# Cognitive Neuroimaging, Predictive Coding, and Unifying Theories of the Brain

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Centre for Cognitive Neuroimaging (CCNi)
Department of Psychology, University of Glasgow, UK

*Edinburgh – 16 June 2010*

# Cognitive Neuroimaging at the CCNi - Glasgow

3T – MRI
Siemens Tim
32 channel

TMS - EEG
128 channel
MR compatible

MEG –
Biomag 4D
248-channel
magnetometer

# CCNi Research

## people

**Principle investigators:**

Pascal Belin

Roberto Caldara

Simon C. Garrod

Marie-Hélène Grosbras

Joachim Gross

Klaus Kessler

Hartmut Leuthold

*Lars Muckli*

Guillaume A. Rousselet

Philippe G. Schyns

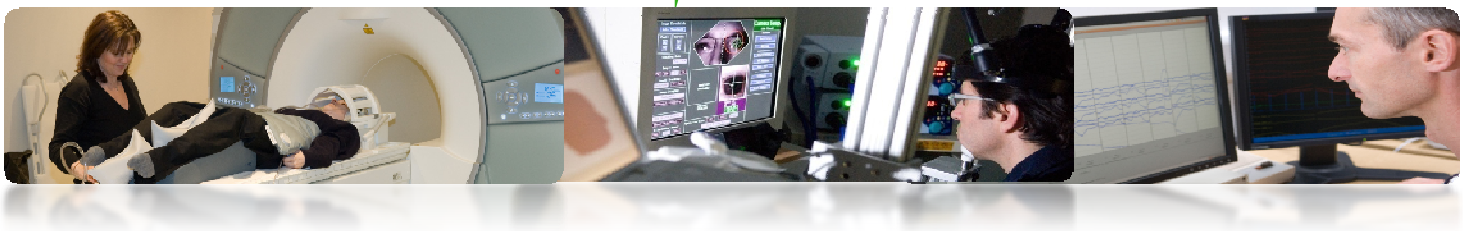
Gregor Thut

## mission

…to advance the understanding of the complex relationship between the brain, cognition and behaviour at multiple levels of analysis

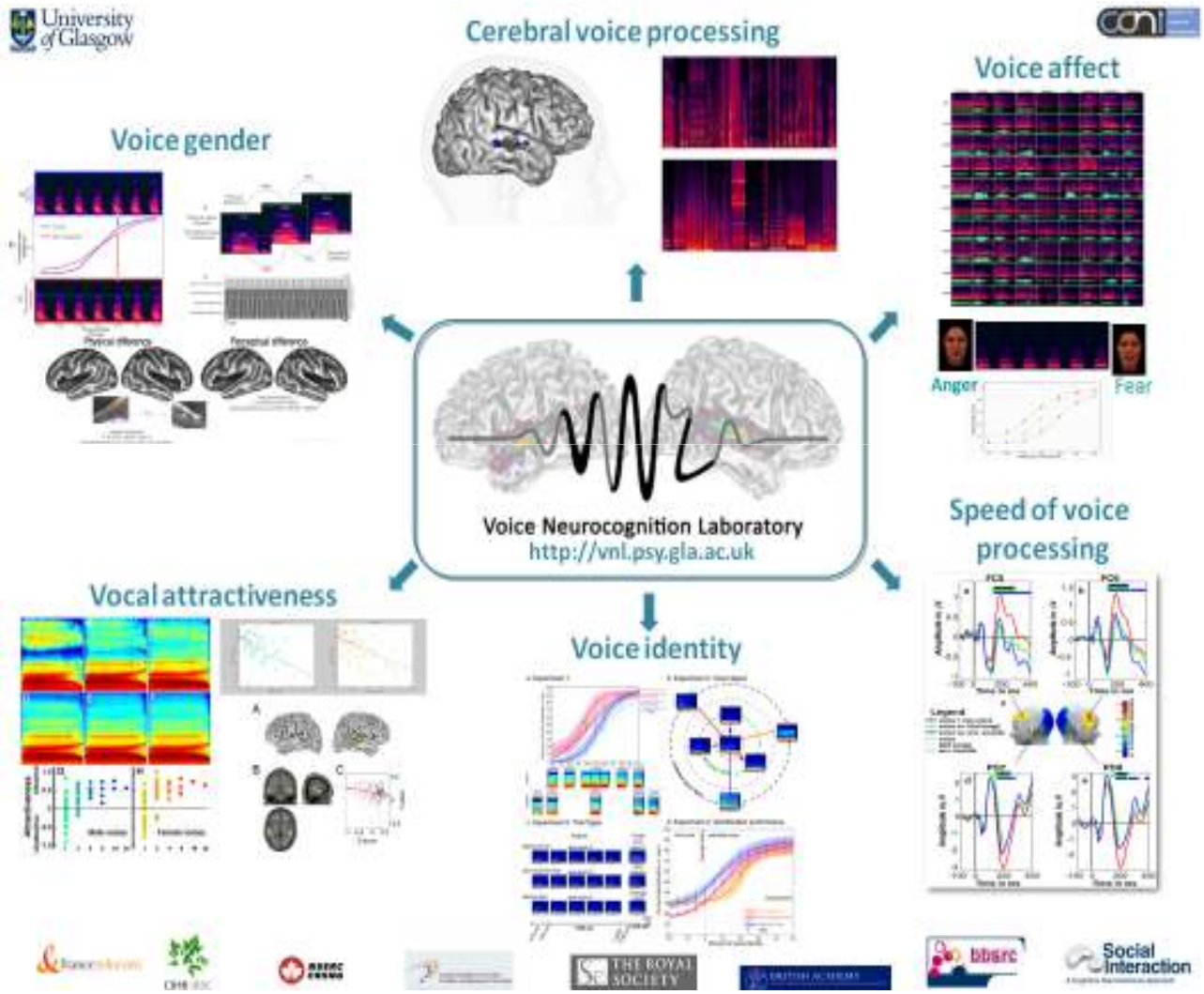
Social Interaction
A Cognitive Neurosciences Approach

bbsrc



Pascal Belin

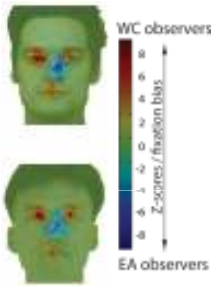
# Voice Neurocognition Laboratory



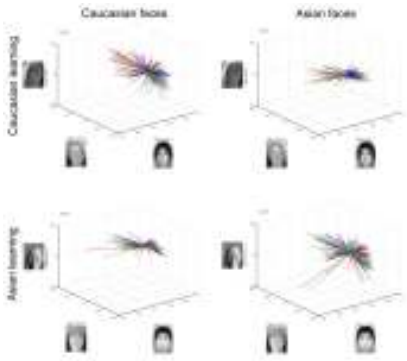
Roberto Caldara

# Cultural Neuroscience

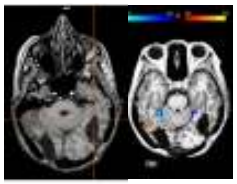
**We aim at mapping human diversity and understanding how *culture* and *race* modulate visual and social cognition, by using a *multidisciplinary approach***




EYE MOVEMENTS

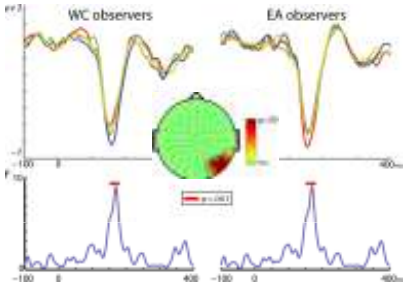


COMPUTATIONAL MODELLING

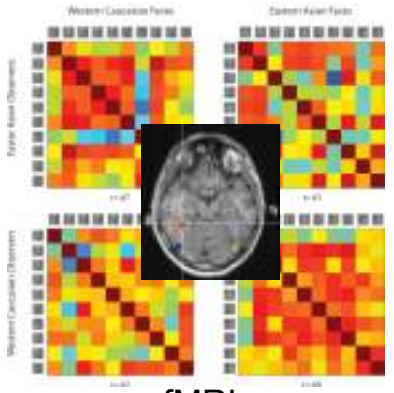


BRAIN DAMAGED PATIENTS

**roberto@psy.gla.ac.uk**




EEG



fMRI

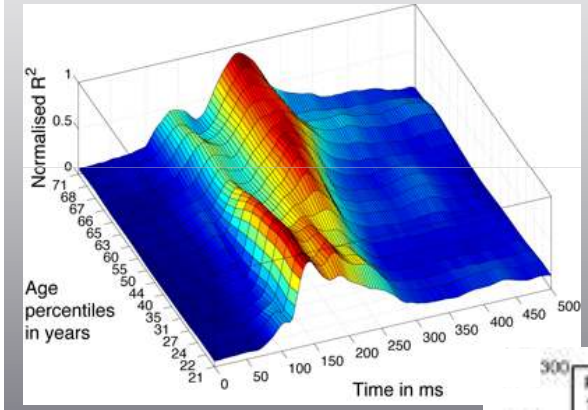
University of Glasgow Department of Psychology

