A Collaborative Brain-Computer Interface to Improve Human Performance in a Visual Search Task

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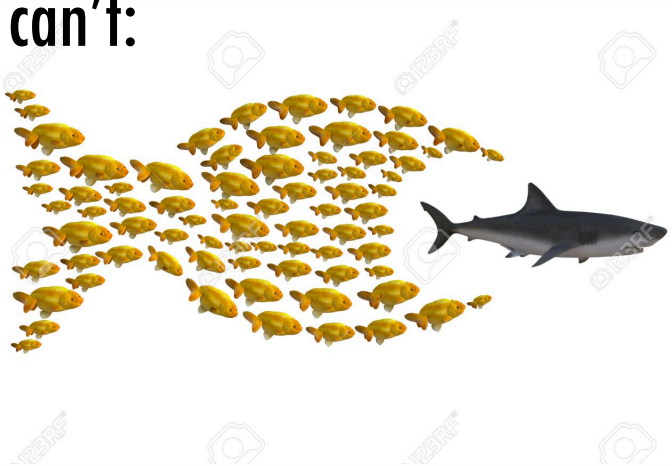
Groups

- Most animals and humans live within groups. Why?
- A group can do things that individuals alone can't:
  - Augmented action capabilities
  - Increased cognition and intelligence
  - Increased sensing capabilities

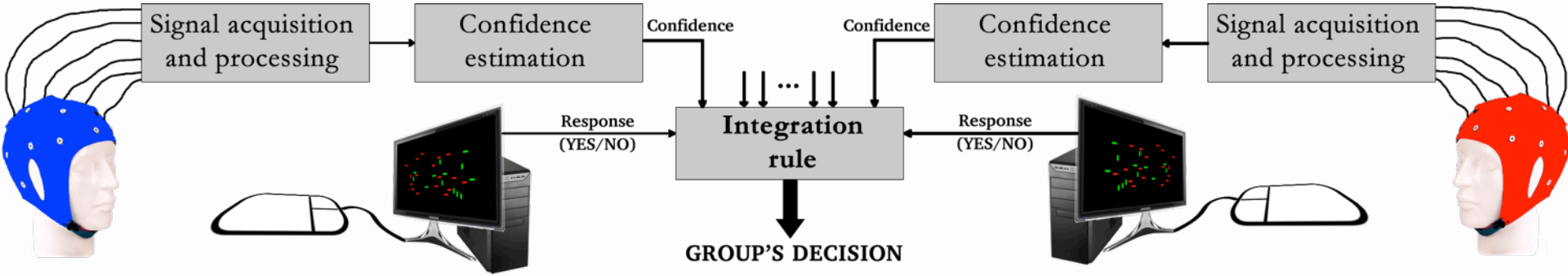


Group Decisions

- Making decisions in groups can be powerful and superior to deciding individually
- BUT… Group decisions may be worse if
  - Quick decisions
  - Strong leadership

cBCI for Aiding Group Decision Making

- Unconscious mind can be better than the conscious one in making decisions
- IDEA: Use collaborative Brain-Computer Interfaces (cBCIs) to tap into the unconscious mind and estimate the decision confidence of each member
- Use this information to weigh individual responses of each person

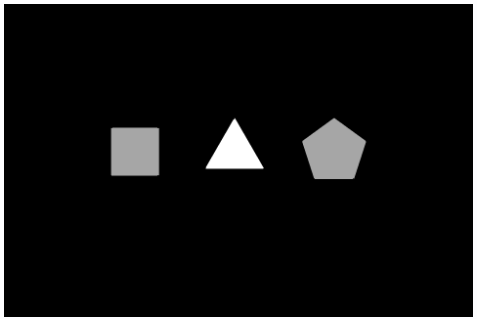


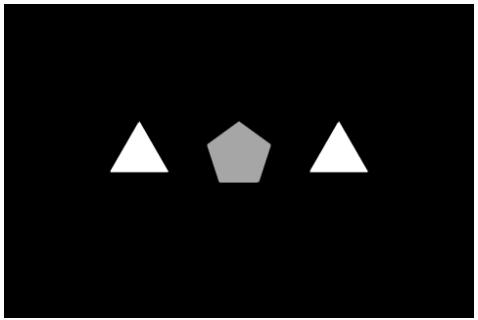
cBCI for Aiding Group Decision Making (cont.)

