Attention, Binding, and Consciousness

1. Perceptual binding, dynamic binding
2. Neural Correlates of Consciousness: Binocular rivalry
3. Attention vs. consciousness
4. Binding revisited:
   Split-brain, split-consciousness

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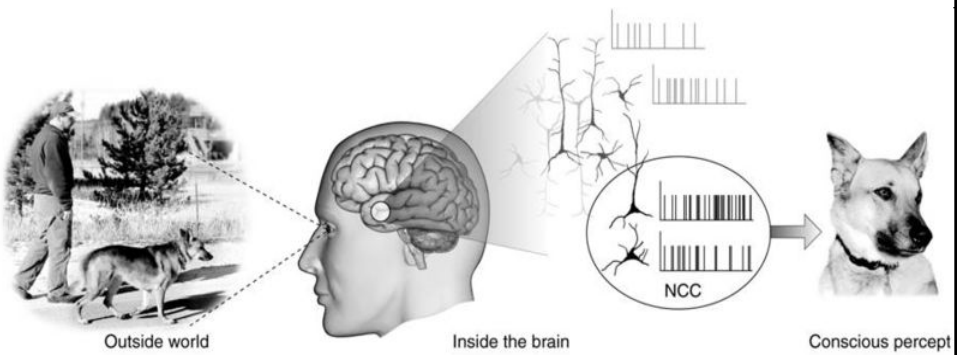
Attention conclusions

- Attention enhances detection and reaction times
- Spatial or feature attention can turn up the firing rates of relevant neurons or their synchronization
- Top-down attention (search) engages frontal areas first, and emphasizes synchronization at lower frequencies (22-34 Hz)
- Bottom-up attention (pop-out) engages posterior parietal cortex first, and emphasizes synchronization at higher frequencies (35-55 Hz)

Neural Correlates of Consciousness (NCC)

The minimal neural activity sufficient for any one specific conscious percept.



