Measuring and modeling attentional functions

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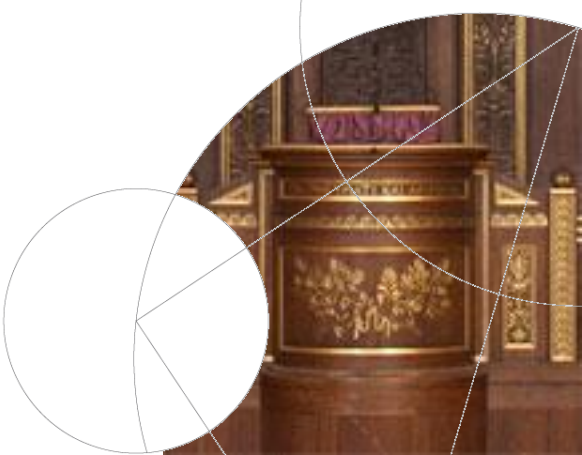
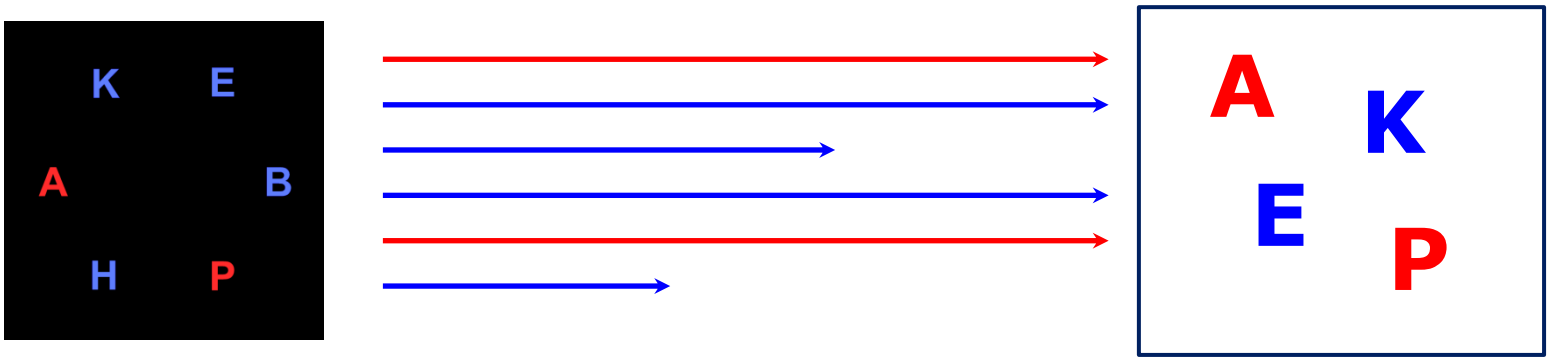


A Neural Theory of Visual Attention

- Attention at the psychological and neurophysiological levels
- Quantification of attentional mechanisms

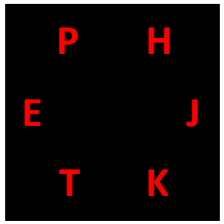


RACE
between visual categorizations

VSTM

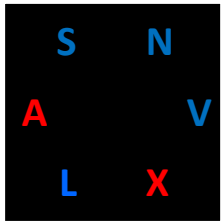
CombiTVA test

(Vangkilde et al., 2011, Psychopharmacology)



