from sleep to attention – lecture 15 – Nov. 5, 2010

the basal forebrain
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 \( \frac{3}{4} \) 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.
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 synaptic 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?

Normally, we think of attention as altering the responsiveness of the cerebral cortex to different types of sensory input. That is, we think of attention as a sub-cortical process that impacts what happens in the cortex or thalamus. In the case of the parietal cortex and prefrontal cortex, we seem to have two systems of the cortex itself that regulate attention. Each of these structures is nevertheless impacted by subcortical inputs (e.g., from basal forebrain or locus coeruleus) and, remarkably, appear to impact activity in the same subcortical structures. Thus, attention is a cyclical process (i.e., a chicken-and-egg type process) that is continuous where what has been attended will affect, to some extent, what is attended to subsequently.
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.

The ‘hemineglect’ syndrome arises from damage to the right parietal cortex and impacts the left side of not just egocentric frames of reference (e.g., the left visual field or left side of the body), but also the left side of objects (i.e., in an object-centered frame of reference).

The ‘hemineglect’ syndrome could conceivably arise because the parietal cortex serves as that brain area where a ‘spatial representation of the world’ is laid out or because the parietal cortex serves to regulate spatial aspects of attention.
questions for midterm 2

we discussed three types of neurophysiological change that appear to accompany attention. Name and describe each. Feel free to draw, but be sure to add labels.

recall two pieces of evidence that suggest that hemineglect can occur not only for egocentric space, but also for object-centered space

compare and contrast the basal forebrain and locus coeruleus in terms of their anatomical projections. based on what was discussed in class, what types of attention might be enhanced under the following three conditions: high ACh; high NE; low NE
in comparison to NE neurons of the locus coeruleus, the projections of the basal forebrain are anatomically more complex

whereas NE neurons projecting to cortex are tightly grouped within the locus coeruleus and may send axons to widely spaced regions of cortex, cortically-projecting basal forebrain neurons form several sub-groups which project to discrete regions of the cortex (e.g., only to prefrontal cortex).

furthermore, at least three types of cortically-projecting basal forebrain neurons exist – ACh-releasing, GABA-releasing, and glutamate-releasing
different types of basal forebrain neurons appear to have different relationships to cortical EEG patterns (note, PV and NPY neurons are different types of GABA neurons)
NE neurons ‘learn’ quickly as shown by quick changes in their responses to stimuli depending on whether they are novel, newly relevant, or newly irrelevant.

Similarly, basal forebrain neurons ‘learn’ quickly: in the figure below, a basal forebrain neuron regularly responds to the ‘red’ visual stimulus when it predicts reward (sucrose drop). Later, when the ‘red’ stimulus now predicts a punishment (saline drop), the neuron ends its response after the first trial.

Wilson and Rolls, J. Neuroscience, 1990
mainlining sensation? – ACh decrements the responses of both ventrobasal thalamic and barrel cortex neurons to inputs from barrel cortex itself – in this way maximal response to only the whiskers themselves may be achieved


electrophysiological evidence that the basal forebrain can independently modulate the responsiveness of somatosensory and visual cortex (via the prefrontal cortex) – Golmayo et al., Neuroscience, 2003 – part I

different regions of prefrontal cortex are activated by stimulation of visual cortex (black squares) versus somatosensory cortex (white circles)

different neurons of the basal forebrain are activated by stimulation of these two different regions of the prefrontal cortex – however, they intermingle anatomically
basal forebrain stimulation increases the amplitude and extends the response of both visual and somatosensory cortex to visual and touch stimuli – this effect is blocked by antagonists of acetylcholine.
ACh depletion in hippocampus decreases the degree of place-cell discrimination for two similar environments – one interpretation is that this arises from a decreased attention to external stimuli that differ between environments.