Measuring engagement in a classroom:
Synchronised neural responses to rich, naturalistic stimuli

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Introduction

We demonstrate that classroom engagement can be measured using students' neural responses to rich naturalistic stimuli. We reliably reproduce the tracking of engagement while watching films, previously demonstrated in a laboratory setting [1]. We show that neural measures of engagement;

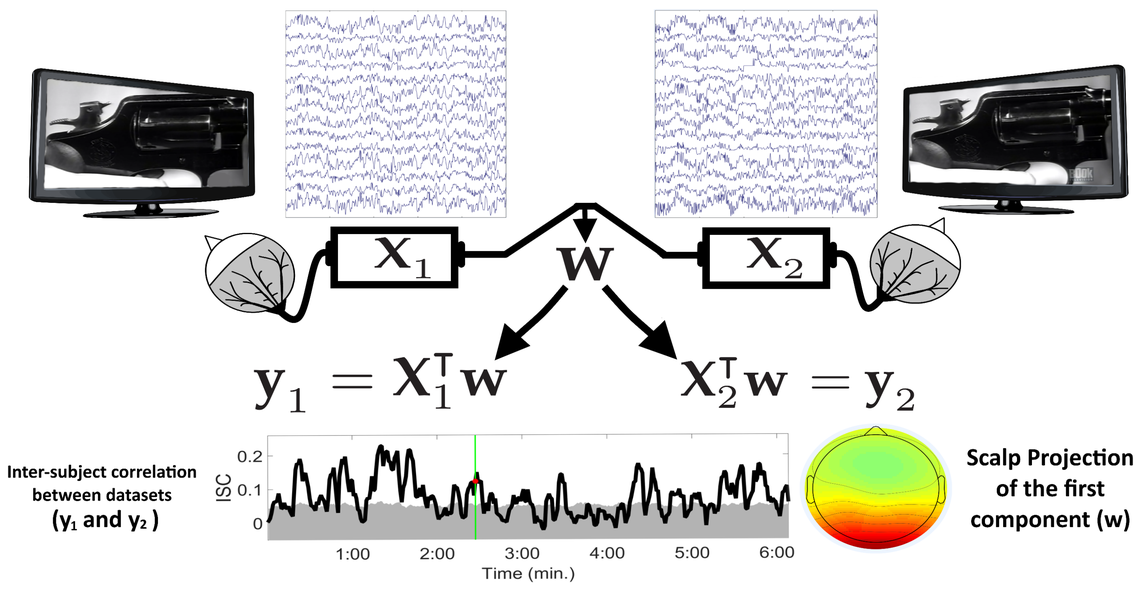
- can be measured using a low-cost, portable EEG system [2].
- can be measured simultaneously from nine students in a classroom.
- might be driven by attentional modulation of visual evoked potentials.

Inter-subject correlation (ISC)

- **Inter-subject correlation (ISC):** Average correlation between all possible parings of subjects.
- **Inter-viewing correlation (IVC):** Correlation between first and second viewing within subjects. Averaged across subjects.

ISC of neural activity while watching films have been shown to predict the popularity and viewership of TV-series and commercials (EEG study, [3]), and shows clinical promises as a measure of consciousness levels in non-responsive patients (fMRI study, [4]).

Finding shared neural activity



Conceptual illustration on finding periods of shared engagement in EEG.

Correlated Component Analysis (CorrCA)

CorrCA is a constrained version of Canonical Correlation Analysis [1]. CorrCA estimates sets of weights, $\mathbf{W}$, for two or more EEG measurements, $\{\mathbf{X}_1, \mathbf{X}_2\}$, such that correlation between the resulting components, $\{\mathbf{y}_1, \mathbf{y}_2\}$, are maximised:

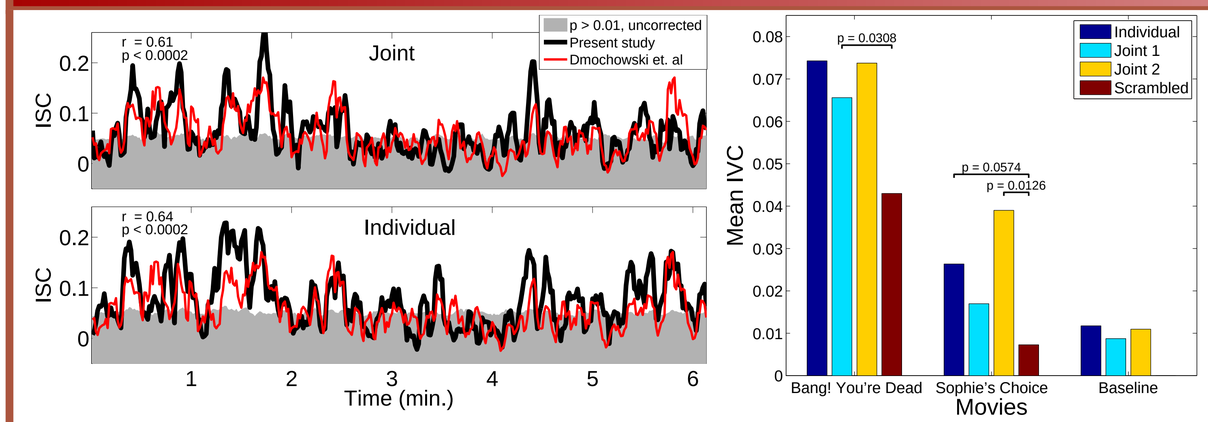
$$\mathbf{y}_1 = \mathbf{X}_1^\mathsf{T}\mathbf{w}, \quad \mathbf{y}_2 = \mathbf{X}_2^\mathsf{T}\mathbf{w}$$

$$\mathbf{w} = \arg\max_{\mathbf{w}} \frac{\mathbf{y}_1^T \mathbf{y}_2}{\|\mathbf{y}_1\| \|\mathbf{y}_2\|}$$