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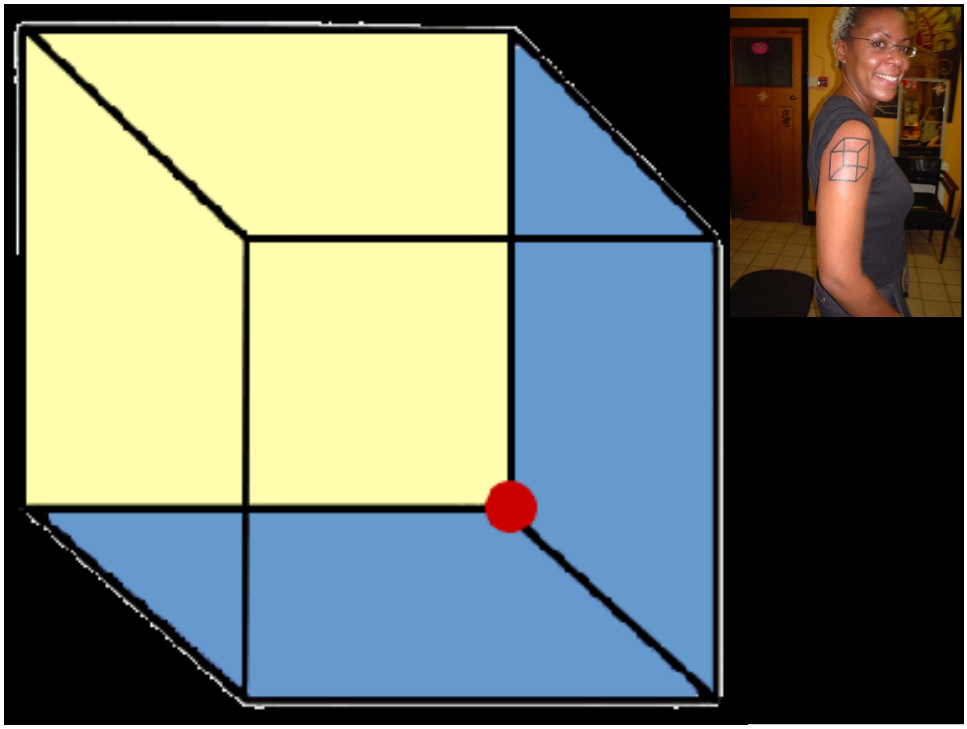
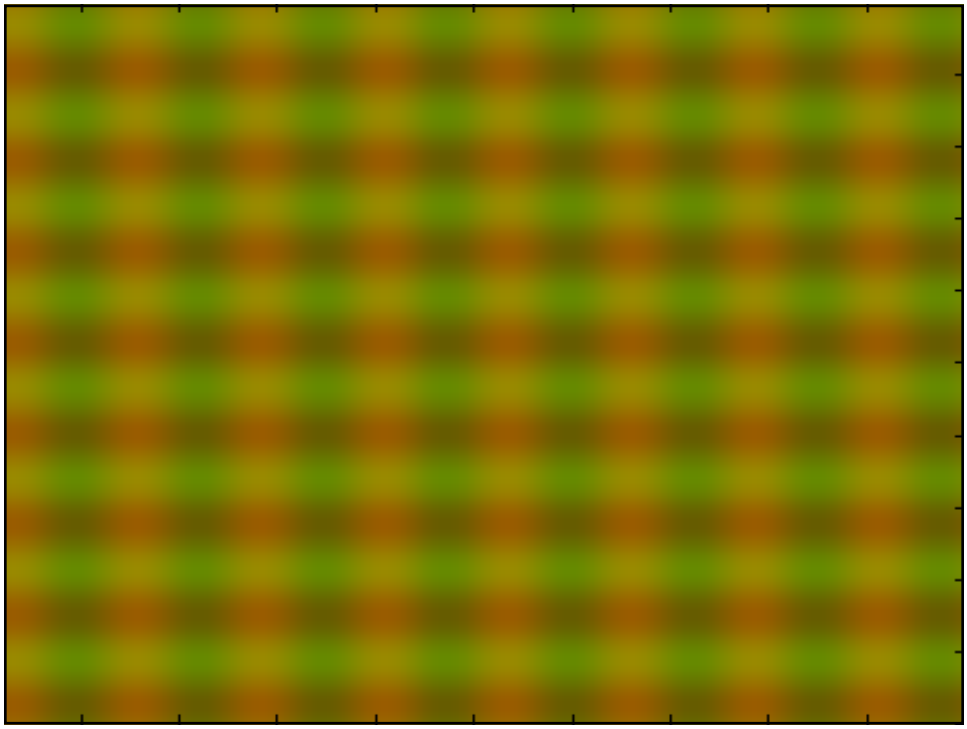
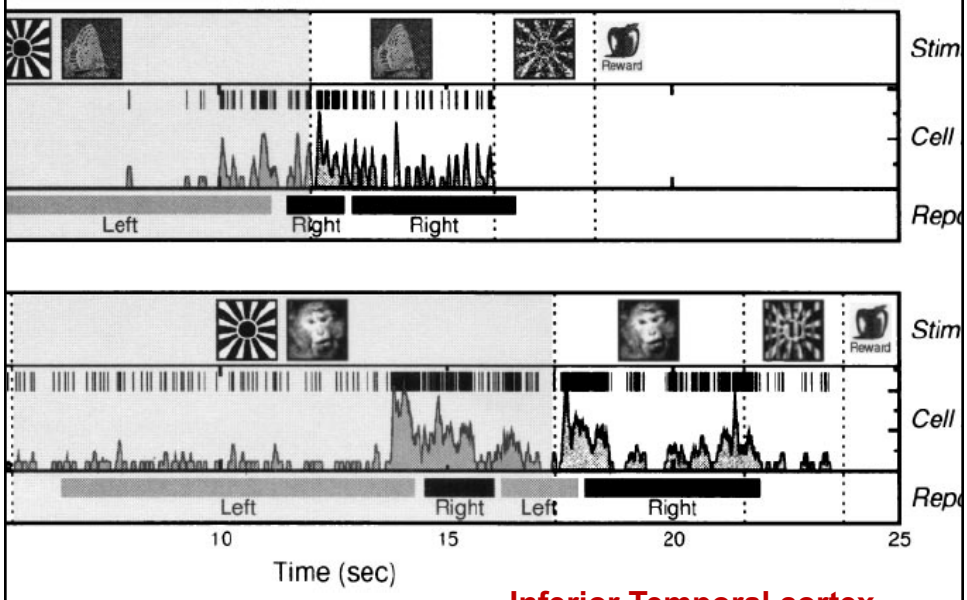
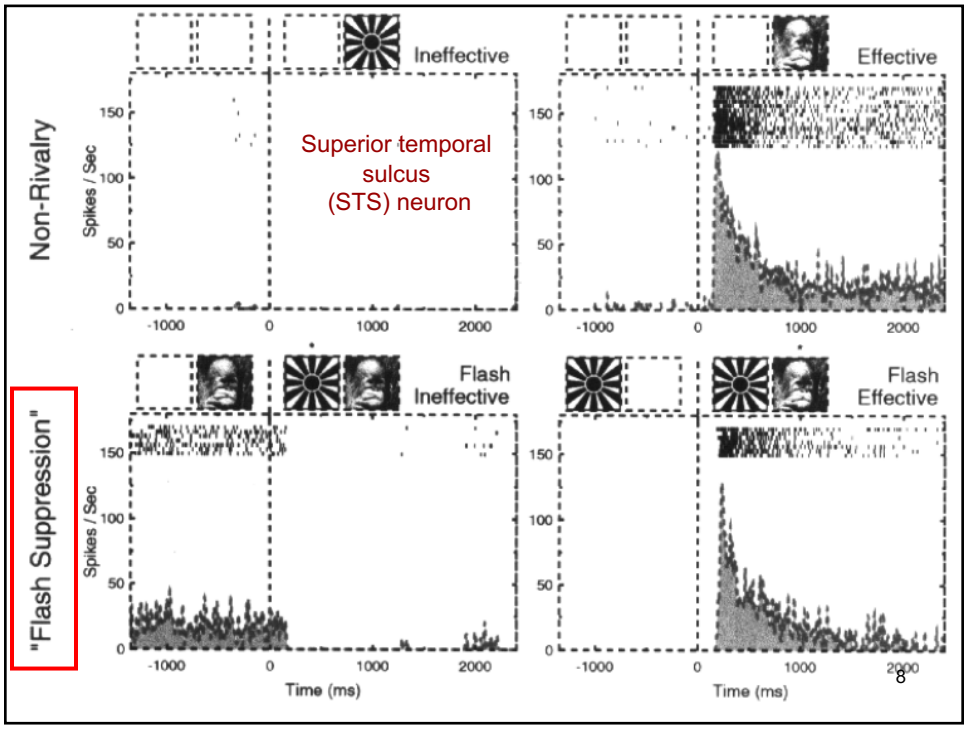




