, write down any letter/s you saw.
Raise your hand if you saw both A and P in the first sequence.
Raise your hand if you saw both X and H in the second sequence.

Attentional Blink

Task: Report white letter, then say if there was an 'X' later in the sequence.

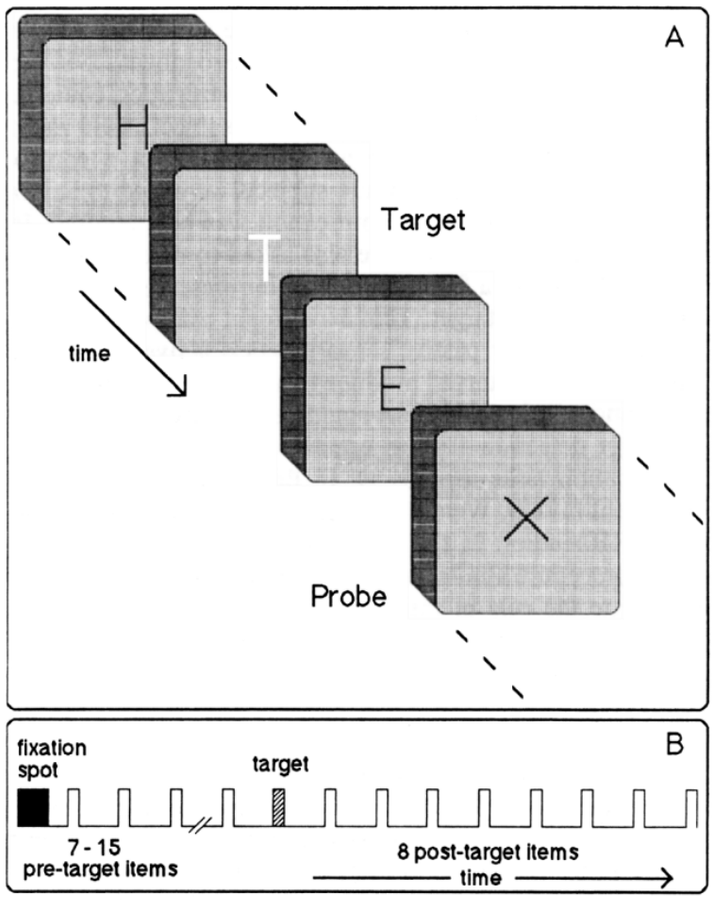
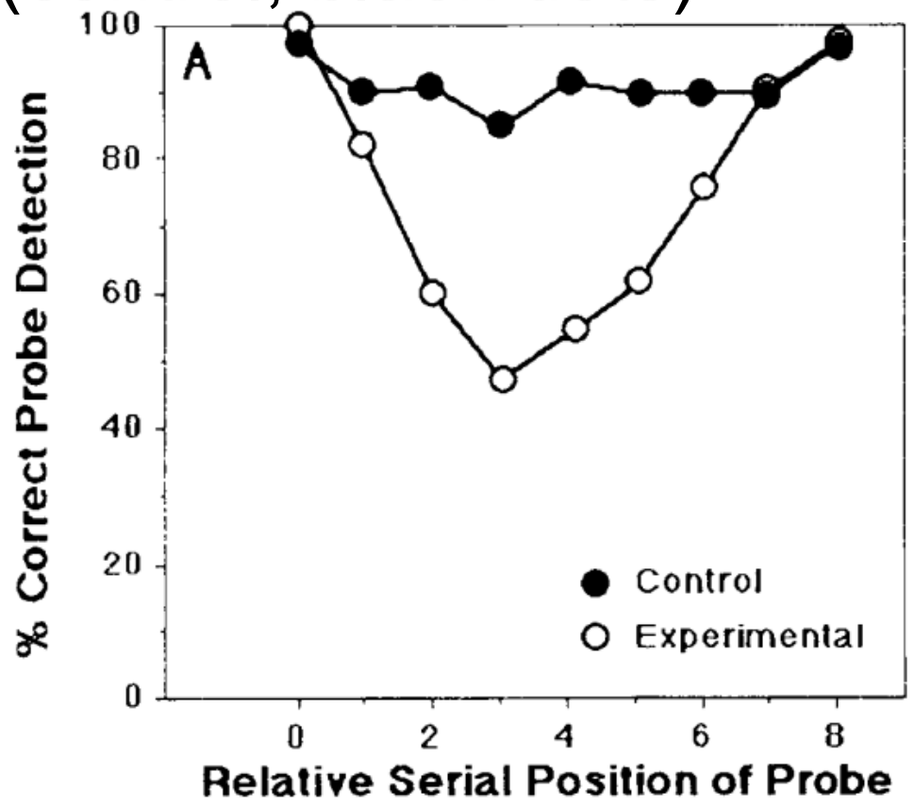


