Real-Time fMRI Neurofeedback

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Overview

- Real-Time fMRI (rtfMRI) and Neurofeedback
- A Typical Neurofeedback Experiment
- Changing the Brain and Behavior
- Conclusion

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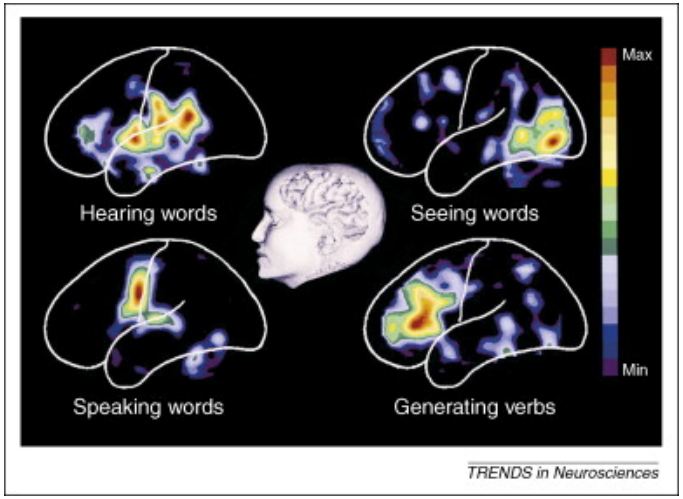
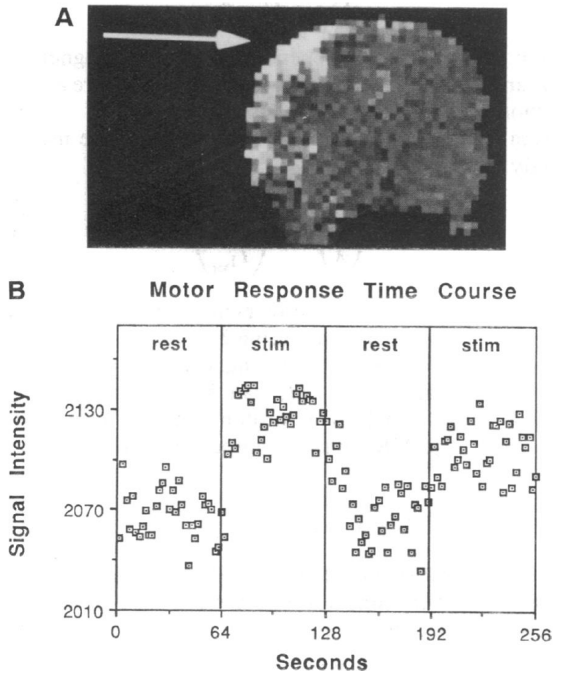
Functional Neuroimaging and fMRI

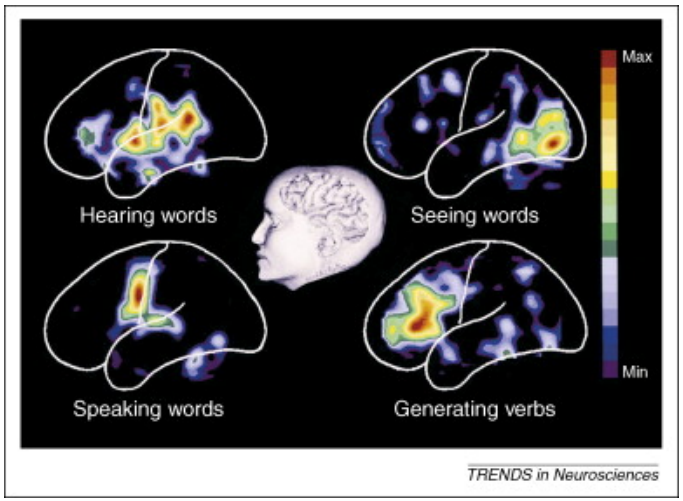


Raichle, TINS 2009, reviewing
Petersen et al., Nature 1988



Kwong et al., PNAS 1992

Functional Neuroimaging and fMRI



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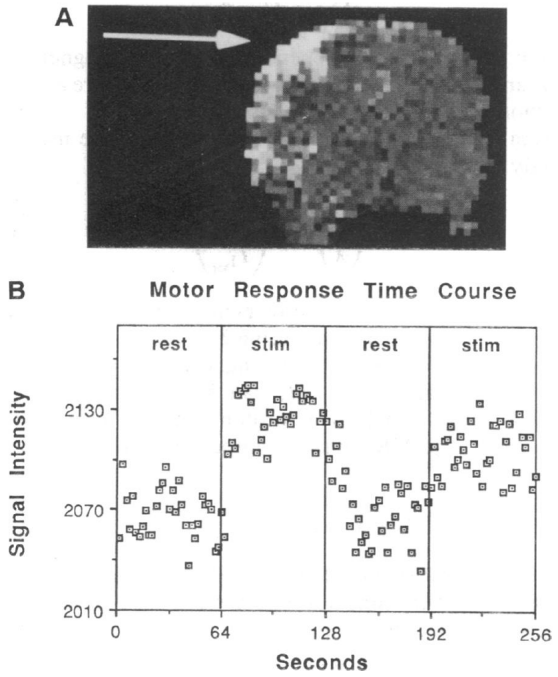
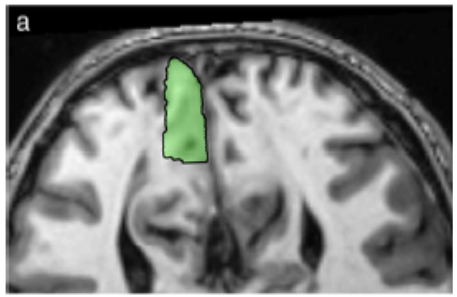
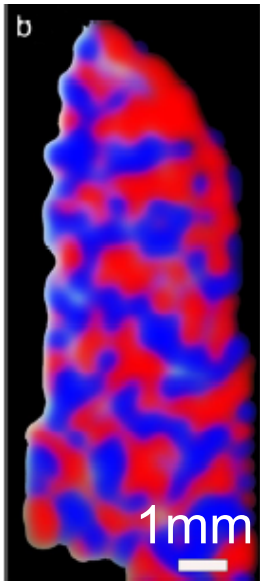


Kwong et al., PNAS 1992

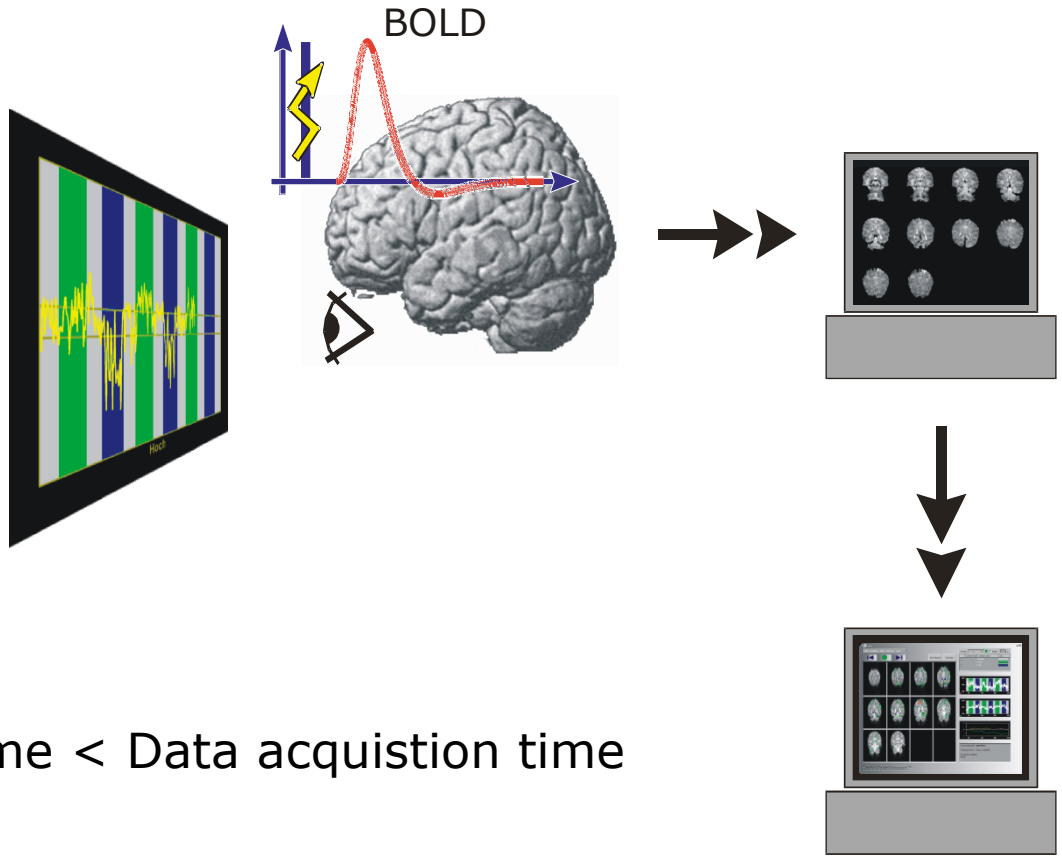


Yacoub et al., PNAS 2008



Now: > 10 x faster and higher resolution

Neurofeedback: Experimental Setup



Processing time < Data acquistion time

Cox et al., Magn. Reson. Med. 1995

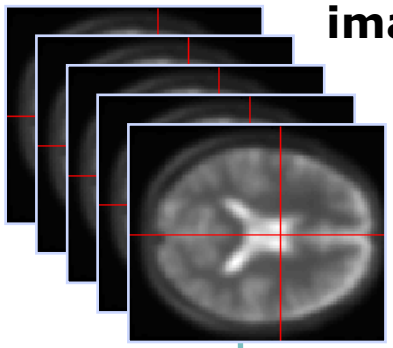
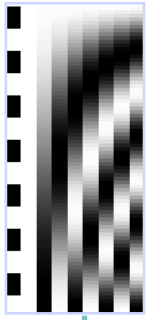
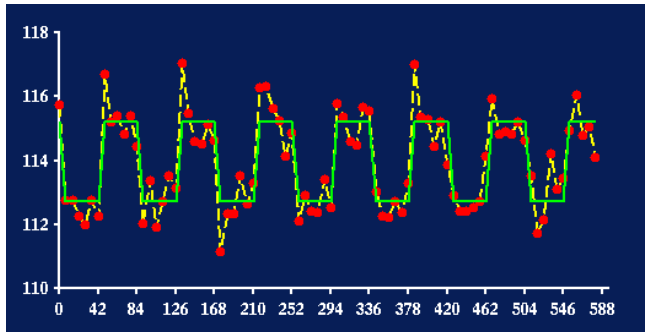


