What You See is What You Get:

A Closer Look at Bias in the Visual World Paradigm

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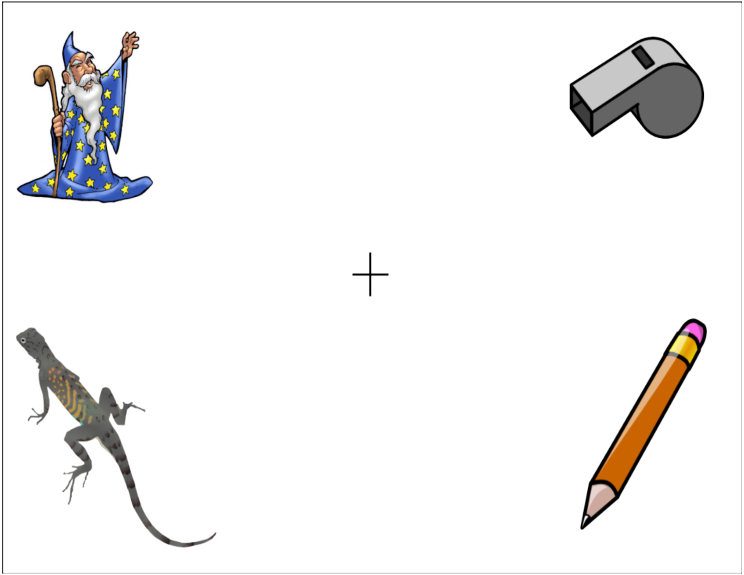
March 8, 2023



Language and Cognition

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

"trink" $\Rightarrow$ "trank" or "trinked"?

Particularly troublesome when we commit too early:

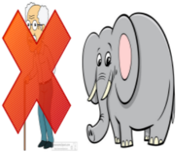
"The horse raced past the barn fell"

Often can not be observed directly

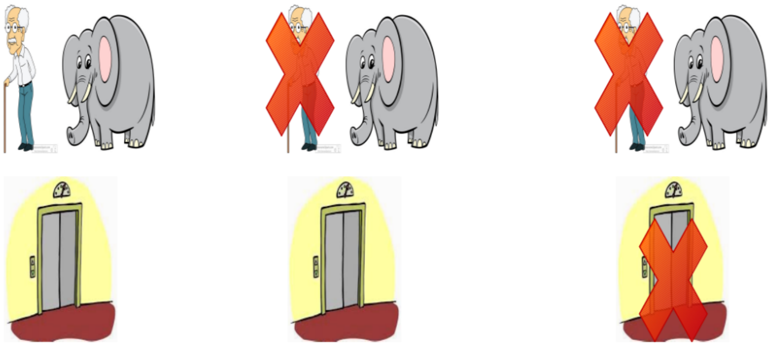
Limit focus to single word recognition start by introducing cohort model as an idea