Whole report

&

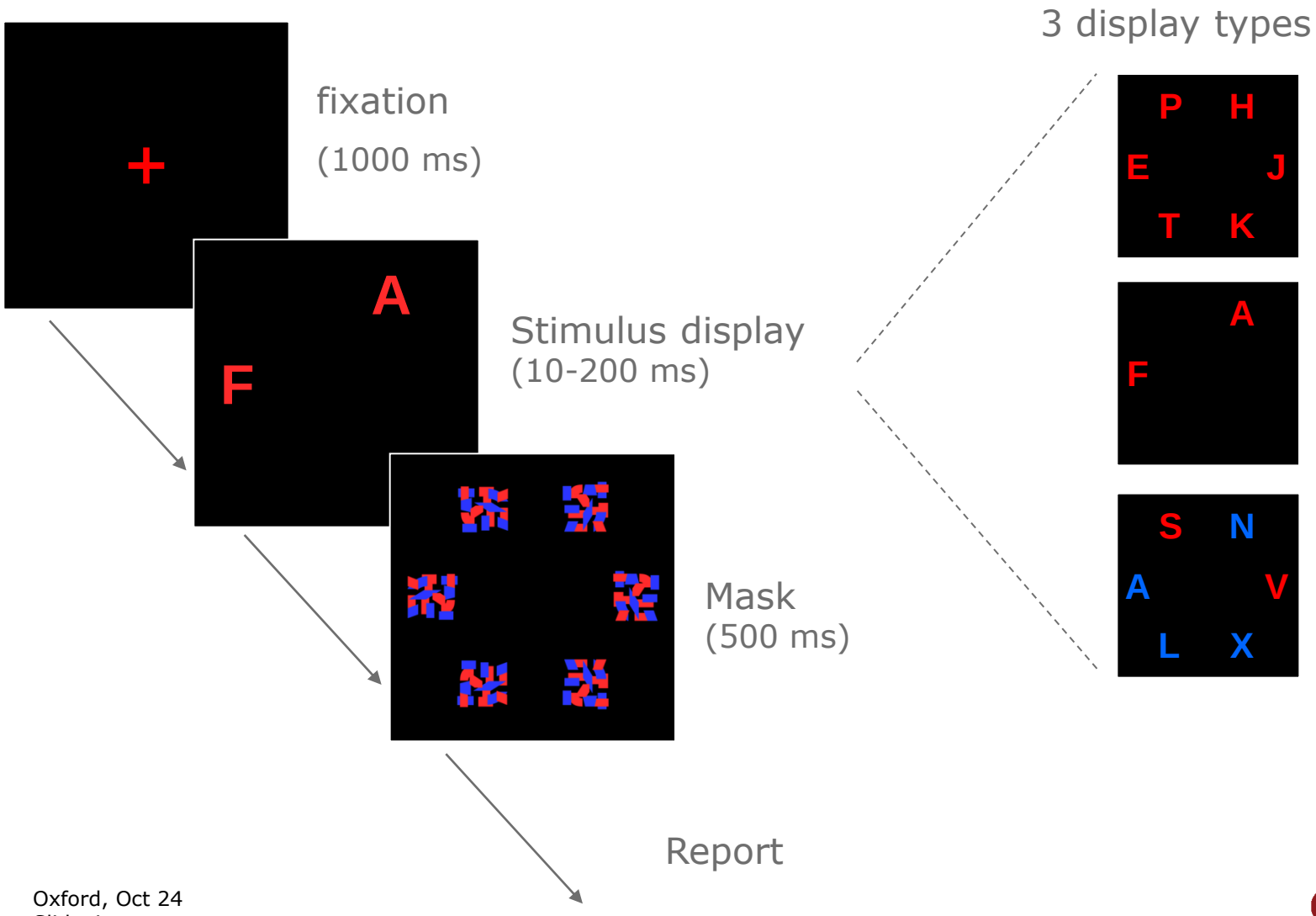


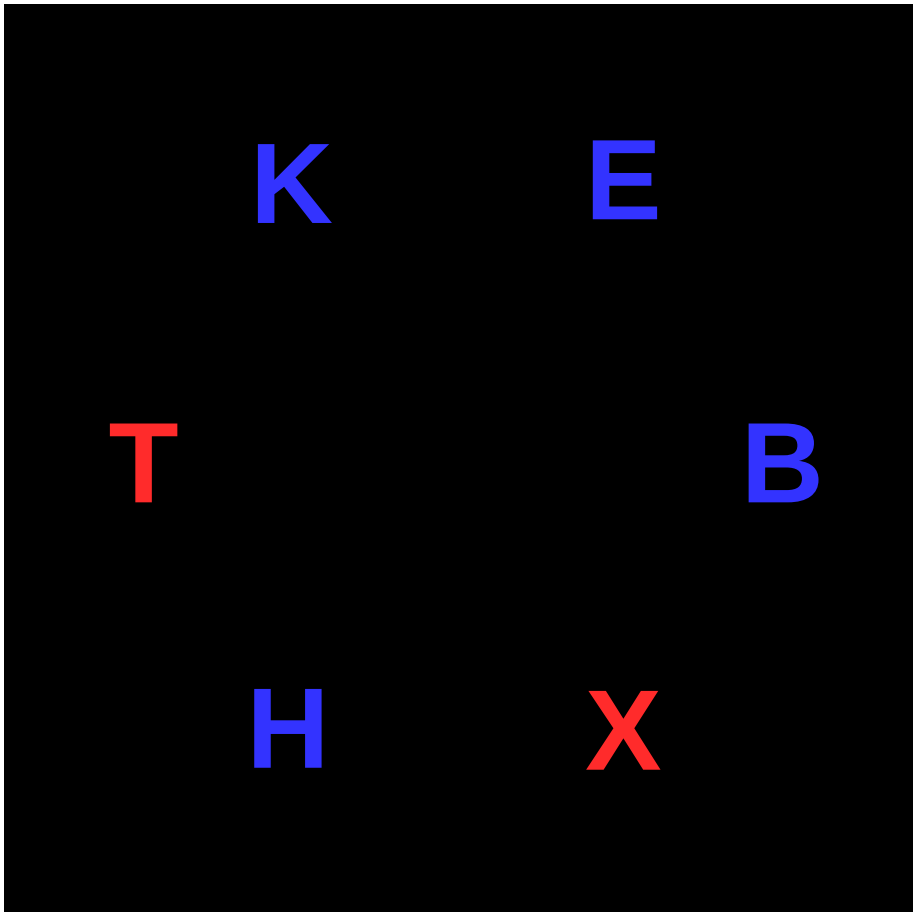
Partial report

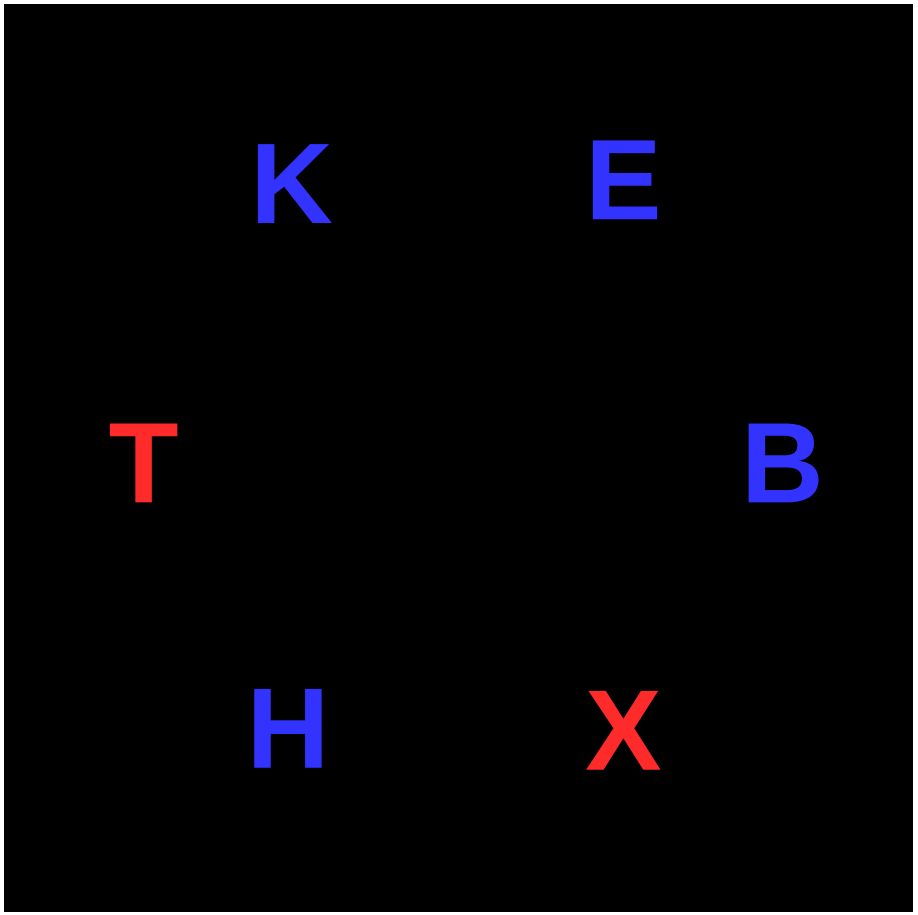
- Report red letters
- Unspeeded => independent of motor component

CombiTVA test

(Vangkilde et al., 2011, Psychopharmacology)




K
E
T
B
H
X


K
E
T
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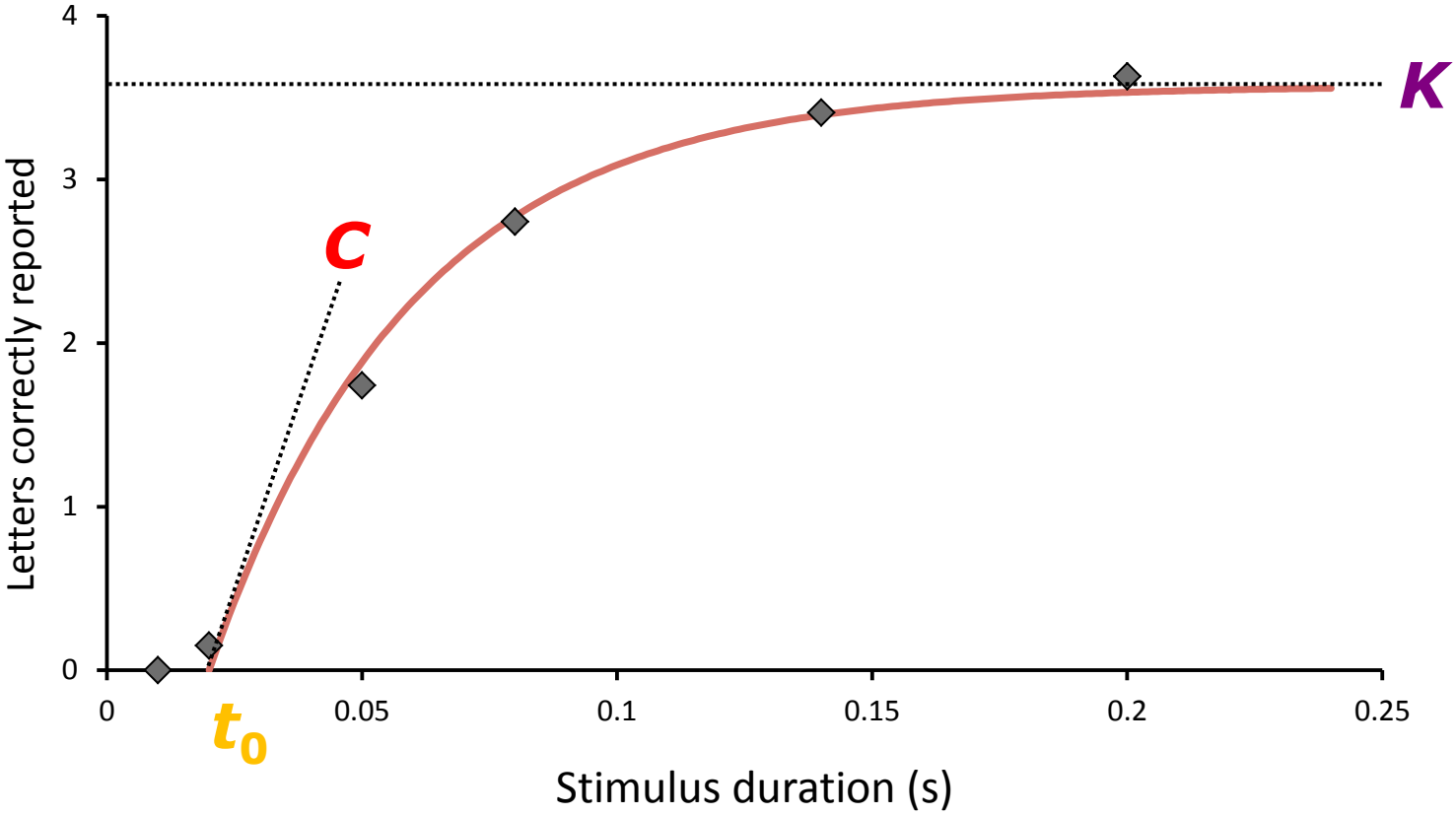
Whole report



Model parameters

Capacity

- K VSTM capacity (items)
- C Processing capacity (items/s)
- t_0 Perceptual threshold (s)

Attentional weights

- w Attentional weights
- α Selectivity

New developments

- Attentional weights are products of spatial and nonspatial components
- Attentional dwell time
- Grounding TVA in cellular neurophysiology
- Perceptual confusability
- Modeling perceptual decisions and reaction times
- EEG and NTVA
- Components of bias in single-stimulus recognition
- Attention to Dopamine

