A Collaborative Brain-Computer Interface for Improving Group Detection of Visual Targets in Complex Natural Environments

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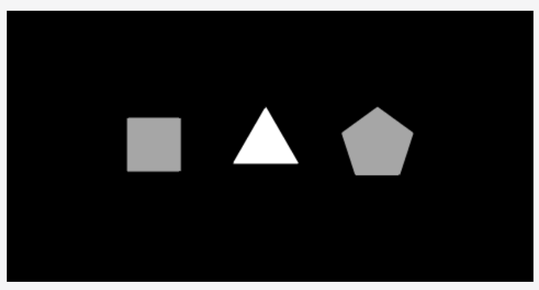
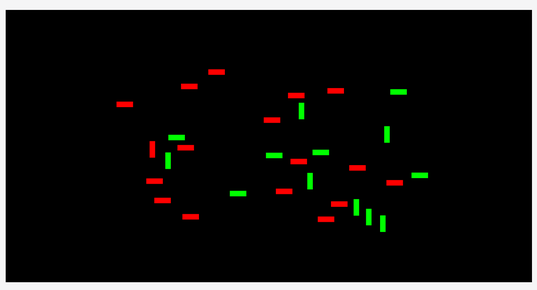
1. Introduction

- Collaborative Brain-Computer Interfaces (cBCIs) are BCIs concurrently controlled by more than one user.
- We have shown that, in difficult target detection tasks, cBCIs can:
  - estimate the decision confidence of participants, and
  - improve group decisions in tasks

  with **simple standard stimuli** (see [1] and [2]).



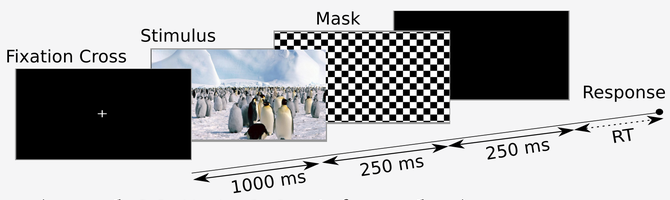


- **Big question:** What happens with more complex stimuli?
- Also, could eye movements help improve our estimates of confidence?

2. Task

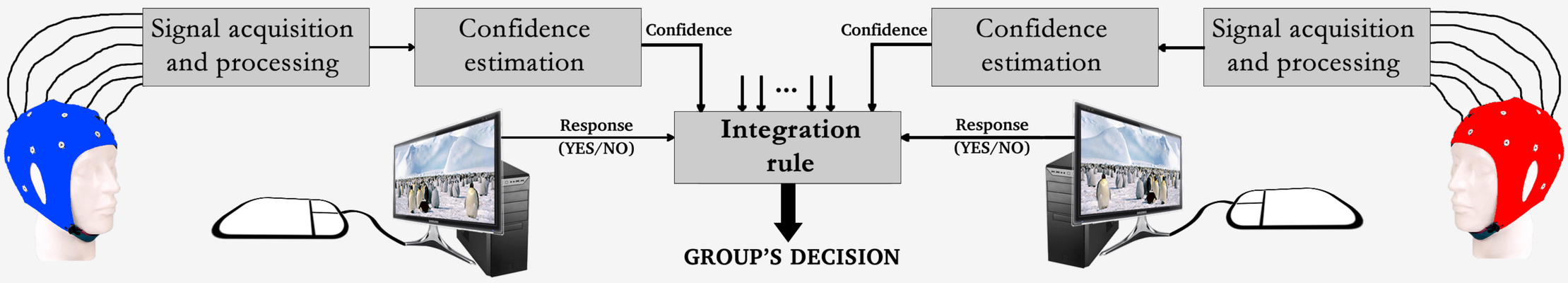
Can you see a bear in 250 ms?

