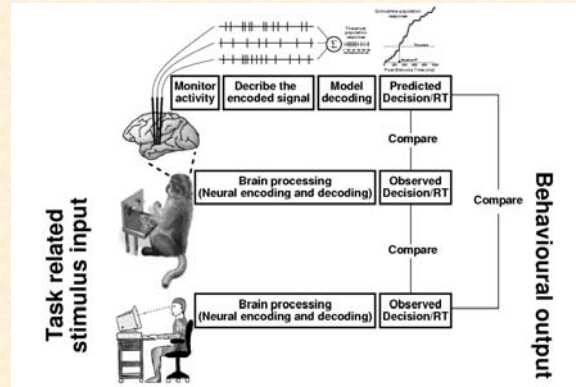


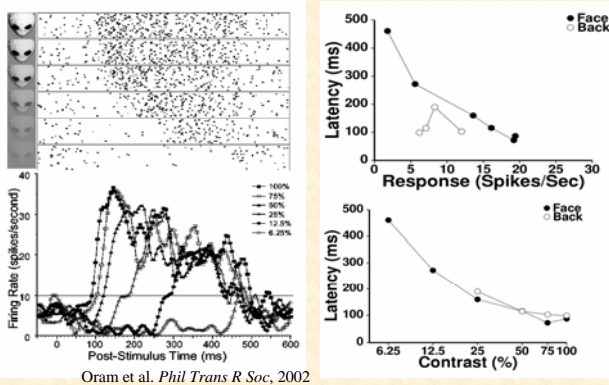
The relationship between neuronal activity and behaviour: From neuronal codes to cognitive processes and perception

Mike Oram
School of Psychology
University of St Andrews

Framework of research



Stimulus contrast and response latency in TE/STS



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

Neural codes in late visual system

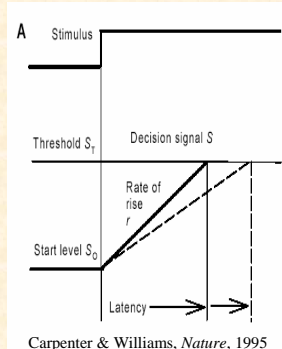
- Evidence for spike count and response latency
 - Information encoded by spike count, latency when
- Do these codes “mean” anything?
 - Spike counts
 - Micro-stimulation studies (e.g. Newsome, Parker)
 - Latency
 - How to test?
 - Can't stimulate to change latency
 - Want to relate to behaviour

Models of decisions

Information acquisition hypothesis

– Decisions when information reaches threshold

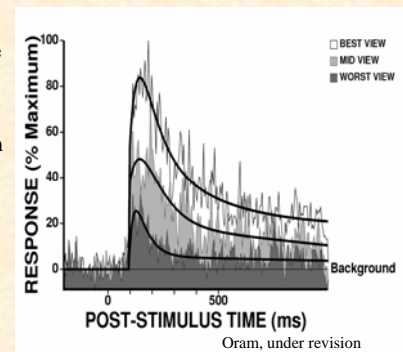
- Ratcliff 1978
- McClelland 1979
- Carpenter & Williams, *Nature* 1995
- Gold & Shadlen, *TICS*, 2001



Carpenter & Williams, *Nature*, 1995

Modeling a decision

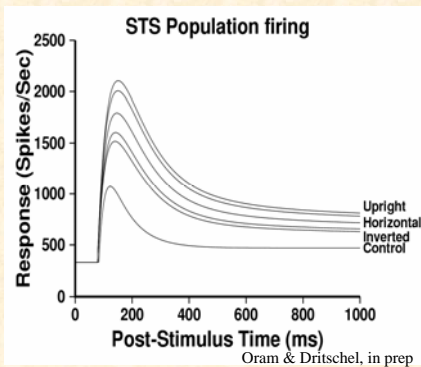
- Use simulated neural responses to generate population responses
- Individual cell response profile from Oram & Perrett 1992