Binocular rivalry: "follow the percept"



Inferior Temporal cortex 7



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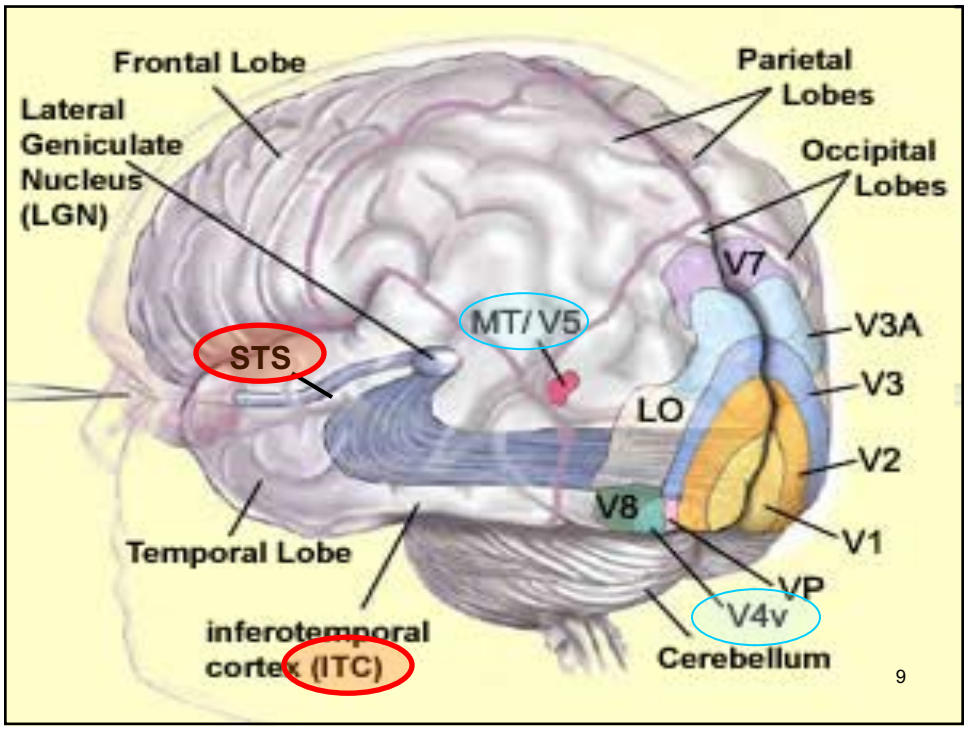

NCC Conclusions so far

- Most cells in higher visual areas (STS, IT) "follow the percept" during rivalry, fewer in lower areas (V4, MT, V1/V2), suggesting that the NCC is not in V1.

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Rhythms of Consciousness: Binocular Rivalry Reveals Large-Scale Oscillatory Network Dynamics Mediating Visual Perception

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Abstract

Consciousness has been proposed to emerge from functionally integrated large-scale ensembles of gamma-synchronous neural populations that form and dissolve at a frequency in the theta band. We propose that discrete moments of perceptual experience are implemented by transient gamma-band synchronization of relevant cortical regions, and that disintegration and reintegration of these assemblies is time-locked to ongoing theta oscillations. In support of this hypothesis we provide evidence that (1) perceptual switching during binocular rivalry is time-locked to gamma-band synchronizations which recur at a theta rate, indicating that the onset of new conscious percepts coincides with the emergence of a new gamma-synchronous assembly that is locked to an ongoing theta rhythm; (2) localization of the generators of these gamma rhythms reveals recurrent prefrontal and parietal sources; (3) theta modulation of gamma-band synchronization is observed between and within the activated brain regions. These results suggest that ongoing theta-modulated-gamma mechanisms periodically reintegrate a large-scale prefrontal-parietal network critical for perceptual experience. Moreover, activation and network inclusion of inferior temporal cortex and motor cortex uniquely occurs on the cycle immediately preceding responses signaling perceptual switching. This suggests that the essential prefrontal-parietal oscillatory network is expanded to include additional cortical regions relevant to tasks and perceptions furnishing consciousness at that moment, in this case image processing and response initiation, and that these activations occur within a time frame consistent with the notion that conscious processes directly affect behaviour.

Dynamic binding by neural synchronization?

"By momentarily **synchronizing the fast oscillations** generated by different regions of cortex, perhaps the brain **binds** together various neural components into a **single perceptual construction**.

The evidence for this idea is indirect, far from proven, and understandably controversial."

