Integrating neural coding into cognitive models

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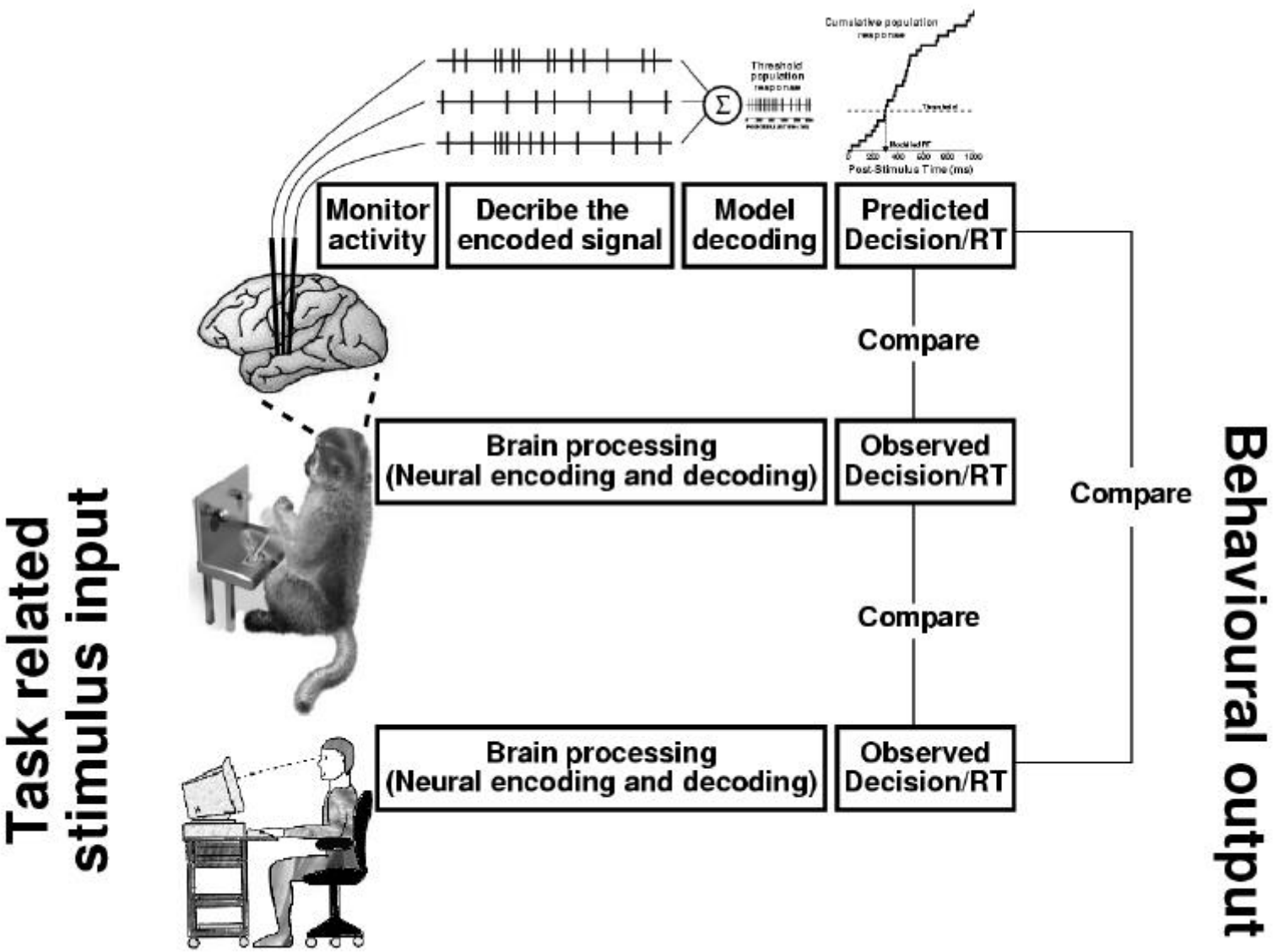
Framework of research

