Single-trial detection with Magnetoencephalography: Application to target detection in images

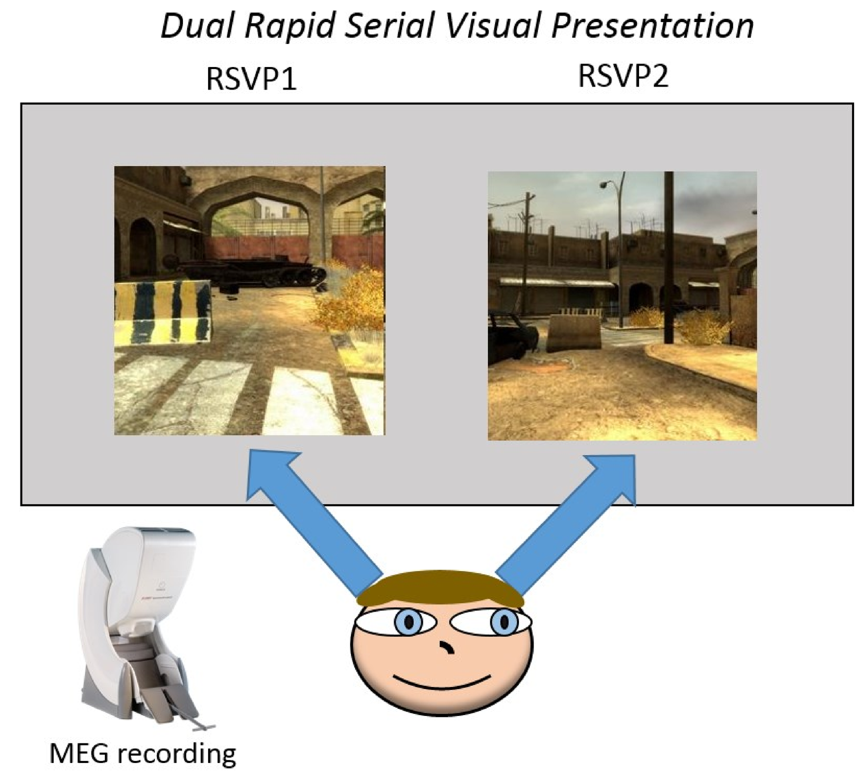
Hubert Cecotti
h.cecotti@ulster.ac.uk
Intelligent Systems Research Centre - School of Computing and Intelligent Systems
University of Ulster, Derry, Northern Ireland, UK

