

Dynamics underlying auditory working memory for maintaining pitch of a simple tone

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Abstract

- We aimed to understand the dynamics underlying auditory working memory for maintaining 'simple' tones. We recorded MEG in 17 subjects while they maintained one of the 2 presented tones or ignored both in the control condition. After 12s, they compared the pitch of a test tone with the maintained tone.
- Analysis of evoked responses showed persistent activity throughout retention compared to the pre-stimulus baseline but enhanced only at the start compared to the control condition. The evoked response during maintenance was localised against baseline to bilateral Aud Cortex. Analysis of the induced responses showed suppressed alpha in the left AC, enhanced theta in the medial PFC, and enhanced beta in the cerebellum.
- 19 new subjects were presented with a tone and a Gabor patch and a cue indicating whether to maintain auditory or visual information for 12s. Analysis of the induced responses in auditory cond yielded similar results. Connectivity analysis showed that the phase-locking of beta activity in the cerebellum with left IFG was correlated to subject's task accuracy. MVPA decoder accuracy at right STG was correlated to subject's performance.
- Our data shows a network involving AC, mPFC, hippocampus, cerebellum & Broca's for maintaining sounds.

Introduction

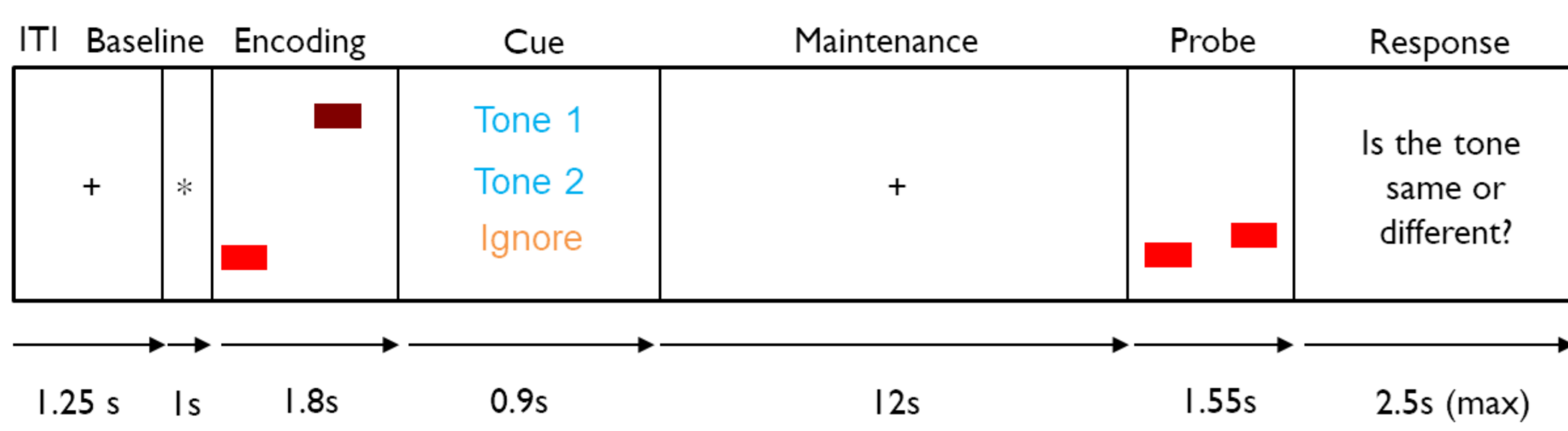
- Auditory working memory (WM) pertains to the process of keeping representations of auditory objects in mind for short durations when the sounds are not in the environment. It is different from phonological WM as the sounds cannot be assigned a semantic label.
- A previous fMRI AWM study [1] in humans with a maintenance delay of 16s showed enhanced BOLD activity in a network consisting of auditory cortex (AC), hippocampus, and inferior frontal gyrus (IFG) but the underlying neuronal dynamics was not known.
- A previous Human ECoG study [2] with a maintenance delay of 3s showed theta enhancement in the hippocampus, and alpha suppression in the auditory cortex.