- ESRs 7 AND 8

Attentional weights are products of spatial and nonspatial components

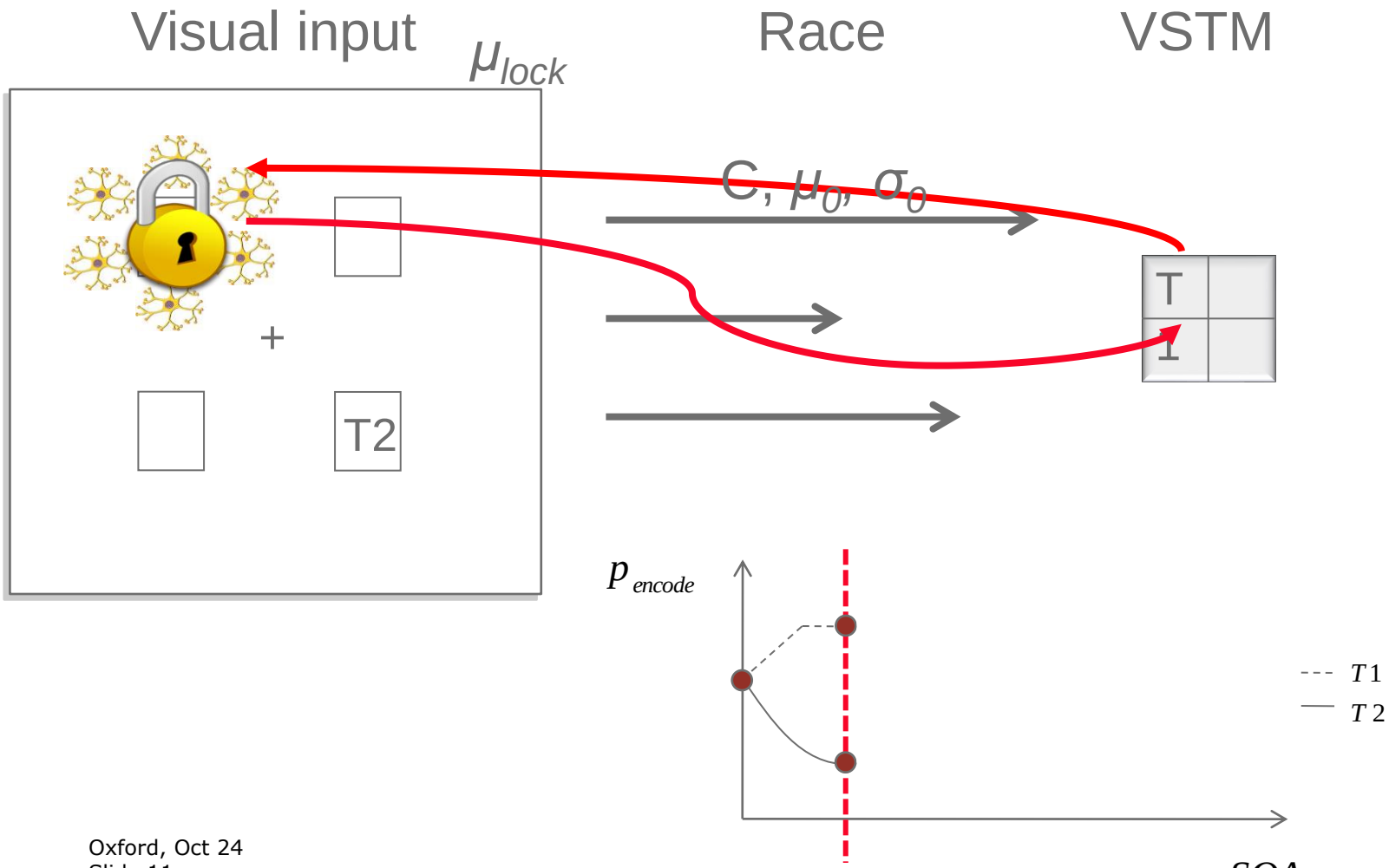
New version of the weight equation:

$$w_x = \sum_{\text{spatial locations } l} \eta(x,l)\pi_l \sum_{\text{nonspatial features } j} \eta(x,j)\pi_j$$

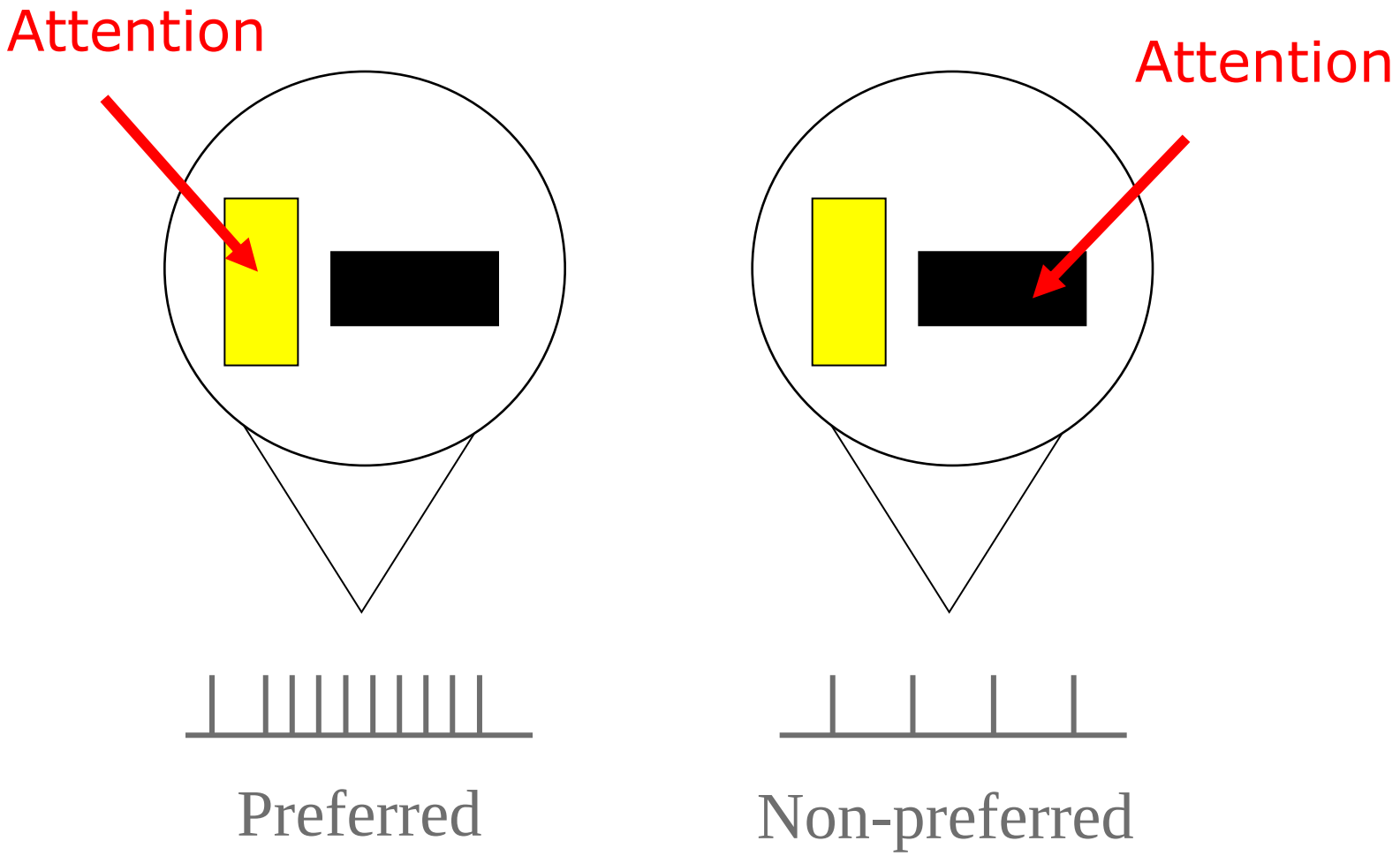
$$\approx \eta[x, \text{location}(x)]\, \pi_{\text{location}(x)} \sum_{\text{nonspatial features } j} \eta(x,j)\pi_j .$$

Attentional dwell time

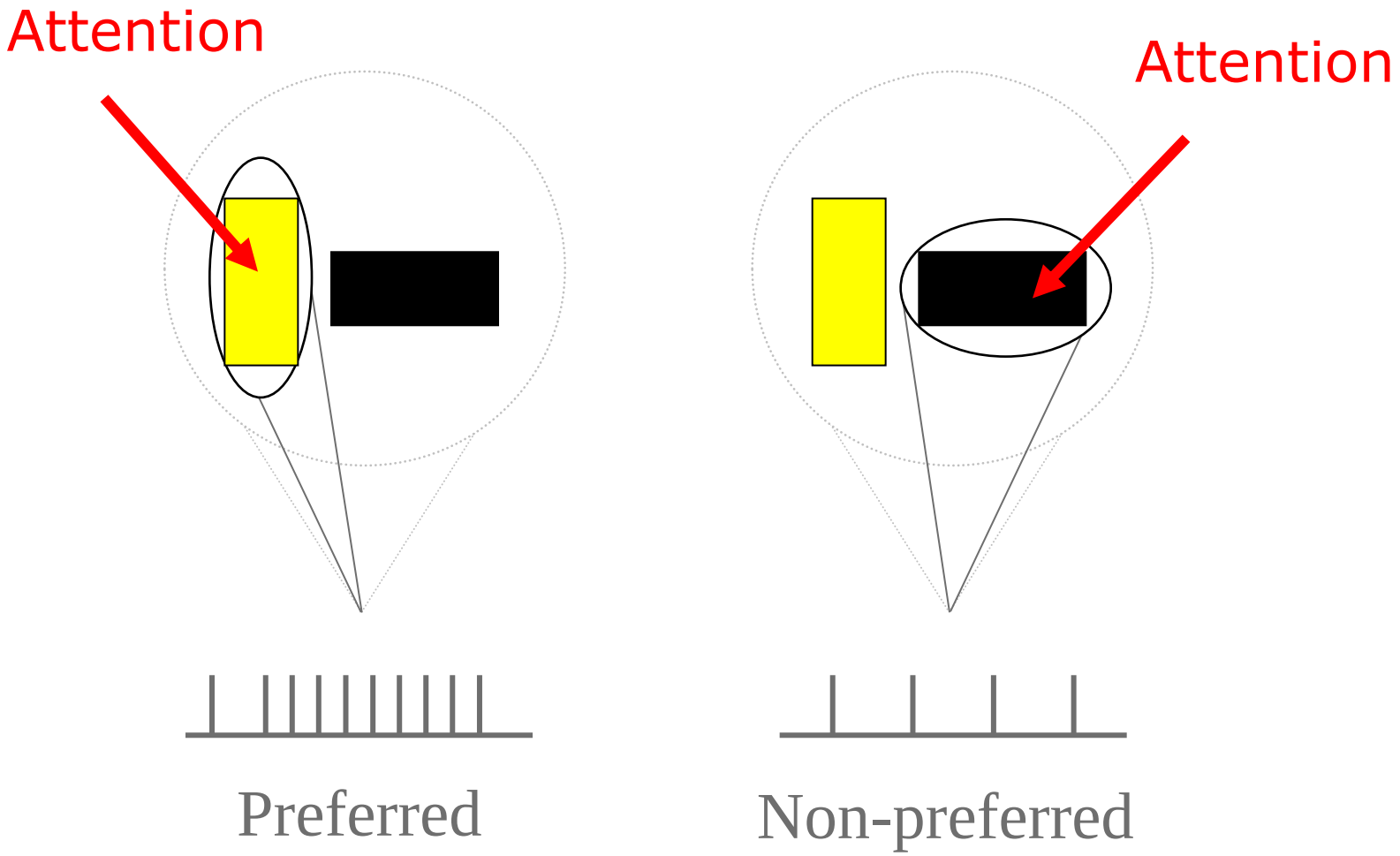
Petersen, Kyllingsbæk, & Bundesen (2012)