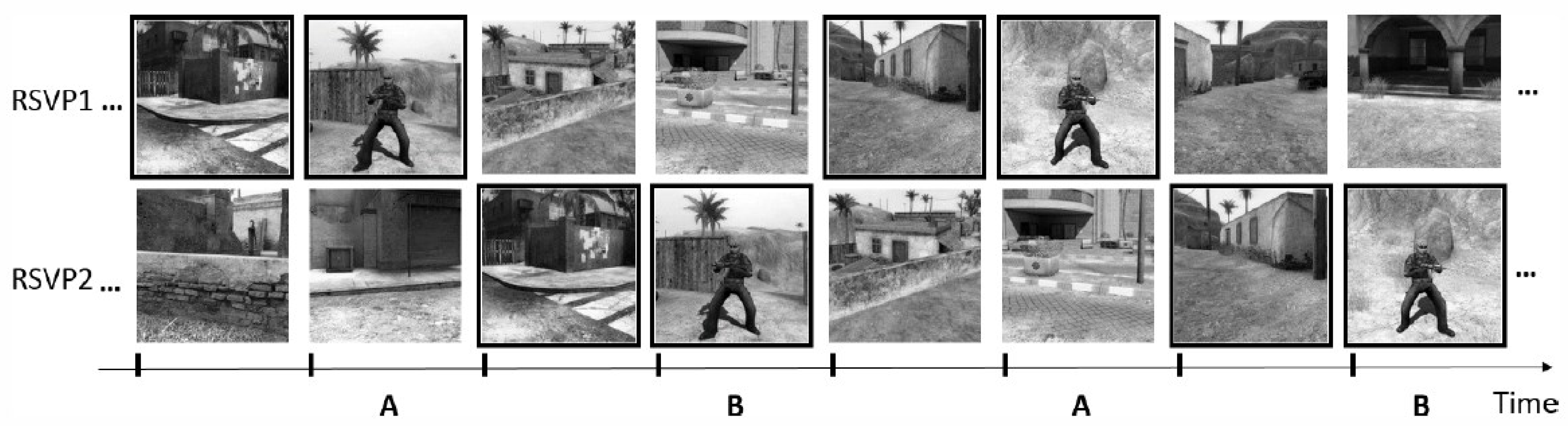
1. Introduction

The detection of brain responses corresponding to the presentation of a particular class of images is a challenge in Brain-Machine Interface (BMI). Current systems based on the detection of brain responses during rapid serial visual presentation (RSVP) tasks possess advantages for both healthy and disabled people, as they are gaze-independent and can offer a high throughput.
We propose a novel paradigm based on a dual RSVP task that assumes a low target probability. Two streams of images are presented simultaneously on the screen, the second stream is identical to the first one, but delayed in time. Participants were asked to detect images containing a person. They follow the first stream until they see a target image, then change their attention to the second stream until the target image reappears, finally they change their attention back to the first stream. The performance of single-trial detection was evaluated on both streams and their combination of the decisions with signal recorded with magnetoencephalography (MEG) during the dual RSVP task. We compare classification performance across different sets of channels (magnetometers, gradiometers) with a BLDA classifier with inputs obtained after spatial filtering.
The results suggest that single-trial detection can be obtained with an area under the ROC curve superior to 0.95, and that an almost perfect accuracy can be obtained with some subjects thanks to the combination of the decisions from two trials, without doubling the duration of the experiment. The present results show that a reliable accuracy can be obtained with MEG for target detection during a dual RSVP task.

2. Experimental paradigm

Dual Rapid Serial Visual Presentation task
(the stream of images on the right is identical to the stream of images on the left, but it is delayed in time (1250 ms)).



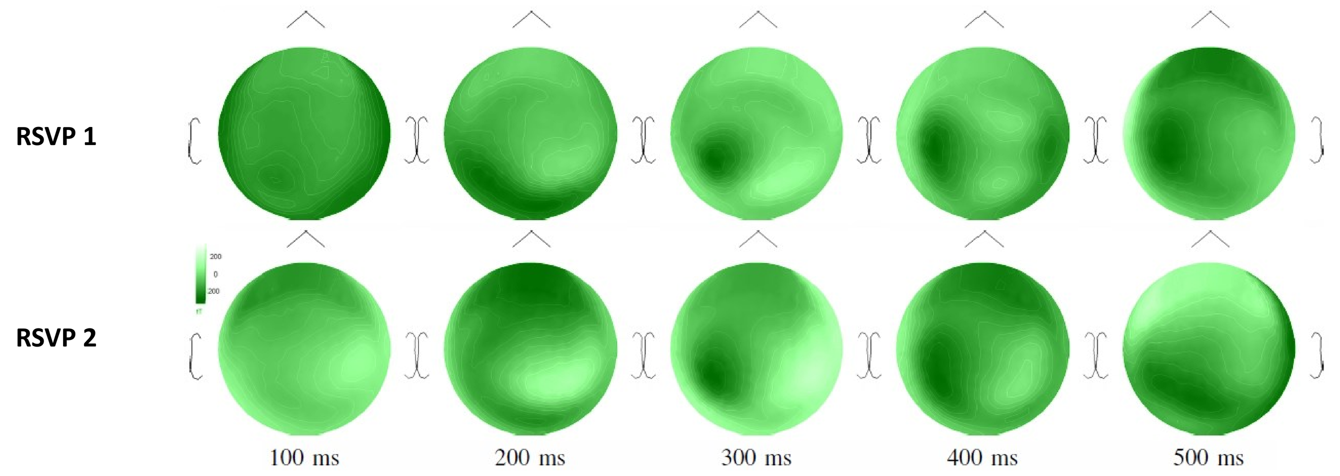


Experimental task:

- A: the subject sees a target in RSVP1, then shifts his attention to RSVP2,
- B: the subject sees a target in RSVP2, and confirms its presence from RSVP1, then shifts his attention back to RSVP1 to detect novel targets.
- The black frame around the images represents the current stream of images that must be observed by the subject.

(The figure depicts a shift of 2 images, the experiments included a shift of 5 images.)

