

What You See is What You Get:

A Closer Look at Bias in the Visual World Paradigm

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The field is itself exceptionally broad, ranging from sentence processing, priming, reading, and word formation

Troublesome when we commit too early:

“The horse raced past the barn fell”

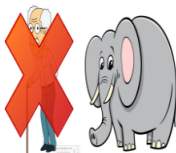
Often can not be observed directly

Limit focus to single word recognition

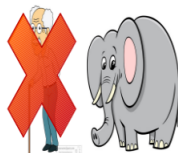
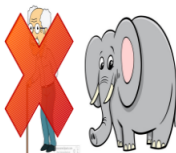
el



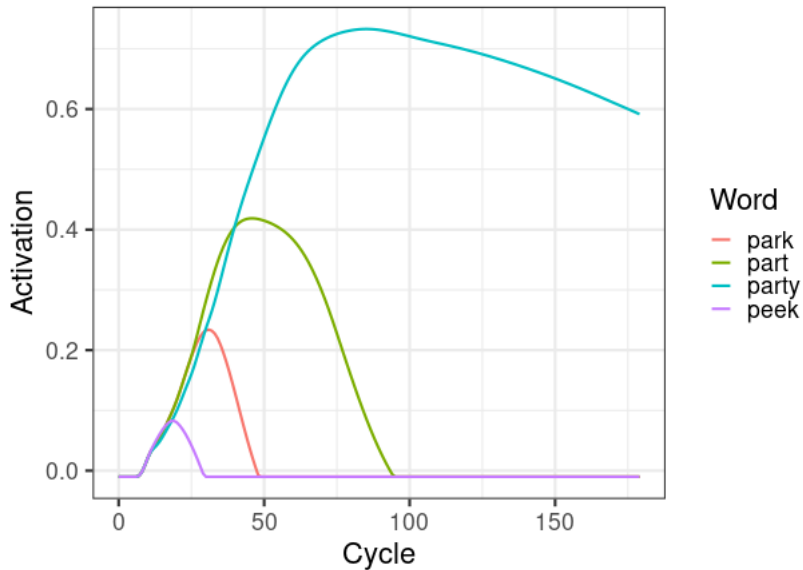
el → ele



el → ele → elephant



TRACE Word Activation: 'party'



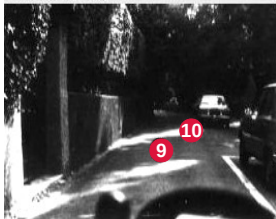
Why do we care?

Typically interested in comparing activation between groups or conditions

- Normal Hearing (NH) vs Cochlear Implants (CI)
- Differentiating cognitive, specific, and non-specific impairments

How do we measure this?

Novice driver



Experienced driver

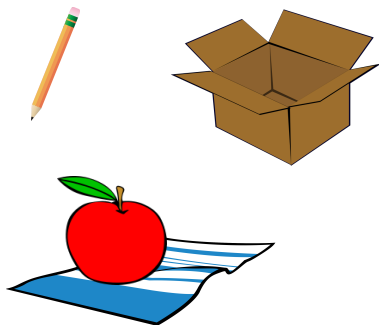


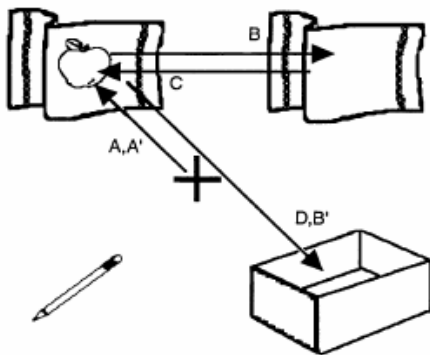
Visual World Paradigm

Visual World Paradigm (VWP)
introduced in 1995

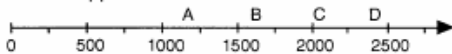
Eye tracking in conjunction
with spoken sentence

“Put the apple on the towel in
the box”

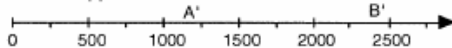




"Put the apple on the towel in the box."



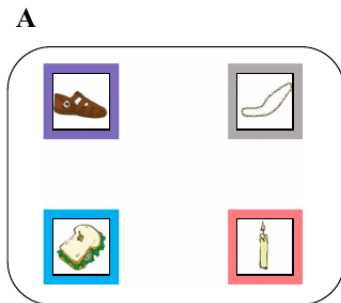
"Put the apple that's on the towel in the box."