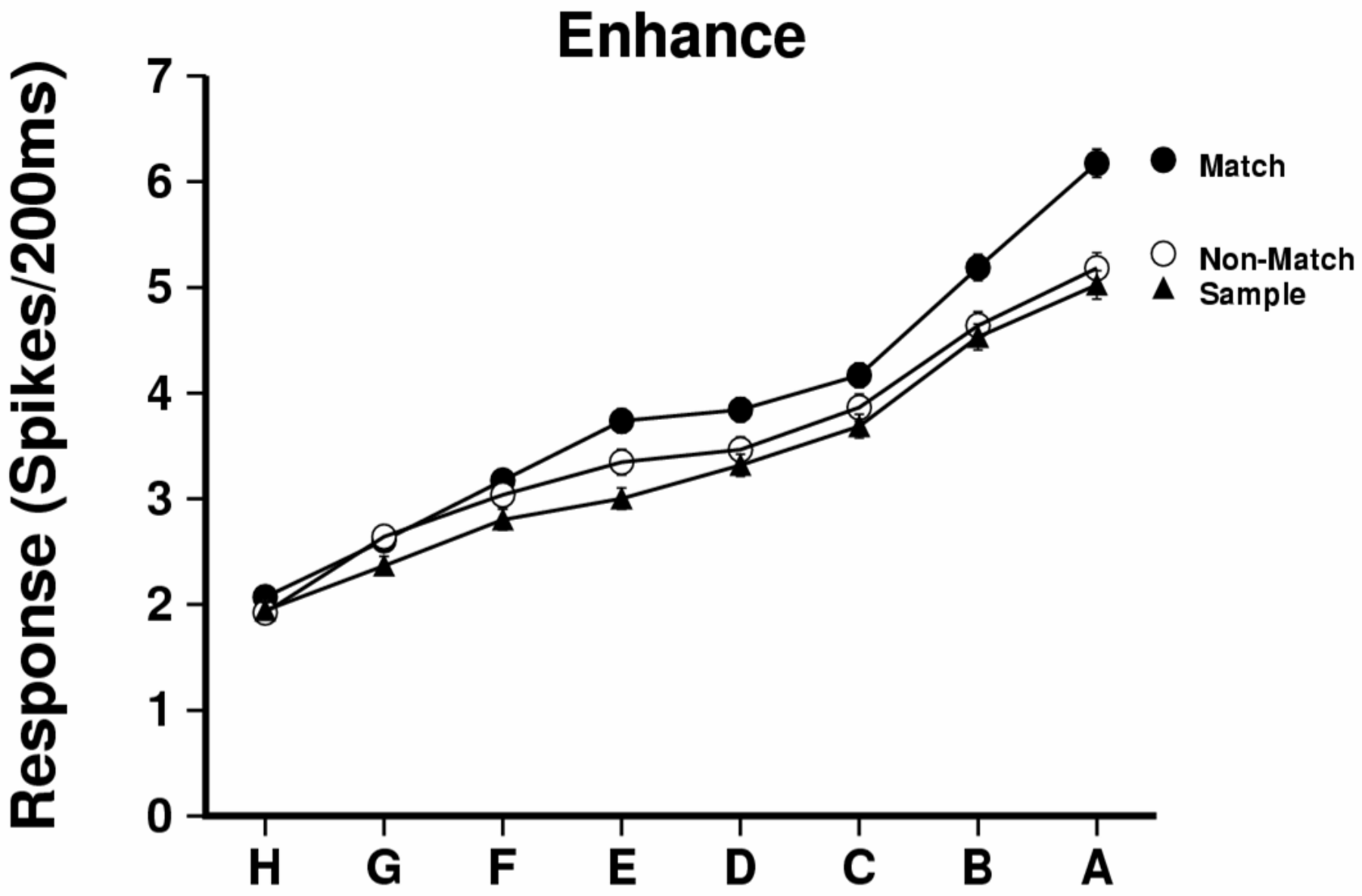


Neural codes and attention

- Fixating monkey doing sequential DMS task

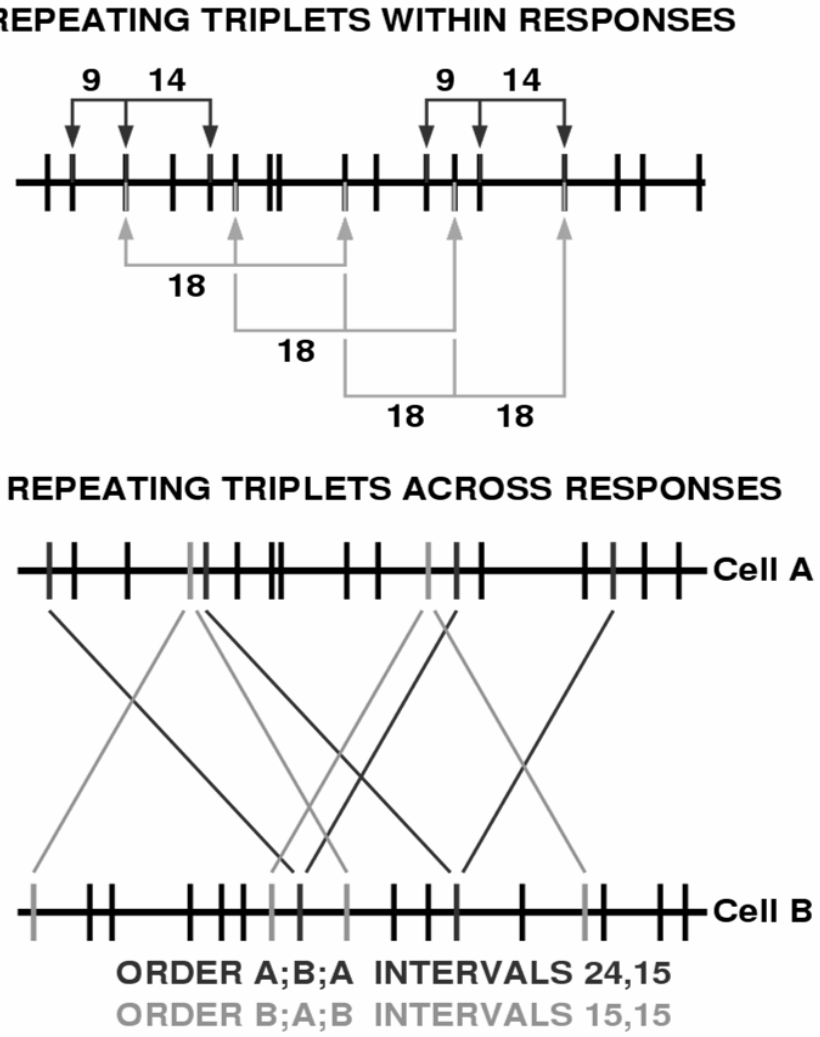
Sample Non-match Non-match Match

Attention and neuronal codes

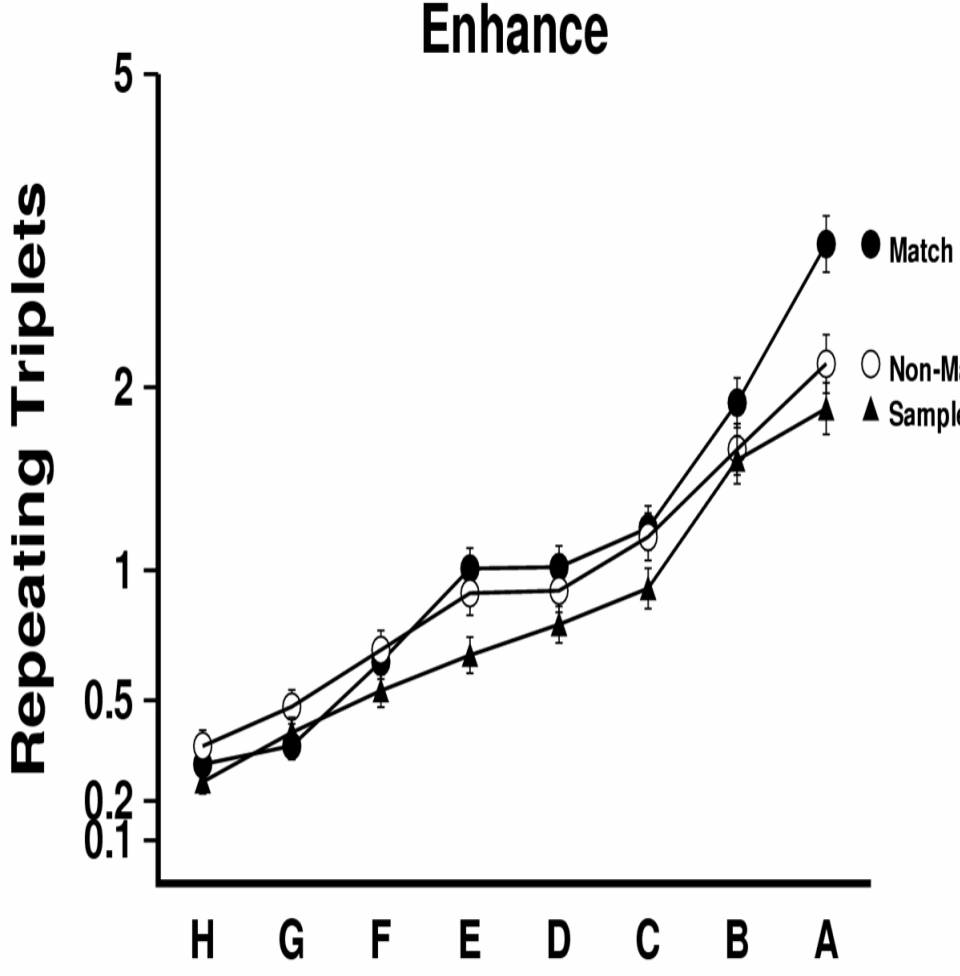


Fine temporal response measures

Identifying repeating triplets

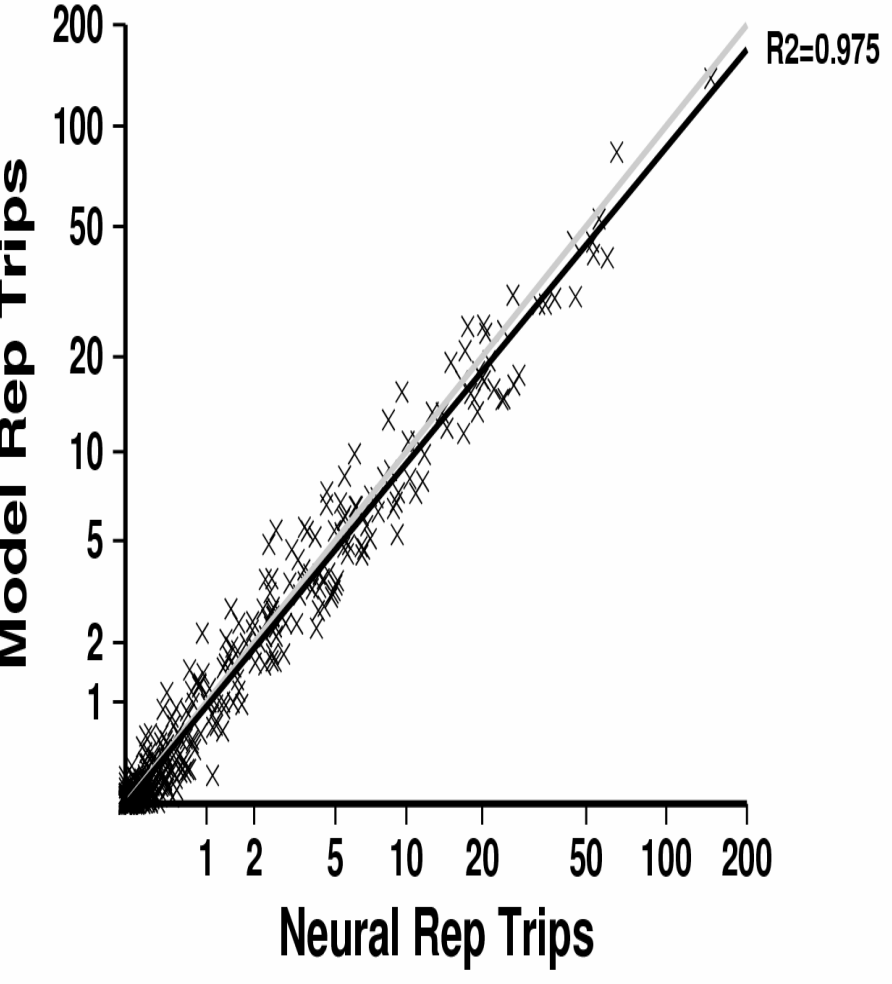


Behavioural relevance

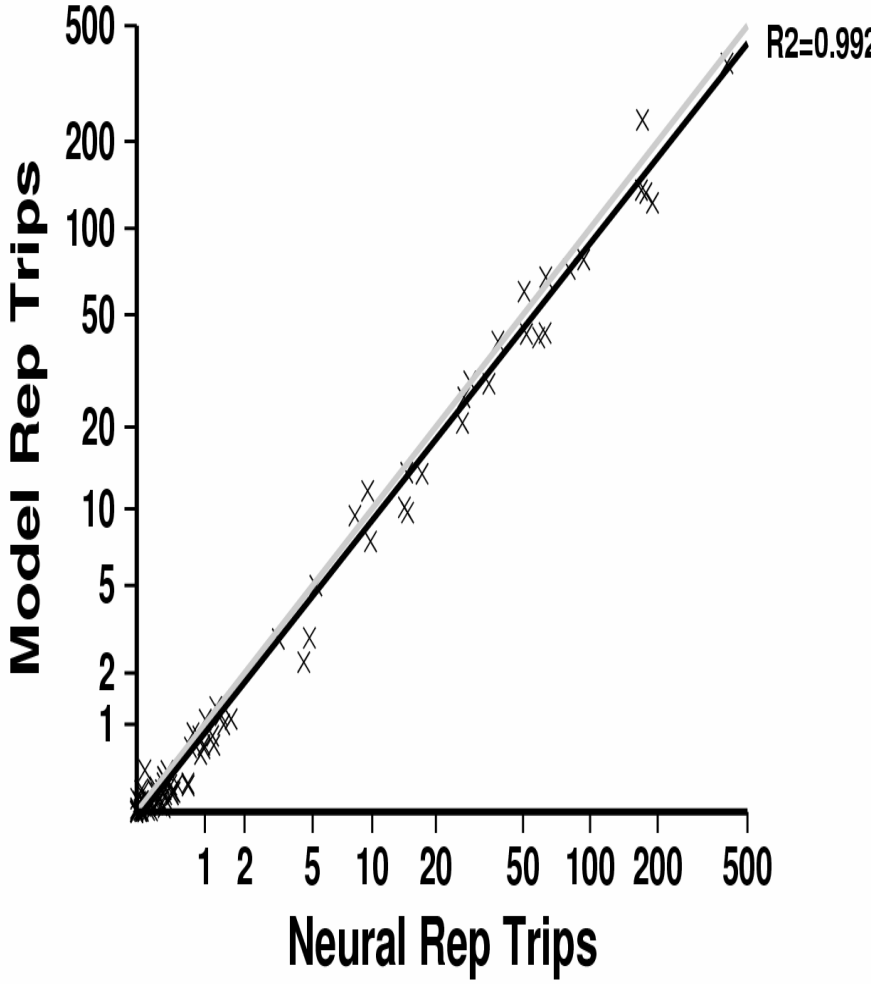


Fine temporal response measures

Within cell repeating triplets



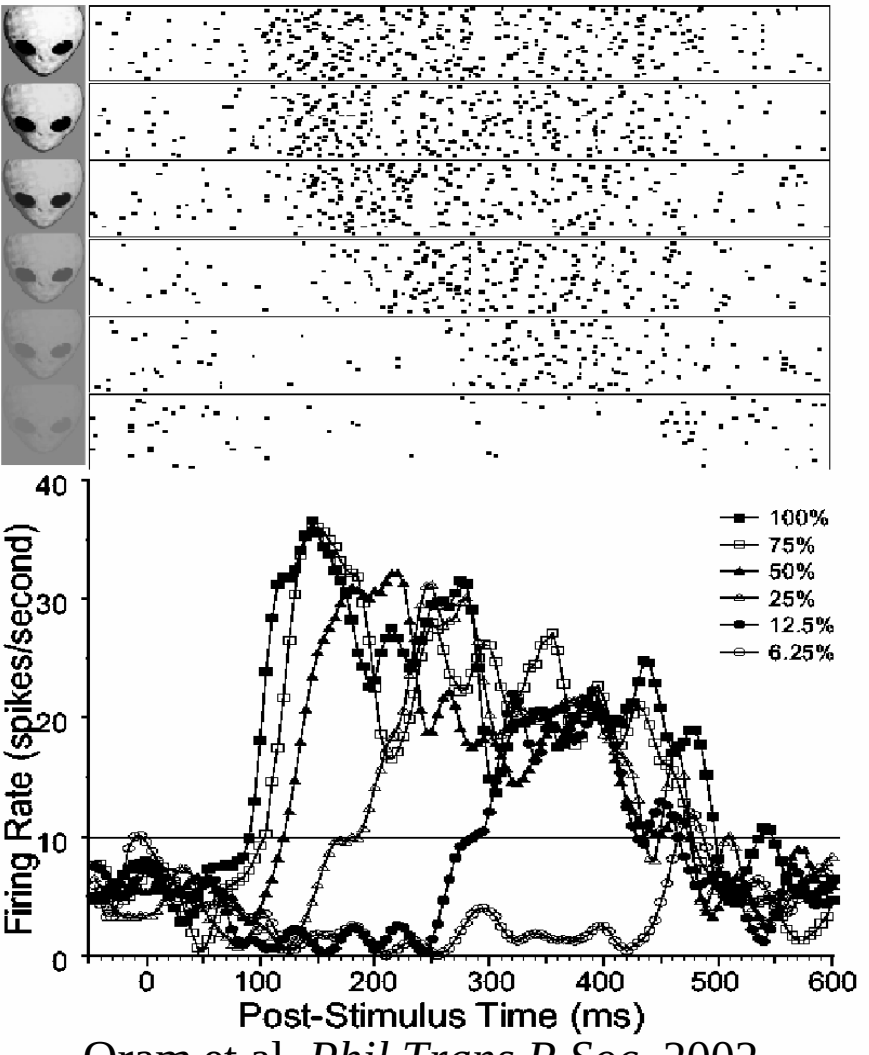
Between cell repeating triplets



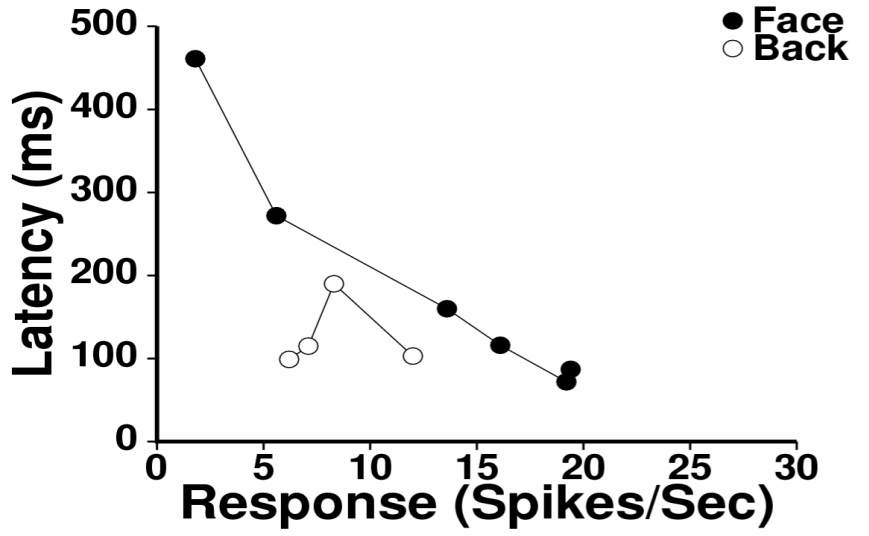
Neural codes in visual system

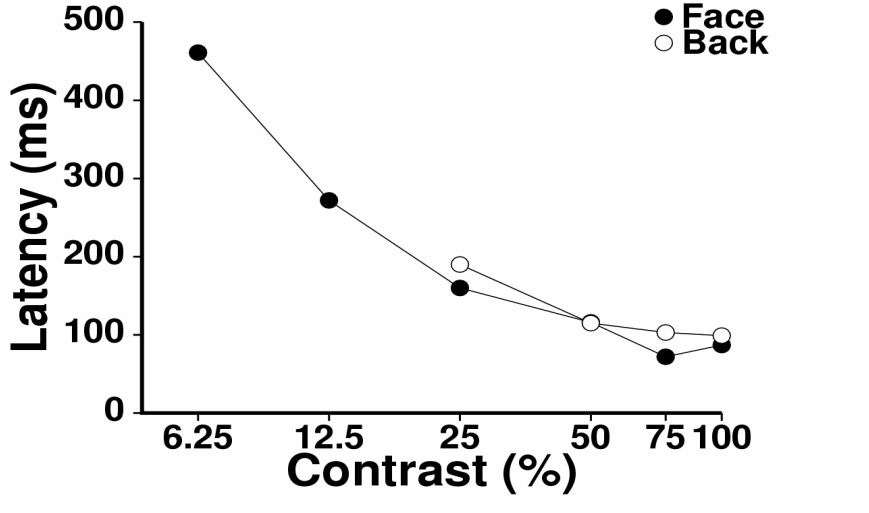
- Coarse/medium (20-500ms resolution)
  - Plenty of evidence for spike count
  - Evidence of medium (Richmond)
- Fine temporal measures (1-2ms resolution)
  - “Synfire chains” (includes synchrony)
    - We find no evidence (LGN, V1, Motor)
