

Analyzing orientation behaviour in animals using Stan

JOHN D. KIRWAN



With the help of...



The Lund Vision Group

Dan-E Nilsson Jochen Smolka James J. Foster Anna Stöckl Ullrika Sahlin Richard McElreath (for *Statistical rethinking*) All those involved in *R*, *Stan* and *brms*



Directions are everywhere!





Compass bearings





Time periods



Analysis is unduly rudimentary



- Reliance on null hypothesis testing
- Assumptions not always met
- Less emphasis on effect size, uncertainty



I. How well can millipedes see?







Response to a visual signal by a millipede









Discretize and apply the psychometric function



$$\psi(x; \alpha, \beta, \gamma, \lambda) = \gamma + (1 - \gamma - \lambda) \cdot F(x; \alpha, \beta)$$

Define threshold by the inflection pt.



Excuse me, sir...



...do you have a moment to talk about Bayes?



Millipedes can resolve a 22° visual signal



$$\begin{split} Y_i &\sim \gamma + \eta \ (1 - \gamma - \lambda) \\ \eta &\sim \text{Binomial}(n_i p_i) \\ \text{logit}(p_i) &= \alpha + \alpha_{\text{individual[i]}} + X_i \beta_i \\ \lambda &\sim \text{Beta}(8,2) \\ \gamma &\sim \text{Normal}(0.2,0.02) \\ \beta_i &\sim \text{Normal}(0,2) \\ \sigma &\sim t_3(0,10) \\ \alpha_{\text{individual[i]}} &\sim t_3(0,10) \end{split}$$



As can velvet worms







II. Do dung beetles orient using polarized light?



James J. Foster, Lund Vision Group

- Use nocturnal celestial cues to roll their dung ball away in straight course
- Sensitive to polarized light cues
- Do they use the *degree of polarization*?



Tested clustering in experimental arena



James J. Foster, Lund Vision Group

- Eight treatments: from almost zero to total polarization
- Released into centre of cylindrical arena
- Compare clustering of tracks



Beetles increasingly orient with more polarization





III. How well do moths track flowers?



Which senses are important?

At what speed?

Night vs. day?



Tracked responses to a robotic flower



Stöckl et al. Phil Trans B. (2017)

- Treatments:
 - Different flower frequency (Hz)
 - Bright vs. dim light
 - Antennae condition
- Outcome is complex!
 - ρ and θ on unit circle



Differences in flower tracking among moths





Anna L. Stöckl et al. Phil. Trans. R. Soc. B 2017

Phase change with multiple predictors



- Both mean and concentration of phase angles vary
- Model both elements of complex outcome?



Summary

- Bayesian multilevel modelling facilitates getting the most from directional data
- Sensory studies benefit from:
 - multiple effects incl. random effects
 - more appropriate models
 - expressing effect size & uncertainty
- Stan/brms makes this possible!



