from sleep to attention – lecture 13 – May 7, 2012

the parietal cortex and the control of spatial attention

It is an ancient problem in philosophy and psychology whether we perceive space as such, or, indeed, for some philosophers whether space itself exists outside our brains! These matters need not detain us here, except to say what is obvious, that we do not sense/perceive space as such. No sets of afferent fibers we possess are activated by "space." When a human subject is placed in a structureless visual surround, a *ganzfeld, he is visually aware of only a gray, fog-like surround.* We perceive space in terms of the spatial locations and relations between objects and events within that space, and the relations of these to our own bodies, and the relations between our body parts, and our relation to the direction of gravity. Thus, spatial perception requires the integration of signals in many different afferent systems, visual, vestibular, somesthetic, proprioceptive, auditory. And, we interpret these in relation to our stored and continually updated central image of the body form, what Head and Holmes called the "body schema," a happy metaphor disguising ignorance.

- Vernon Mountcastle

themes I –

Brain mechanisms for sleep and attention overlap extensively. For example, the cerebral cortex, where conscious perception is realized, undergoes radical changes in the patterning of synaptic potentials (as revealed by EEG/LFP recordings) between the lowest-attention state (stage ¾ non-REM sleep) and high attention states (waking, REM sleep).

Changes in sleep/wake state and attention are sometimes mediated by groups of neurons that are highly interconnected (brainstem reticular and thalamic reticular neurons).

The classroom can be very hot.

REM sleep appears to be associated with a maximal frequency of events associated with reorientation of attention (as in a startle response) while non-REM sleep is associated with a minimal frequency of such events. The frequency of such events in the waking state lies between the two sleep states. Oddly enough, a similar pattern is observed for brain metabolism.

Work attempting to uncover the function of sleep typically takes either a species-comparison approach, a sleep-deprivation approach, or an approach involving recording of specific neurobiological characteristics of sleep.

Theories as to the function of sleep nearly always suggest that the function pertains to the brain as opposed to the rest of the body.

themes II –

Neurally, attention is associated with either changes in the overall patterns of firing across a group of neurons (increased action potentials in response to the attended stimulus, and fewer to the unattended stimuli) and/or changes in the temporal firing patterns of neurons (neurons responding to attended stimuli fire in tune with a gamma rhythm). Such changes may, in part, be brought about by changing the subset of synpatic inputs to which a neuron responds most strongly.

Overall, attention appears to involve changes in the neural dynamics of multiple brain regions. Does this reflect the fact that the brain is extremely complex and best studied by considering the system as a whole, or does it reflect the fact that attention is defined in so many different ways?

what do we know so far (since midterm 1 material)?

Neural mechanisms for attention fall into 3 basic categories. 1) changes in signal-to-noise ratio. Here differences in the selectivity for firing responses of neurons are accentuated, in one or another form, by attention; 2) changes in the temporal coherence of neurons. Here, attention increases the degree to which neurons fire with temporal relation to a gamma frequency. 3) changes in the functional anatomy of neurons. Although neurons usually have thousands of synaptic inputs, they are not always 'listening' to all of them. Even synapses that are strong (more depolarizing when activated) can be depressed temporarily.

