Differential effects of attention and stimulus parameters in auditory bistability

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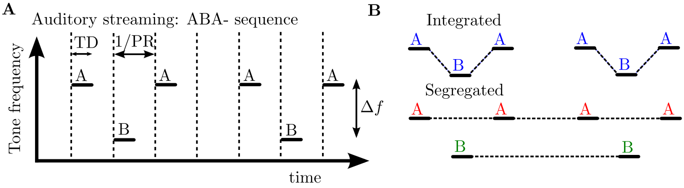

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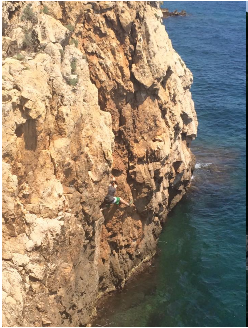
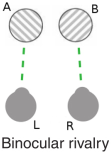
Life on the Côte d’Azur

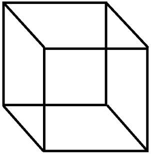
Cap d’Antibes:

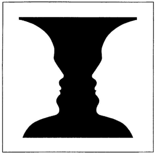


Common characteristics of perceptual bistability

Bistability due to **ambiguity** in various visual cues including, binocular, depth, figure-ground, motion, . . .







Common properties of rivalry (Leopold and Logothetis 1999):

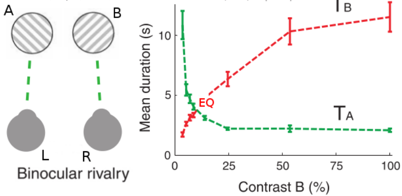
- Exclusivity: one interpretation at a time
- Inevitability: percept changes eventually
- Randomness: variable durations

Common relationship between stimulus parameters and mean dominance durations?

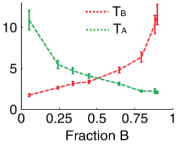
Asymmetry and stimulus parameters

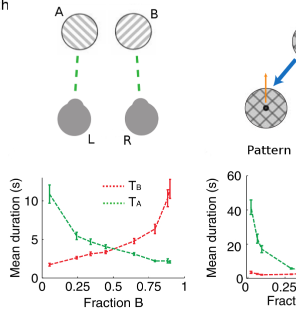
Moreno-Bote et al (2010) stimulus parameters around equidominance and generalised Levelt's Proposition II (1968).

Moreno-Bote, Shpiro, Rinzel, & Rubin *Journal of Vision* (2010)



Redefine stimulus strength as percentage time B

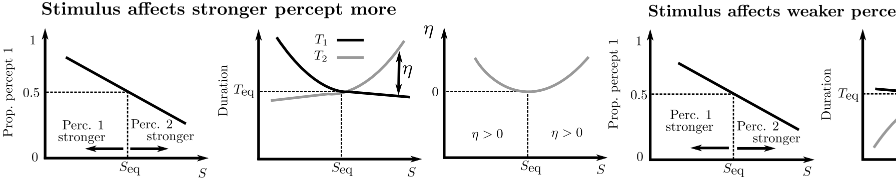




With increased input strength: The mean dominance duration of the stronger percept changes more than the weaker percept.

General bistability experiment

- Consider alternations between Percet 1 and Percept 2
- Parameter S shifts proportion dominance from P1 to P2.
- Equidominance at S_{eq}

