Event-related potentials in humans during spatial navigation

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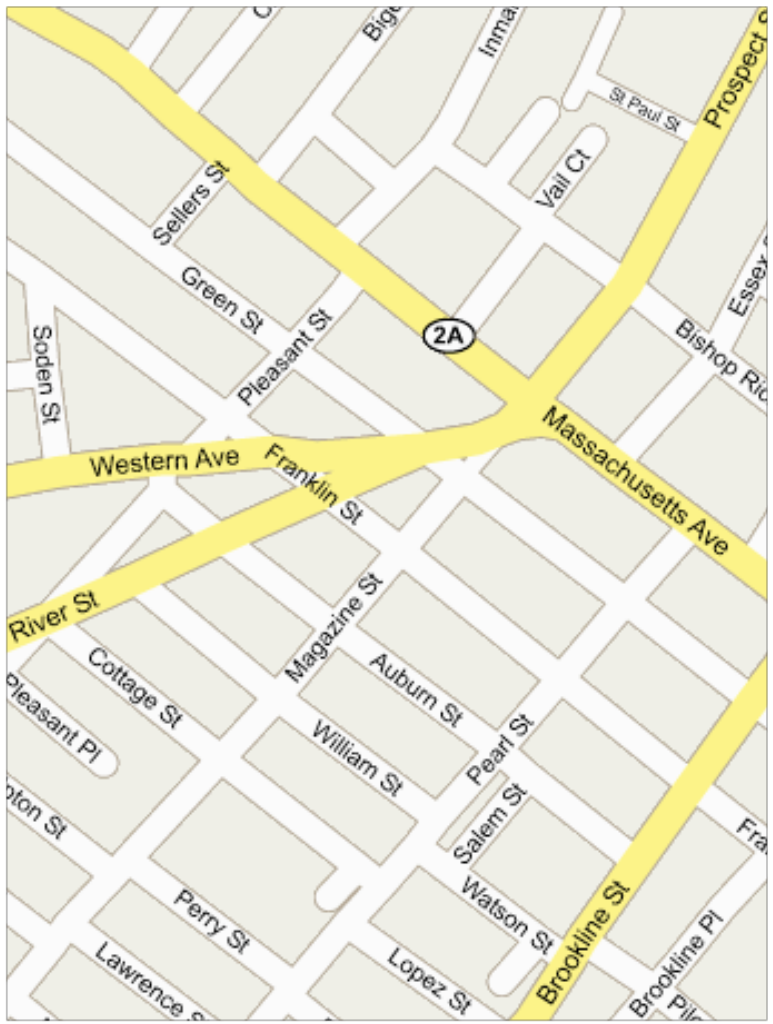
Overview

- Computer-generated three-dimensional environments resembling towns were used to study spatial navigation and implicit recognition of landmarks
- Electrical activity on the scalp was recorded during task
  - Event-related potentials (ERPs) calculated for appearance of specific landmarks within the virtual towns
    - Hypothesize that increased cortical activity occurs when a target landmark is seen

Why study spatial navigation?

- An essential part of our daily lives
- Studied in lower mammals for many decades (Tolman, 1948)
- Recently there has been a strong interested in humans (Caplan et al., 2003; Newman et al., in press)
- Scalp electroencephalography (EEG) has never been used to look at implicit landmark recognition during a dynamic, complex task