image data

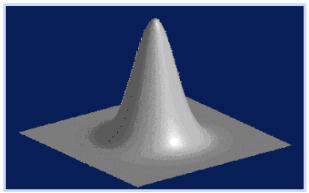
design matrix



Parameter estimates



kernel



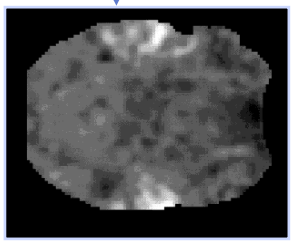
realignment & motion correction

smoothing

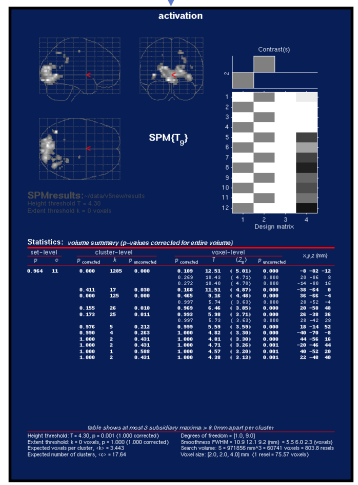
General Linear Model
- model fitting
- statistic image

random field theory

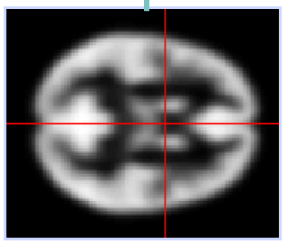
normalisation



Statistical Parametric Map



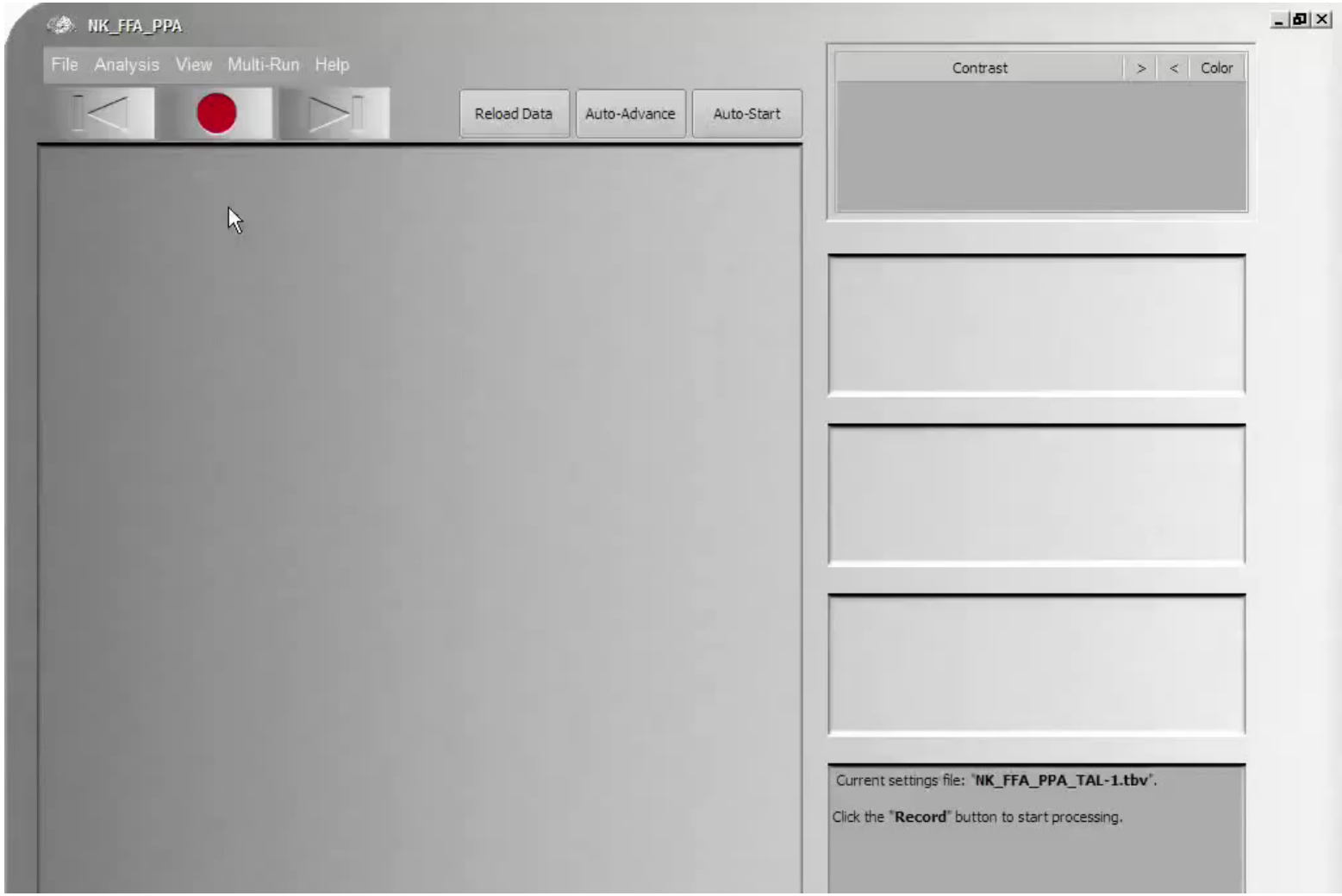
corrected *p*-values



anatomical reference

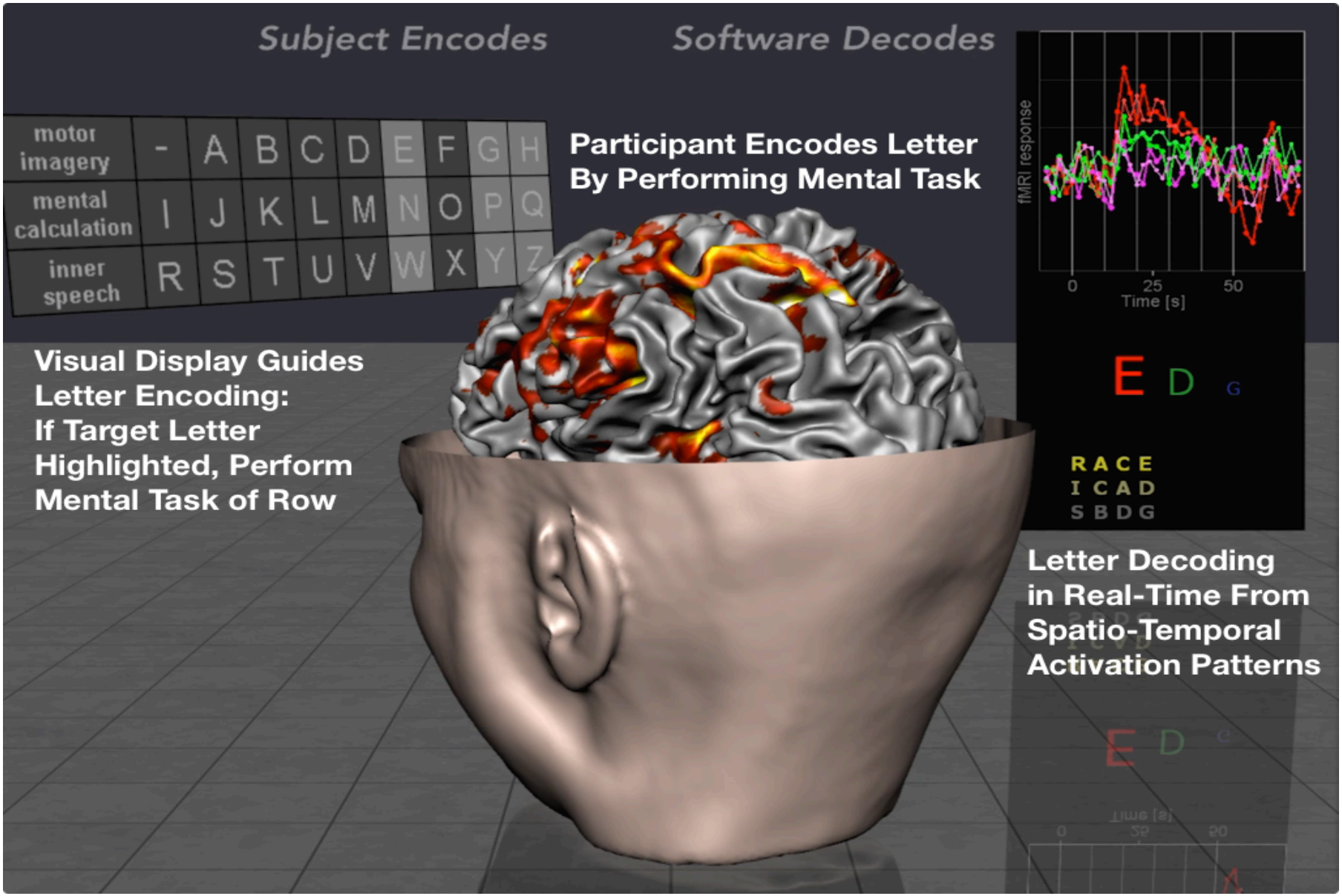
SPM Central (http://www.fil.ion.ucl.ac.uk/spm)