CENTRE FOR COGNITIVE NEUROIMAGING

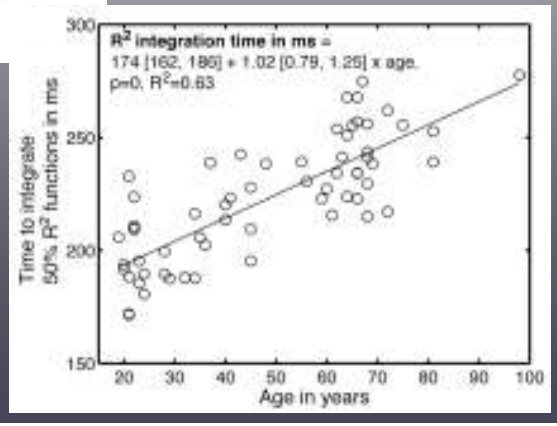
THE UNIVERSITY OF EDINBURGH

**Single-trial parametric GLM of EEG data**

Guillaume A. Rousselet & Cyril R. Pernet




**age-related delay in EEG sensitivity to phase noise**




Rousselet, Pernet et al.

*BMC Neuroscience* 2008
*BMC Neuroscience* 2009
*Frontiers in Perception Science* 2010

g.rousselet@psy.gla.ac.uk

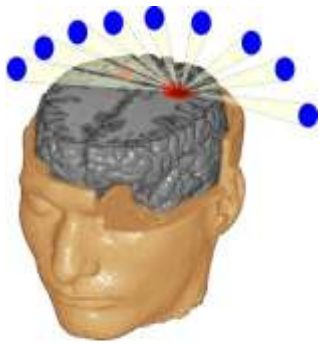
# Joachim Gross

**Research Interest:**

Large-scale neural communication

Role of neural oscillations in cognition

Conscious perception



**Methods**:

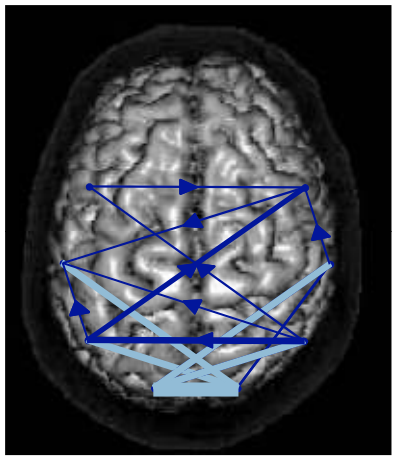
Magnetoencephalography (MEG)