    - Even with behavioural relevance (TE: Oram, Lui, Richmond, in prep)
  - Synchrony
    - No evidence (TE/STS, Rolls et al. 2003, 2004)

Stimulus contrast and response latency in TE/STS

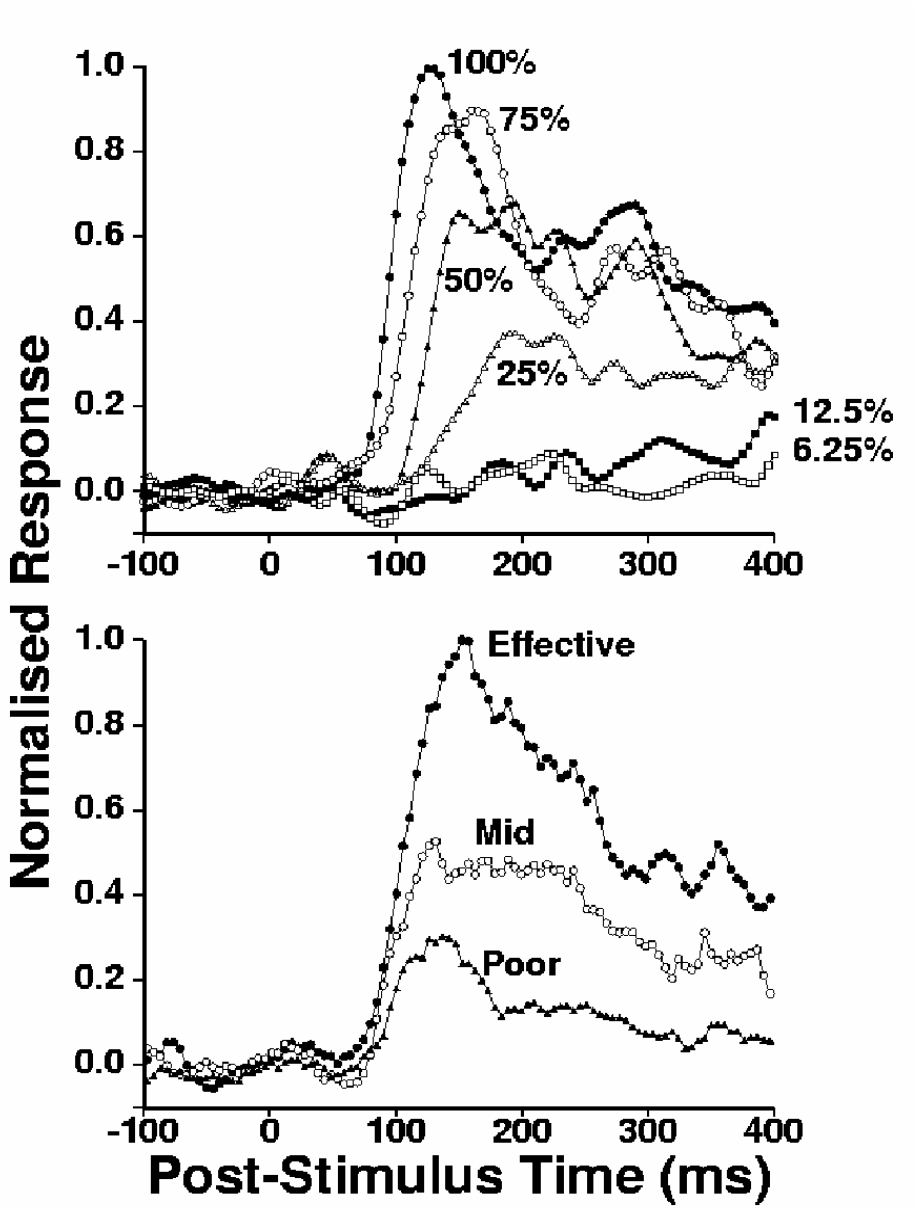


Oram et al. *Phil Trans R Soc*, 2002





Stimulus contrast and TE/STS

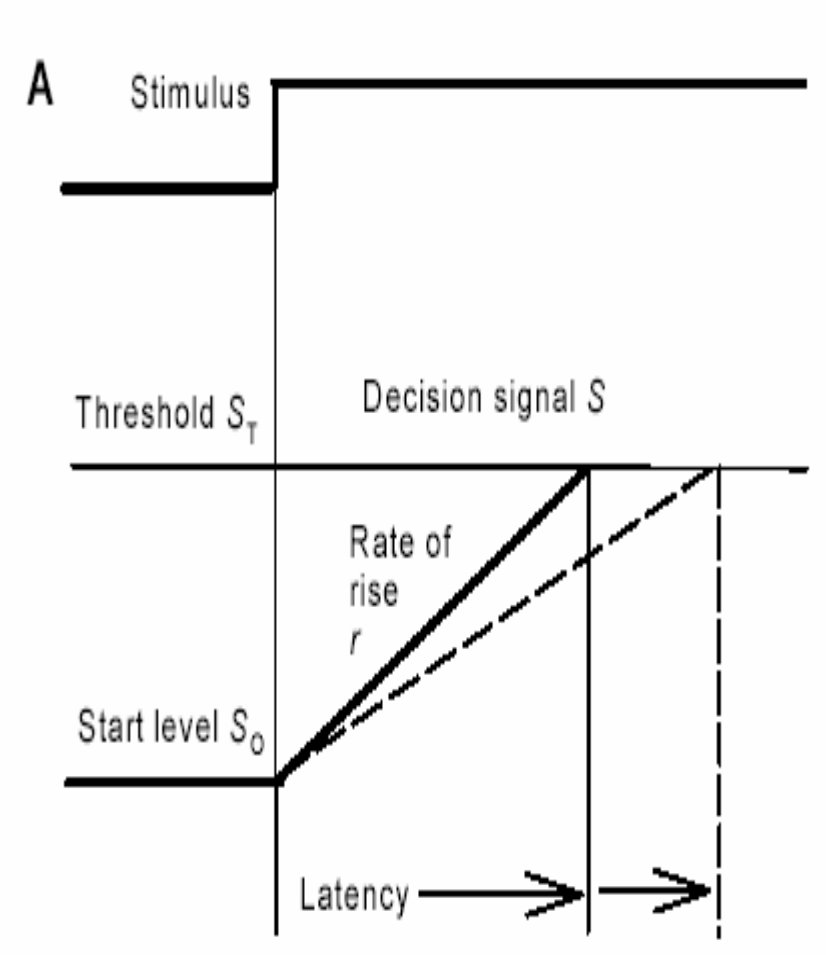


Neural codes in late visual system

- **Evidence for spike count and response latency**
  - Information encoded by spike count, latency when
- **Do these codes “mean” anything?**
  - Spike counts
    - Micro-stimulation studies (e.g. Newsome, Parker)
  - Latency
    - How to test?
    - Can’t stimulate to change latency
    - Want to relate to behaviour

Cognitive models of decisions

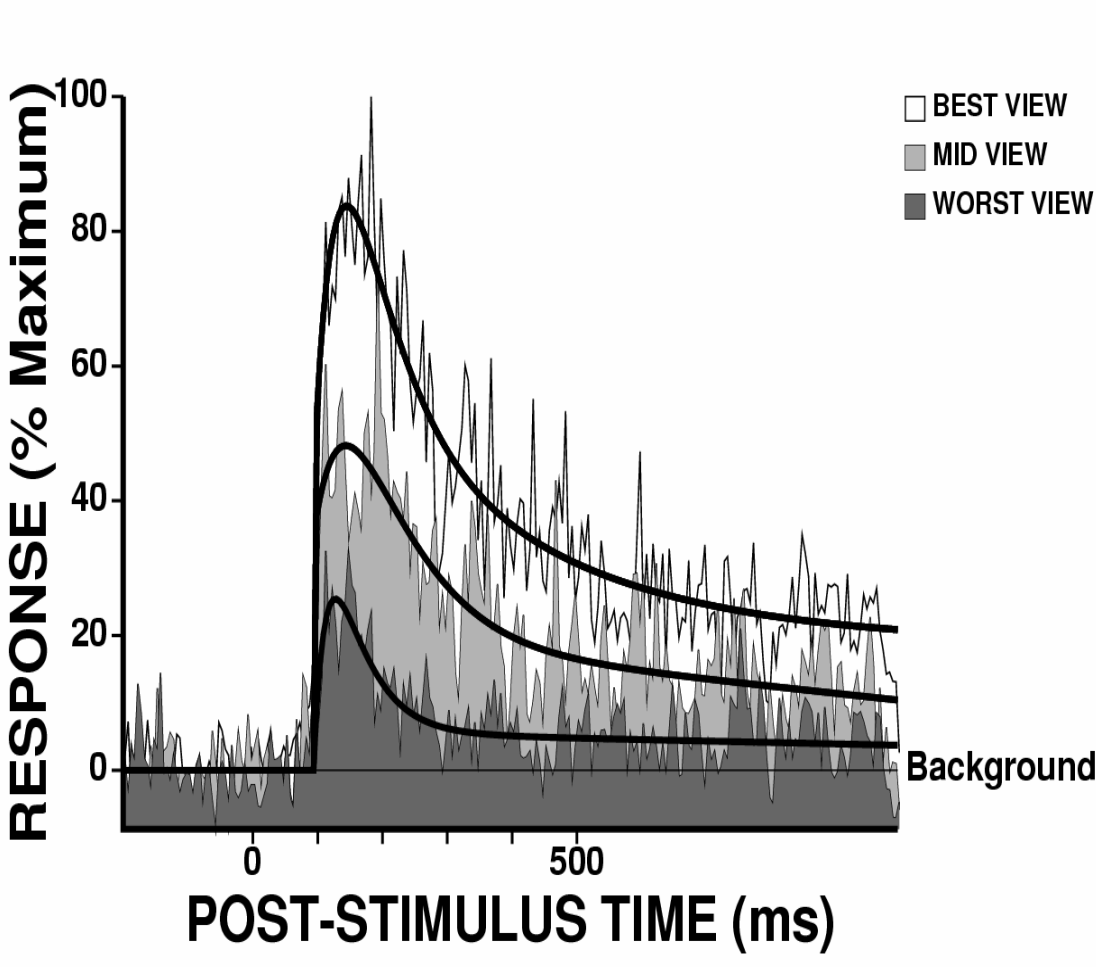
- Information acquisition hypothesis
  - Loftus et al. *Q J Exp Psychol*, 1983
  - Decisions (behavioural RT) made when information reaches threshold
    - Carpenter & Williams, *Nature* 1995
    - Gold & Shadlen, *TICS*, 2001