- The system collects the responses of each participant through mouse buttons (hybrid BCI)
- cBCI system to enhance human capability
- Applications in many contexts (politics, defence, ...) with many people (not only disabled)

Previous Research

- Positive results have been obtained with this approach (Poli et al., PLoS ONE, 2014)
- Simple visual-matching task





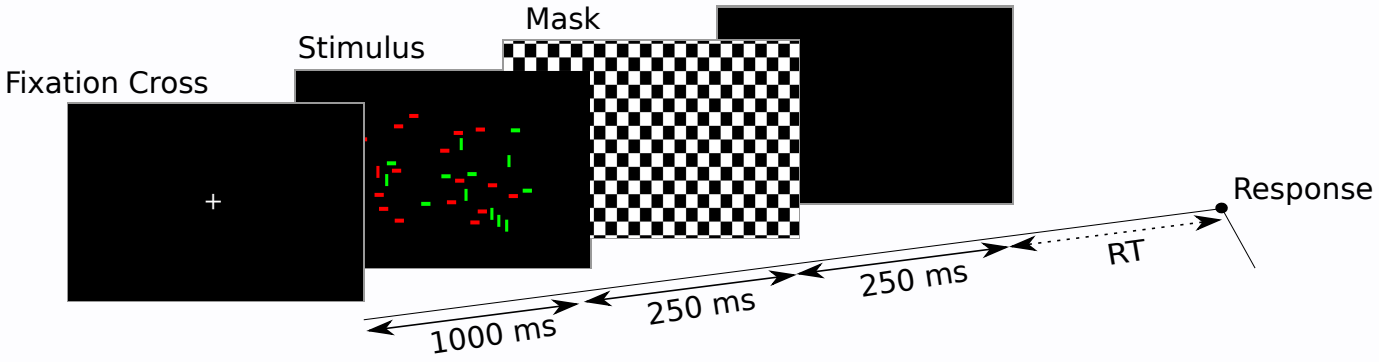
- cBCI system decisions significantly better than individuals and non-BCI groups