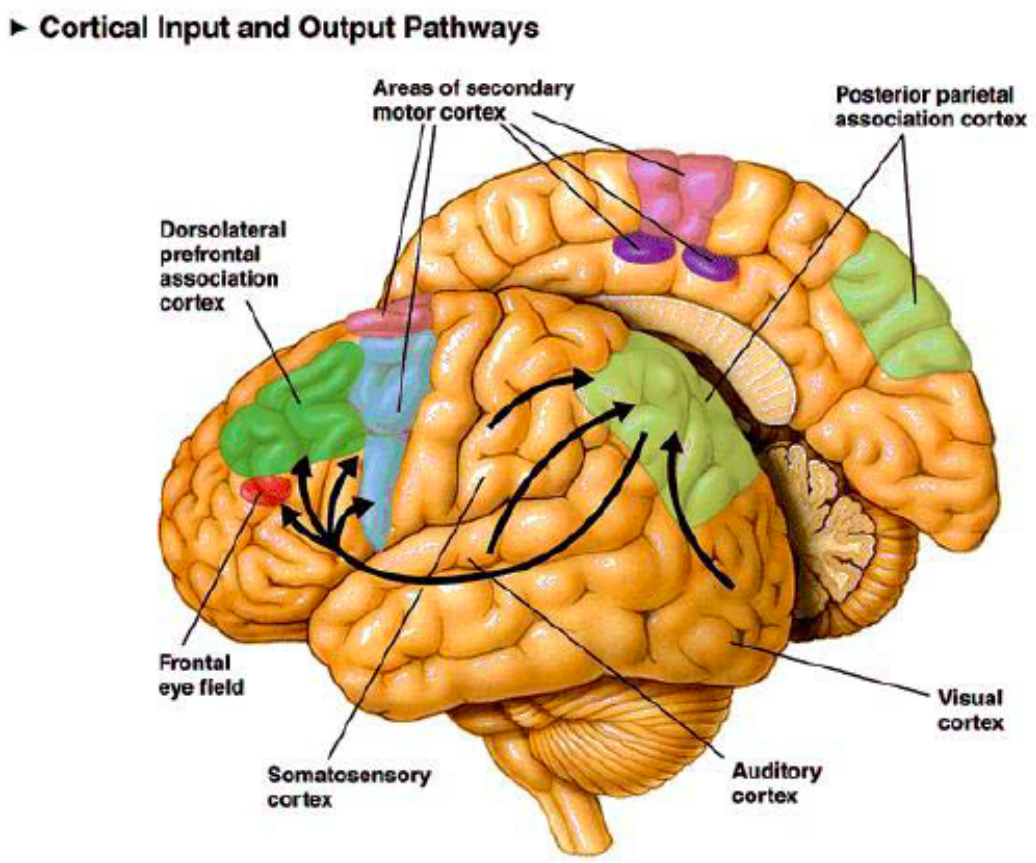
Acetylcholine and norepinephrine appear to be intimately involved in both altering the strength of responses of neurons to stimuli when they are attended and in altering, dynamically, the 'strength' of different synaptic inputs to a neuron.

parietal cortex contains a 'mental map' across which the positioning of items in the environment are distributed

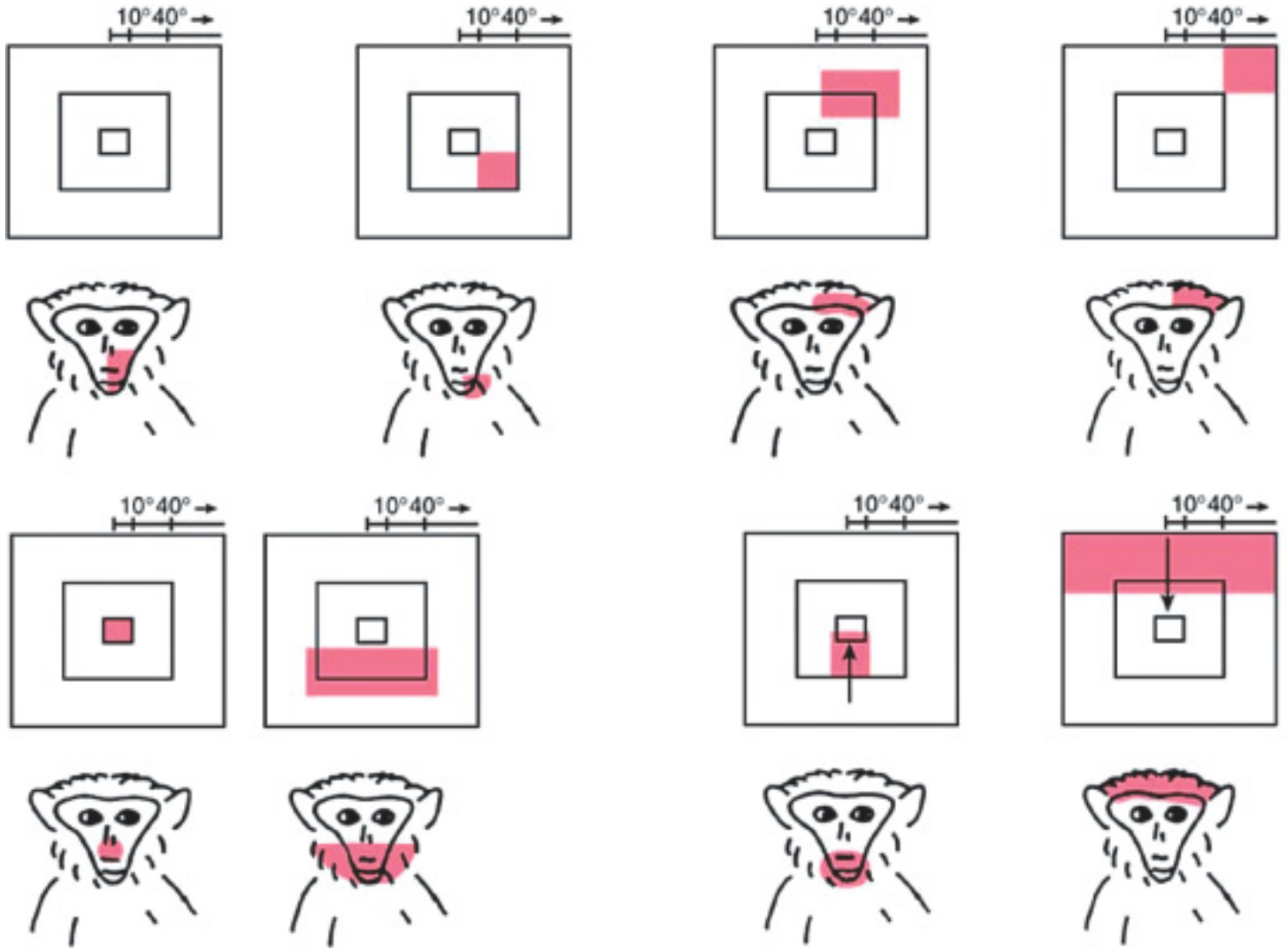
parietal cortex is the end-point for the 'where' pathway for visual processing

