Eye-Hand Coordination and EEG Correlates of Rapid Pointing under Risk and Uncertainty

Markus Plank[1], He C. Huang[1], Dongpyo Lee[1], Joseph Snider[1], Diosalyn Alonzo[1], Sergei Gepshtein[2], Steven A. Hillyard[3], & Howard Poizner[1]

[1]Institute for Neural Computation, UCSD; [2]SALK Institute for Biological Studies, La Jolla; [3]Department of Neurosciences, UCSD

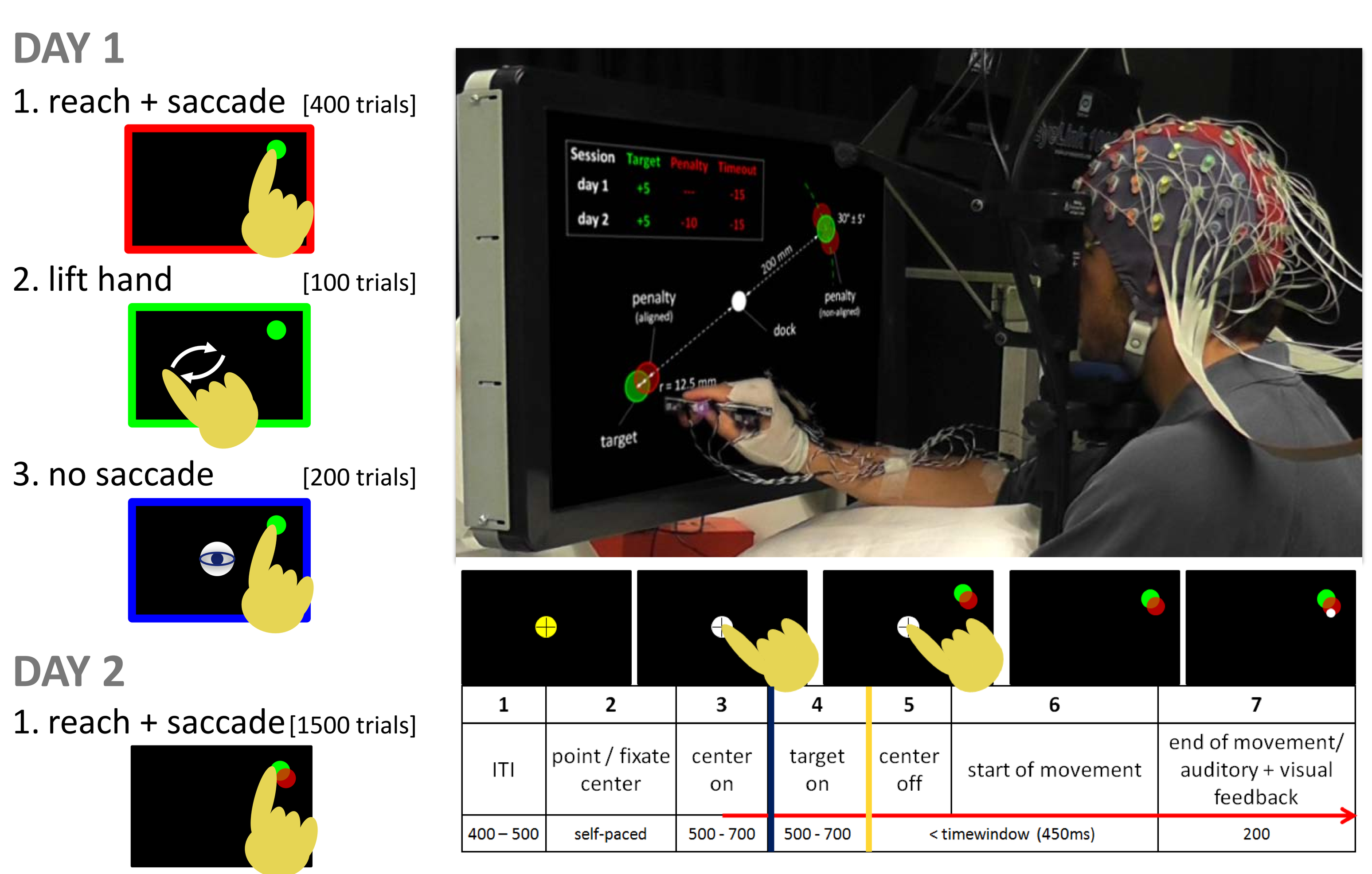
1. Introduction

- Goal-oriented reaching movements have to be pre-planned, initiated, and continuously monitored by the nervous system. In all phases, task-relevant movement variability has to be taken into account in order to minimize the probability of movement error-related losses in the execution phase (Gepshtein et al., 2007).
- In order to establish and dynamically modulate this representation of motor uncertainty, polymodal sensory input from visual, vestibular, kinesthetic, and proprioceptive systems have to be integrated and adapted to current task requirements.
- What are the neural substrates of planning, coordination and execution of error-prone movements under risk?
- Subjects performed rapid spatially-directed movements to peripheral visual targets either with or without support of the eyes.