Grounding TVA in cellular neurophysiology



Grounding TVA in cellular neurophysiology



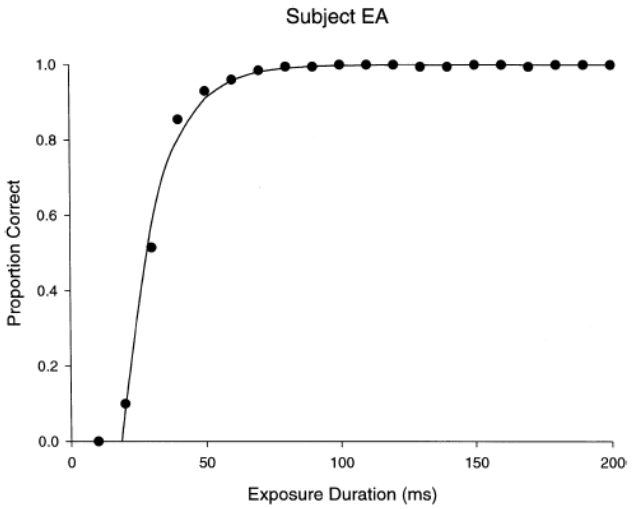
Perceptual Confusability

Immediate perception

- based on the first categorization
- exponential

Mediate perception

- based on accumulation of information

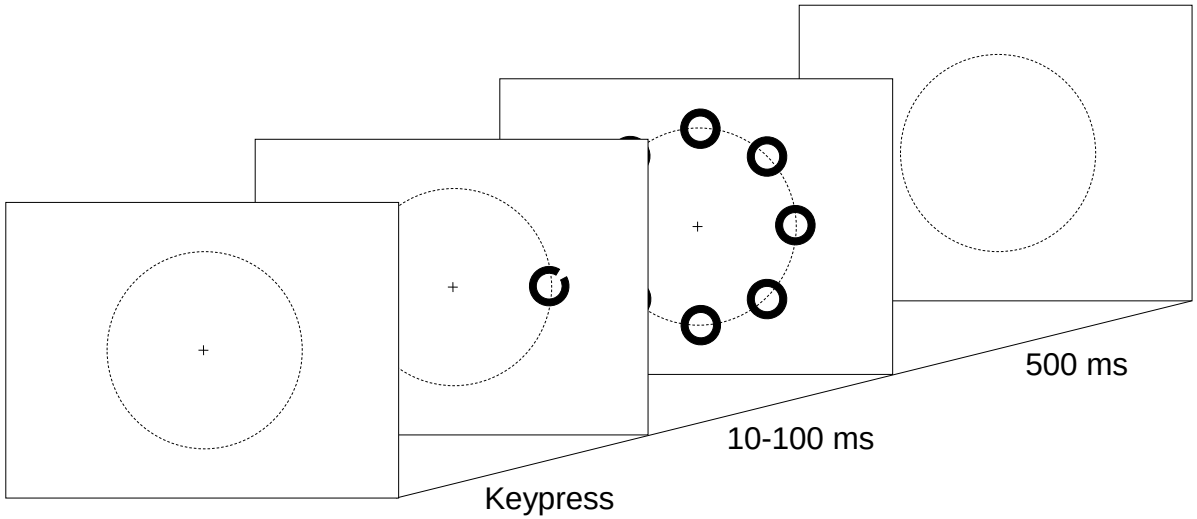


Bundesen & Harms (1999)

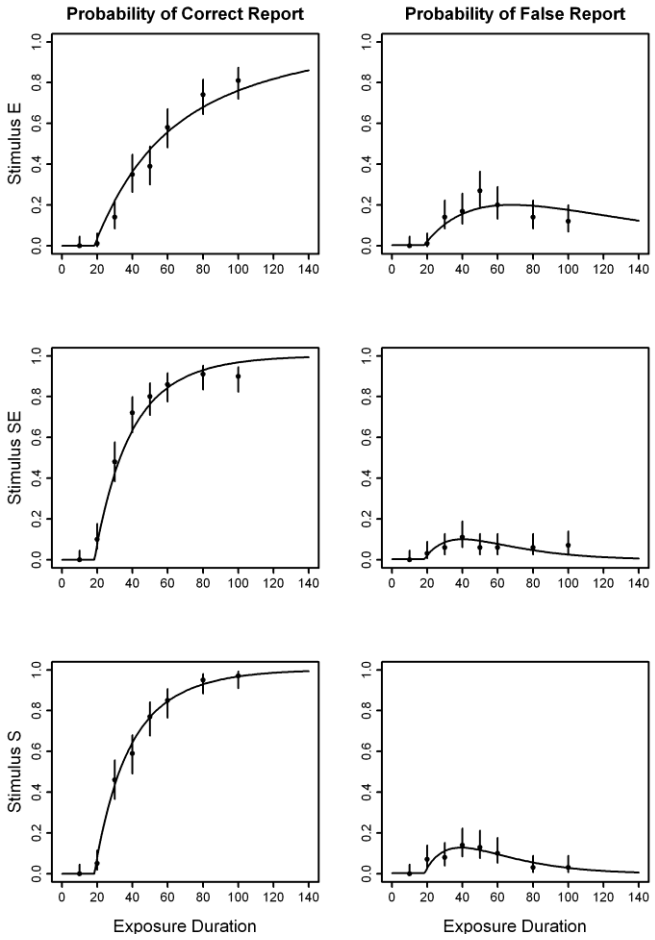
A Poisson Counter Model of Visual Identification

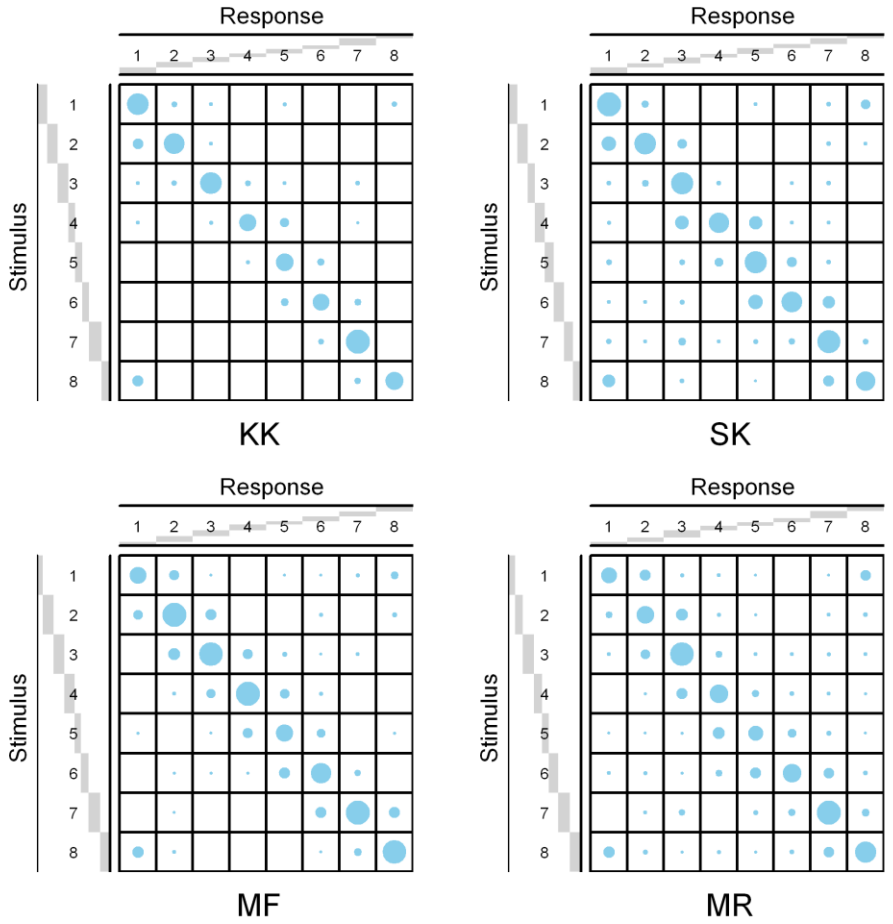
- One counter for each response *j*
- Tentative categorizations with a constant Poisson rate $v(i,j)$
- Highest counter => final categorization
- Ties are solved by guessing
- Perceptual threshold t_0
- Guesses with probability $P_g(j)$ on category *j* if all counters are zero

