

# **Getting beyond Rate Codes: Oscillations and Attention in the Human Brain**

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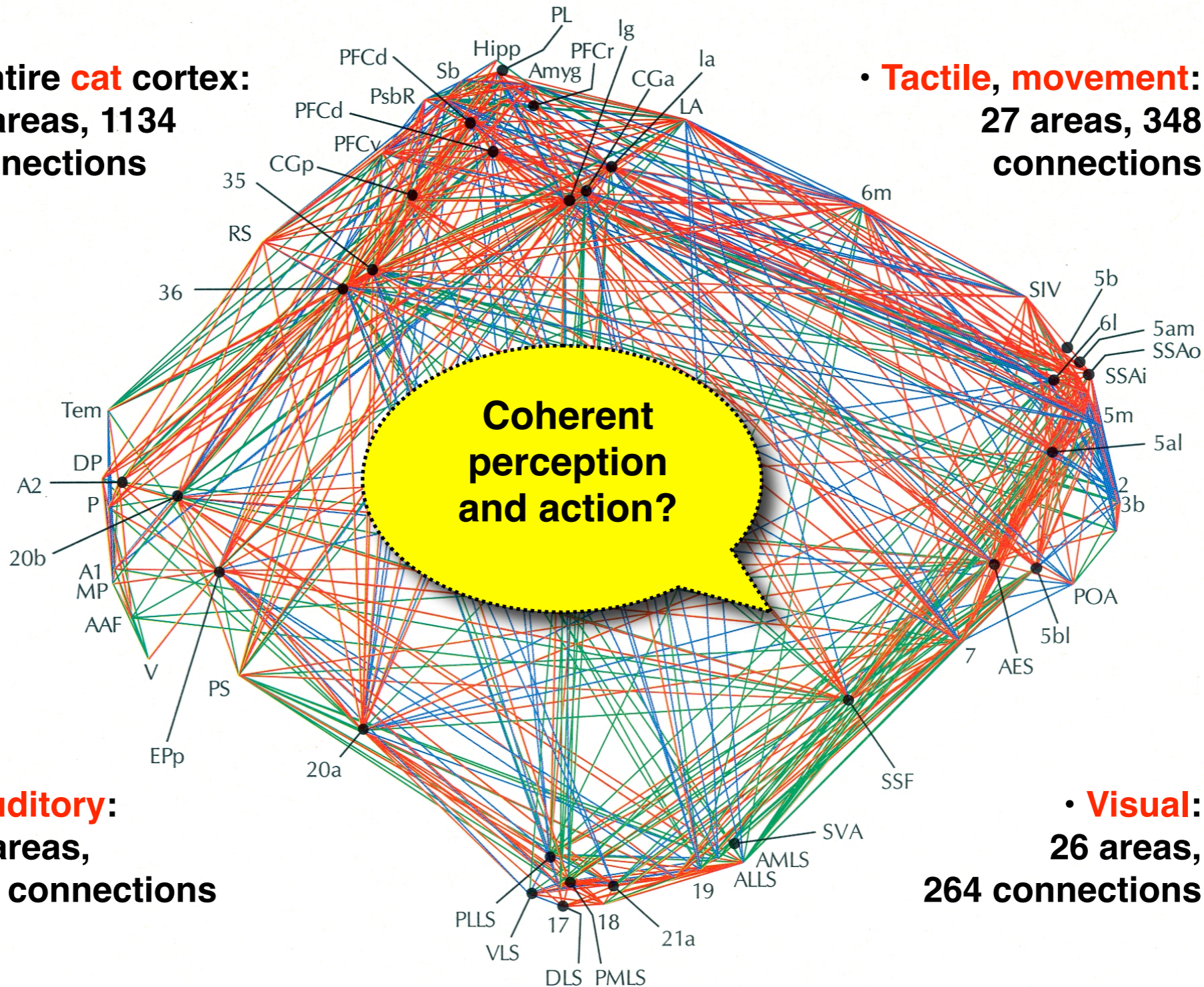
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URL: [www.40hz.net](http://www.40hz.net)**

# Computing in a Complex Network of Cortical Areas

(Scannell & Young, Current Biology 1993)

• **Entire cat cortex:**  
64 areas, 1134 connections

• **Tactile, movement:**  
27 areas, 348 connections



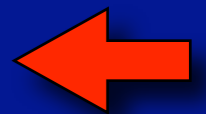
• **Auditory:**  
20 areas,  
153 connections

• **Visual:**  
26 areas,  
264 connections

# Some ICT-Relevant Neurobiological Principles

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- **Plasticity, experience-dependent structural changes**
  - Experience-dependent connectivity changes; function strongly shapes structure in nervous systems
- **Temporal codes**
  - Use temporal coherence to establish dynamic relations between distributed signals
- **Cross-system and cross-modal interactions**
  - Dynamic cross-modal interactions to improve detection, object recognition, navigation
- **Anticipation and 'top-down' influences**
  - Brains constantly make predictions about upcoming events, perform fast and efficient 'hypothesis-driven' selection based on action intentions
- **Attention**
  - Multi-modal process that selects relevant signals in the context of action
- **Awareness**
  - System function that makes highly important information rapidly available to all modules