—Bear p.592

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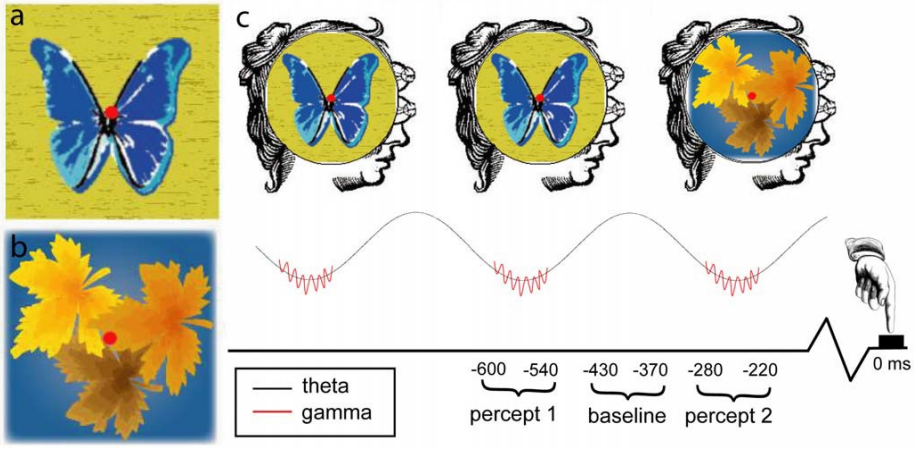

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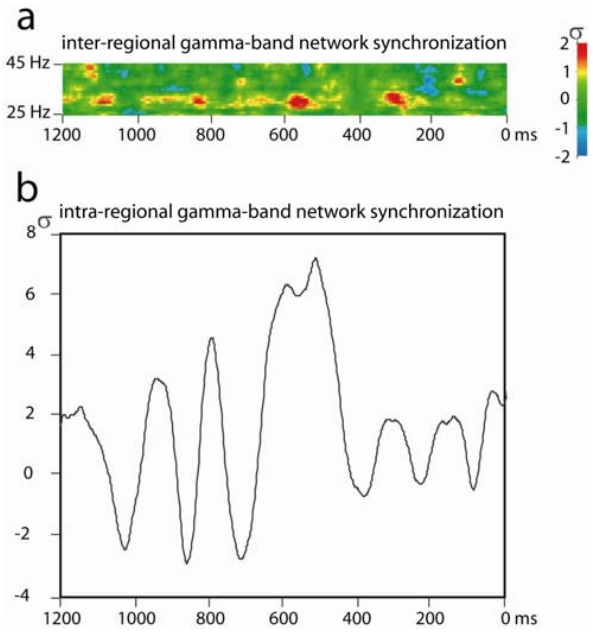

Gamma synchrony is organized by theta rhythm before stable percept onsets

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More NCC Conclusions

- Most cells in higher visual areas (STS, IT) "follow the percept" during rivalry, fewer in lower areas (V4, MT, V1/V2), suggesting that the NCC is not in V1.

- Conscious perception may also correspond to bursts of gamma synchronized neural activity organized by theta rhythms

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Behavioral/Systems/Cognitive

Neural Dissociation between Visual Awareness a Attention

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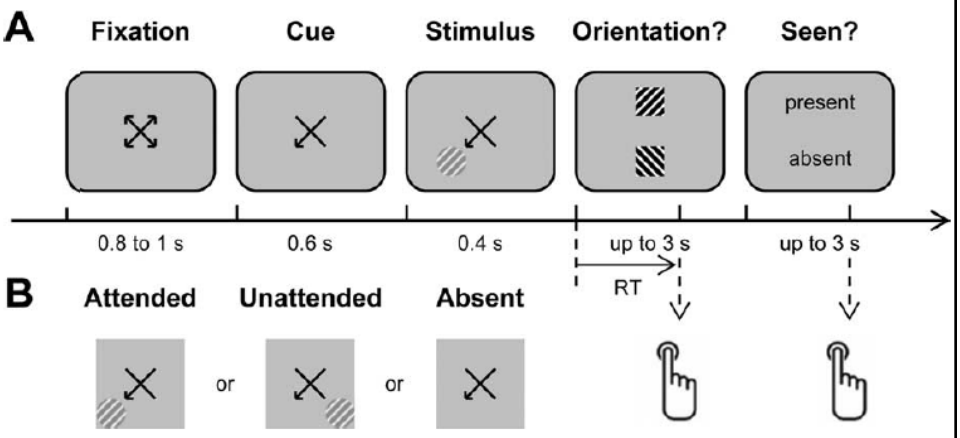
To what extent does what we consciously see depend on where we attend to? Psychologists have long stressed the tight relationship between visual awareness and spatial attention at the behavioral level. However, the amount of overlap between their neural correlates remains a matter of debate. We recorded magnetoencephalographic signals while human subjects attended toward or away from faint stimuli that were reported as consciously seen only half of the time. Visually identical stimuli could thus be attended or not and consciously seen or not. Although attended stimuli were consciously seen slightly more often than unattended ones, the factorial analysis of stimulus-induced oscillatory brain activity revealed distinct and independent neural correlates of visual awareness and spatial attention at different frequencies in the gamma range (30–150 Hz). Whether attended or not, consciously seen stimuli induced increased mid-frequency gamma-band activity over the contralateral visual cortex, whereas spatial attention modulated high-frequency gamma-band activity in response to both consciously seen and unseen stimuli. A parametric analysis of the data at the single-trial level confirmed that the awareness-related mid-frequency activity drove the seen–unseen decision but also revealed a small influence of the attention-related high-frequency activity on the decision. These results suggest that subjective visual experience is shaped by the cumulative contribution of two processes operating independently at the neural level, one reflecting visual awareness per se and the other reflecting spatial attention.