Perceptual Confusability

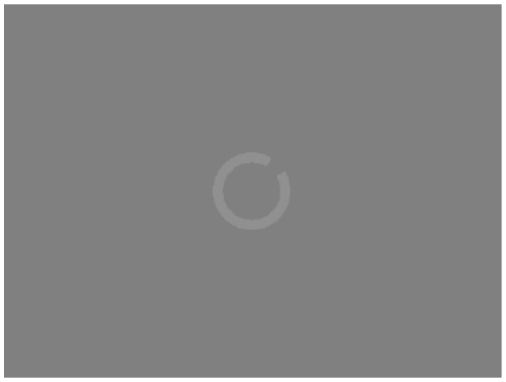


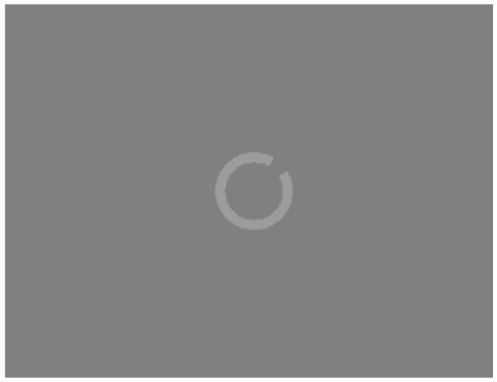
Perceptual Confusability



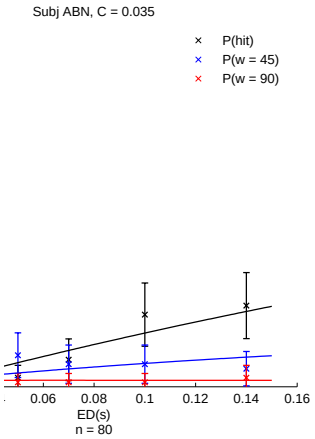


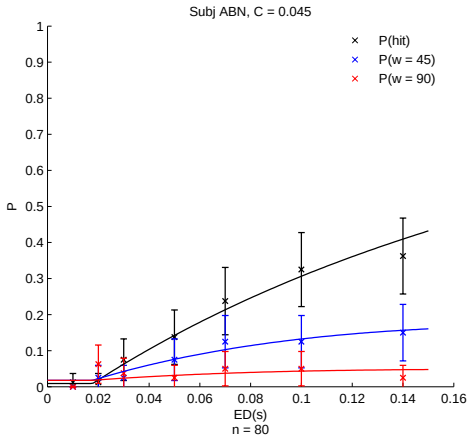
Perceptual Confusability

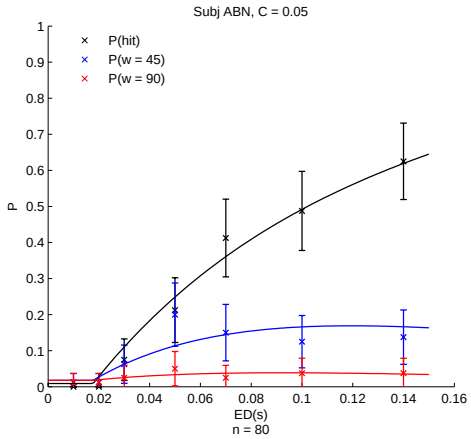


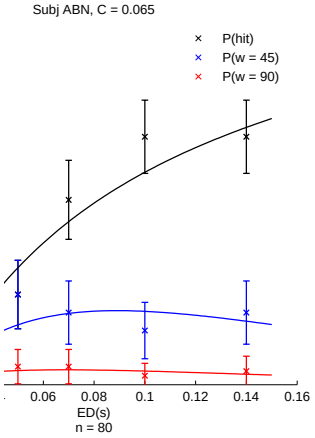


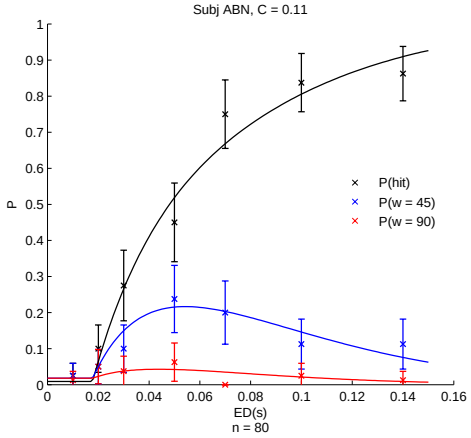
Perceptual Confusability











Performance of 5 levels of contrast.
Fitted with PCM (solid lines)

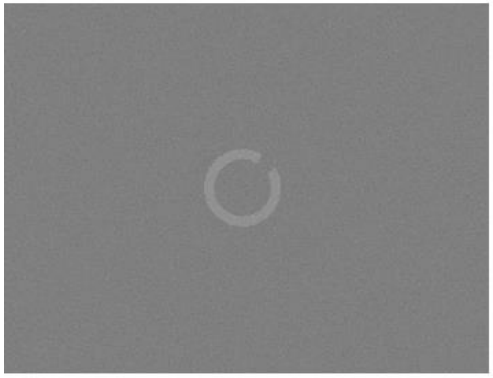
errorbars: 95% confidence intervals of the proportions.

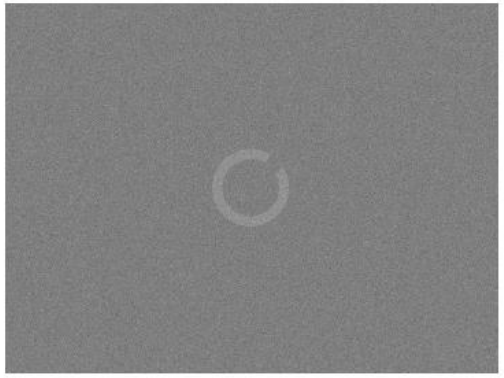
w: angular distance from true orientation of target Landolt.

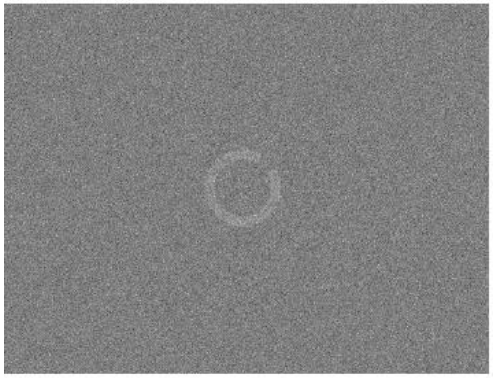
Fitted with:
1 t0
20 processing rates (5 contrast x 4 response categories)
8 guessing probabilities
1 P(no response)

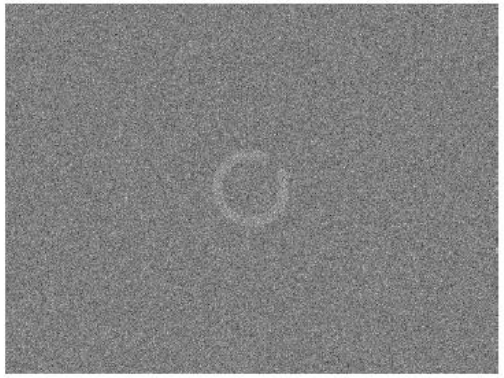
Total 30 parameters to predict 175 independent response probabilities (5 exposure durations, 5 response categories)

Perceptual Confusability





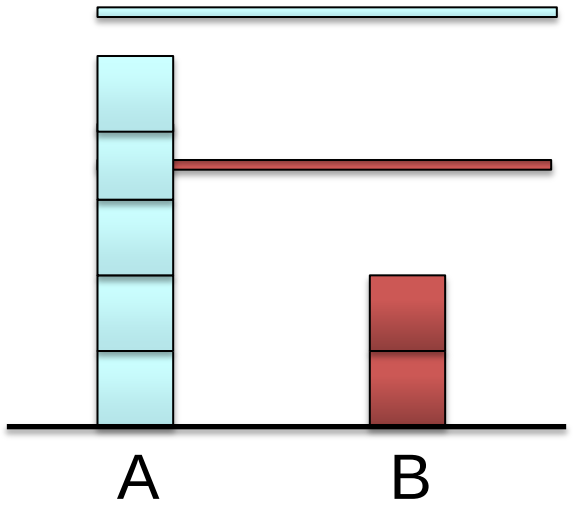




Modeling perceptual decisions and reaction times

Poisson Counter Model

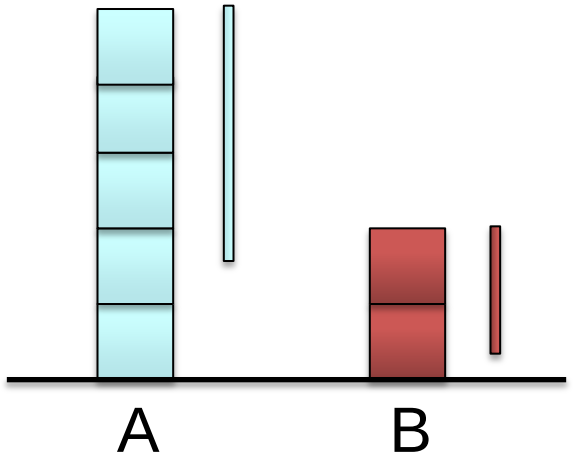
- Collection of input in independent counters for each response type
- Counts are Poisson distributed
- *Absolute* threshold for each counter
- Non decision time constant