# Relation to Current ICT Calls

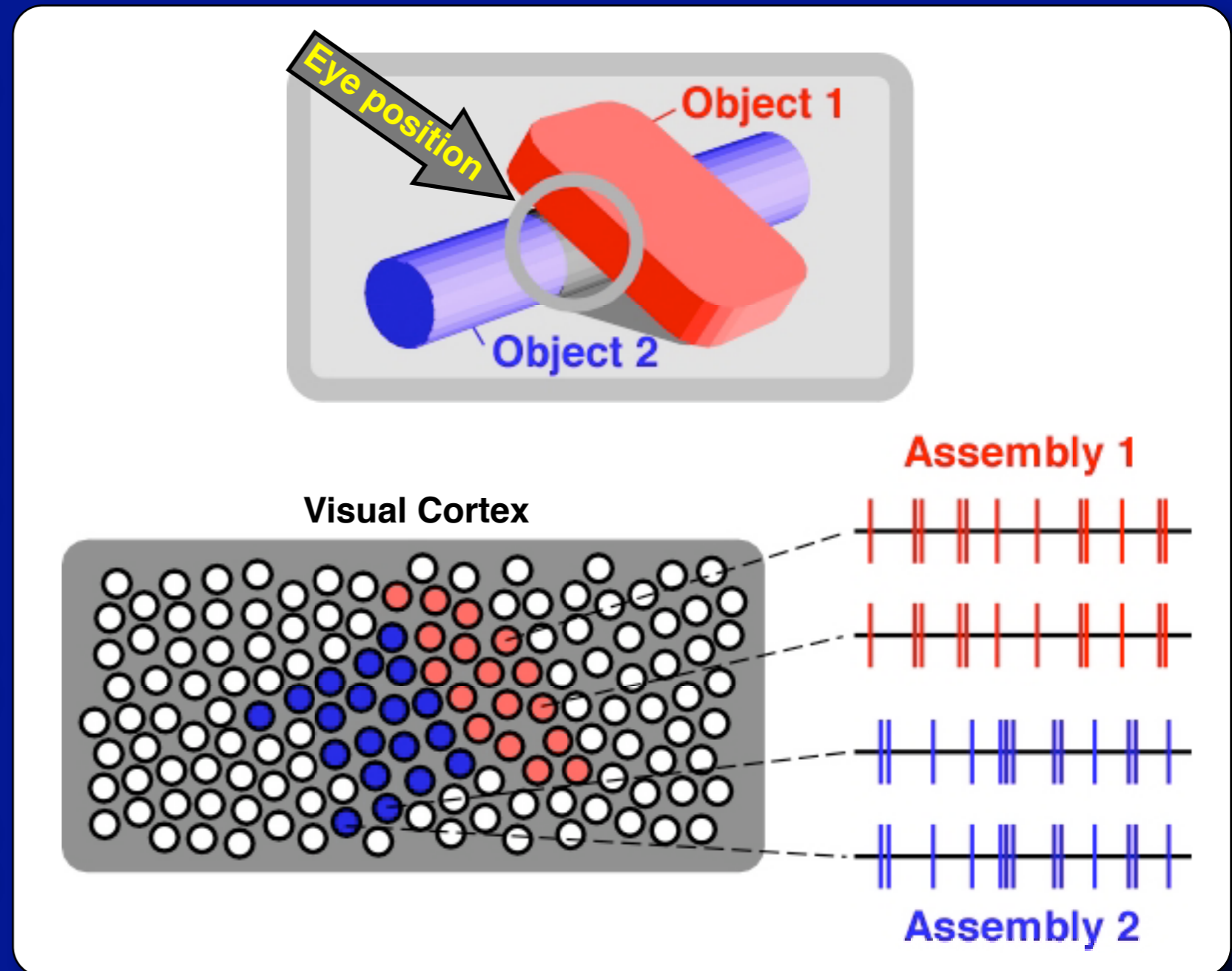
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- **HEALTH-2007-2.2.1-2: Coding in neural assemblies**
  - Research should focus on mechanisms of coding at the level of neuronal assemblies or microcircuits, aimed at understanding the interface between neuronal activity and behavioural performance.
- **ICT-2007.8.3: FET proactive 3: Bio-ICT convergence**
  - Target outcome: new perspectives in ICT that **exploit** the understanding of information processing in **biological systems**
  - **Novel computing paradigms**, derived from the information representation and processing capabilities of biological systems
  - Fundamental **rethinking of notions of information and computation** that may be better suited for certain classes of problems and that can be implemented in biological, biomimetic or biohybrid devices