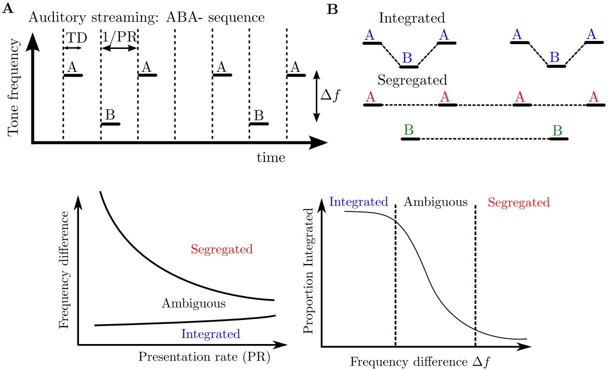


Define η: Difference between upper and lower branches

- $\eta > 0$: effects stronger more
- $\eta < 0$: effects weaker more

Bistability in auditory streaming

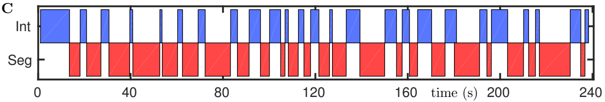
A bistable auditory stimulus [df1 df15] (van Noorden 1975):



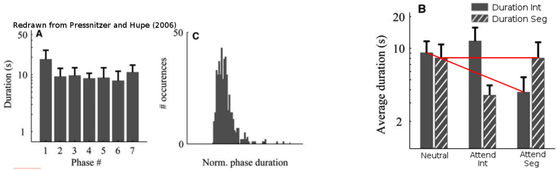
Question: Does varying Δf in auditory bistability affect stronger percept more?

Auditory bistability and attention

Experiment 4 minute trial:



- Pressnitzer and Hupé (2006) found exclusivity, inevitability and randomness



- Also looked at attention (e. g. "hold segregated")

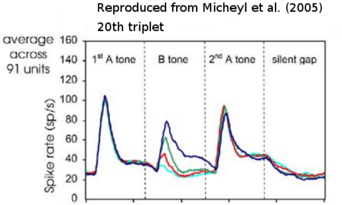
With attention: Mean dominance duration of the unattended (weaker) percept changes more than that of the attended percept. ($\eta < 0$)

Goals

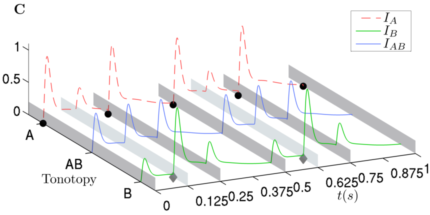
- Develop a physiologically motivated, **neuromechanistic model** of the dynamics of auditory bistability
- Question: Does varying Δf in auditory bistability affect stronger percept more?
- Investigate this question with our model and test predictions in new **psychoacoustic experiments**
- Explain differences between stimulus parameter manipulations and attention with our model

Model above and taking input from A1

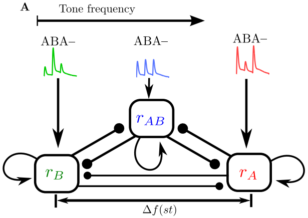
A1 recordings in Macaque (Micheyl et al 2005):



We mimic the Δf-dependence of A1 responses:



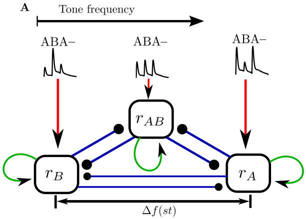
Our model:



Three unit model (above A1) inspired by Fishman et al (2001):

- Input to each unit depends on Δf

Mechanistic details for three-unit model



Mechanisms for competition:

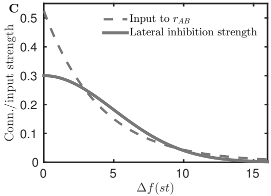
- Mutual inhibition (depends on Δf)
- Adaptation (spike frequency w/ str g)
- Noise (indep. OU-process per unit: χ_*)

(Laing & Chow 2002, Shpiro etal 2009)

$$\tau_r \dot{r}_{\mathrm{AB}} = -r_{\mathrm{AB}} + F\Big(\beta_e e_{\mathrm{AB}} - C_i(0) r_{\mathrm{AB}} - C_i(\Delta f/2)(r_{\mathrm{A}} + r_{\mathrm{B}}) - g a_{\mathrm{AB}} + w(\Delta f/2)(I_{\mathrm{A}} + I_{\mathrm{B}}) + \chi_{\mathrm{AB}}\Big).$$