parietal cortex is an 'association area' in that it receives sensory input of many types: auditory, visual, proprioceptive, vestibular, somatosensory

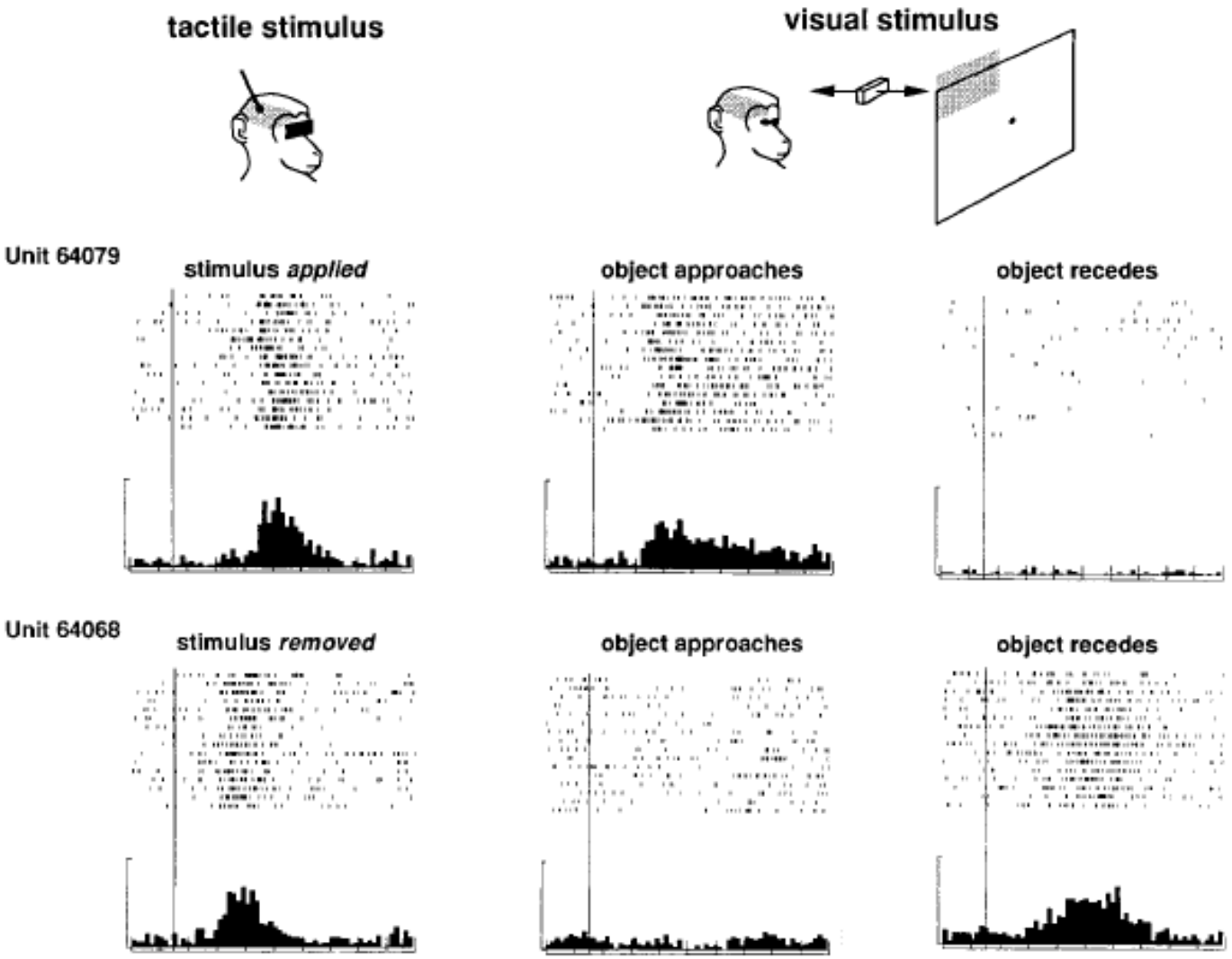
parietal cortex sends output to both sensory, motor, premotor, and prefrontal cortex