# Functional Role of Correlated Neural Activity

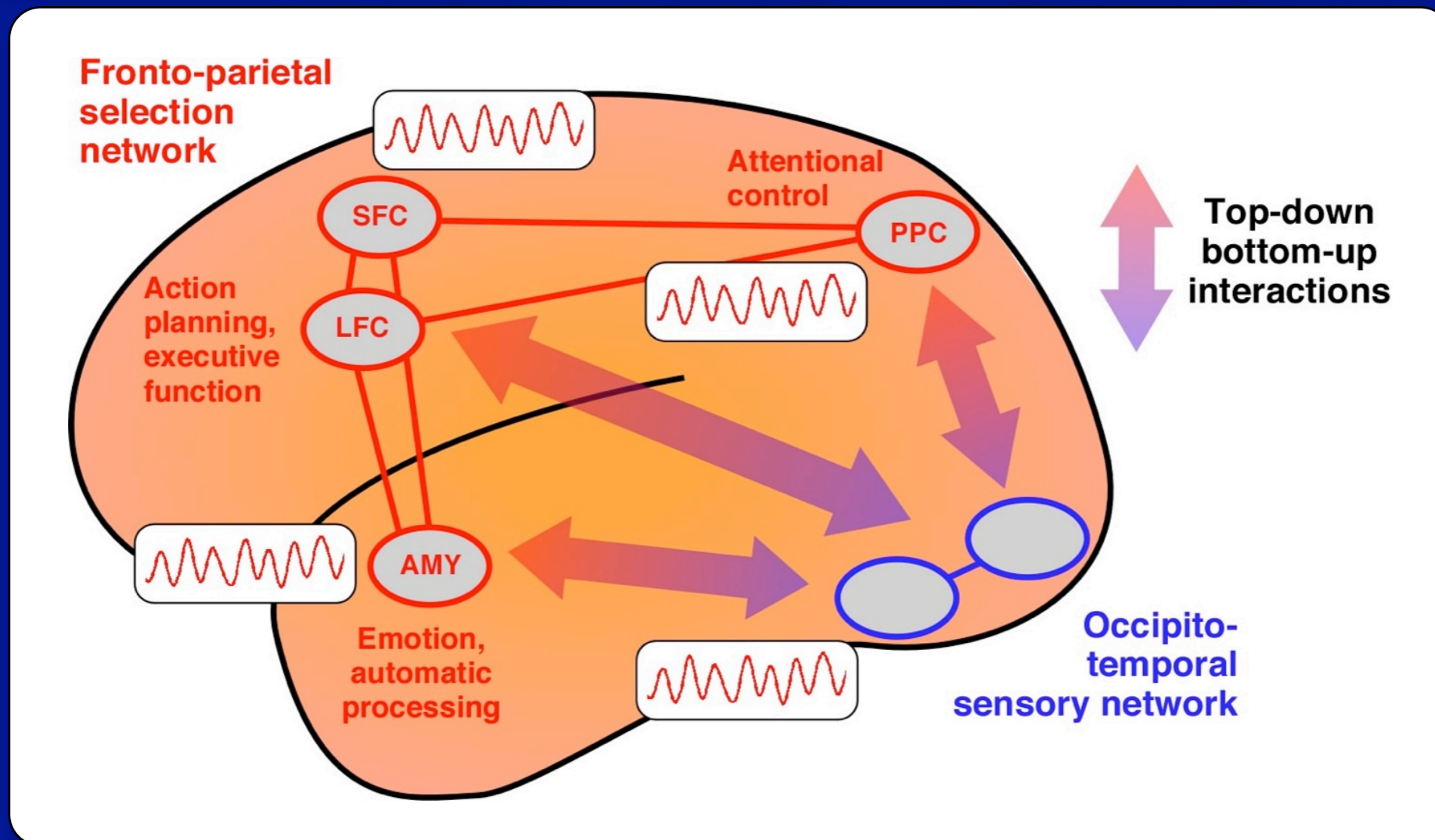
(Milner 1974; von der Malsburg 1981; Abeles 1982)

- **Neural synchrony** causally relevant for sensory processing
  - Encodes the **relatedness of features**; leads to the buildup of **coherent object representations**
  - Same mechanism highly **relevant** for attention, learning, multisensory integration, sensorimotor coordination, consciousness
- (1) **Selection** of important signals for preferential „routing“ through the network
- (2) **Large-scale coherence** across brain regions may allow to set up a **„global workspace“** for cognition



# The Dynamic Core Hypothesis

(Tononi & Edelman, Science 1998; Thompson & Varela, Trends Cogn Sci 2001; Engel, Fries & Singer, Nat Rev Neurosci 2001)



- Cognitive processes strongly determined by a **network of regions** involved in action planning, attentional control, memory and emotion
- **Large-scale assemblies** activated in this network provide the substrate for a **‘global workspace’** for cognition
- **Coherence** among the regions of this functional cluster (the **‘dynamic core’**) is of critical importance for the emergence of cognitive states

# Involvement in FP6 STREPs

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- **IST - Cognitive Systems: „POP- Perception on Purpose“**
  - Radu Houraud (Grenoble, F)
  - Peter König (Osnabrück, D)
  - Helder Araujo (Coimbra, P)
  - Martin Cooke (Sheffield, UK)
  