Rapid Mapping of Visual Areas: Fusiform Face Area (FFA) and Parahippocampal Place Area (PPA)



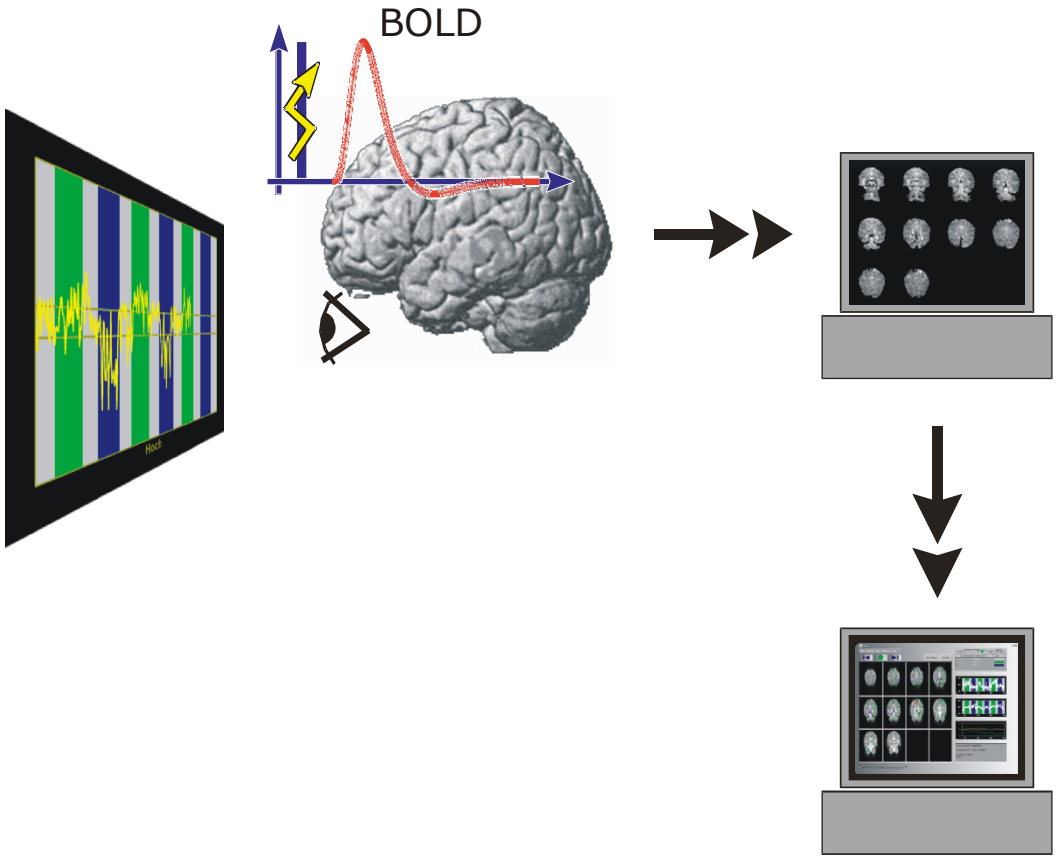
Courtesy: Goebel, Maastricht

Speller: Decoding of Brain Activity Patterns

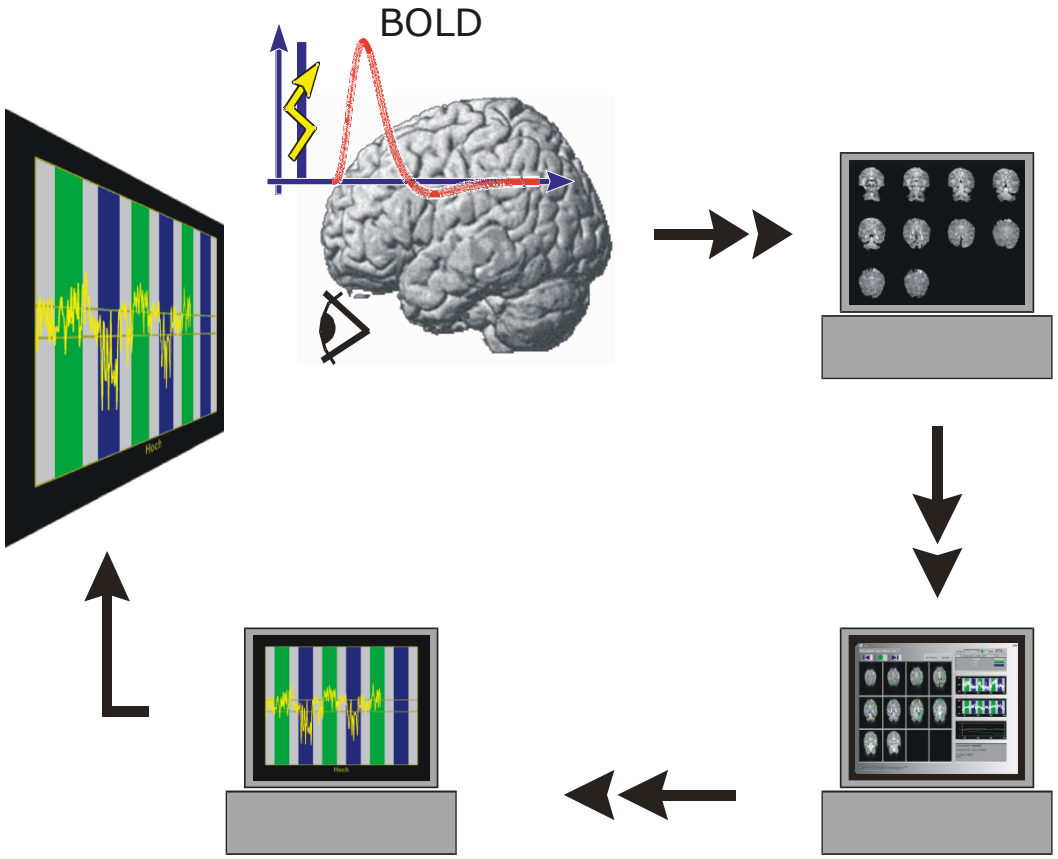


Sorger et al., Current Biology 2012

Neurofeedback: Closing the Loop

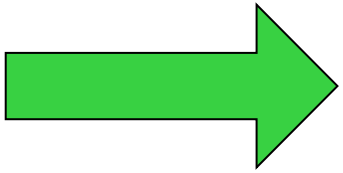


Neurofeedback: Closing the Loop



The Classic Neuroimaging Experiment

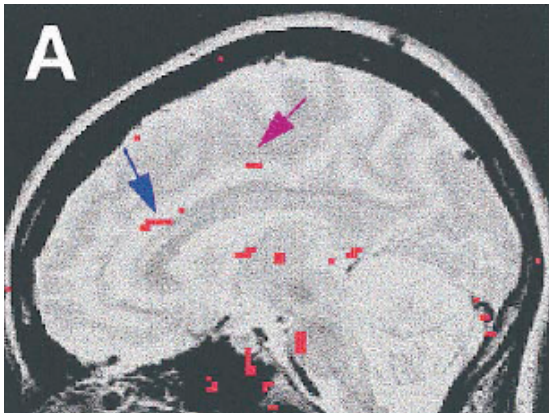
Behavior/ Stimulus



Neuronal Activity

Painful electric stimulus

ACC BOLD activity is increased



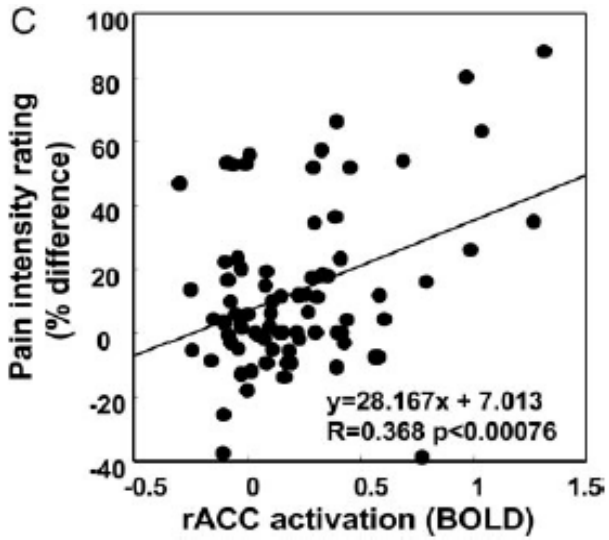
Davis et al., J Neurophys 1997

Neurofeedback: Swapping the Variables

Behavior/ Stimulus

Neuronal Activity

Pain rating changes



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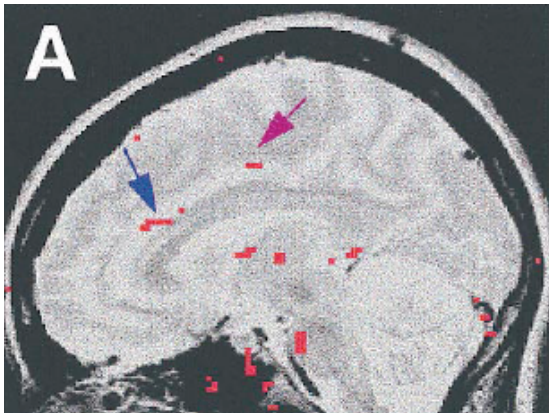

deCharms et al., PNAS 2005

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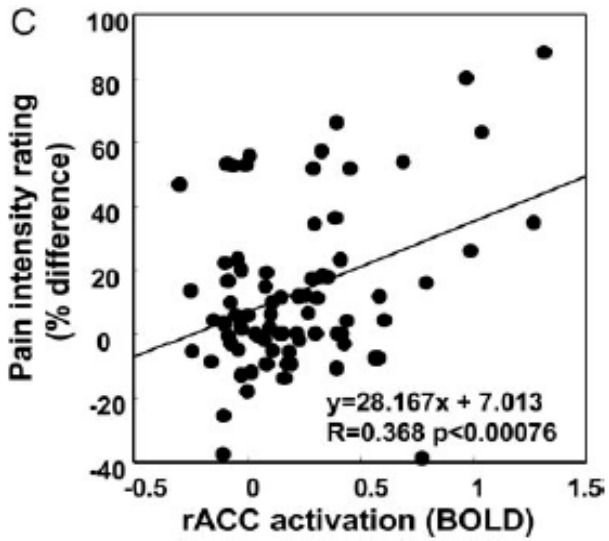

