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Neurodynamical Model for the Multi-stable Perception of Biological Motion

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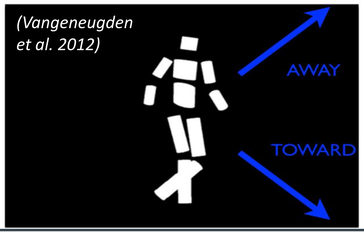
Introduction

- Body motion stimulus can induce bistable perception (Vanrie et al. 2004; 2006; Vangeneugden et al. 2012; Schouten et al. 2011).
- The perception of body motion has been modelled using physiologically plausible architectures (Giese & Poggio, 2003; Lange & Lappe, 2006). These models cannot deal with perceptual multi-stability.
- **Repetition suppression/enhancement**: response adaptation to repetitive stimuli is important in fMRI paradigms in order to increase selectivity of analysis.
- Ambiguous results from fMRI adaptation paradigms for action stimuli (e.g. Dinstein et al. 2006; Lingnau et al. 2009).
- No or very weak repetition suppression observed at the single cell level for action stimuli (Caggiano et al. 2013; Kilner et al. 2014).

Bistable body-motion stimulus



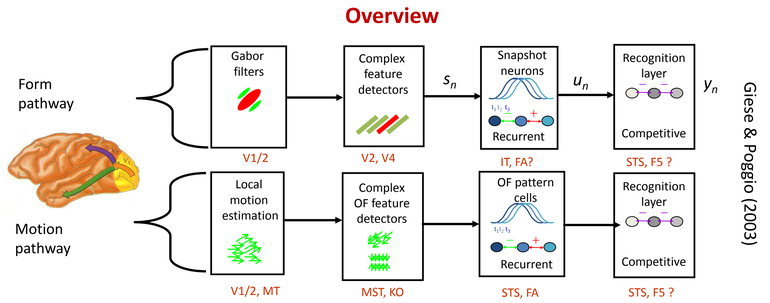
- No disparity cues.
- Upper and lower body consistent with motion in different directions.
- Two movement directions are perceived in alternation; perceptual switching (Vanrie et al. 2006).
- Similar multi-stability for natural walkers in oblique projection.
- Perceptual multi-stability observed for many other perceptual phenomena (reviews e.g. Blake et al. 2001, Leopold et al. 1999).

Goal

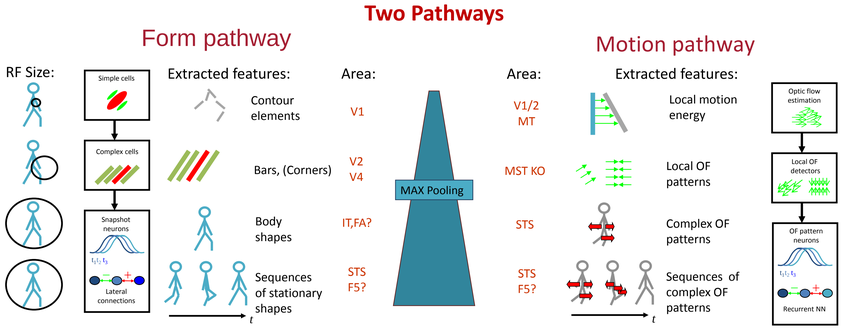
- **Development of a model that accounts for these dynamic phenomena in body motion perception.**

Neural model for body motion perception

Overview



Two Pathways



Mechanism for temporal sequence selectivity: 1D Neural Field

Dynamics of the membrane potential of snapshot neurons: DNF (Amari, 1977)

$$\tau_u \dot{u}(\theta,t) = -u(\theta,t) + w(\theta) * 1(u(\theta,t)) + s(\theta,t) - h$$

- Sequence selectivity emerging from asymmetric lateral connections.
- Stimulus-locked **stable travelling pulse solution.** (Zhang 1996; Xie & Giese 2002).

u: membrane potential
s: shape detector output
θ: snapshot no.
w: interaction kernel
h: resting potential
*: convolution

Extension: 2D Neural Field for view selectivity

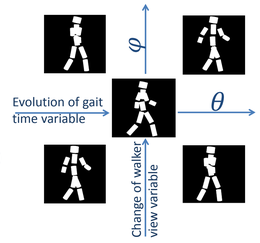
$$\tau_u \dot{u}(\varphi,\theta,t) = -u(\varphi,\theta,t) + w(\varphi,\theta) * 1(u(\varphi,\theta,t)) + s(\varphi,\theta,t) - h$$

$$-\alpha a(\varphi,\theta,t) + \varepsilon(\varphi,\theta,t);$$

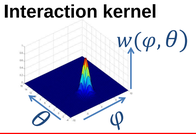
$$\tau_a \dot{a}(\varphi,\theta,t) = -a(\varphi,\theta,t) + 1\big(u(\varphi,\theta,t)\big);$$

- Second dimension: view angle φ.
- Noise term: ε.
- Adaptation process (adaptation level a) increases thresholds of activated neurons.