- **NEST - Pathfinder: „MindBridge - Measuring Consciousness“**
  - Geraint Rees (London, UK)
  - Morton Overgaard (Hammel, DK)
  - Steven Laurys (Liege, B)
  - Axel Cleeremans (Brussels, B)
  - Kai Vogeley (Köln, D)

# Noninvasive Human Recording Approaches



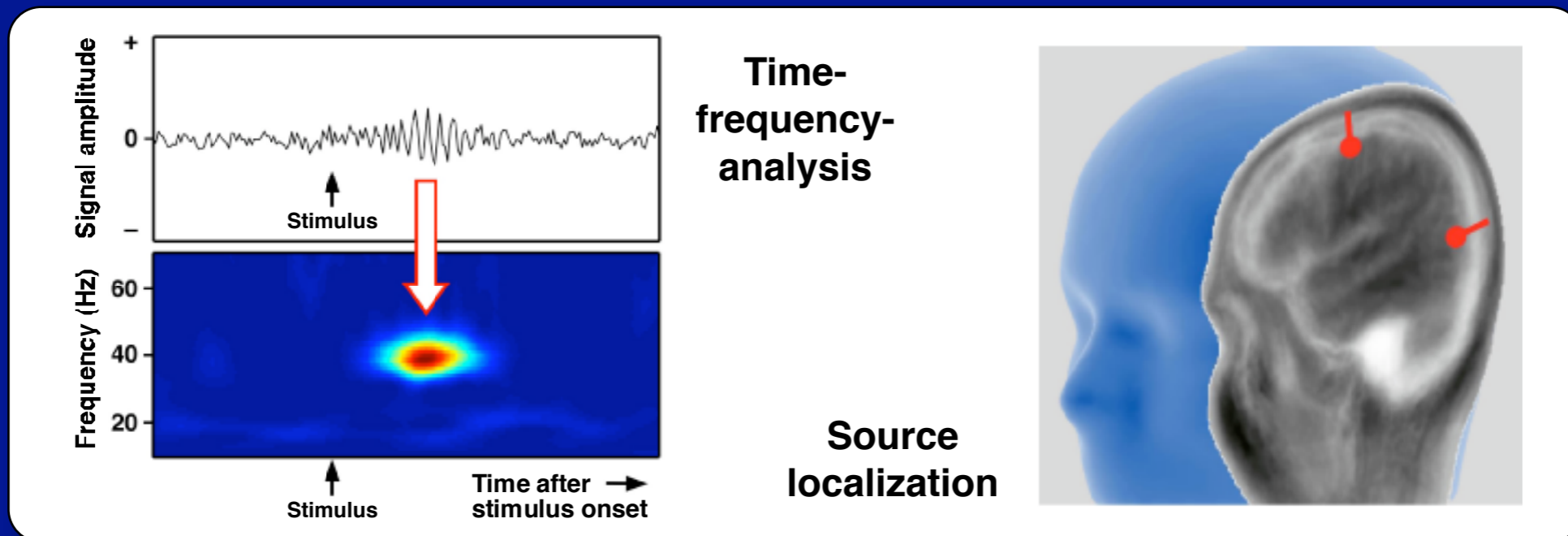
128-  
Channel-  
EEG

- Recording of **electrical potential fluctuations** with **EEG**