Sources: Wassermann, T. Brain Stim.; T. Varco

Overview

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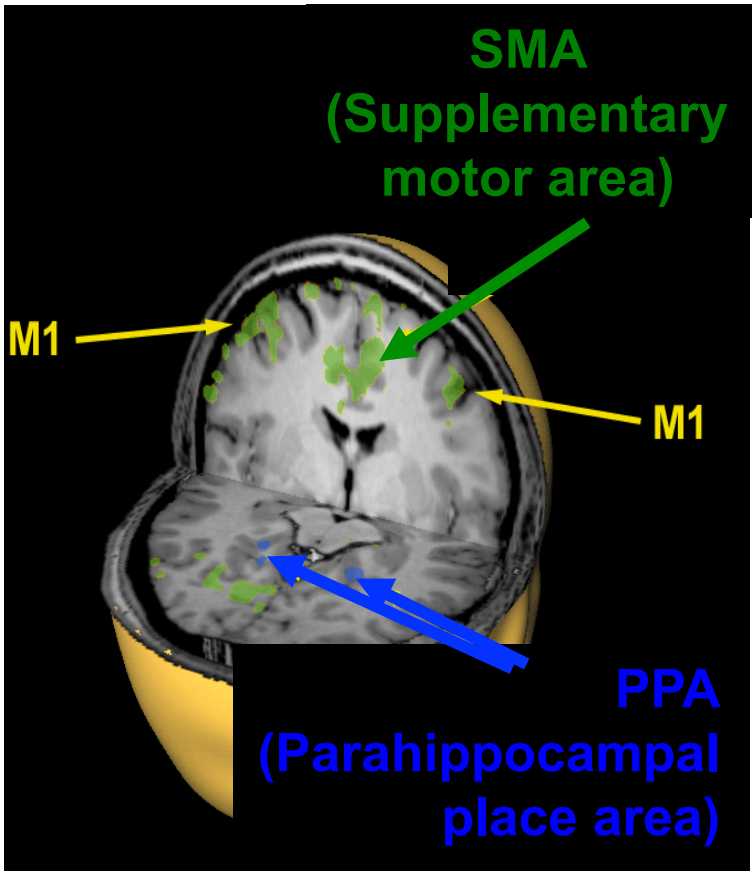
Target Areas for Self-Regulation: Supplementary Motor Area (SMA) and Parahippocampal Place Area (PPA)

- Functional role
  - **SMA:** movement, motor imagery
  - **PPA:** views of scenes, navigation, memory

- Functional localizers
  - **SMA:** bimanual finger opposition
  - **PPA:** images of faces/houses

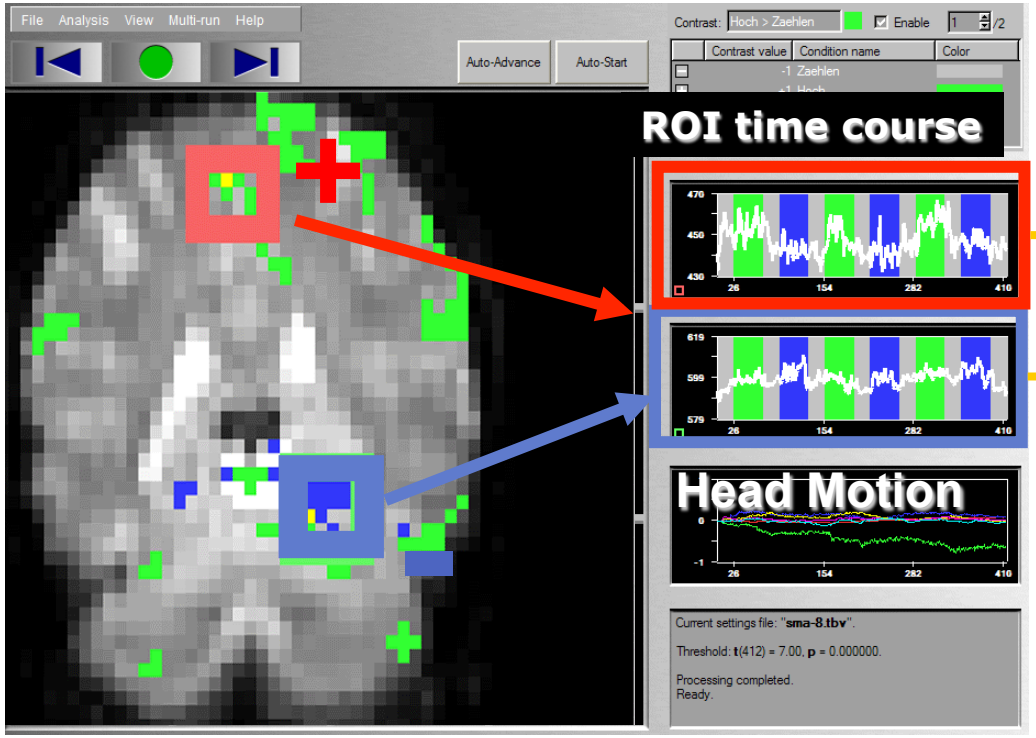


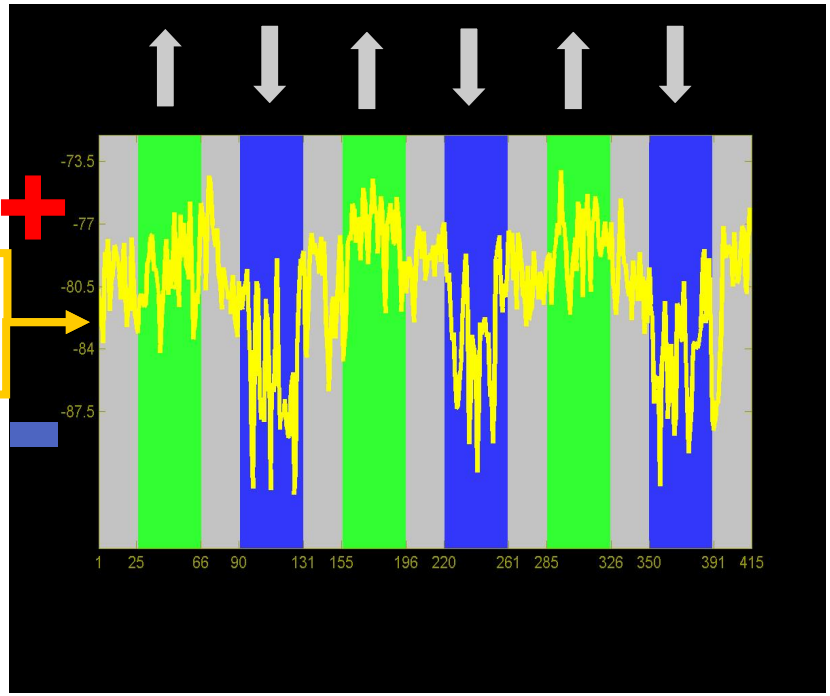
Weiskopf et al., IEEE TBME 2004; Scharnowski et al., Biol. Psychol. 2015