Key words: magnetoencephalography; gamma; alpha; vision; consciousness; attention

Experimental design



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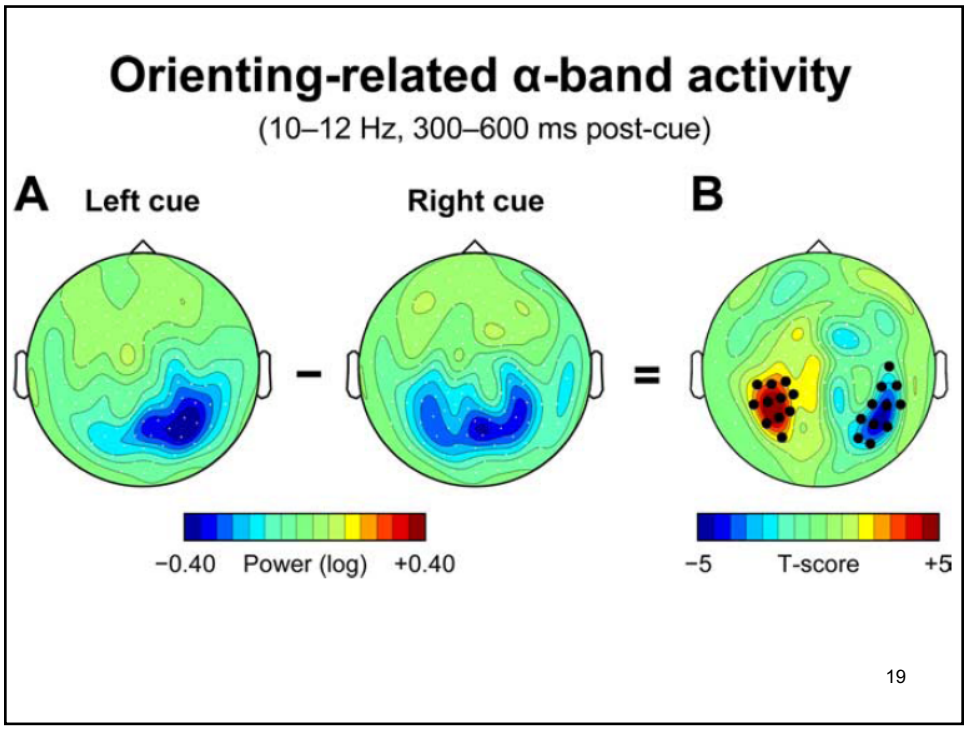
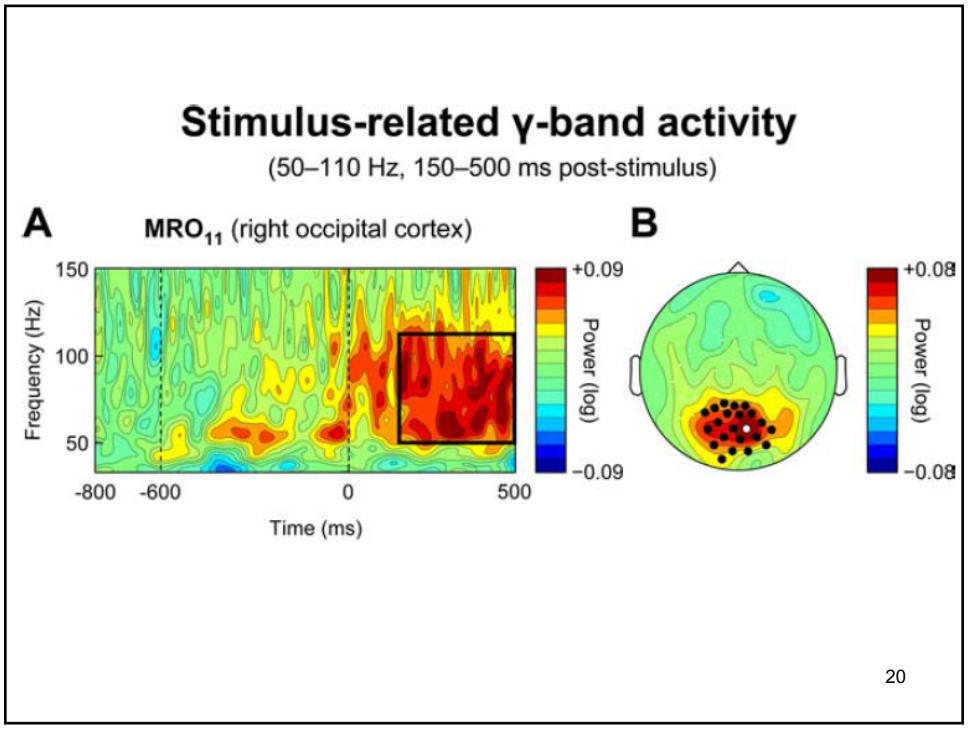
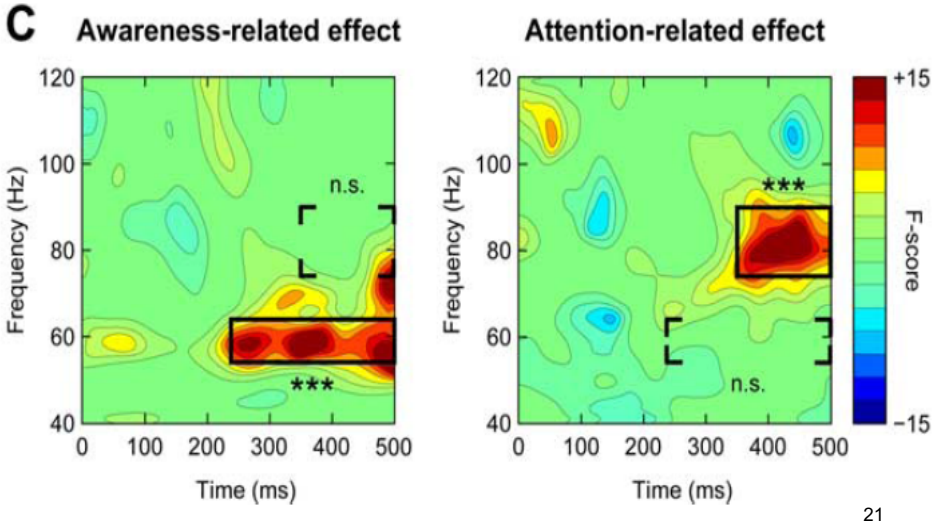