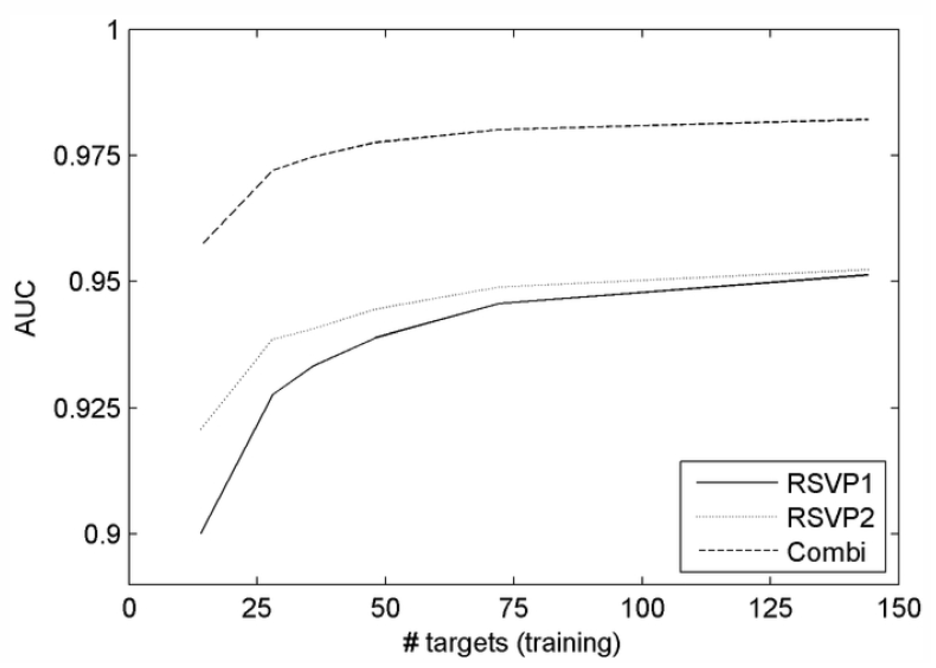
3. Spatial distribution



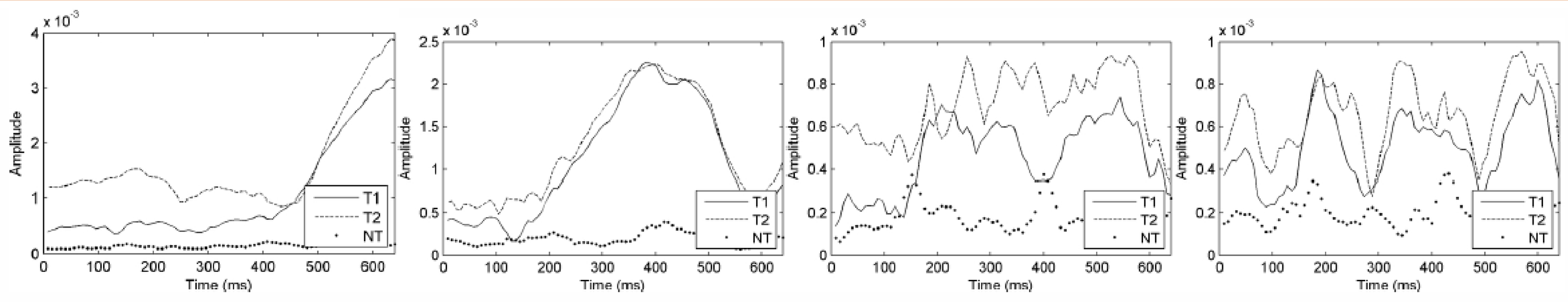
Magnetic field distribution corresponding to the difference between targets and non-target at different time points. (top: RSVP1, bottom: RSVP2).