Spectral analysis

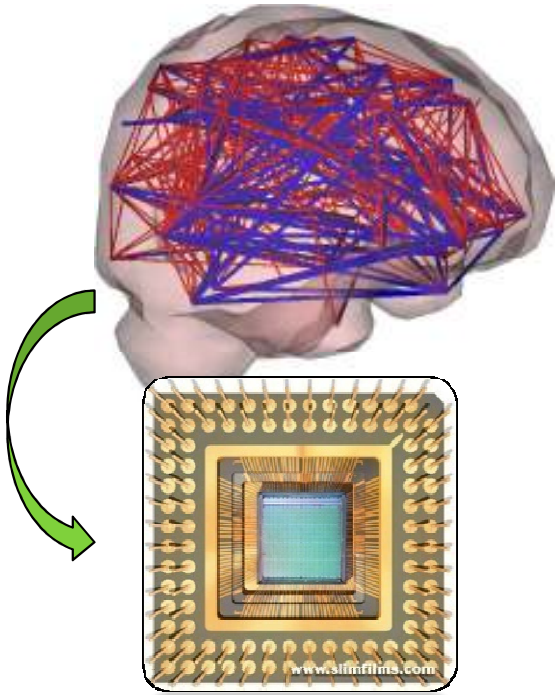
Granger causality

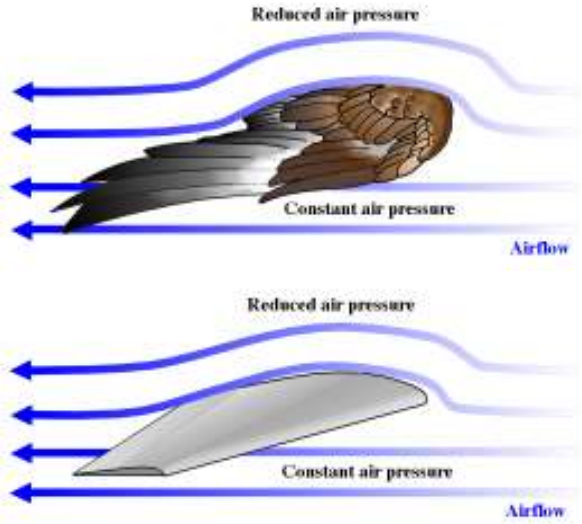
Graph Theory

Synchronisation analysis



# cortical coding principles

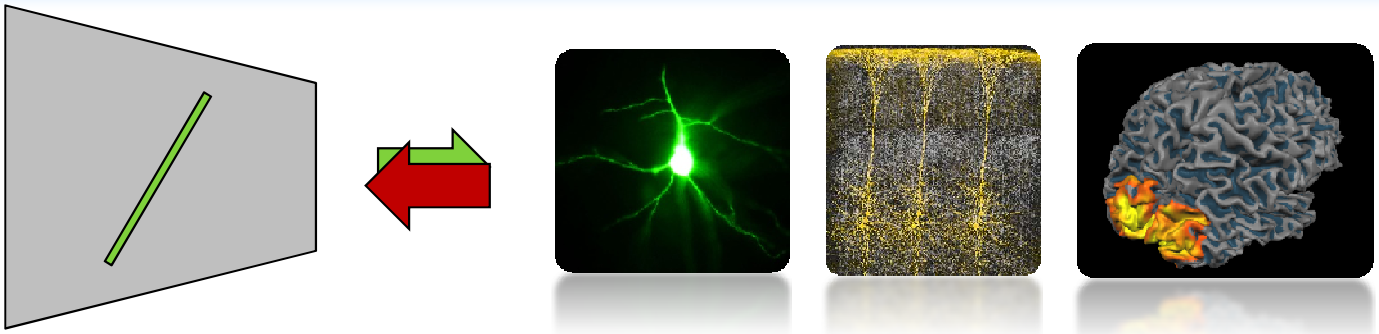


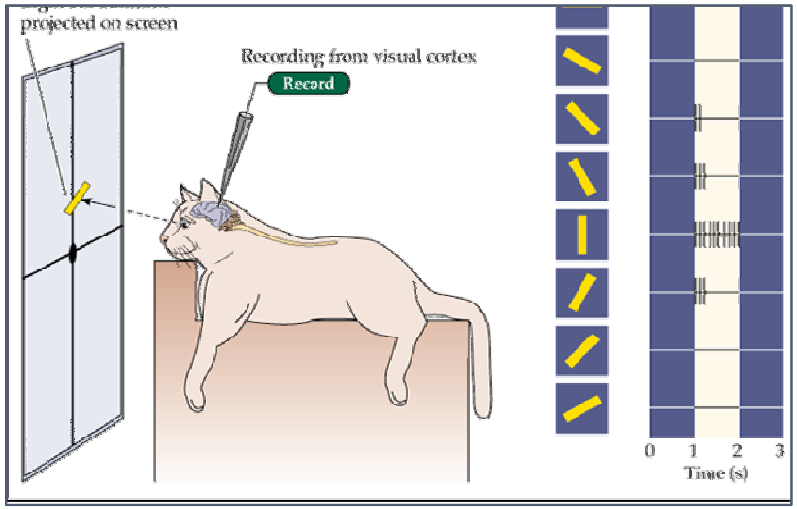



i.e. cortical predictions

Friston, K.
free energy principle

# Lars Muckli – Predictive coding

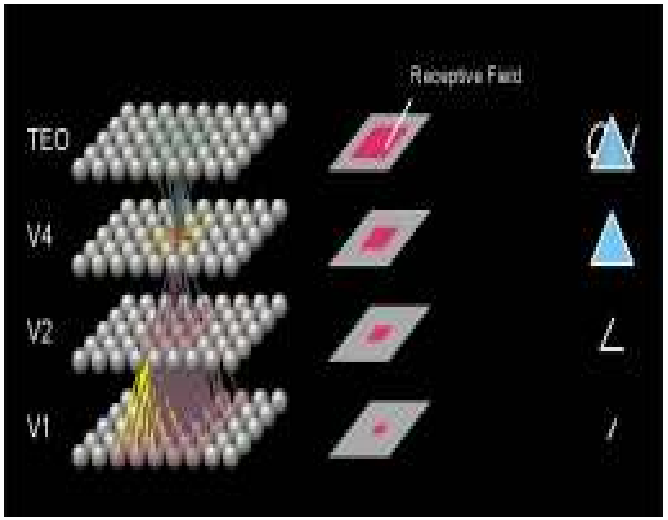




# Neurophysiological models for economic neural encoding

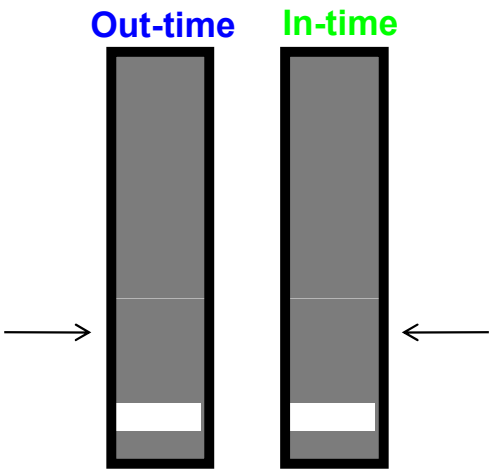
Attneave1954:

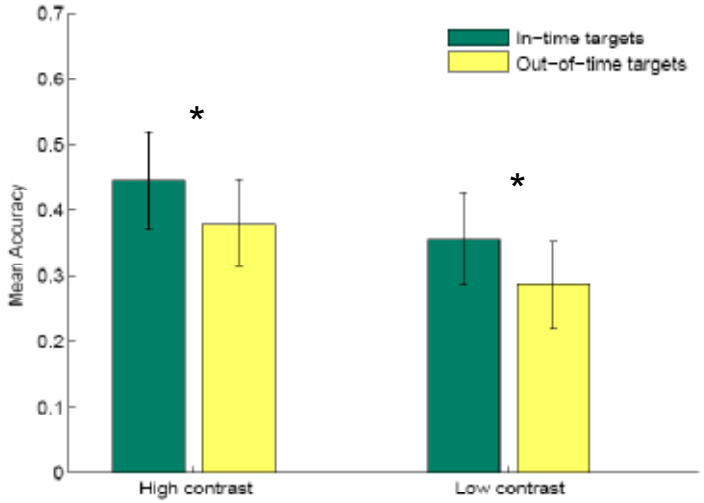
*"It appears likely that a major function of the perceptual machinery is to strip away some of the redundancy of stimulation, to describe or encode incoming information in a form more economical than that in which it impinges on the receptors"*




- **Mumford 1992: *On the computational architecture of the neocortex***
  - Higher cortical areas try to predict information that is present in lower cortical areas based on abstract information about the world.
  - Lower areas signal only the information that they contain which is not predicted by higher areas.
  - Predictions and error signals are transmitted via a thalamo-cortical loop

# Extension: V5 is sending a spatial-temporal precise prediction to V1

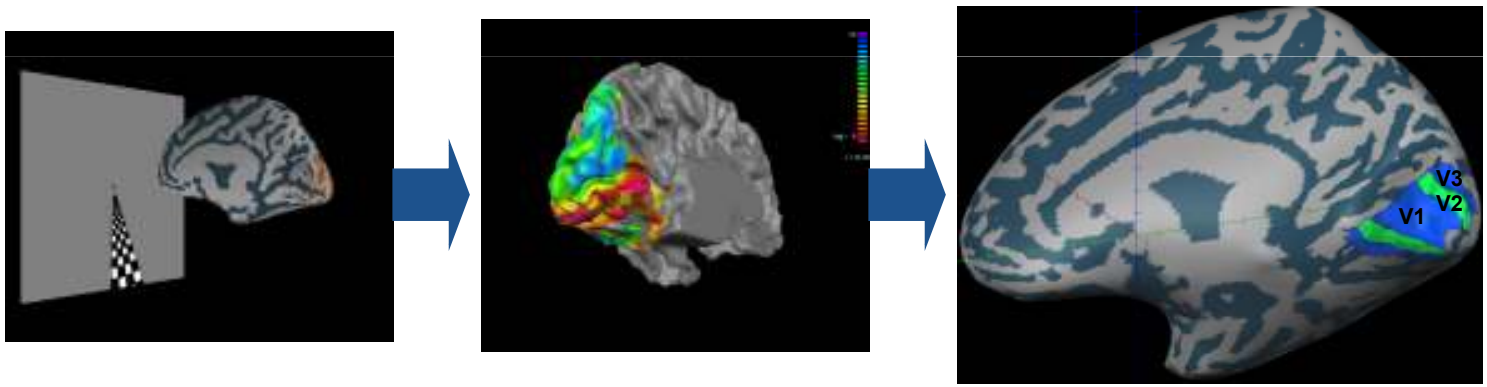


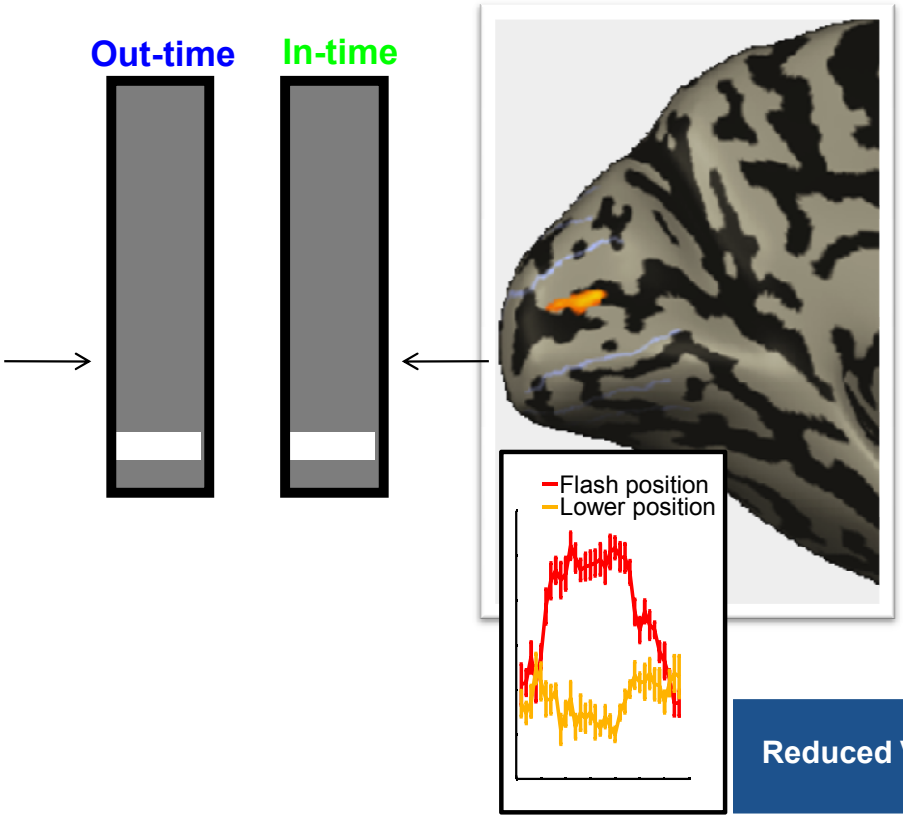

*Alink, Schwiedrzik,Kohler,Singer & Muckli (2010) J Neurosci.*

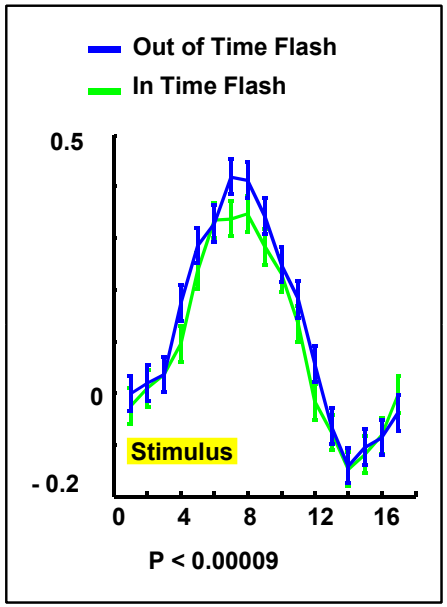
# Lars Muckli – Predictive Coding in Vision