Modeling perceptual decisions and reaction times

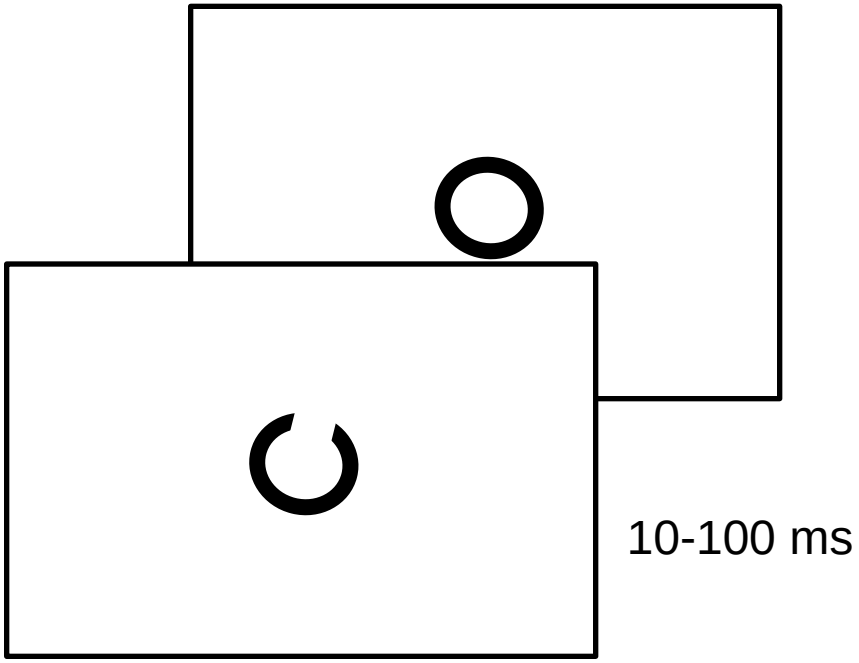
Poisson Random Walk Model

- Collection of input in independent counters for each response type
- Counts are Poisson distributed
- *Relative difference* threshold for each counter
- Non decision time constant

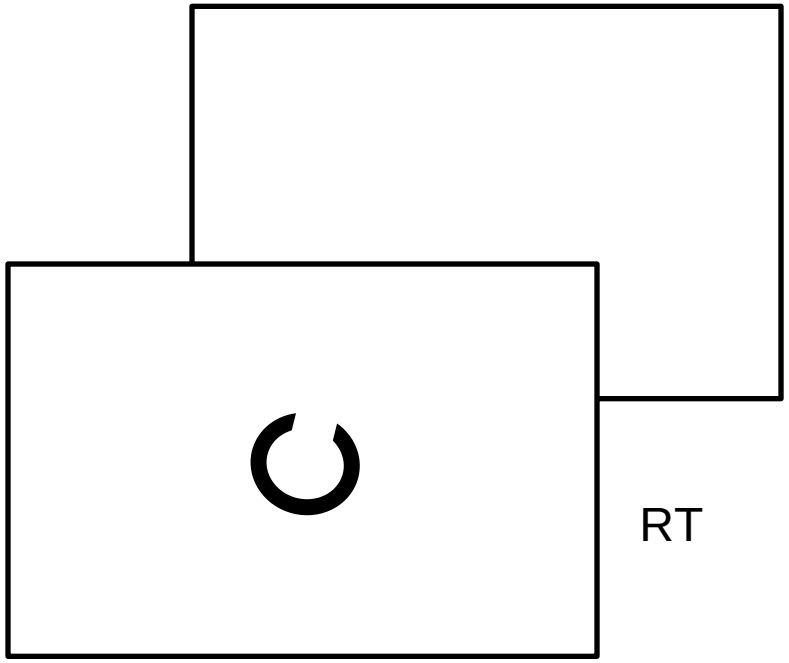


Modeling perceptual decisions and reaction times

Accuracy



Reaction time

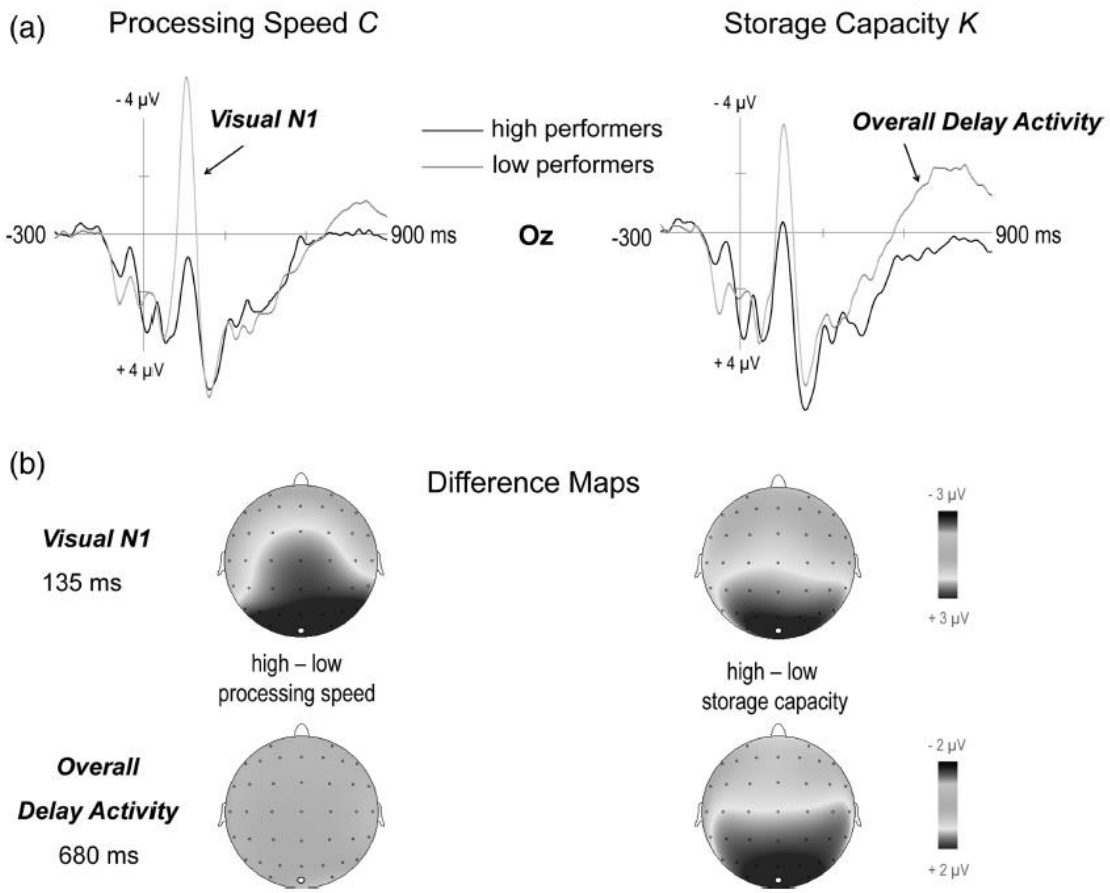


Estimate rates of processing → Accumulation rates

EEG and NTVA

- Relation between C and posterior N1
- Pre-stimulus alpha activity
- Relation between N2pc and weight and rate parameters

EEG and NTVA



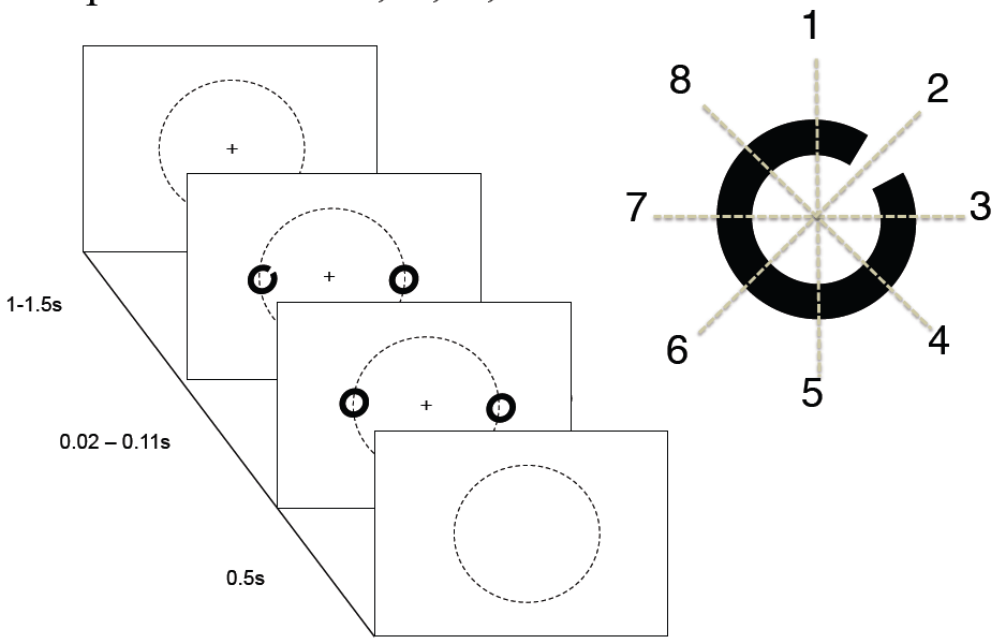
Wiegard, Töllner, Habekost, Dyrholm, Müller, & Finke (2013)

