MEG responses to sound in guinea pig and mouse

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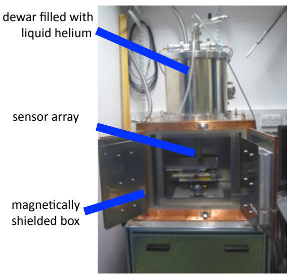
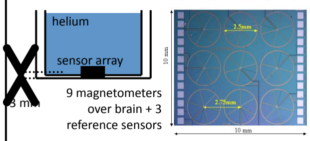
ABSTRACT

Using a newly developed magnetoencephalograph (MEG) for small animals, we have recorded auditory-evoked cortical responses non-invasively in both guinea pig and mouse. The small-animal MEG system has 9 magnetometers placed in an 8x8 mm square array at 3 mm from the outer surface of the liquid helium-filled dewar. An additional set of 3 magnetometers and one accelerometer are used to measure and suppress environmental noise. Sound is delivered either free-field, or via short tubes from Etymotics transducers. Signal processing is crucial to extract the tiny brain responses from noise, and several new techniques have been developed for that purpose. Using these techniques, we can detect cortical responses evoked by sound onsets, transitions and binaural disparities in tone, noise and chirp stimuli, in both guinea pigs and mice. Up to 5 distinct spatio-temporal response components have been observed in these datasets. Additionally, we demonstrate that stimulus-specific adaptation (SSA), hypothesized to be a neural correlate of mismatch negativity (MMN), can be observed in MEG responses to deviant events within trains of standards, and we compare these responses to similar responses observed in humans. These results pave the way for joint MEG and electrophysiology in the same animals to elucidate the neural basis of the MEG response, bridging the gap between human brain imaging and invasive animal electrophysiology.

METHODS

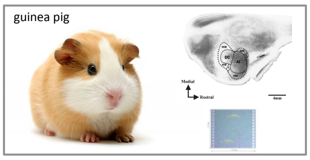
APPARATUS

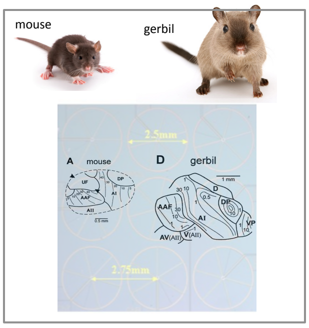




Miyamoto M, Kawai J, Adachi Y, Haruta Y, Komamura K, Uehara G (2008) Development of an MCG/MEG system for small animals and its noise reduction method. Journal of Physics: Conf. series 97: 012258.

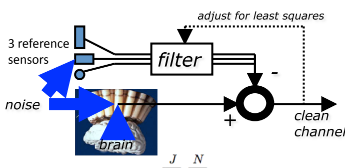
ANIMALS & BRAINS





SIGNAL PROCESSING

TSPCA



$$\hat{s}_k(t) = s_k(t) - \sum_{j=1}^{J}\sum_{\tau=1}^{N}\alpha_{kj\tau} r_j(t+\tau)$$

Suppresses environental noise.

DSS

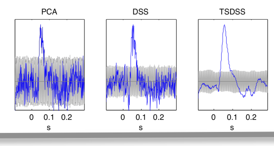
$$\tilde{s}_{k'}(t) = \sum_{k=1}^{K} a_{kk'} s_k(t)$$

Designs a set of optimal spatial filters to improve SNR.

TSDSS

$$y_k(t) = \sum_{j,\tau} a_{kjd} x_j(t-d)$$

Designs a set of optimal spatiotemporal filters.



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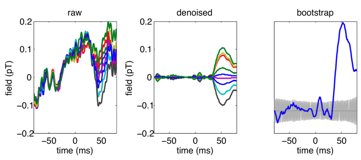
-de Cheveigné A, Simon JZ. Denoising based on time-shift PCA. J Neurosci Methods 2007; 165: 297-305
-de Cheveigné A, Simon JZ. Sensor Noise Suppression, J Neurosci Methods 2008a; 168: 195-202
-de Cheveigné A, Simon JZ. Denoising based on spatial filtering, J Neurosci Methods 2008b, 171: 331-339
-de Cheveignee A. Time-shift denoising source separation, J Neurosci Methods 2010, in press.

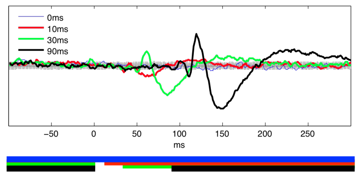
RESULTS

Tone onset response in guinea pig:



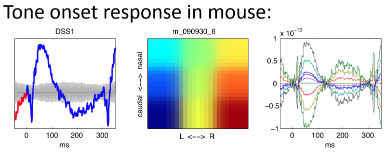
Stimulus: 2500 repetitions of 50ms 2kHz tone pip, IOI = 1000 ms, ~80dB SPL

Gap detection in guinea pig:



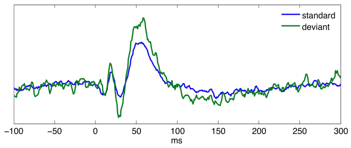
Stimulus: ongoing diotic noise, 10000 gaps, IOI=301ms, ~70dB SPL

Tone onset response in mouse:



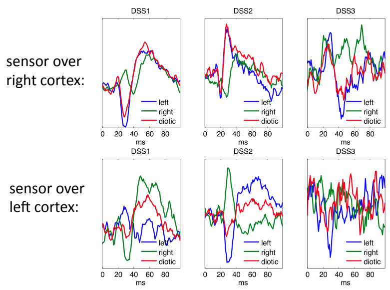
Stimulus: 10000 repetitions of 15ms 2kHz tone pip, IOI = 301 ms, ~65dB SPL

MMN / SSA in guinea pig:



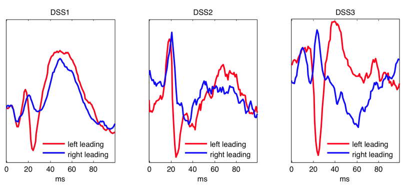
Stimulus: 10000 tone pips, IOI=301ms, f=1kHz / 2 kHz, p=0.8 / 0.2

Ear-specific responses in guinea pig:



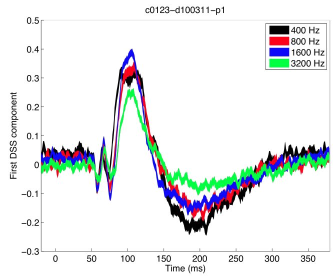
Stimulus: 10000 x 15 ms noise bursts, IOI = 301ms, left/right/diotic, ~ 70dB SPL

ITD sensitivity in guinea pig:



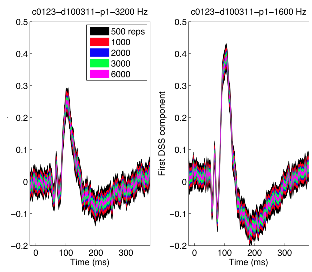
Stimulus: 10000 x 15ms noise bursts, IOI=301ms, +500us / -500us, ~70dB SPL

frequency dependency in guinea pig:



Stimulus: 50 ms tone pips, IOI=500ms

response variability in guinea pig:



Stimulus: 50 ms tone pips, IOI=500ms

CONCLUSIONS

- We can measure magnetic correlates of brain activity in response to sound in common animal models such as guinea pig,mouse or gerbil.
- This technique offers a “stepping stone” between invasive electrophysiology and human brain imaging.
- Features: measure of large scale activity, non-terminal (limits number of animals required), enables longitudinal studies in same animal.
- Future: joint MEG / electrophysiology.