Orienting-related α-band activity
(10–12 Hz, 300–600 ms post-cue)
A
Left cue
Right cue
B
−0.40 Power (log) +0.40
−5 T-score +5
19


Stimulus-related γ-band activity
(50–110 Hz, 150–500 ms post-stimulus)
A
MRO11 (right occipital cortex)
B
150
100
50
Frequency (Hz)
-800
-600
0
500
Time (ms)
+0.09
Power (log)
−0.09
+0.08
Power (log)
−0.08
20

Attention and awareness recruit different oscillation frequencies



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Neural Synchrony Conclusions

1. Attention and awareness (and dreaming) are all associated with increased synchronization of gamma oscillations

2. Distinct processes recruit distinct areas and frequencies

3. → "A fundamental mechanism engaged whenever neural cooperativity is required."

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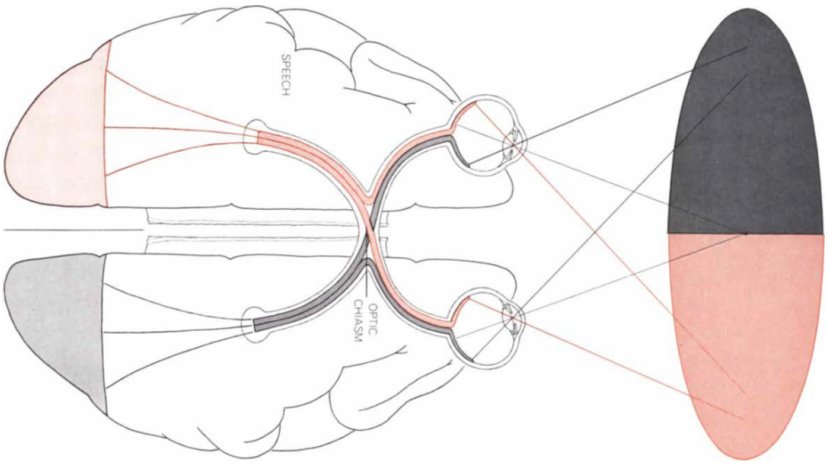
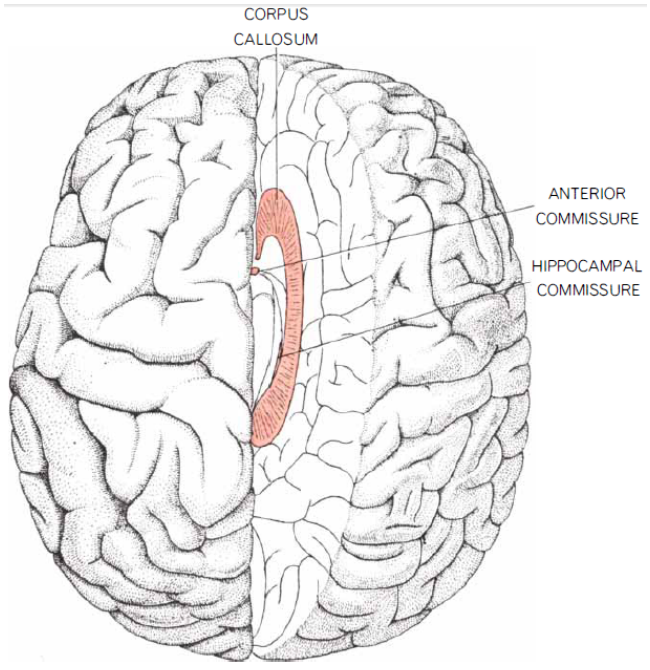
WHAT UNITY OF CONSCIOUSNESS?