EEG and NTVA

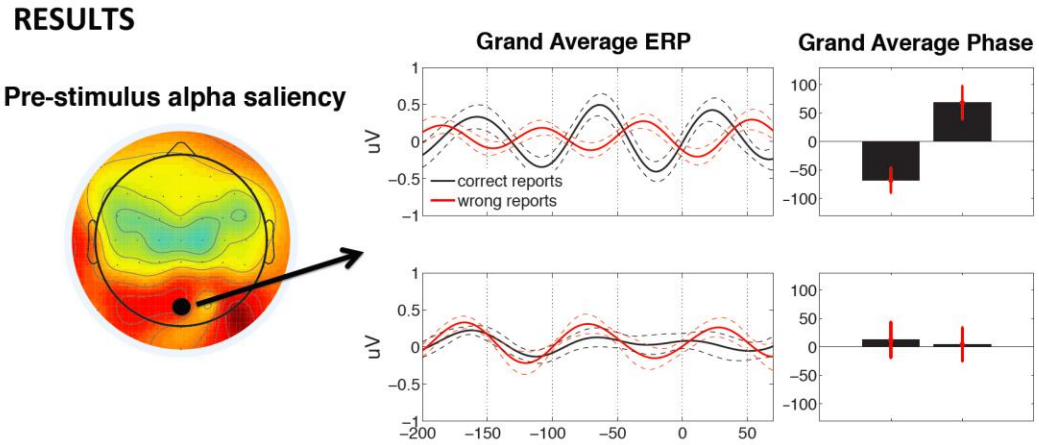
TASK

Contrast: 7% and 28%

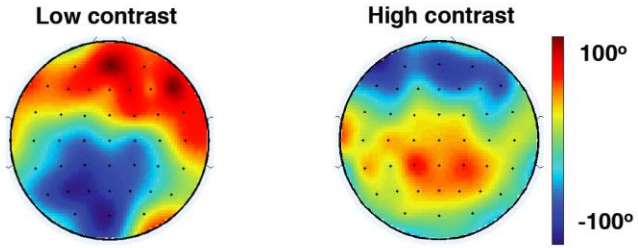
Exposure times: 20,40,70, & 110ms



EEG and NTVA



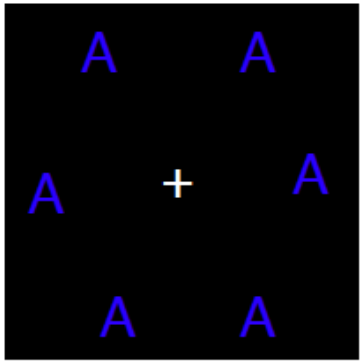
Left: topographic saliency map of alpha power from 500ms pre-stimulus period. Mid: Grand average ERP after filtering the raw EEG with individual alpha-band. Right: Circular means of phase distribution for correct and incorrect responses.

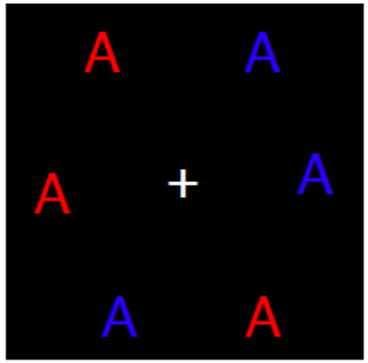


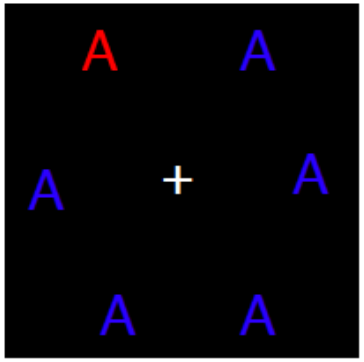
Topography of phase difference (correct – incorrect) at low and high contrast. At low contrast, central occipital areas show large difference. At high contrast, the difference is no longer visible at occipital regions.

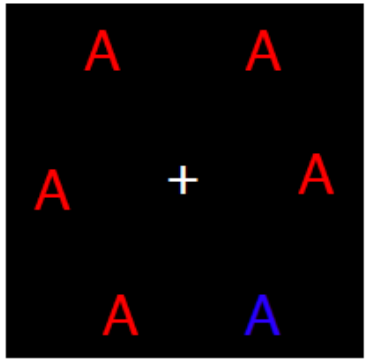
Christensen, Dyrholm, & Kyllingsbæk (2013)

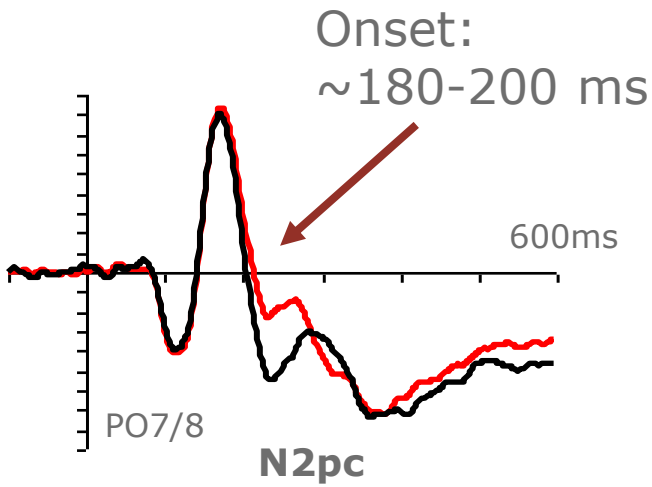
EEG and NTVA


A A
A + A
A A


A A
A + A
A A


A A
A + A
A A


A A
A + A
A A


Onset:
~180-200 ms
600ms
PO7/8
N2pc

Components of bias in single-stimulus recognition

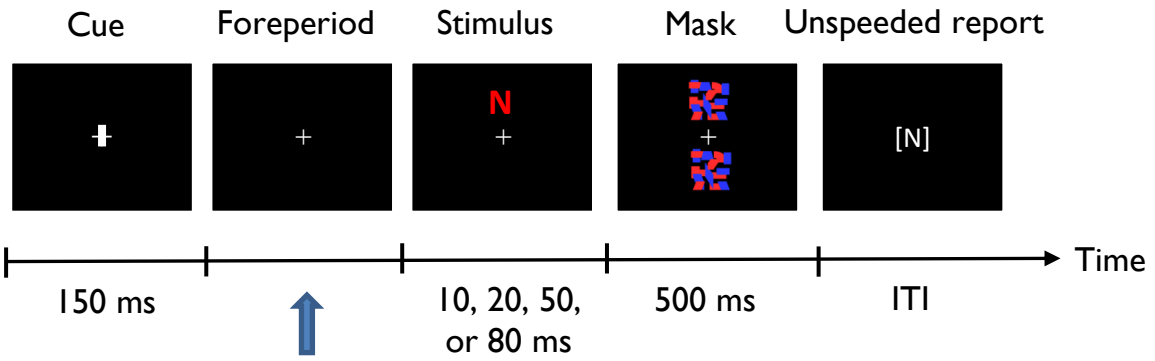
Perceptual bias, β, is the product of three terms:

$$\beta_i = A\, p_i\, u_i$$

Alertness (A)
Subjective prior probability (p_i)
Subjective utility (u_i)

Investigate bias using **temporal expectations** to manipulate alertness:

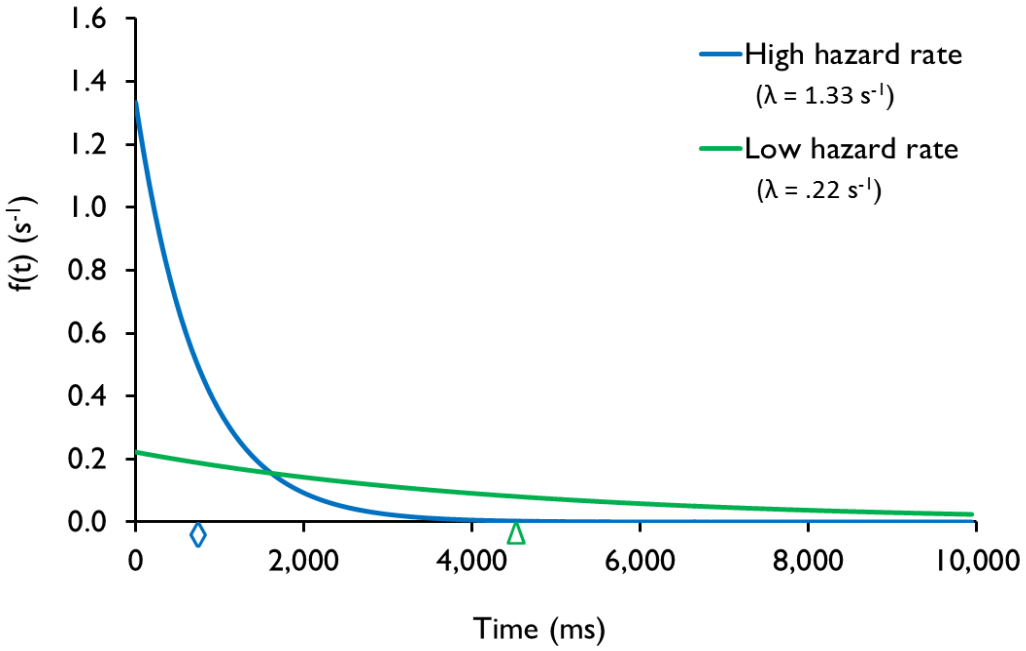
- Waiting time paradigm with single stimulus recognition
- Exponentially distributed waiting times ⇨ constant levels of expectations over time
- Should affect processing speed but not perceptual thresholds



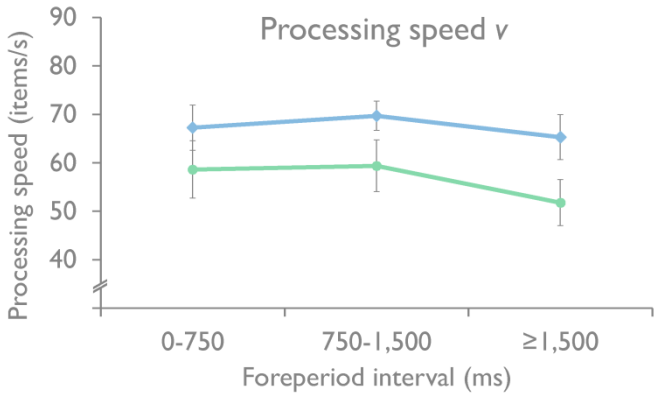
Components of bias in single-stimulus recognition