1. ongoing activity before stimulus onset..
2. non stimulated regions
   - during motion illusion
   - during scene processing



# spatial-temporal precise prediction in V1



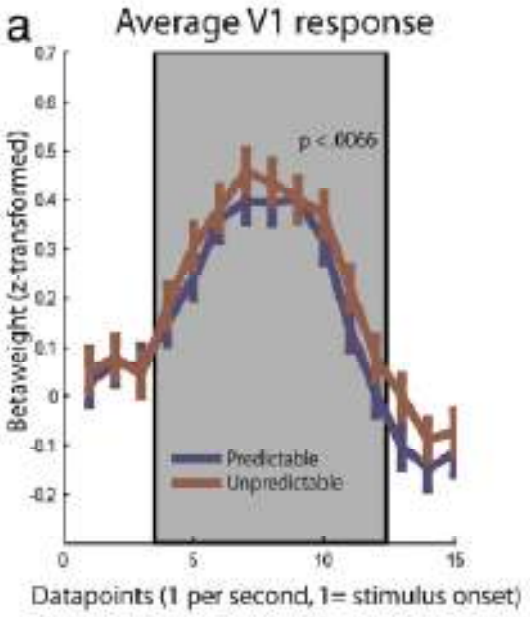

**Reduced V1 BOLD in response to anticipated stimuli**

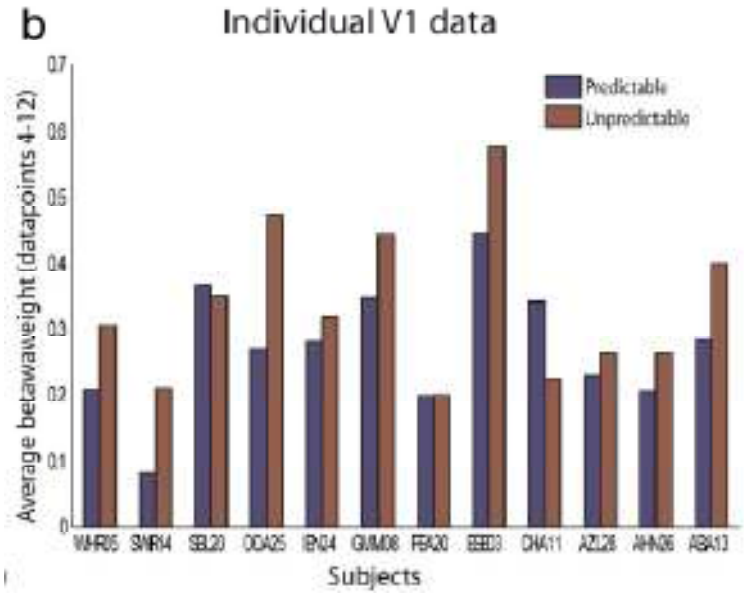
*Alink, Schwiedrzik,Kohler,Singer & Muckli (2010) J Neurosci.*

# Our experiment, Part 1

Region-Of-Interest based Analysis Results:

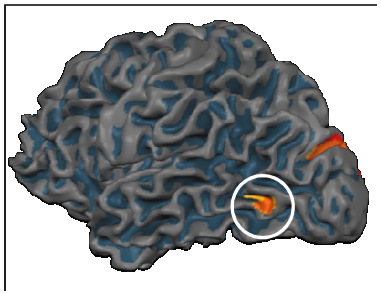
**Primary visual cortex 12 subjects**

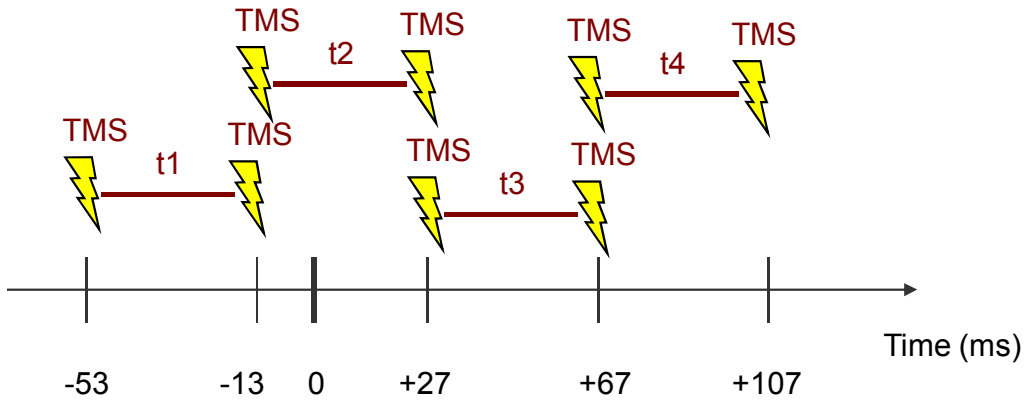


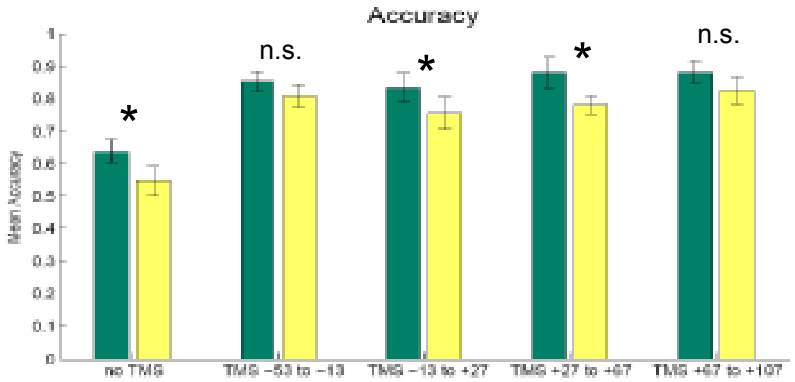
# Disruption of feedback from V5 to V1 with TMS