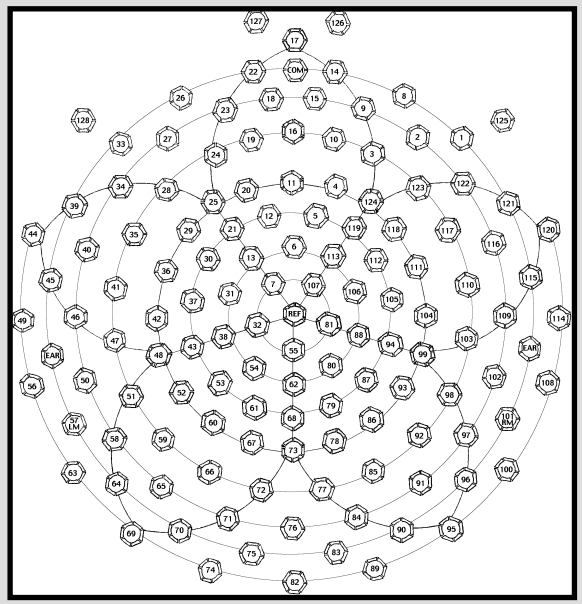


Previous research overview

- "Cognitive map" theory (Tolman, 1948)
- We navigate using allocentric and egocentric associations between landmarks (salient objects) (Shelton et al., 2001; Hartley, Trinkler, & Burgess, 2004)
  - Allocentric: Spatial relationship between salient objects
  - Egocentric: Relationship formed upon viewing a specific salient object in a specific context
- Spatial navigation using intracranial EEG in epileptic patients (Ekstrom et al. 2003; Caplan et al., 2003)

Scalp EEG

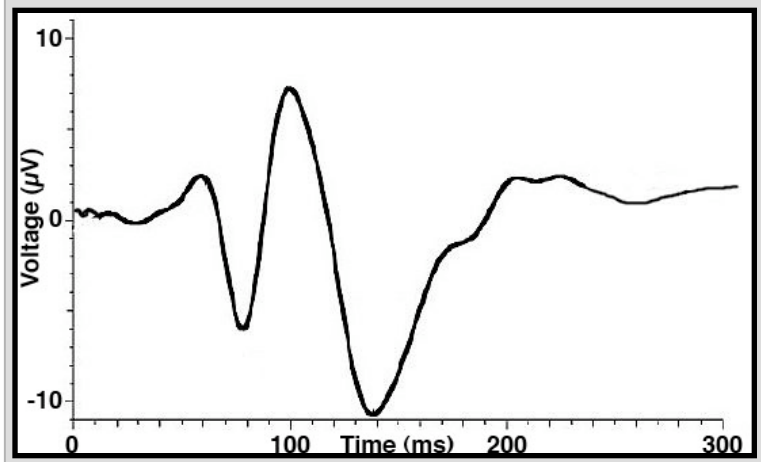
- Electrical fluctuations on the scalp are induced by underlying neural activity
  - Neural activity can be associated with specific cognitive processes (Rugg & Coles 1995)
- Recorded using a 128-channel cap from Electrical Geodesics, Inc.



Event-related potentials (ERP)

- An ERP is calculated by averaging across many epochs of stimulus-locked EEG signal
- Measured in microvolts (μV) over milliseconds (ms)
- Useful tools in memory research
  - High temporal resolution
  - Correlate neural activity with behavior
  - Compare activity at multiple locations

A exemplary ERP



Visual oddball-stimulus paradigm

- Goal in our task similar to oddball-stimulus task
  - Infrequent target stimuli interspersed throughout presentation of standard stimuli (Squires, Squires, & Hillyard, 1975)
- Unexpected target stimuli elicit a larger positive-going deflection at 100 ms (P1) in right frontal and at 300 ms (P300) in right parieto-occipital
- Researchers believe P300 is associated with attentional aspects of stimulus processing (Donchin & Coles, 1988)