Time (ms)

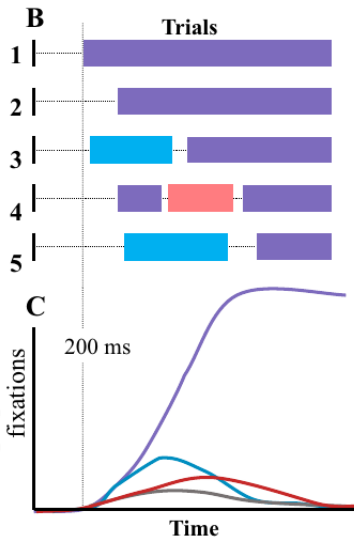
- Eye tracking and the VWP
- Methodology
 - Proportion of Fixations Method
 - Bias
 - Look Onset Method
- Simulation

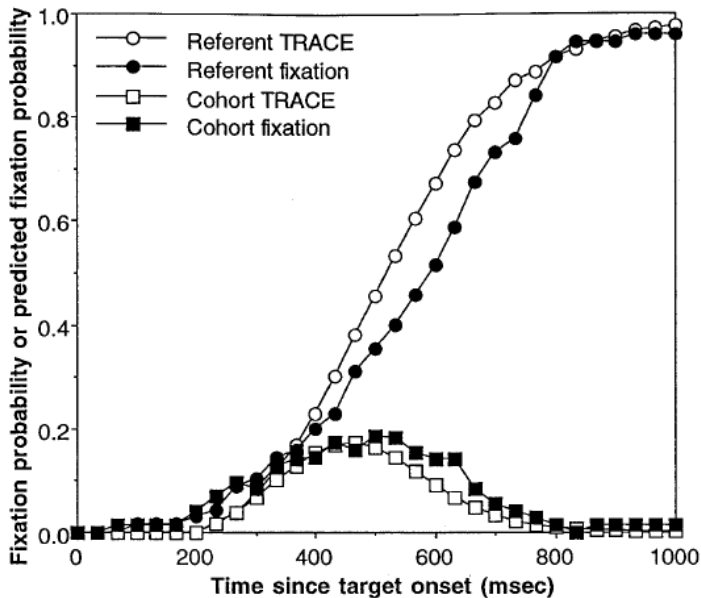
VWP Trials



Target
Cohort
Rhyme
Unrelated

Sandal
Sandwich
Candle
Necklace





So how does this relate to VWP

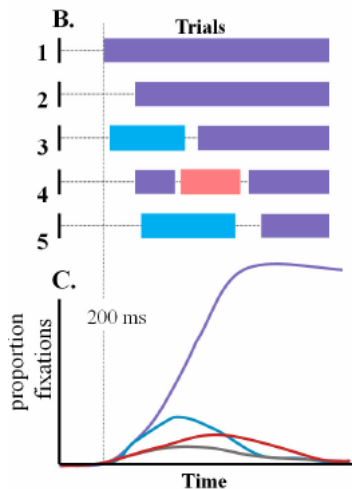
“Proportion of fixations” method

Letting z_{jt} represent an indicator of fixation at time t for trial $j = 1, \dots, J$, we have empirical curve

$$y_t = \frac{1}{J} \sum_j z_{jt}$$

and find

$$\hat{\theta} = \operatorname{argmin}_{\theta} \mathcal{L}(f_{\theta}, y)$$



Proportion of Fixation Data

Fixation Trial Data

Trial	t	Target	Trial	t	Target
1	0	0	2	0	1
1	4	0	2	4	1
1	8	0	2	8	1
1	12	0	2	12	1
1	16	0	2	16	1
\vdots	\vdots	\vdots	\vdots	\vdots	\vdots
1	1596	1	2	1596	1
1	1600	1	2	1600	1

