



# fMRI Data driven Modelling of Human Eye Movements, with Dynamic Causal Modelling.

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## Overview:

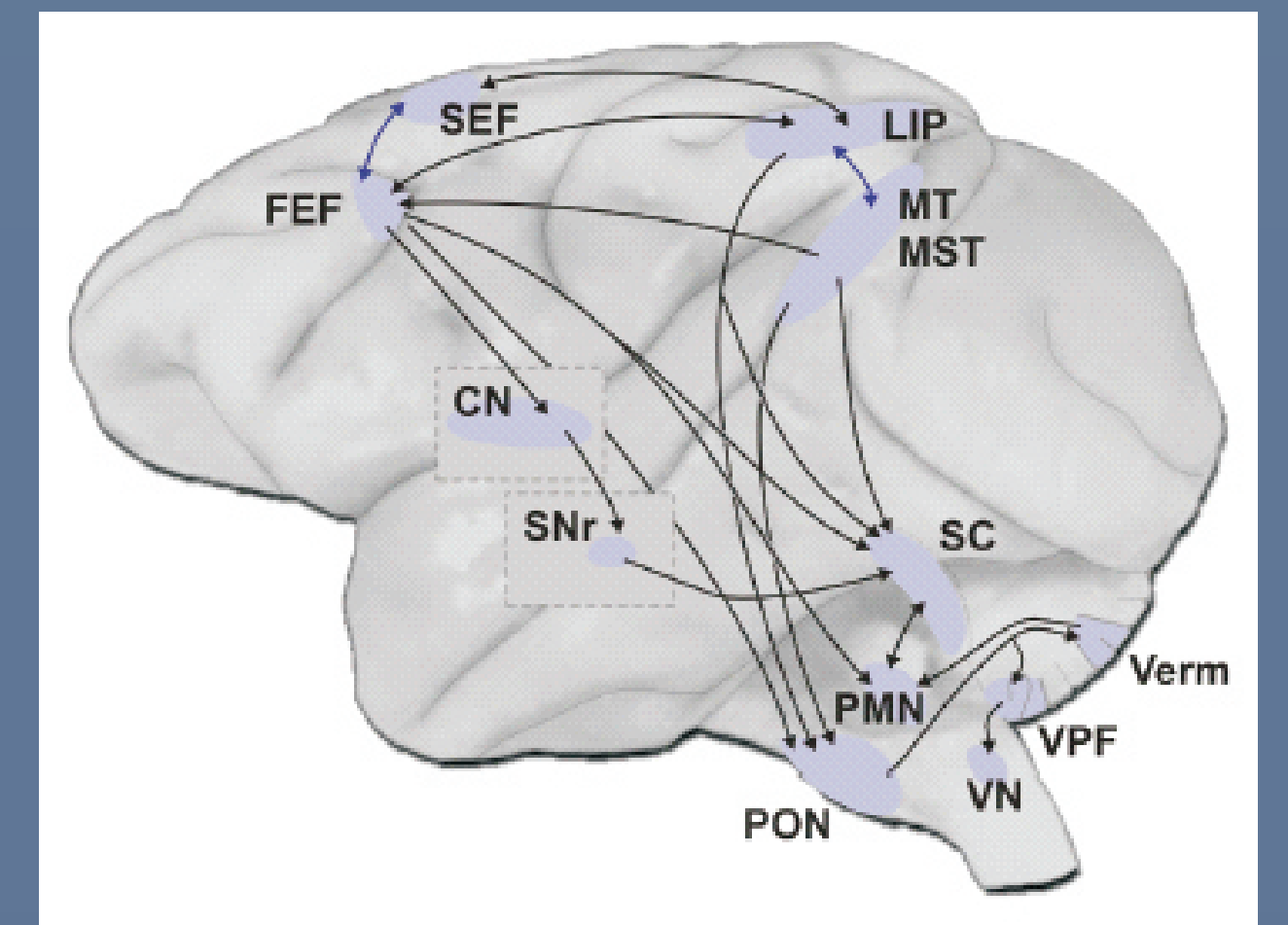
The purpose of this project is to explore the possibilities of closing the gap between fMRI data measurement and the construction of artificial neural networks, especially mean field networks (Brunel, 2003). These models simulate the behaviour of massive biological cell assemblies. The system dynamics of interconnected massive biological cell assemblies in human brains became measurable with functional Magnetic Resonance Imaging and the data analysis method of Dynamic Causal Modelling (Friston, 2003 & Fig. 4). DCM requires assumptions about the connectivity between brain regions, for this purpose, Krauzlis' (2005) model of attentional eye movement processing was applied for the human brain (Fig. 1). Here are the results of a DCM single subject study, exploring the dynamics of certain brain regions during different attention conditions to moving stimuli.