- Protocol:



- 10 volunteers (aged 28.5 ± 6.0, 4 females)
- 8 blocks of 40 trials (25% targets)
- Left/right click for target/non-target

3. cBCI Architecture



4. Features

Integration of three different features to estimate the confidence:

- *Neural features*, extracted applying the spatial CSP filter on the EEG signals recorded from 64 electrodes
- *Response times*, as they are inversely proportional with the degree of confidence
- *Eye-movement features*, extracted from the vertical component of the eye movements recorded with an eye tracker

Least Angle Regression (LARS) was used to predict the confidence via a 10-fold cross-validation loop.

5. Methods

We used four different methods to combine the individual responses and build the group decision:

M1 – ordinary majority rule.

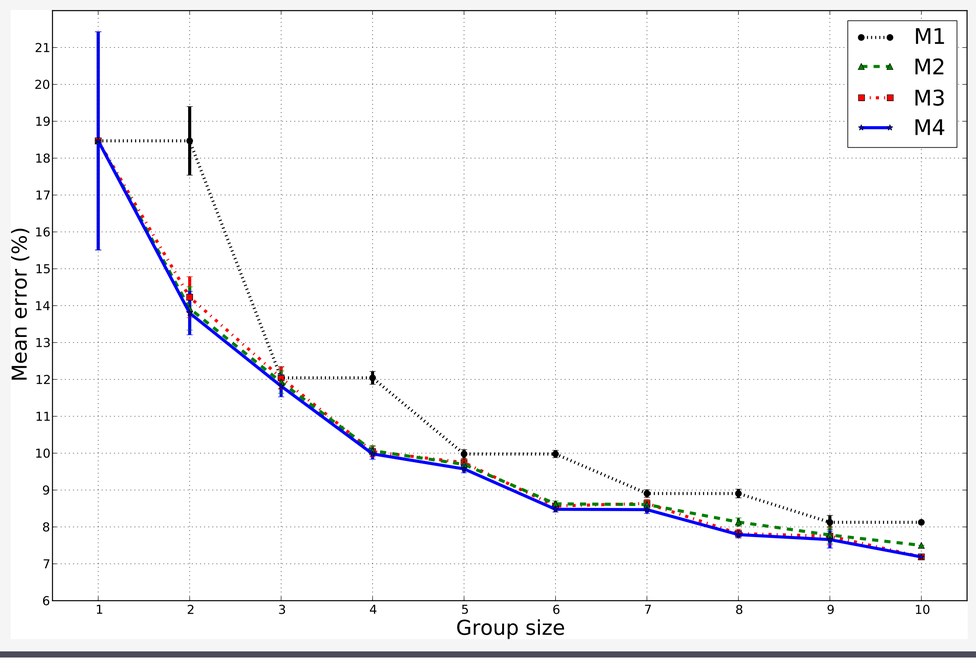
M2 – a cBCI exploiting only neural features and response times.

M3 – a cBCI based on neural and eye-movement features.

M4 – a cBCI using neural and eye-movement features and response times.

6. Results

Mean errors (across all possible groups, in %) for different group sizes using the four methods are shown below:



7. Conclusions

- Results show that our best cBCI is statistically significantly better than equally-sized groups using straight majority.
- Even with more complex stimuli and extremely difficult tasks, **our cBCI is more accurate than a single non-BCI user and equally-sized groups of non-BCI users.**
- Adding the information about eye movements to the cBCI system further improves the performance.
- cBCI may soon be ready for deployment in visual search activities, e.g., for suspect detection in policing or defence.

Acknowledgements

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References

[1] R. Poli, D. Valeriani, and C. Cinel, "Collaborative Brain-Computer Interface for Aiding Decision-Making," *PLoS ONE*, vol. 9, no. 7, Jul. 2014. [Online]. Available: http://dx.plos.org/10.1371/journal.pone.0102693

[2] D. Valeriani, R. Poli, and C. Cinel, "A Collaborative Brain-Computer Interface to Improve Human Performance in a Visual Search Task," in *7th International IEEE EMBS Neural Engineering Conference*, 2015.

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