area VIP of parietal cortex I: bringing together personal spaces of the somatosensory and visual systems



area VIP of parietal cortex II: bringing together personal (egocentric) spaces of the somatosensory and visual systems …and movement related to them



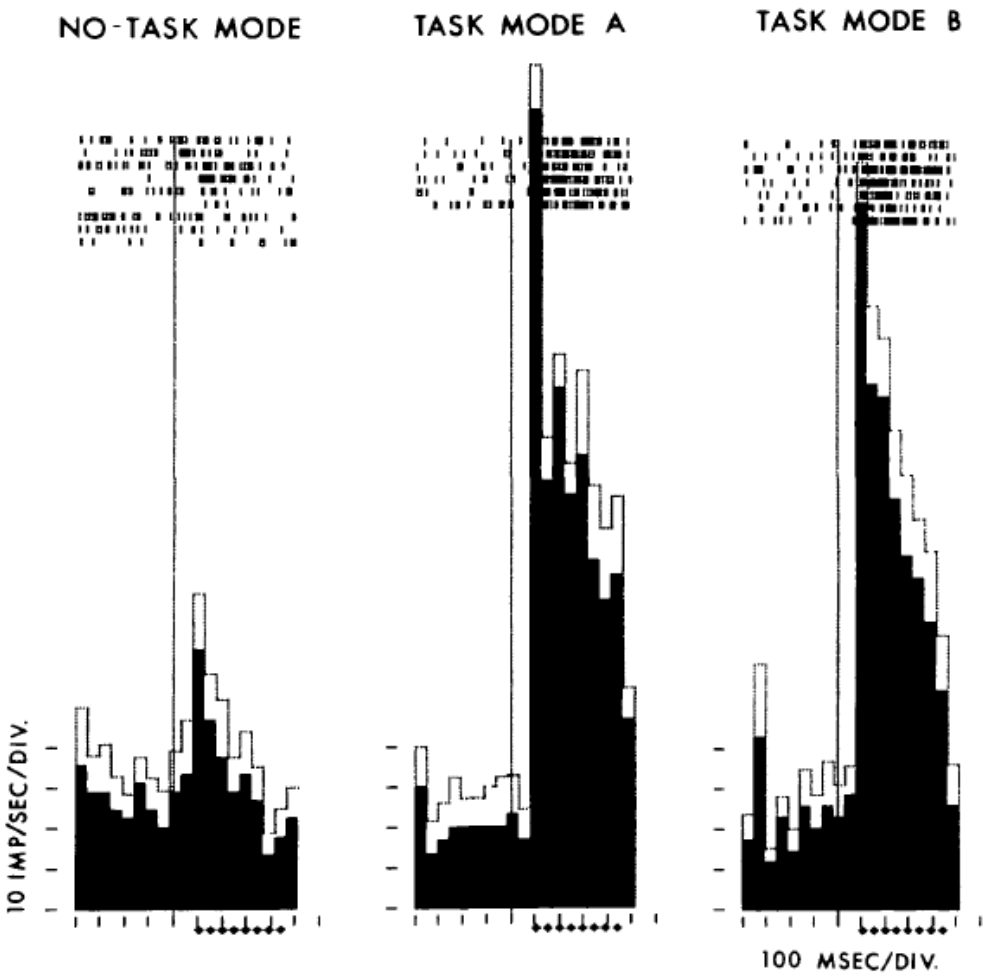
Duhamel et al., JNP, 1998

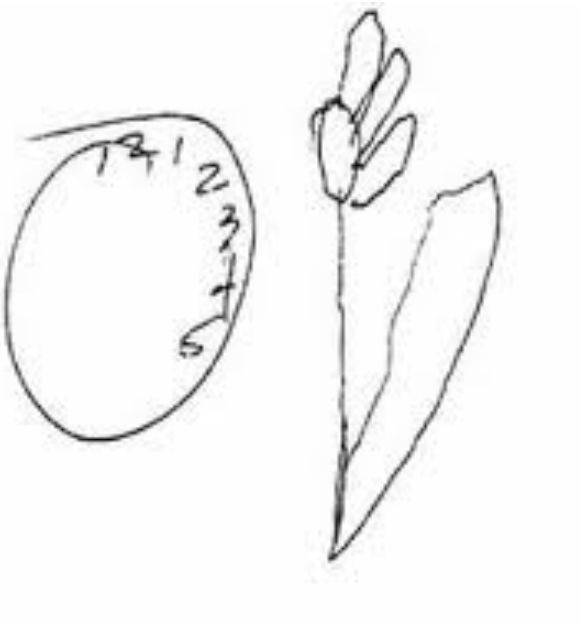
more early Mountcastle data showing that position-specific responses of parietal neurons to visual stimuli are strongly modulated by attention:

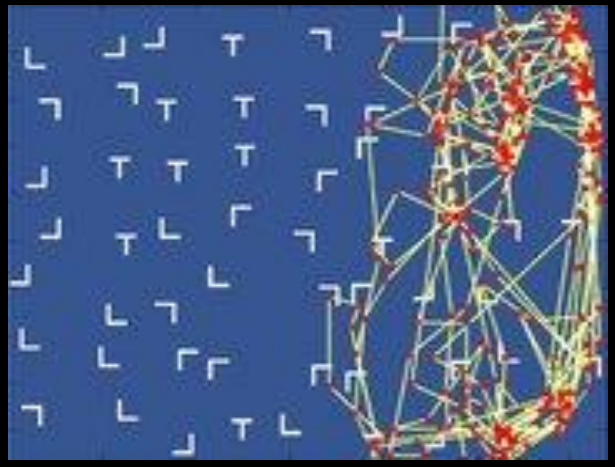
in the 'no-task' mode, a monkey fixates a central cross while a visual stimulus is placed within the preferred visual field of a recorded neuron – the neuron responds to the stimulus, but only weakly