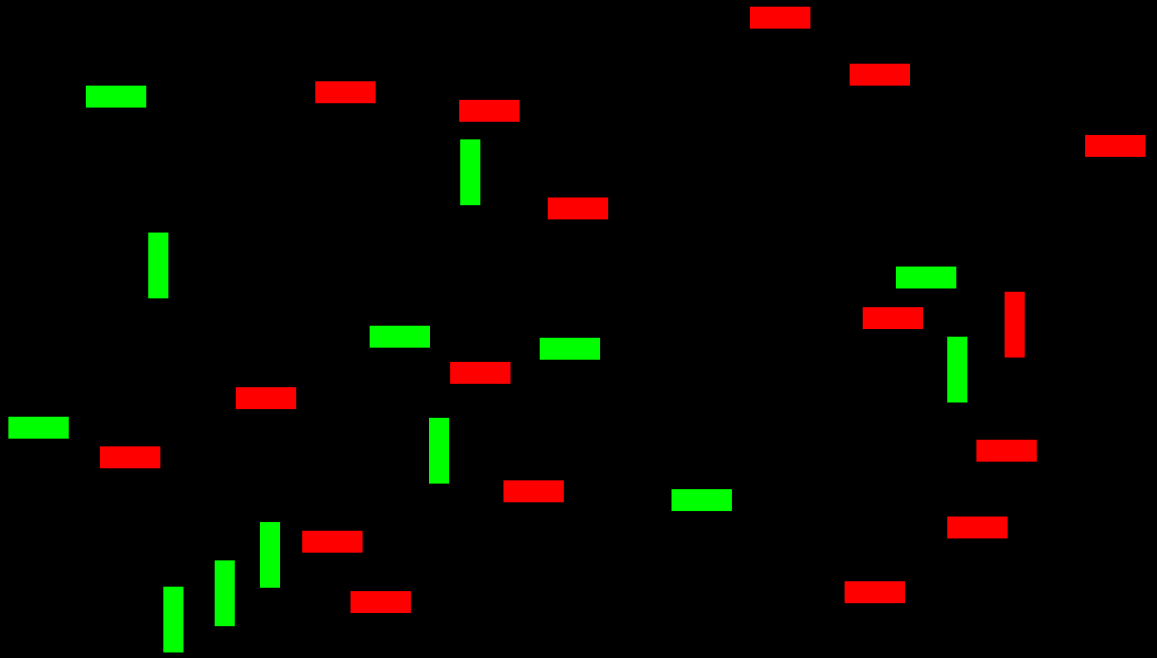
Present Study

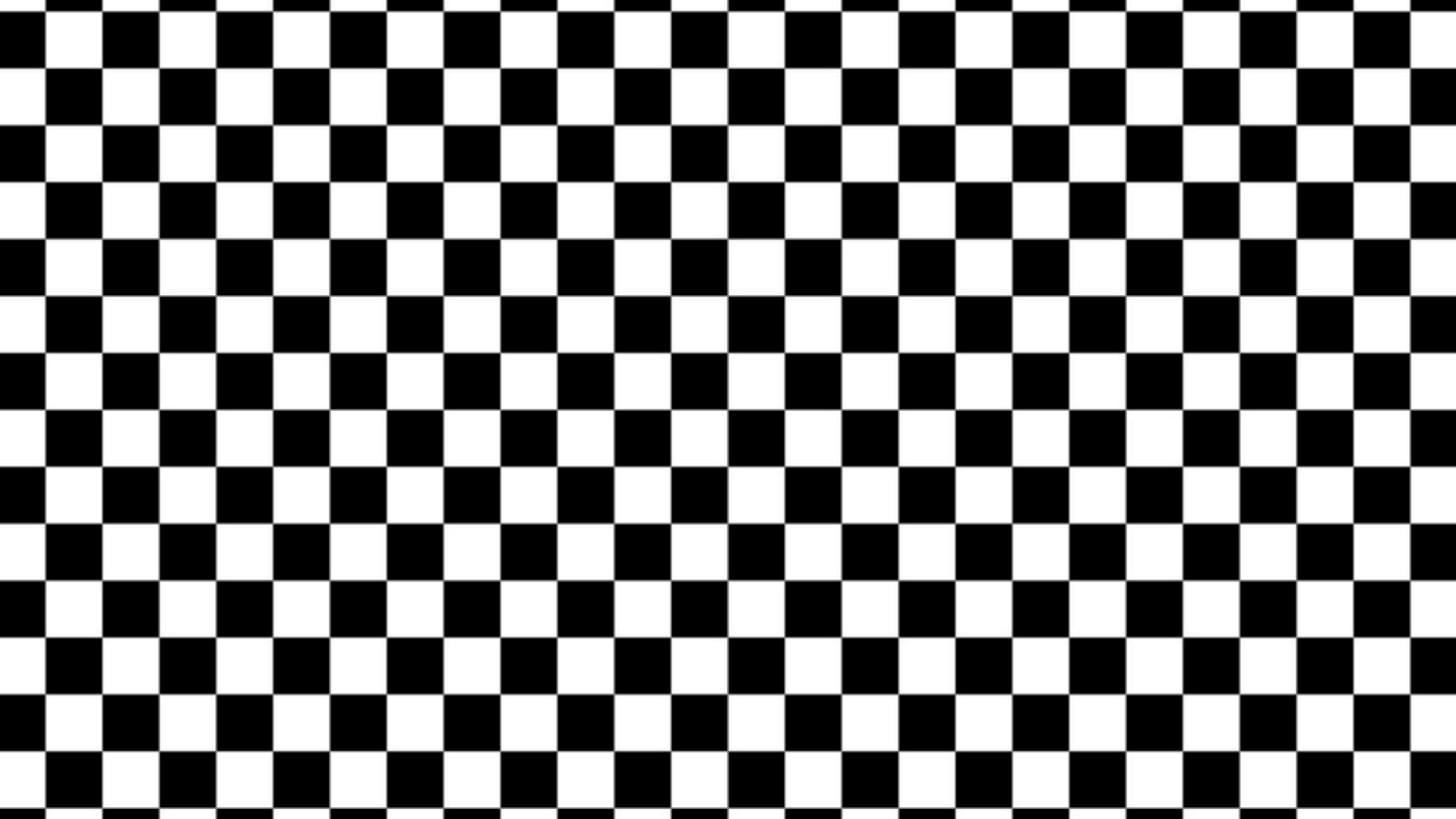
- Extension of previous research along two main directions
  - Use of a difficult visual search task
  - Different method to estimate the confidence
    - Quicker
    - More effective