Differential & Bidirectional Regulation: SMA/PPA

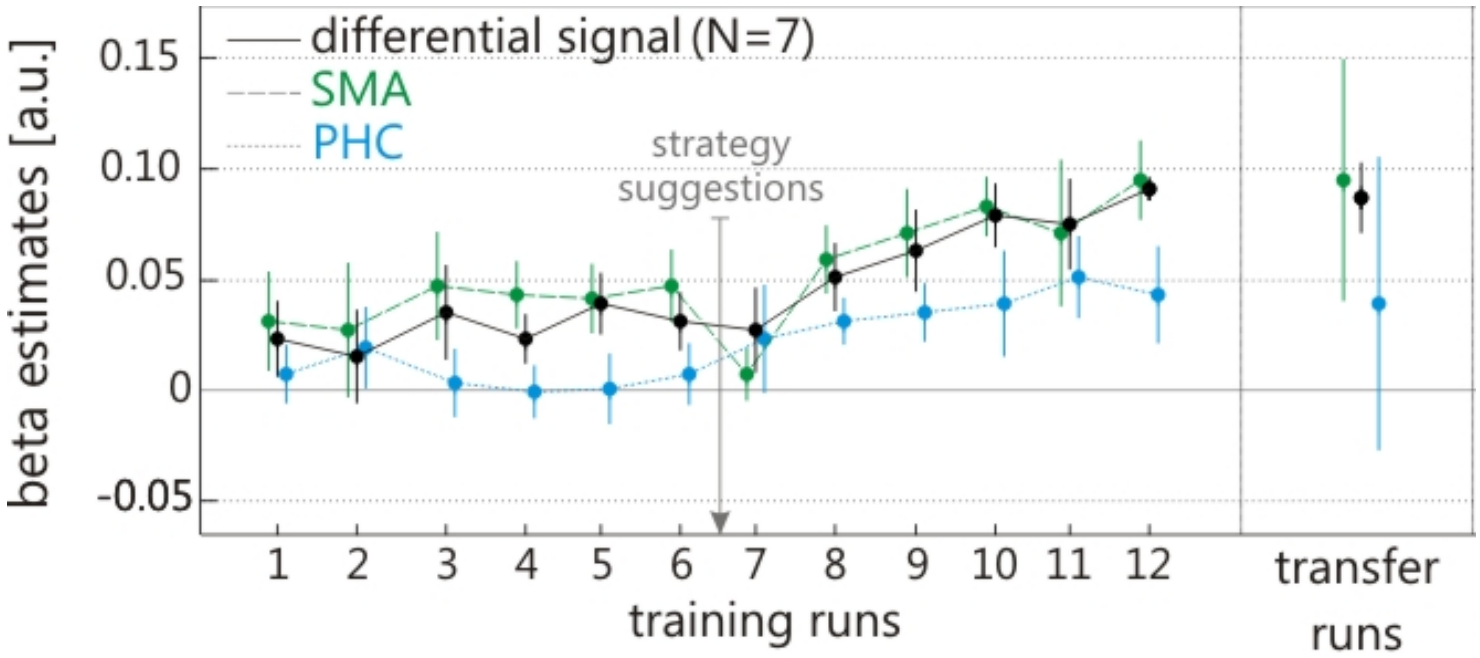
Experimenter's screen

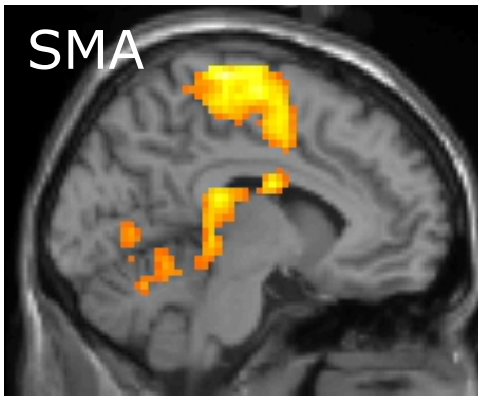
Feedback screen



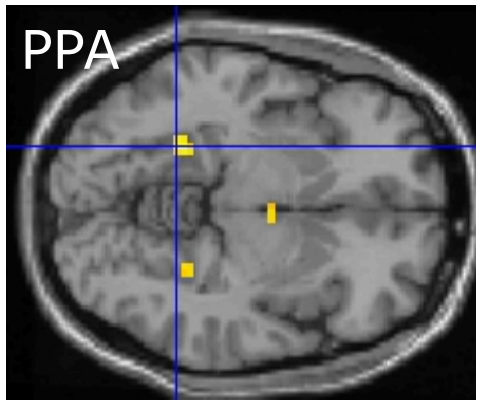


Learning of Self-Regulation: SMA/PPA





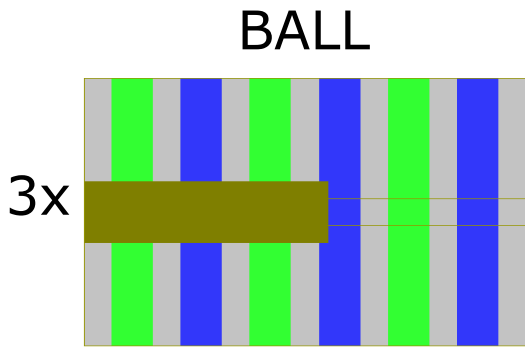
p < 0.001



n = 7
p < 0.005

Improved Memory Encoding: SMA/PPA

- Self-regulation without feedback
- Visual presentation of words
  (6 words + pseudo-word / block)
- Unexpected memory test



Scharnowski et al., Biol. Psychol. 2015

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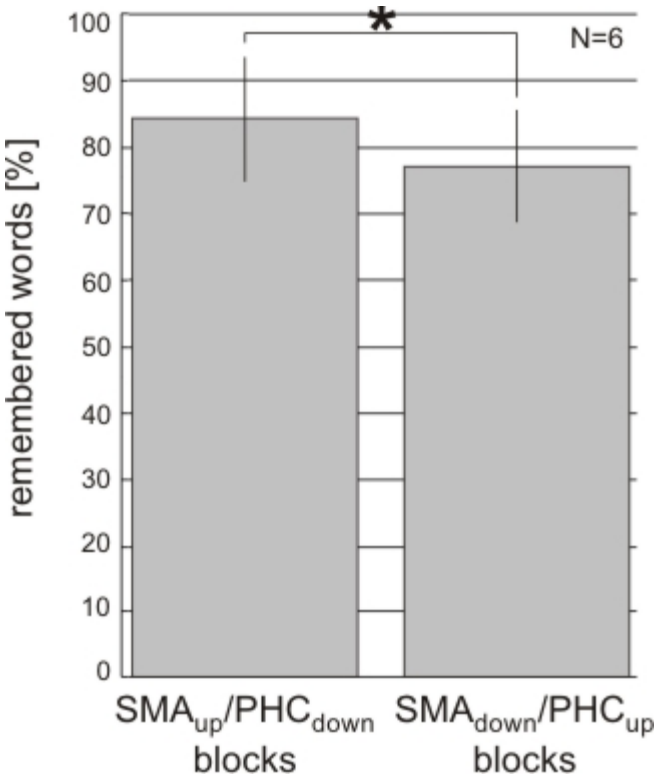

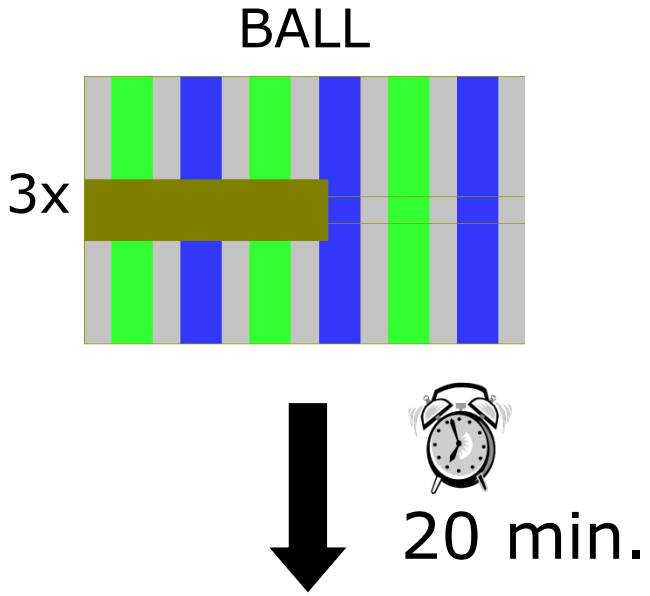

Recognition Test

•BALL	•sure	•unsure	•new
•ECHO	•sure	•unsure	•new

Scharnowski et al., Biol. Psychol. 2015

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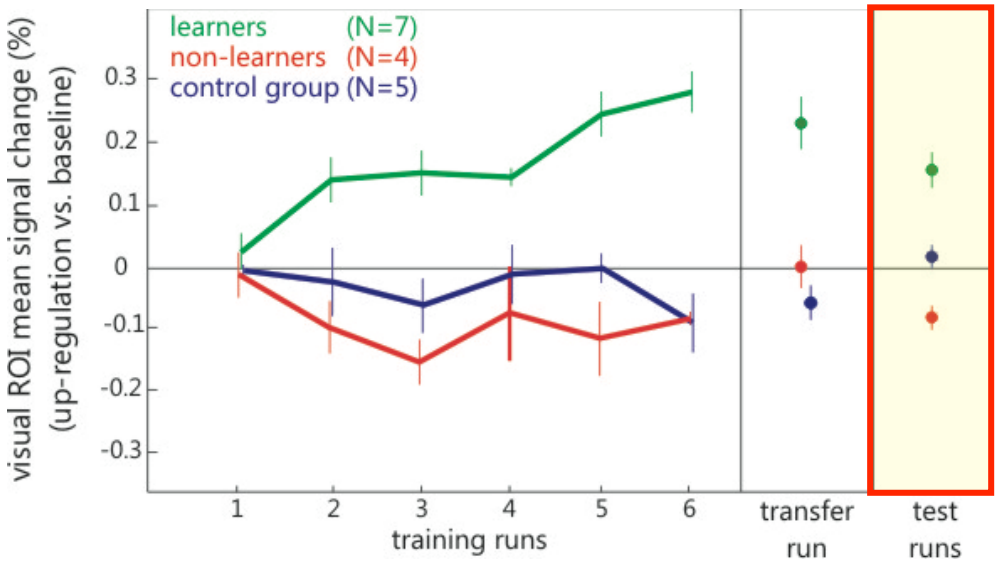
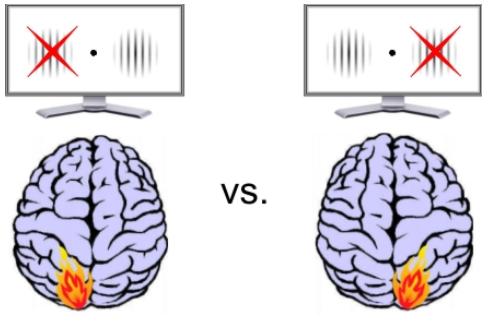
Training of Visual Cortex: Improved Perception