*Vetter, Grosbras , & Muckli (in prep.)*





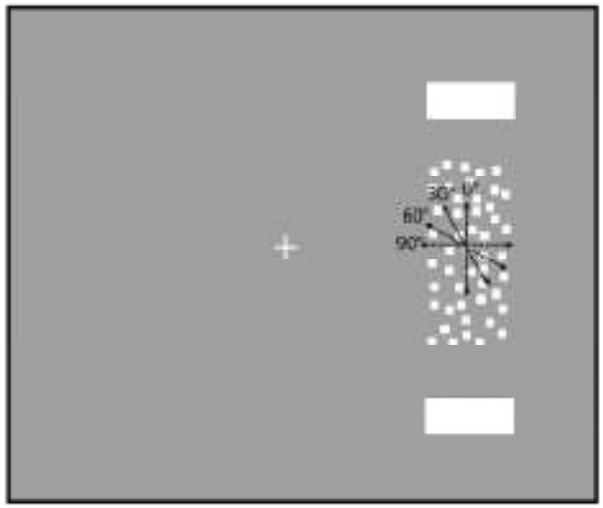

Target onset



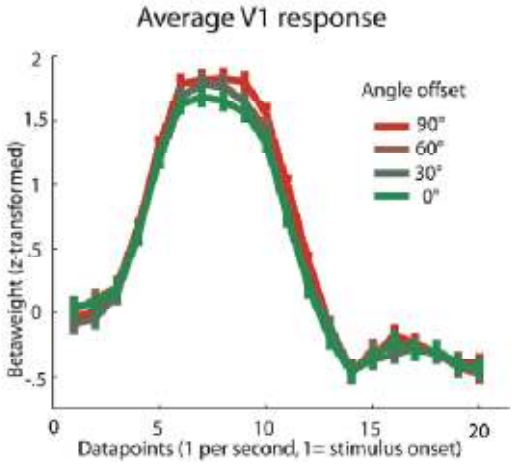
# Our experiment, Part 2

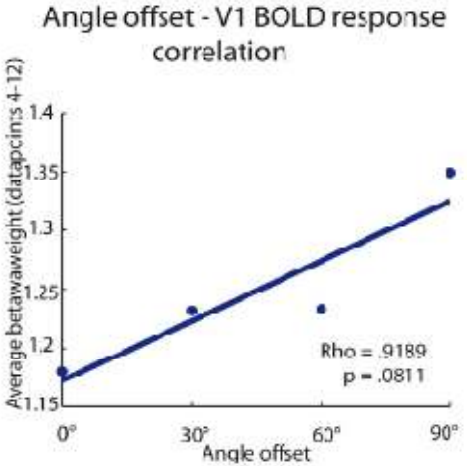
*The more predictable a visual stimulus is the less early visual areas will respond to that stimulus*

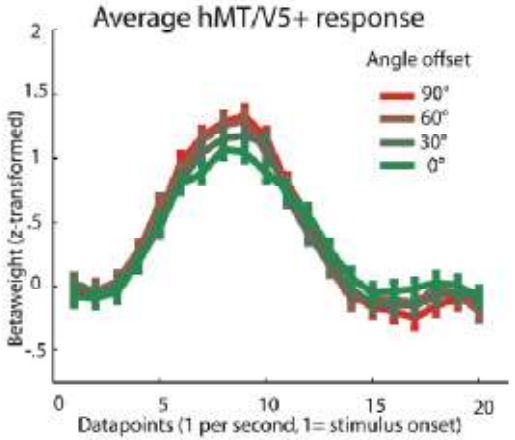
Parametric Design:
**Moving dots on the AM path with a variable angle**

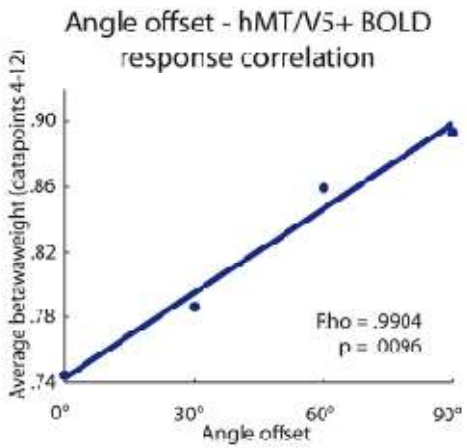


# Our experiment, Part 2

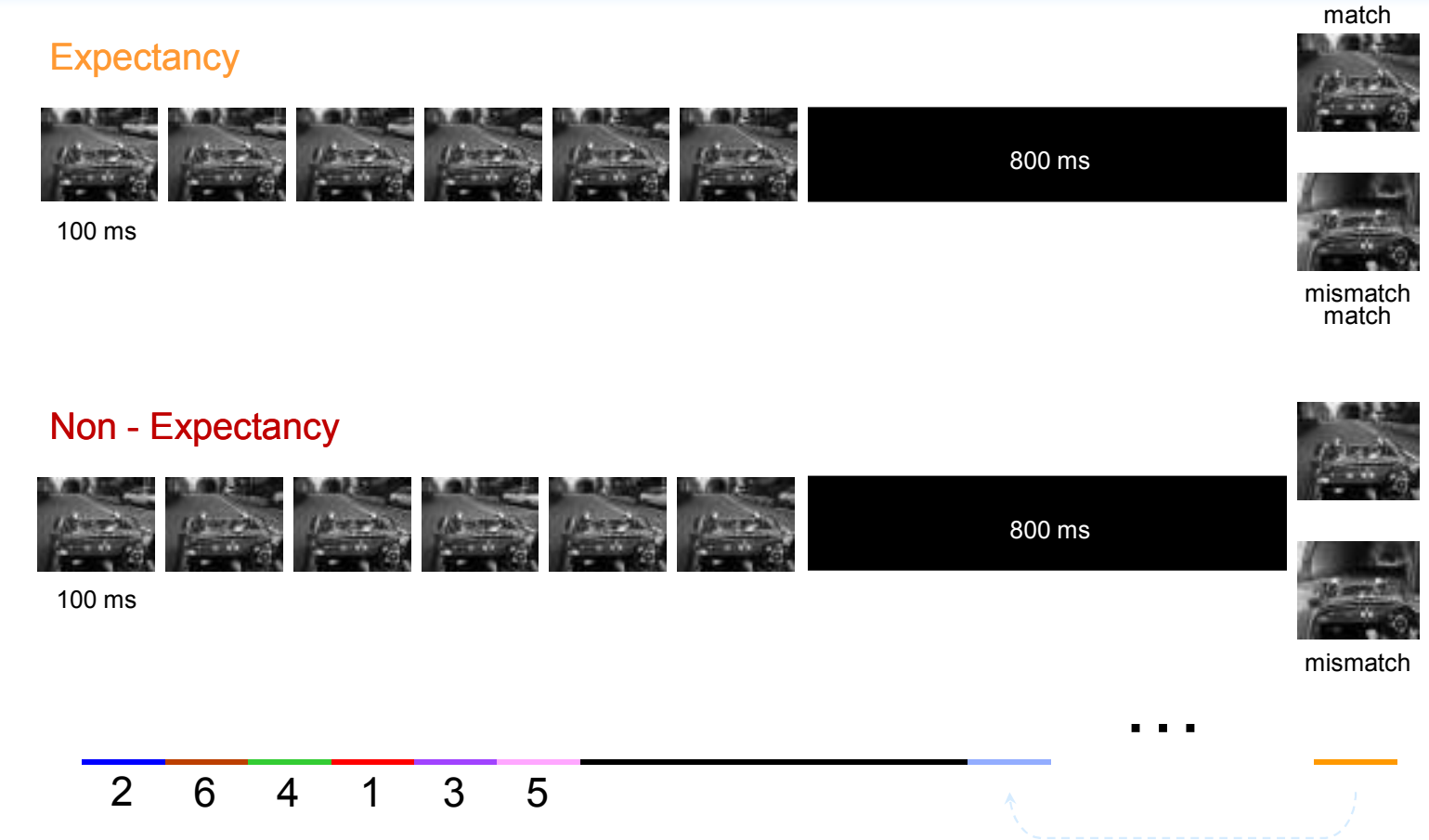


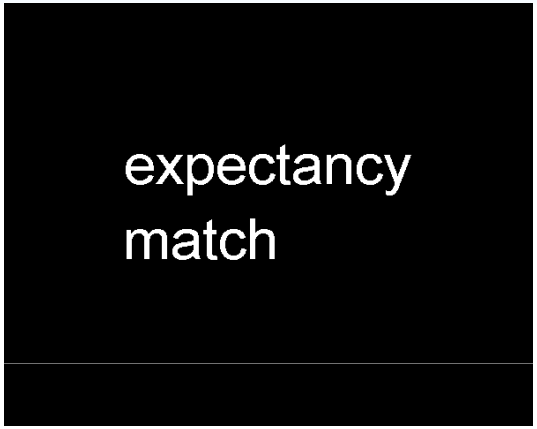



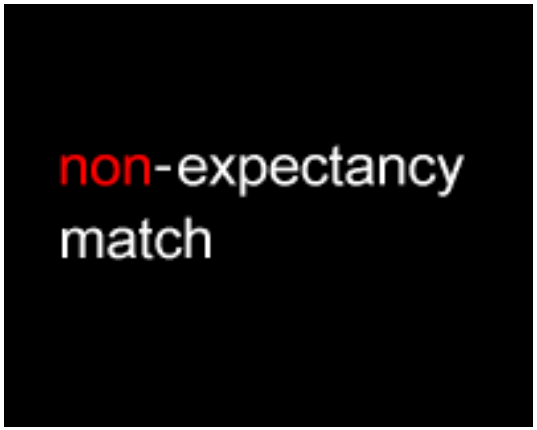
# Apparent motion in natural visual scenes