Aims

- We sought to reveal the spectral and temporal dynamics underlying the neuronal activity during maintenance of pitch of a single tone in humans using MEG. What is the role of alpha, theta, and beta oscillations? Is the evoked activity transient or persistent?

Experiment 1

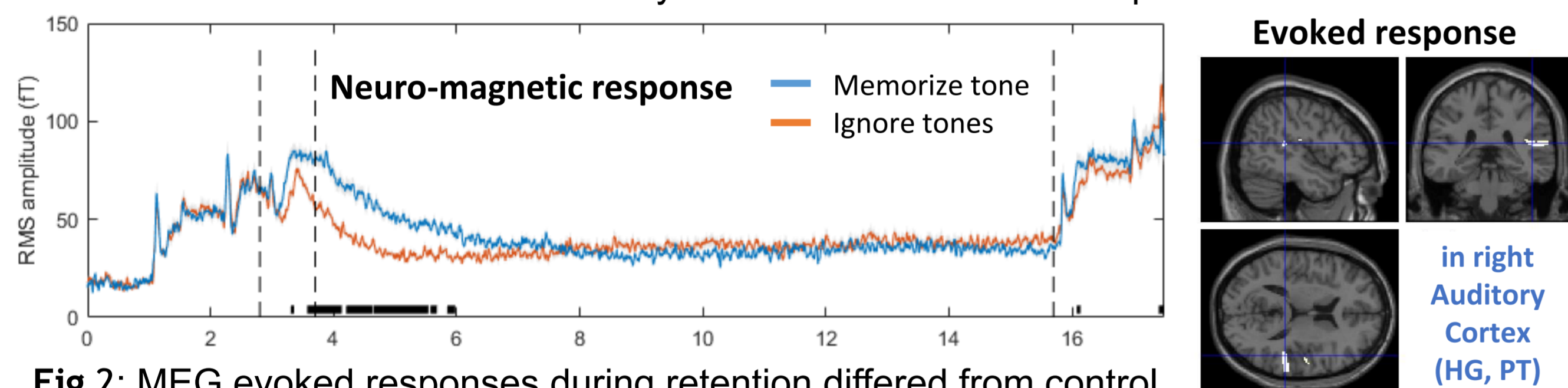
- Delayed match to sample paradigm was employed: pitch of a test tone was matched against the maintained tone. Button press conveyed same or different response



- Whole head 275-channel MEG data was recorded from 17 subjects using CTF scanner
- MEG data pre-processing: Low pass at 120 Hz. Down-sampled to 300 Hz. SPM's eye-blink artefact rejection applied. Manual artefact rejection (using z-score) performed: 5 subjects rejected. Baseline corrected to pre-stimulus [0 1s] interval.

Results 1

- Behaviour: Avg. accuracy in AWM task was 79% while in control task was 91%.
- Enhanced evoked activity persistent throughout maintenance as compared to silent pre-stimulus baseline. But enhanced only at start of retention as compared to control condition.



- Greedy Search based source localisation of evoked response in the right auditory cortex (HG, PT) during the 1st sec of retention.
- DICS beamforming based source localisation of induced activity during the 1st sec of maintenance in different frequency bands contrasted against the silent pre-stimulus baseline.
- Theta** (4-8 Hz) was enhanced (cluster corrected) in medial pre-frontal cortex which was phase locked [7] to activity in left temporal pole. Frontal midline theta during WM retention is known [3].
- Gamma (30-60 Hz) was suppressed (FWE) in Ant Cing Gyrus.
- Alpha** (8-12 Hz) was suppressed (cluster corr.) in left Auditory Cortex in line with mnemonic retention: inhibition of relevant sensory cortex [4]
- Beta** (13-30 Hz) was enhanced (small vol. corr.) in cerebellum. Previous studies [5] has shown cerebellar involvement in verbal WM for covert rehearsal. The cerebellum result from Experiment II was used as spatial prior in small volume correction.
- Theta** and **Beta** was suppressed (FWE) in left supra-marginal gyrus (SMG). This suggests suppression of the phonological loop which is implicated in verbal WM studies [6].