High expectancy
(1/6)

Low expectancy
(1/12)

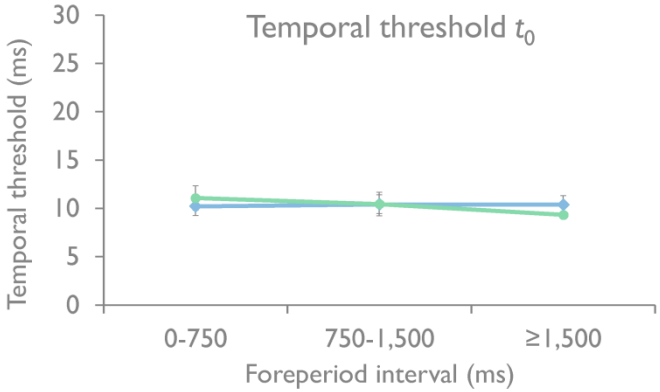


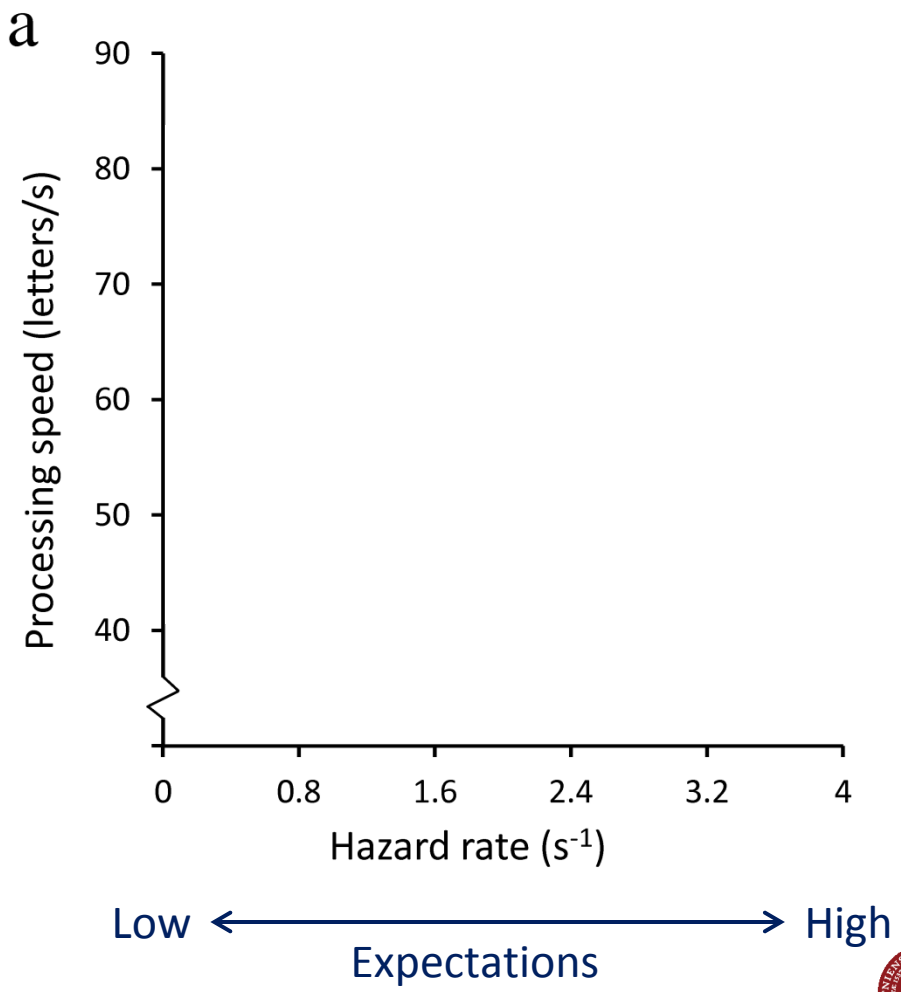
Components of bias in single-stimulus recognition



High expectations

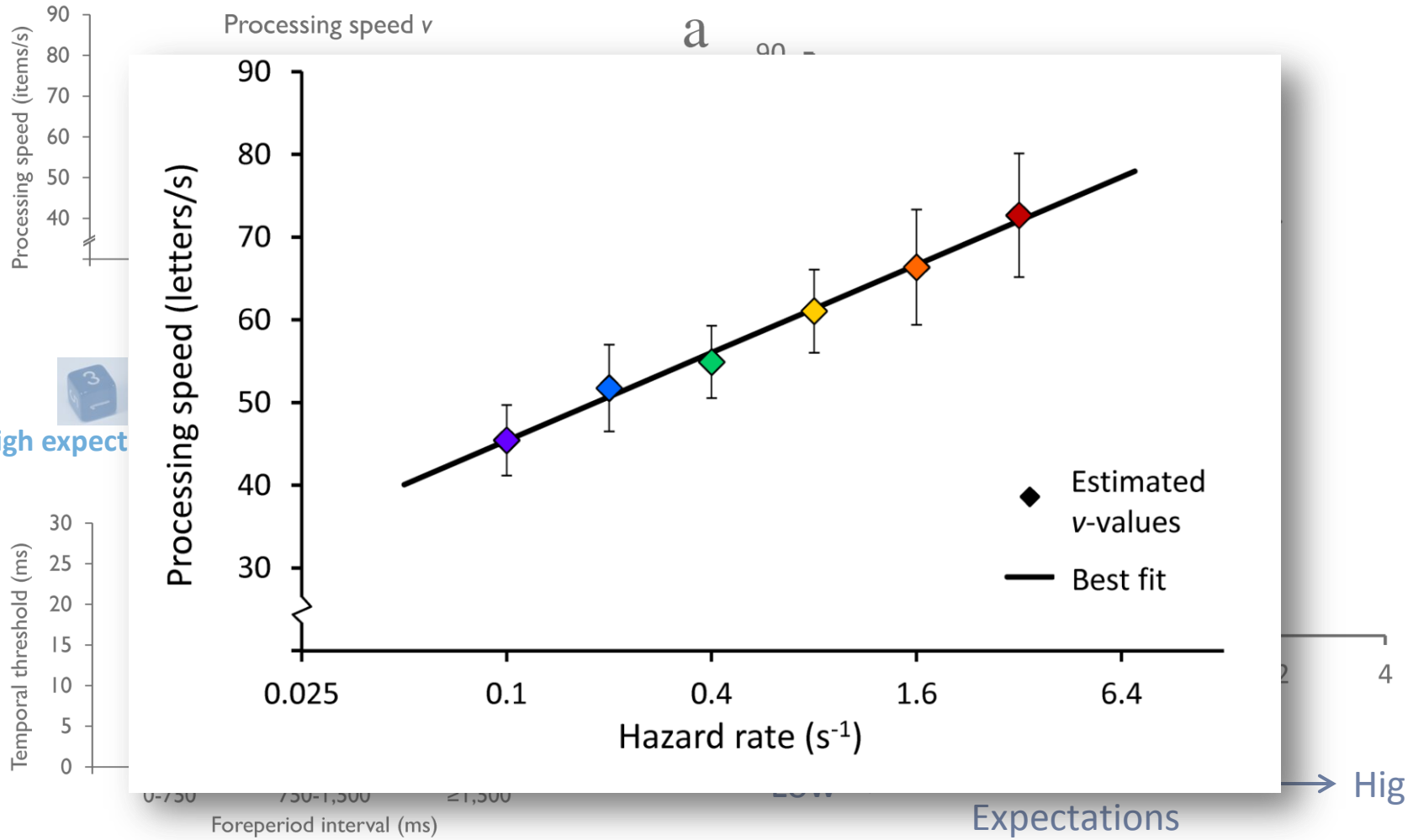
Low expectations





Vangkilde, Coull & Bundesen (2012) JEP:HPP
Vangkilde, Petersen & Bundesen (2013) Phil Trans R Soc B

Components of bias in single-stimulus recognition



Vangkilde, Coull & Bundesen (2012) JEP:HPP
Vangkilde, Petersen & Bundesen (2013) Phil Trans R Soc B

Attention to Dopamine

Relationship between visual attention, dopamine, and ADHD.

Central hypotheses:

- TVA-based testing can profile changes in attentional functions in children and adults with ADHD
- Dopamine plays a critical role in modulating these functions
- Specific attentional alterations seen in ADHD patients can be reproduced in genetic mouse models.

WPs

- TVA-based neuropsychological testing in human subjects (ADHD children and adults, healthy controls) together with assessment of the brain dopamine balance by PET-scanning
- use genetic mouse models to link dopaminergic dysfunction at the molecular level to changes in attentional functions
- integrate behavioral characterization in genetic mouse models with TVA-based psychological testing in humans to develop new behavioral paradigms for ADHD.

ESRs 7 AND 8

- **Sustained attention to the task**
  - partial report by computing how efficiency of selection (parameter *a*) changes during the course of the test.
  - whole report, by computing how processing capacity (parameter *C*) changes over time.
- **Sensitivity to reward**
  - single-stimulus recognition paradigm in which correct detection of certain feature values is strongly rewarded and misses of the same values are strongly penalized, whereas detection of other feature values is only weakly rewarded and misses of these feature values are only weakly penalized.
- **Efficiency of task switching**
  - varying the selection criterion in partial report. The selection criterion may specified by a spoken cue (e.g., "blue", "red").