space and time in the brain – cogs260 – Nitz – spring, 2011

week 3 – egocentric mapping, motor cortex, movement space
brain-computer interfaces for movement – what is the optimal basis for control?

neural mappings for movement direction and speed between effector start and goal sites?

neural mappings for coordinated muscle activation/inactivation patterns?

neural mappings for joint angles and kinematics?

coding transformations made possible by complexities of spinal cord interneuron types/connections makes any of these mapping schemes a possibility

spinal cord interneurons:
1. can be excitatory (green) or inhibitory (red)
2. are interconnected with themselves and motorneurons
3. may have axons which cross the commissure and/or extend into other segments
4. are recipients of both converging and diverging motor cortex inputs
10-12 muscles of the rat forearm are recorded while rats perform reaching movements to grasp sucrose pellets

by using ‘independent components’ analysis (a new form of principal components analysis), motor ‘synergies’ could be defined – these are combinations of muscle activation/inactivation patterns

individual motor cortex neurons exhibited activity patterns that correlated strongly with the strength of expression of a motor synergy across the time of a reach

so…perhaps a transformation of a motor cortex directional tuning map to a muscle activation pattern isn’t necessary after all
center out movements in eight directions

calculate pre-movement firing rates (yellow periods) for each direction (only 3 shown)

firing rates for different directions (polar coordinates) can be used to calculate a ‘preferred direction’ (green arrow)

different neurons exhibit different preferred directions and degree of tuning is given by arrow length
Georgopoulos showed that motor cortex neuronal activity rates were closely related to the direction of movement.

Moran and Schwarts (J. Neurophysiology, 1999) showed that when you average out differences in firing rate according to movement direction, a relationship between firing rate (left trace) and subsequent movement speed (right trace) is observed based on this, one could consider motor cortex activity as mapping direction and speed...or...one could consider the direction and speed correlations of motor cortex neurons and epiphenomenal to the associated muscle activity patterns.
Georgopoulos et al., Science 1989 – ‘mental rotation’ in the motor cortex as revealed by changing directional tuning mapped by a population of neurons – can motor cortex transformations be considered a form of thinking?
the same directions of movement are made with three different starting wrist postures such that muscle activity and direction of movement are dissociated – who wins? – no one – some motor cortex neurons clearly map to muscles, some appear to maintain map to direction.
Finally, a temporal component is considered.

A. Preferred direction is now calculated for different times over the course of a center-out movement – oddly enough, preferred directions are different for these different timepoints.

B. Monkeys are now asked to move in complex paths given by a series of targets.

C. When preferred direction is calculated using preceding, current, and subsequent movement directions, preferred directions change in the same way as during the center-out task.

D. The series of preferred directions for any given neuron defines a ‘pathlet’ – a preferred spatiotemporal trajectory.
predicted vs actual firing rates for M1 and PMv neurons for five full oval completions

predicted values are based on pre-movement preferred directions calculated during the center-out task

for all M1 and PMv neurons, the shift in time that yields the strongest correlation between predicted and actual firing rate across five oval completions is given

the interpretation is that neurons with positive values have activity prior to actual movements in the preferred direction while those with negative values have activity tuned to recently realized preferred-direction movements
shown are the actual hand trajectories (blue), the cursor trajectories (green), and the ‘neural trajectories’ (red) across cycles 1-3 where oval-shaped hand trajectories yield oval-shaped cursor trajectories and cycles 4-5 where horizontal hand movement yields greater horizontal cursor movement than vertical hand movement yields vertical cursor movement

the ‘neural trajectory’ is based on the full population of M1 or PMv neurons – based on which cells are firing and how much and based on each neuron’s preferred direction, an educated guess is made as to what direction of movement is currently being mapped

the result of the horizontal acceleration in cycles 4,5 yields a requirement for circular movement of the hand to create oval-shaped cursor movement (itself required for successful task performance)

the monkey adapts (makes circular hand movements) – the monkey doesn’t see his hand and doesn’t know about the change in cycles 4,5 – so… proprioceptive information about arm movement and visual information (cursor movement) do not agree – in this case, humans ‘believe’ the visual information and perceive having made oval-shaped arm movements – … and monkeys?

premotor neurons map cursor-directions while M1 neurons map arm directions when these are not the same (cycles 4,5)
quantification of the effects shown in figure 3

**Fig. 4.** Eccentricities of illusion and control trajectories. Error bars are the 95% confidence intervals calculated across five repetitions of the task.