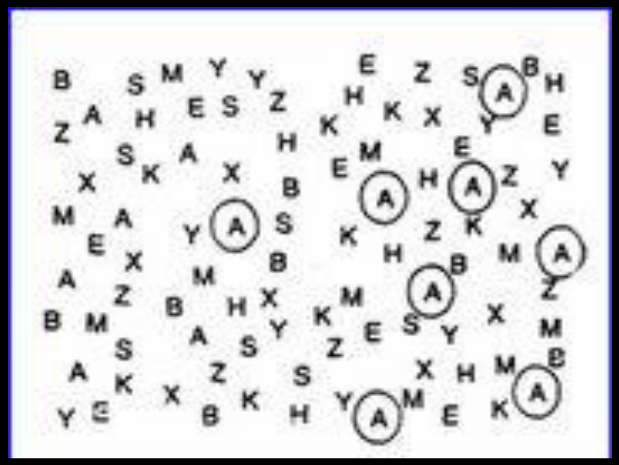
in 'task' modes A and B, the monkey must monitor the stimulus placed in the visual field to detect when it dims - the neuron's response to the same stimulus when attended is much stronger

thus, the neuron is simultaneously sensitive to the spatial position of a stimulus and to the degree to which that position requires attention




12
1
2
3
4
5





hemi-neglect following right parietal cortex injury

graded lack of responsiveness to stimuli presented to L side of body or to L side of visual field (contrast with sharp cutoff with, for example, occipital cortex injury)

lack of responsiveness is multimodal - pertains to tactile, visual, and auditory stimuli as well as to motor movements (e.g., the position of a hand movement's goal)