4. Results

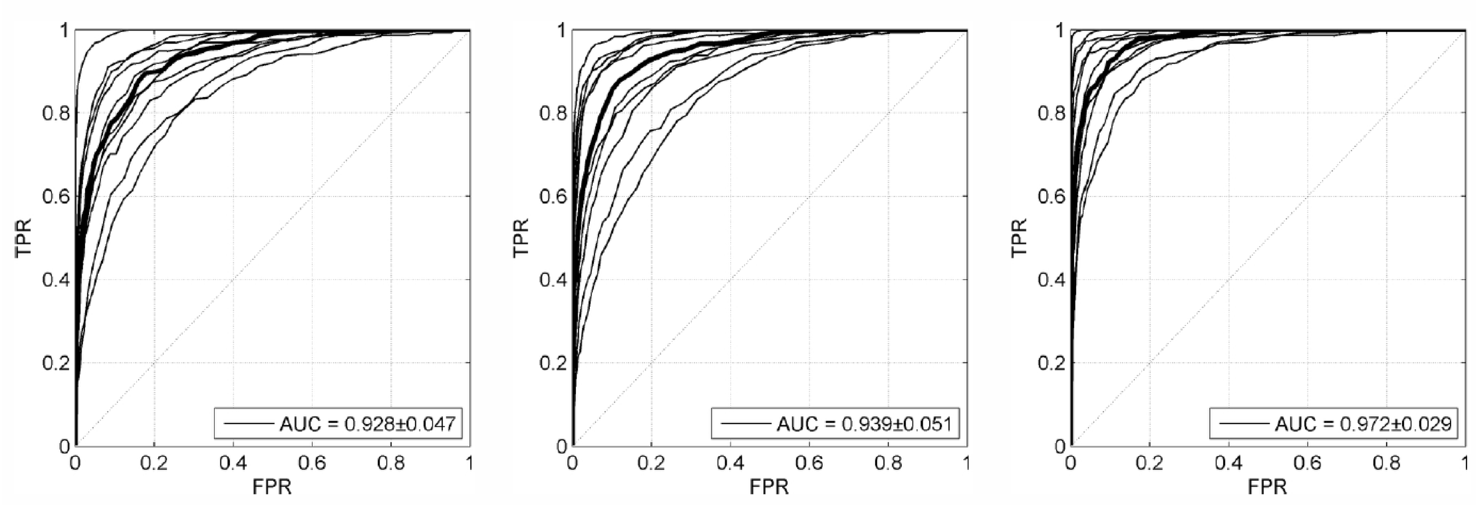
Performance of single-trial detection and target detection measured by the Area under the ROC curve.



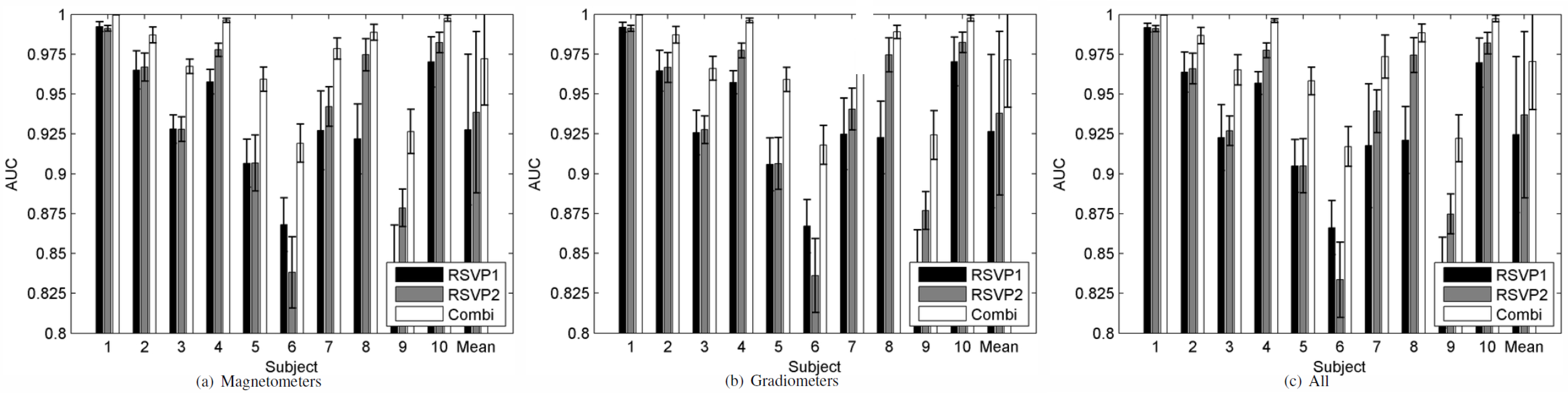
Evolution of the performance in relation to the number of trials representing a target.