## Experimental Design:

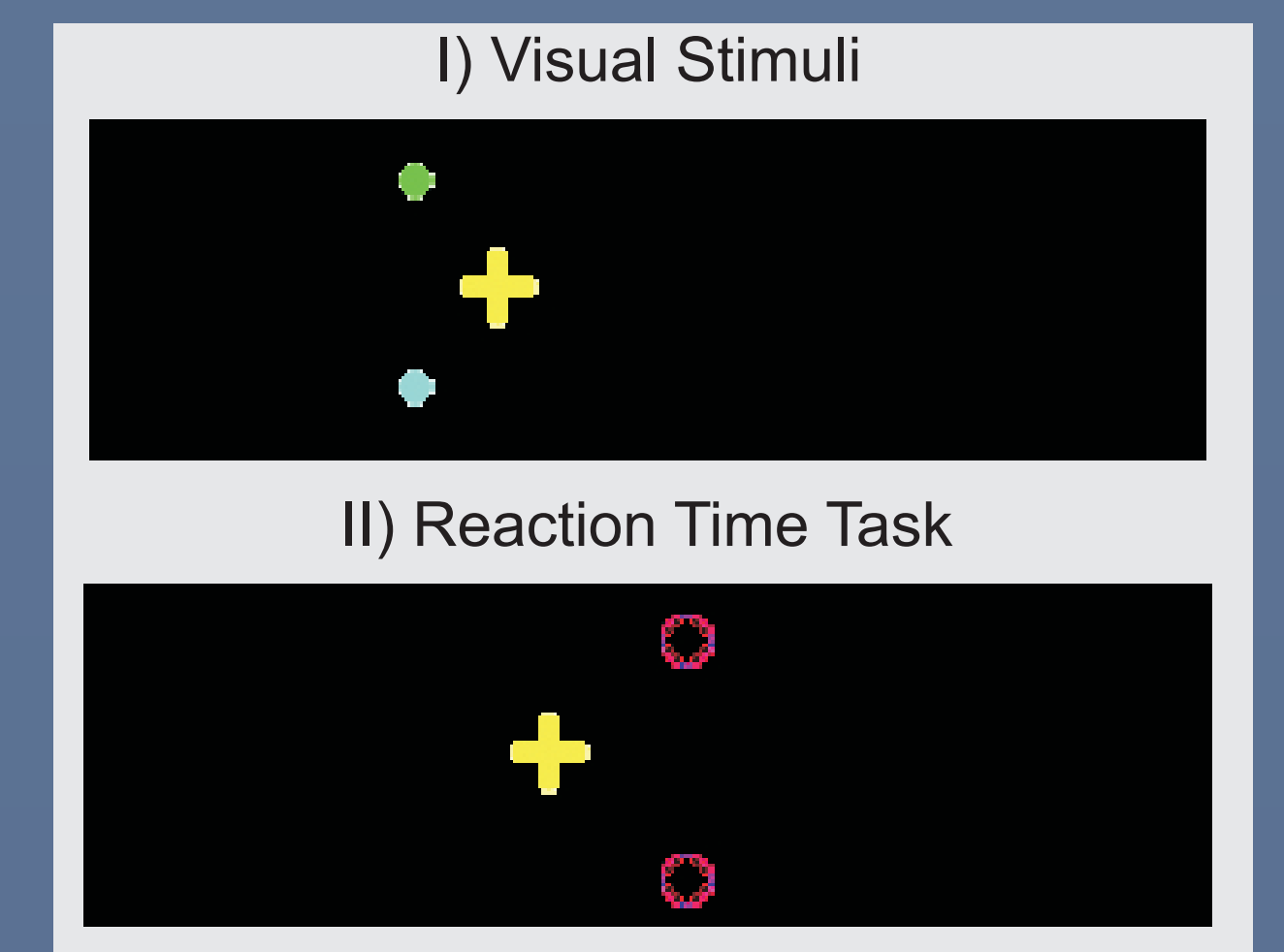
The experiment was conducted with a 3T Siemens Allegra MRT scanner (TR=2s, 32 slices, 3x3x3 mm Voxel Size). A total of 1156 functional scans were acquired, total running time was 38 minutes. The subject saw two moving dots and a fixation cross in his visual field. The upper dot made smooth sinusoidal movements, the lower dot was the target for triple step saccades in both directions. (Fig. 2,I). A simple block design was used (Tab. 1), the Blocks differed only in the instruction for the subject. Either the subject had to follow one of the dots (A,B) or the subject had to fixate the yellow cross and shift his attention towards the upper (C) or the lower (D) dot. The rest condition (R) was used to acquire a baseline, only the fixation cross was visible and the subject had to fixate it. Occasionally, with a probability of 0.05% per frame, both dots changed their color, this was an reaction time task to test the concentration of the subject (Fig. 2,II).