Oram, under revision

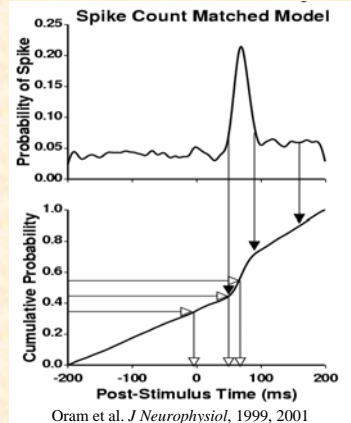
Modeling a decision

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

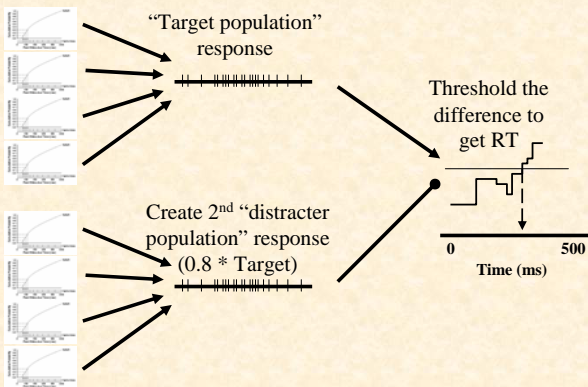


Modelling a decision

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



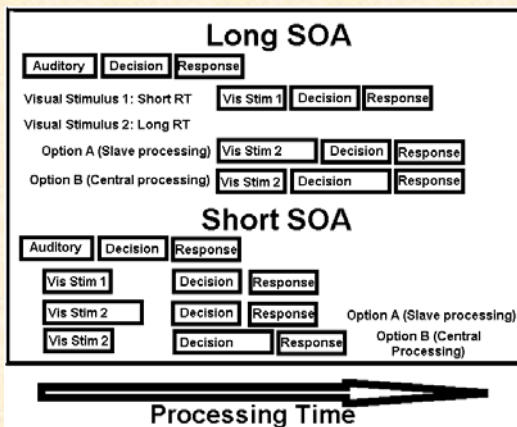
Modeling a decision



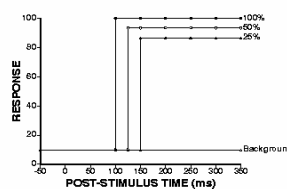
Modeling a decision

- What do neural codes predict for RT?
 - Latency (change contrast)
 - Magnitude (change orientation)
- What happens experimentally?
 - Are the codes reflected in behaviour (i.e. "mean" anything)?

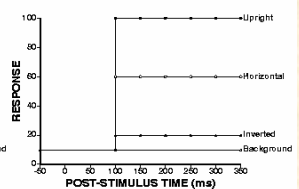
Bottle neck & dual task experiments



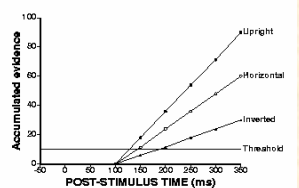
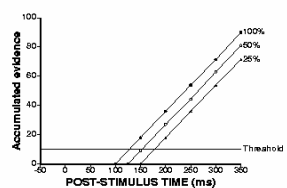
Latency change