2. Methods

Subjects and Setup

- 4 healthy, right-handed subjects (*age: 21.3±3.8 yrs*, 1 female).
- Synchronized recordings of finger/hand/arm movements (PhaseSpace, 120 Hz), eye movements (EyeLink, 1000 Hz), and scalp EEG (70 Biosemi active electrodes, 10-20 system, 512 Hz).



Experimental Manipulation

- Target placement: **lower left** vs. **upper right** with respect to screen center
- Placement of penalty region: **aligned** vs. **non-aligned** with movement direction

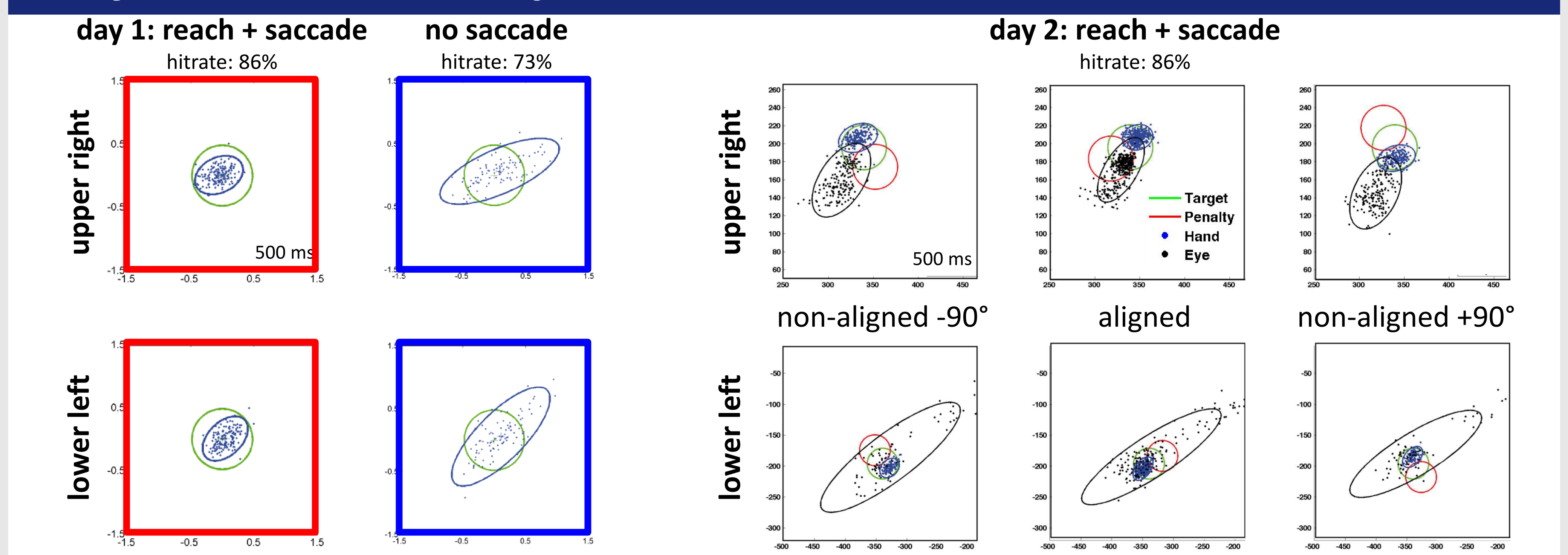
Dependent Variables

- Exclusion of trials with RT > 500 ms
- Finger endpoint (2-D distance, variable error)

EEG Processing

- EEG data was re-referenced off-line to averaged mastoids; 1 Hz HPF, 55 Hz LPF; Epochs with excessive peak-to-peak voltage fluctuations (> 70 uV) and epochs with artifactual electromyographic activity were removed.

