Independent Junior Research Group
Neurocognition of Decision Making

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Perceptual Decision Making

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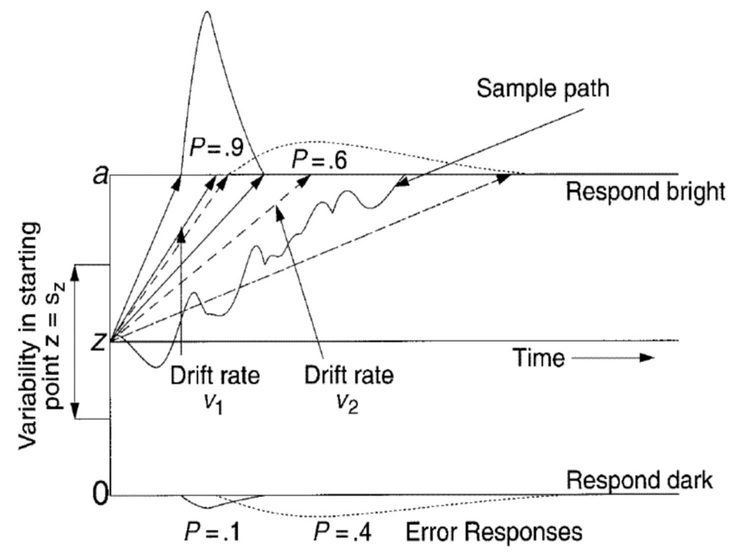
Background & Approach

- Mathematical modelling of behavioural data (e.g. diffusion model, Ratcliff et al. 2002) has long suggested temporal integration of evidence as a key mechanism for decision making.
- Recent neurophysiological work in monkeys has revealed a neural integrator of sensory evidence in a sensorimotor region (Mazurek et al. 2003).



- Here, we investigate, whether there is neurophysiological evidence of sensory evidence-accumulation in humans by using noninvasive recording techniques (EEG, MEG, fMRI).