Current experiment: YellowCab II

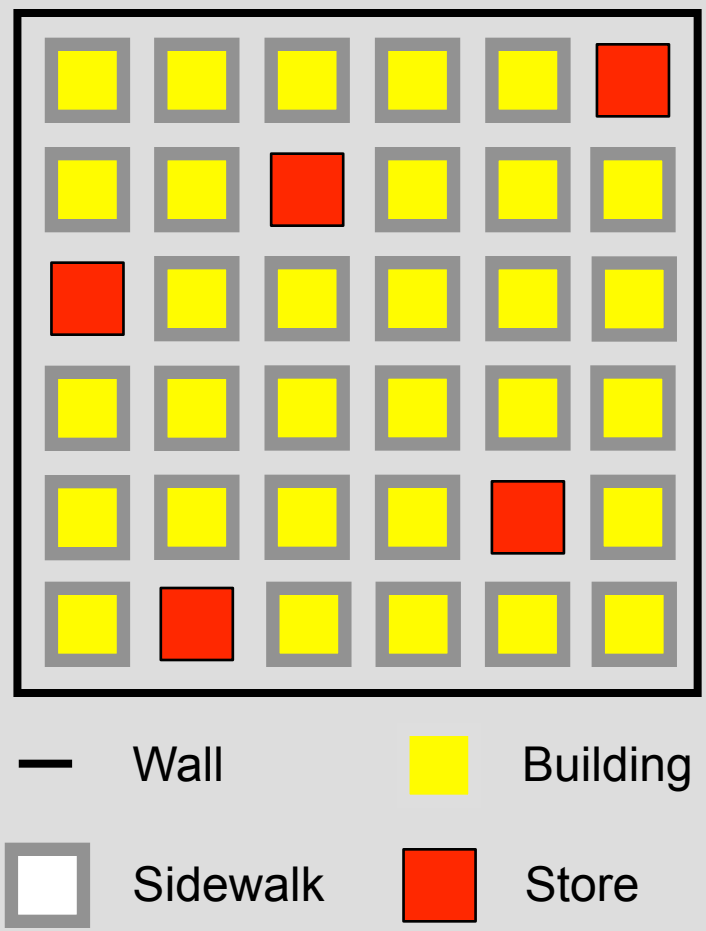
- Participants play the role of a taxi driver
  - Pickup passengers and take them to a specific location, i.e., a target store
- Earn “points” for deliveries
- Rich visual context: virtual town
  - Buildings, stores, passengers
  - Randomly generated during task, with constraints on store placement