Carpenter & Williams, *Nature*, 1995

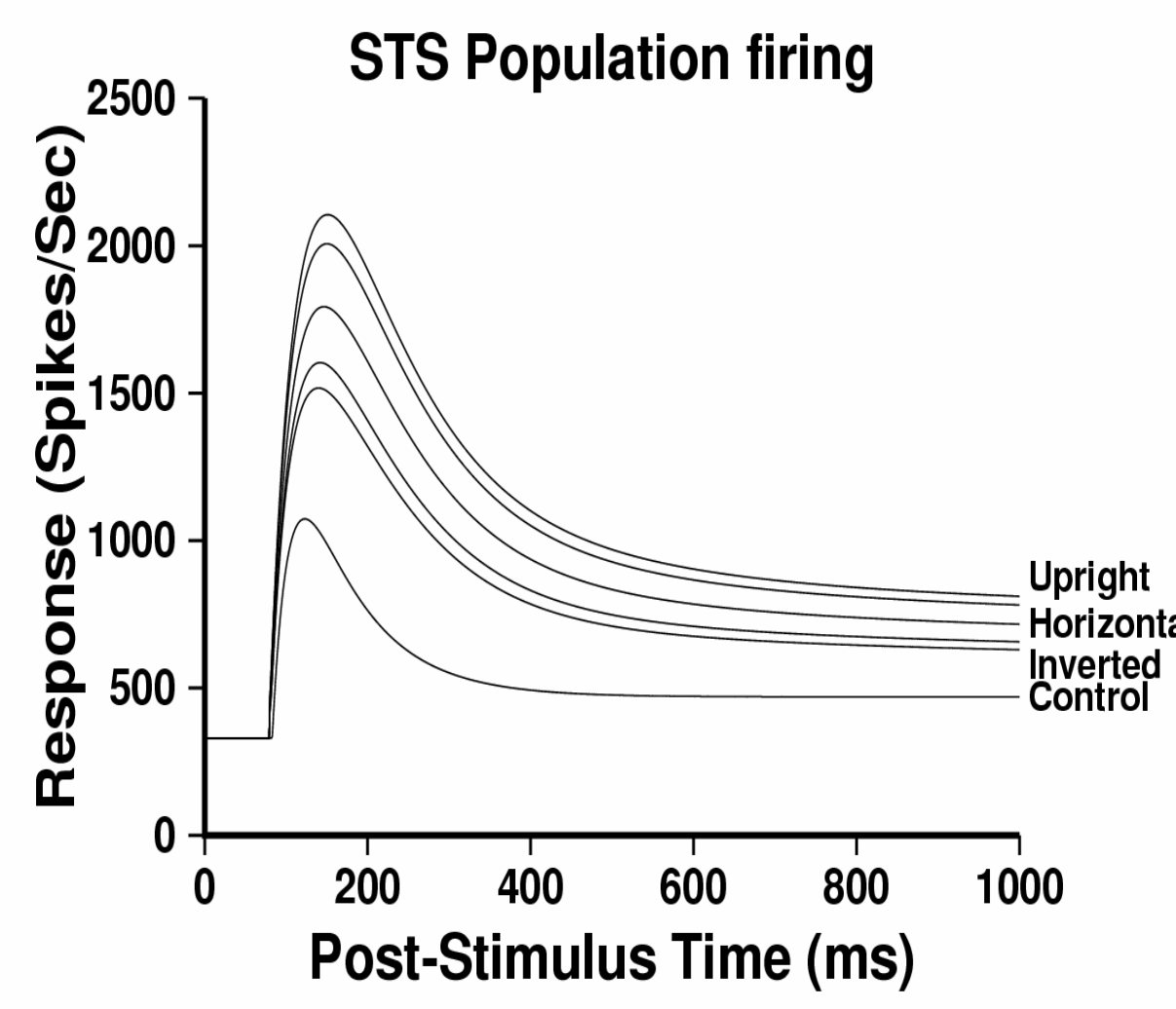
Modeling a decision

- Use simulated neural responses to generate population responses
- Individual cell response profile from Oram & Perrett 1992



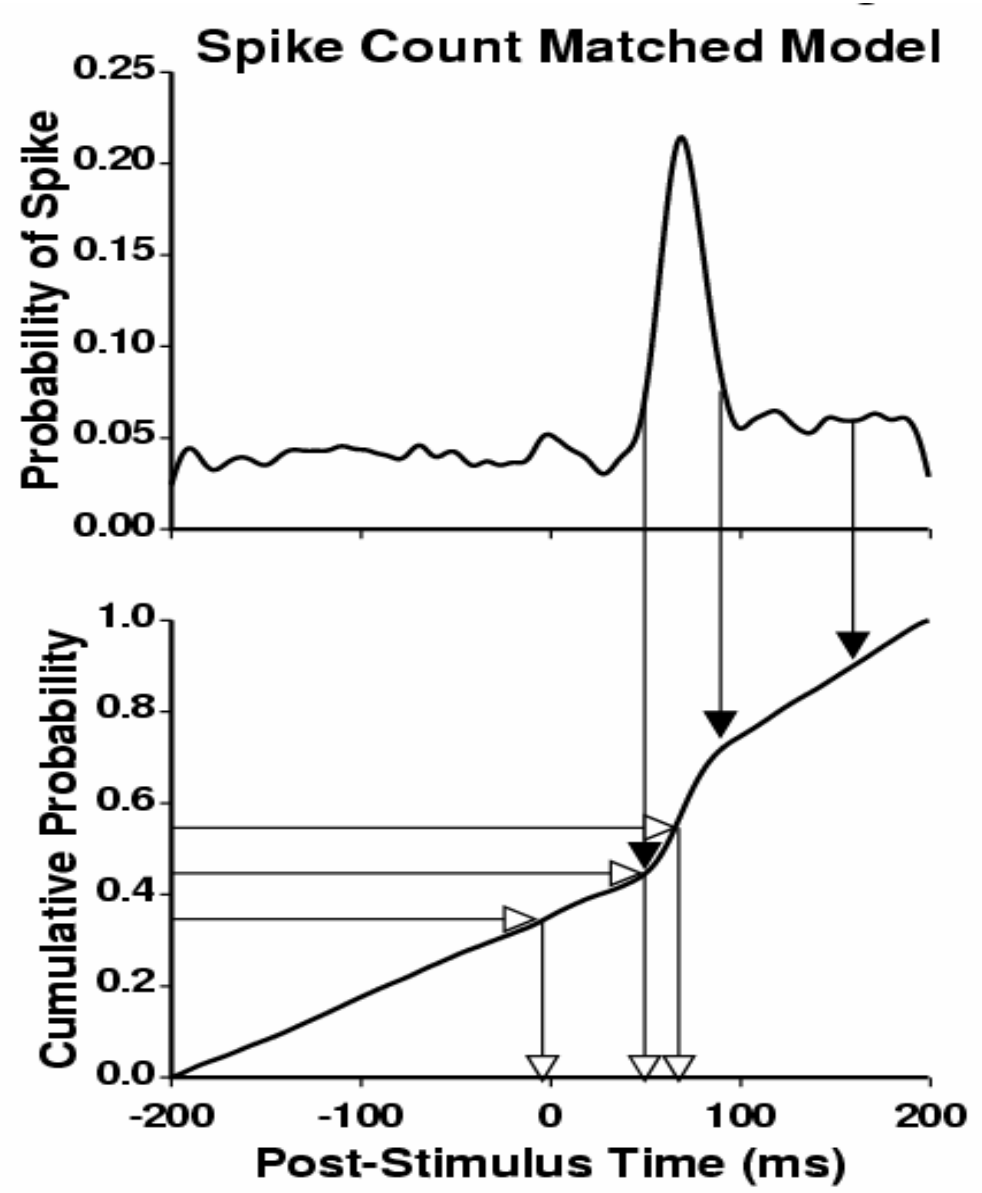
Modeling a decision

Cell tuning and distribution of cells "preferred view" (Perrett et al. 1991)



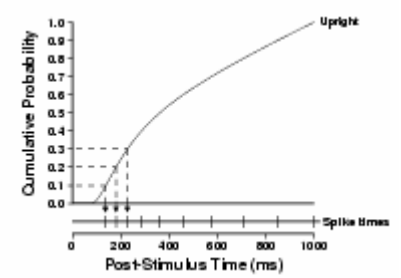
Modelling a decision

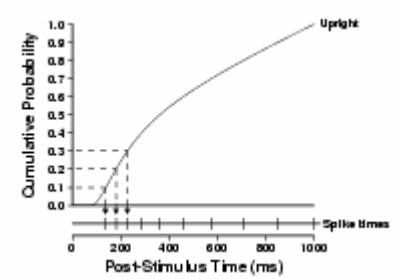
- Use SCM to generate responses of individual neurones
  - Use Fano factor of 1.5

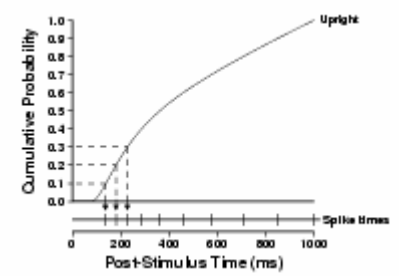


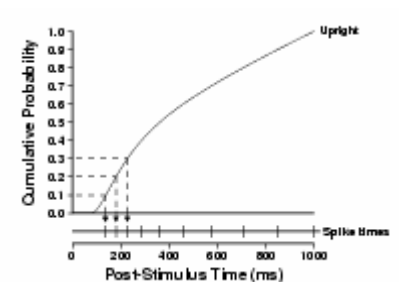
Oram et al., *J Neurophysiol*, 1999, 2001