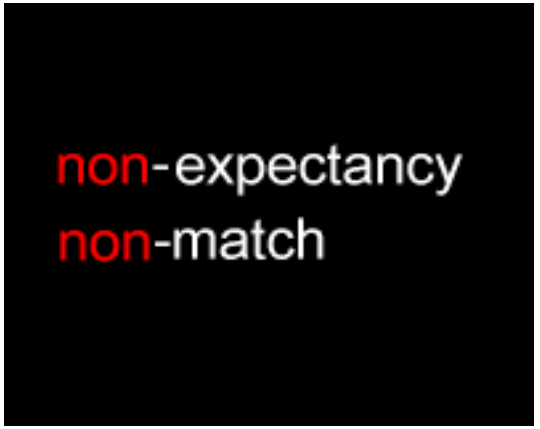



*Carvalho, Smith & Muckli (2009) HBM Meeting, in prep*

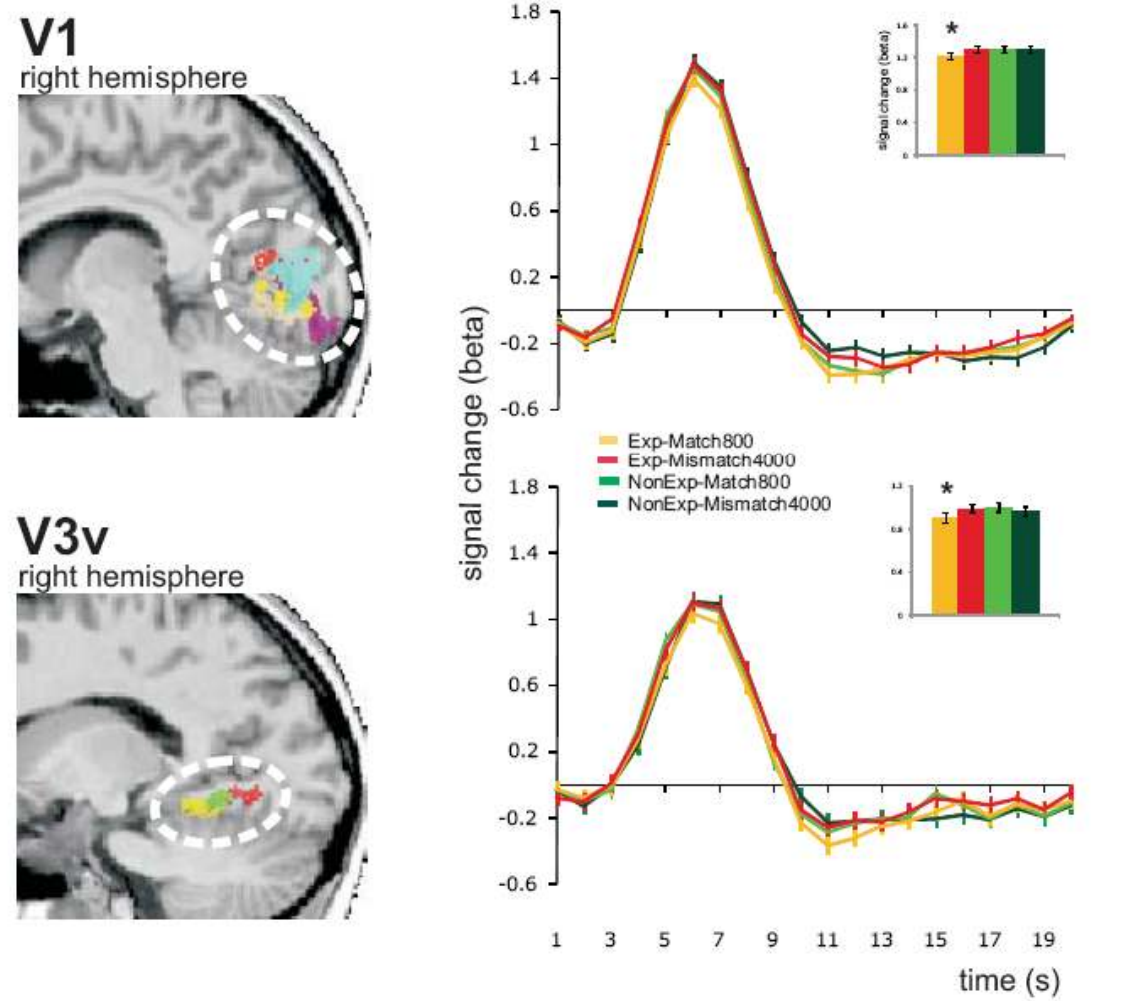
# Visual Stimulation





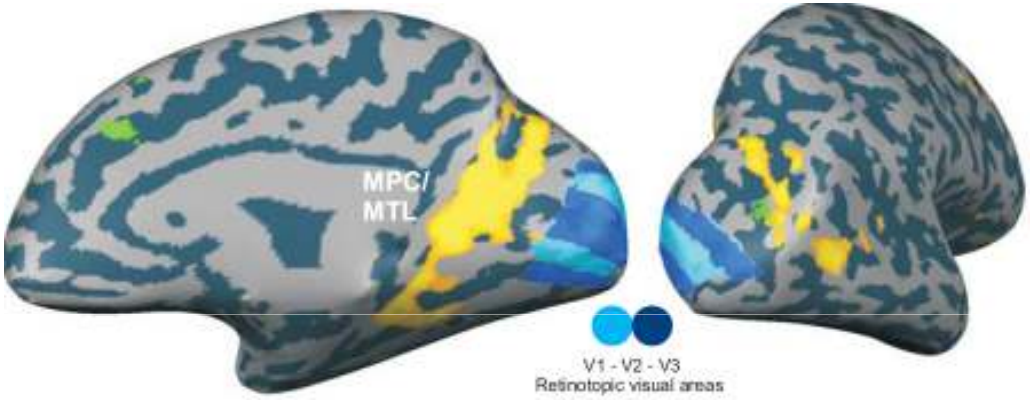



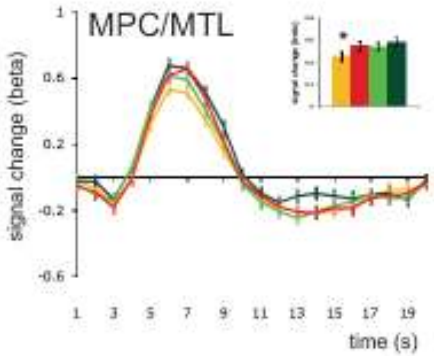

*Carvalho, Smith & Muckli (2009) HBM Abstract*


V1
right hemisphere
V3v
right hemisphere
signal change (beta)
time (s)
Exp-Match800
Exp-Mismatch4000
NonExp-Match800
NonExp-Mismatch4000
1.8
1.4
1
0.6
0.2
-0.2
-0.6
1
3
5
7
9
11
13
15
17
19
*
*

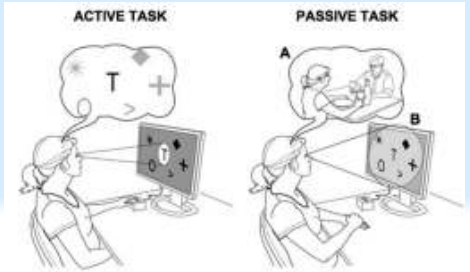
20

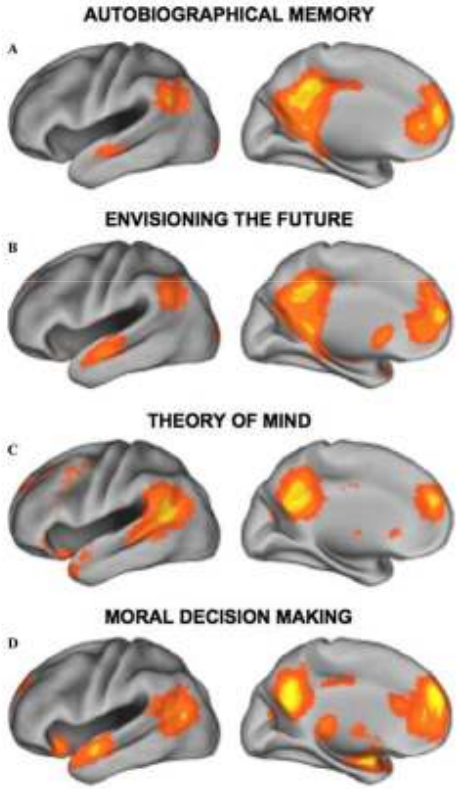
# Predictive coding – default mode network




