Whatchu lookin' at, Willis?

Using eyetracking as a proxy for cognitive word activation

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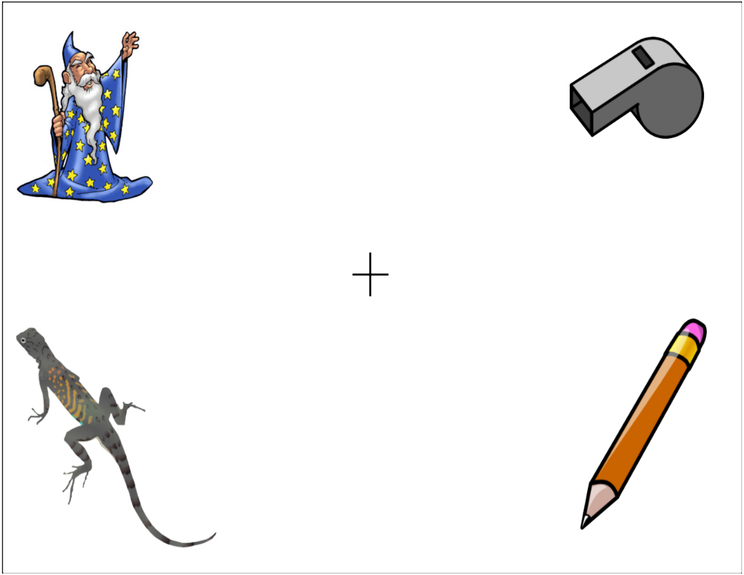


Outline

What is this talk going to be about?

- Cognition/Activation
- Eyetracking
- VWP
- Future Directions

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"

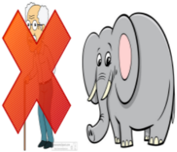
Often can not be observed directly

We are going to limit our focus today to single word recognition

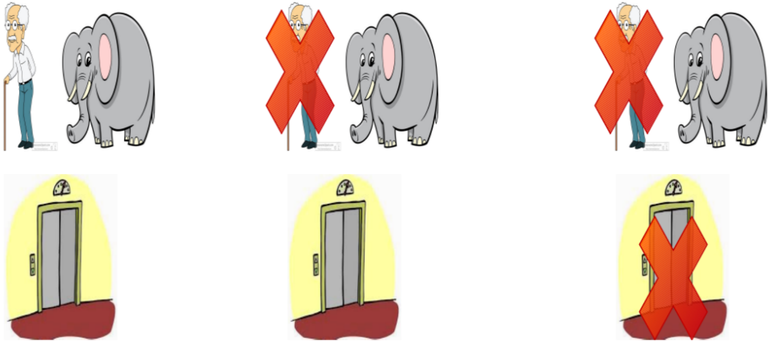
el

el → ele



el → ele → elephant

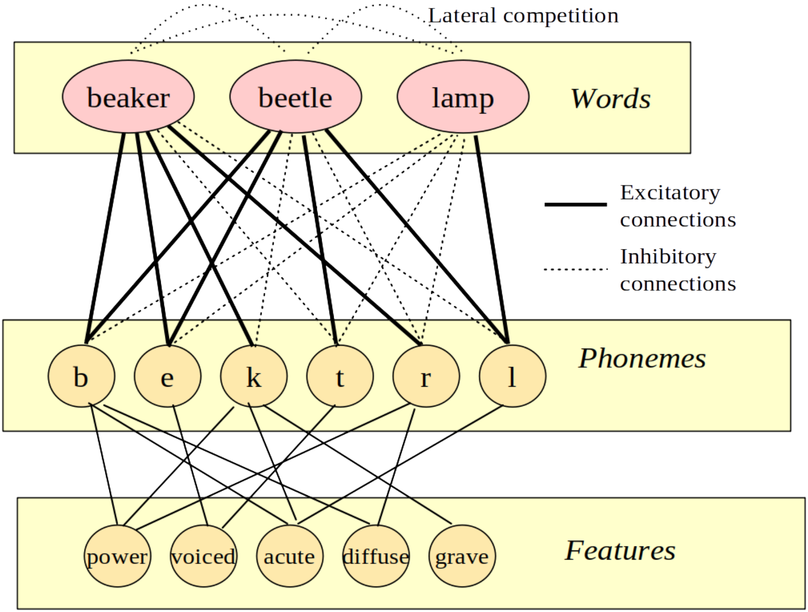


How does this evolve in time?