Visual ROI





Scharnowski et al., J Neurosc 2012

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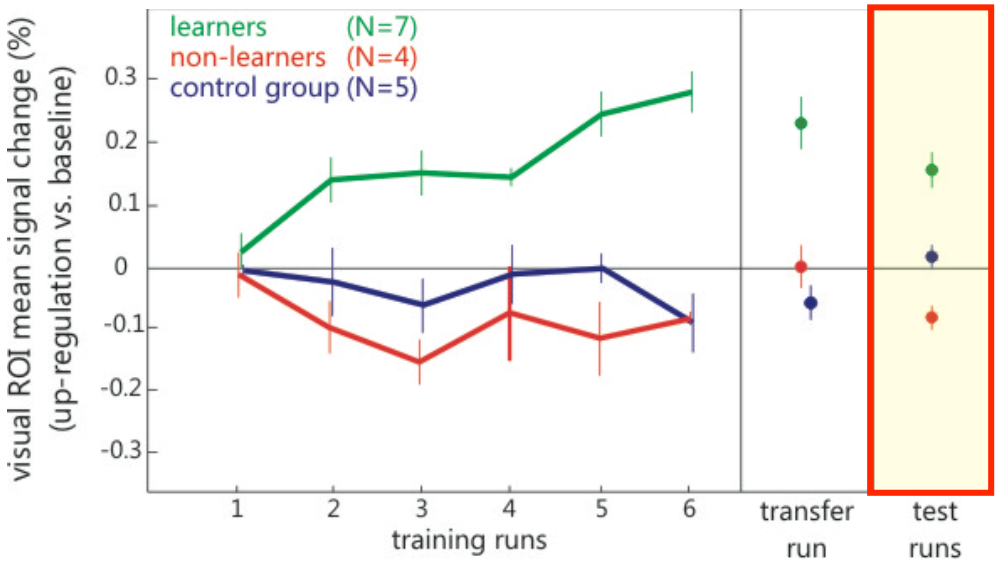
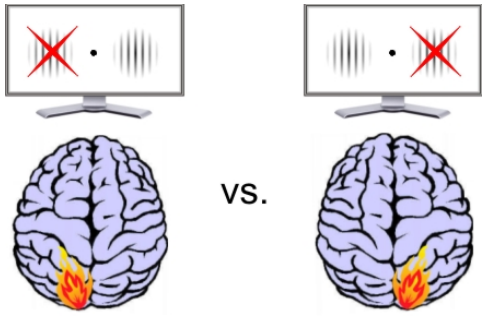
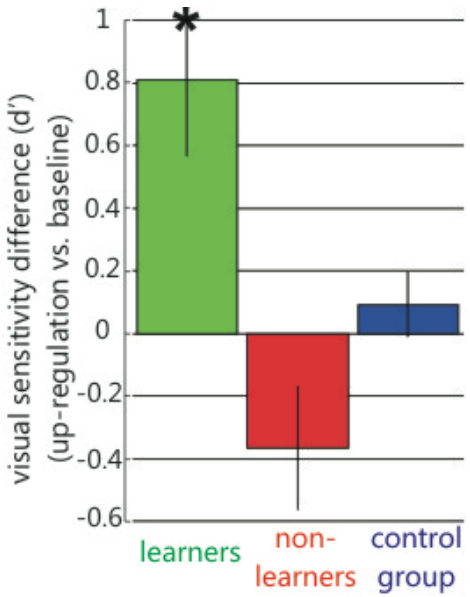




Improved visual sensitivity during up-regulation (relative to baseline)

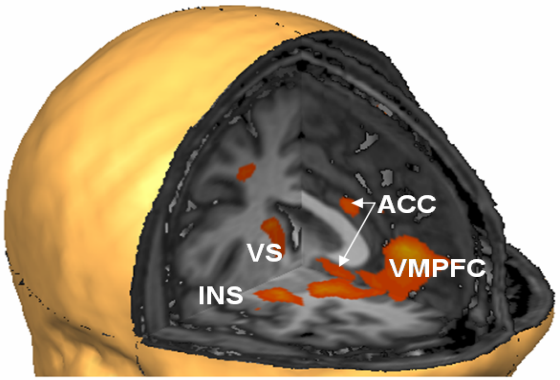


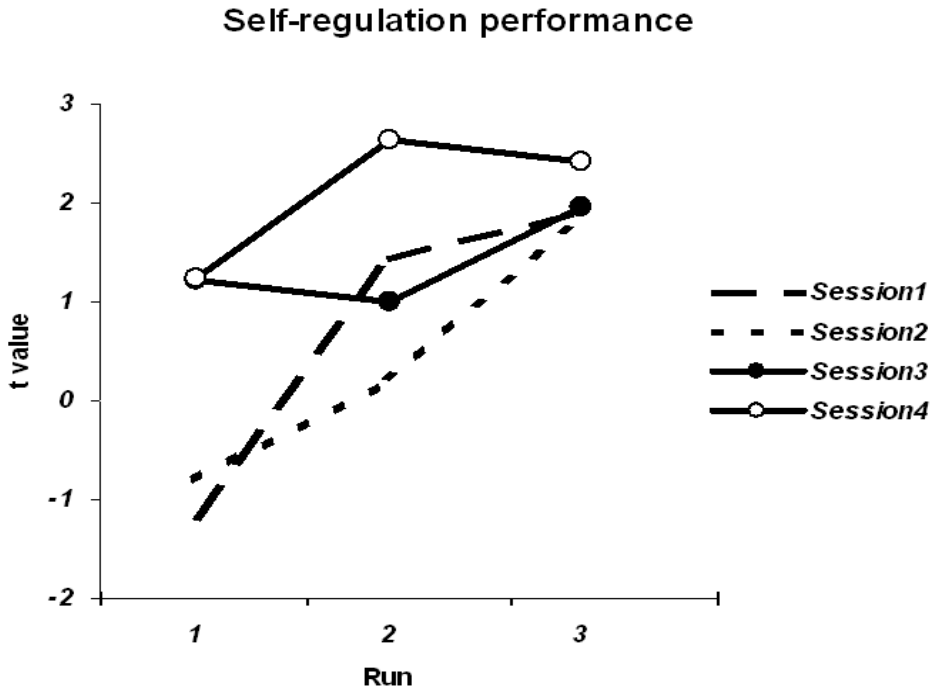
Behavior follows BOLD.

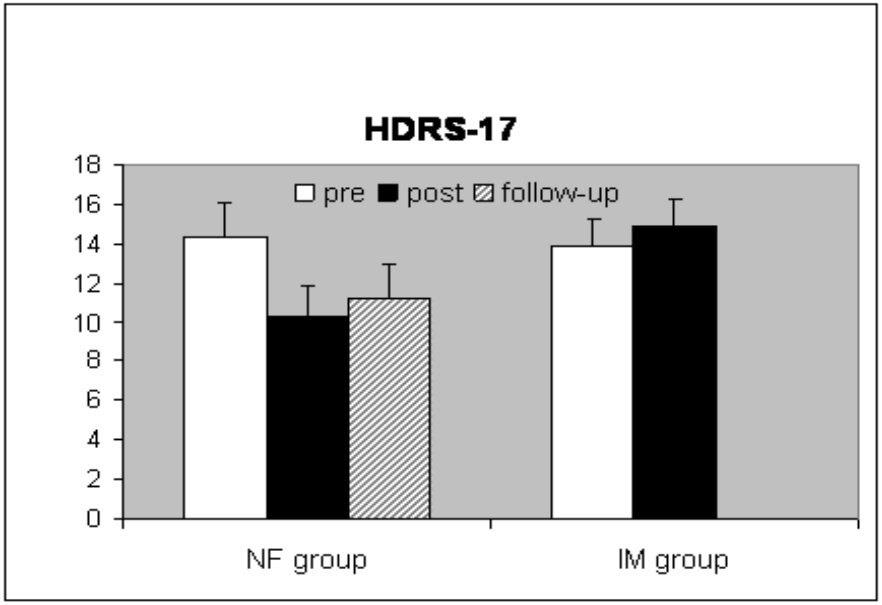
This **improvement was specific** to the visual field corresponding to the self-regulated ROI, i.e. no improvements were found for the ipsilateral visual field.