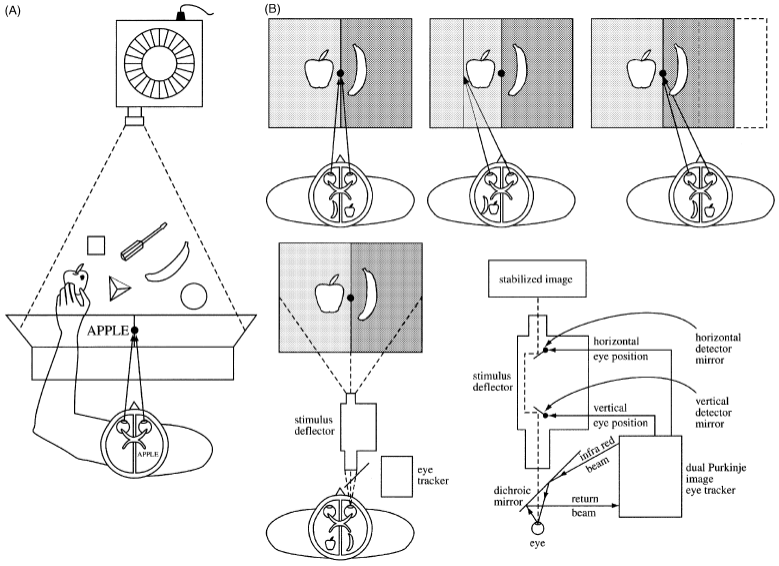


The Split Brain

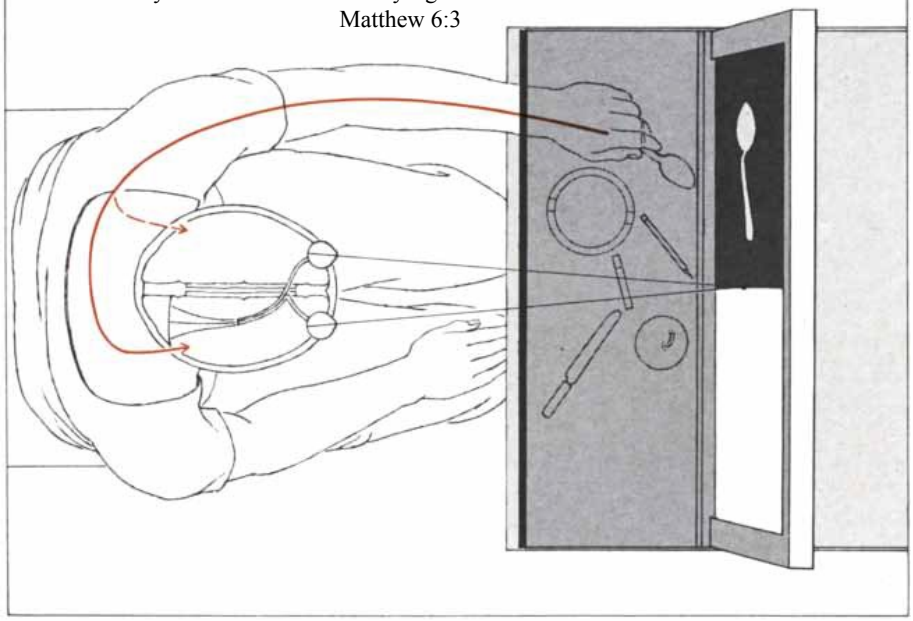
Mike Gazzaniga 1967



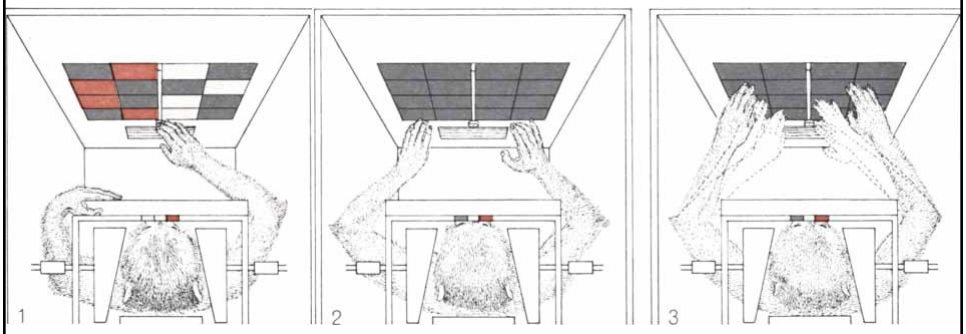
Communicating with a single hemisphere



"…let not thy left hand know what thy right hand doeth."
Matthew 6:3

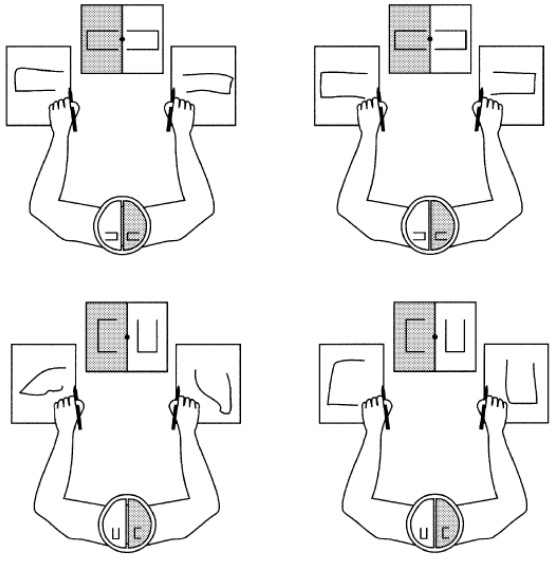


Multitasking: splitting the attentional bottleneck



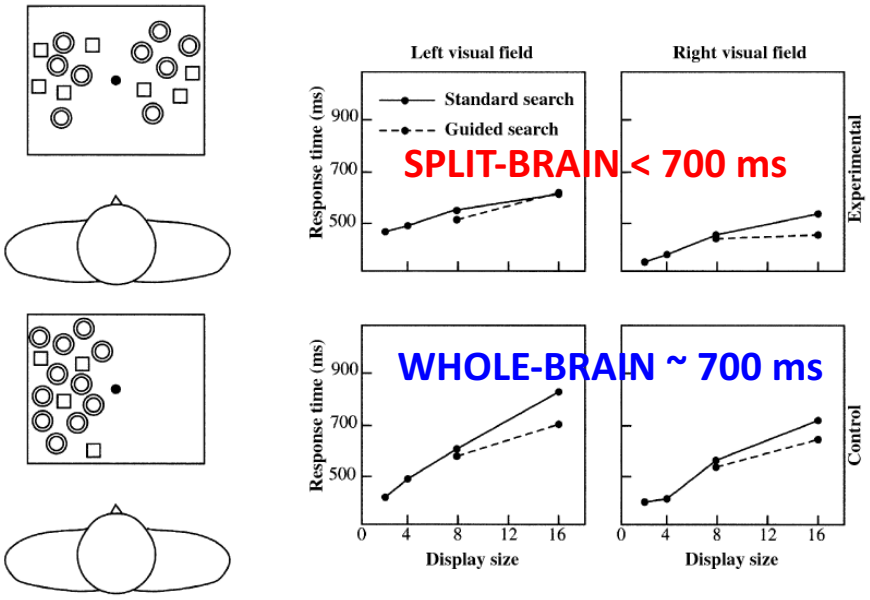
SPLIT-BRAIN MONKEYS can handle more visual information than normal animals. When the monkey pulls a knob (*1*), eight of the 16 panels light momentarily. The monkey must then start at the bottom and punch the lights that were lit and no others (*2*). With the panels lit for 600 milliseconds normal monkeys get up to the third row from the bottom before forgetting which panels were lit (*3*). Split-brain monkeys complete the entire task with the panels lit only 200 milliseconds. The monkeys look at the panels through filters; since the optic chiasm is cut in these animals, the filters allow each hemisphere to see the colored panels on one side only.