Task and Protocol

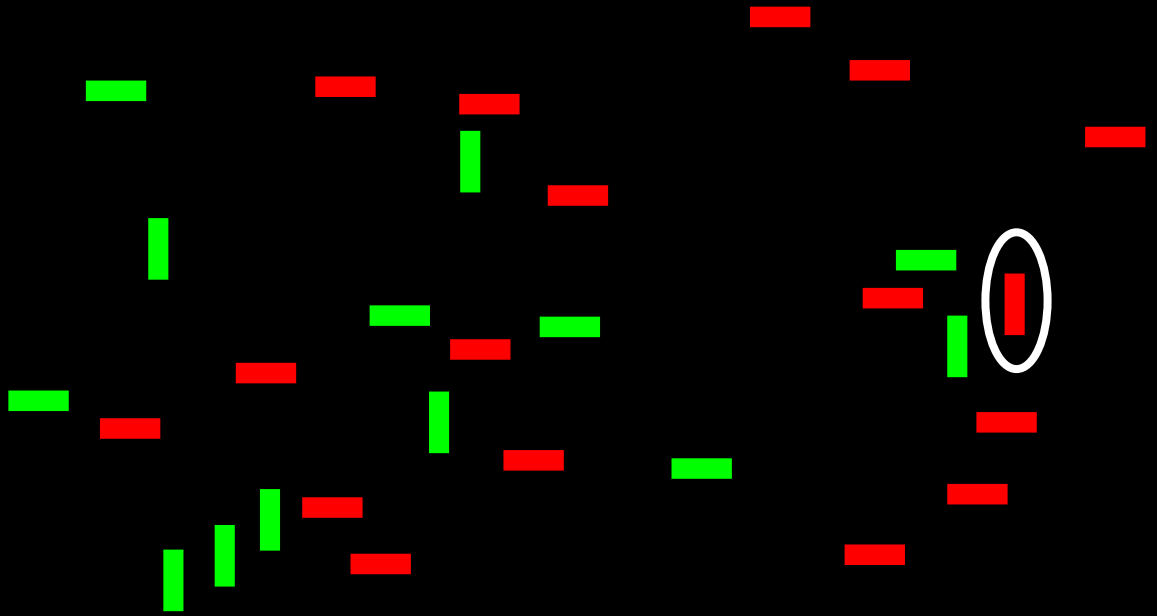
- 10 participants, 8 blocks of 40 trials
- Trial: display containing a set of 40 bars for ¼ second
  - Red or green, horizontal or vertical
- Decision: have you seen a vertical red bar?





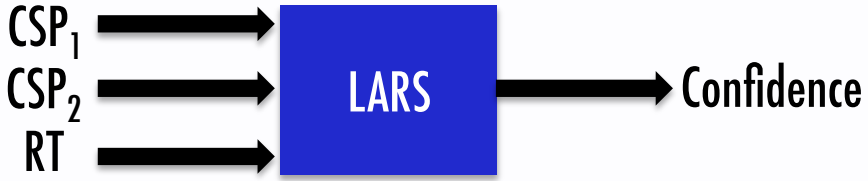


Have you seen a vertical red bar?