A passenger within the town

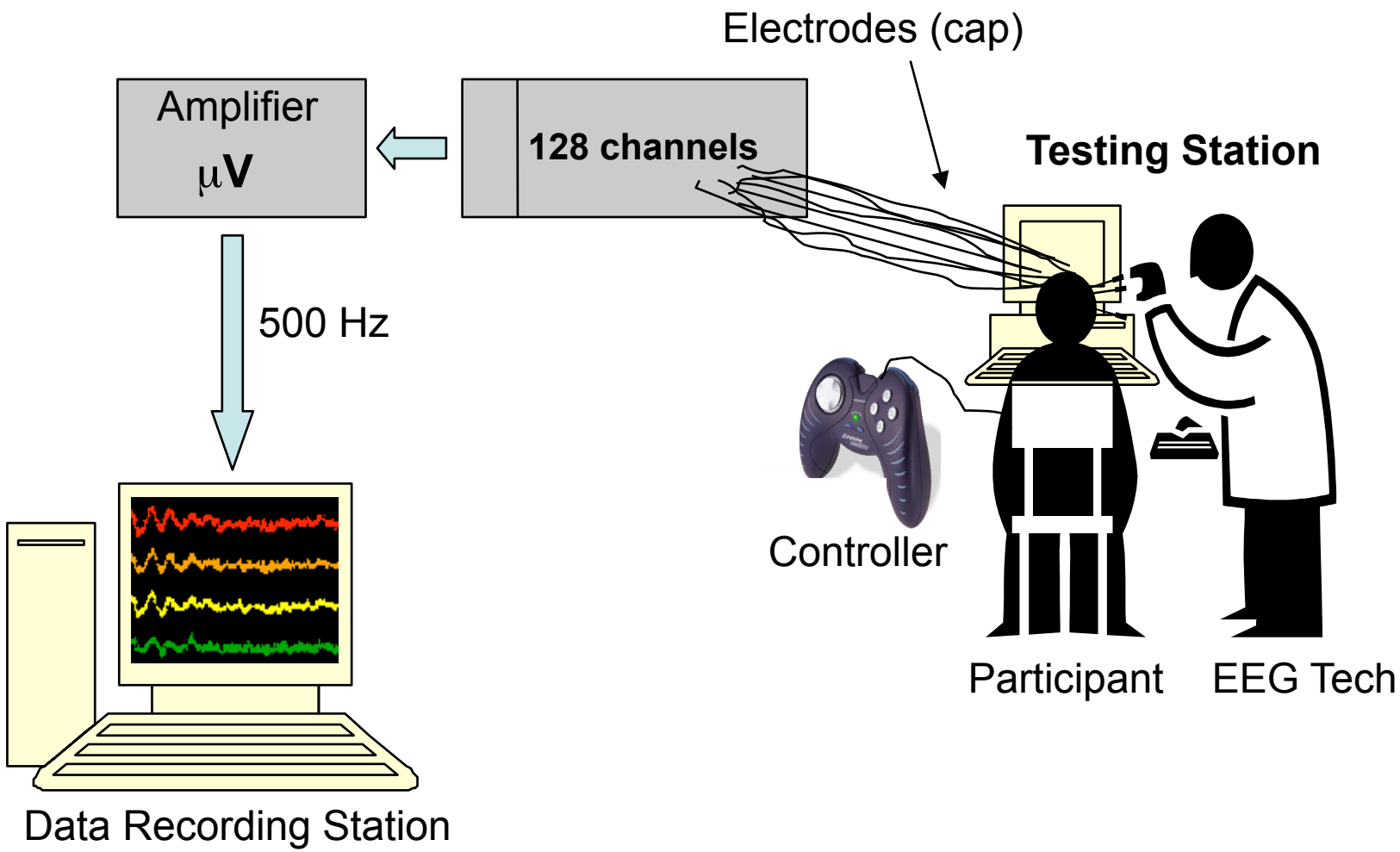
YellowCab II

- In each of 3 sessions:
  - 3 towns, A B A’
    - 15 deliveries to 5 different stores
    - 31 buildings as context