Fig 3: DICS source localisation of induced response- 1st s of retention

Conclusions

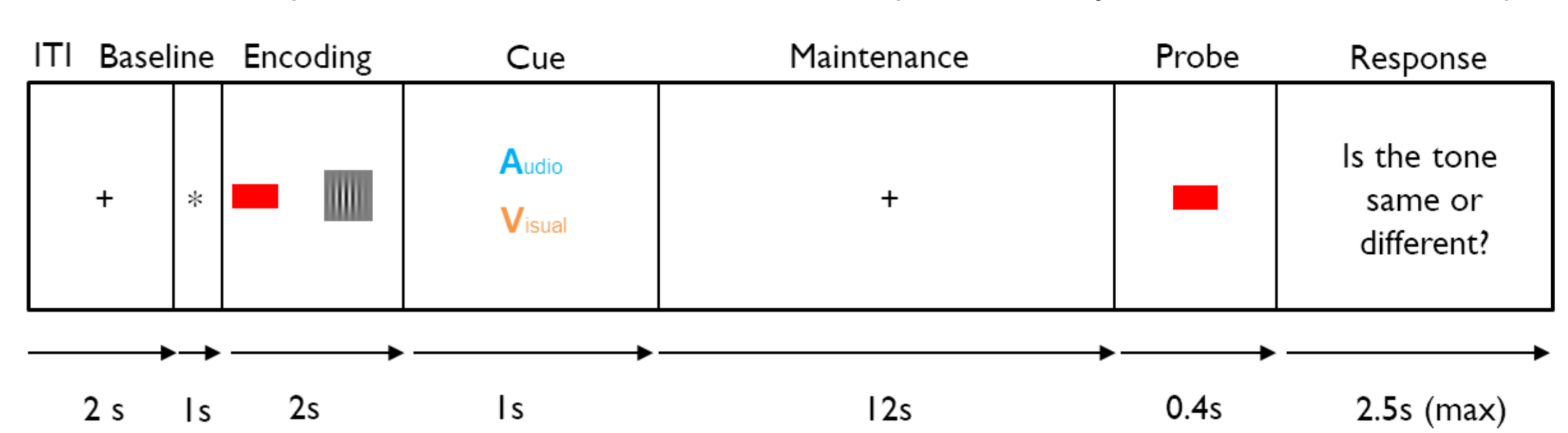
- Auditory Cortex retains representations of sounds for short durations.
- We speculate that this is enabled by focus of attention via the prefrontal cortex and covert rehearsal by Broca's area.

References:

- [1] Kumar S, et al., (2016) J Neurosci.
 [2] Kumar S, et al., (2021) Neuropsychologia.
 [3] Hsieh & C Ranganath, (2014) Neuroimage.
 [4] Freek van Ede, (2018) EJM.
 [5] Marvel, C.L. and Desmond, J.E., (2010) Neuropsychology review
 [6] Deschamps et al., (2014), Neuropsychologia