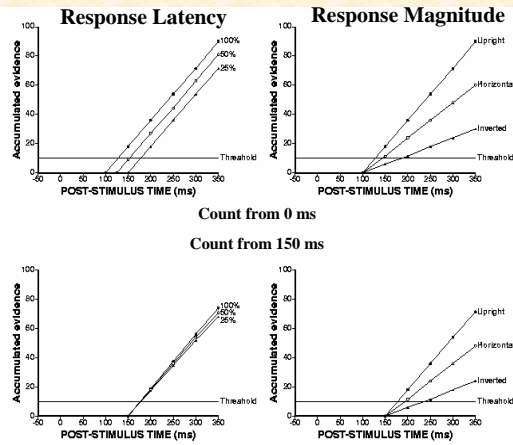
Change of magnitude



Both predict change in RT

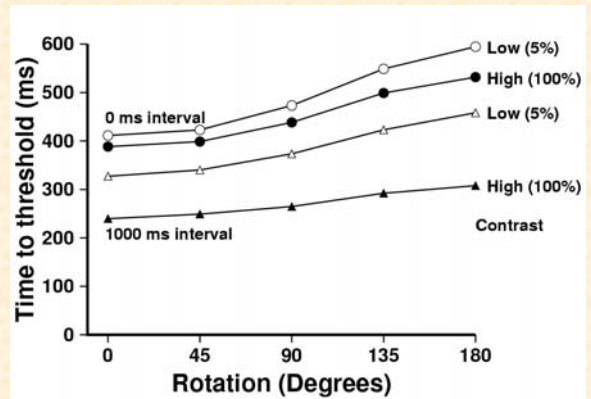


Both give RT changes



Unless can delay the start of counting

Predicting mean RT

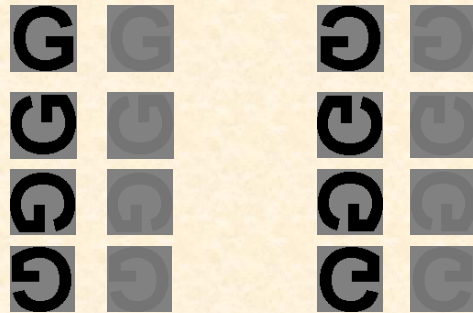


Testing mean RT predictions

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

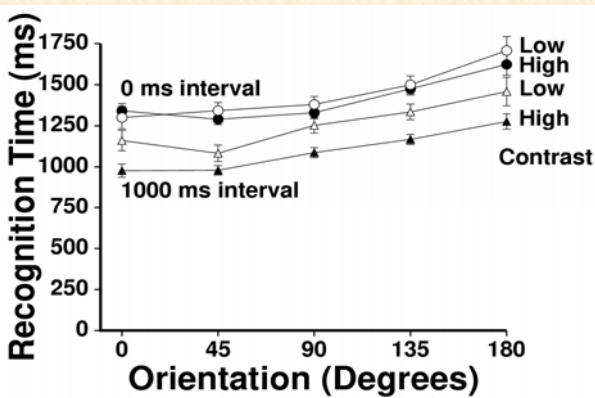
Testing mean RT predictions

Is the letter normal or mirror form?



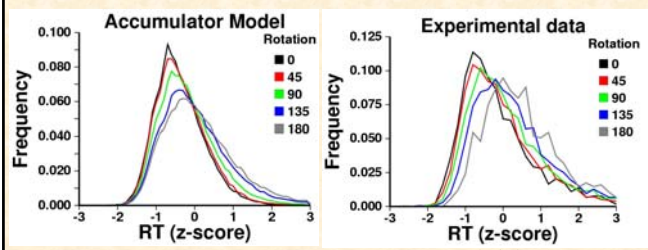
Used G and R

Testing mean RT predictions



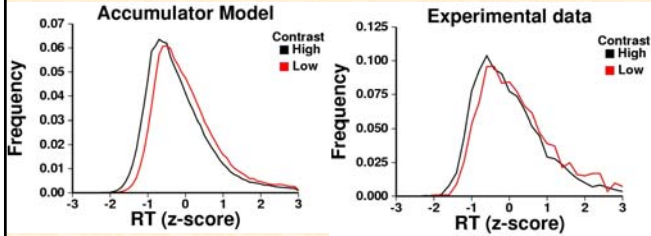
Oram et al. *Phil Trans R Soc*, 2002

Change of response magnitude causes skewing of RT distribution



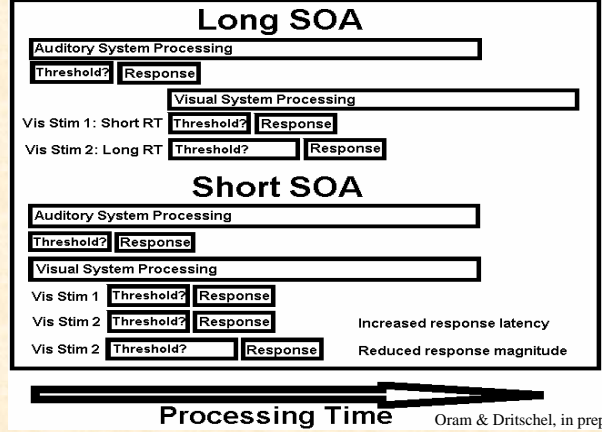
Oram, In submission, 2005

Change of response latency causes shifting of RT distribution



Oram, In submission, 2005

Time to threshold & dual task experiments



Oram & Dritschel, in prep

Visual search as signal processing

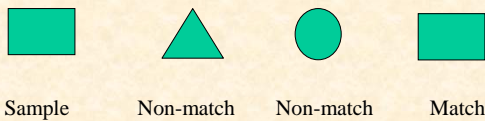
- Use the same model and apply to visual search
- Target is attended (looked for)
 - Gives a neural response “gain” of about 1.2 to 1.5
- Inhibitory interactions between neurones
 - Attention biases the interactions (see Reynolds)

A little diversion: Why is attention limited?