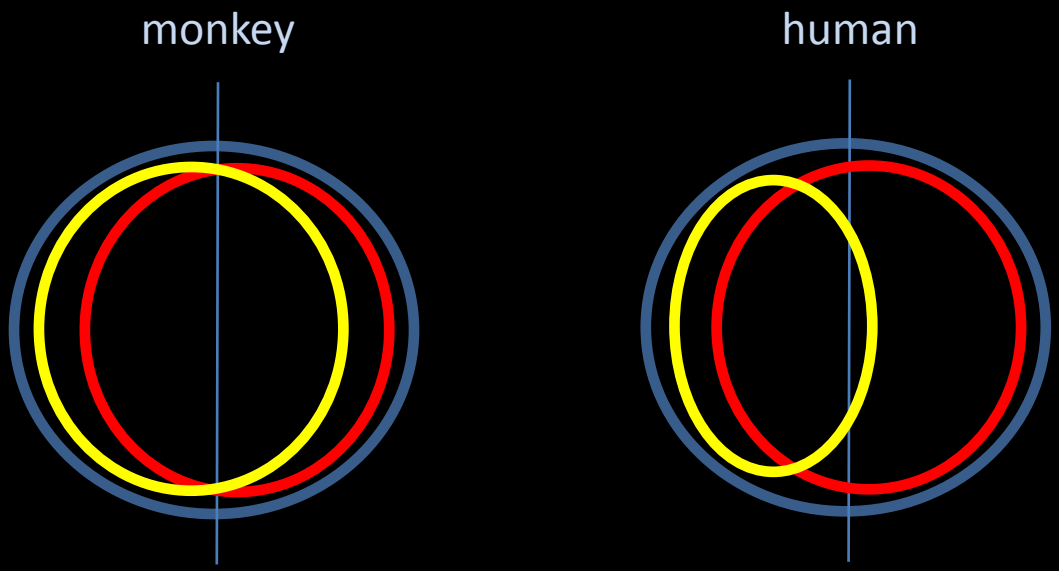
lack of responsiveness to stimuli on L side is exacerbated by competition with simultaneous stimuli on R side (competition applies across sensory modalities)

postural dependence - improved responsiveness to L side stimuli when head or eyes are directed to R of body or if stimulation of proprioceptive neurons mimic such postural changes

some potential explanations for features of hemi-neglect

graded lack of responsiveness to stimuli presented to L side of body or to L side of visual field (contrast with sharp cutoff with, for example, occipital cortex injury)

why the neglect only of L side with R parietal lesions and not vice versa? – why graded?

