Cortically Coupled Computer Vision for Rapid Image Search

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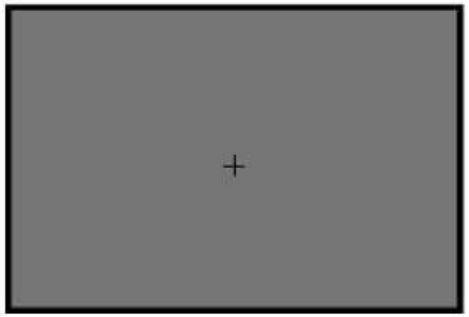
Introduction

- Computers are slow at some things humans are fast at.
  - For example, image recognition
- Can we use brain responses to classify images that a subject is seeing?

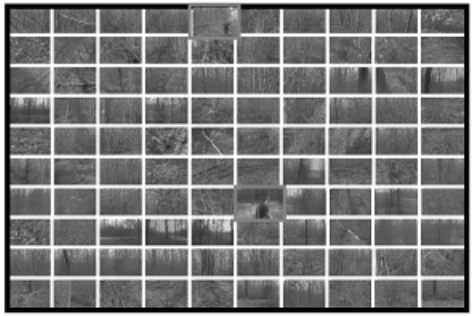
Experimental Setup (In A Figure)



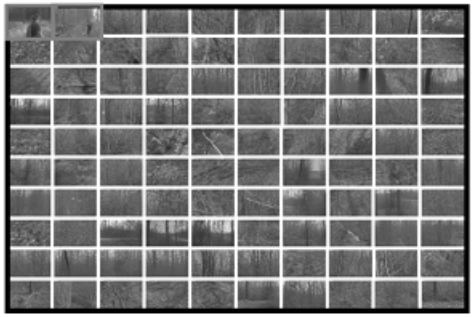
Fixation
(2 seconds)

RSVP Sequence
(100 ms / image)

Target



Pre-triage



Post-triage

	Pre-triage	Post-triage
Image 1	5	1
Image 2	66	2
Average across trials:		
Image 1	32	3
Image 2	65	5

Summary

Experimental Setup (In A Slide)

- Rapid Serial Visual Presentation (RSVP)
  - Present a series of images for 100ms each
  - 2% of images are 'targets,' randomly distributed
  - others 'distractors'
- 'Sequence':
  - 100 images, followed by a matrix of thumbnails
  - Thumbnails sorted sorted by EEG, re-presented
- Trial:
  - Two 'blocks' of 50 sequences
  - Second block includes mouse press to ID targets.
  - Grayscale images of natural scenes
  - Targets: Any image that includes a person

Analysis

- Artifact reduction - control for eye movements.
- Classification
  - Linear Discriminant Analysis
  - Various window times and onset intervals tested
- Triage
  - Display results to subject
- Bayes' Theorem for button results

$$p(\text{target}|RT) = \frac{p(RT|\text{target})p(\text{target})}{p(RT|\text{target})p(\text{target}) + p(RT|\text{nontarget})p(\text{nontarget})}$$

Math (LDA)

$$y_c(t) = \mathbf{w}_{\tau,\delta}^T \mathbf{x}_c(t) + b_{\tau,\delta}$$

$$\mathbf{w}_{\tau,\delta} = \boldsymbol{\Sigma}_{\text{pool}}^{\#} \boldsymbol{\mu}_1 - \boldsymbol{\Sigma}_{\text{pool}}^{\#} \boldsymbol{\mu}_0$$

$$b_{\tau,\delta} = \frac{1}{2} \left[\boldsymbol{\mu}_0 \boldsymbol{\Sigma}_{\text{pool}}^{\#} \boldsymbol{\mu}_0 - \boldsymbol{\mu}_1 \boldsymbol{\Sigma}_{\text{pool}}^{\#} \boldsymbol{\mu}_1 \right]$$

$$\boldsymbol{\Sigma}_{\text{pool}} = ((N_0 \boldsymbol{\Sigma}_0 + N_1 \boldsymbol{\Sigma}_1)/(N_0 + N_1))$$