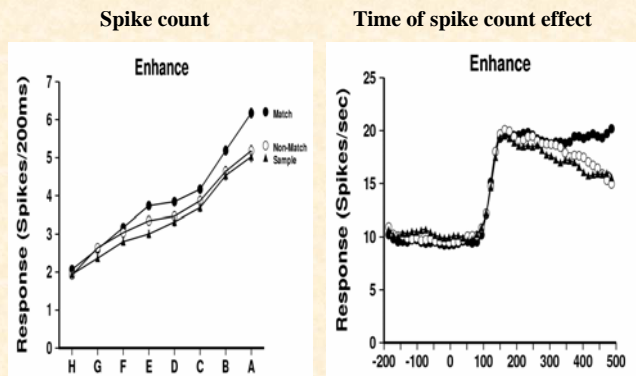
- Performance in perceptual (and other) tasks involves attention
 - Response magnitude to attended stimuli boosted
- Attention helps – but why is it limited?
 - Examine decoding of neuronal signals to help answer

Neural codes and attention

- Fixating monkey doing sequential DMS task



Coarse & medium temporal measures

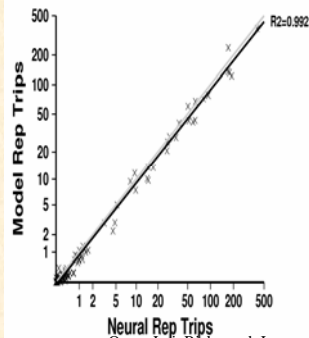
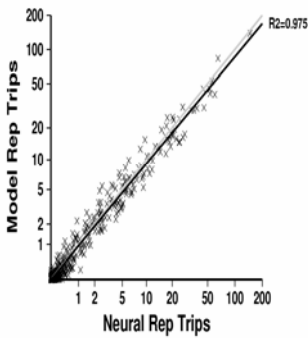


Oram, Lui, Richmond, In prep

Fine temporal response measures

Within cell repeating triplets

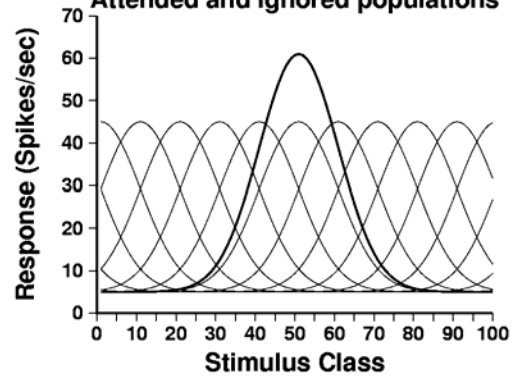
Between cell repeating triplets



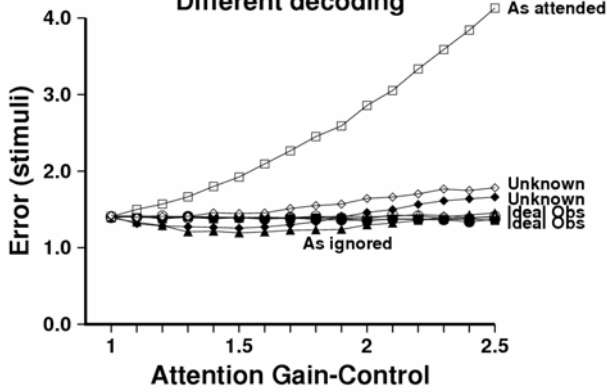
Oram, Lli, Richmond, In prep

Why is attention limited?

Attended and ignored populations



Different decoding



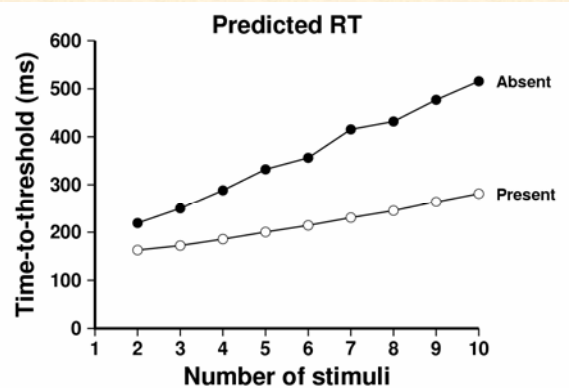
Why is attention limited?

