Co-registration of eye movements and event-related potentials in reading

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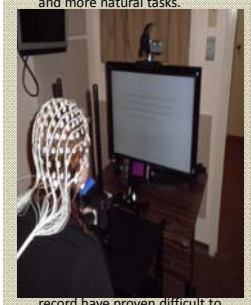
Introduction

- Eye-tracking is widely used to provide online measures of information processing across a variety of tasks.
- Event-related potentials (ERPs) provide online measures of neural processing across a variety of tasks.
- Combining these techniques would result in richer datasets and more natural tasks.



record have proven difficult to deal with.

- Recent work has attempted to combine these techniques by co-registering eye movements with the ERPs, allowing for the investigations of ERPs time locked to fixation onset (e.g. Dimigen et al., 2011).
- Independent component analyses (ICA) has been employed to remove eye-movement related artifacts (e.g. Plochl et al., 2012), attenuating or eliminating them.
- A potential concern is removal of non-eye movement related activity with the artifacts (e.g. Henderson et al., submitted).

Questions

the eyes move about every 200ms?

- Can eye-movement artifacts be removed without removing non-eye-movement activity?
- Can eye movement artifacts be removed using ICA without pre-training?

References

Dimigen, O., Sommer, W., Hohlfeld, A., Jacobs, A. M., & Kliegl, R. (2011). Coregistration of eye movements and EEG in natural reading: Analyses and review. Journal of Experimental Psychology: General, 140(4), 552-572.

Henderson, J. M., Luke, S. G., Schmidt, J., Richards, J. E. (Submitted). Co-registration of Eye Movements and Event-Related Potentials in Connected-Text Paragraph Reading. Frontiers in Systems Neuroscience.

Plochl, M., Ossandon, J.P, & Konig, P. (2012). Combining EEG and eye tracking: identification, characterization, and correction of eye movement artifacts in electroencephalographic data. Frontiers in Human Neuroscience, 6, 278.

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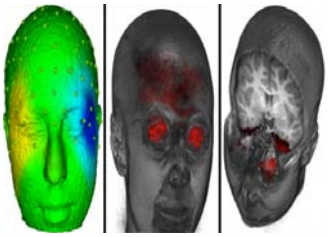
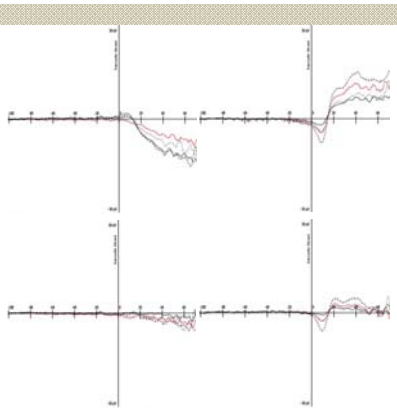
Methods

Example Scan Patterns for Normal Reading and Pseudo-text Reading

- ICA was used to identify and remove the components resulting from eye movement activity. After removal, residual EEG activity was reconstructed and analyzed for fixation-related ERPs.
- Eye movement components were identified using three criteria:
  1) Component loadings on the surface of the head were consistent with an eye movement.
  2) Source analysis localized the component to the eyes using realistic finite element method (FEM) head model obtained from each subject's structural MRI scan.
  3) Temporal activation of the component occurred at the time of the eye movement and differed for right and left eye.movements.

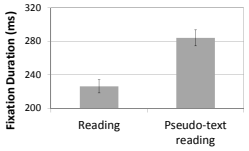


Left panel: ICA component loading on the surface of the head.
Middle panel: ICA component source localized to the eyes.
Right panel: Current density reconstruction of the ICA component in the left panel.

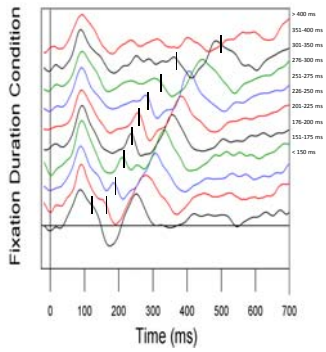


Top: Uncorrected data from 4 eye channels for rightward eye movements during reading.
Bottom: Corrected data.