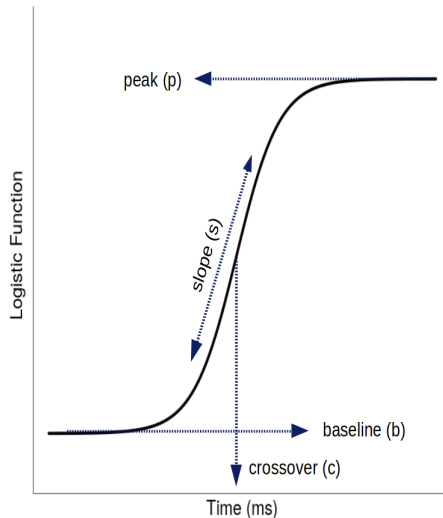


Proportion Data

t	Target
0	0.00
4	0.01
8	0.02
12	0.02
16	0.04
\vdots	\vdots
1596	0.91
1600	0.92

Target – Logistic

$$f(t|\theta) = b + \frac{p - b}{1 + \exp\left(\frac{4s}{p-b}(c - t)\right)}$$



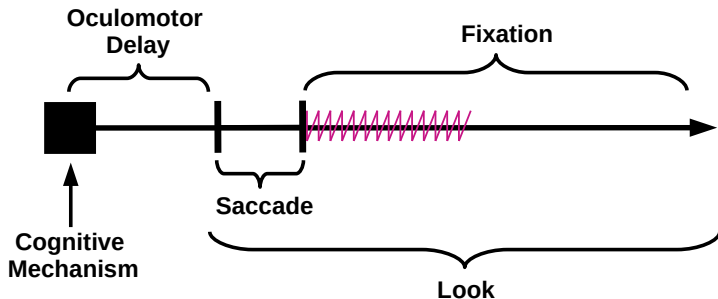
My dissertation

Proportion of Fixations Method

Despite visual similarities between the proportion of fixations, y_t and lexical activation f , there is an issue with the equivalence

Eye mechanics made up of distinct mechanisms that are differentially related to activation

Visualizing Eye Mechanics



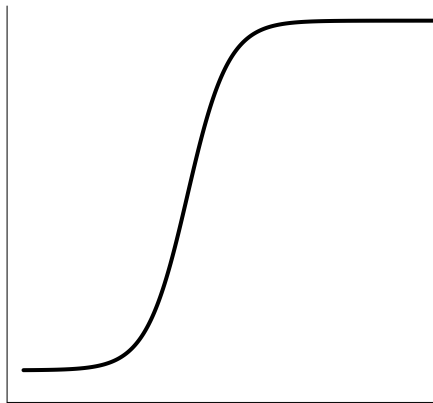
Added Observation Bias

There are two primary sources of bias to address

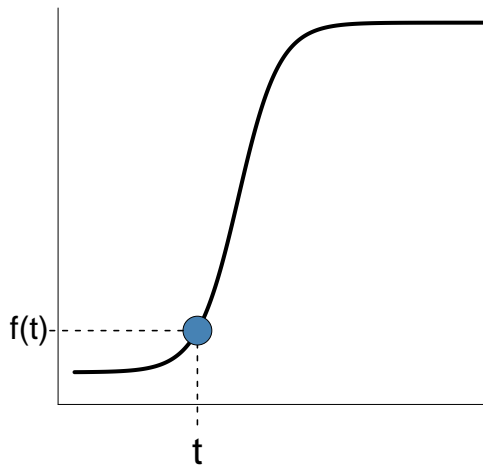
- Added observation bias
- Oculomotor delay

Added observation bias arises from the conflation of two distinct (though likely correlated) processes: the decision to initiate an eye movement to a particular place and the duration of a fixation

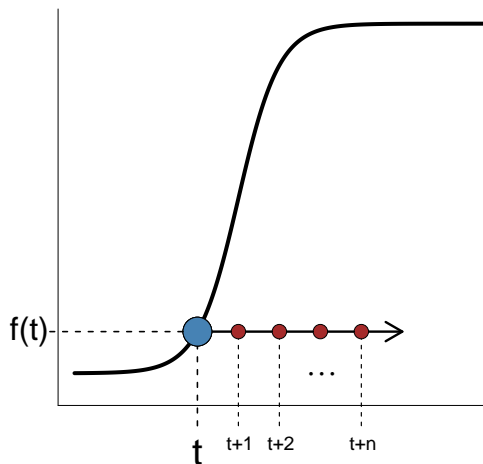
Activation curve



Onset of look



...followed by fixation



Look Onset Method

Only the initial moment of look onset and its location, s_k , is considered relevant in the recovery of latent activation, where a look initiated at time t_k follows

$$s_k \sim \text{Bern}[f(t_k|\theta)].$$

This gives us instead a set of ordered pairs, $\mathcal{S} = \{(s_k, t_k)\}_{k=1}^K$ rather than a time ordered vector of proportions