Much of the 20th century was filled with debate over the process for word recognition, with some of the proposals being particularly interesting

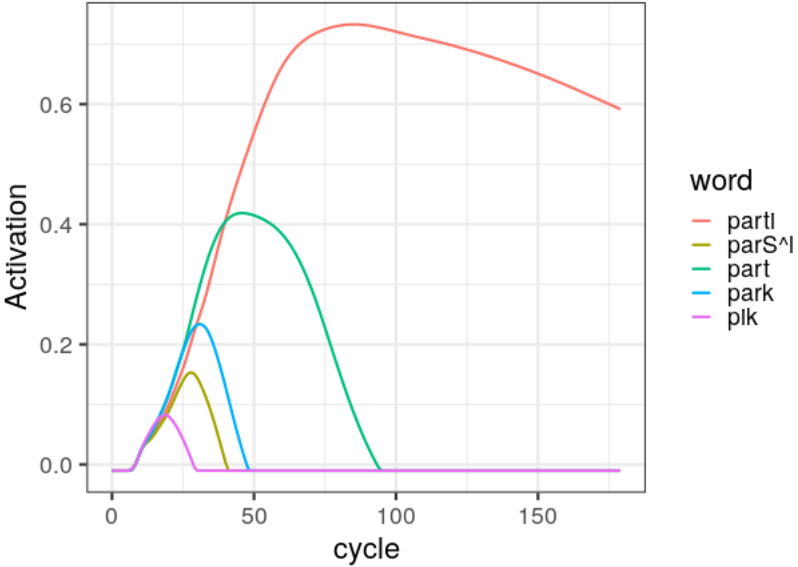
The connectionist model TRACE has since become the theoretical standard in word recognition

- Network structure
- Feedback and feedforward



TRACE (McClelland & Elman, 1986)

TRACE Word Activation



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
- Phonological perceptions

Fortunately there is expertly written software to help accomplish this

Ok, so how do we get access?

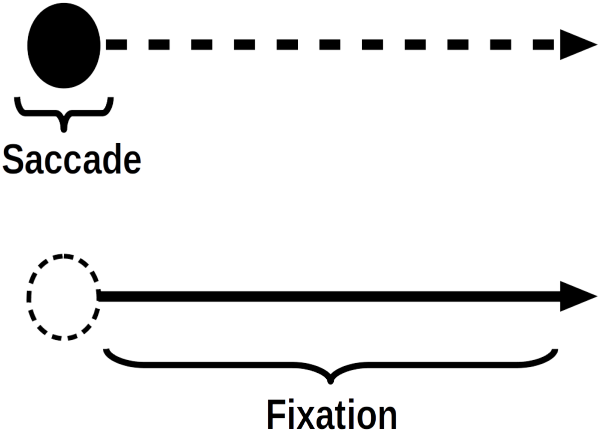
Cognitive activation is not something that can be measured directly

Our eyes reveal a terrifying amount of information about what we are considering

This has been empirically tested and confirmed in countless experiments

Cohen 1983

Visualizing Eye Mechanics



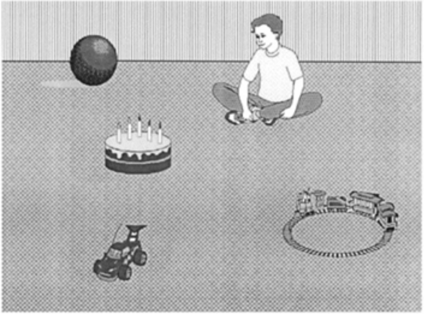
Visual World Paradigm

Visual World Paradigm introduced in 1995

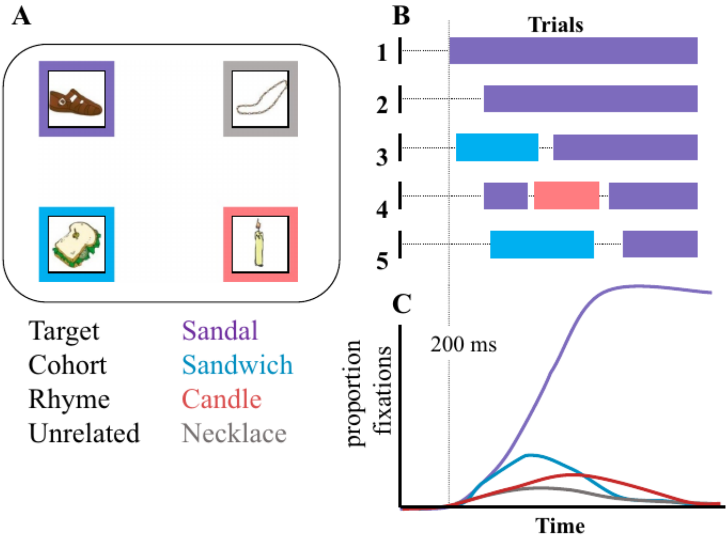
Eyetracking software in conjunction with spoken sentence