Decision making in a tactile discrimination task

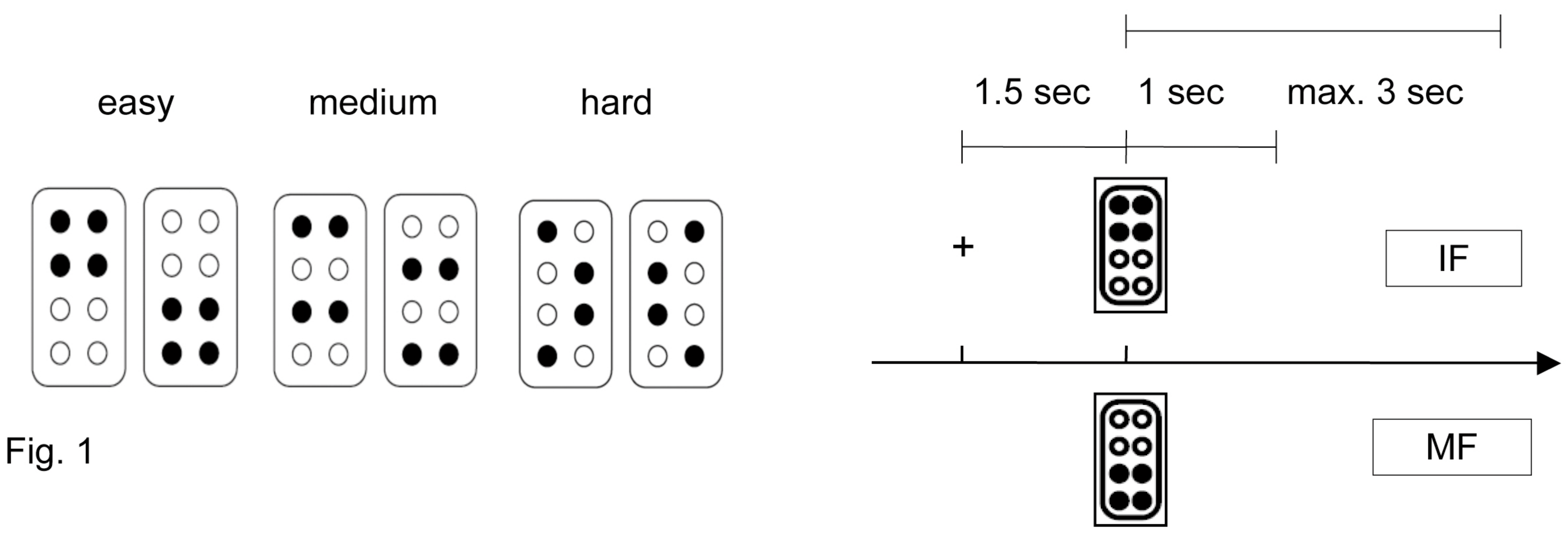


Fig. 1

Fig. 1: Experimental task
- 2AFC pattern discrimination task, three different Braille pattern pairs, identical stimulus energy
- One pair per block of trials discriminated, one stimulus presented per trial
- Response according to a prelearned stimulus-response-mapping.

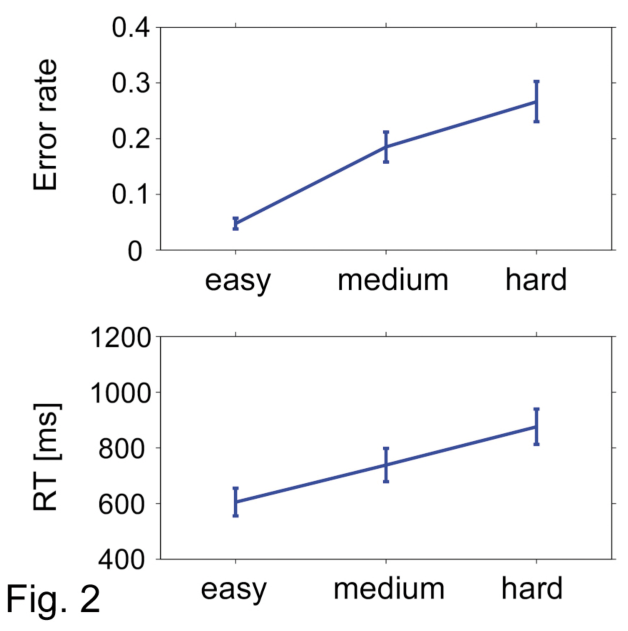


Fig. 2

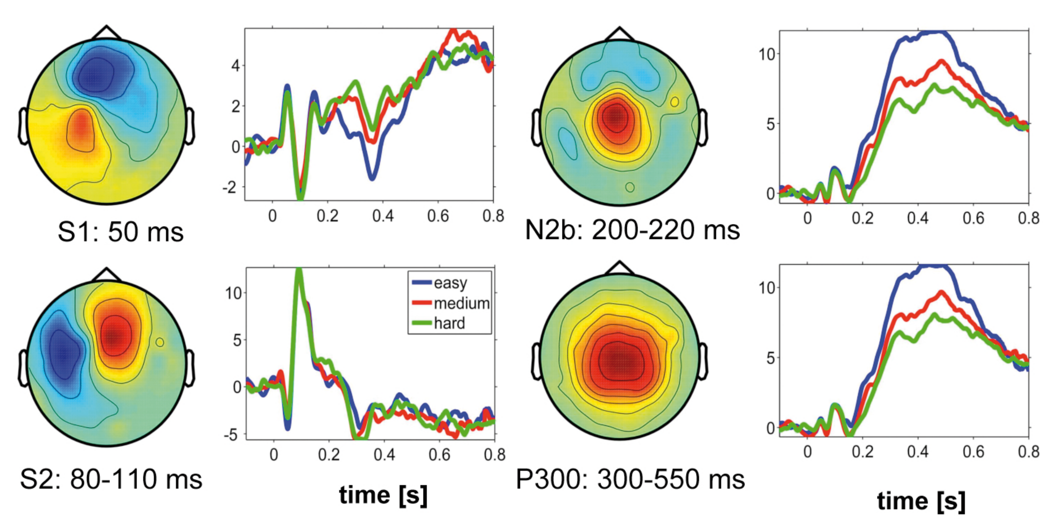


Fig. 3

Fig. 2: Behavioural data:
- Increase of error rates from 5% (easy) to 28% (difficult); increase in RT from 600 to 880 ms.

