week 9/10 – interval timing
extra credit term paper: potential topics

- snapshot consciousness
- space in memory and reality
  - Einstein’s brain
- tool use / extended personal space
- body dysmorphic disorder
  - Steiner lines
  - the binding problem
  - the pinocchio effect
- internal alarm clocks
  - the pineal gland
- prism adaptation
- crossover of space, time, and language
  - backwards causation
  - the man who lost his body
- temporal discounting
  - the distal reward problem
- territorial / social space
  - homing pigeons and electromagnetic space
  - bee directions
  - Picasso / Pollock / Dali / Van Gogh
  - cross-generation navigation (butterflies)
  - ants navigation / dead reckoning
  - bird caching of food
overview of issues in time interval estimation

anatomical locus?

cross-modal generalization?

interval timing vs. duration comparison

single mechanism vs. multiple mechanisms

embodied?

scalar / Weber’s law?

models:

  oscillator-accumulator

  emergent

  energy

  working memory
to localize or not to localize? – why trying to place interval timing as the function of a given brain region might be foolish

Bostan and Strick, Neuropsych. Rev., 2010

Lesion studies implicate prefrontal cortex, parietal cortex, basal ganglia, and cerebellum in interval timing and some argue over which structure is actually crucial.

Strick, however, makes a strong case for distinct cortical-basal ganglia-cerebellar ‘loops’ where particular regions of cortex are interconnected with specific sub-regions of the basal ganglia and cerebellum – the approach emphasizes all these sub-regions working as a group.
duration comparison is a common task employed in monkey interval timing experiments – here C1 is displayed for some period of time (typically 0.5-1.5 secs) followed after a delay by a shorter or longer C2 stimulus – after a second delay, the animal chooses the one displayed for a longer time.


blue and pink lines depict durations and colors of C1 and C2 stimuli – black ticks depict spike times – lower graphs depict cross-trial firing rates subsequent to C1 presentation at time 1.0

duration-sensitive neurons in prefrontal cortex: neuron A exhibits an activity peak at approximately 0.8 secs after the start of the C1 stimulus – neurons B and C display a ramping-type of activity that is time-dependent.

but does such activity representation time or simply a decision on the part of the animal that enough time has passed that the C2 stimulus is likely to be longer – notably, on trials where C1 activity peaks show up earlier, the animal is more likely to have incorrectly picked C2 as longer.
another duration-comparison experiment, one examining parietal (LIP) activity – LIP activity over the standard cue presentation appears to reveal a ‘assume the first cue is shorter’ strategy on the part of the monkey – ramping activity during the test (second) cue presentation is considered to reflect a ‘timing’ mechanism
‘dedicated’ timing systems – typically involve the notion of oscillatory signals (rhythmically-firing neurons), some mechanism for accumulating the number of spikes following some reset time, and neurons with spike firing thresholded to the level of accumulation

– note that the mechanism for clock ‘reset’ has not been defined

- note that an ‘energy’ accumulator version of this general mechanism has also been proposed which would not require an oscillator and would allow for independent interval timing within any sensory system
another ‘dedicated’ timing system – here a population of neurons firing rhythmically at different frequencies are temporally aligned (reset) such that at a specific interval of time afterward, some set of them fire simultaneously (the ‘beat’ frequency) – a reporter neuron fires only when all three neurons supply excitation to it.
DS neuron D fires here. The combined effect of PFC neurons A, B and C triggers depolarization.
the interval timing field’s equivalent of the “place cell” ??

referee quote: “…the field has been waiting decades for this…”


'emergent' (one might also say 'accidental') timing systems are postulated to arise from specific sequences of activity in a population of neurons that propagates as a result of a specific stimulus (e.g., the 'start-timing' stimulus)

in this scheme, a reporter neuron is activated by a specific pattern of activity among the neurons of the network (because of its unique pattern of inputs)

if the network patterns always propagate the same way in response to a given stimulus, the time at which the reporter fires after the reset will always be the same
among a population of neurons whose activity peaks are NOT temporally related to the actual saccades, the times of activity peaks are regularly/consistently distributed in time in this way, the fixation stimulus, the go stimuli, and the target off stimuli drive a pattern of activity that changes over time thus, there are different patterns that regularly occur at specific time intervals following a stimulus support, in principle, of an interval timing system that detects specific patterns
beyond the initial responses to a electrical stimulation at either E1 or E2 (arrows in figures), responses of neurons in culture may continue for some time (i.e., an activity pattern propagates among the group). Emergent patterns corresponding to interval times...in a dish!

propagation is enhanced by 'interval' stimulation patterns over 'in-phase' patterns and propagation duration tends to match the time interval between E1 and E2 stimulation – but what if something interferes and what about transfer?
true interval estimation (absent duration comparisons) – a role for working memory?
in a task where the monkey simply times button release to an interval whose length is specified by a cue, premotor neurons exhibit working-memory like activity that is specific to the interval demanded – the slope of graded increases and decreases in rate across time matches the required interval – but what expands or compresses such activity patterns within the network?