Possible town layout



Scalp EEG equipment setup

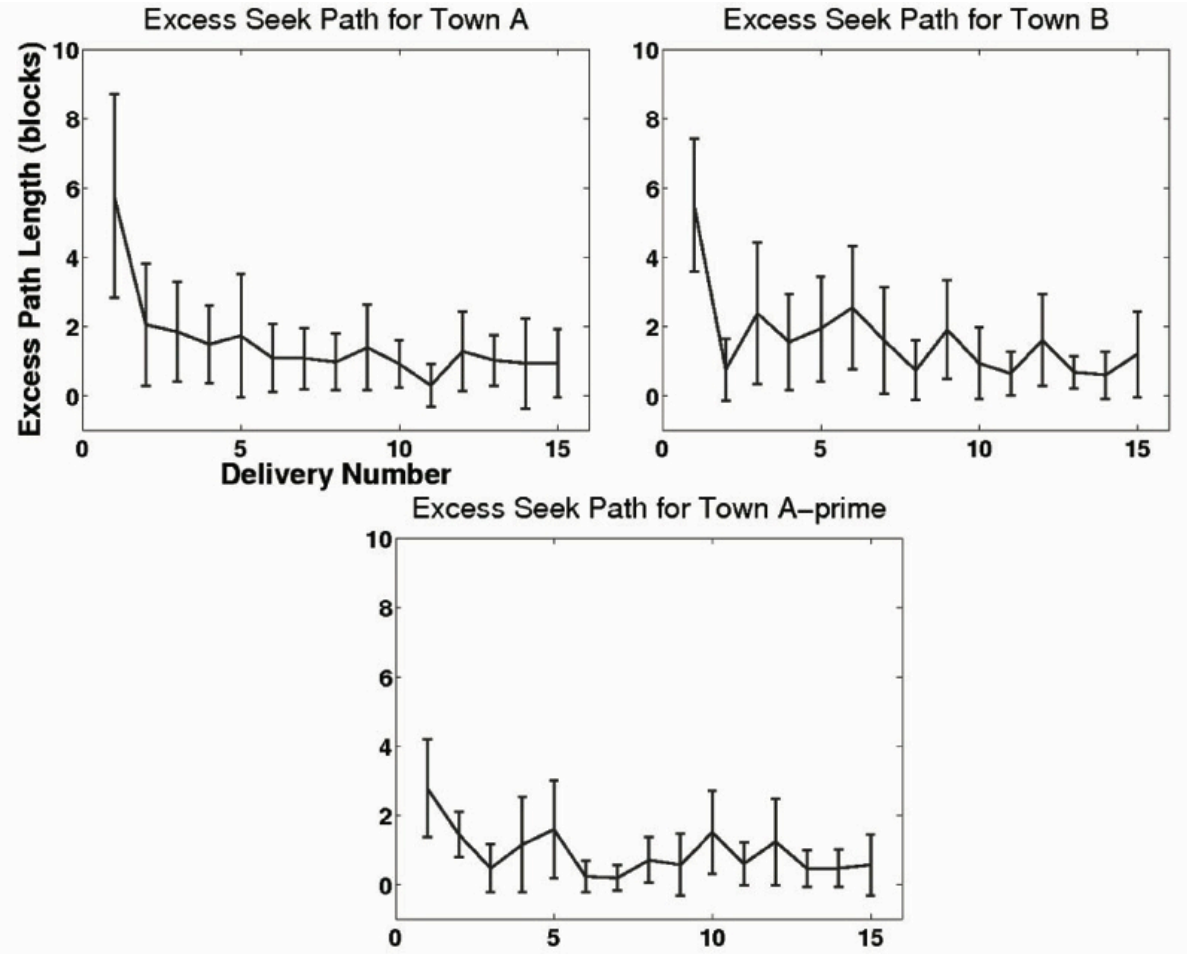


Example of the task

Behavioral data

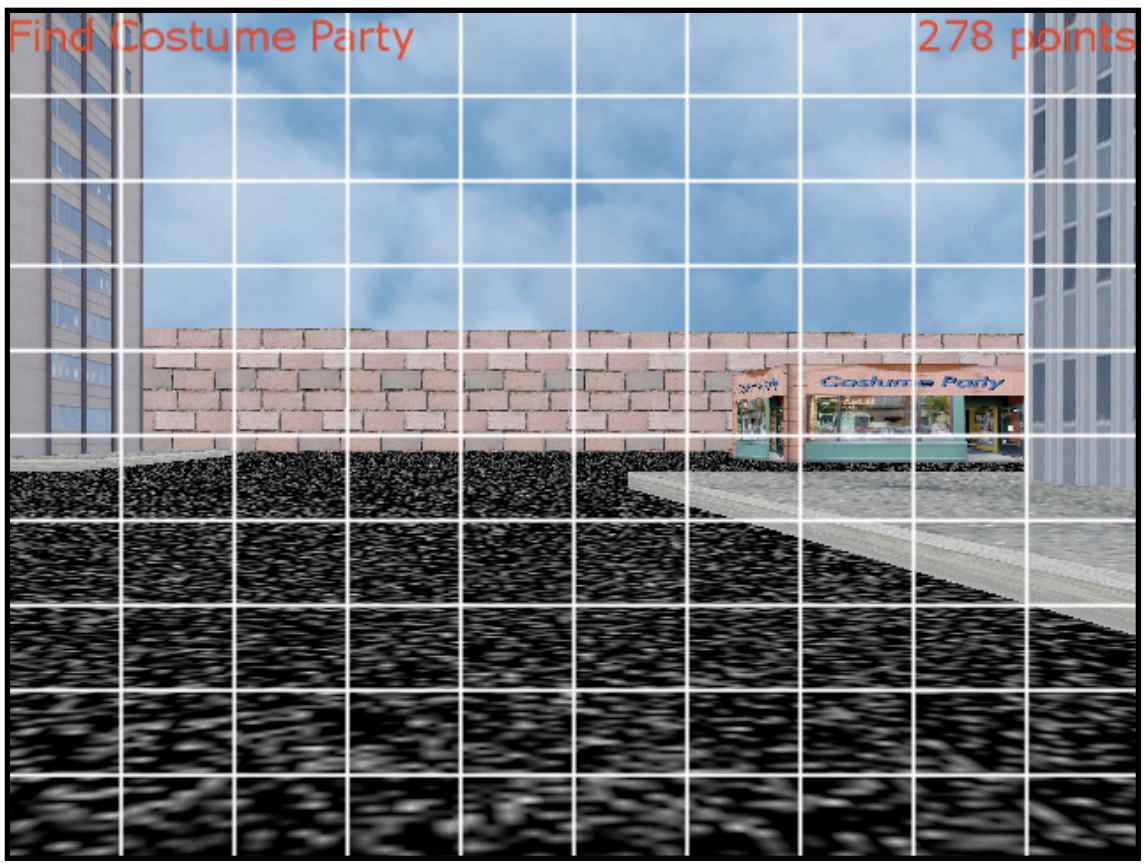
To assess learning within a town look at excess path during deliveries (Newman et al., in press)