Exp Match
Exp non-match
Non-exp 'match'
Non-exp 'non-match'

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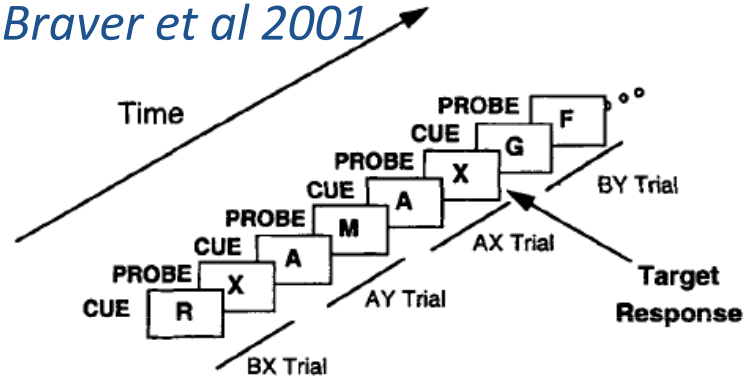
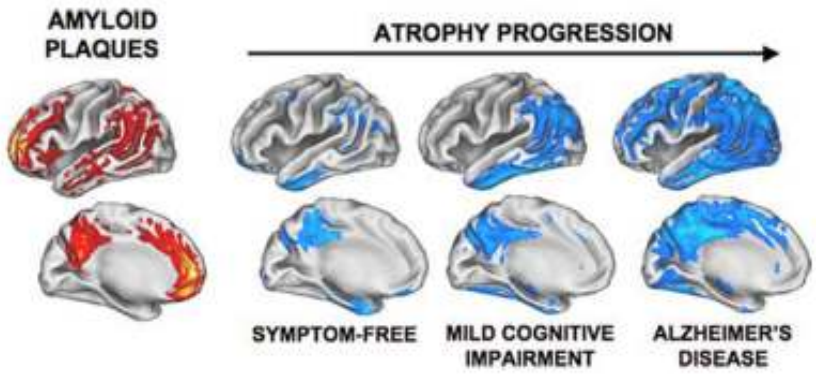
## ***Processing of Context Information AND Aging***

(Paxton et al 2006 Psychology and Aging)

*Braver et al 2001*




*predictive coding*
*In DMN affected*
*by aging*




Paxton et al (2006)Psychology and Aging



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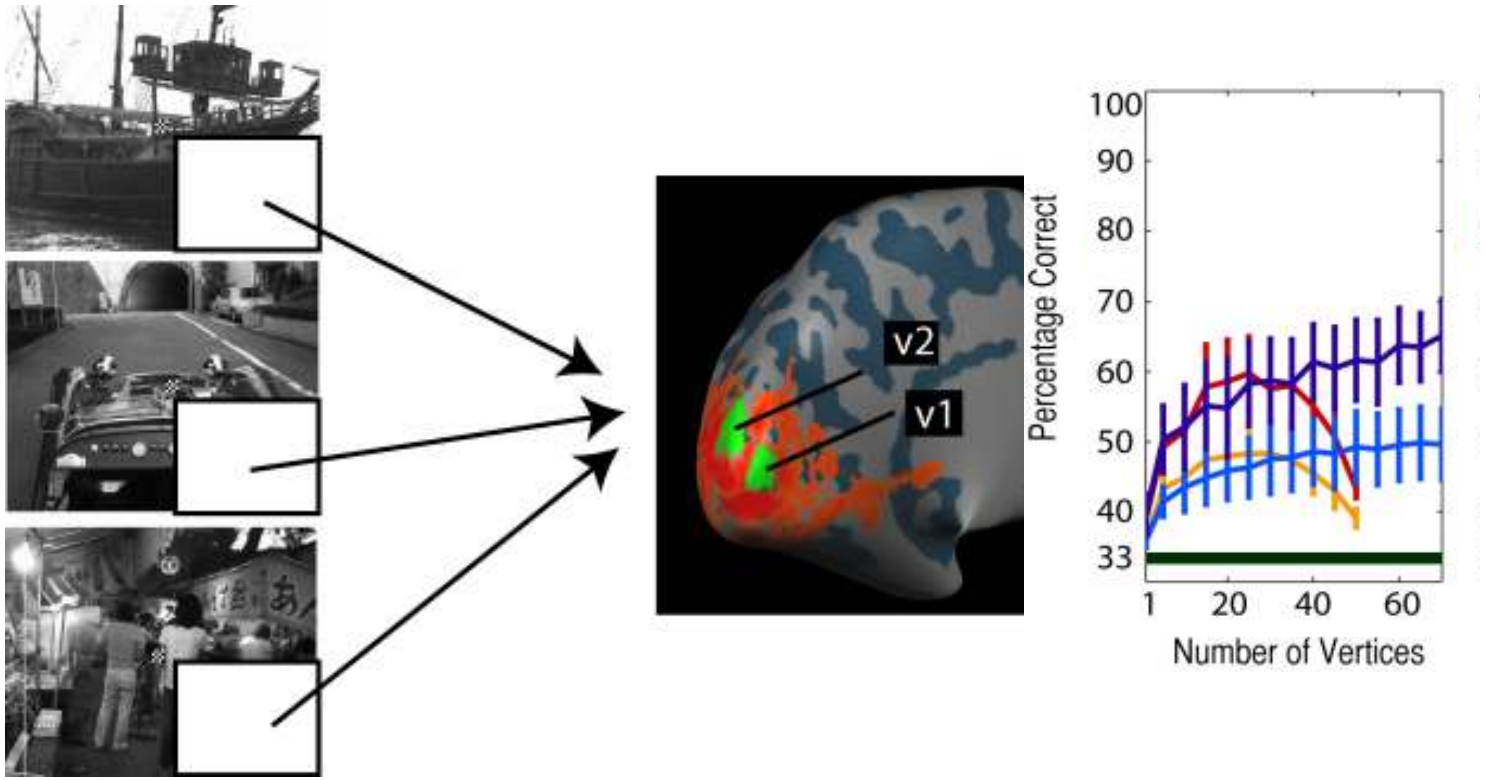
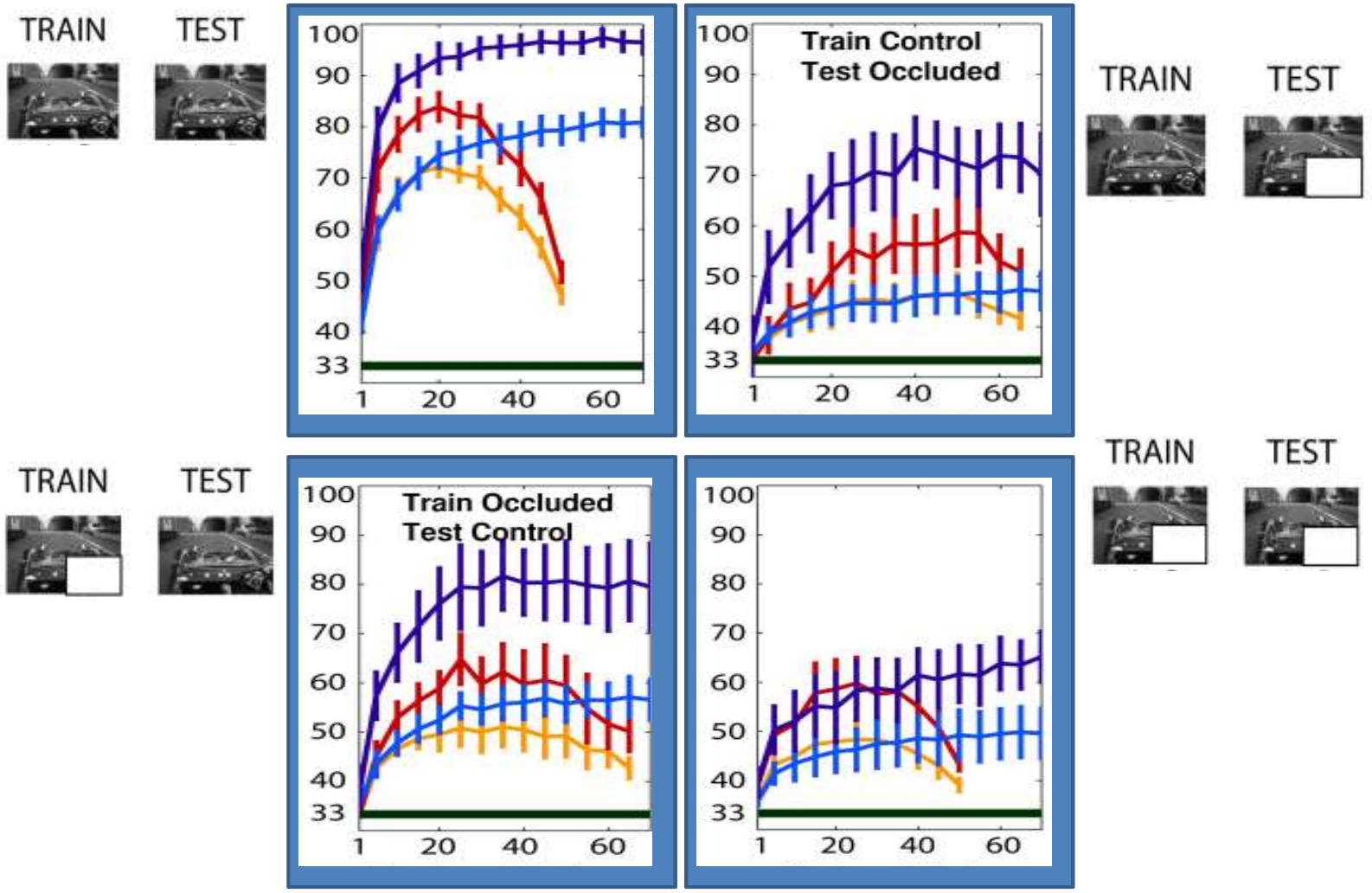
# Context decoding in V1 (brain reading 1st)