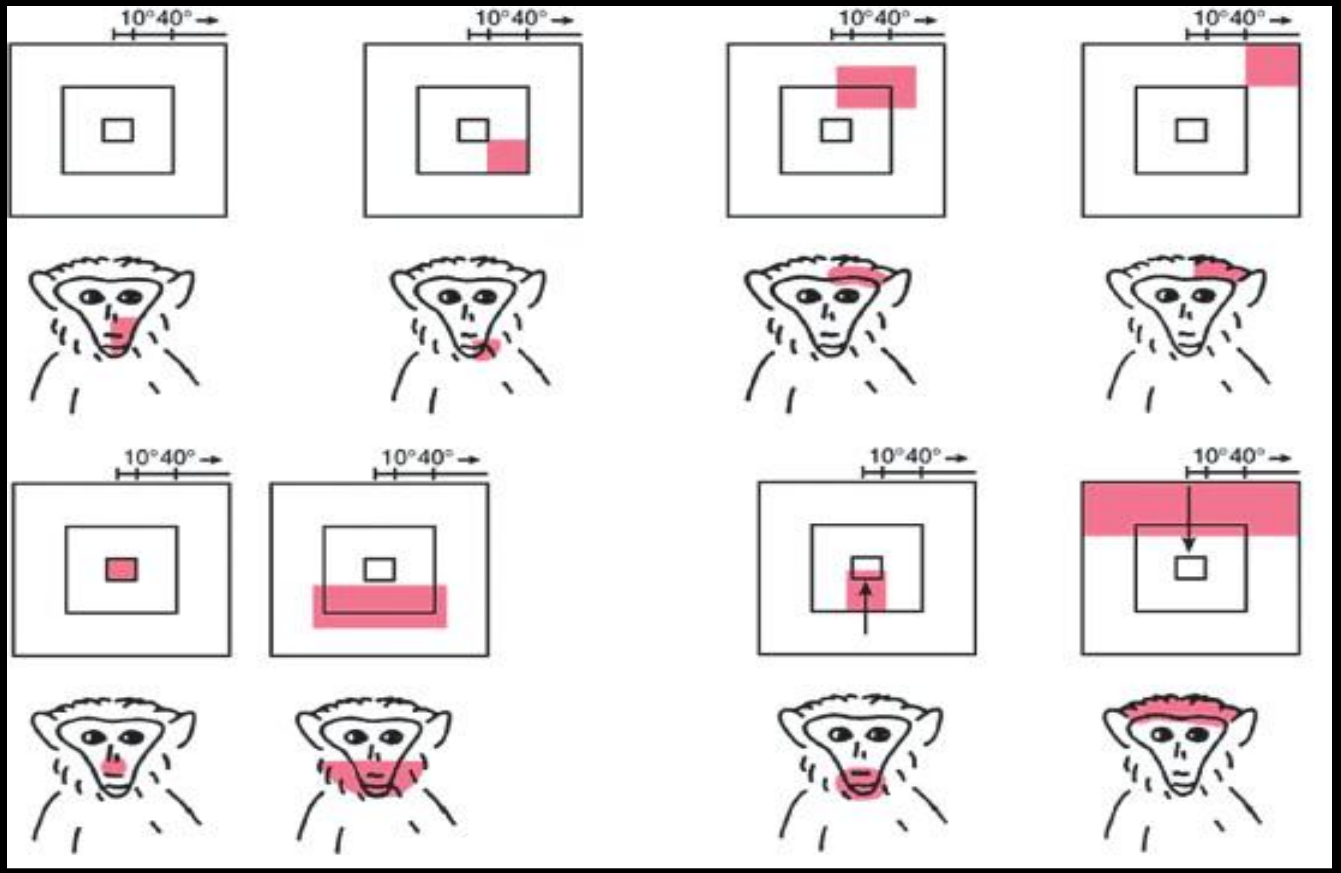


in monkeys, for whom right parietal lesions do not produce hemi-neglect, L and R parietal neuron populations respond mainly to R- and L-visual field stimuli (respectively), but a small population in each hemisphere responds to stimuli in the ipsilateral visual field

in humans, it is possible (and some EEG studies agree) that R parietal cortex is sensitive to L and R visual fields, but L parietal cortex is sensitive only to the R visual field

some potential explanations for features of hemi-neglect

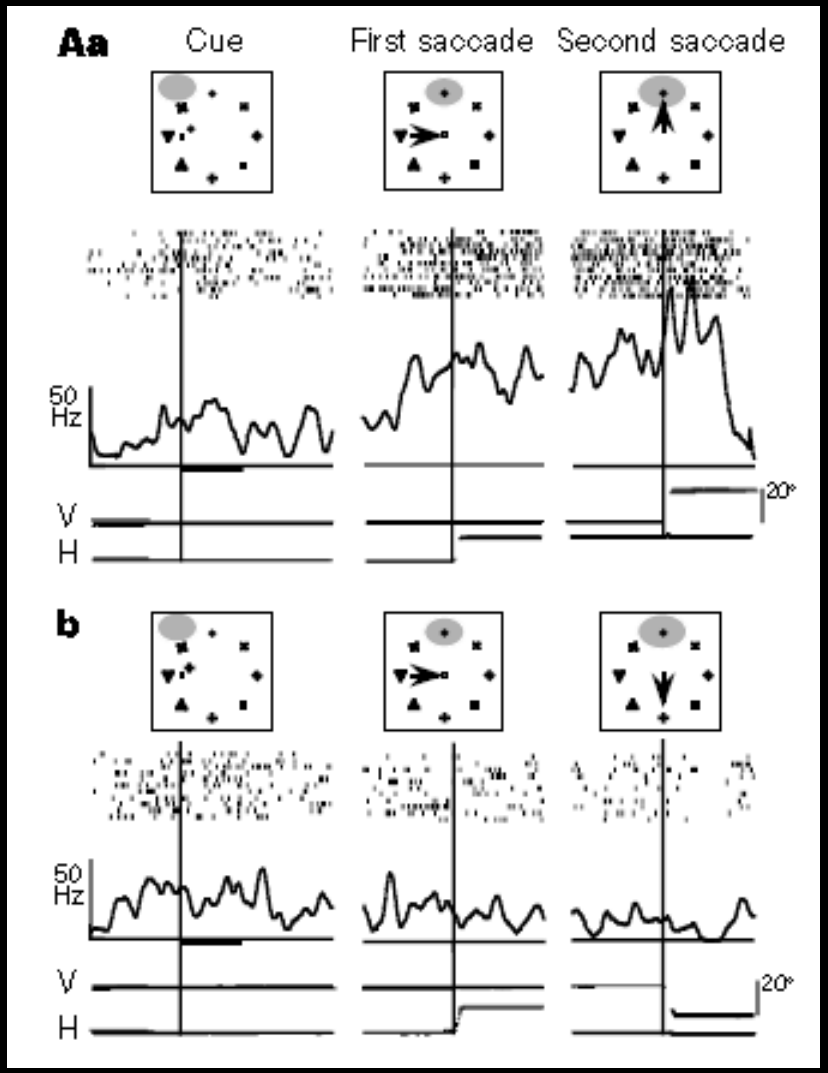
lack of responsiveness is multimodal - pertains to tactile, visual, and auditory stimuli as well as to motor movements (e.g., the position of a hand movement's goal)