Almost all learning is done within first three deliveries



Selecting events

3% of screen is occupied by the store



We do not know exactly when a participant will look at a store

Leads to some latency variability in making ERPs

Used 3% of screen as an event-threshold

EEG data processing

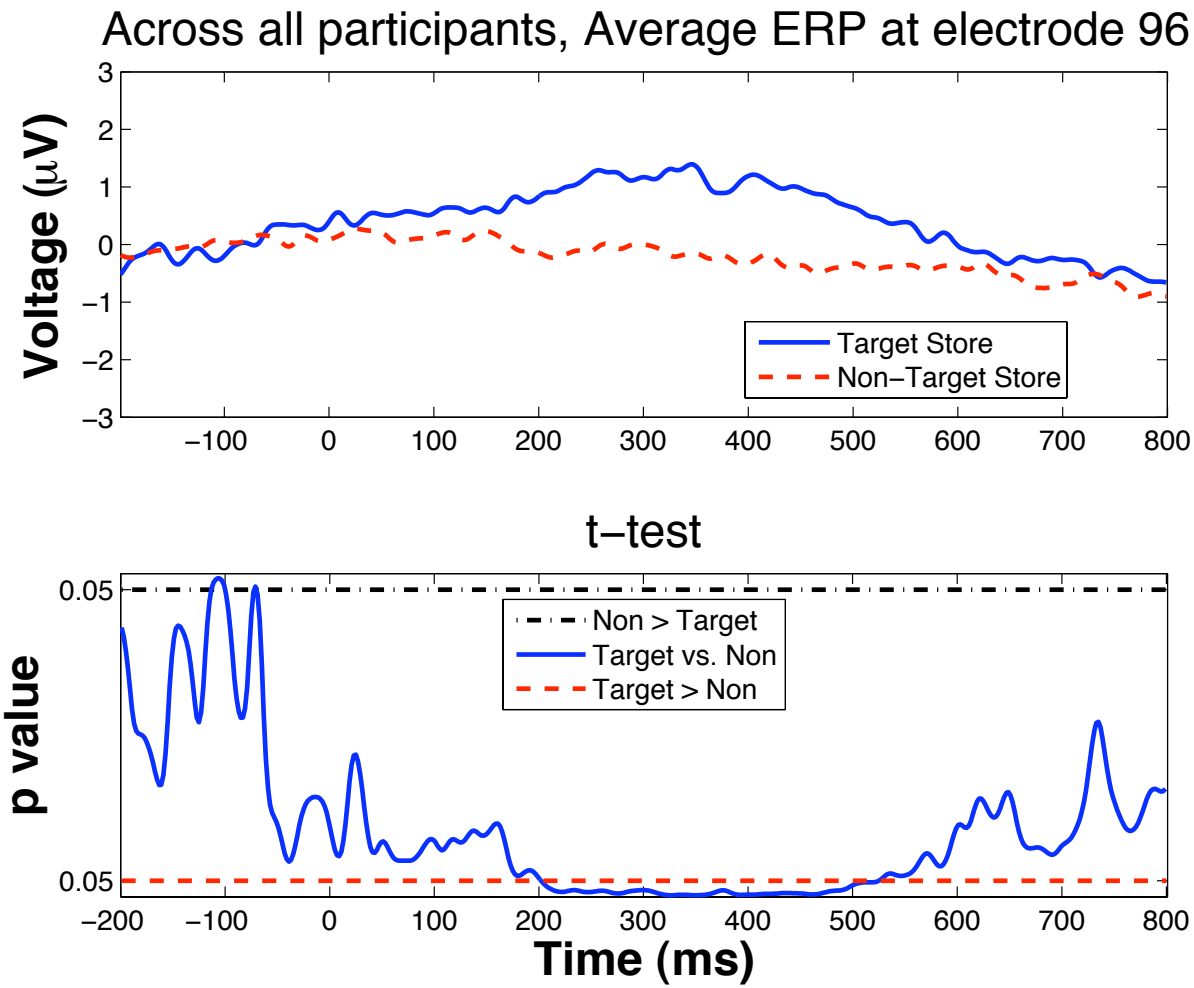
- Eye artifact detection (Electro-oculogram > 100 µV)
- Bad channel detection (20% EEG > 100 µV)
- Average rereference