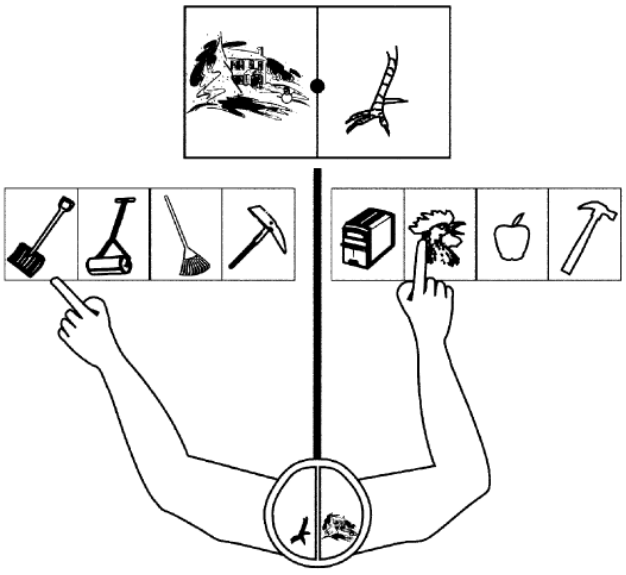
Inter-hemispheric interference



control patient

Serial search — in parallel!





The left-hemisphere **interpreter** establishes a *running narrative* and **self**-concept

Hemispheric specialization

Left is better at

- Speaking, language
- Problem solving, planning, intelligence
- Interpretation, hypothesizing, story-making, confabulation
- Voluntary smiling, top-down attention

Right is better at

- Pattern matching
- Face recognition
- Perceptual grouping/illusory contours
- Dual tasks
- 3D drawing
- Being veridical
- Global attention

Conclusions from split-brain studies

- Although the right hemisphere has very limited verbal abilities, surgically separating the hemispheres appear to result in **two independent consciousnesses**, one in each hemisphere: split-brain, split consciousness.
- This result does not conflict with the observation or claim that **consciousness is an intrinsically unified state**

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