parietal cortex sub-regions are most often sensitive to more than one sensory modality (e.g., VIP sensitive to tactile, visual, vestibular stimuli, LIP sensitive to visual and auditory stimuli, PPR sensitive to visual and auditory stimuli as they relate to hand movements)

hemi-neglect following right parietal cortex injury

lack of responsiveness to stimuli on L side is exacerbated by competition with simultaneous stimuli on R side (competition applies across sensory modalities)



parietal responses to visual stimuli are strongly dependent on salience as shown in this figure from Gottlieb et al. (Nature, 1998) where the response to a visual stimulus within the cell's receptive field (gray areas) depends on whether that stimulus matches one given during the cue period

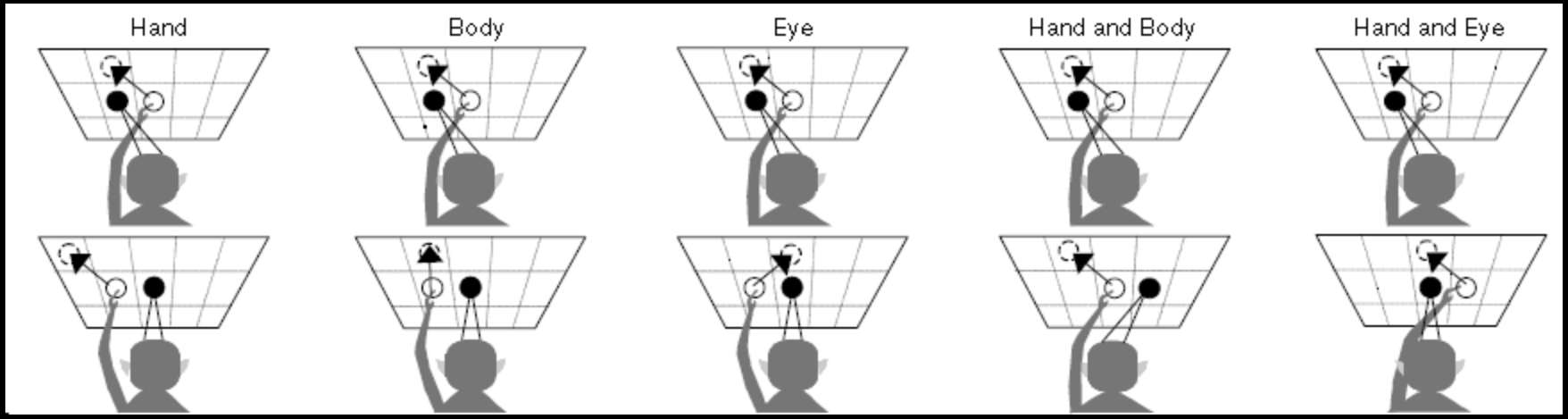
thus, the presence of a right field visual stimulus in a hemi-neglect patient may attain salience (be attended to) over another visual stimulus within the L visual field

in this case, the responses of those few L parietal neurons sensitive to L visual field stimuli may be non-existent

note that this also means that what doesn't register in the form of neural activity in the parietal cortex does not register perceptually

hemi-neglect following right parietal cortex injury

postural dependence - improved responsiveness to L side stimuli when head or eyes are directed to R of body or if stimulation of proprioceptive neurons mimic such postural changes



answers lie in defining parietal cortex receptive fields, spatial frames of reference, and…gain fields?