275-  
Channel-  
MEG

- Recording of **magnetic fields** from the brain with **MEG**

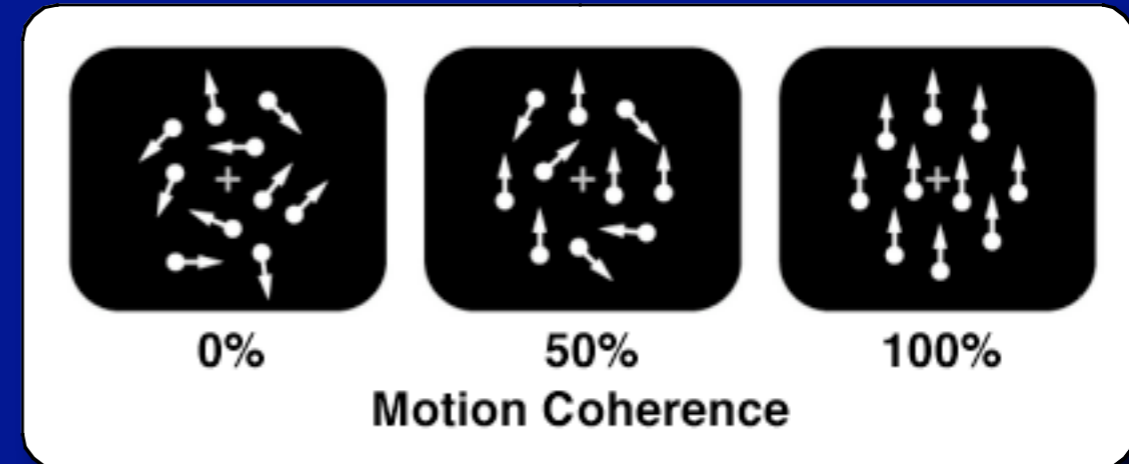




# MEG-Study of Gamma-Band Responses in the Human Brain

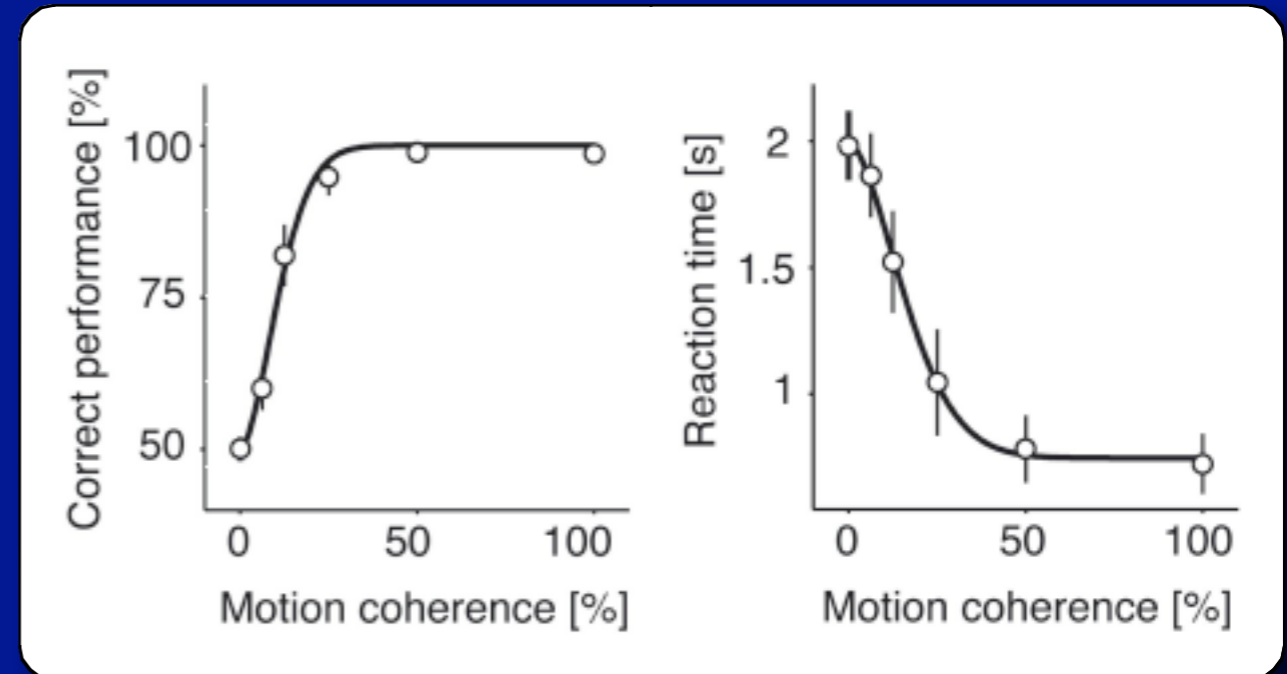
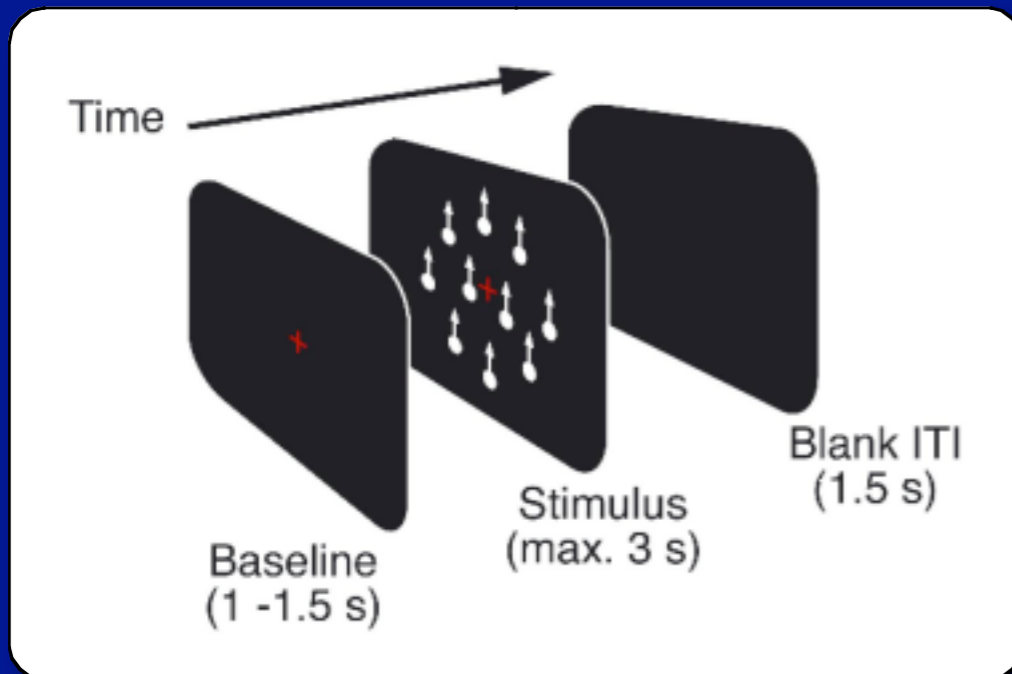
(Siegel, Donner, Oostenveld, Fries & Engel, Cerebral Cortex 2006)