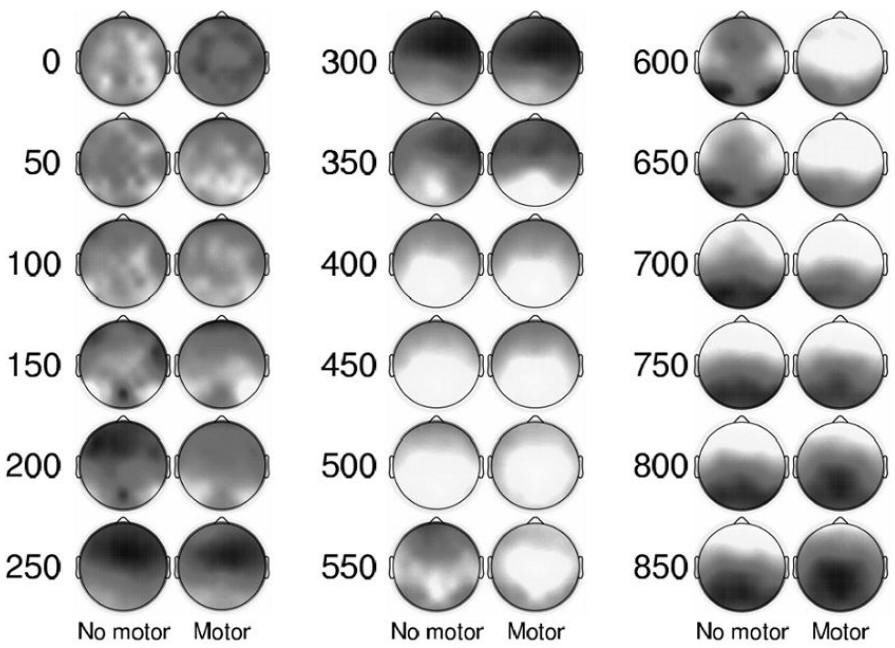
Results

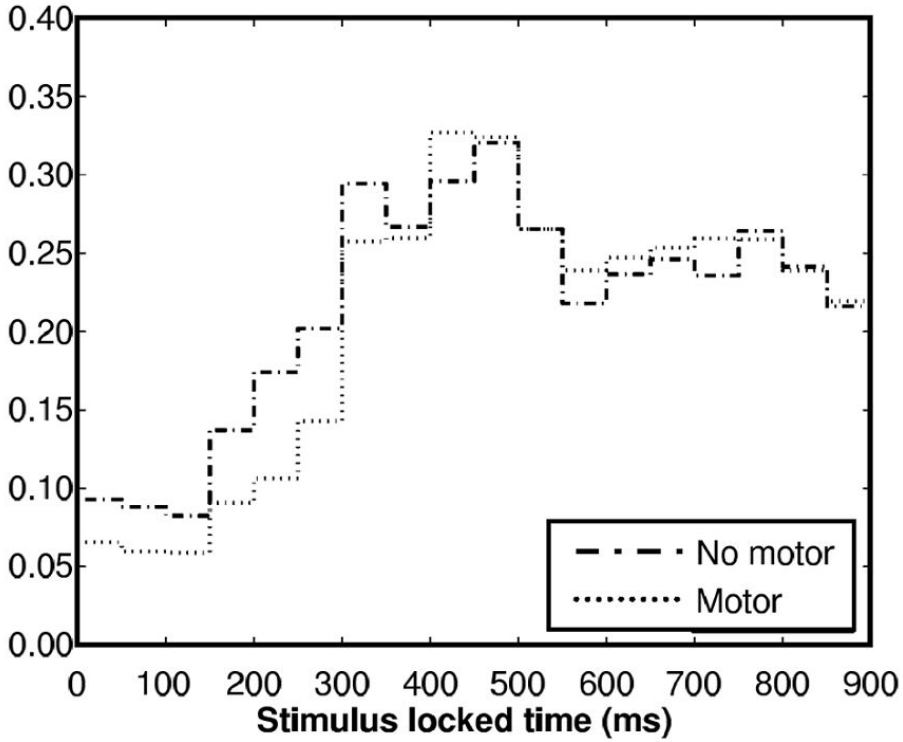
TABLE I
TRIAGE PERFORMANCE AND BEHAVIORAL RESULTS

Subject	EEG (no motor)	EEG (motor)	Button	EEG (motor) and Button	RT (training) (ms)	RT (testing) (ms)	% Correct (training)	% Correct (testing)	Response bias c, (testing)
1	0.92	0.91	0.87	0.94	418 ± 133	413 ± 101	88	86	-0.8
2	0.94	0.96	0.86	0.97	412 ± 64	450 ± 64	94	74	-1.2
3	0.90	0.87	0.96	0.96	445 ± 79	423 ± 59	86	94	-0.7
4	0.91	0.92	0.98	0.98	433 ± 74	445 ± 59	98	98	-0.5
5	0.91	0.93	0.98	0.98	398 ± 86	402 ± 58	96	96	-0.9
Group	0.91 ± 0.02	0.92 ± 0.03	0.93 ± 0.06	0.97 ± 0.02	421 ± 91	426 ± 71	92 ± 5	90 ± 10	-0.8 ± 0.3

- 92+/- 5% correct responses
- Some subjects better classify images via EEG than via button