We are able to use an identical procedure as before,

$$\hat{\theta} = \underset{\theta}{\operatorname{argmin}} \mathcal{L}(f_{\theta}, \mathcal{S})$$

Look Onset Data

Look Onset Data

t	Target
100	0
500	0
900	1
400	0
700	1
1400	0
\vdots	\vdots
800	0
1200	1

Proportion Data

t	Target
0	0.00
4	0.01
8	0.02
12	0.02
16	0.04
\vdots	\vdots
1596	0.91
1600	0.92

Delayed Observation

Between the cognitive mechanism and the initiation of look onset is a period of oculomotor delay, ρ

This gives distribution of look onset,

$$s_j \sim \text{Bern}[f(t_j - \rho)|\theta)].$$

It is “roughly” estimated to be around 200ms, and this is typically accounted for by subtracting 200ms from observations

We show that varying degree of randomness in this process have an impact in observed error and successful recovery

Simulation

Create simulated VWP trials with eye mechanics oriented towards Target, the goal of recovering activation curve, $f(t|\theta)$

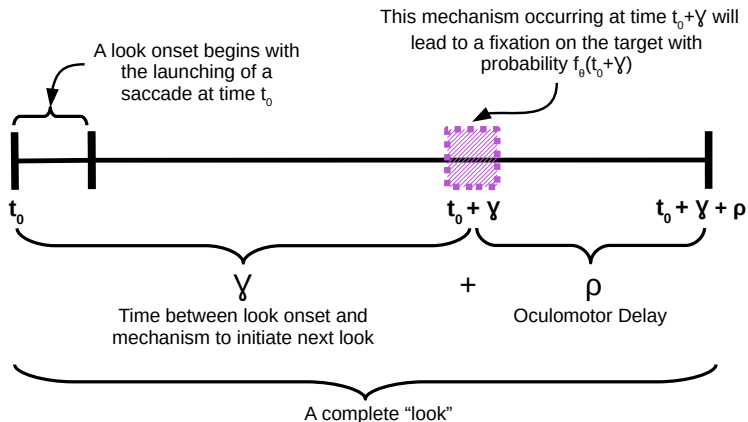
Each subject draws individual θ_i and performs 300 trials

1,000 total subjects

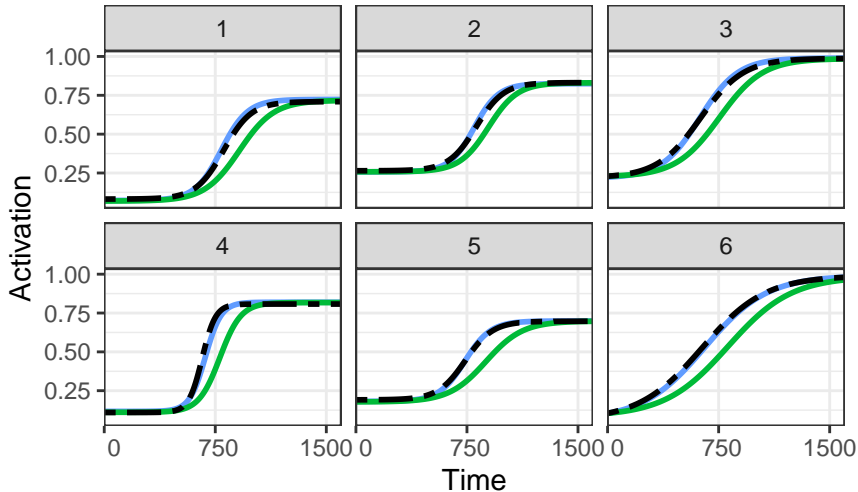
Estimate generating function using both methods