Joint recording in classroom setting

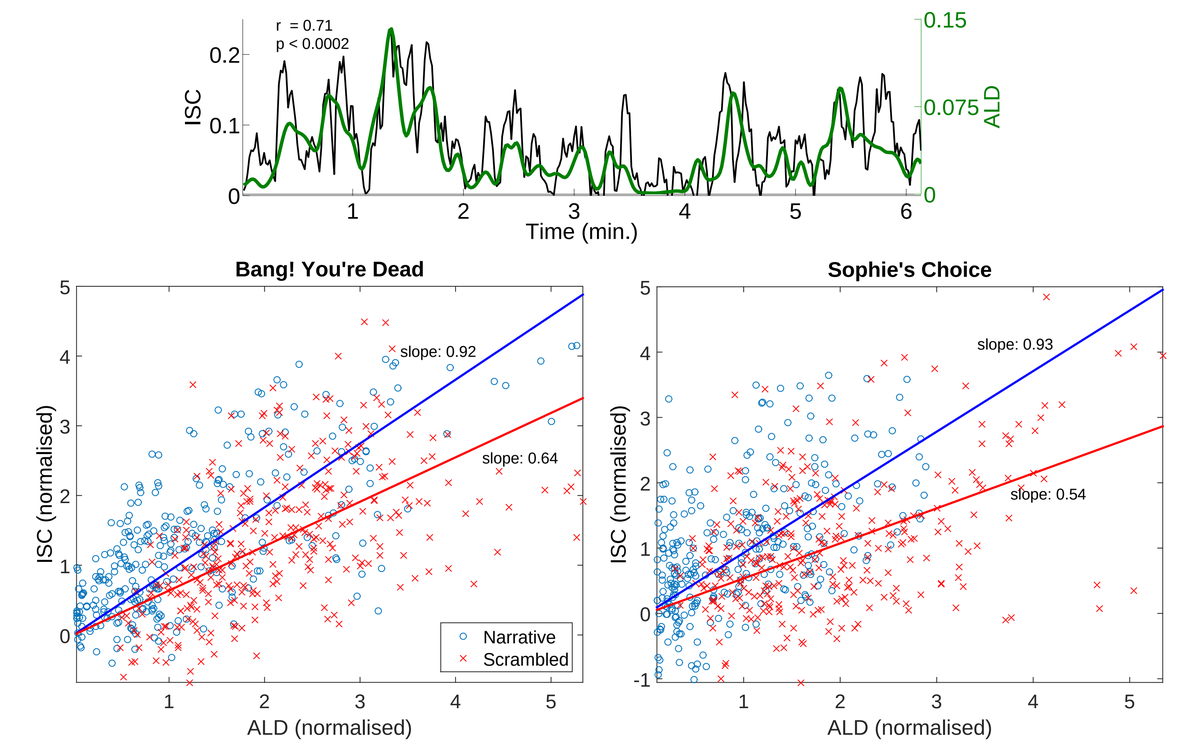
Simultaneous EEG from nine subjects using portable low-cost equipment
EEG was recorded from subjects (N=42) watching 6 min. clips of the two films *Bang! You're Dead*, *Sophie's Choice*, and of a non-narrative control video. One group watched the films alone and two groups of nine watched them together. An additional control stimulus was created for a final group by scrambling the order of the scenes in two films to disrupt the narrative, following previous research [5].

Results



Simultaneous EEG from nine subjects using portable low-cost equipment reliably reproduce results obtained with laboratory grade equipment.
(Left) Comparison between the ISC obtained in [1] and the present study. **(Right)** Mean intra-viewing correlation (IVC) calculated for the strongest correlated component averaged in time.

Attentional modulation of visual evoked responses



Disrupted film narrative lowers ISC correlation with changes in luminosity.
(Top) ISC correlates highly with average luminance difference (ALD). **(Bottom)** Moments with higher luminance fluctuations (hight ALD) result in higher correlation of brain activity across subjects (high ISC). There is a significant drop in the slope ($p < 0.01$: block permutation test with block size $B = 25\,s$) from the original narrative (blue) compared to the less engaging scrambled version of both films (red).

Conclusion

For educational technology, cost and robustness are key features. We have shown that:

- Salient aspects of the attentional modulation to rich naturalistic stimuli, can be reproduced in a realistic setting.
- Neural measures of engagement can be captured using low-cost consumer grade equipment.
- Modulation of visual evoked responses by attention has been previously documented [6]. We have quantified how attention amplifies ISC.

Acknowledgement

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