Fig. 3: Evoked potentials (EP):
- No modulation of early components, late radial components and late feedback activity in early sensory regions show a monotonic covariation with task difficulty.
- No latency differences, despite strong reaction time differences.

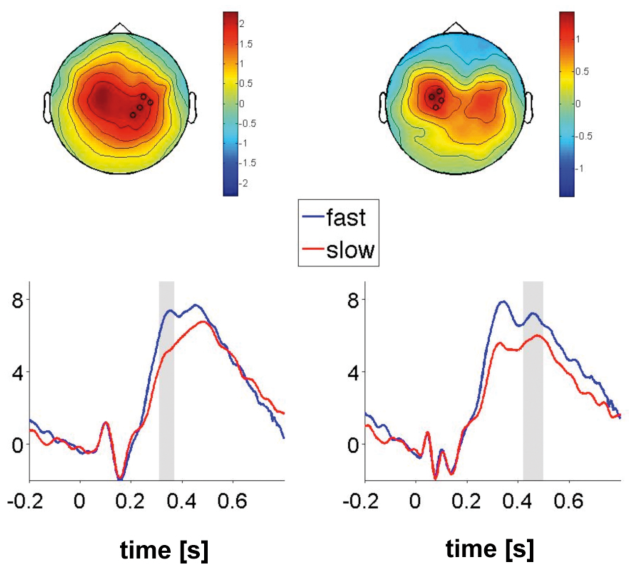


Fig. 4

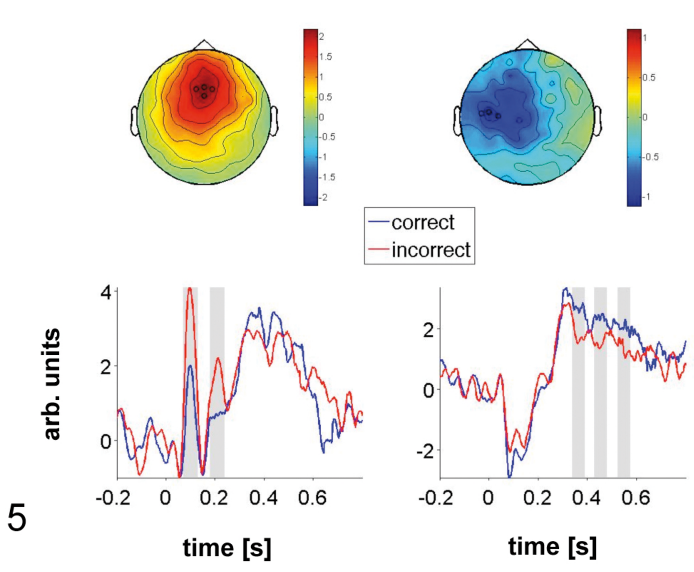


Fig. 5

Fig. 4 fast vs slow trials:
- No latency differences for fast vs slow trials.

Fig. 5 correct vs incorrect responses:
- Very early (100ms) enhanced frontocentral component for error trials accompanied by a reduced amplitude in presumably secondary somatosensory cortex.