Scharnowski et al., J Neurosc 2012

Training of Activity Pattern in Depression

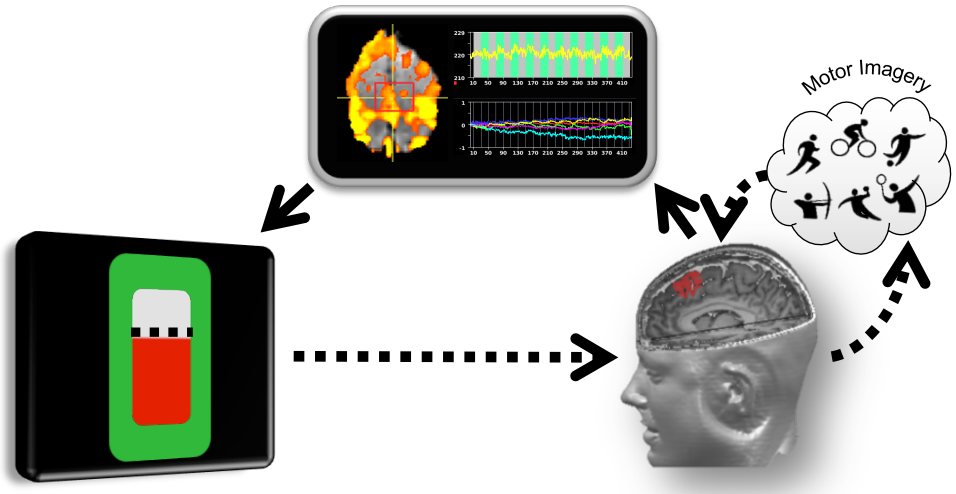


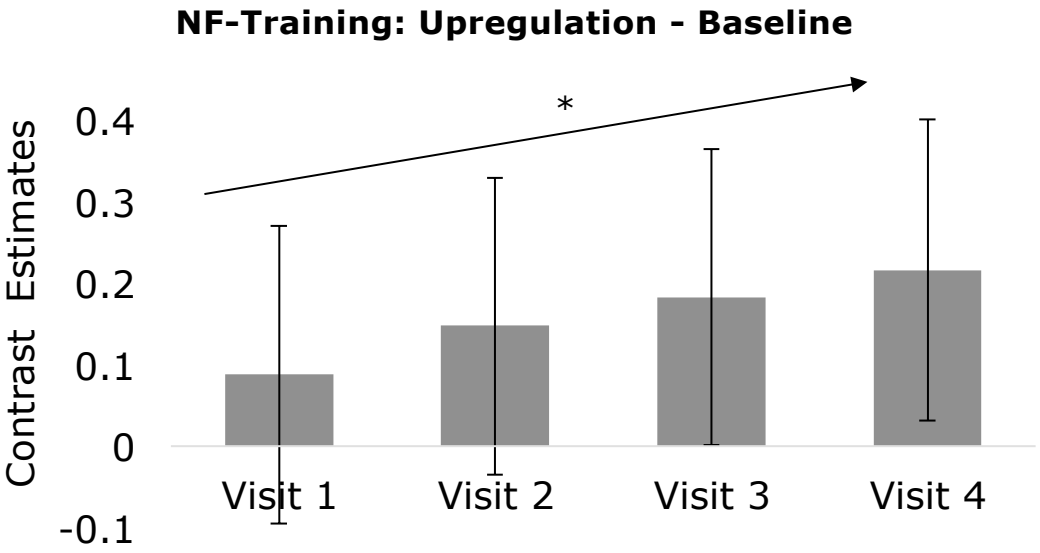


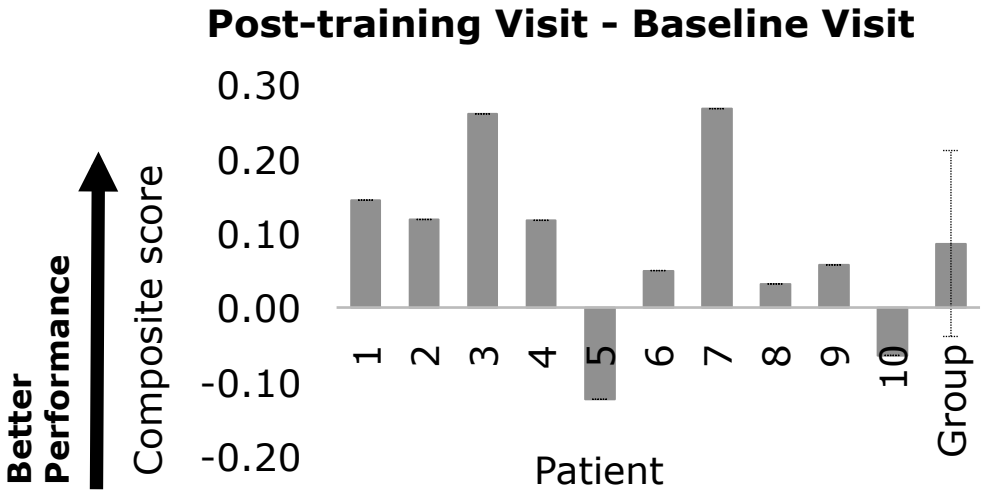


Linden et al., PLoS One 2012

Pre-SMA Training in Huntington's Disease



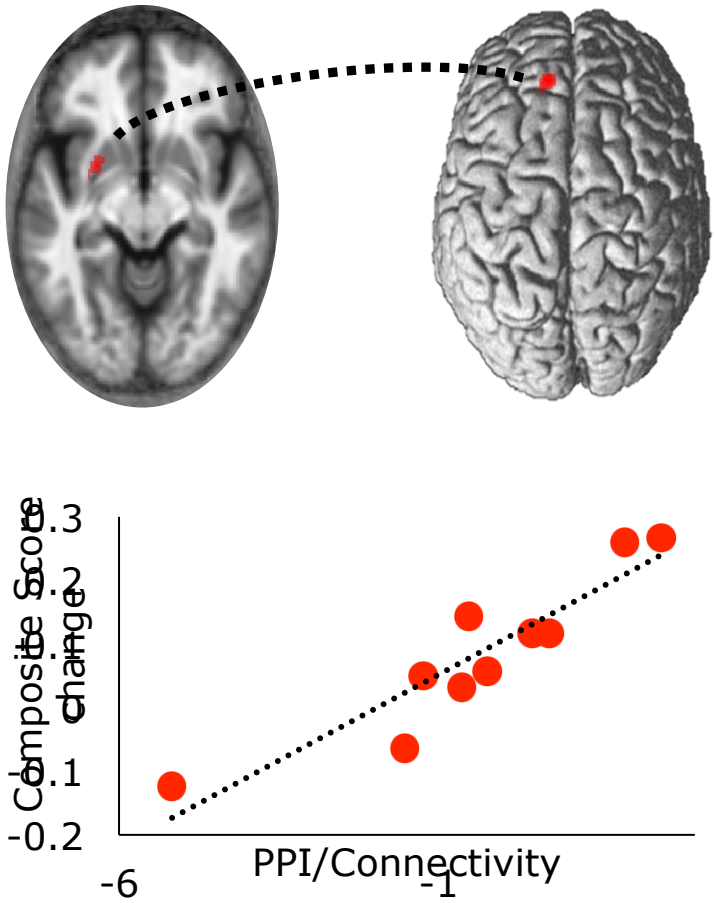




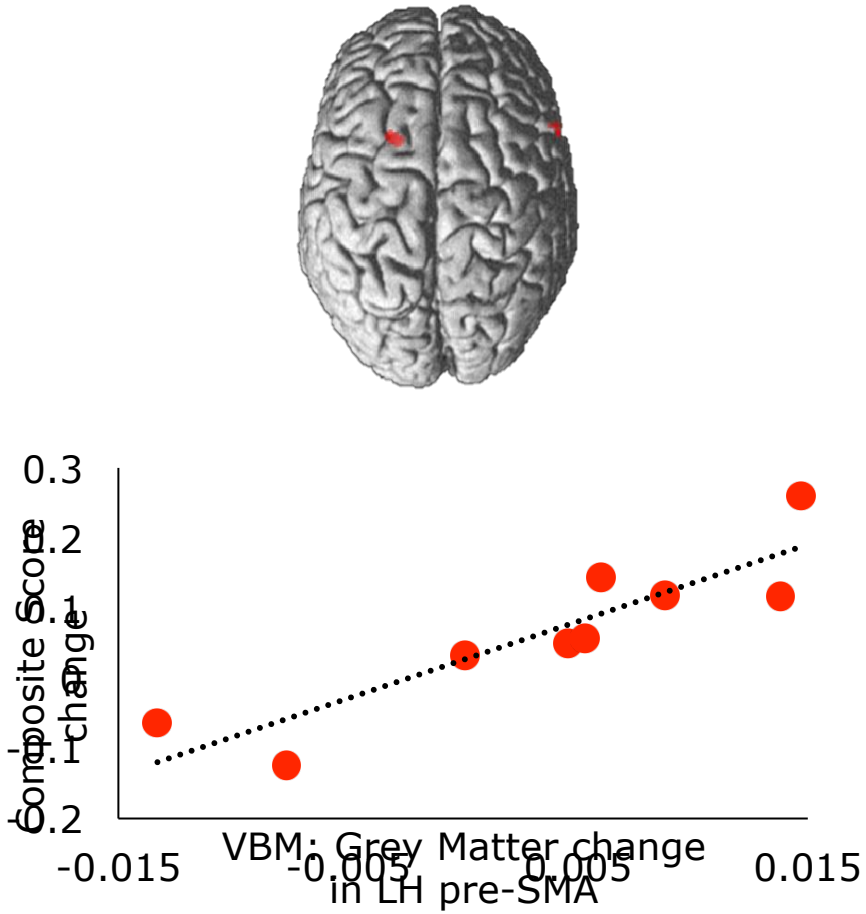
Papoutsi et al., in preparation

Pre-SMA Training in Huntington's Disease

Stronger connectivity in motor network: Putamen-Target ROI



Anatomical changes in left pre-SMA



Papoutsi et al., in preparation

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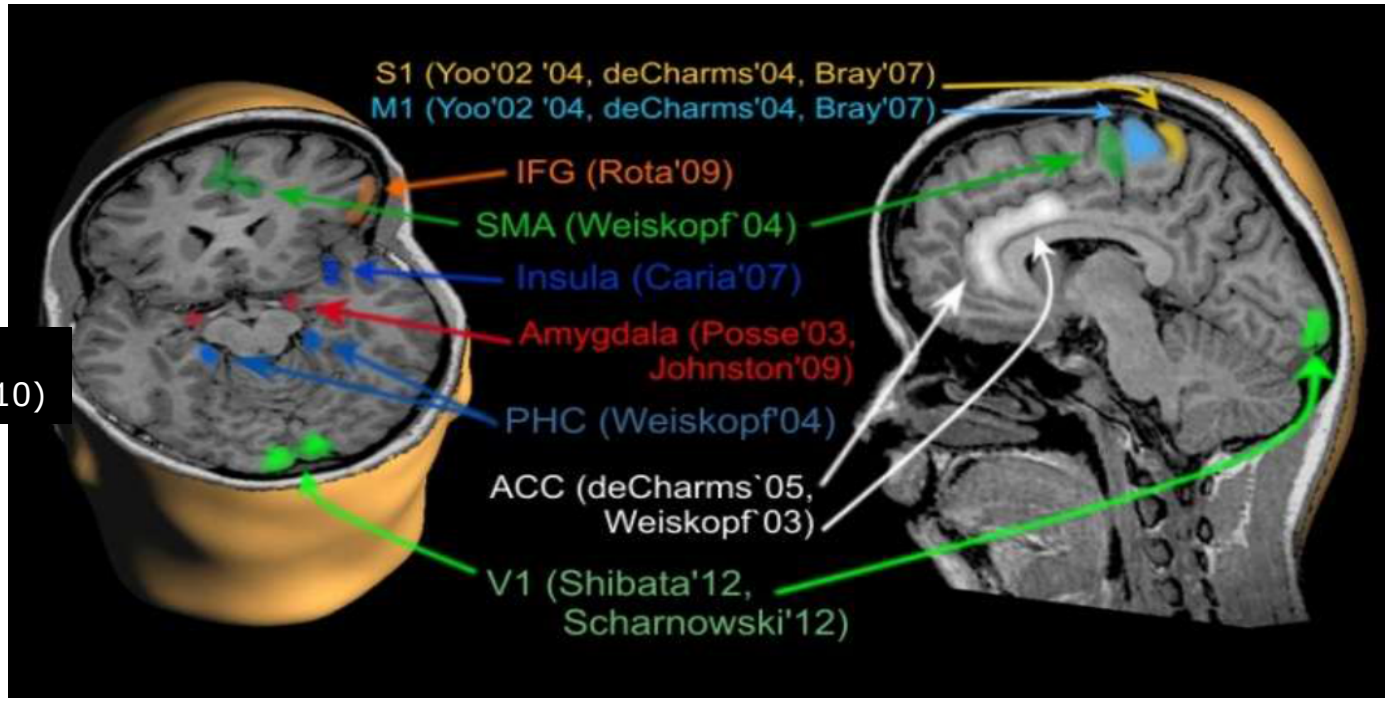
Conclusion