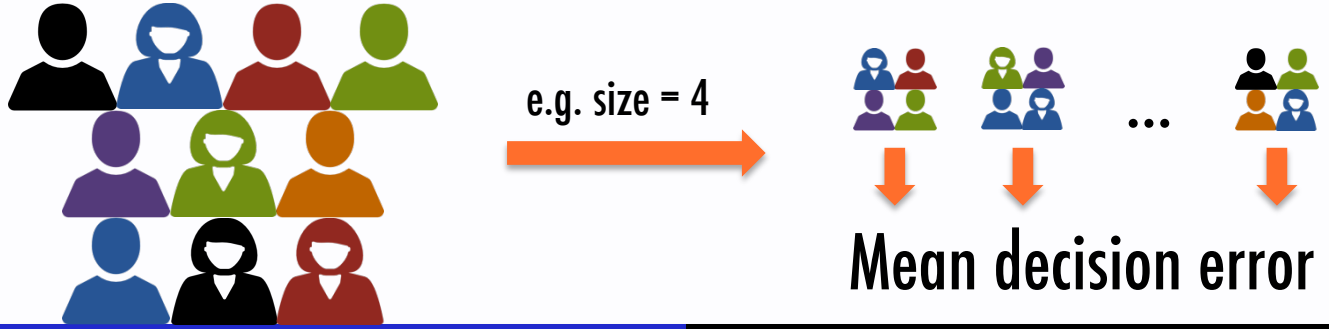
Confidence Estimators

- Neural features: 2 Common Spatial Patterns NEW
  - Response-locked data
  - Stimulus-locked data NEW
- Response times (RTs)
- Least Angle Regression (LARS) to predict the confidence NEW