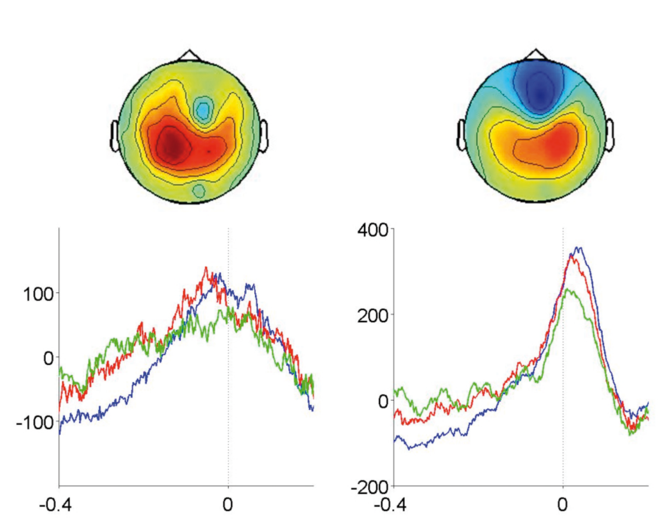


Fig. 6 A

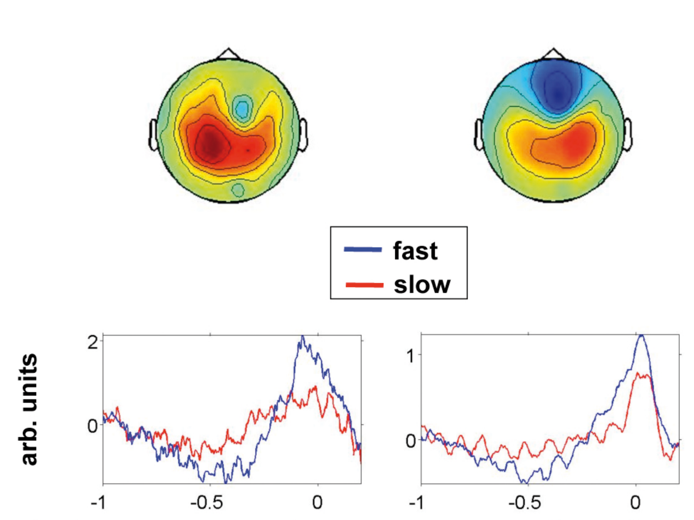


Fig. 6 B

Fig. 6 Response-locked EP
- Fig. 6A: slope of the timecourse in electrodes contralateral to stimulated hand covaries with task difficulty. Post-response amplitude effects over motor cortex suggest differences in response kinetics
- Fig. 6B: slower responses have a slower increase over time, consistent with Fig. 6A.

Decision making in a visual discrimination task

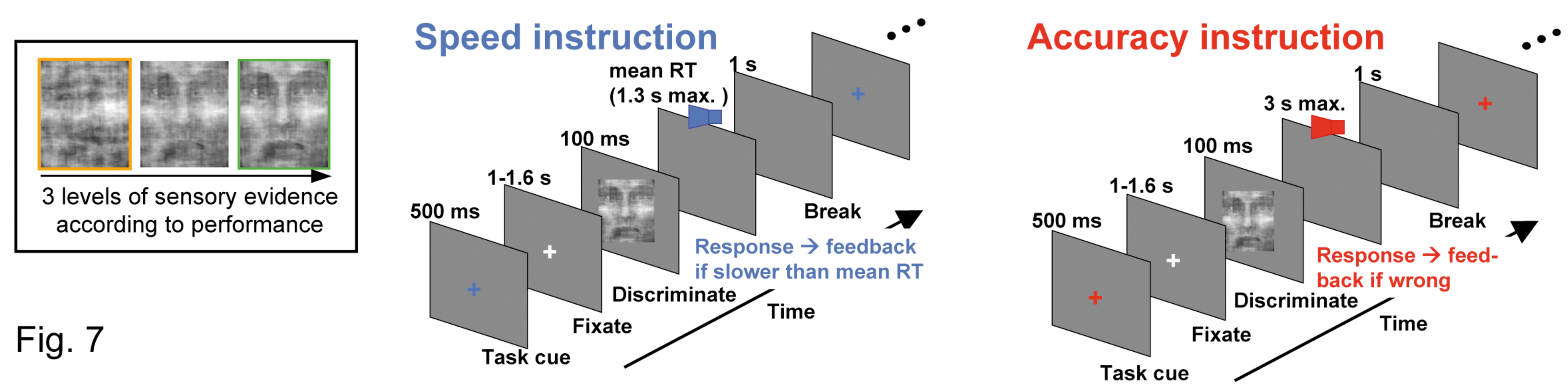


Fig. 7

Fig. 7: Experimental Task:
- 2AFC face-house discrimination task, phase-scrambled images to yield individual performance levels of 95%, 82% and 70%.
- Speed or accuracy are emphasized in different blocks by instruction. Differential feedback (aversive tone) for too slow responses ("speed") or for incorrect responses ("accuracy")

