We Find Before We Look: Neural Signatures of Target Detection Preceding Saccades During Visual Search

An Luo[1]. Lucas C. Parra[2] and Paul Sajda[1]

[1]Department of Biomedical Engineering, Columbia University

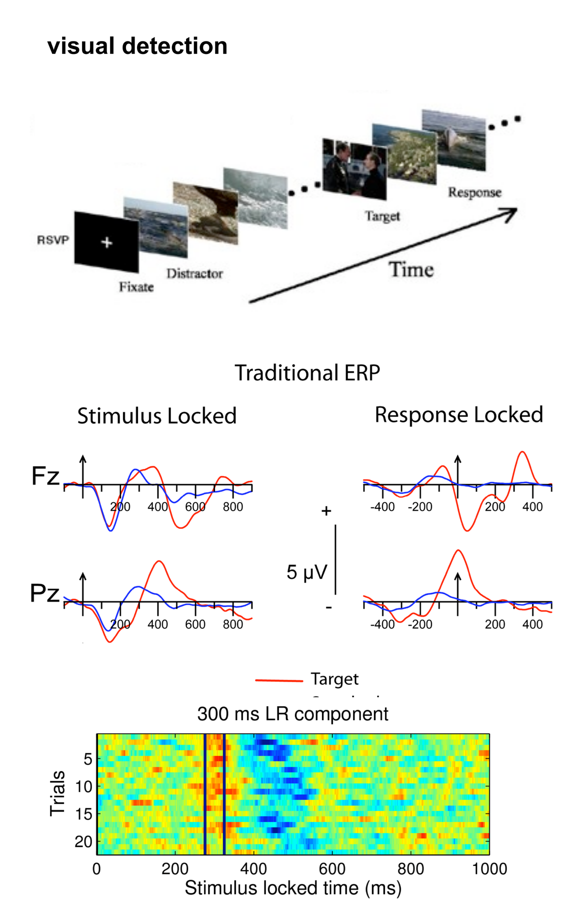
[2]Department of Biomedical Engineering, City College of New York

Abstract

We investigated neural correlates of target detection in the electroencephalogram (EEG) during a free viewing search task and analyzed signals locked to saccadic events. We adopted stimuli similar to ones we used previously to study target detection in serial presentations of briefly flashed images. Subjects performed the search task for multiple random scenes while we simultaneously recorded 64 channels of EEG and tracked subjects' eye position. For each subject we identified target saccades (TS) and distractor saccades (DS). For TS we used saccades which were aimed directly to the target and were followed by a correct behavioral response (button press); for DS, we used saccades in correctly responded trials having no target (these were 28% of the trials). We sampled the sets of TS and DS saccades such that they were equalized/matched for saccade direction and duration, ensuring that no information in the saccade properties themselves was discriminating for their type. We aligned EEG to the saccade onset and used logistic regression (LR), in the space of the 64 electrodes, to identify activity discriminating a TS from a DS on a single-trial basis. Specifically, LR was applied to the signals from 50ms time windows preceding and following saccade onset for varying latencies. We found that there is significant discriminating activity in the EEG both before and after the saccade—average discriminability across 7 subjects was AUC=0.64, 80 ms before the saccade, and AUC=0.68, 60 ms after the saccade (p<0.01 established using bootstrap resampling). Between these time periods we saw substantial reduction in discriminating activity (mean AUC=0.59). We conclude that we can identify neural signatures of detection both before and after the saccade, indicating that subjects anticipate the target before the last saccade which serves to foveate and confirm it target identity.

Neural Correlates of Target Detection

- Traditional paradigms for studying neural correlates of target detection utilize event locking (stimulus onset or response).
- In this case we see classic ERPs such as the P300.
- Methods for single-trial EEG analysis can also reveal components which capture trial-to-trial variability of neural correlates target detection.