- **MEG-study** of induced **gamma-band activity** in the visual system
- Effects of changes in **coherence** of moving dots; systematic variation of the strength of visible **motion**



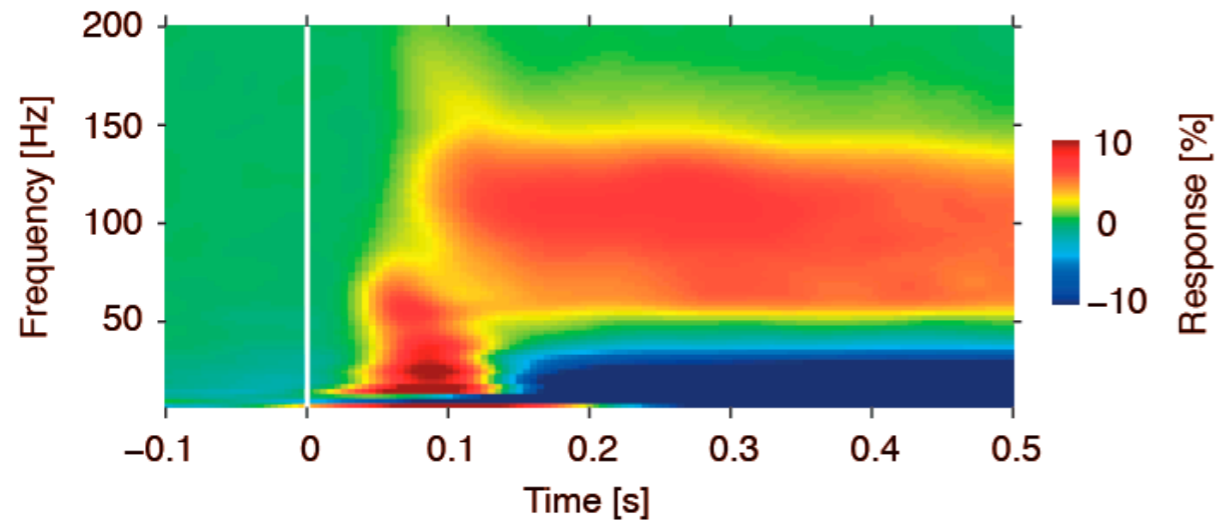
- Paradigm: **2-AFC task**; subjects had to indicate upward/downward motion

- Behaviour: **performance increase**, **reaction time decrease** with increasing motion coherence

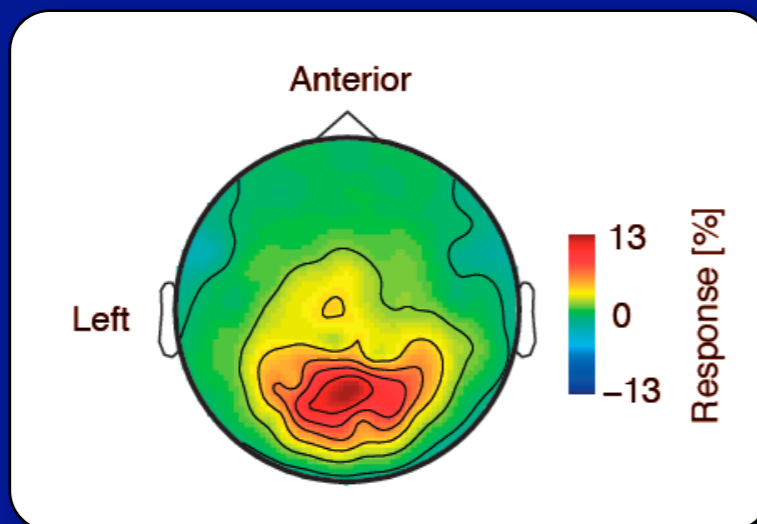


# Motion Strength and Gamma-Band Response

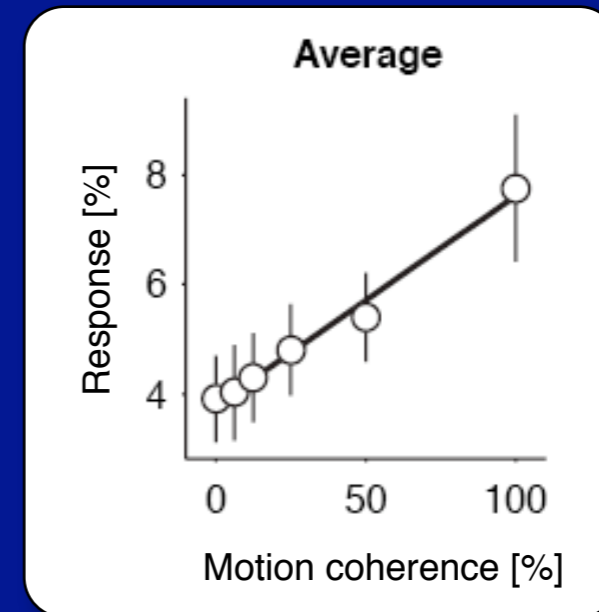
(Siegel, Donner, Oostenveld, Fries & Engel, Cerebral Cortex 2006)