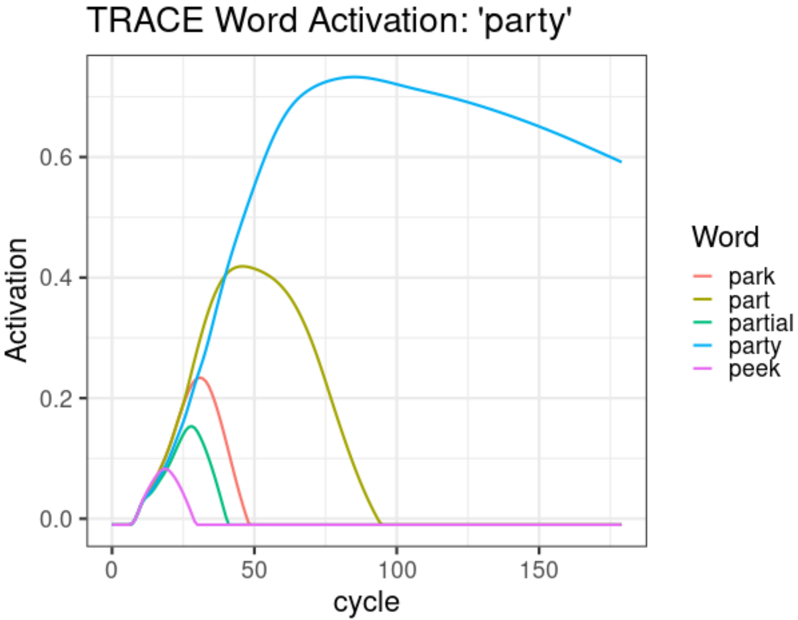
el


el → ele



el → ele → elephant



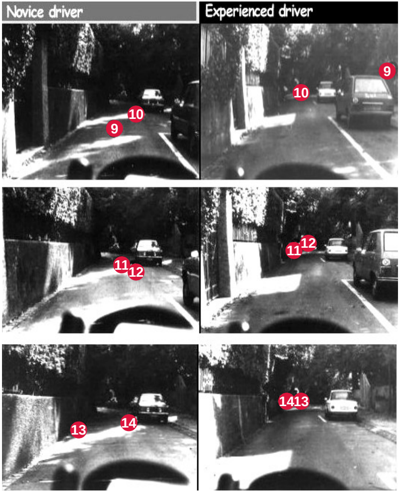

TRACE Word Activation: 'party'
Activation
0.0
0.2
0.4
0.6
0
50
100
150
cycle
Word
park
part
partial
party
peek

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

What's in a look?



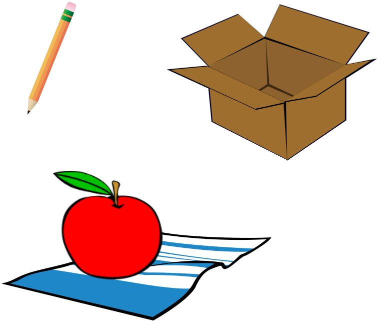
Cohen 1983

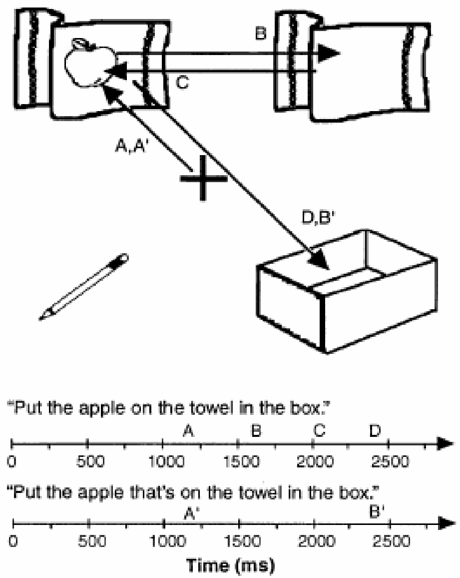
Visual World Paradigm

Visual World Paradigm introduced in 1995

Eye-tracking in conjunction with spoken sentence

"Put the apple on the towel in the box"