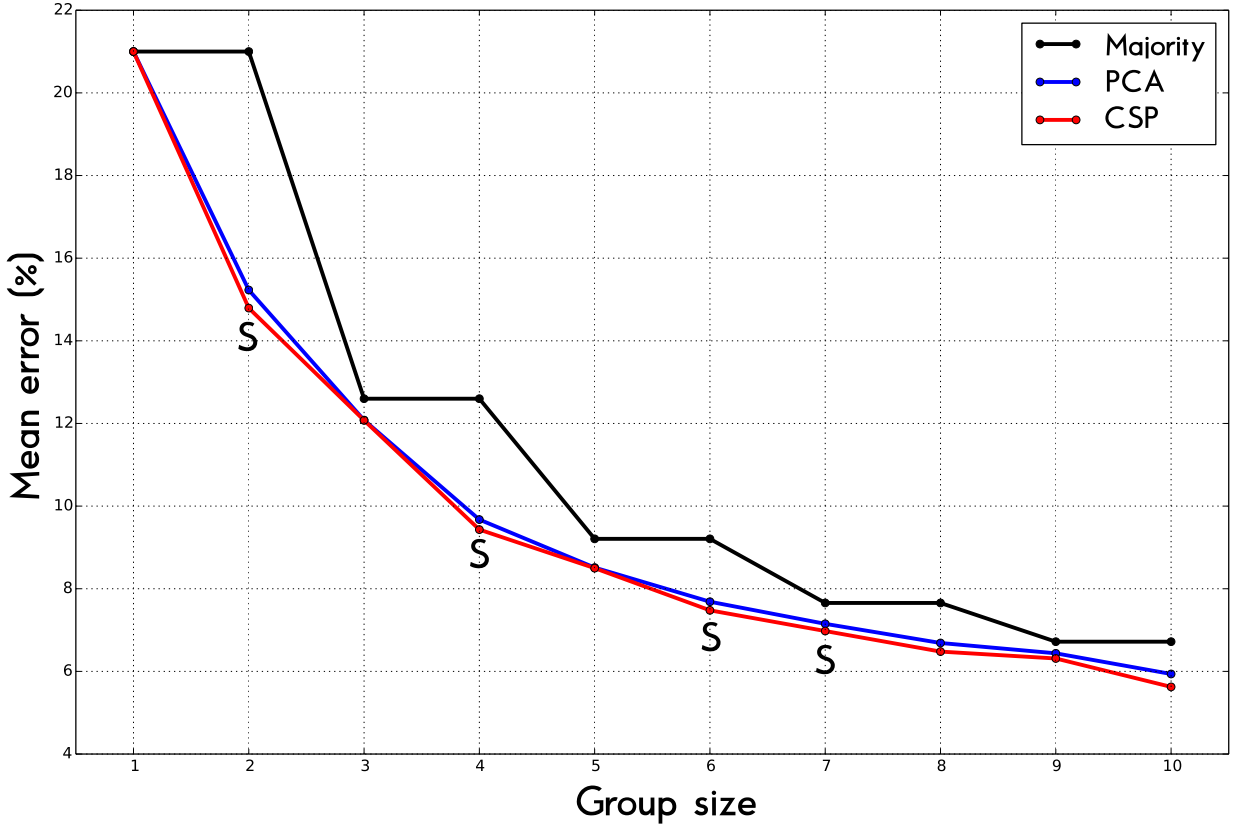


Offline Analysis

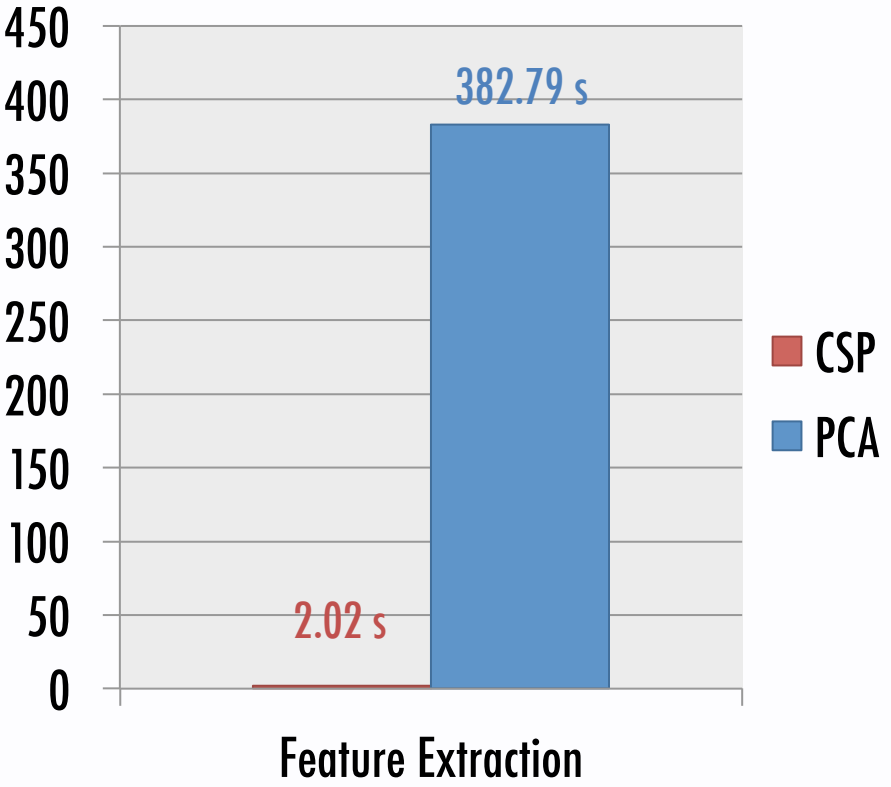
- Data collected offline from each participant
- Real behaviour simulated by combining all the participants in groups of different group sizes
- Average performance of the cBCI system compared with non-BCI groups by building all the possible groups of each size