"The boy will move the cake"

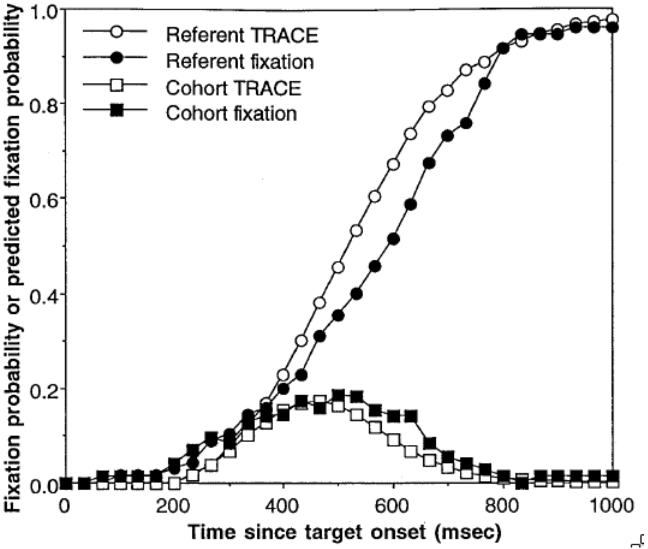
How do we go from this to word recognition?



VWP Trials


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

Original study



So how does this relate to VWP

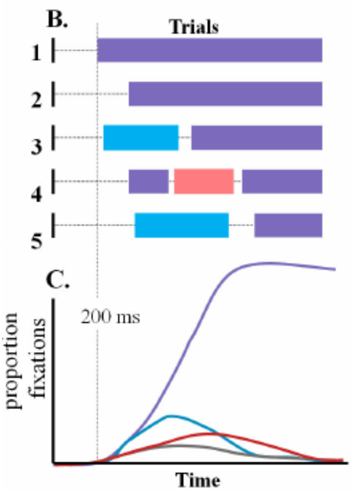
To make the problem more tractable, curves given a (usually) parameteric form, $f_\theta(t)$ or $f(t|\theta)$

Letting z_{ijt} represent fixation at time t for trial j, we have empirical curve

$$y_{it} = \sum_j z_{ijt}$$

and find

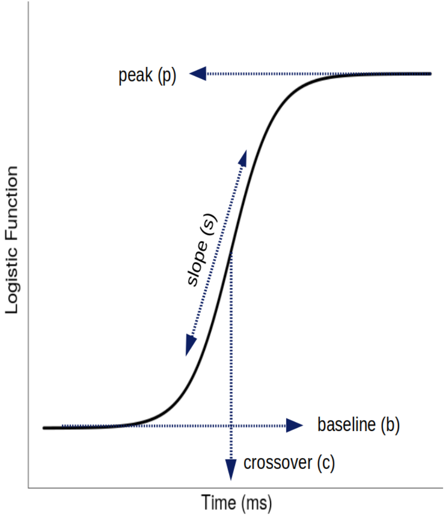
$$\hat{\theta} = \underset{\theta}{\text{argmin}}\, \mathcal{L}(f_\theta, y)$$



Parametric Function

Here, for example, is a four-parameter logistic function, typically used for the referent:

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



But there's a problem

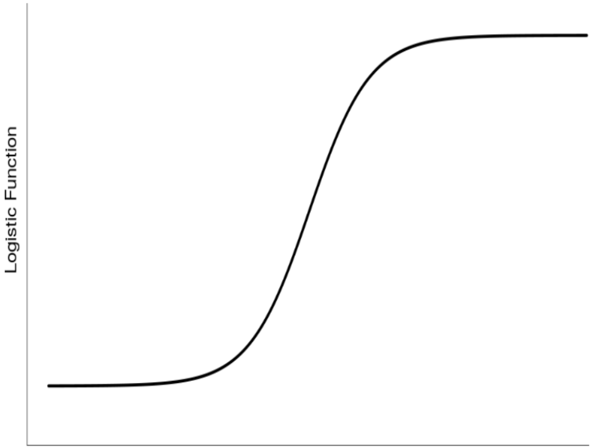
We are interested in some latent cognitive variable unfolding in time.