Modeling a decision

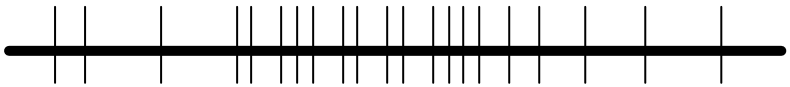








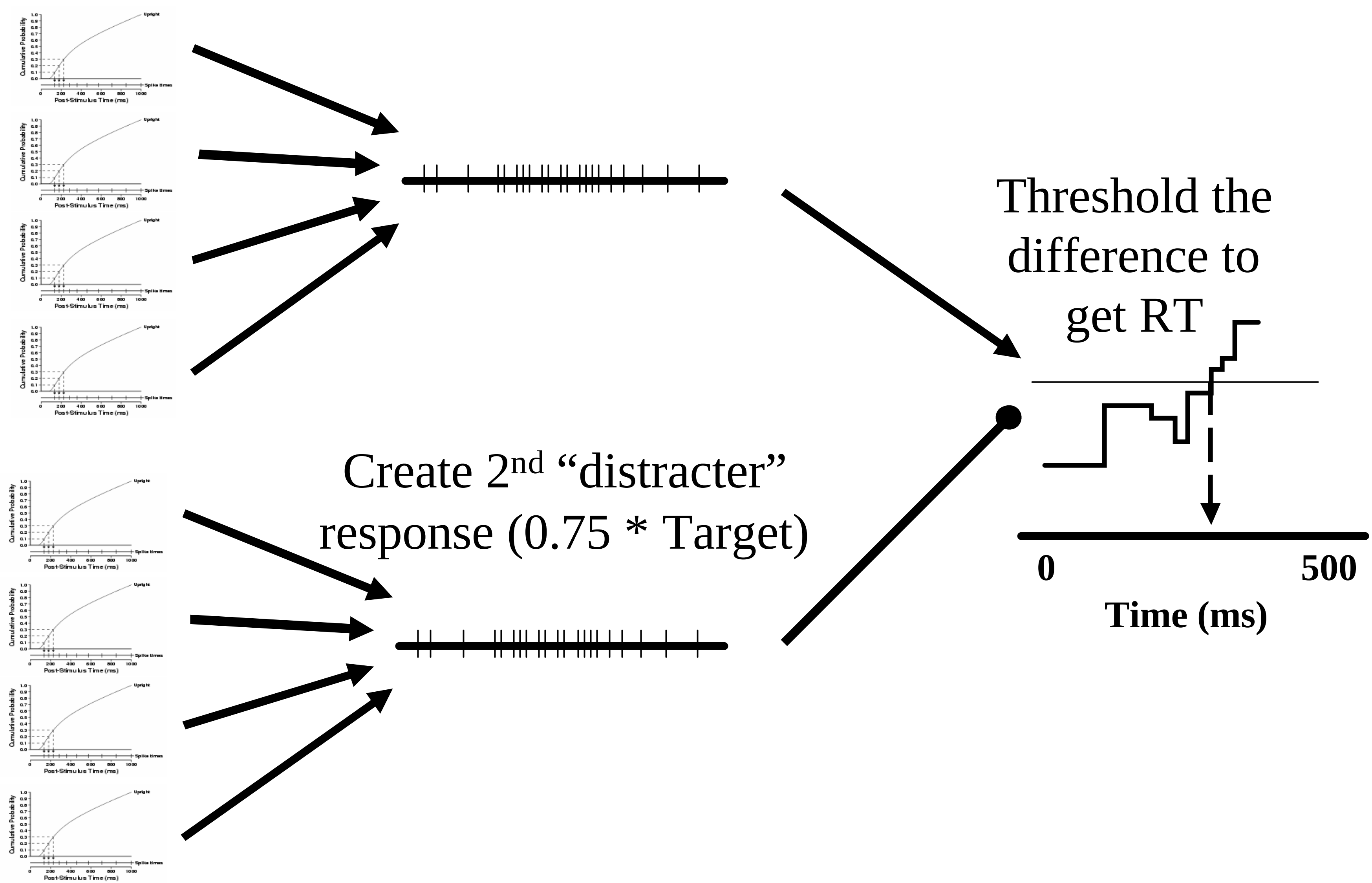
Sum individual responses
to get population response
to “target” stimulus



Modelling a decision

- Target is attended (looked for)
  - Desimone, Maunsell
  - Gives a neural response “gain” of about 1.2 to 1.5
  - Gain to the neural responses, not a particular stimulus

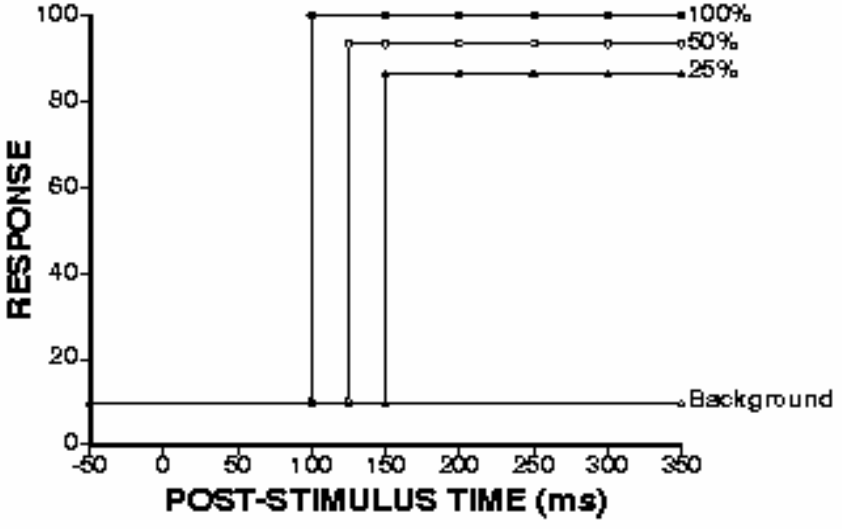
Modeling a decision



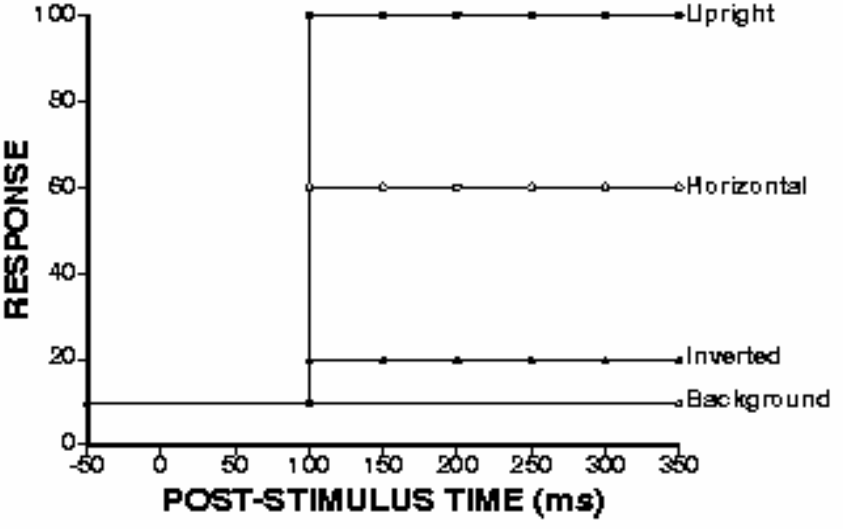
Modeling a decision

- Do as simplest computation
  - Mutually inhibitory populations
  - Also done as integrate & fire neurones in simple network (van der Meer, van Rossum, Edinburgh)
    - Get same results as the poor mans version
    - Poor man's version MUCH quicker
- What do neural codes predict for RT?