- rtfMRI provides information about current brain/BOLD activity
- Neurofeedback enables self-regulation of specific brain areas
- Specific behavioral effects due to self-regulation

Auditory cortex
(Yoo ’07; Haller `10)

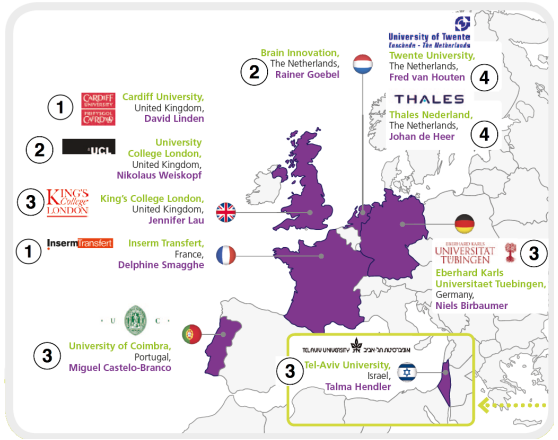


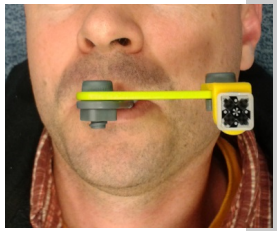
For reviews: Sulzer et al., Neuroimage 2013; Weiskopf et al., Neuroimage 2012

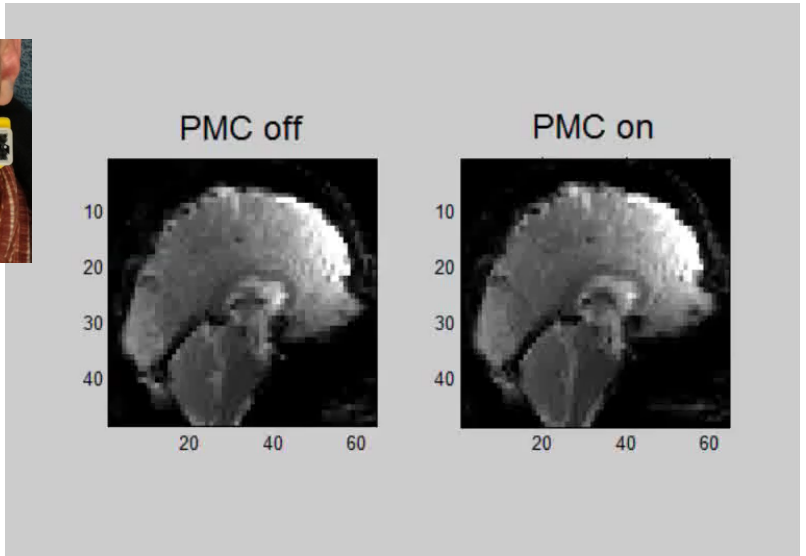
What is Next?

- Neuroscience
  - How are learning and self-regulation mediated?
  - What are the anatomical and physiological consequences?
- Clinical
  - What are the best targets and experimental designs?
  - Ongoing clinical trials in movement disorders and mental disorders
- Technology
  - Fast reliable feedback: ultrafast fMRI, prospective motion correction
  - Networks and connectivity
  - Multi-modal approaches

braintrainproject.eu

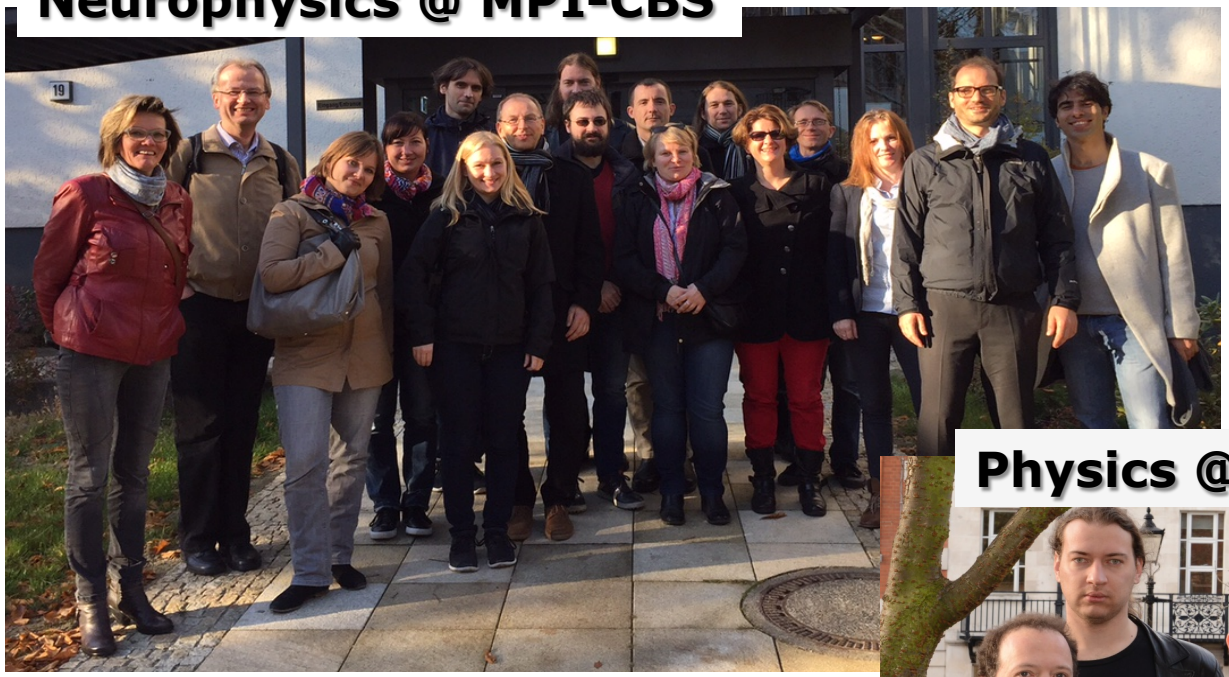






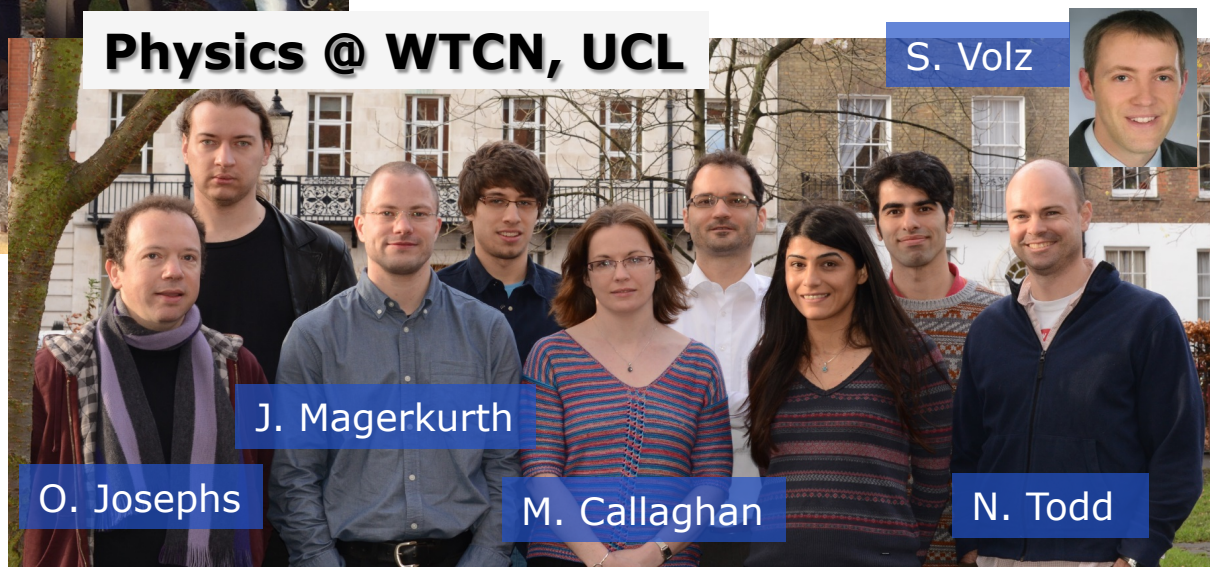
Thank you

Neurophysics @ MPI-CBS



M. Papoutsi, G. Rees, S. Tabrizi (UCL)
R. Goebel, B. Sorger (Maastricht)
F. Scharnowski (Zuerich)
N. Birbaumer, R. Veit (Tuebingen)
C. Hutton (Siemens UK)
K. Mathiak (Aachen)
M. Zaitsev, M. Herbst (Freiburg)

Physics @ WTCN, UCL



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End of Presentation