Target store vs. non-target store: ERPs

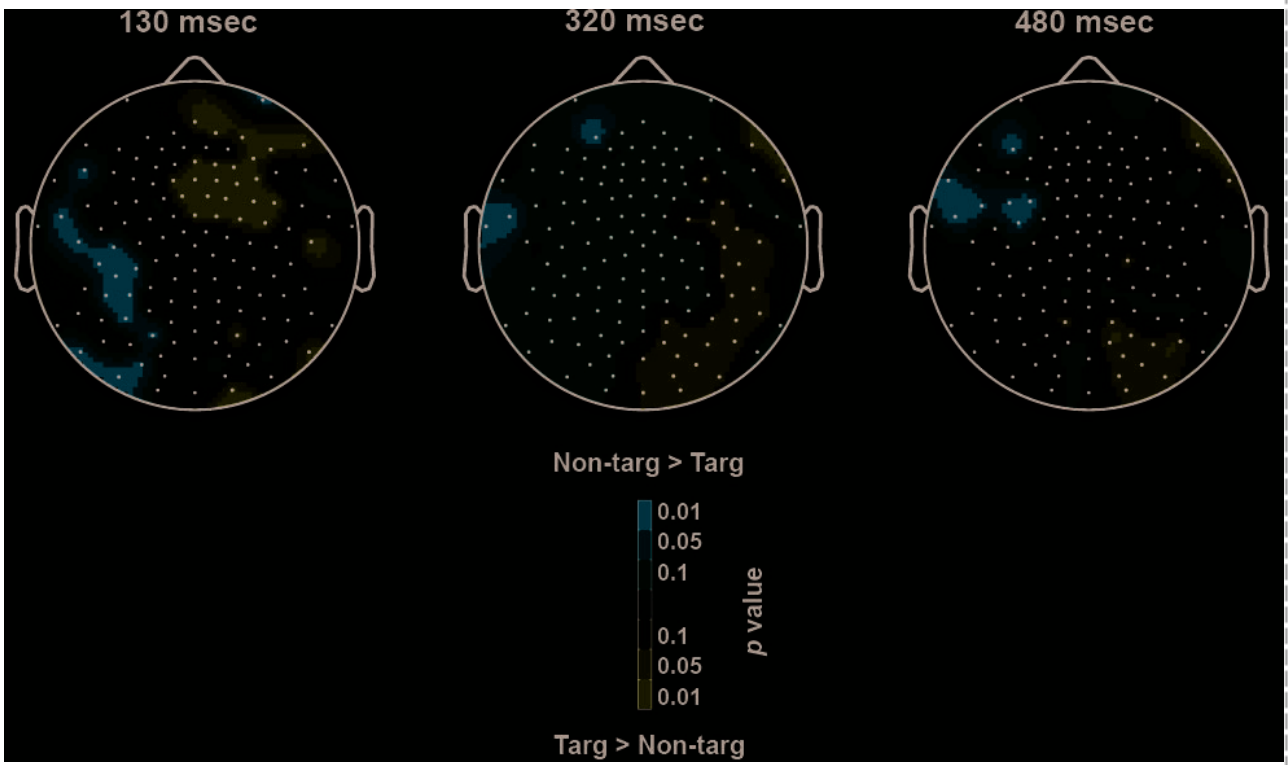
Positive deflection around 300 ms for target store events (*M*=328 ms, *SD*=49.78)