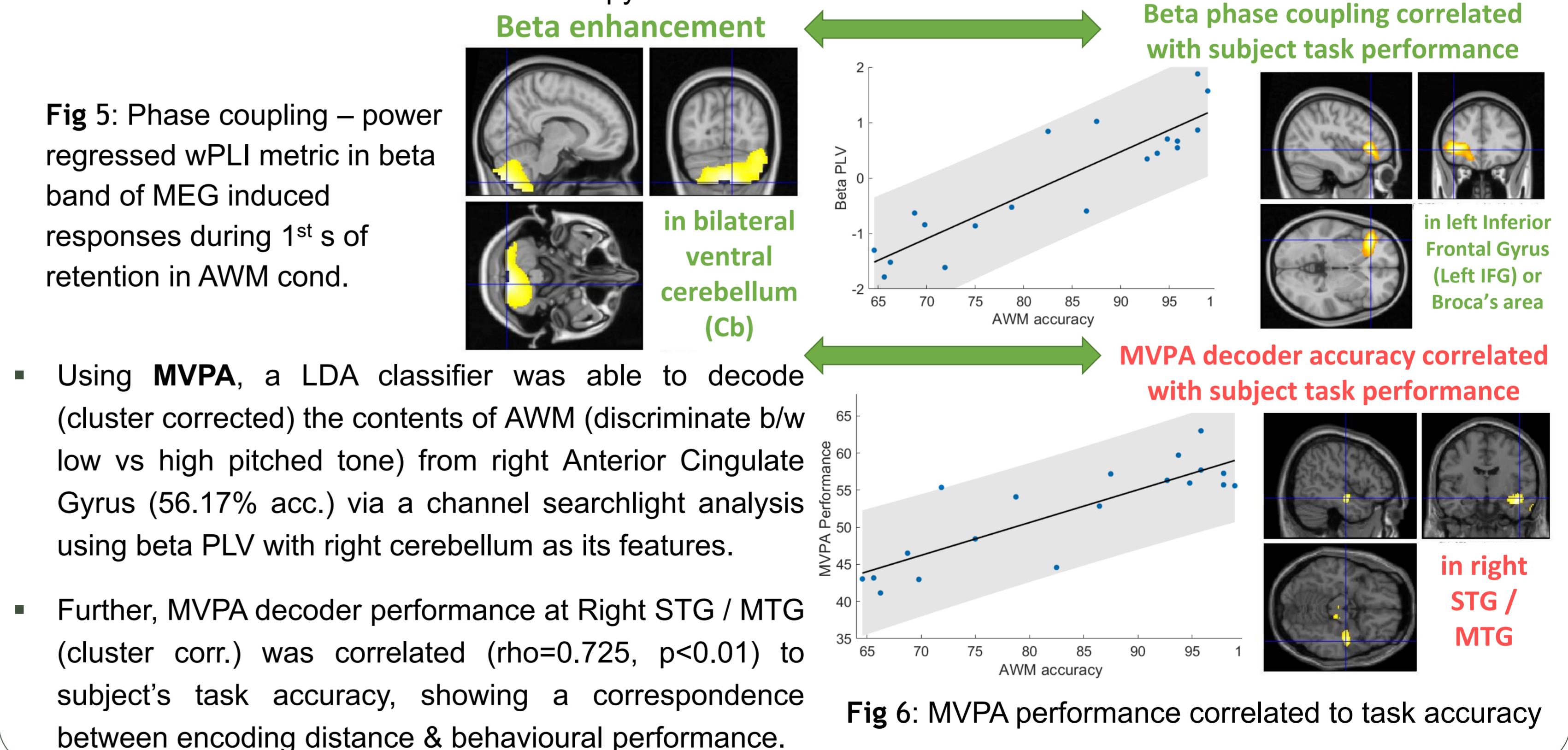
Experiment 2

- Delayed match to sample paradigm was employed in 19 new subjects: pitch of a pure tone was maintained for 12s or width of a Gabor patch in alternate visual task. Button press conveyed same or different response