Figure 1. Panel A depicts an illustration of the rapid serial visual presentation stimuli presentation used in all of the experiments. (The target, embedded in the stimulus stream, was a white letter that subjects were required to identify in some experiments. The probe was used in Experiments 2–4. It was always a black X presented at a variable serial position after the target [except in Experiment 2, where it was also presented as the target on some trials].) Panel B depicts a diagram of the temporal arrangement used in stimulus presentation. (See text for details.)

Results: Prob detection of X when doing white-letter task (exptl, white dot) versus not (control, black dots).



Failure to see X even when you are looking for it!
Limitation on temporal attention/awareness.
Happens for lots of kinds of stimuli.
Is that unreported item processed?
How might you test w/ fMRI?

Raymond et al., 1992

Task:
detect a specific face (T1), then scene (T2).

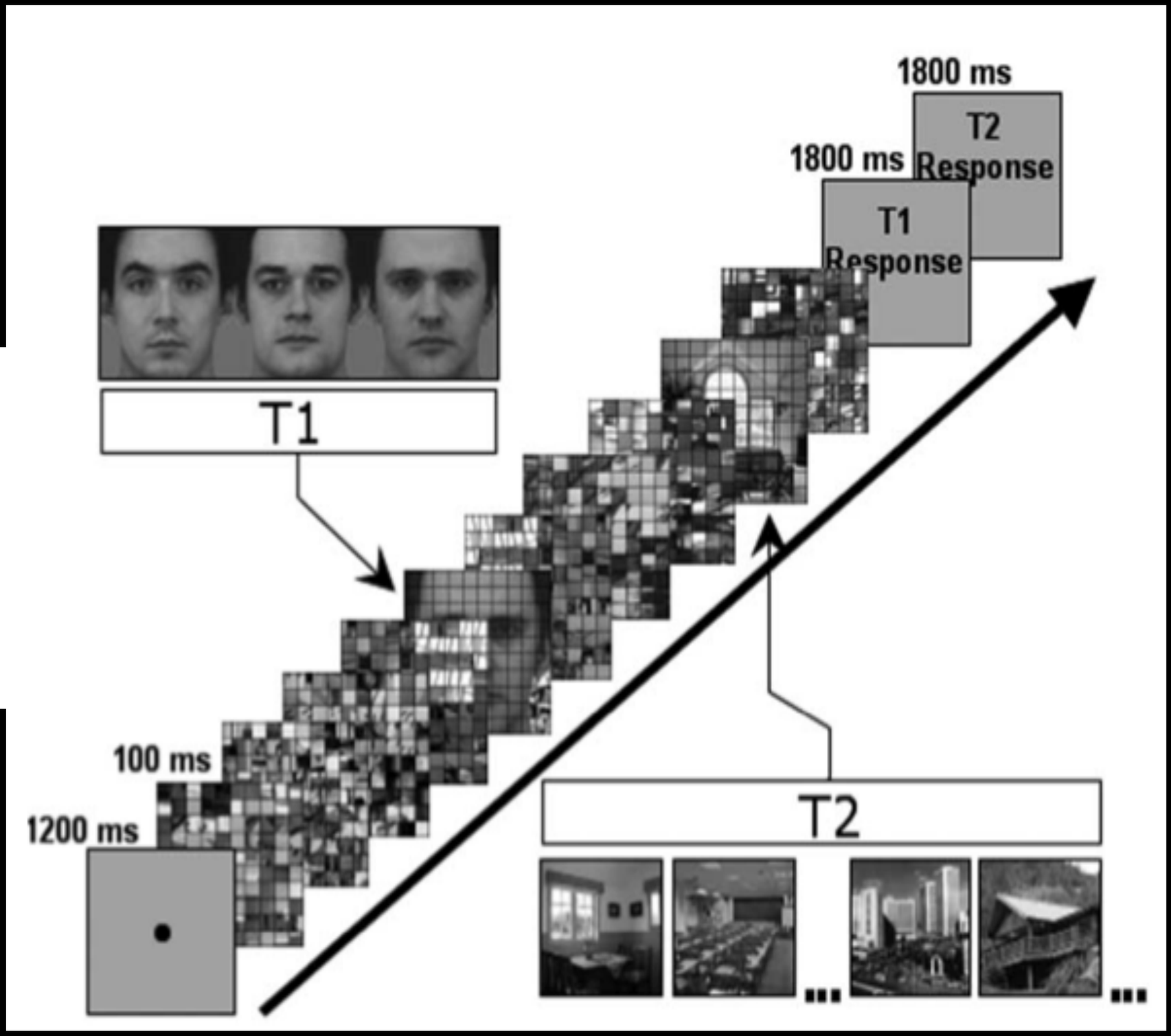


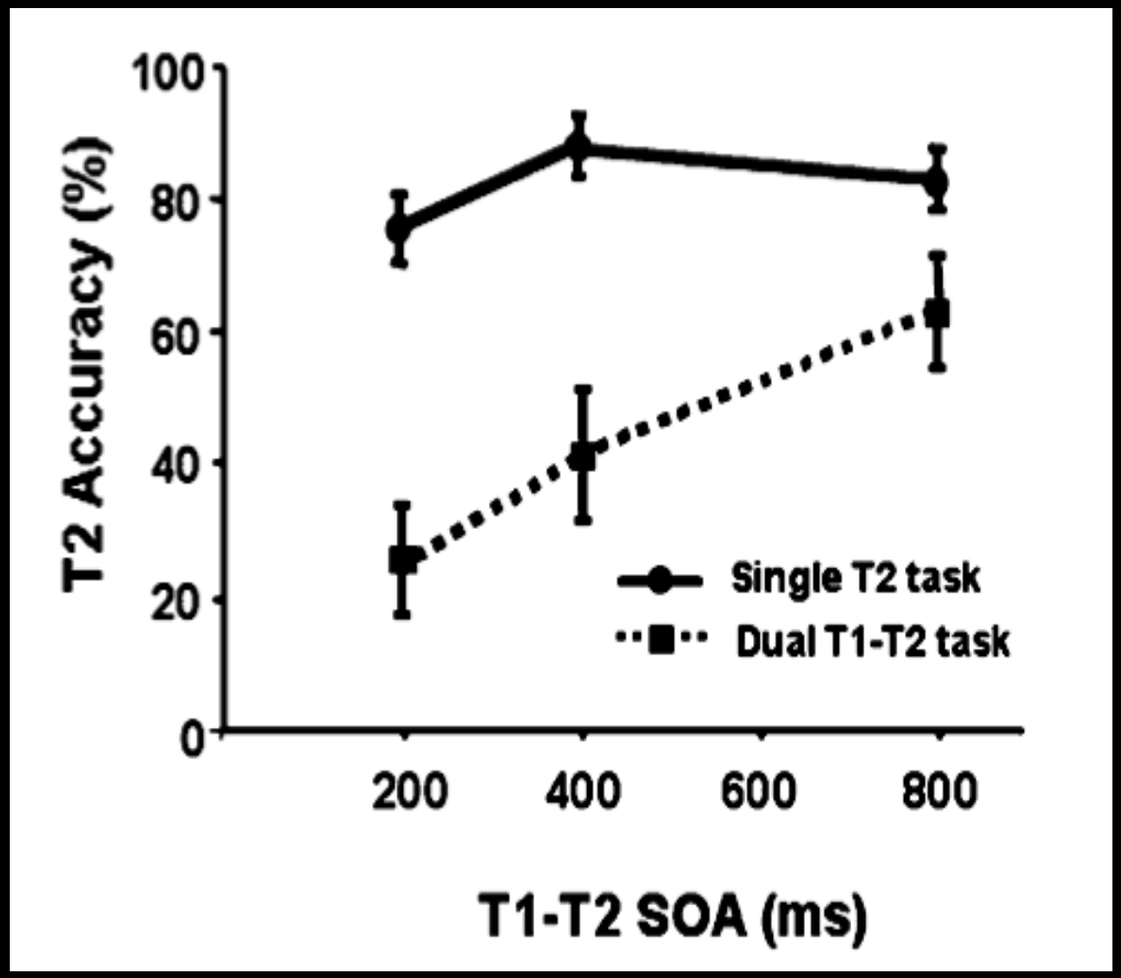
Figure 1. Experimental Design

In the dual-task experiment, subjects searched for a face target (T1) and a scene target (T2) presented in an RSVP of scrambled distractor scenes. The SOA between T1 and T2 was varied. The single-task experiment was identical except that subjects searched only for the target scene. Insets show the three face targets and examples of both indoor and outdoor scene targets.