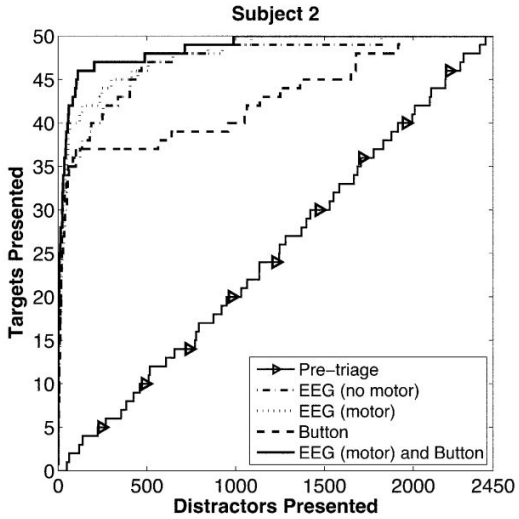
More Results



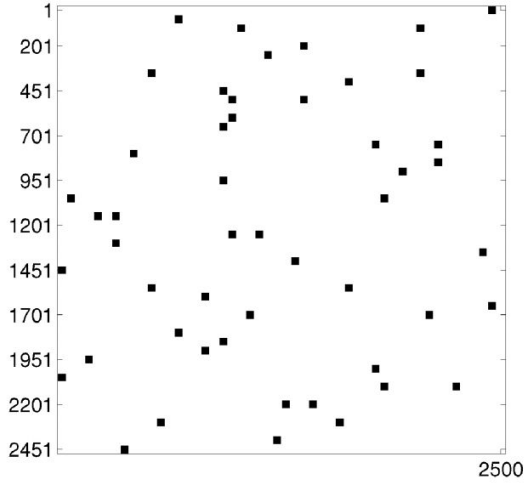


- Avg of many trials/classifiers.
- Motor and no-motor similar until 550ms

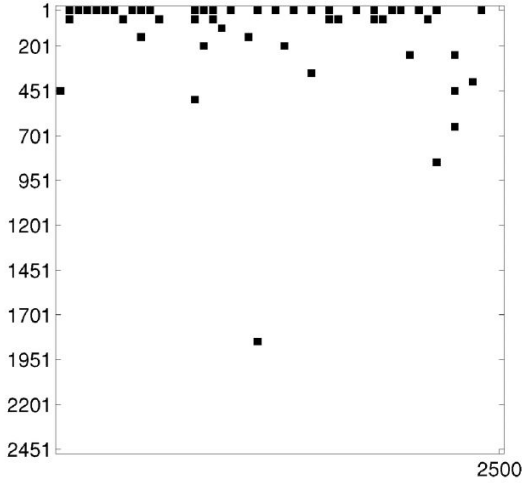
Even More Results



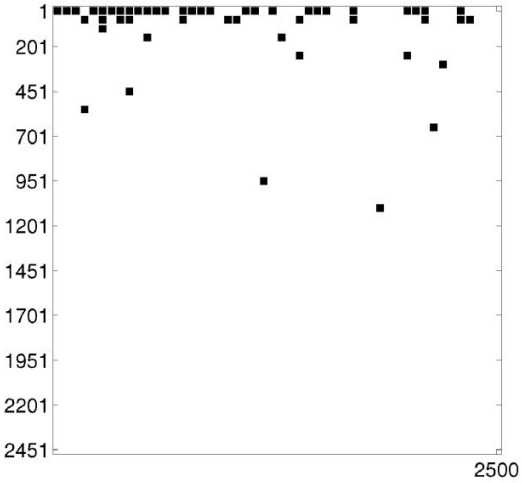
(a) Triage performance



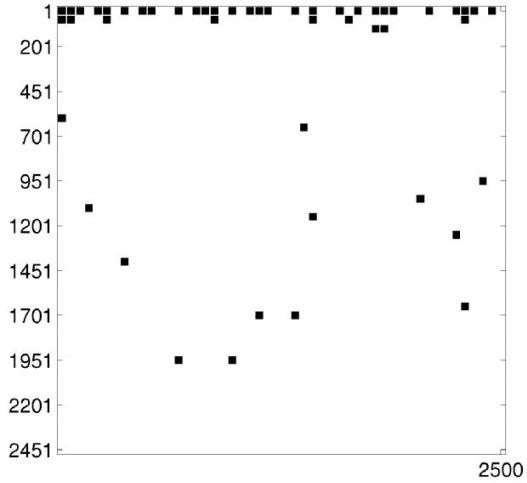
(b) Original sequence



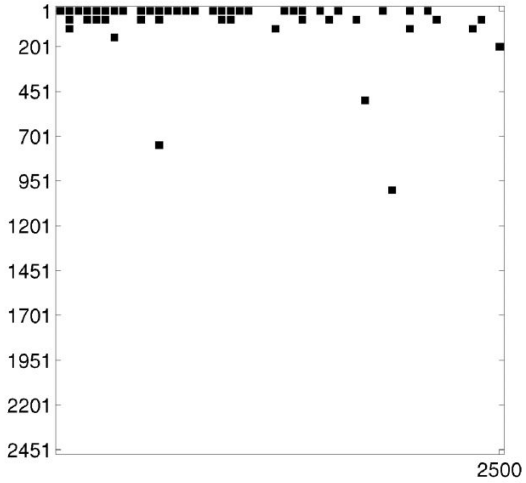
(c) EEG (no motor)



(d) EEG (motor)



(e) Button



(f) EEG (motor) and Button

Discussion and Extension

- No feedbackless control
- No control for 'surprise'
  - Is there one?
- Minimal mention of fatigue
- Is this practical?
- Is this ethical?