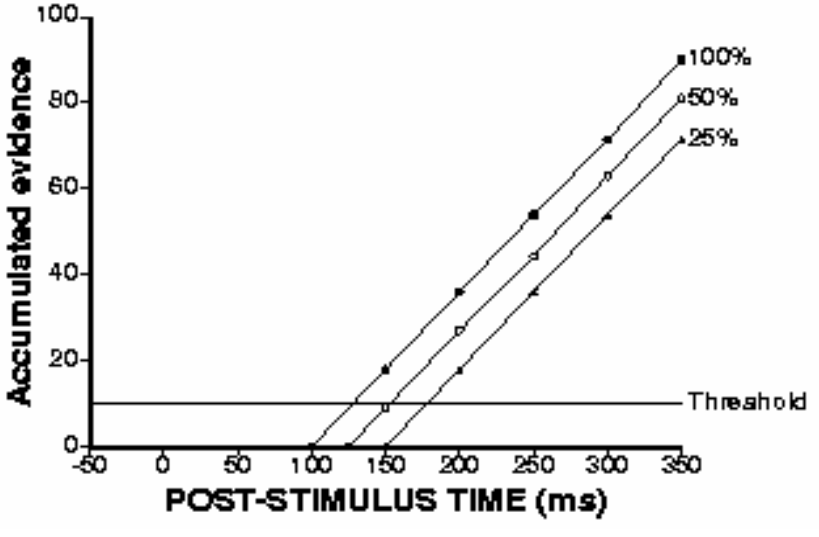
Latency change

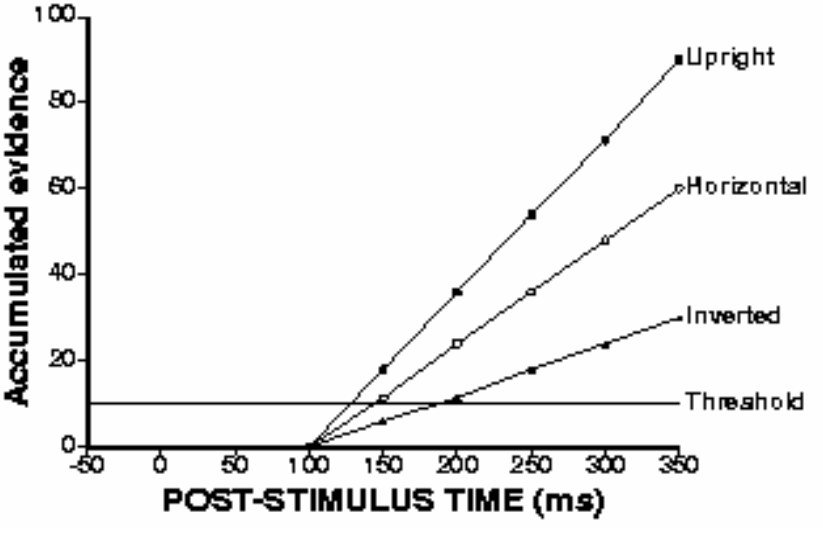


Change of magnitude



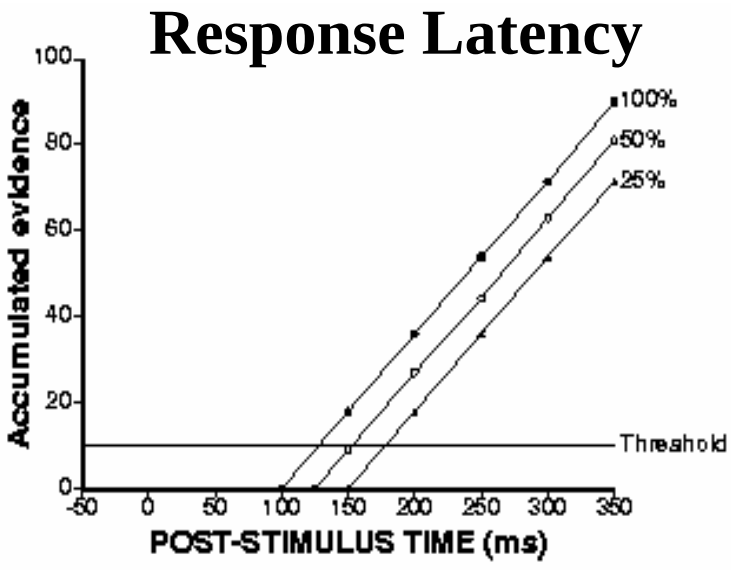
Both predict change in RT

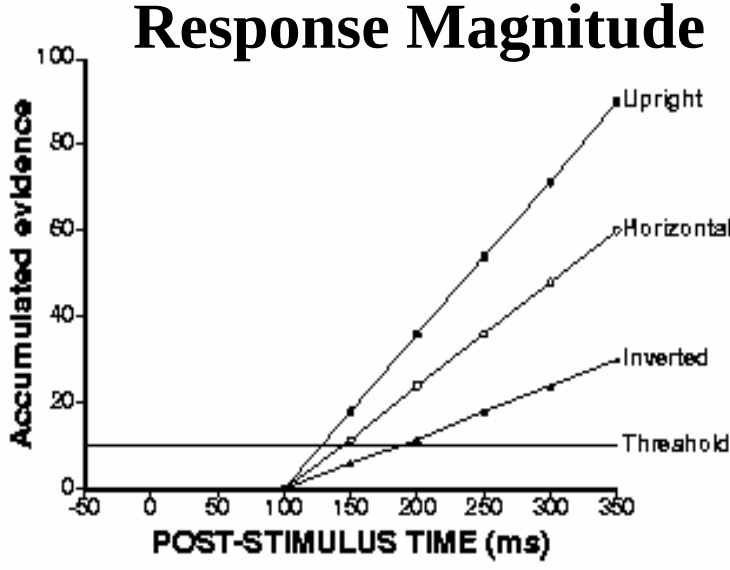




Both give RT changes

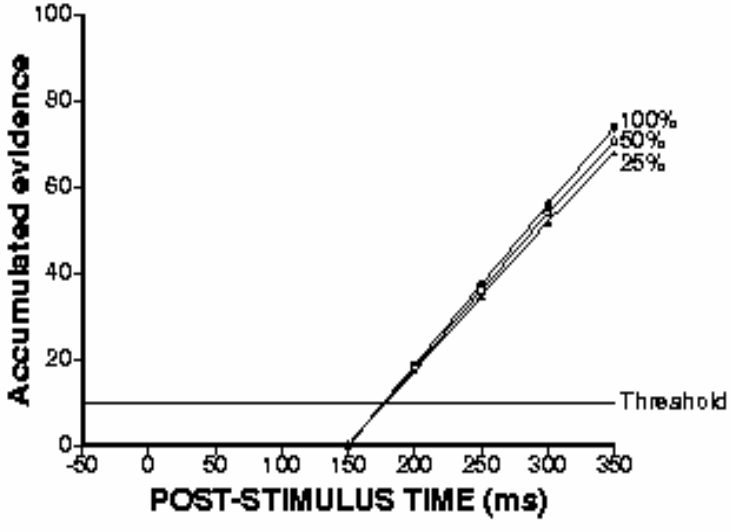
Unless can delay the start of counting

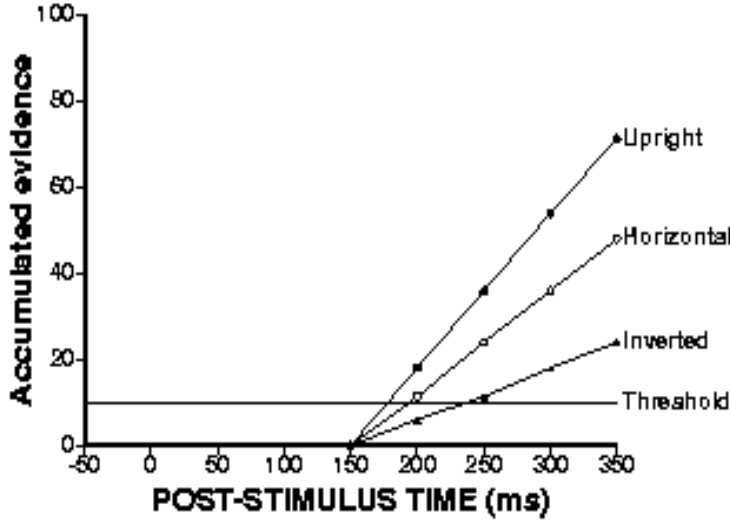




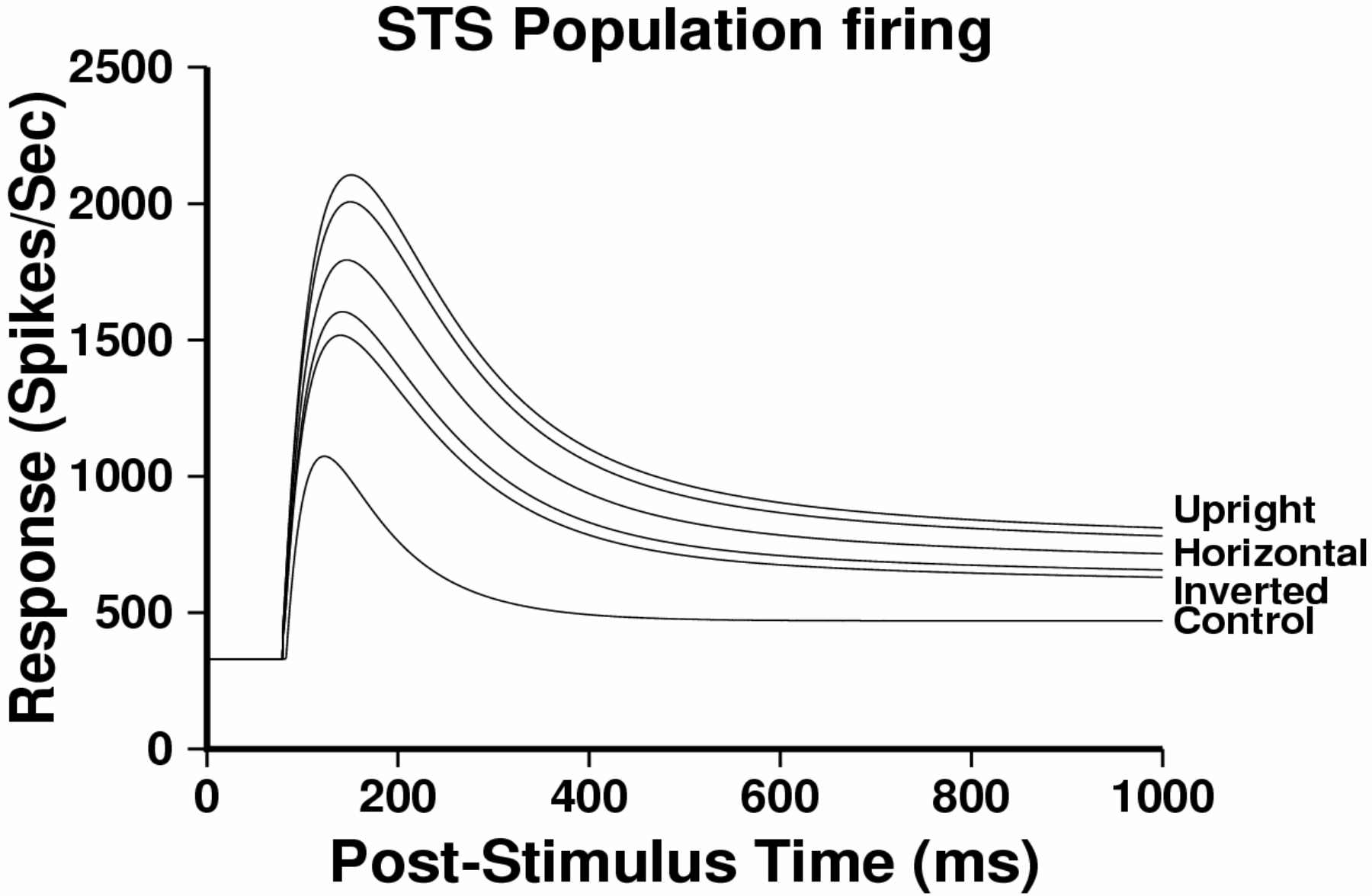
Count from 0 ms

Count from 150 ms