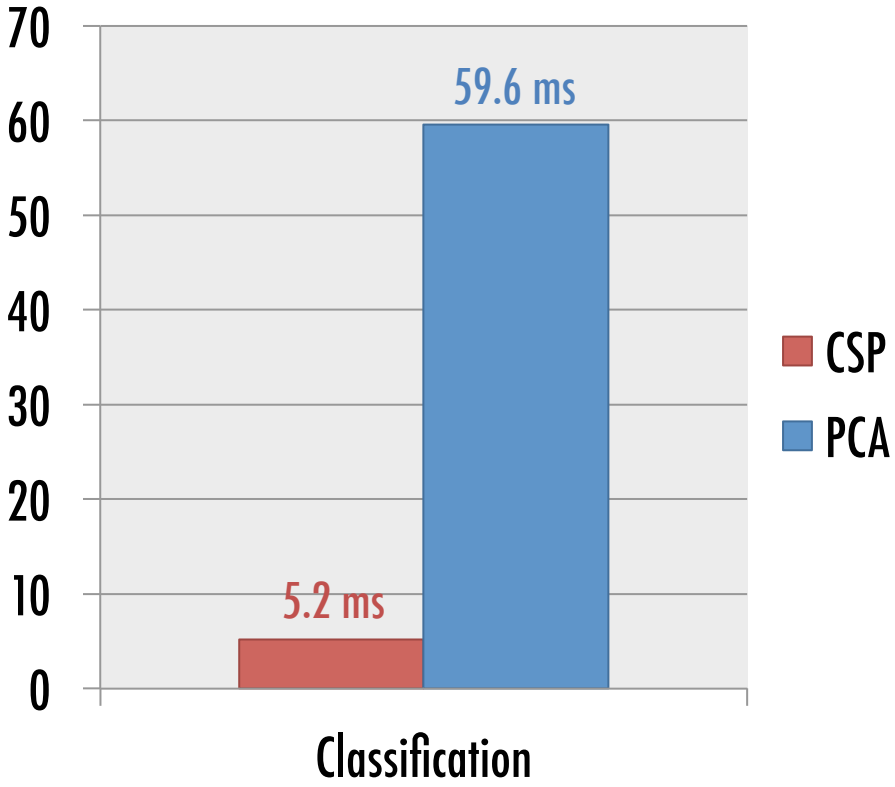


Results – Mean Errors



Results – Time





Conclusions

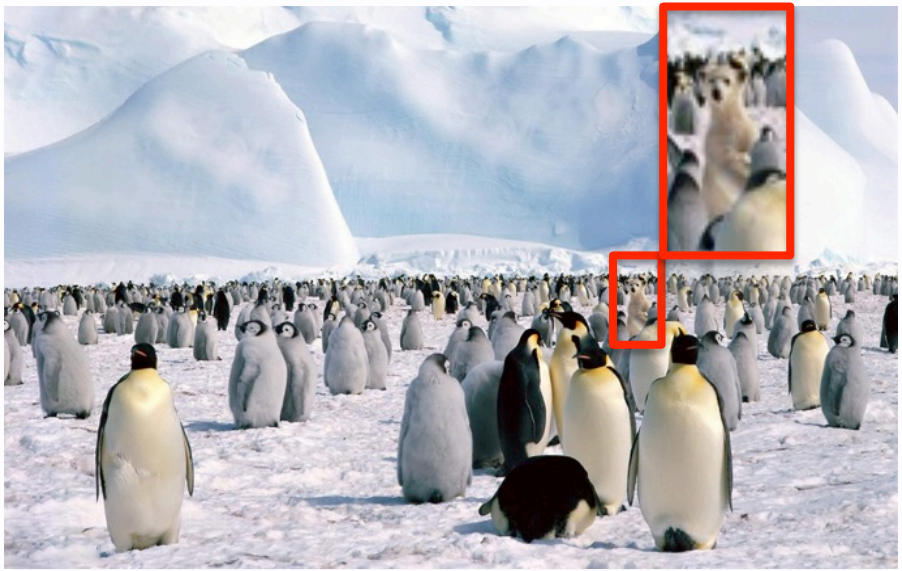
- We have derived correlates that are predictive of unconscious behaviours (decision confidence) without communicating or asking the users
- The proposed cBCI achieves much better decisions than both individuals and non-BCI groups in a very difficult visual search task
- Our cBCI does not specifically target users with impaired communication and motor control capabilities