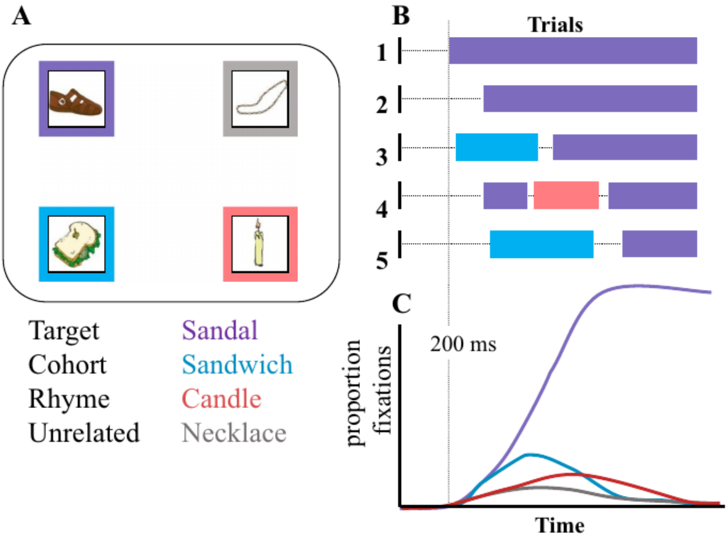

B
C
A,A'
D,B'
"Put the apple on the towel in the box."
A
B
C
D
0
500
1000
1500
2000
2500
"Put the apple that's on the towel in the box."
A'
B'
0
500
1000
1500
2000
2500
Time (ms)

Outline

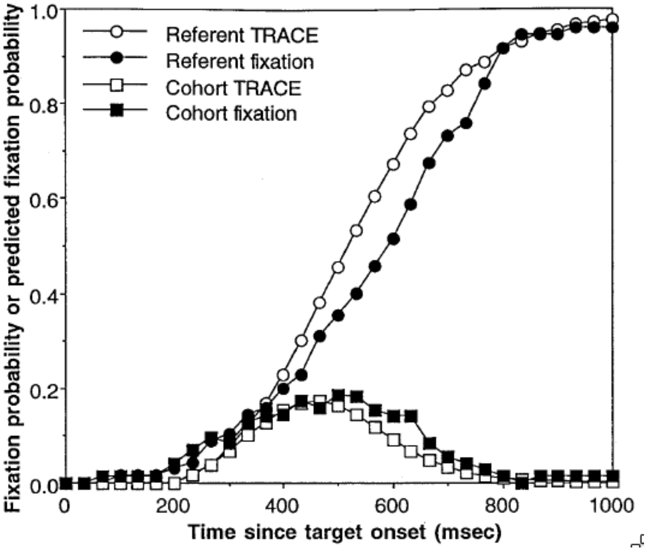
words

-
- Eyetracking and the VWP
- Methodology and Bias
-

VWP Trials


A
Target
Cohort
Rhyme
Unrelated
Sandal
Sandwich
Candle
Necklace
B
Trials
1
2
3
4
5
C
200 ms
proportion fixations
Time

Original study



So how does this relate to VWP

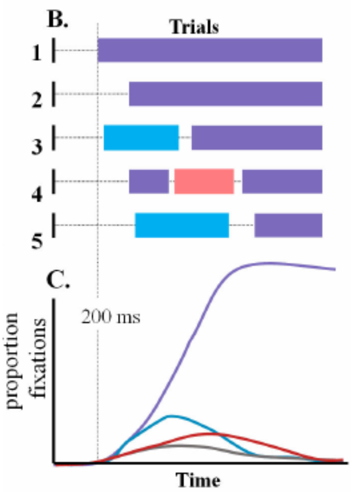
To make the problem more tractable, curves given a (usually) parametric form, $f(t|\theta)$

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

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

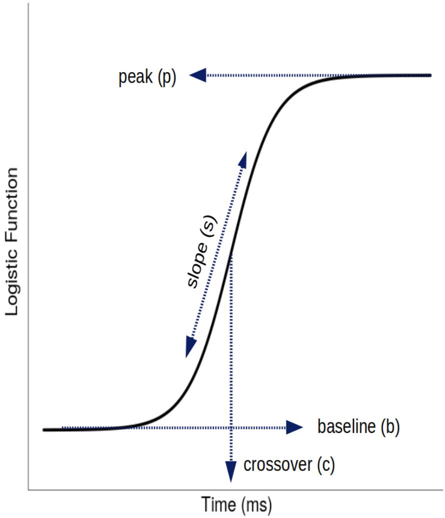
and find

$$\hat{\theta} = \underset{\theta}{\text{argmin}}\, \mathcal{L}(f_\theta, y)$$



Parametric Function

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




Collin's dissertation
Proportion of Fixations Method


The next 20 slides
Proportion of Fixations Method

Linking hypothesis

Have used $f(t|\theta)$ as functional form for proportion of fixations, but relation to activation still implicit/undefined