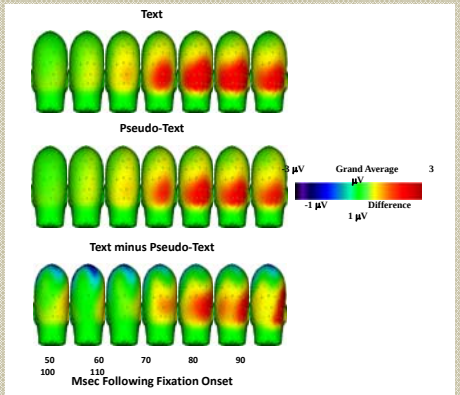
Results



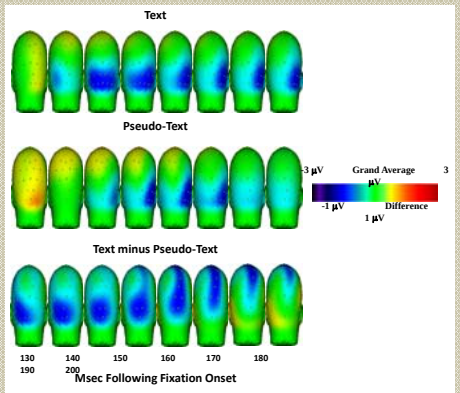
Replicating prior research, fixation durations were significantly longer in the pseudo-text control condition $F(1,8)= 40.1$, MSE= 373, $p<.001$



ERP waveforms stratified by fixation duration. Mean fixation duration is depicted with a vertical line on each ERP waveform, range is listed on the right. Note that shortly after fixation offset , the next fixation generates a large P1.

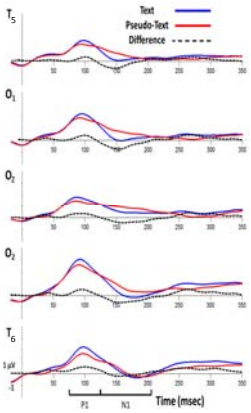


Grand average ERP activity during the P1 interval (50 to 110 ms after word fixation onset) for text-reading (top), pseudo- text reading (middle) and the difference (bottom).



Grand average ERP activity during the N1 interval (130 to 200 ms after word fixation onset) for text-reading (top), pseudo- text reading (middle) and the difference (bottom). Note that the N1 starts on the left, intensifies and moves to the right hemisphere over time.

Results



Grand average waveforms time-locked to fixation onset showing activity at virtual electrodes T5, O1, Oz, O2, and T6.

In the time window of the P1 we found significantly higher amplitudes in text-reading than in pseudo-reading at all tested electrodes (all $ts > 3.65$, all $ps < .001$)

In the time window of the N1 we found significantly more negative amplitudes for text-reading than pseudo-reading at all tested electrodes (all $ts > 2.33$, all $ps < .05$). Note, the N1 peaked earlier for text-reading than for pseudo-reading at the left hemisphere electrodes sites.

Discussion

- Generally able to identify and remove eye–movement related artifacts from the ERP record.
- Non-eye-movement related activity was left relatively intact by source localizing the eye-movement components and selectively removing those localized to the eyes.
- Given that P1/N1 components tend to occur shortly after fixation onset and many fixations only last 200ms, overlapping ERP components are produced. Investigation of fixation related ERPs will require correcting for eye-movement-related artifacts and de-convolving activity related to future fixations from the current fixation-related activity.

Future Work

- Source localize the fixation-related P1s/N1s to show that the next fixation's P1/N1 is indeed coming from the same neural generators.
- Look more closely for frequency effects.
- Explore changes in the ERP waveform related to changes in fixation duration.
- Look at pre-saccadic ERPs time locked to saccade onset. Other work has already investigated the muscular related components tied to saccade onset, but what are the cognitive components tied to saccade generation and where do they source localize?