Summary of CI model 11/27/18

**Current state and direction of CI behavioral modeling project**

**Goals**

1. Demonstrate that monkeys can be trained to perform a task requiring a causal inference that can be linked to human behavioral literature.
   1. Monkeys can accurately localize two stimuli presented simultaneously
   2. These stimulus pairs can result in fused percepts (average saccades)
   3. Targets that are closer together in space are more likely to be fused
   4. The behavior matches up with expectations given the limitations of auditory and visual sensory systems
2. Determine whether this behavior is well described by optimal Bayesian causal inference (specifically model averaging), or if alternatives such as model selection or probability matching provide better fits
   1. Existing models are built on either explicit or implicit CI, not both at the same time. Also must be adapted to continuous variables (saccade endpoints).
   2. Compare/contrast with humans on same task to address species vs. task differences with literature
3. Set up expected neural correlates

**Current State**

* Have data from 8 humans and 2 monkeys performing the AV causal inference task.
* Compensated for explicit/implicit modeling issue by fitting the model only to saccade location (implicit CI), while subsampling multi-saccade trials (expectation is that over many trials average saccade behavior should match on to probability distribution estimated by model).
* CI model quantitatively outperforms the trivial alternatives (figure 3 in technical report doc) in terms of location estimation for both monkeys and humans. Have not yet compared to various non-optimal alternatives.
* Qualitatively the model provides surprisingly poor fits on monkey datasets and some human datasets (figure 2 in technical report doc), seemingly because it greatly overestimates the amount of variance in auditory localization. This is likely because there is persistent auditory bias that cannot be accounted for in the model in any other way. It could also be because of the inclusion of very inaccurate saccades not being acceptable under the assumed Gaussian distribution.
* The model is much more effective on 7/8 humans performing the same task, providing both qualitative and quantitatively better fits. This is despite the fact that there is much less data available from each subject.

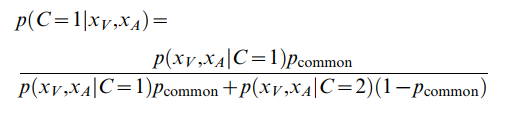
**Summary of methods**

**Behavioral task**

Subjects respond to either a visual or auditory cue by making a saccade to their estimate of that cue’s location. Cues are either unisensory (just visual or just auditory), or are presented simultaneously with varying degrees of spatial separation. When the targets are widely separated monkeys make two saccades (one to each target), but when they are in the same place monkeys must make only a single saccade. Ideally this provides both a readout of explicit causal inference (number of targets = number of saccades) as well as implicit CI (influence between modalities when only one target is reported).

**Brief description of model**

I am building a model of multisensory causal inference based on the work of Konrad Kording and others (<https://doi.org/10.1371/journal.pone.0000943>). Briefly, given some visual and auditory estimates with respective means and variances, plus some prior bias, there is an optimal way to determine whether these originated from the same cause. Assuming only 1 or 2 causes:



We can solve this analytically to get the posterior, and then use that to decide how to combine the location estimate distributions which come from assumed optimal integration. For common cause the optimal location estimate is:

And for two separate causes:

, ,

I determine the “combined” distribution that can be compared to the data by summing the common and separate cause distributions together, weighted by the posterior on common cause [p(C=1|xa,xv)]. So if post\_common = 1, it’s a single normal distribution given by the first set of equations (). I fit the model by calculating the negative log likelihood of the observed real saccade endpoints, summed across all conditions, and using fminsearch to find the optimal parameter values.

Currently, I’m fitting this model with 5 free parameters: . The variance for auditory responses is split into two components (c, close and f, far) because there is a lot more variance in the eccentric targets than the central targets. The values xA and xV are assumed to be the actual target locations in space, and μp is assumed to be zero. I’ve tried including both an overall prior bias as well as an auditory specific one, but these had essentially no effect on model performance.