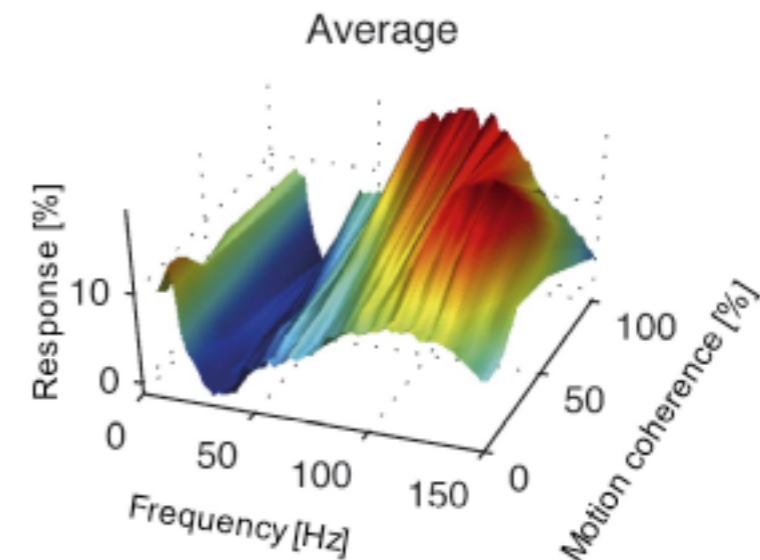
- Strong **gamma-band activity** (50-110Hz) induced by the stimuli



- **Sensor-level distribution** of gamma activity: strong power increase over visual cortex