Pursuit	Saccades	Attention Pursuit	Attention Saccades	Relax
A	B	C	D	R

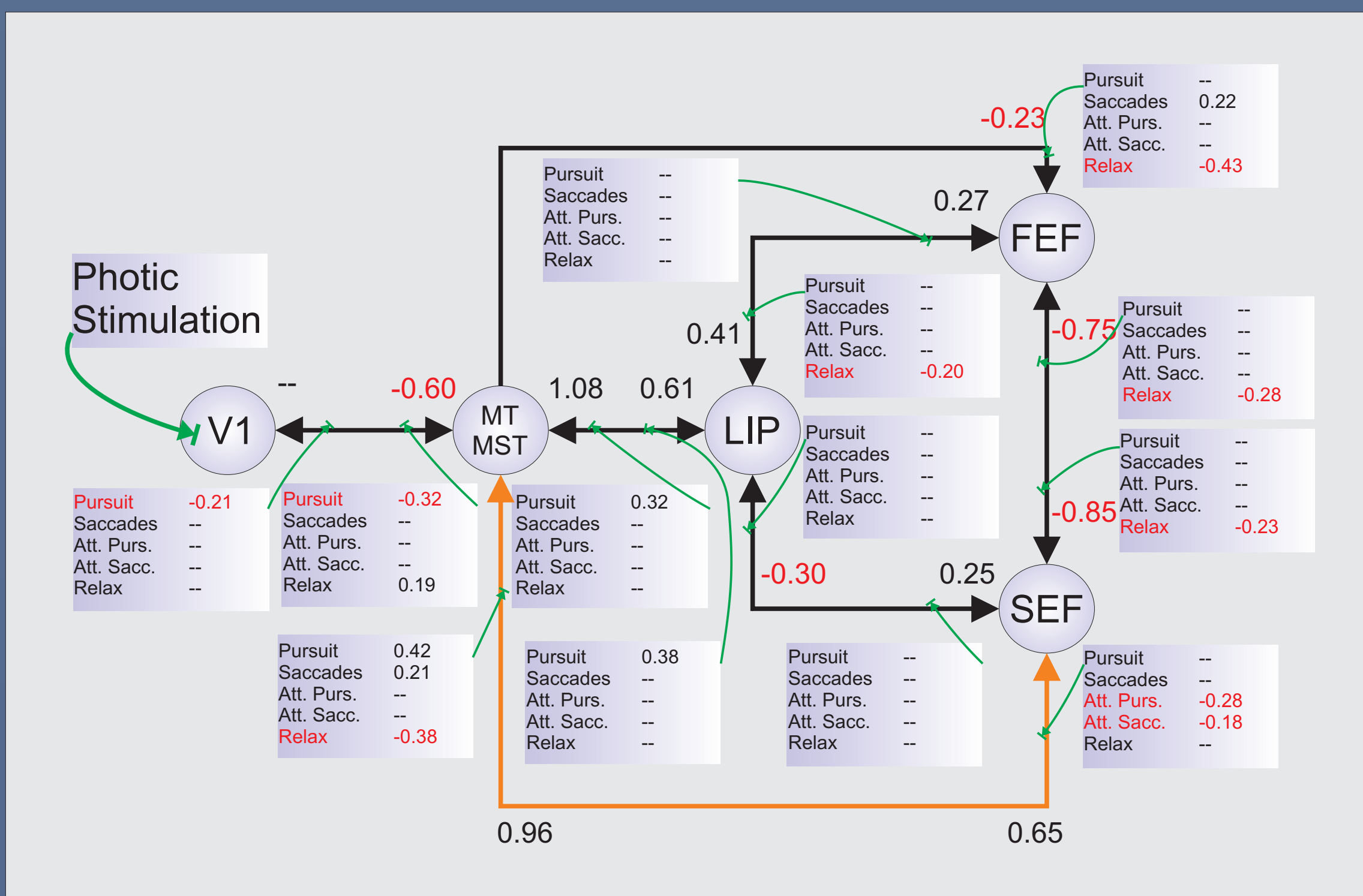
**Table 1:** The fMRI Block Design. The duration of each block was 30s, 15 volume scans were acquired per block. Each block was preceded by a display of the visual instructions for 6 seconds. The order of the blocks was permuted by the method of the latin square.