"The default interpretation is greater fixation proportions indicate greater activation in the underlying processing system" (Magnuson 2019)

Our primary proposal is that it is the underlying activation, rather than observed data, that should be modeled explicitly as $f(t|\theta)$

Issues

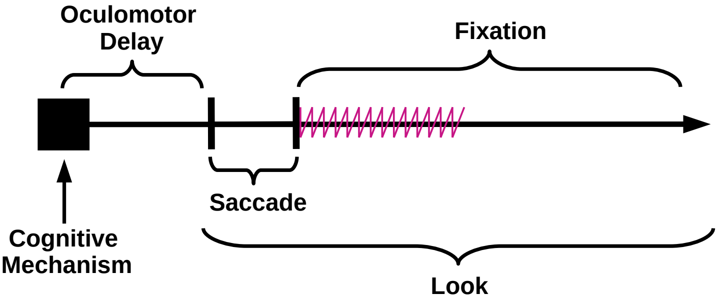
Actually, let's move delay observation bias until *after* look onset introduced since its unrelated, but relevant for sim
maybe move illustration of saccade/OM/fixation to immediately after this slide?
in light of this... Despite visual similarities between the proportion of fixations and activation, there is an issue with the equivalence

$$y_{it} \equiv f(t|\theta_i)$$

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

maybe don't specifically say anything here, save discussion for next slide then move on to added observation bias

Visualizing Eye Mechanics



Added Observation Bias

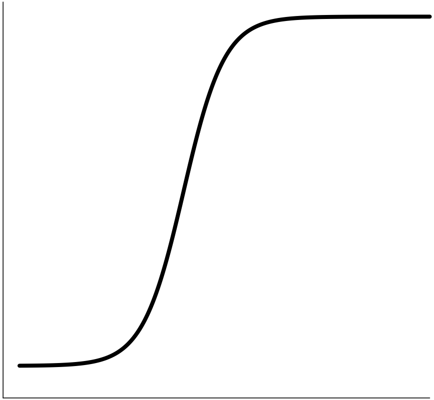
Added observation bias arises from the conflation of two distinct (though likely correlated) processes: the decision to initiate an eye movement to a particular place and the duration of a fixation

We are interested in the process that probabilistically determines the *location* of a fixation

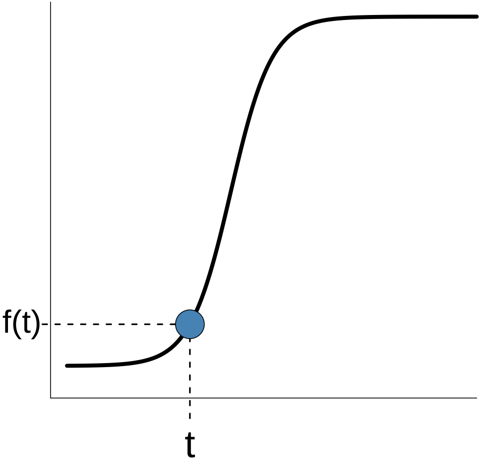
At some time t, a saccade is launched, and we know from length of saccade until *at least* refractory period for fixation, it is impossible for our eyes to go anywhere else

By including the entire length of the fixation as "observed" data relating to this process, we are both inflating the amount of data we have with data that is necessarily biased