Metric for efficacy is MISE between generating and recovered curve

Simulation Mechanics

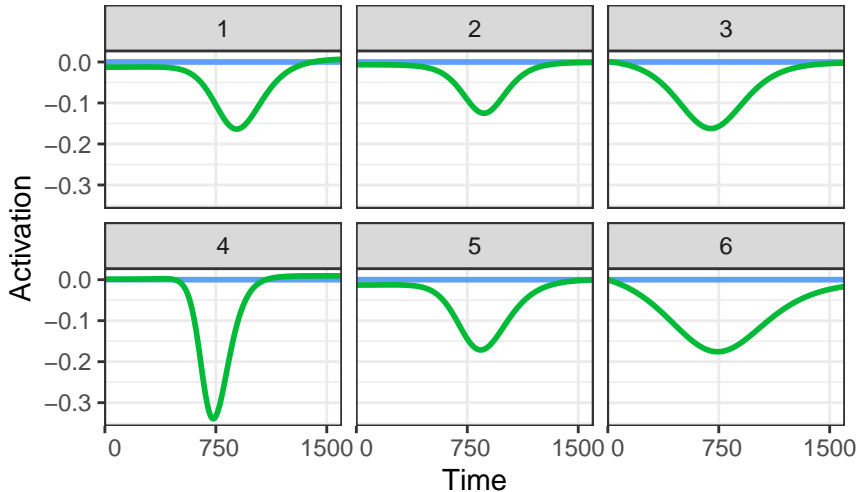


Representative Curves, No Delay



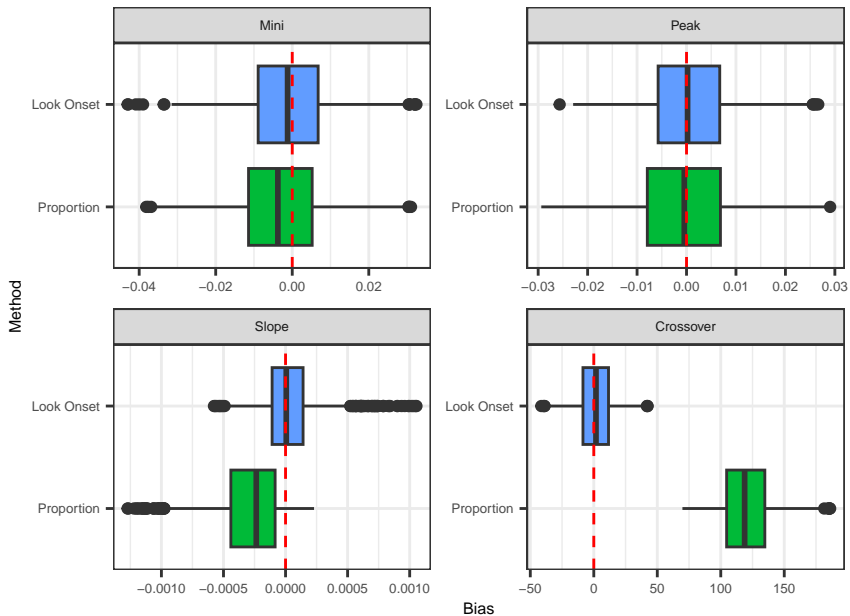
Curve — Look Onset — Proportion - - True