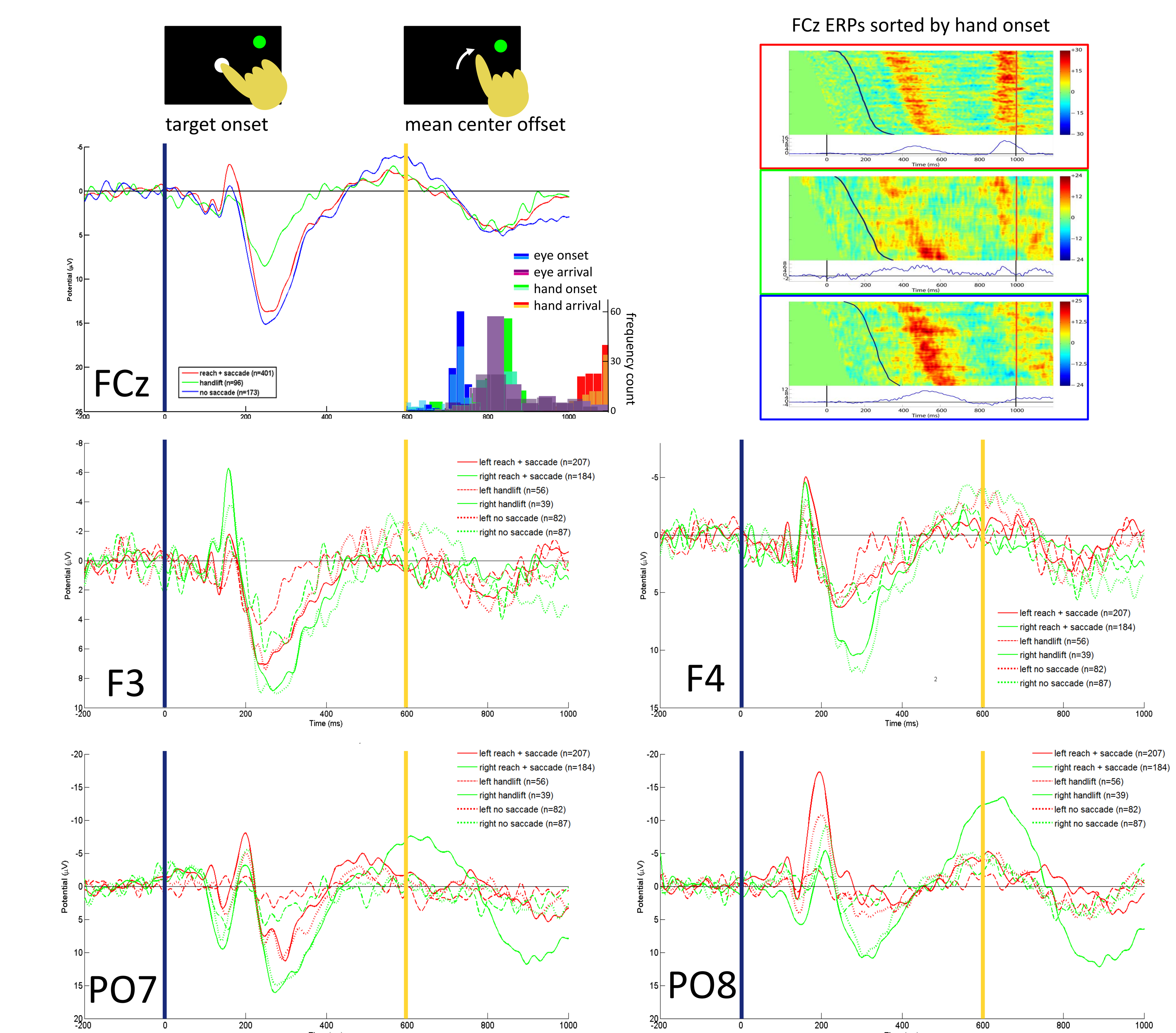
3. Eye and Hand Endpoints



Results:

- Decrease in accuracy when no saccades are possible.
- Differentially oriented hand- and eye endpoint ellipses for upper right and lower left.