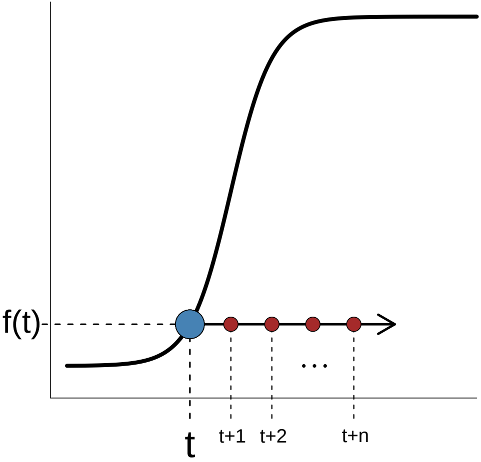
Activation curve



Onset of look



...followed by fixation



Look Onset Method

As the cognitive mechanism responsible for initiating an eye movement is probabilistically (allopenna) related to activation, we argue that the instance of a look onset is a more theoretically consistent and physiologically defensible observation to treat as relevant data

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

$$s_j \sim Bern\left[f(t_j|\theta)\right].$$

This gives us instead a set of ordered pairs, $\mathcal{S} = \{(s_j, t_j)\}$ rather than a time ordered vector of proportions

Fortunately, we are able to use nearly an identical procedure as before,

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

Delayed Observation

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

This gives distribution of look onset,

$$s_j \sim Bern\left[f(t_j - \rho)|\theta)\right]$$

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

We show that varying degrees of randomness in this process and drastically impact error in recovery

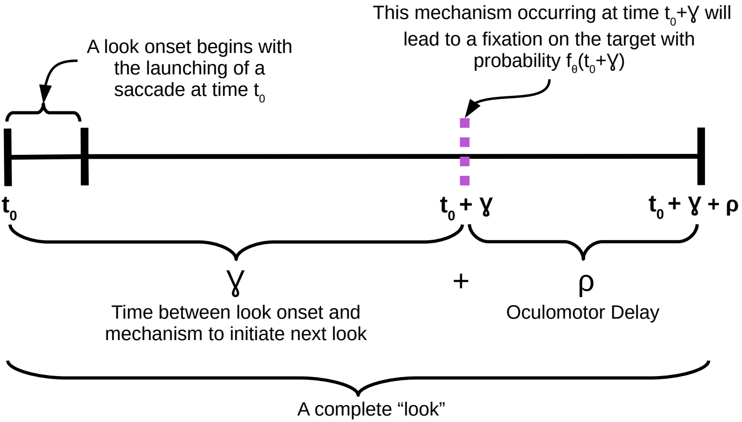
Simulation

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

Each subject draws individual θ_i from empirically determined distribution and will perform 300 trials. 1,000 total subjects

Metric for efficacy is MISE between generating function and recovered curve

Simulation (explain in words, could have less detail here)



notes on results section

[all meta commentary here, will delete slide]

Probably not necessary to include all simulations, I'll just choose two

I can make the proportion curves look as good or bad as I want by modifying the γ parameter. I don't think that's necessary here as I can comment as to why small changes make a large difference in subsequent analysis

For weibull delay, im only going to compare par bias for onset method against no delay since after the first sim there is really no reason to look at proportion method again