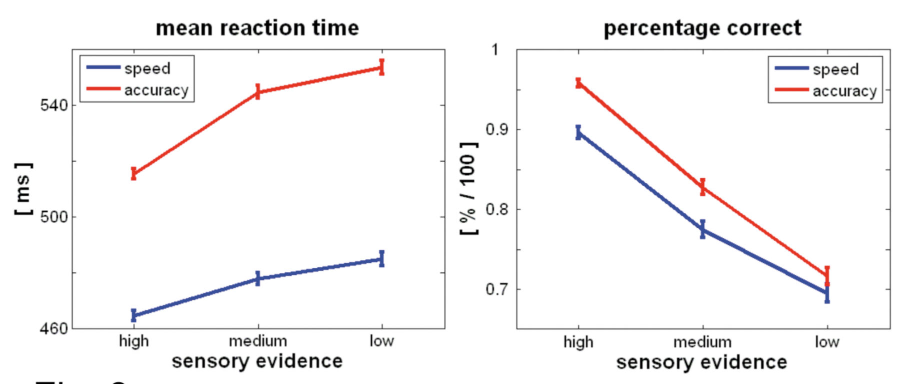


Fig. 8

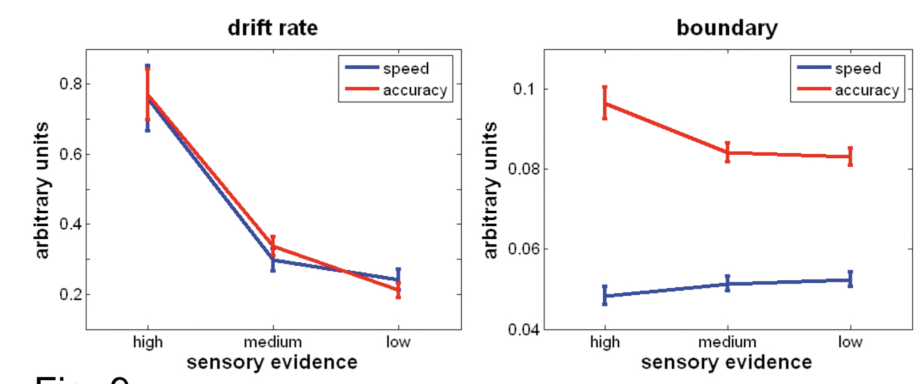


Fig. 9

Figure 8: Descriptive statistics behavioural data:
- Lower sensory evidence lead to higher error rates and longer reaction times. In the speed condition, subjects are faster but commit more errors compared to the accuracy condition.

Figure 9: Parameters from diffusion modelling:
- Lower sensory evidence reduces drift rate, with only weak effects on boundary. Instruction has a strong impact on boundary (higher boundary for "accuracy"), no effect on drift rate.

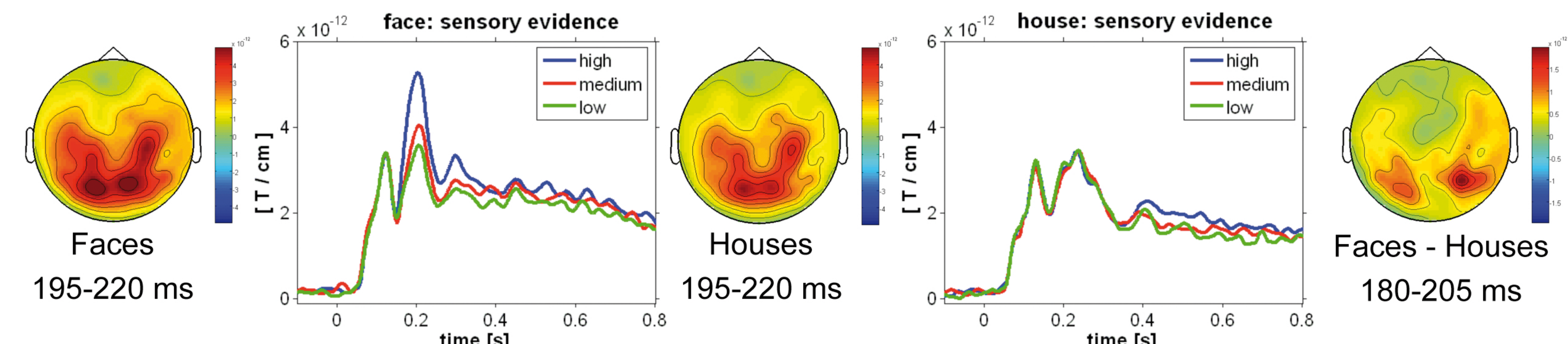


Fig. 10

Figure 10: Planar gradient evoked fields (EF):
- Face selective component ~190 ms over predominantly right occipito-temporal regions, consistent with Fusiform Face Area.
- Component is monotonically related to the amount of sensory evidence, for face-images only.
- No effect of "speed"- vs. "accuracy"-instruction in the stimulus locked EF.

