Selection of arm movements during evidence accumulation

Jason Friedman & Matthew Finkbeiner
ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, Sydney, Australia

Introduction

- Most studies of arm movements have focused on point-to-point trajectories
- Here we look at arm movements made while subjects are still accumulating evidence about which target to reach to
- We show that subjects use the partially accumulated evidence in planning their arm movements.

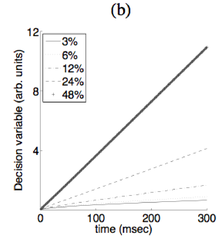
Methods

- Subjects saw a random dot kinematogram for 300 ms with various coherence levels (3%, 6%, 12%, 24%, 48% coherence)
- 3 subjects each performed 1500 trials over 3 days, of which we used 800 trials (160 per condition)
- They had to point to a box on a touch screen to indicate whether the dots were moving left or right
- The subjects were required to start moving before 350 ms, but had plenty of time (3 s) to complete the movement.
- The trajectories of the index finger were recorded using an Optotrak motion capture system at 200 Hz.
- The main dependent variable we used was the "heading angle" - the direction the subjects initially started moving in (measured when they are 1 cm towards the screen).
- We model the heading angle in a similar way to saccade deviation due to microstimulation of FEF in monkeys (Gold & Shadlen, 2003)

The models - partial plan vs. complete plan

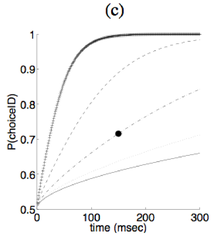
We assume that the probability of making a correct movement increases as a function of time and coherence level

(b)



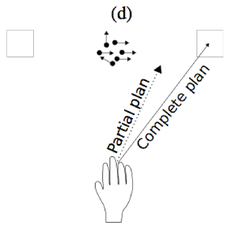
We estimate the linear accumulation of evidence (decision variable) that will give the accuracy shown in (a)

(c)



We can then calculate the probability of selecting a target, given the decision variable.

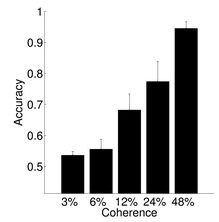
(d)



Based on this probability, we can hypothesize two options - either move directly to the target with more evidence [complete plan] or move according to the amount of accumulated evidence [partial plan], where the angle is linearly related to P(choice|D)

Results: Accuracy

An ANOVA confirmed that the accuracy increases with the coherence level ($p<0.001$)



Results: Mean (and standard deviation) of correct trajectories for one subject to the right target

As the task becomes more difficult, the paths become more curved and more variable.

Results: Histograms and kernel density estimates of heading angle

This shows the kernel density (smoothed histogram) estimates for one subject at 12% coherence. The partial plan model better fits the data. The black arrows shows the heading angle of all movements.

The partial plan predicts different distributions of heading angles for different conditions, as is observed

Results: Heading angles as a function of time

According to the partial plan model, the heading angles should become more towards the target (in this case, the right, at 57 degrees) as a function of time (as more evidence is accumulated). The regression fits at both high and low coherence levels are significant ($p<0.05$)

Results: Distance between the peaks of the kernel density estimates

The distance between the peaks of the kernel density estimates increase as a function of coherence - as the task becomes easier, subjects move more directly towards the target

Conclusions

- When forced to move before a final decision has been made, subjects initially move in an intermediate direction, constrained by the accumulated evidence.
- Supports the notion that initial direction and final target are planned separately (Scheidt & Ghez, 2007)
- This technique also provides a way of studying the temporal dynamics of evidence accumulation in humans while a decision is being made.

Poster on the web:
http://www.curiousjason.com/sfn2011