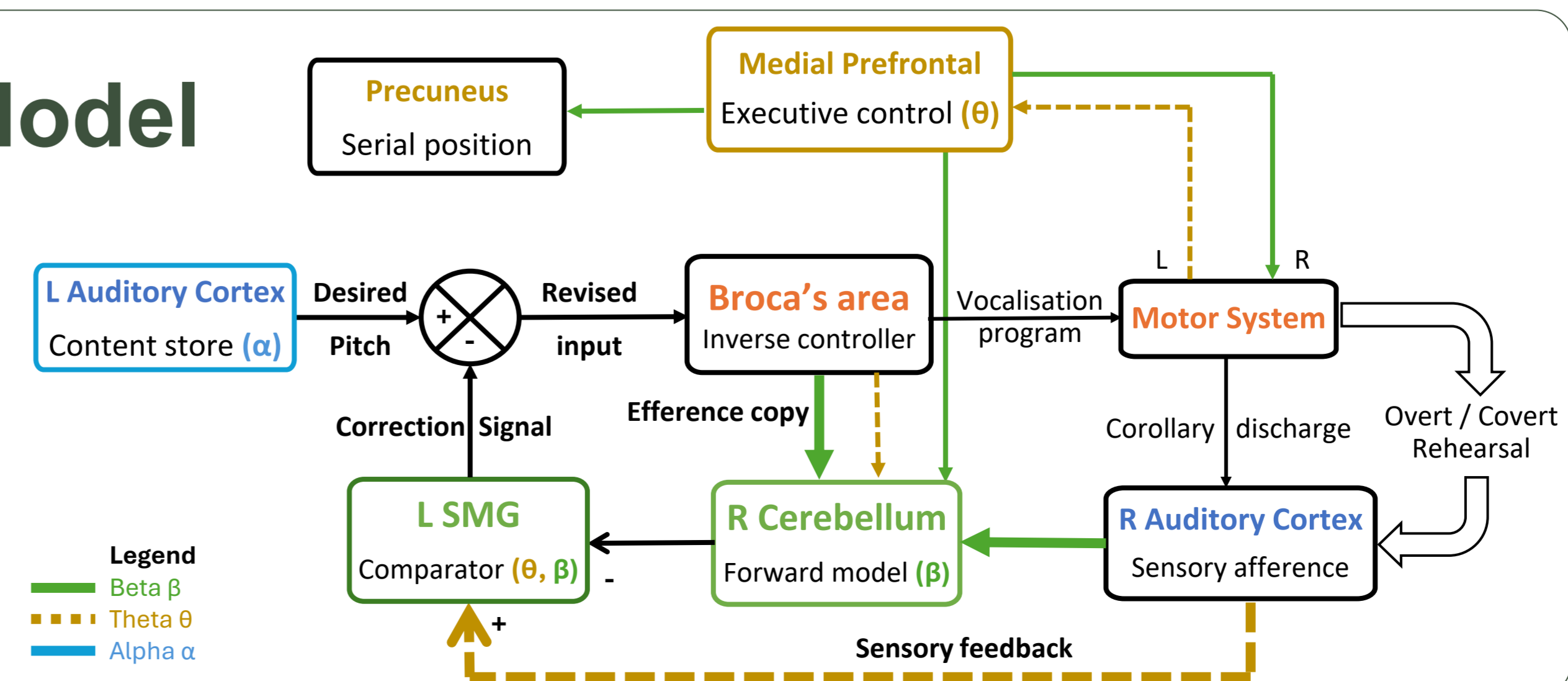


Results 2

- Behaviour: Avg. accuracy in AWM task was 83% while in VWM task was 65%.
- Using DICS, 1st sec of retention was localised contrasted by pre-stimulus baseline.
- Alpha** (8-12 Hz) was suppressed (FWE) in left Auditory Cortex during AWM. This is in line with alpha's mnemonic retention role [4]
- Theta** (4-8 Hz) was enhanced (FWE) in medial prefrontal. Frontal midline theta activity during WM retention is well known [3].
- Beta** (13-30 Hz) was enhanced (FWE) in cerebellum whose phase locking (FWE) with activity in Broca's area was correlated to subject task accuracy ($\rho = 0.857$, $p < 0.001$). It hints at covert rehearsal [5] of tones as a strategy.
- Theta** and **Beta** was suppressed (FWE) in left SMG. Possible role as comparator of sensory feedback & transformation of efference copy.



Model



Funders