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

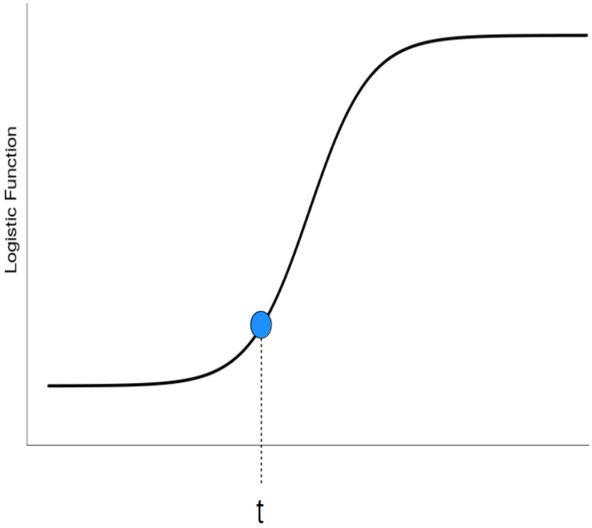
So at time $t, t+1, \ldots, t+n$, we are acting like we have collected more information than we actually have

The result is bias

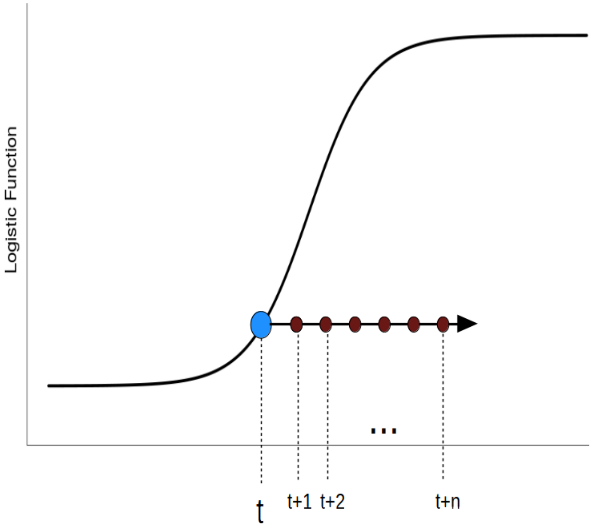
Activation curve



Followed by a saccade...



...with fixation



“Saccade Method”

In this light, we think of the activation curve as some function of probability rom which the saccades are directly sampled:

$$s_j \sim Bern(f_\theta(t_j))$$

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,

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

Determining efficacy

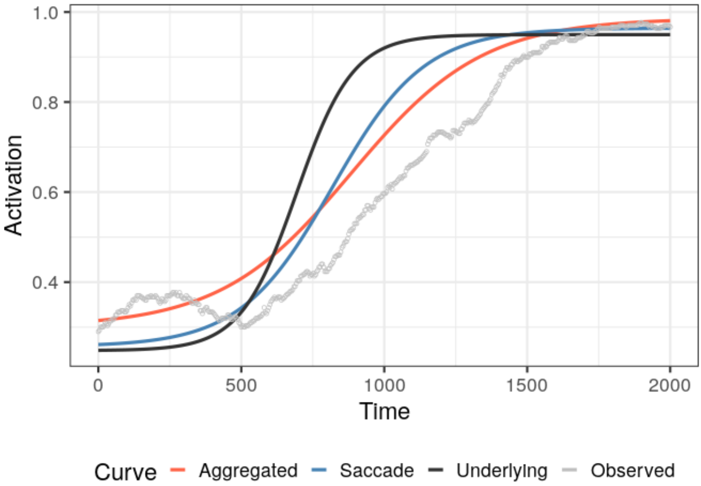
There is no "true" curve with which to compare it

Our model more tractable without conflating types of data

For now, have results comparing the two methods from simulated eye-tracking data

In the process of recollecting and modeling with TRACE

Simulation (N = 300)



	Aggregate	Saccade	Underlying
MISE	5.04	1.77	0.00

Ok, so where from here?

