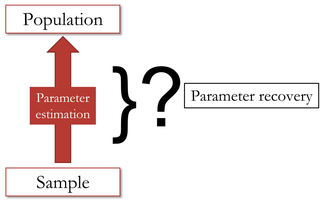
Classical Maximum Likelihood Estimation in Shifted-Wald Models of Response Times

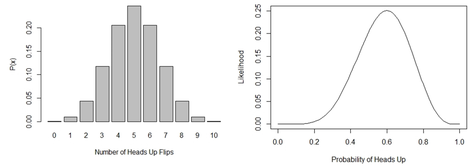
Bryanna L. Scheuler & Thomas J. Faulkenberry
Department of Psychological Sciences, Tarleton State University

Background

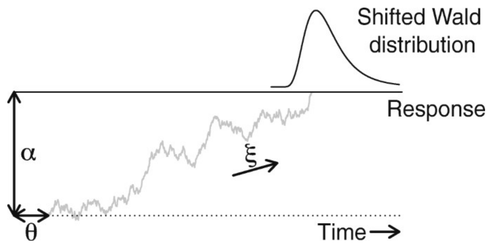
Response times are a crucial component of understanding and measuring cognitive processes. But, how do we know that the parameters we are estimating from a response time distribution are representative of the true population parameters? One beautiful solution: A parameter recovery study.



This study focused on classical maximum likelihood estimation (CMLE), an estimation method that compares the relative likelihoods of parameter probabilities. But what does it mean to compare likelihoods of parameter probabilities?



CMLE was tested on a specific model of response times, known as the shifted-Wald model. The shifted-Wald model is composed of three parameters: shift, drift rate, and response threshold.



By completing a parameter recovery study, we can gauge how well CMLE can estimate these parameters from a shifted-Wald model.

Method

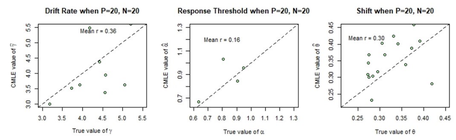
For this study, we simulated data using the parameters reported by Faulkenberry et al. (2018). This was composed of four main steps:

- Generate 'artificial' people from parent population
- Generate response times for artifical people
- Fit shifted-Wald model to RT distribution with CMLE
- Compare estimates to original parameters

This process was applied to 5 sub-experiments in a design used by Farrell and Ludwig (2008). These sub-experiments had 5, 20, or 80 participants, with 20, 80, or 500 trials per particpant.

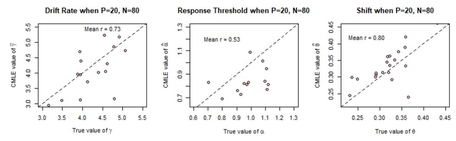
Experiments

Experiment 1: Participants = 20, Trials = 20



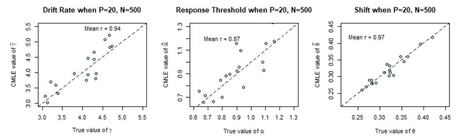
Comparison Method	Drift Rate (γ)	Response Threshold (α)	Shift (Θ)
Correlation	0.36	0.16	0.30
RMSD	2.42	3.47	0.24
Mean Bias	0.58(0.58)	0.96(0.98)	-0.05(0.06)

Experiment 2: Participants = 20, Trials = 80



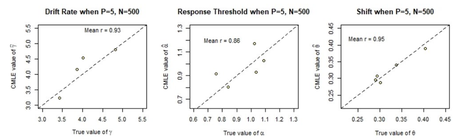
Comparison Method	Drift Rate (γ)	Response Threshold (α)	Shift (Θ)
Correlation	0.73	0.53	0.80
RMSD	0.66	0.30	0.04
Mean Bias	0.06(0.15)	0.03(0.07)	0.00(0.01)

Experiment 3: Participants = 20, Trials = 500



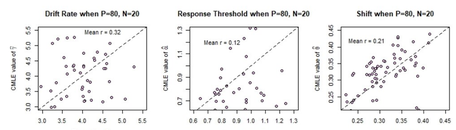
Comparison Method	Drift Rate (γ)	Response Threshold (α)	Shift (Θ)
Correlation	0.94	0.87	0.97
RMSD	0.24	0.09	0.01
Mean Bias	0.01(0.05)	0.00(0.02)	0.00(0.00)

Experiment 4: Participants = 5, Trials = 500



Comparison Method	Drift Rate (γ)	Response Threshold (α)	Shift (Θ)
Correlation	0.93	0.86	0.95
RMSD	0.23	0.09	0.01
Mean Bias	0.02(0.10)	0.01(0.04)	0.00(0.01)

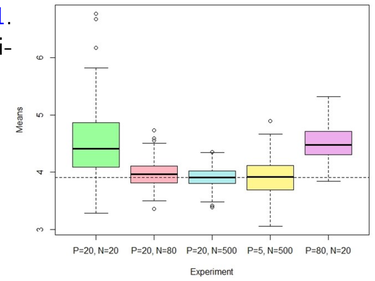
Experiment 5: Participants = 80, Trials = 20



Comparison Method	Drift Rate (γ)	Response Threshold (α)	Shift (Θ)
Correlation	0.32	0.12	0.21
RMSD	2.65	4.17	0.27
Mean Bias	0.61(0.31)	0.98(0.48)	-0.05(0.04)

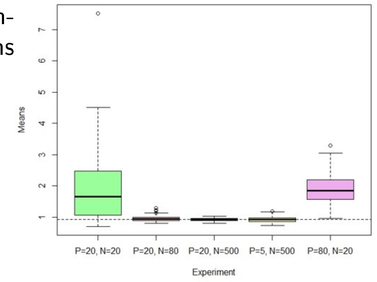
Drift Rate

The true mean for drift rate was 3.91. The estimated means in each experiment were as follows:
Experiment 1 = 4.49 (0.60)
Experiment 2 = 3.97 (0.23)
Experiment 3 = 3.91 (0.17)
Experiment 4 = 3.92 (0.32)
Experiment 5 = 4.52 (0.31)



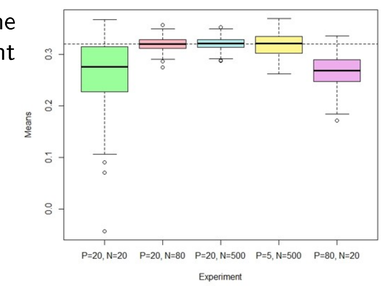
Response Threshold

The true mean for response threshold was 0.92. The estimated means in each experiment were as follows:
Experiment 1 = 1.88 (0.98)
Experiment 2 = 0.95 (0.08)
Experiment 3 = 0.92 (0.04)
Experiment 4 = 0.92 (0.09)
Experiment 5 = 1.89 (0.45)



Shift

The true mean for shift was 0.32. The estimated means in each experiment were as follows:
Experiment 1 = 0.27 (0.06)
Experiment 2 = 0.32 (0.01)
Experiment 3 = 0.32 (0.01)
Experiment 4 = 0.32 (0.02)
Experiment 5 = 0.27 (0.03)



Discussion

There are still many questions left to be answered:

- How do other tools compare to CMLE in shifted-Wald models?
- Is there a goal trial size when using CMLE for these models?
- How can we use this information about participant versus trial size to make informed decisions?