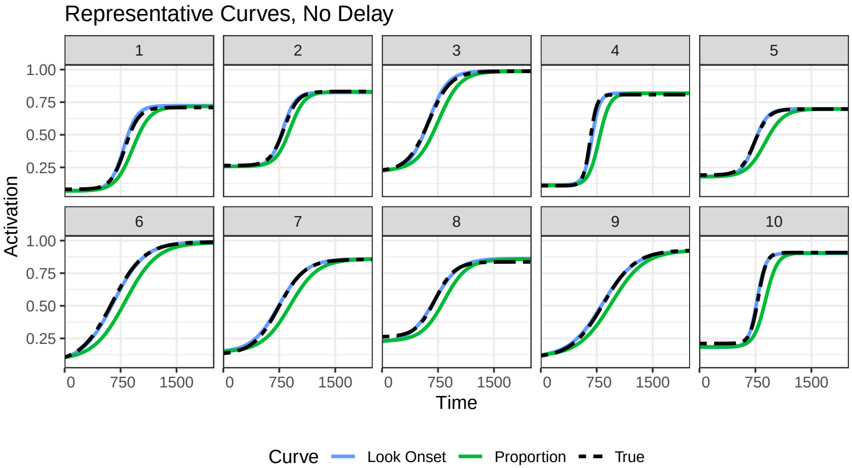
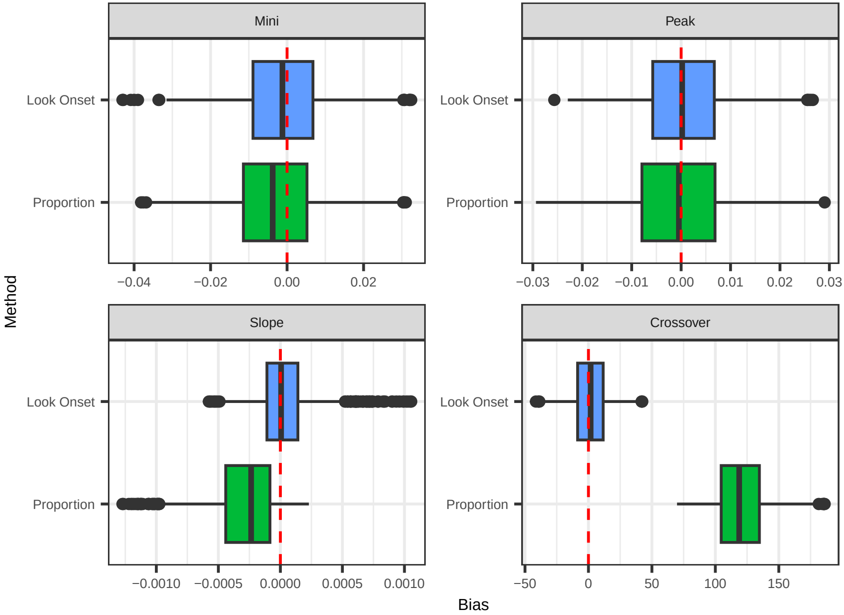
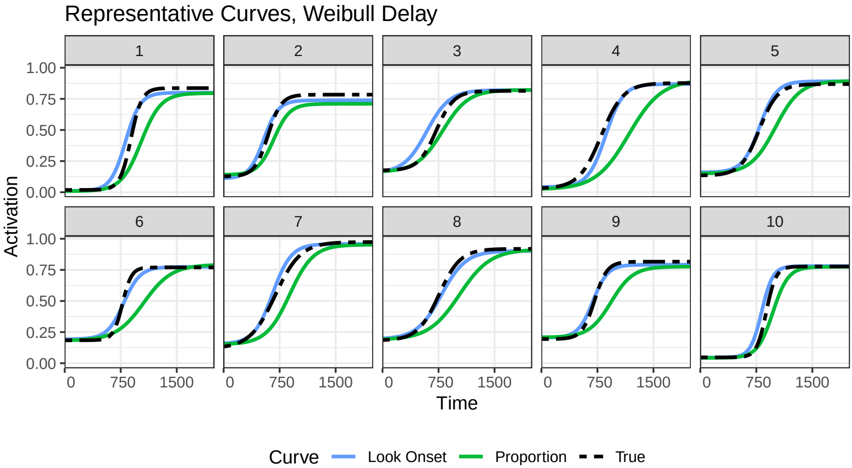