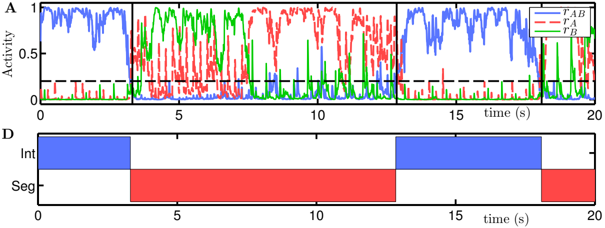
Features specific to auditory model:

- Pulsatile inputs with silent epochs
- Slow NMDA-excitation to sustain activity
- Δf-dependence of input and inhibition

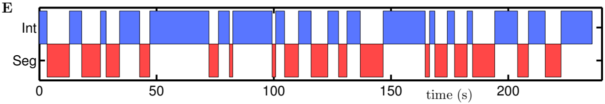


Encoding the competing percepts in the model

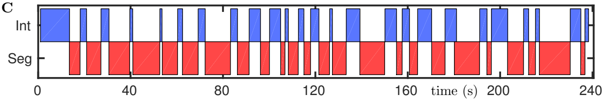
- r_{AB} encodes integrated
- r_A and r_B encode segregated



Model 4 minute simulation:



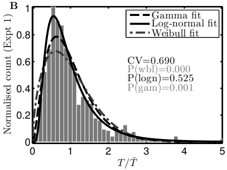
Experiment 4 minute trial:



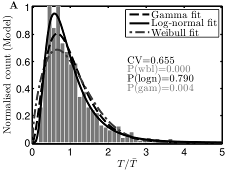
Switch statistics and van Noorden

Switching rate and CV used to constrain parameters.

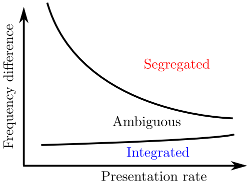
Pilot data ($\Delta f = 5\,\mathrm{st}$):



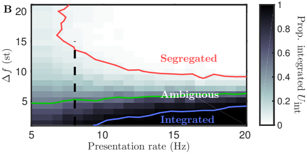
Model ($\Delta f = 5\,\mathrm{st}$):



van Noorden (1975), 1st phase only:



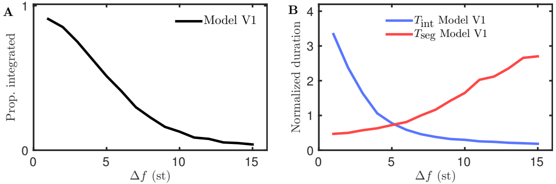
Model (2nd+ phases):



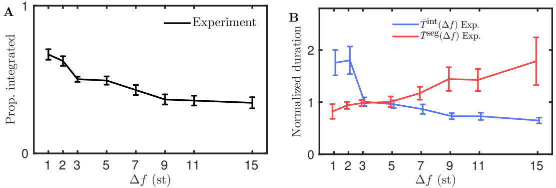
Assumption: post build-up alternations conform to a van-Noorden-like regions of perceptual dominance

Model prediction for varying Δf

Model prediction (in line with visual bistability):



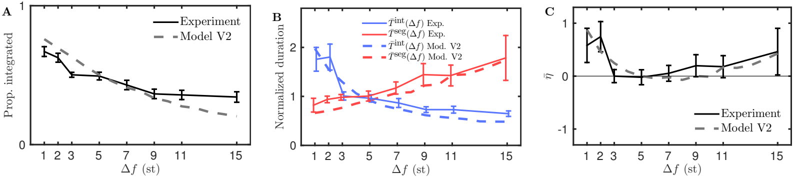
Experiment with $N = 15$ subjects, 4 minute trials (3 repeats), 2AFC task, data for 2nd+ durations only.