*Smith & Muckli (under review)*


TRAIN
TEST
100
90
80
70
60
50
40
33
1
20
40
60
Train Control
Test Occluded
TRAIN
TEST
TRAIN
TEST
Train Occluded
Test Control
TRAIN
TEST

## Basic Research

**Predictive Coding**
Apparent motion
Complex scenes
Contextual information

## Models

**Unifying theories of the brain**
Free energy principle

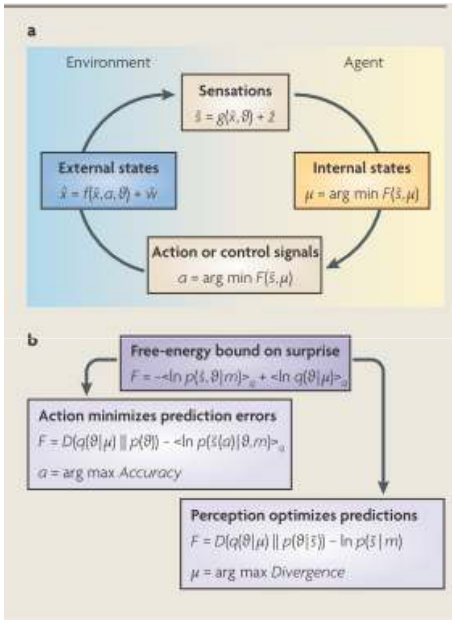
## Clinical applications

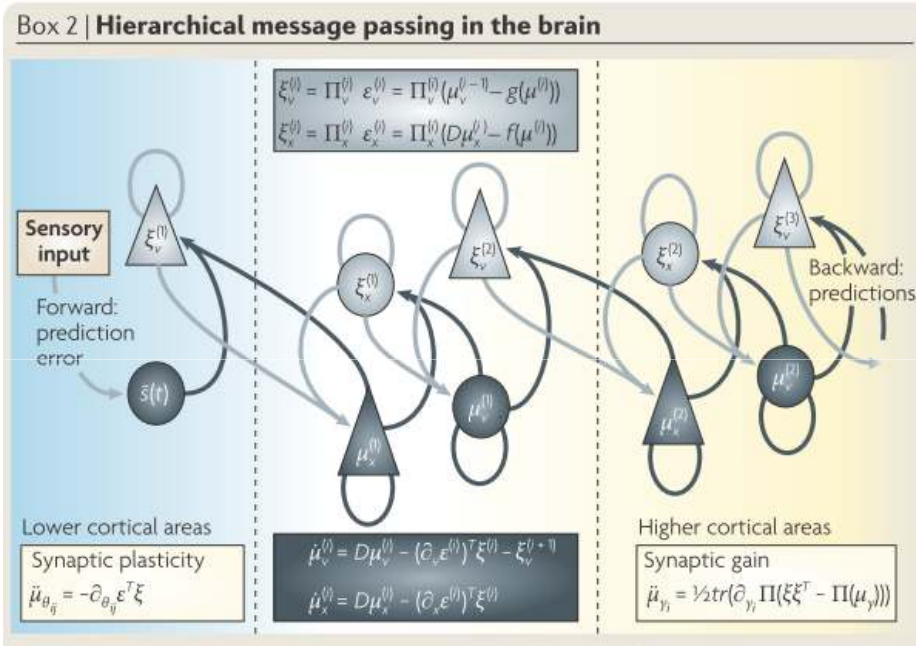
**Aging**
**Mental Disorder**

## AI applications

**Applications for artificial intelligence**
**Face recognition**
**Body motion recognition**

# ..unifying theories of the brain



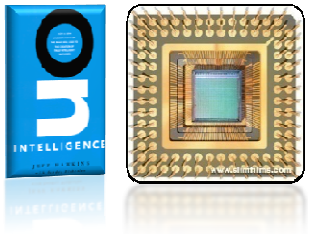



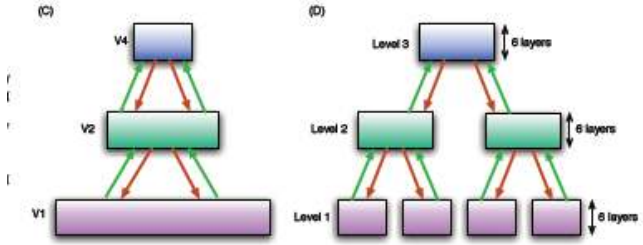

**Friston et al., 2006: A free energy principle for the brain**

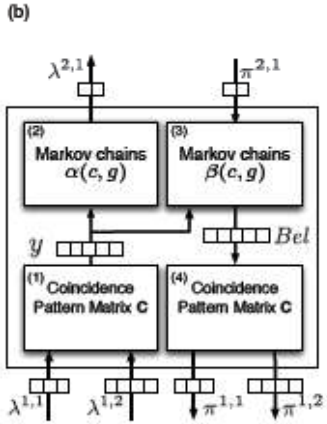
Neural systems attempt to minimize state changes by changing it's sampling of the environment.

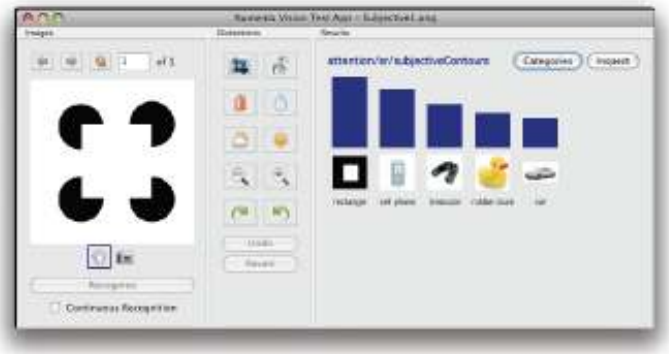
This is realized by anticipating upcoming events based on learned rules and the statistics of the environment

# HTM Bayesian believe propagation (Markov chains)





George & Hawkins (2010)

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