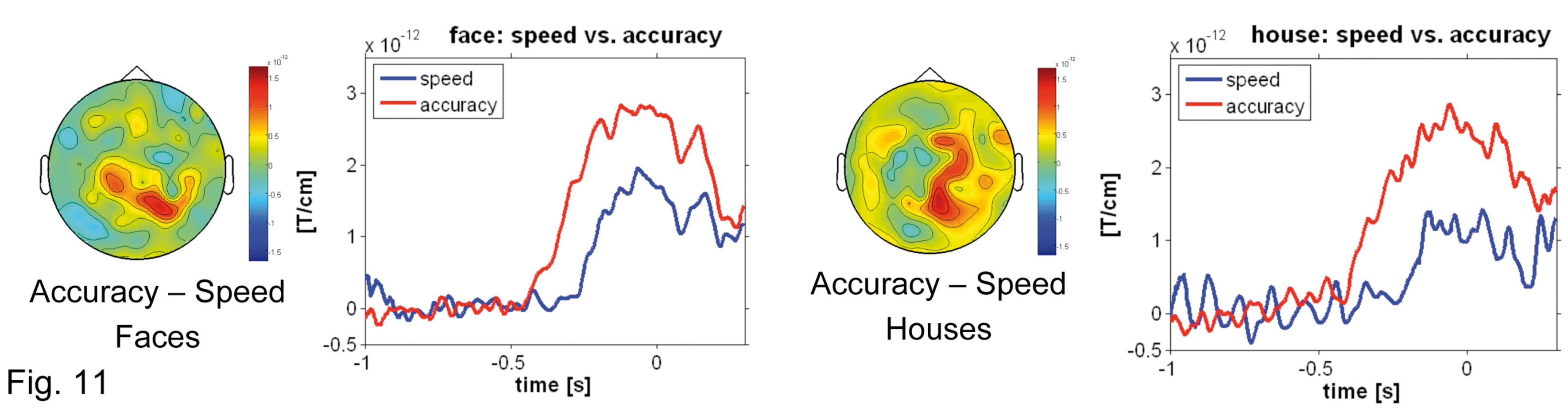


Fig. 11

Fig. 11: Response-locked EF:
- Larger activity preceding response for "accuracy" instruction - consistent with a diffusion to boundary mechanism - higher activity is required to pass the threshold for more accurate decisions.
- Observed for both, faces and houses, with specific topographies

Conclusion & Outlook

- Current results - together with the work of Heekeren et al. (2004,2006) and Philiastides et al. (2006) - suggest that investigations into the microstructure of perceptual decision making are possible with human recording techniques.
- The present data improve our understanding of sensory processing and highlight a so far neglected phenomenon: the presence of response locked activations in sensory cortex. With their timing characteristics and correlations with behaviour and task requirements they have all characteristics of a sensory evidence-accumulation process. Their timecourse may reflect the gradual build-up of subjective evidence (or likelihood) for one perceptual alternative and may be instrumental in sending the final signal for the release of the motor response.
- A major question remains - what are the compuational processes during such evidence accumulation? Both studies have revealed clear evidence of top-down feedback-loops to early sensory areas. Recurrent processing between different levels of the hierarchy may be crucial for sharpening the mental representation of stimuli. This will be further investigated, together with simultaneous EEG-fMRI recordings for advanced source reconstruction purposes.

Collaborations

- **Tactile perceptual decision-making and MEG:** Jon Driver, Institute of Cognitive Neuroscience at UCL, UCL London, UK
- **Visual perceptual decision-making and MEG:** Burkhard Maess & Angela Friederici, MPI for Human Cognitive and Brain Science Cognitive Neuroscience, Leipzig, Germany