Future Work

- Verify our findings by using real-world stimuli

Visual Search of Real-World Scenes

- We repeated the experiment with natural environment stimuli

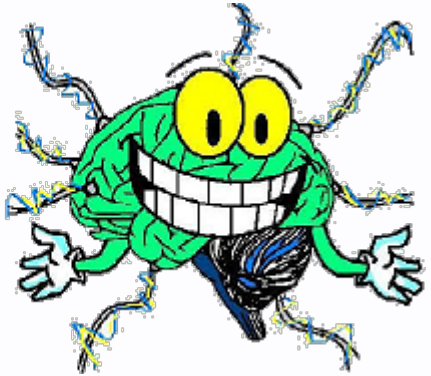


- Same results (see our poster in WeAT1.7)

Future Work

- Verify our findings by using real-world stimuli ✔
- Verify our offline findings with an online experiment 
- Use extension of CSP for feature extraction
- Use extra features from physiological signals as confidence indicators

Questions?



THANK YOU

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Two-Tailed Wilcoxon Signed-Rank Test

	Group size								
Comparison	2	3	4	5	6	7	8	9	Wins
PCA vs Majority	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.2070	7
CSP vs Majority	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0312*	8
CSP vs PCA	0.0123*	0.9978	0.0004*	0.9983	0.0003*	0.0018*	0.0546	0.3438	4
Sample size	45	120	210	252	210	120	45	10	

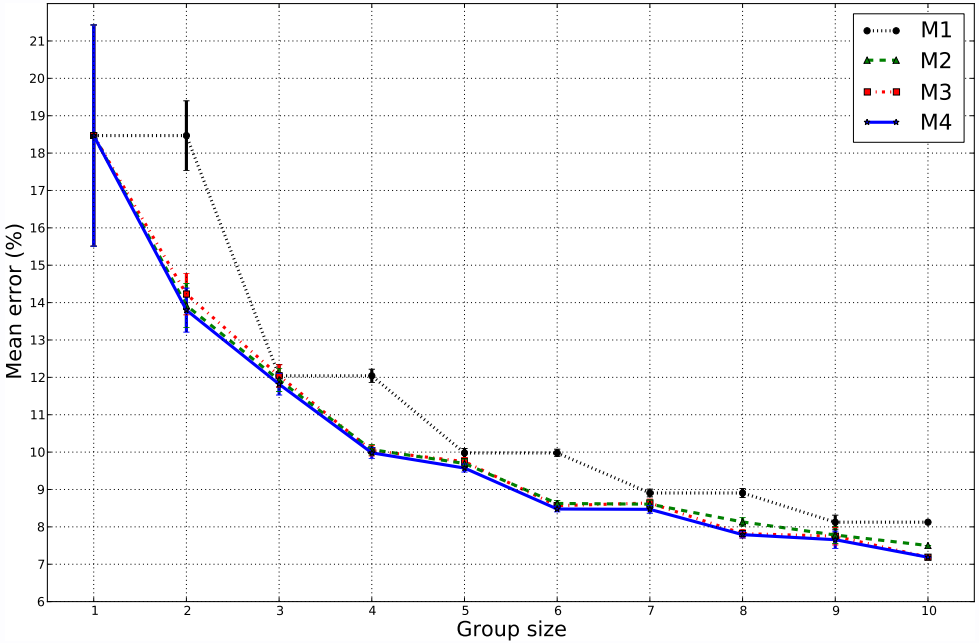
*statistically significant

Mean Errors (%)

Group size	Majority	PCA	CSP
1	21.000	21.000	21.000
2	21.000	15.229*	14.792**
3	12.599	12.081*	12.076*
4	12.599	9.674*	9.432**
5	9.208	8.512*	8.498*
6	9.208	7.686*	7.478**
7	7.656	7.151*	6.977**
8	7.656	6.687*	6.479*
9	6.719	6.438	6.312*
10	6.719	5.938	5.625

*statistically significant

Mean Errors (%) with Natural Stimuli



Group size	Majority	cBCI
1	18.47	18.47
2	18.47	15.04*
3	12.04	11.99
4	12.04	10.44*
5	9.98	9.75*
6	9.98	8.79*
7	8.91	8.64*
8	8.91	8.01*
9	8.12	7.78*
10	8.12	7.19

*statistically significant