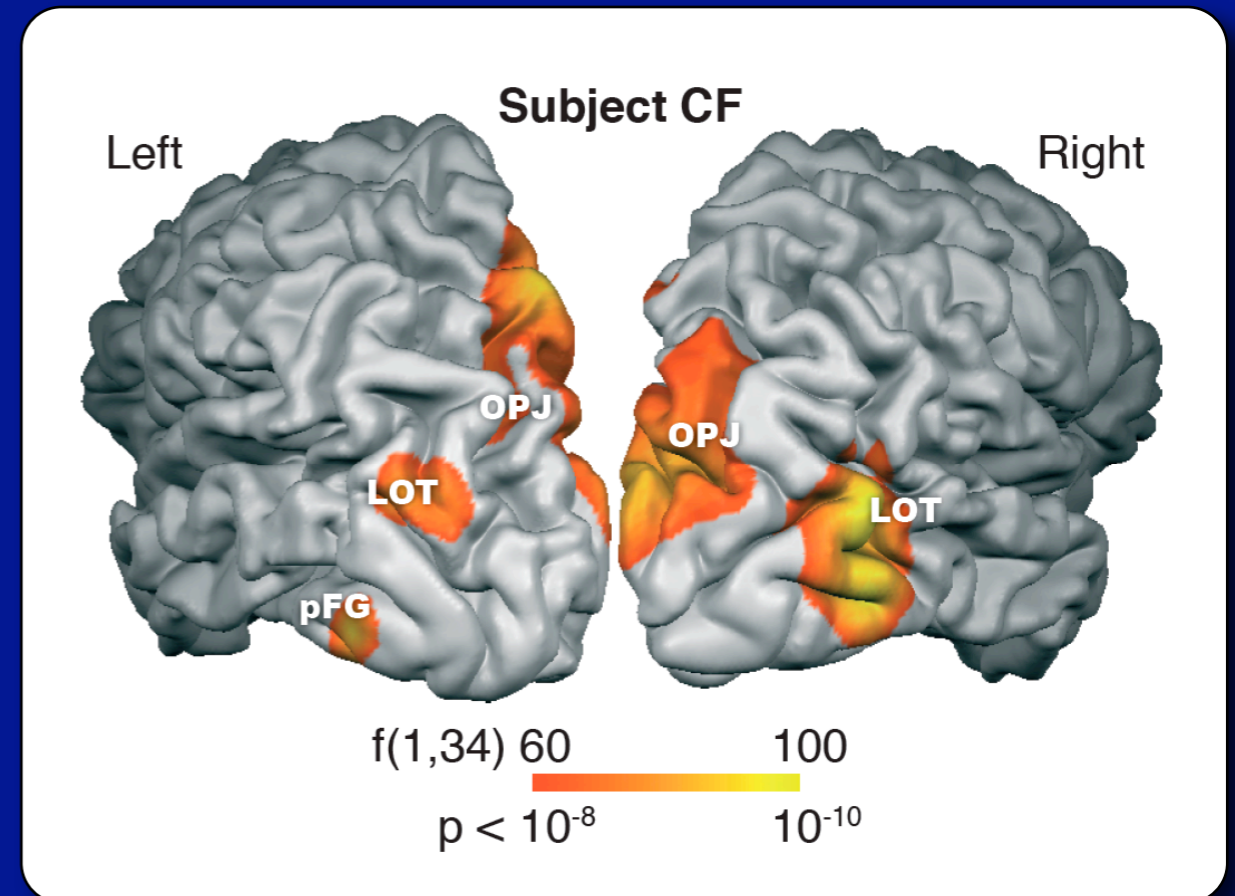
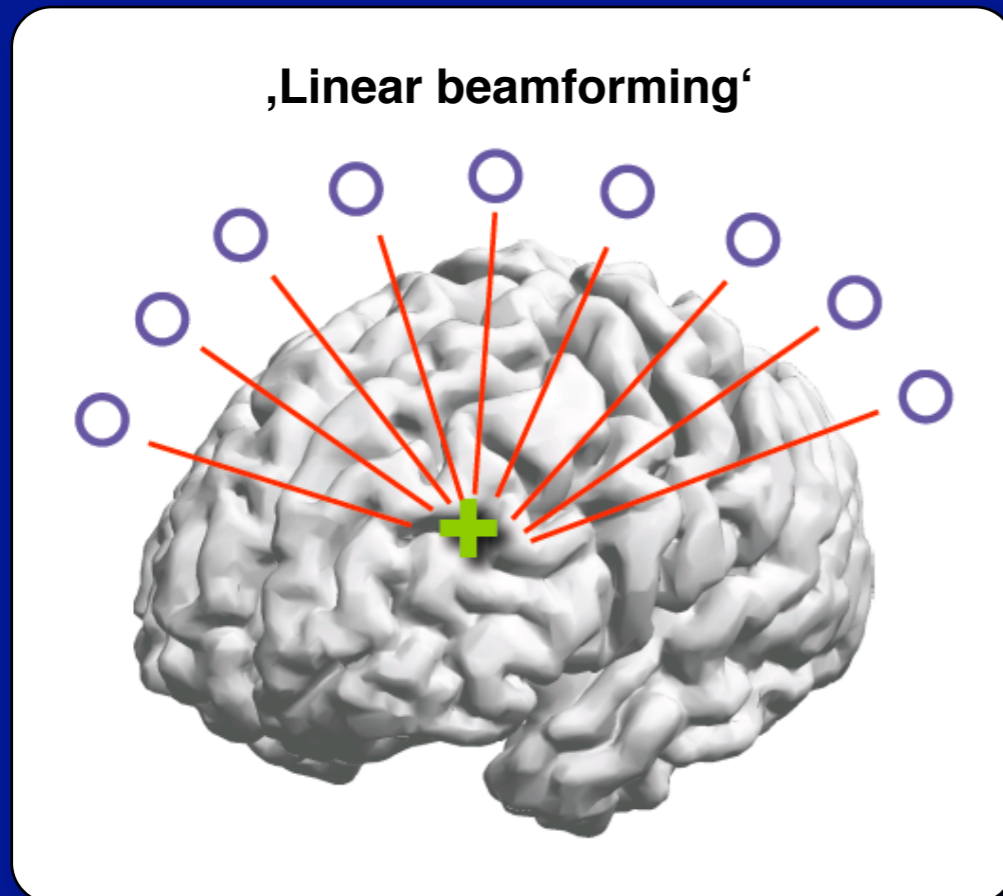
- **Linear increase of gamma power** with motion coherence



- Effects are **frequency specific**: e.g. alpha (10Hz) is anti-correlated

# Source-Level Analysis of Gamma-Band Response

(Siegel, Donner, Oostenveld, Fries & Engel, Cerebral Cortex 2006)



- Construction of a **spatial filter**; passes activity **from one location with unit gain** while maximally suppressing other sources

- Localization of **gamma-band effect**: maximal change with stimulus coherence **in motion-sensitive regions** (LOT, OPJ, pFG)

# MEG-Study of Spatial Attention in the Visual System

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[... this and several of the subsequent slides presented at the meeting contained unpublished materials and were deleted therefore, sorry ...]

# Outlook: Intrinsic Dynamics and Cognitive Processing

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- **Intrinsic assembly dynamics** („dynamic core“) is of key importance to cognitive processes, determining these to a much greater extent than external stimuli at any given moment
- Temporal patterning provides a **fundamental constructive principle** that allows the brain to generate coherent and meaningful action
- Synchrony seems to play a **key role** in perceptual **integration**, attentional **selection**, **cross-modal** binding, **sensorimotor** coupling and **learning**
- Coherent oscillations are potentially important to establish specific relations between distributed processes (**compositionality**); to facilitate routing of information through a network („**saliency** by synchrony“); to match bottom-up with top-down signals (dynamic contextual **prediction**)
- Although presumably for each of such functions „cheaper“ engineering solutions can be found, it might be worth studying synchrony as a biologically plausible principle in **ICT architectures**