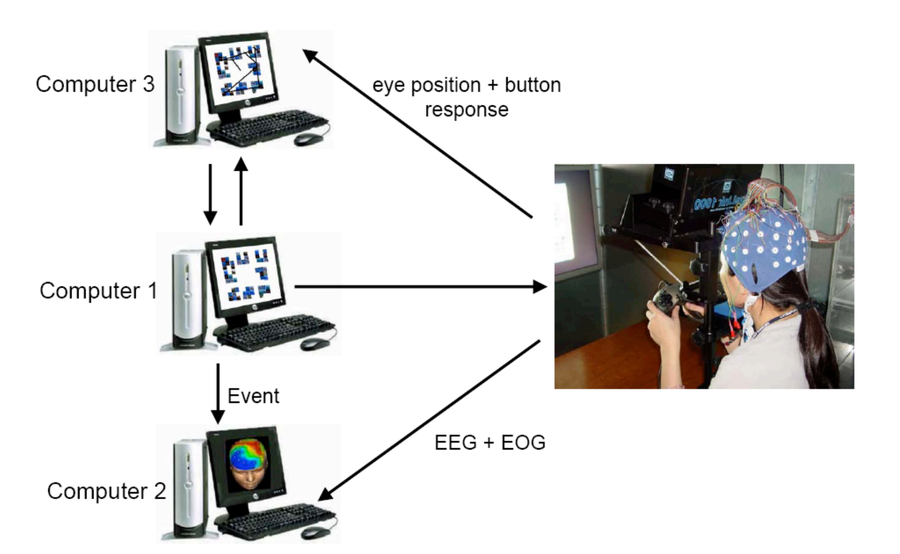


- The situation is not so simple in free-viewing visual search.
- Each eye movement (saccade) can be seen as an event in which to lock the EEG. In addition, the events are clearly not independent of one another.
- Can we identify, single-trial, neural correlates of target detection during visual search?

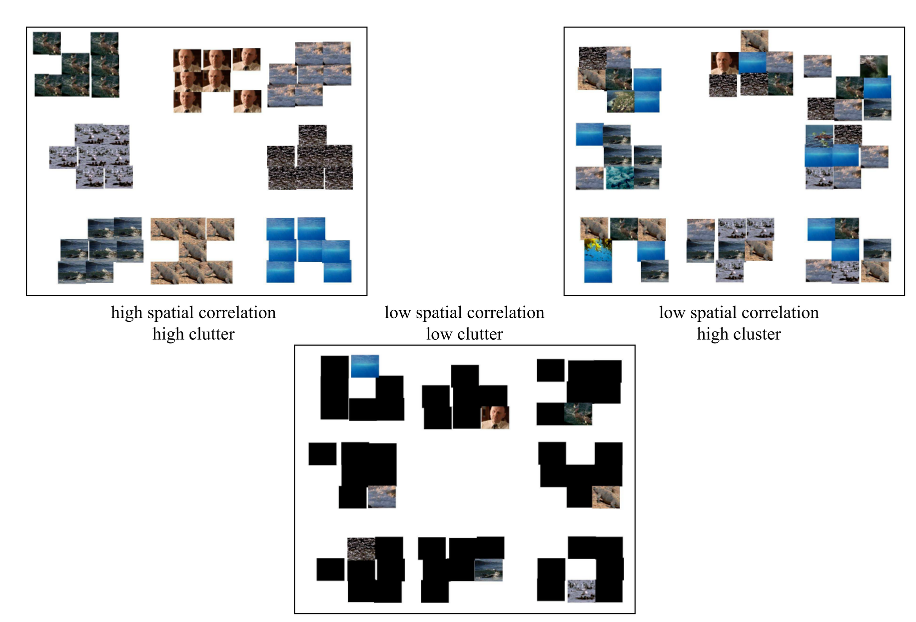
Summary of Experimental Paradigm

- 7 Subjects, 3 stimulus conditions
- **Scene** to be searched consisted of 8 **clusters** of image **chips**. Each cluster had 7 image chips, where each chip was 128x96 pixels and spanned 1.5deg visual field.
- For each condition, we generate 125 scenes with target chip(s), where targets are image chips of person/people, and 50 scenes with no target chip(s), which are chips of natural environments including animals.
- Each subject views (125 + 50) x 3 = 525 trials. These trials are divided into 5 sessions of 105 trials. Each trial in a session is chosen at random from the possible 525 trials.
- Subjects are told to respond with a button press when they find a target or conclude there is no target in the scene.
- The trial times out after 10s if they do not respond.