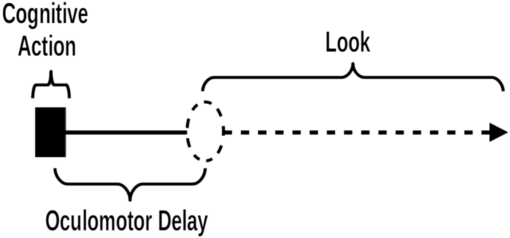
- bdots
- Simulation for eyetracking/physiology
- Extending the model (number of saccades, search patterns, etc.,)
- Oculomotor delay

Oculomotor delay

Though we talk about saccades and fixations, what we are *actually* interested in is this latent cognitive mechanism

It happens in our head first and then our eyes move. This delay, typically around 200ms, is random, and can bias our estimates

We will call the length of an oculomotor delay $\rho(t)$



Oculomotor delay, cont.

A saccade observed at time t_j is likely a sample from the activation curve f_θ at some point prior to t_j. We might then consider our saccades to be

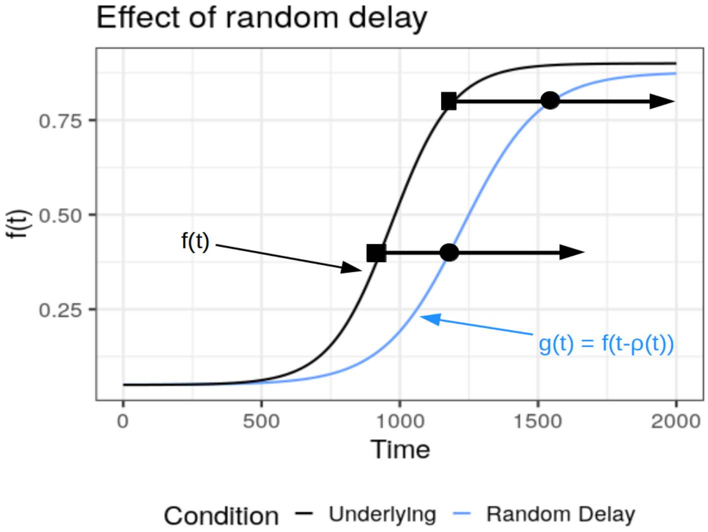
$$s_j \sim Bern[f_\theta(t_j - \rho(t_j))],$$

where $\rho(t)$ represents our oculomotor delay. It may be the case that:

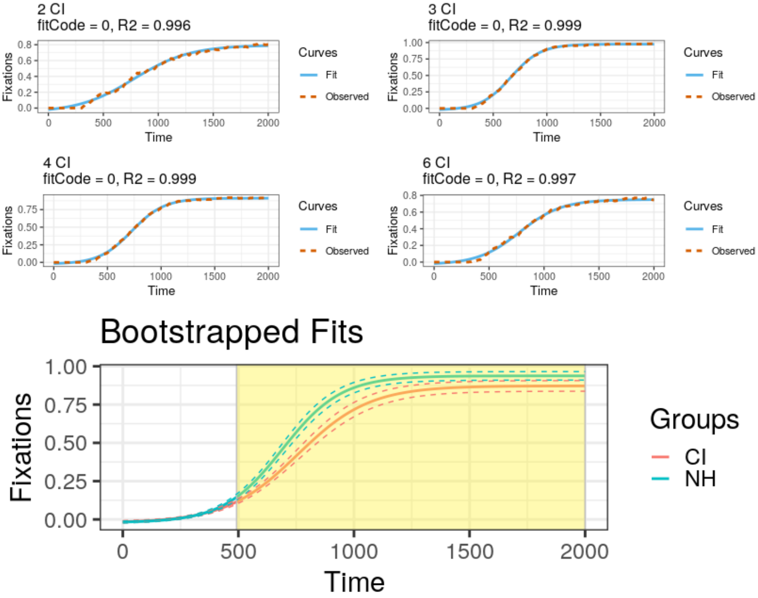
1. $\rho(t)$ is a constant function (including 0)
2. $\rho(t)$ is a random variable, independent on the value of t
3. $\rho(t)$ is a random variable, dependent on t and possibly other aspects of the trial

For clarity, then, we might call $f_\theta(t)$ the (latent) activation curve, with $g_\theta(t) = f_\theta(t - \rho(t))$ our (observed) saccade curve

Impact of random delay



Bootstrapped differences in time series – `bdots`



Concluding remarks

What can we take away from this:

- VWP used to collect eye tracking data as proxy for word recognition
- Saccade method results in less bias in estimating generating curve
- Software and methodology to investigate these

And where are we going from here?

- Oculomotor delay
- Simulating eyetracking data (linking hypothesis)
- Expanding domain of `bdots`

References

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McMurray, Bob **Fixation Curves in the Visual World Paradigm** 2020(?)

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

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