4. Spatio-temporal EEG Characteristics: ERP Analysis

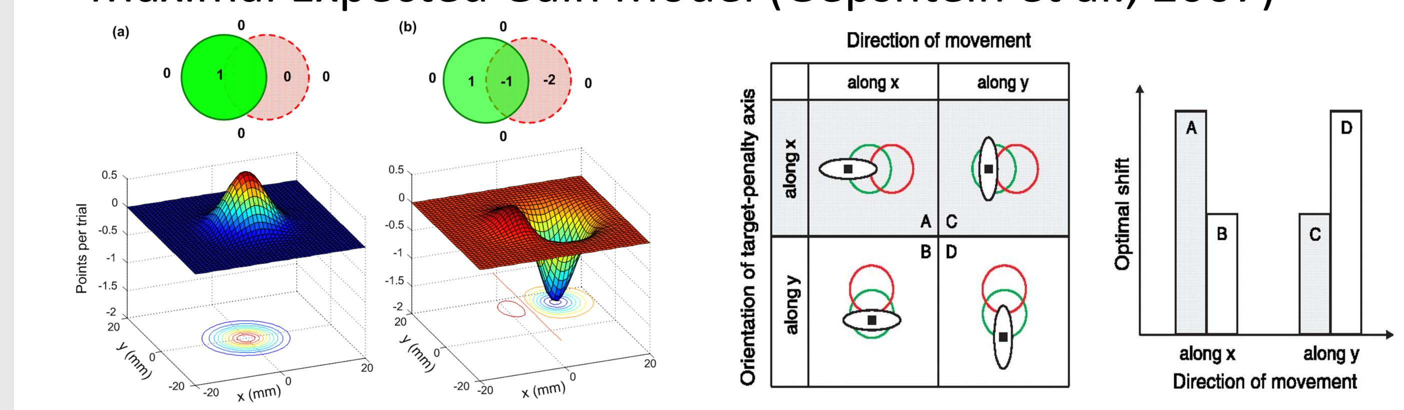


Results:

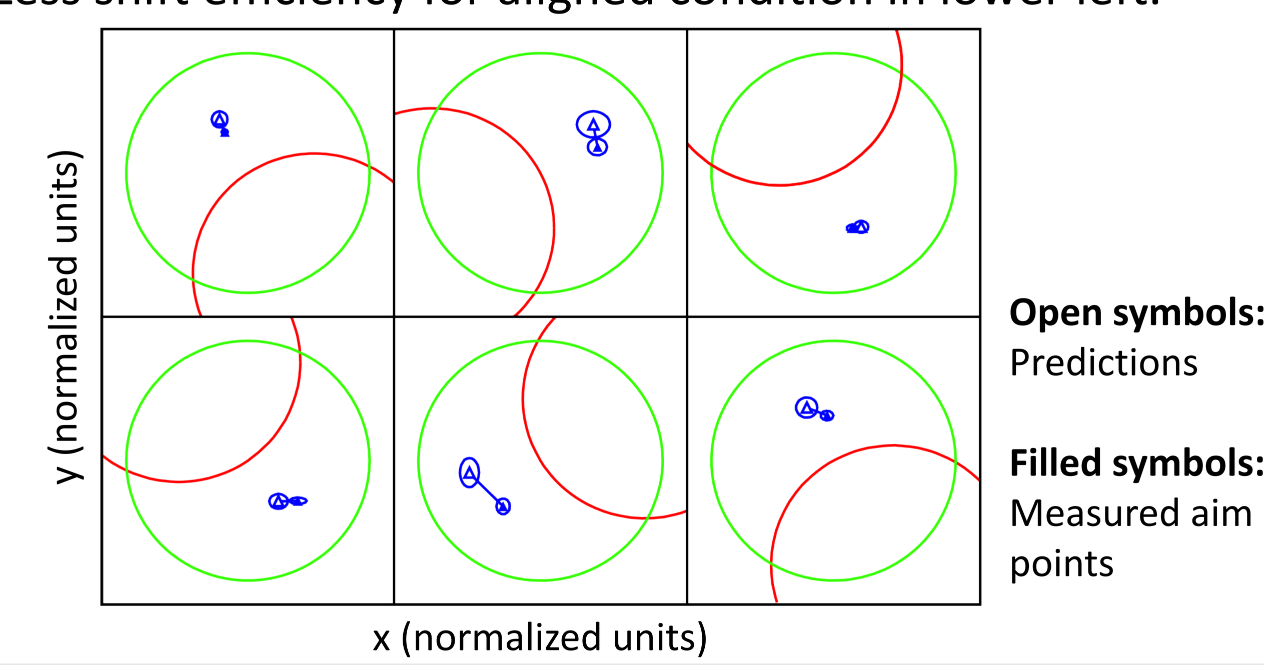
- Early components of the ERP to the target onset were larger when hand movements had to be directed to the target (as compared to hand-lift condition).

5. Comparison with Ideal Planner

- Maximal Expected Gain Model (Gepshtein et al., 2007)



- With zero penalty, aiming at target center is optimal.
- With non-zero penalty, the aim has to be shifted away from penalty, for a distance that depends on the size of error.
- The predicted shift depends on the direction of movement: the shift is larger in the direction of larger error.
- Less shift efficiency for aligned condition in lower left.



6. Discussion

- We investigated the interaction of neural and sensorimotor systems supporting the optimization of motor accuracy with a fully-integrated recording system.
- Pointing accuracy decreases when movements are not guided by eyes.
- Increased negativity for "reach + saccade" condition as compared to "no saccade" and "lift hand": Anticipation of movement (Kutas et al., 1980).

Next Steps

- Will continue analyzing the movement data and EEG, particularly localizing the neural generators of task-related ERP components associated with optimal and non-optimal performance, and test further subjects.

7. Acknowledgements

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email: mplank@ucsd.edu