t tests reveal a significant difference between the two conditions

In parieto-occipital: $t(13) = +2.81$, $p < 0.001$, one-tailed



Target store vs. non-target store: topographic plots



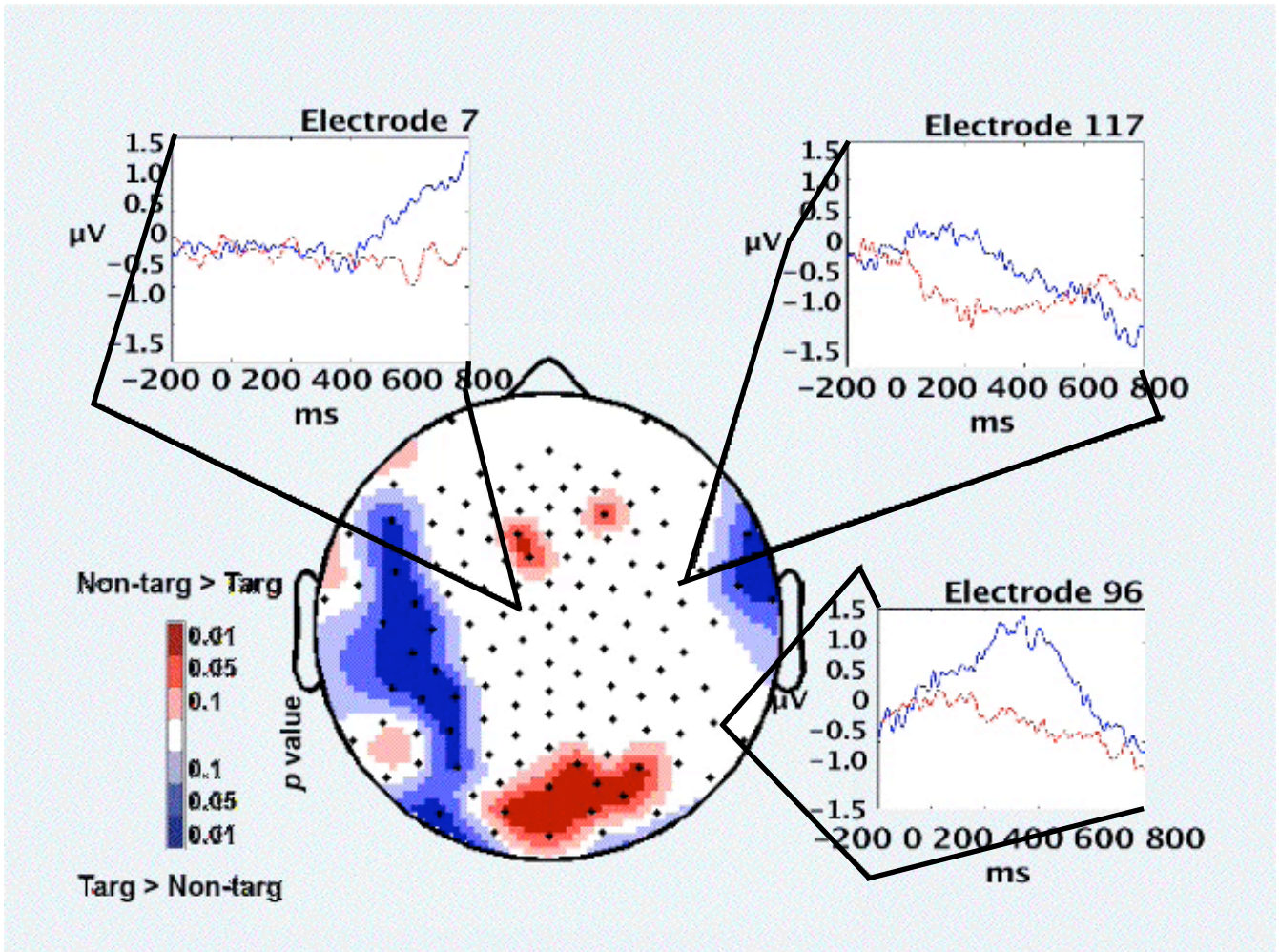
Seeing a target store:

130 ms: significant activity ($p < 0.01$) in right frontal

320 ms: significant activity ($p < 0.05$) in right parieto-occipital

Consistent with related literature

Animation of neural activity



Consistency with oddball-stimulus literature

- Right frontal to right parieto-occipital activation
- Early visual recognition evokes P1 in right frontal (Townsend, Harris, & Courchesne, 1996)
- Target stimulus processing elicits a larger P300 in right parieto-occipital (Katajama & Polich, 1999)

Future considerations

- Improvements to ERPs
  - Experimental improvements
    - Eye-tracker
    - Other event indicators
  - Analytical improvements
    - “Peak-picking”
    - Cross-correlational filter, e.g., Woody filter (Woody 1967)
- Correlate with intracranial EEG navigation data

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