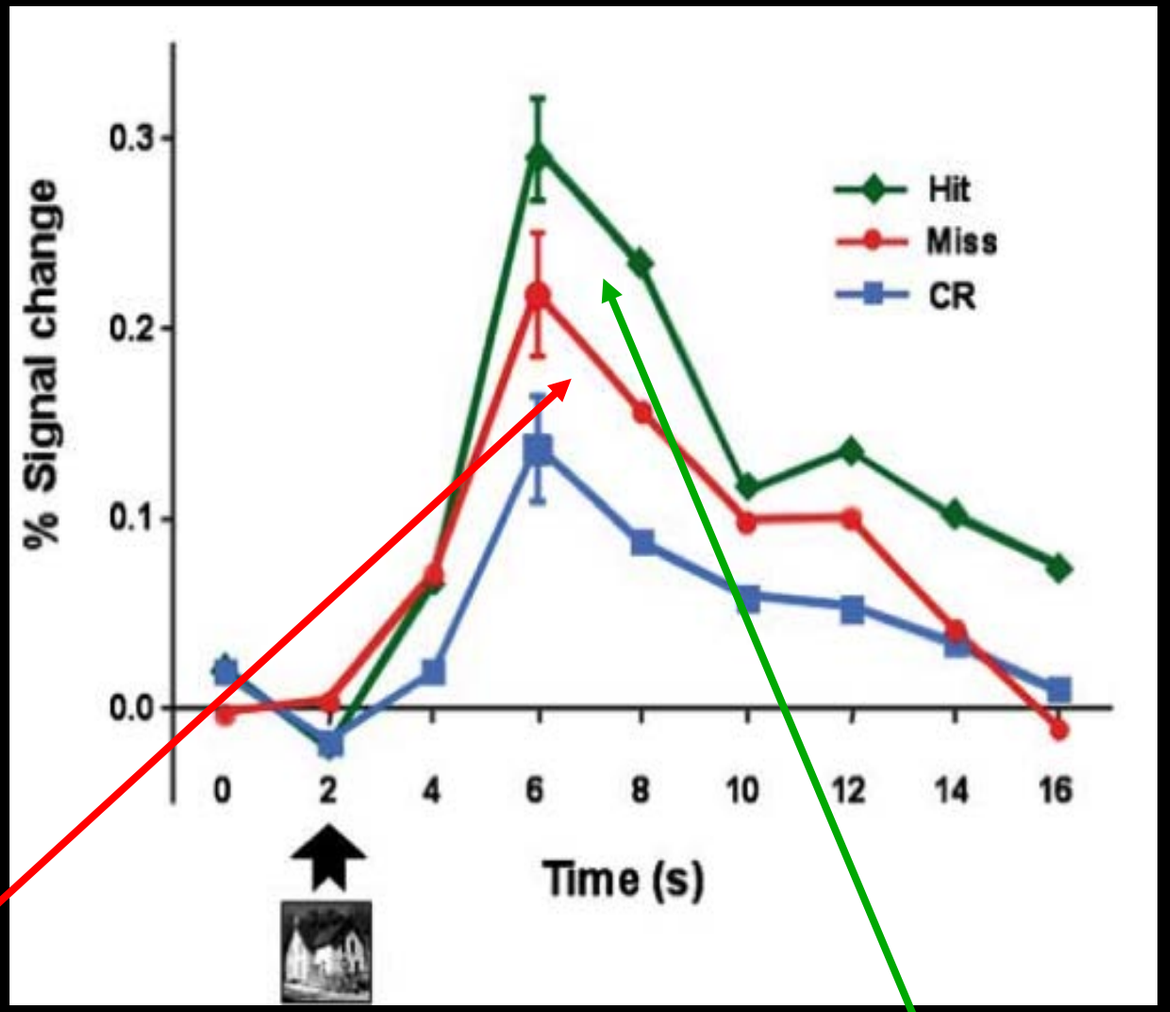
Marois et al (2004)

Neural Correlates of Attentional Blink

Behavioral Data (scene detection):



fMRI Data - Response of PPA:



Perceptual Representation without awareness

Marois et al (2004)

Awareness correlated with strength of response

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III. Neural correlates of awareness

Binocular rivalry

Neural response correlated with awareness, unconfounded from stimulus

Attentional blink

Some evidence for perceptual representation without awareness

9.13 The Human Brain
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