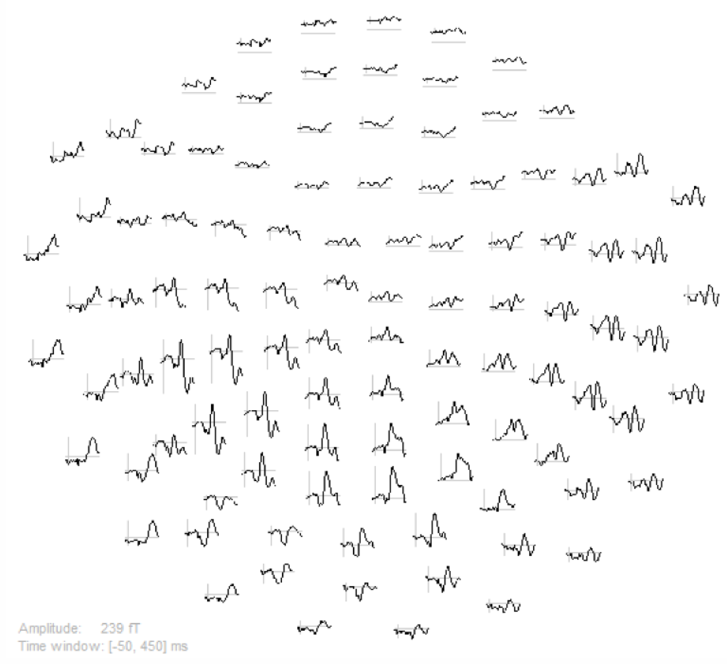
Absolute grand average waveform after spatial filtering for the target on RSVP1 (T1), the target on RSVP2 (T2), and non-target (NT). From left to right, it represents the first four best spatial filters obtained by xDAWN.

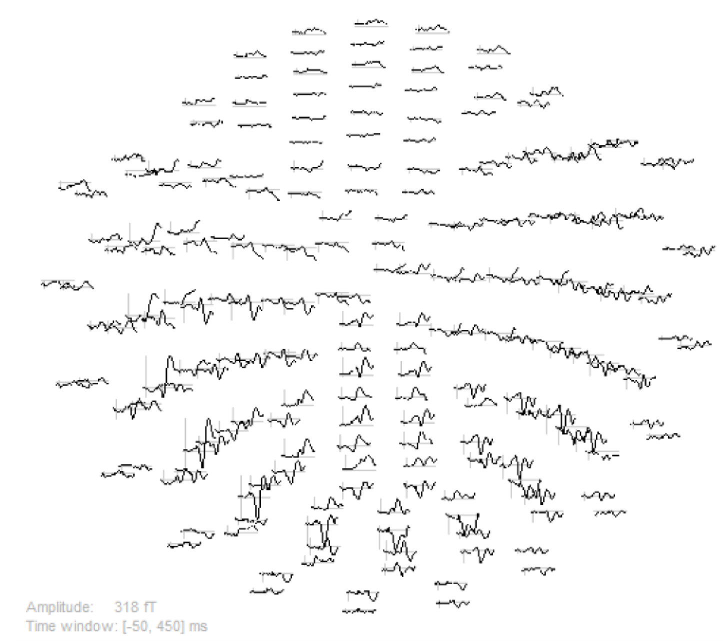


ROC curves with magnetometer channels as input signals, RSVP1 (left), RSVP2 (middle), Combi (right).
The bold curve represents an estimation of the mean AUC across subjects based on a normal distribution.



Single-trial detection for each subject, each classification task (RSVP1, RSVP2, and Combi), and each set of channels (Magnetometers (102), Gradiometers (204), and all (306)).
The error bars correspond to the standard deviation across subjects.





Representation of the grand averaged difference between targets and non-target for both magnetometers (**top**) and gradiometers (bottom) for a representative subject (Subject 1).

5. Conclusion

For the BMI community, leveraging the interest of BMI for healthy people for commercial and/or clinical applications is a real challenge. It requires the development of novel tasks that can take into account the constraints of the brain evoked responses.

- The improvement should come from machine learning, signal processing, and human-computer interface. We have shown that a dual-RSVP setting can be used in parallel for processing targets from multiple image streams by assuming a low target probability. It allows to combine the decision of two trials to significantly improve target detection, without repeating two times the whole sequence of images.
- We have shown that it is possible to achieve high performance for single-trial detection of brain responses corresponding to the presentation of realistic images during a rapid serial visualization task with MEG signals, and with a limited number of trials during training.
- The performance with magnetometers was overall similar to the performance using gradiometers.
- The results show that only 102 channels are enough to perform robust single-trial detection with MEG.

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