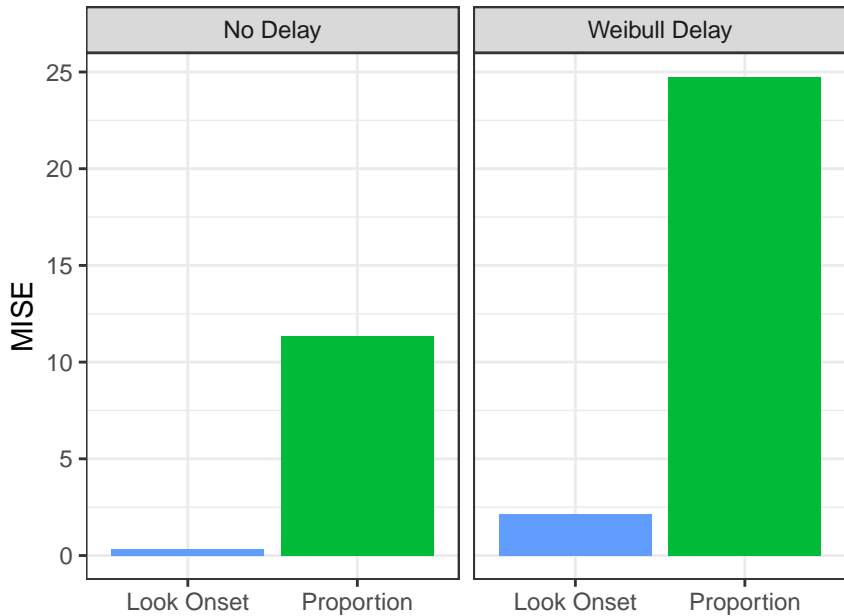
Representative Error Curves, No Delay



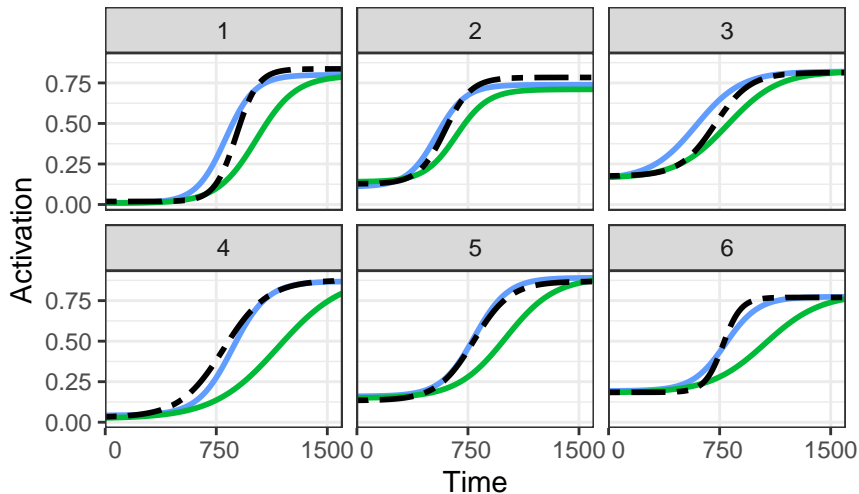
Curve — Look Onset — Proportion

No Delay



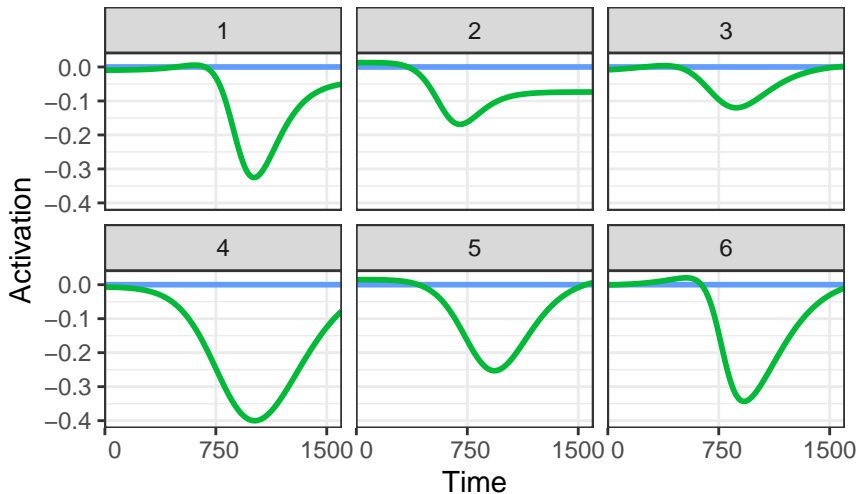


Representative Curves, Weibull Delay



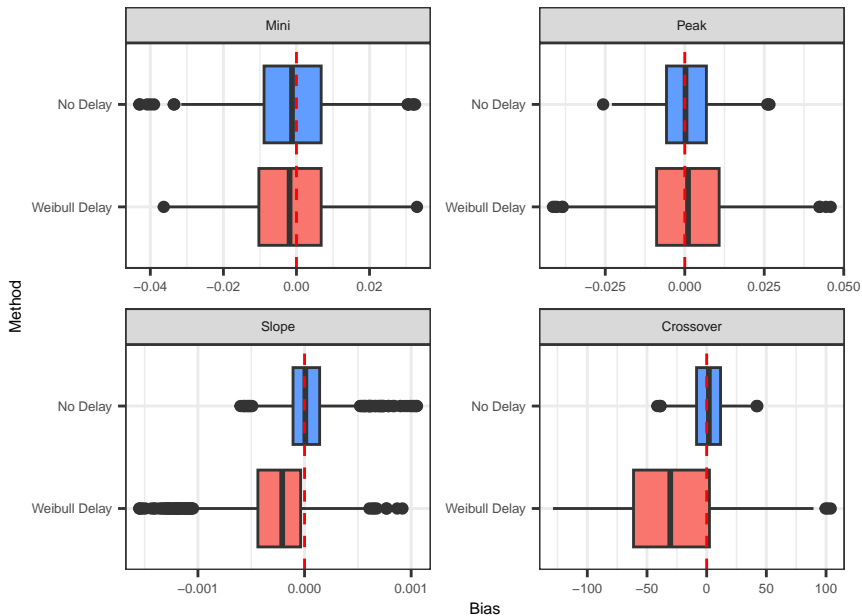
Curve — Look Onset — Proportion - - True

Representative Error Curves, Weibull Delay



Curve — Look Onset — Proportion

Look Onset, No Delay vs. Weibull Delay



What else?