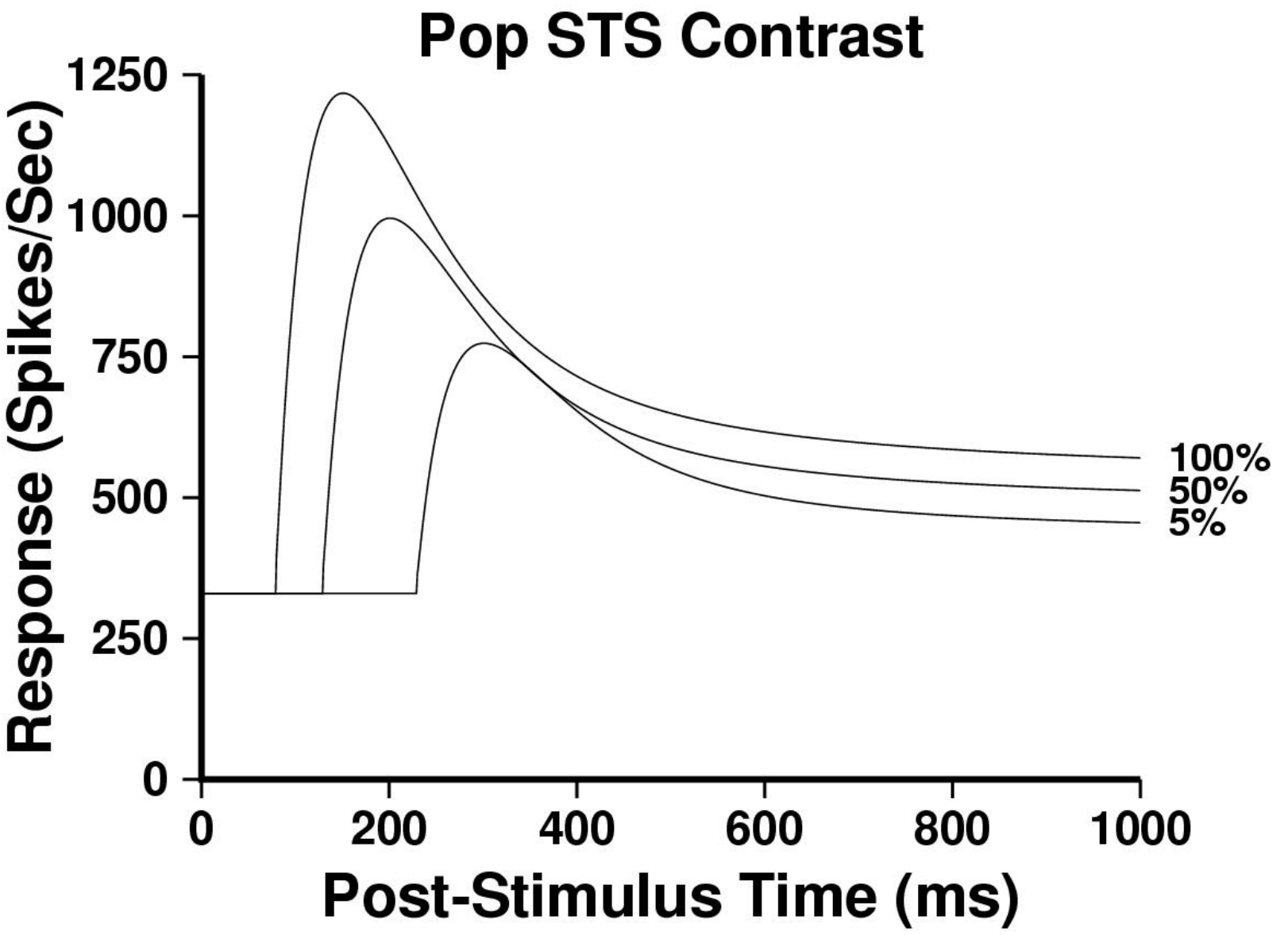




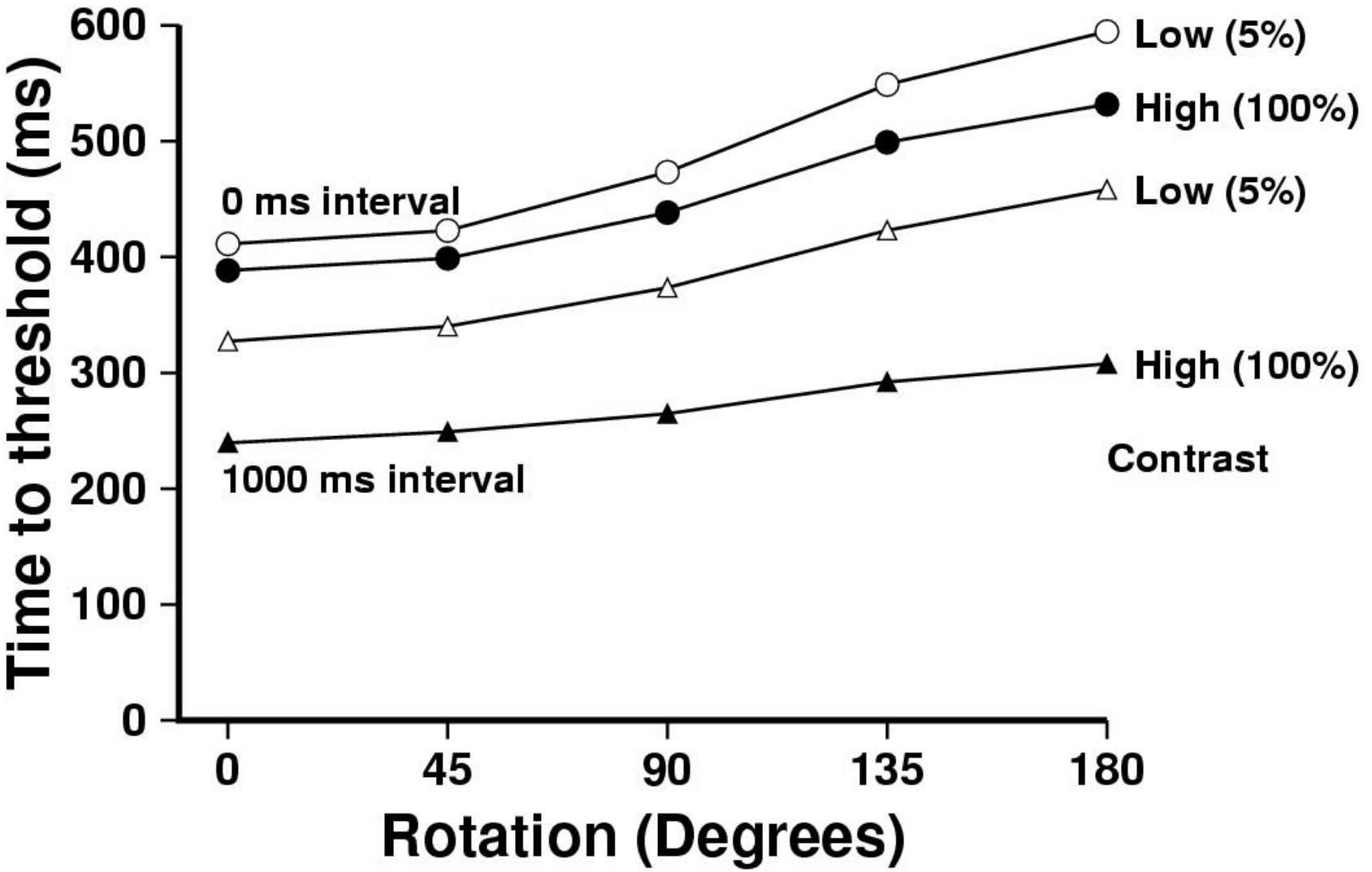
Modelling magnitude



Modelling contrast



Predicting mean RT

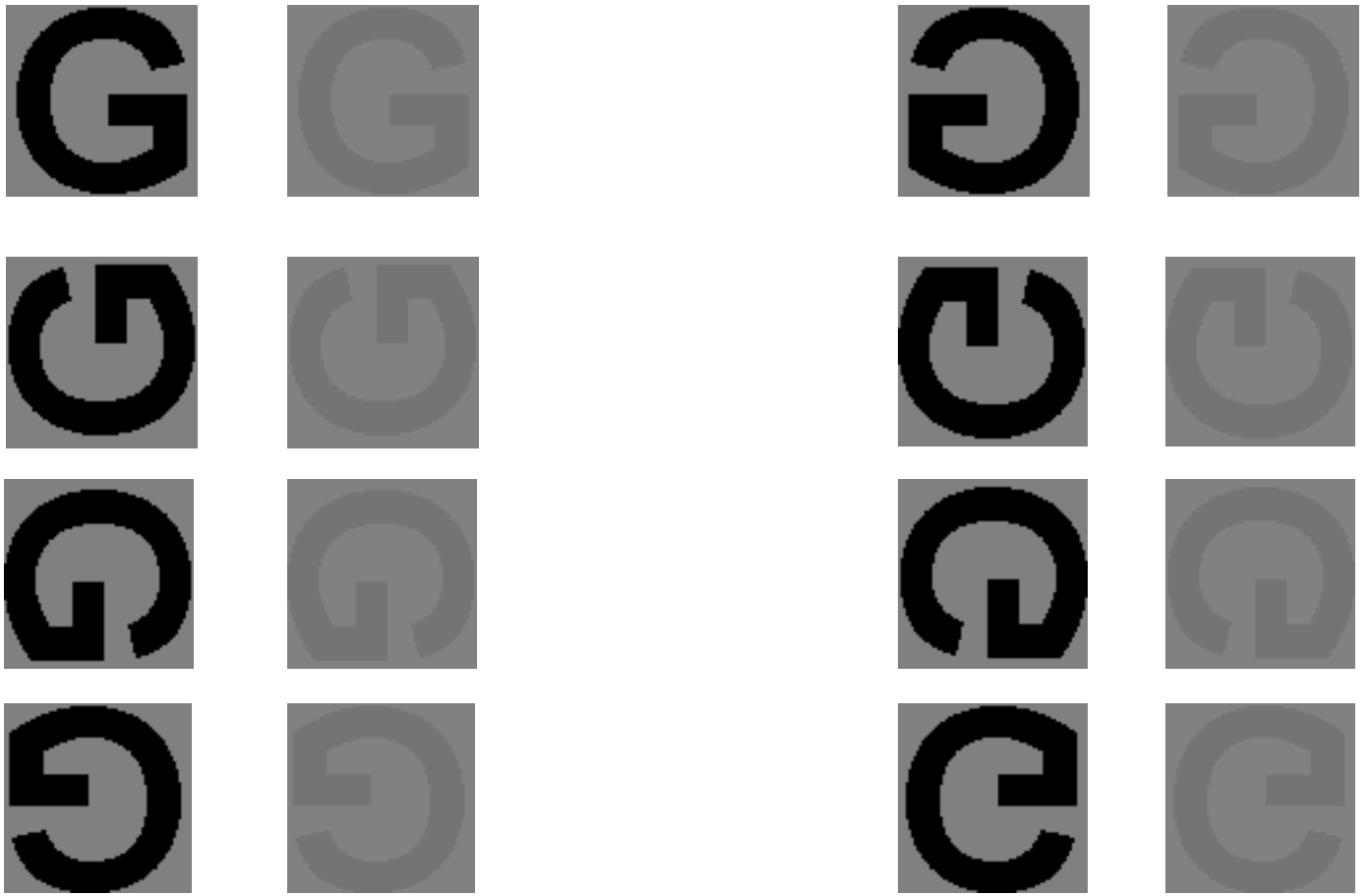


Testing mean RT predictions

- Used a dual task experimental paradigm
- Auditory task
  - odd or even number of pips
- Visual task
  - mental rotation experiment with contrast changes

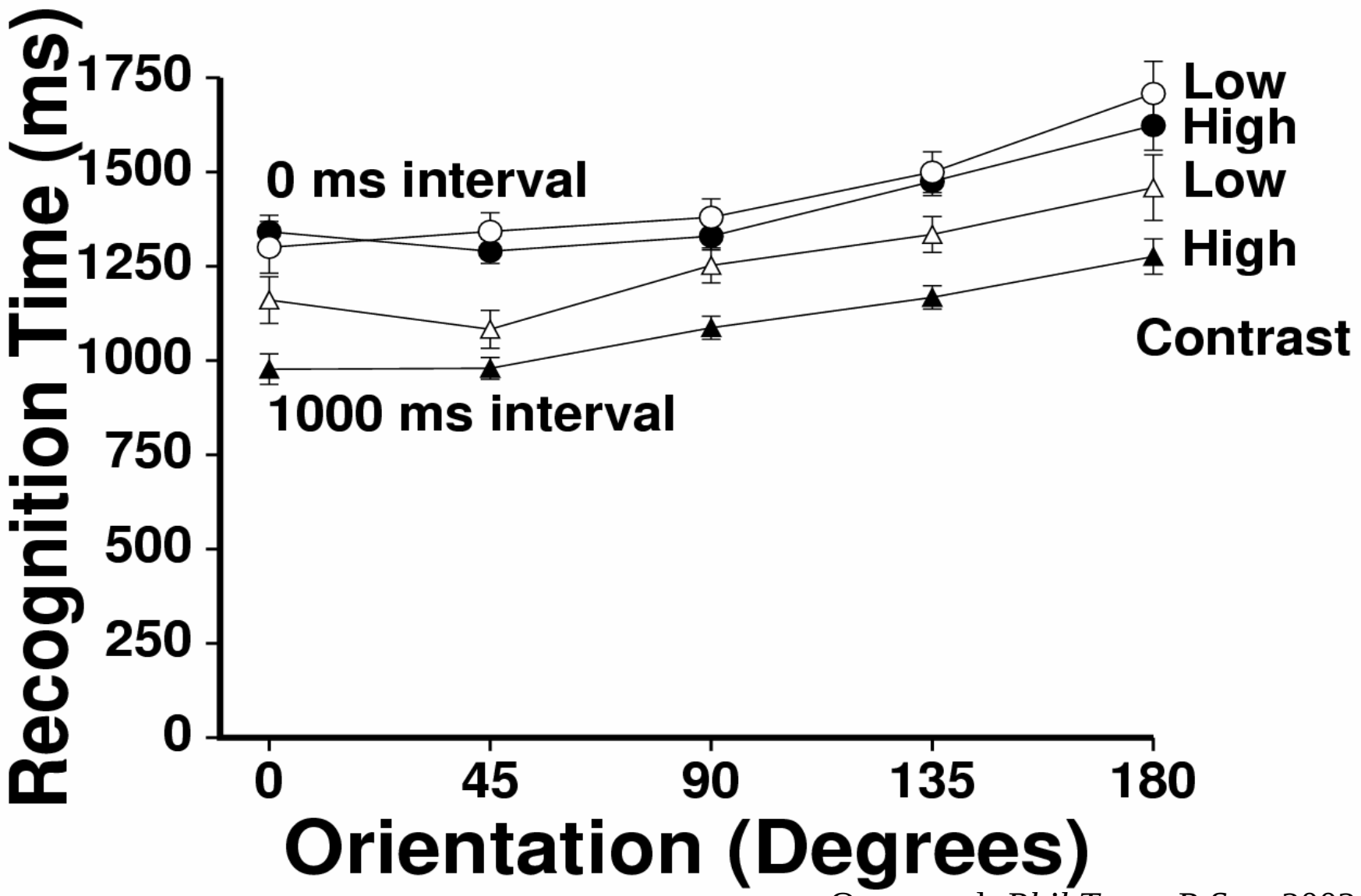
Testing mean RT predictions

Is the letter normal or mirror form?