Field dimensions



Interaction kernel

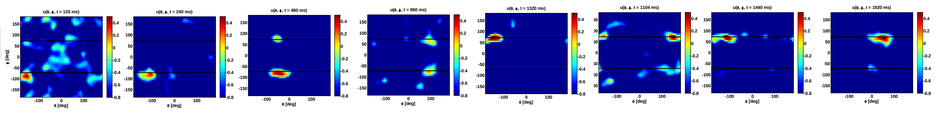


Simulation results

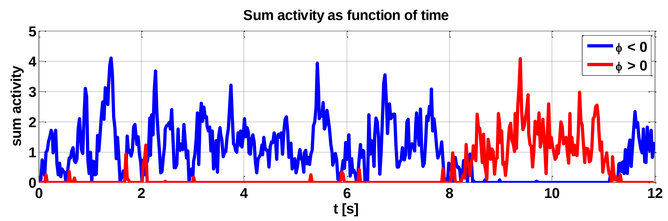
1) Reproduction of perceptual bistability:

- Ambiguous view results in competition between solutions representing two opposite views.
- Perceptual switches induced mainly by internal noise (adaptation too weak).

Time course of activation distribution for a perceptual switch



Sum activity as function of time

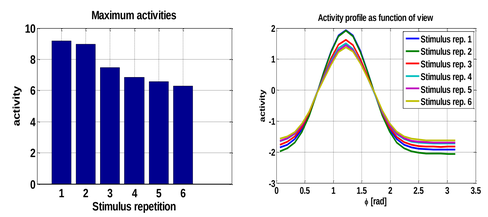


- Sum activity of neurons encoding *negative* views
- Sum activity of neurons encoding *positive* views

Giese (2014)

2) Reproduction of adaptation data for static stimuli in area IT:

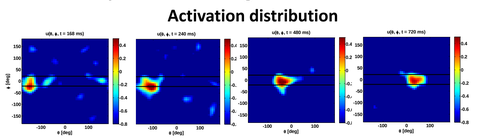
- Fitting parameters for symmetric interaction kernel.
- Reproduction of data from area IT (de Baene & Vogels, 2010).
- Activity decays by about 30 %.
- Tuning curve becomes wider and deforms no 'output fatigue' mechanism (e.g. Grill-Spector et al. 2006).



Prediction I) Bifurcation dependent on difference of compatible view angles

- For view angle differences below ±30 deg bistable solution becomes monostable and peak follows the average view (side view).

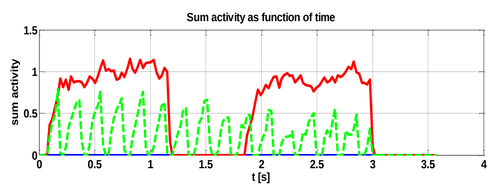
Activation distribution



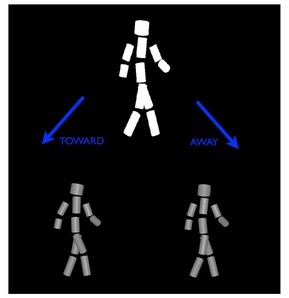
Prediction II) New action stimulus that leads to stronger adaptation

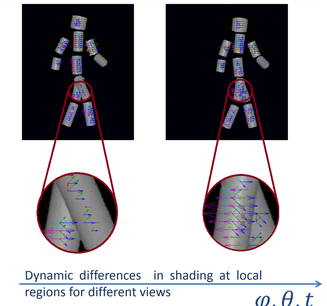
- Reproduction of weak adaptation for single repetition of action stimulus.
- Much stronger adaptation for stimulus that repeats a short sequence (for same total stimulus duration).

- Single stimulus repetition (Caggiano et al. 2012; Kilner et al. 2014)
- New stimulus

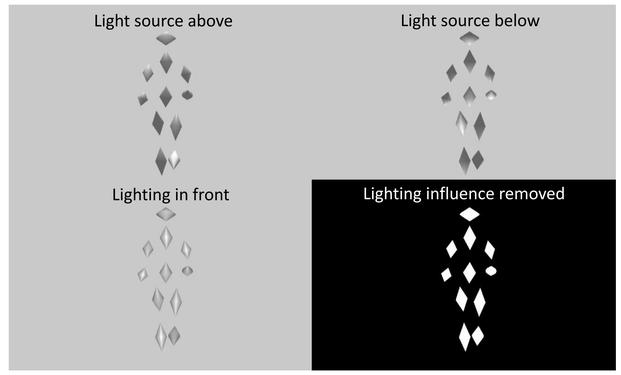


Extension: 'shading pathway'





- Addition of shading removes the bistability with respect to view.
- Model need extension by 'shading pathway'.
- Extraction of internal shading gradients provides discriminative features.
- Extraction by modified filter hierarchy.
- Interesting **new illusion** shows influence of illumination direction: 'Lighting from above prior'



Conclusions

- Extension of neurodynamical model for the encoding of body motion can account for multi-stability.
- Perceptual switches likely not driven by adaptation.
- Model accounts for weak adaptation in repetition suppression paradigms with action stimuli.
- Prediction of a new stimulus that should result in stronger adaptation.
- Influence of lighting direction on the perception of biological motion.

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Acknowledgements

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