Figure 2: Representative curves with no oculomotor delay

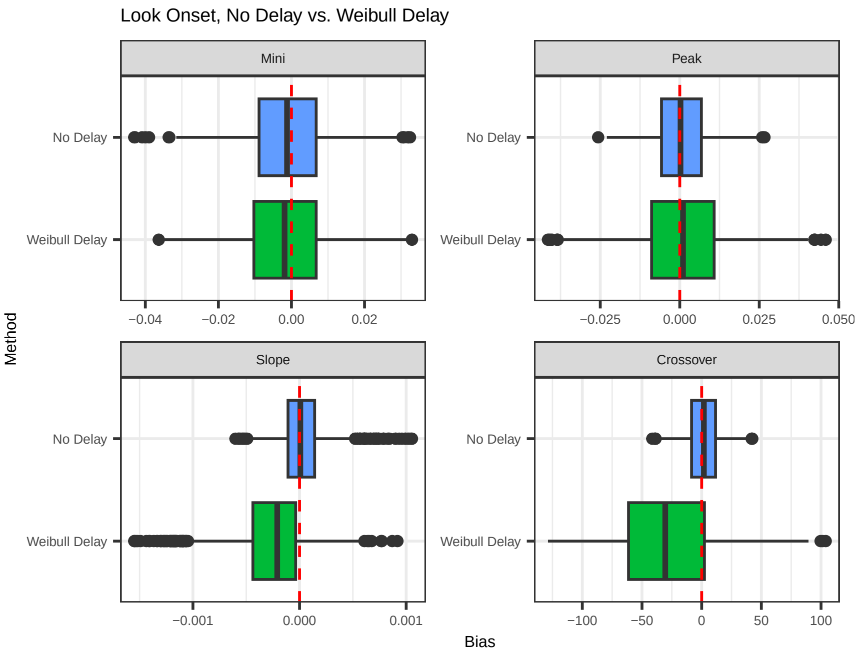
No Delay



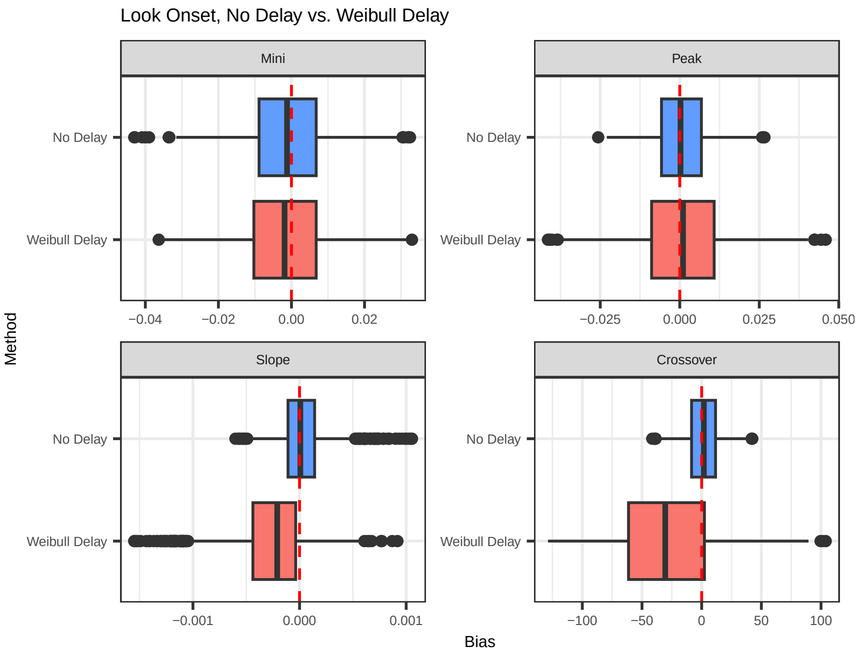
Mini
Peak
Slope
Crossover
Look Onset
Proportion
Method
Bias
−0.04
−0.02
0.00
0.02
−0.03
−0.02
−0.01
0.00
0.01
0.02
0.03
−0.0010
−0.0005
0.0000
0.0005
0.0010
−50
0
50
100
150