**Figure 1:** The connectivity between brain regions relevant to attentional eye movement processing. This is the schematic illustration of a macaque monkey brain, because effective connectivity data for humans are still rare. (From Krauzlis, 2005)



**Figure 2:** I) The visual stimuli used in the experiment. Sinusoidal moving dots with an amplitude of 9° in the visual field and a frequency of 0.77 Hz. II) Shows the change of the stimuli for the reaction time task. This stimulus appeared with a probability of 0.05% per frame (70Hz) and lasted 200ms. The subject had to press a button with the index finger upon detection



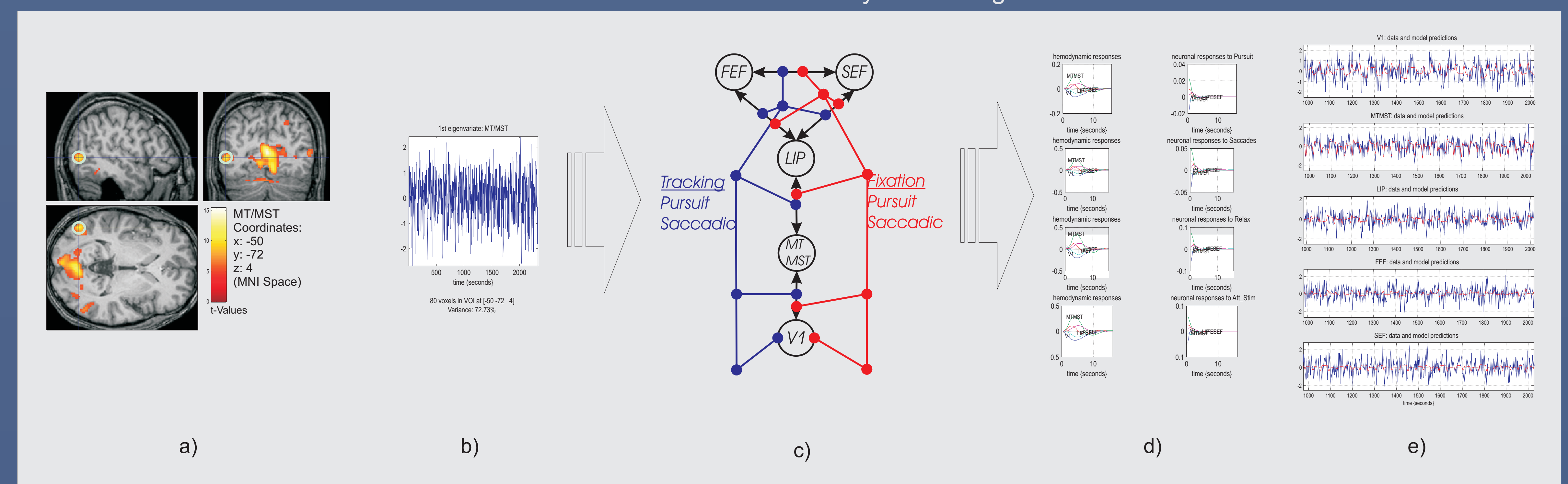
**Figure 3:** The resulting final DCM model. Five regions of interest have two-way connections, indicated by the black arrows connecting the circles. The numbers represent the connection strength between regions, the unit of measurement is Hz. The larger the number, the faster a modulational effect between the regions will propagate, indicating a stronger connection. The large numbers are the intrinsic connections strengths. They are modulated by the different conditions affecting the internal processing state of the system (boxes with green arrows). However the box 'Photic Stimulation' describes the external stimuli entering the visual system through retinal activation, these external stimuli are perturbing the system and are necessary to determine the modulational effects of internal processing states. The orange line, connecting MT/MST and SEF directly, lacks of physiological evidence. But the attentional shifting effect visible here, suggest that either there is a direct connection or one important area in the pathway between these regions is missing