- **Results**
 - Optimal decoding does not give highest information!!!!
 - Does about stimulus/attention combination
 - Decoding assuming ignored “better”
 - Information to attended stimuli rises faster than ideal observer
 - Error has local minimum
- **Implications**
 - Don’t want to multiplex signals about attention
 - Attention is limited because of processing constraints
 - This is NOT an “energy” based argument
 - More “energy” gives poorer performance
 - Attention is “locked” in a local minima
 - Attention is limited because of this minima

Visual search as signal processing

- Take the modelled activity levels
 - For each stimulus
 - Population 1 = maximally excited by stimulus
 - Population 2 = 0.8 max excited
 - Target population has “attention” gain
 - Do Pop1 vs 2 in **parallel** using the accumulator model

Modelling visual search



Visual search experiment



Visual search: Accumulator model

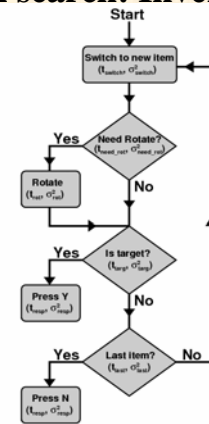
- **RT(Y) determined by orientation of target**
 - Last time-to-threshold when target identified
 - With all upright:
 - Target upright vs distracter upright
 - With all inverted:
 - Target inverted vs distracter inverted
 - With half upright, half inverted:
 - **Target upright:** Target upright vs distracter upright
 - **Target inverted:** Target inverted vs distracter inverted
- **All upright=Mix upright < All inverted=mix inverted**

Visual search: Accumulator model

- **RT(N)**
 - With all upright:
 - Non-target upright vs distracter upright
 - With all inverted:
 - Non-target inverted vs distracter inverted
 - With half upright half inverted:
 - **Non-target upright:** some non-target inverted vs distracter inverted (same as all inverted)
 - **Non-target inverted:** Non-target inverted vs distracter inverted (same as all inverted)
- **RT(N): all upright < mix inversion=all inverted**

Modelling visual search: Inversion

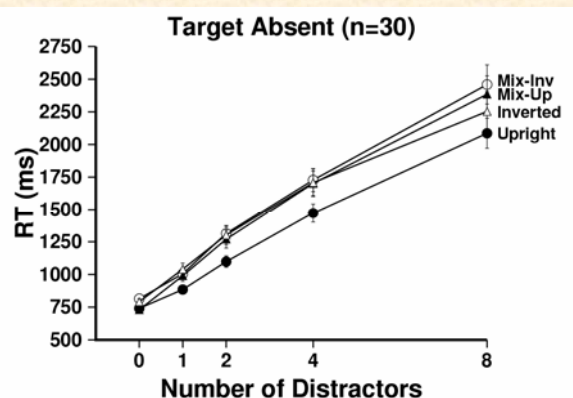
- STSS like visual search and inversion
- Guided search gives comparable predictions



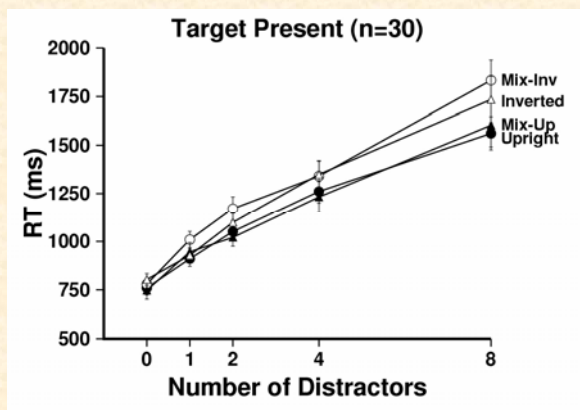
Visual search with mixed inversion

- **Self-terminating serial search model**
 - $RT(Y_{mix})$ 1/2 way between $RT(Y_{up})$ and $RT(Y_{inv})$
 - $RT(Y_{mix_up})=RT(Y_{mix_inv})$
 - $RT(N_{mix})$ 1/2 way between $RT(N_{up})$ and $RT(N_{inv})$
- **Accumulator model:**
 - $RT(Y_{up})=RT(Y_{mix_up}) < RT(Y_{inv})=RT(Y_{mix_inv})$
 - $RT(N_{up}) < RT(N_{mix})=RT(N_{inv})$

Visual search: Mixed orientation



Visual search: Mixed orientation



Neural codes & RT

- Neural codes in TE/STS
 - ✓ Spike count and latency
- Implications of neural codes for cognition
 - Predicts “dual-task” and mental rotation results
 - Change response latency:
 - RT depends on SOA (Mean~SD relationship changes)
 - Change response magnitude:
 - RT independent of SOA (Mean~SD relationship constant)
 - Predicts “visual search” results
 - Data support accumulator model over search model
 - Seen with ½ inversion conditions