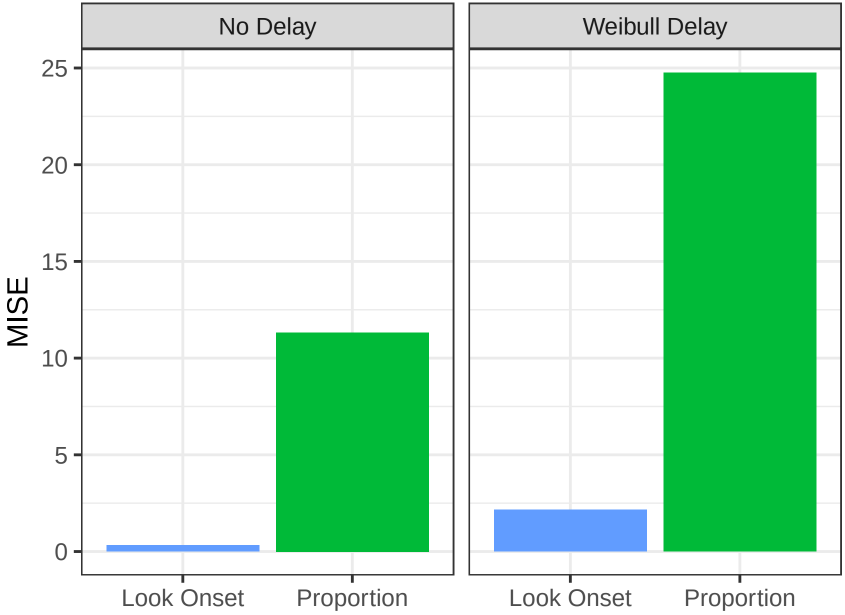


Representative Curves, Weibull Delay
1
2
3
4
5
6
7
8
9
10
Activation
1.00
0.75
0.50
0.25
0.00
Time
0
750
1500
Curve
Look Onset
Proportion
True



Look Onset, No Delay vs. Weibull Delay
Mini
Peak
Slope
Crossover
No Delay
Weibull Delay
−0.04
−0.02
0.00
0.02
−0.025
0.000
0.025
0.050
−0.001
0.000
0.001
−100
−50
0
50
100
Method
Bias


Look Onset, No Delay vs. Weibull Delay
Mini
Peak
Slope
Crossover
No Delay
Weibull Delay
Method
Bias
−0.04
−0.02
0.00
0.02
−0.025
0.000
0.025
0.050
−0.001
0.000
0.001
−100
−50
0
50
100

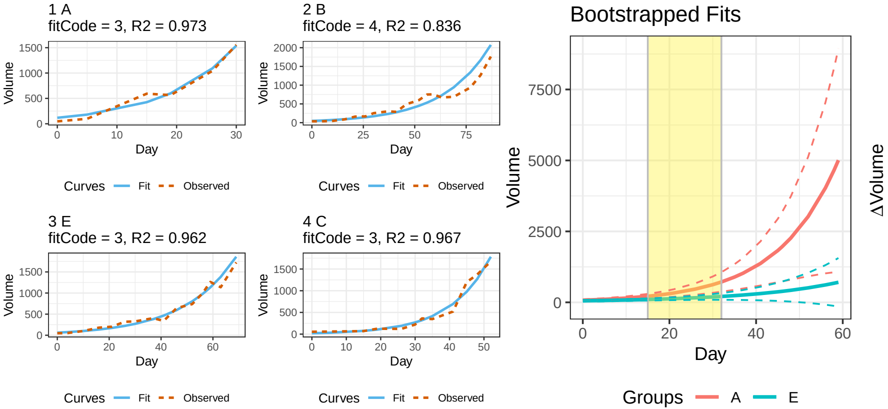

No Delay
Weibull Delay
MISE
25
20
15
10
5
0
Look Onset
Proportion
Look Onset
Proportion

What else?

what else did i do in my dissertation, i wrote some bitchin software that does stuff and i significantly improved an old method slam fuckin dunk?

- `bdots`
- more `bdots`.

Bootstrapped differences in time series – `bdots`



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