System Overview

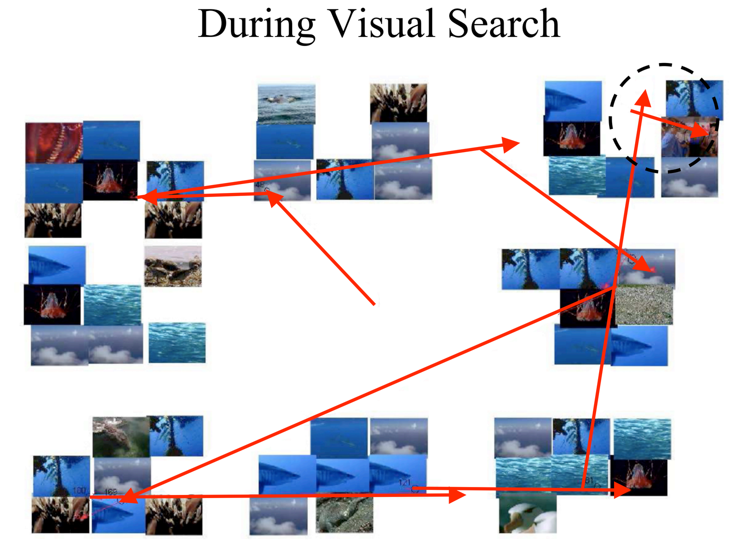


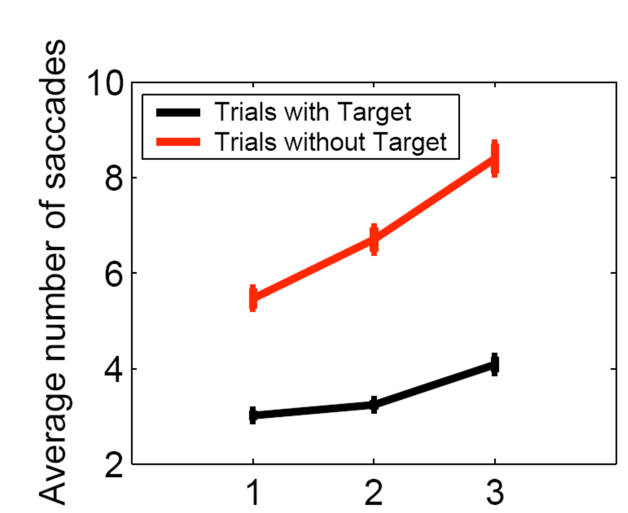
Three Search Conditions



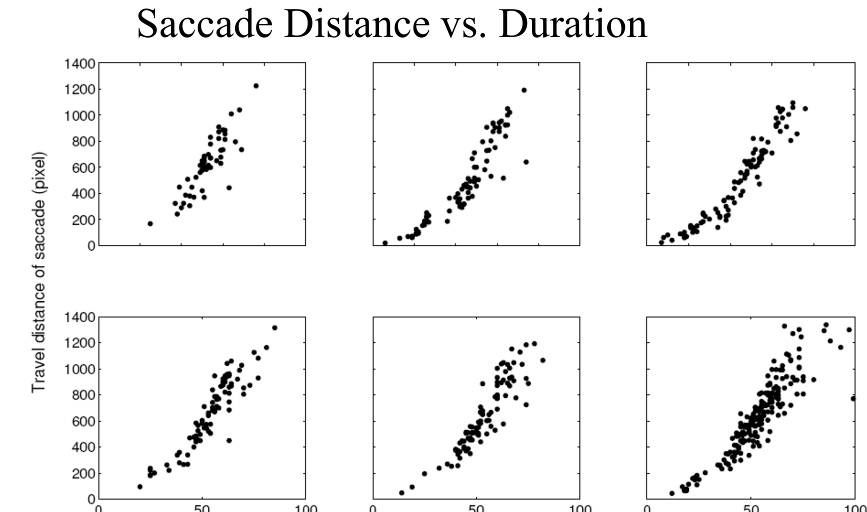
Behavioral Results

Example of Saccades Made During Visual Search



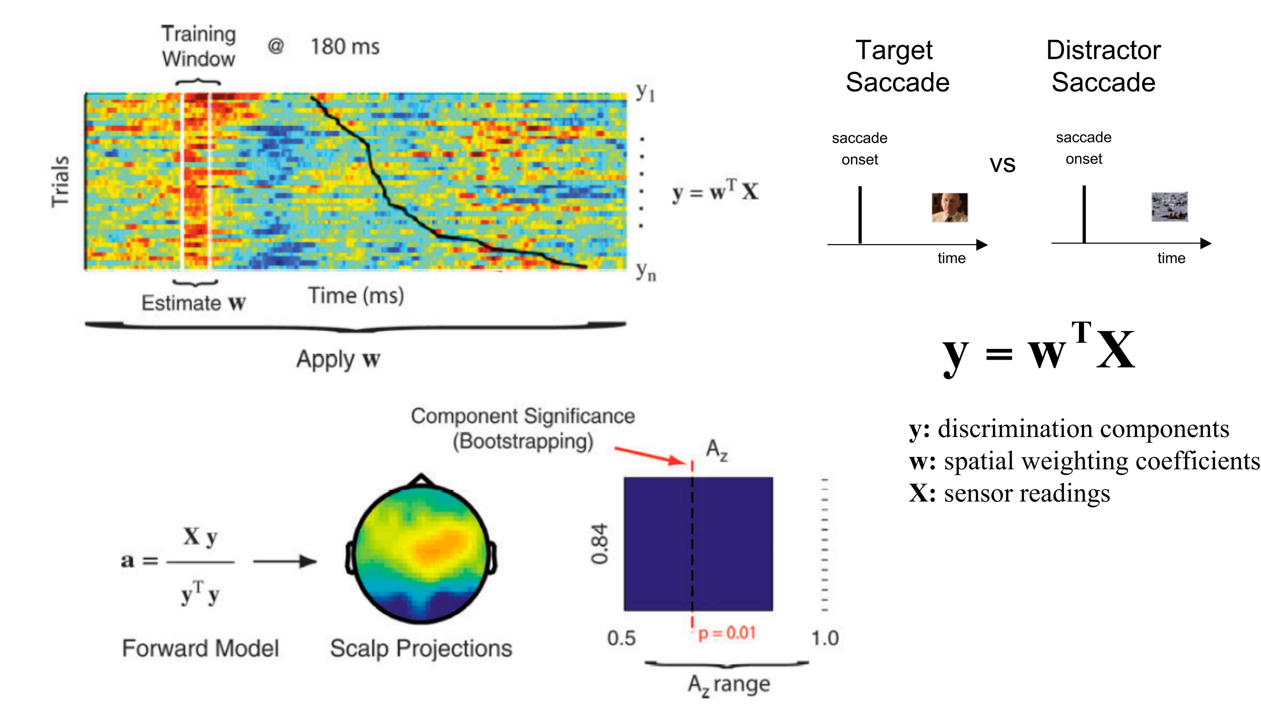


Saccade Distance vs. Duration

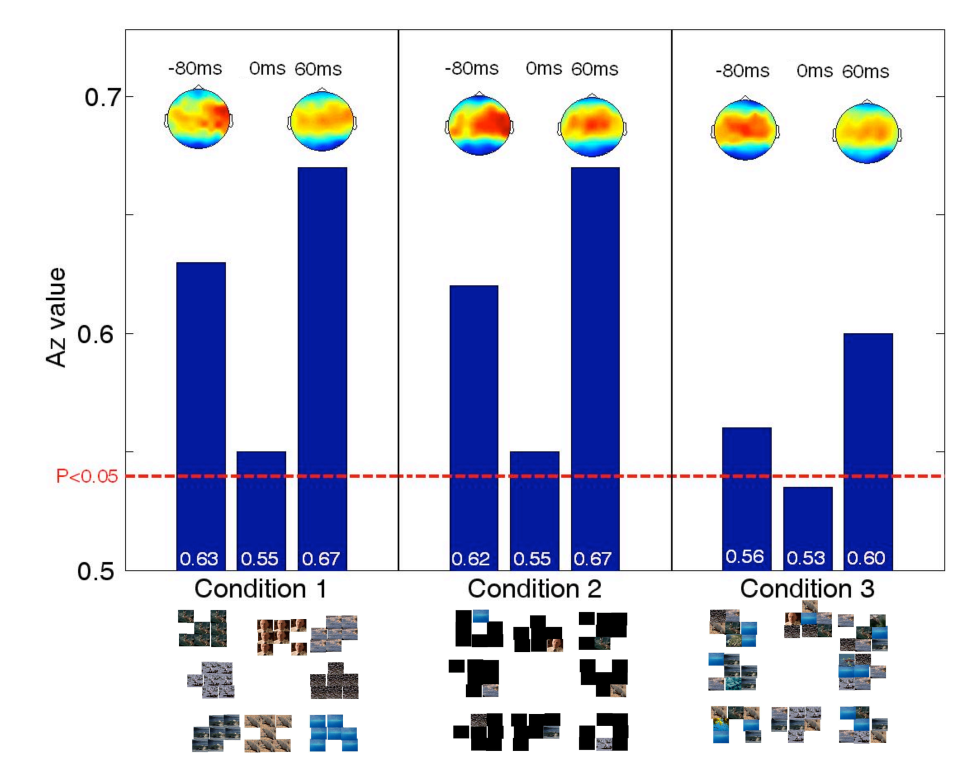


We match (via resampling) the distributions for the target saccades and distractor saccades to factor out any discriminatory information which lie in saccadic features.

Single-trial EEG Analysis



Identifying discriminative components in the EEG using time-locked spatial filters yielding discriminative projections.



- We see significant pre and post-saccade discrimination.
- Discriminability correlates with target salience.

Summary/Conclusions/Questions

Our results suggest that in fact we know the location of the target (**we "see" it**) prior to making a saccade to it (**before we "look"**).

However there are still many open questions, a few include,

- Does the pre-saccade discriminability represent evidence accumulation or peripheral detection?
- The timing and scalp topologies we find are different than what one observers for typical stimulus locked target detection (P300)--does this implicate different processing and/or cortical networks involved in target detection during free-viewing?

Acknowledgments

This work was supported by DARPA