`bdots` package

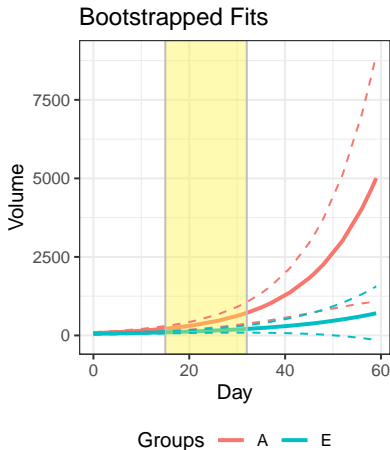
- Significant overhaul to interface
- Broad expansion of capabilities

Underlying methodology

- Introduced two new methods
- Type I Error
- Power

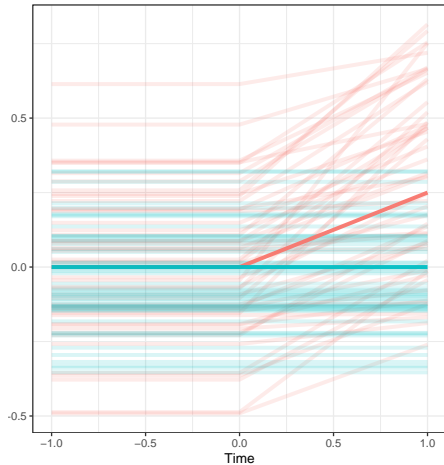
Bootstrapped differences in time series – bdot s

```
fit <- bfit(data = dat,  
            y = "Volume",  
            subject = "ID",  
            time = "Day",  
            group = "Treatment",  
            curveFun = expCurve())  
  
boot <- bboot(Volume ~ Treatment(A, E),  
              bd0bj = fit)  
  
plot(boot)
```



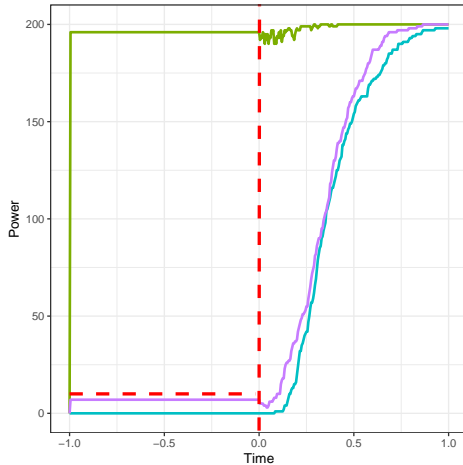
Methodology

Piecewise Distribution



Condition — Effect — No Effect

Power Simulation



Method — Het. Boot — Hom. Boot — Permutation

thanks

References

Magnuson, James S. **Fixations in the visual world paradigm: where, when, why?** 2019-09 *Journal of Cultural Cognitive Science*, Vol. 3, No. 2 Springer Science and Business Media LLC p. 113-139

McMurray, Bob **I'm not sure that curve means what you think it means: Towards a [more] realistic understanding of the role of eye-movement generation in the visual world paradigm** 2022 *Psychonomic Bulletin & Review* p 1-45

Oleson, Jacob J; Cavanaugh, Joseph E, McMurray, Bob; Brown, Grant **Detecting time-specific differences between temporal nonlinear curves: Analyzing data from the visual world paradigm** 2017 *Statistical Methods in Medical Research*, Vol. 26, No. 6 p 2708-2725

Paul D. Allopenna, James S. Magnuson, Michael K. Tanenhaus **Tracking the Time Course of Spoken Word Recognition Using Eye Movements: Evidence for Continuous Mapping Models** 1998 *Journal of Memory and Language*, Vol. 38, Issue 4 p 419-439