Qualitative prediction is correct, quantitative agreement poor.

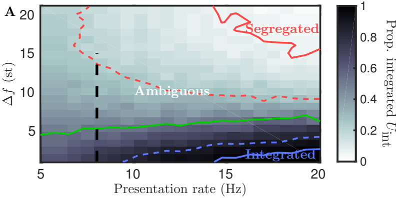
Relax van Noorden assumption, improve fit

Change to global inhibition (rather than decay with Δf).

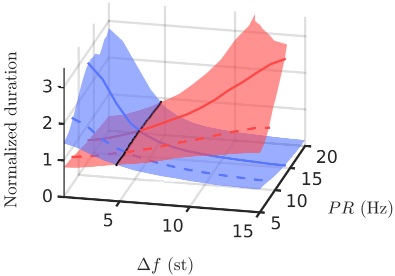


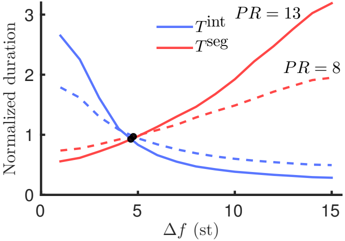
Further predictions from constrained model

Alternations over wider range of Δf and PR:



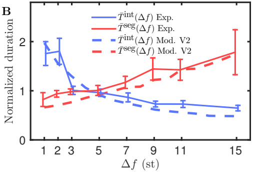
Bias towards stronger percept should increase with PR:

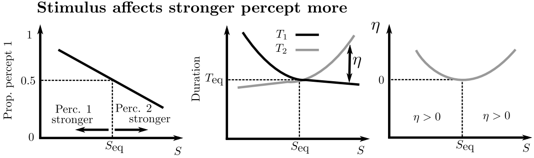




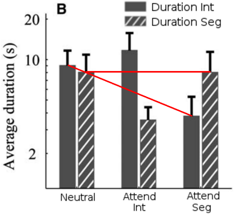
Opposite effect of stimulus and attention

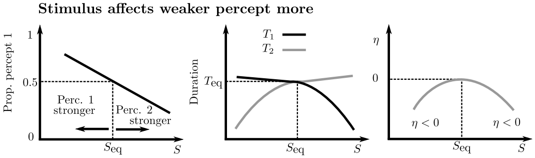
Stimulus parameter Δf affects stronger percept more:





Attention effects weaker percept more:



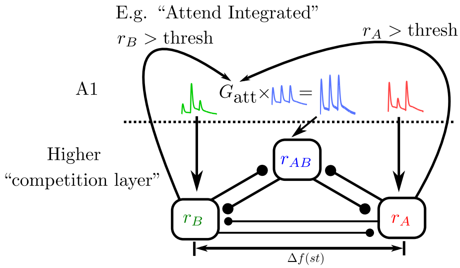


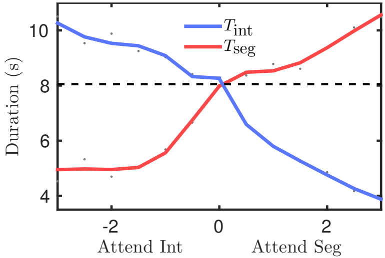
How can we explain this with our model?

Top-down attentional control mechanism

We propose a state-dependent input gain mechanism

- e.g. "Attend integrated": give extra input to r_{AB}, but **only when** r_A and r_B are active





Summary

Main results:

- **Neuromechanistic model** captures bistable dynamics
- The predicted **bias towards the stronger percept** for stimulus manipulations confirmed in new experiments

Predictions:

- Model predicts **switching over wider range than van Noorden** (supports findings of Denham et al 2013)
- Bias towards stronger percept increases with PR

Mechanistic explanation:

- Proposed **top-down** control mechanism can account for differences in stimulus manipulations and attention