Used G and R

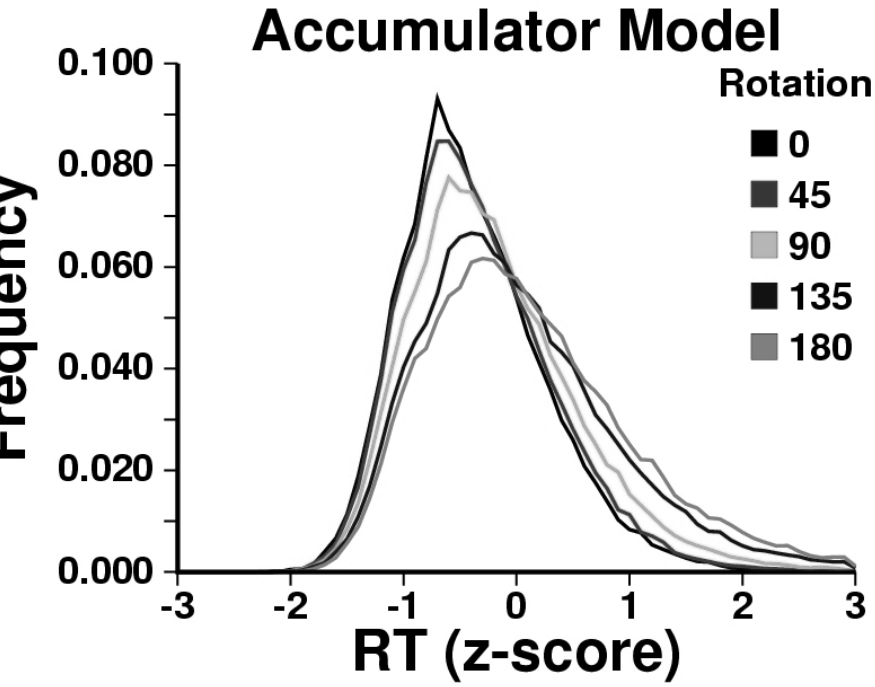
Testing mean RT predictions

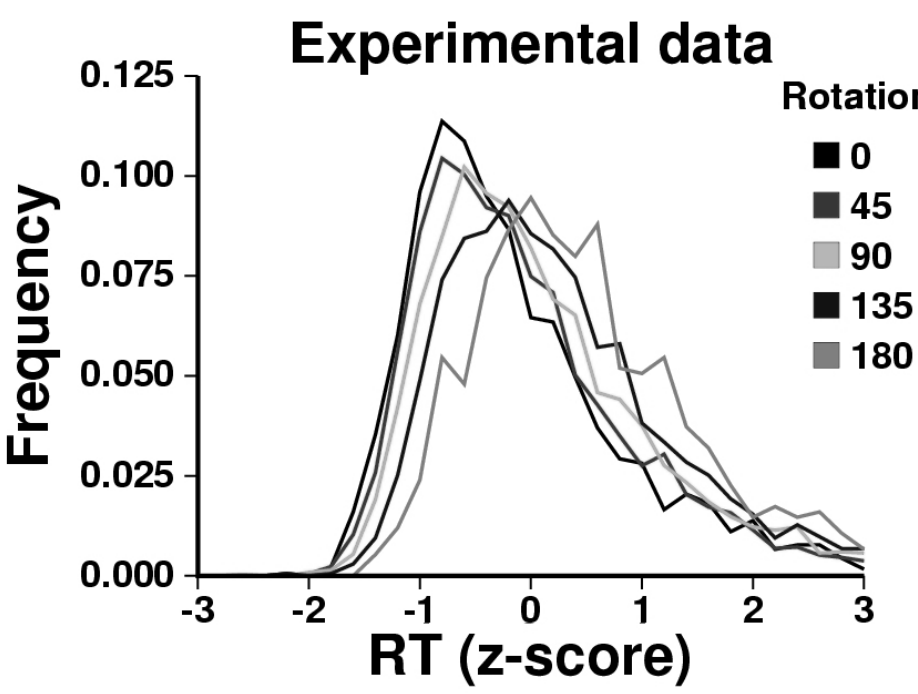


Oram et al. *Phil Trans R Soc*, 2002

Testing RT distributions

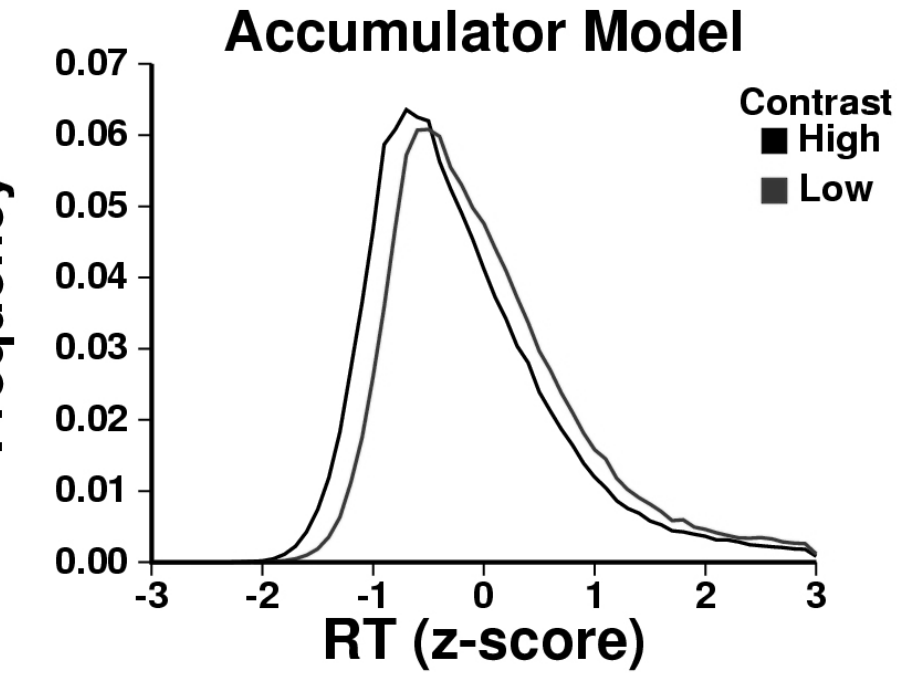
Changing orientation -> “skewing of distribution”

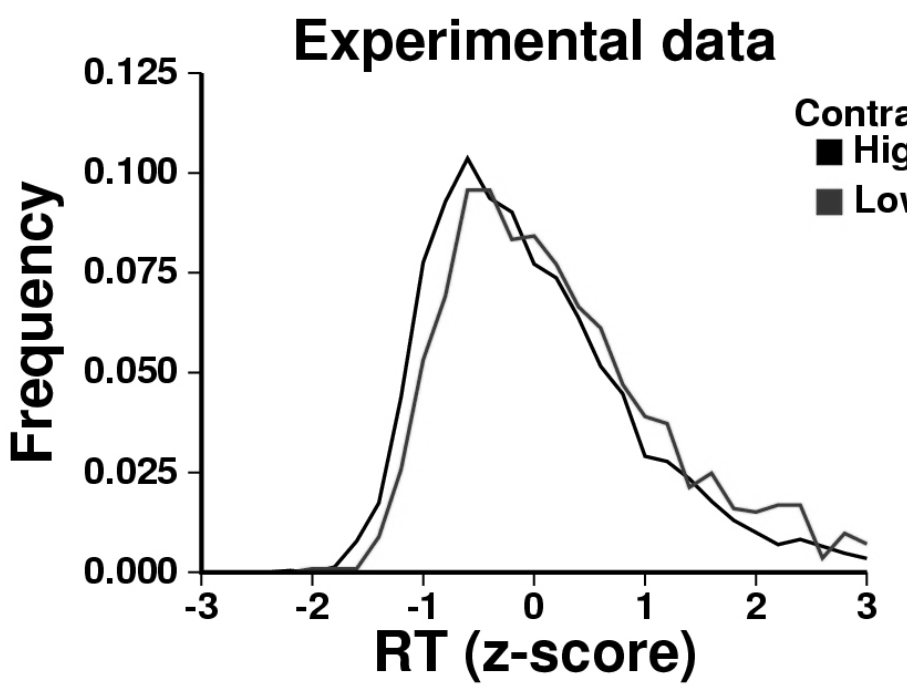




Testing RT distributions

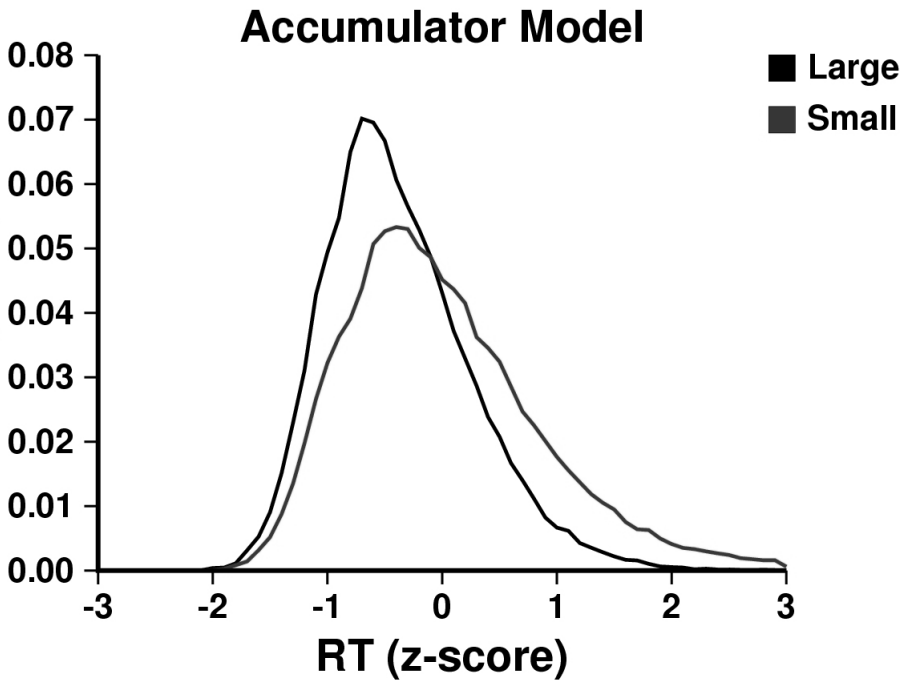
Changing contrast -> “shifting of distribution”

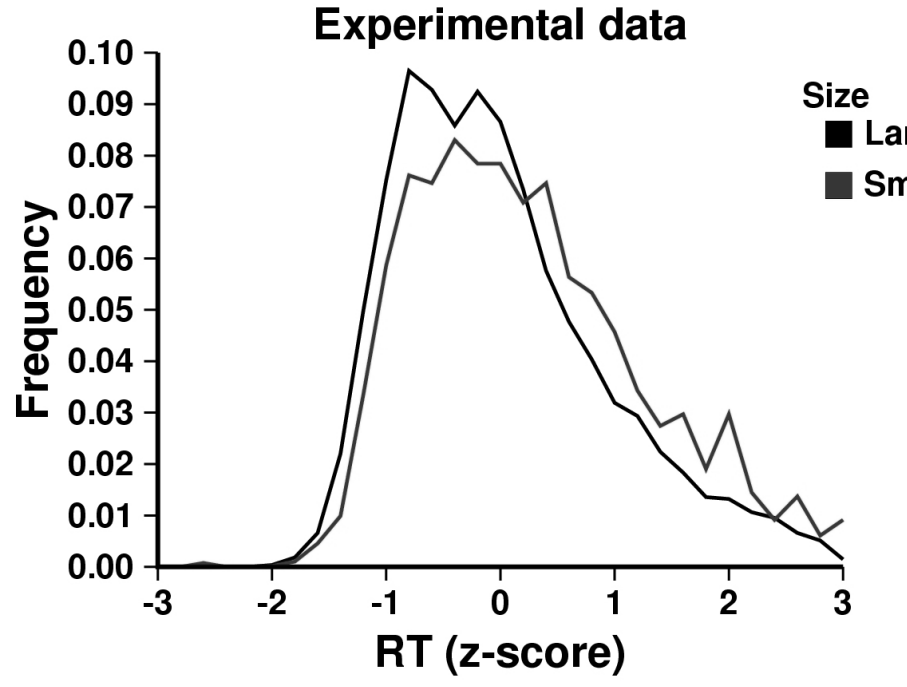




Testing RT distributions

Changing size -> “skewing of distribution”





Neural codes & cognition

- Neural codes in TE/STS
  - ✓Spike count and latency
- Implications of neural codes for cognition
  - Predicts “dual-task” results
    - Change response latency:
      - RT depends on SOA (Mean~SD relationship changes)
    - Change response magnitude:
      - RT independent of SOA (Mean~SD relationship constant)