## Results:

Comparing six DCM models after parameter estimation, the model shown on the left provided most information (Fig. 3). The model comparison used pairwise testing of the models, the measures were the Bayesian Information Criterion and Akaike Information Criterion (Penny, 2004). Nearly every connection specified in the model passed the significance threshold (>90%, Bayesian posterior probability). Only the connection from MT/MST to V1 failed this criterion. In general, the cognitive areas were less sensible to the changes of the direct tracking tasks (A,B). The general inhibitory effect of V1 to MT/MST is weakened by smooth pursuit stimuli. The MT/MST - LIP interaction is enhanced by these stimuli. The interplay of higher processing areas (SEF, FEF) was mainly affected by the rest condition, with an inhibitory effect. Attentional shifting effects (C,D) could not be reproduced. However a modified model (Fig. 3, orange line) leaving LIP away and modelling a direct connection between MT/MST and SEF showed clear bottom up inhibitory effects.

## Discussion:

That MT/MST failed to show an significant connection to V1 is not surprising, because a top down connection between these areas is assumed to be very weak (Krauzlis, 2005). The effects of smooth pursuit stimuli to the V1->MT/MST->LIP connections are to be expected, saccadic stimuli seem to affect only the connection from MT/MST to FEF, the activation effect might be caused by the programming of eye movement vectors. That the Relax condition affects mainly the connections to and from higher areas (FEF,SEF) is a bit surprising here, and has to be further researched. Finally the missing effect of attentional shifting in a five region model but clearly evident in a four region model may be due to the fact that one important area for attentional modulation may be missing.



**Figure 4:** Schematic steps for a DCM fMRI single subject analysis:  
a) After a conventional GLM analysis a region of interest has to be marked, in this picture it is the MT/MST area in a human brain.  
b) The volume time course if this region is extracted. It consists of the 1<sup>st</sup> eigenvariate of all BOLD signals of the Voxels within this region. Steps a) and b) have to be repeated for every Region of Interest.  
c) A DCM model has to be specified. The connectivity in the model should be evident from theoretical assumptions and knowledge about the effective connectivity between these Regions.  
d) The parameter estimation, estimates the neural activity for each region from the BOLD response. During several iterative computing steps the model is fitted on the data until:  
e) The model data (red) approximate the measured BOLD time course (blue) according to a gradient descent algorithm using a Laplace approximation.

## Literature:

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