Oscillatory correlates of implicit landmark recognition during virtual navigation

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Introduction

- We examine whether the EEG patterns found in working memory tasks appear in a complex virtual navigation task. Specifically, we inspect the scalp topography produced by goal-directed behavior in the frequency domain.

Previous findings

- One report of differences in EEG signals for target recognition in virtual navigation (Bayliss & Ballard, 2000).
- Theta (4–8 Hz) power increases at the parietal scalp area for stimulus recognition (Klimesch et al., 2000).
- Elevated theta power during movement (Kahana et al., 1999) and rotation (Korolev, 2005) in a virtual navigation task.

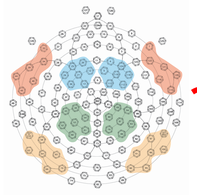
Hypotheses

- Our previous research found significant ERP differences for landmark recognition (Mollison et al., 2006). Our next question was whether this effect was also present in any of several frequency bands, and if so, in what way it manifests at the scalp.

The Yellow Cab Task

- Participants played the role of a taxi-driver in a virtual town as they learned the layout of specific destinations to which passengers ask to be delivered, called *target stores* (Newman et al., 2007).
- Each town: 6 × 6 grid, with a single store or building on each block (36 landmarks). 5 stores and 31 buildings in a town, each with a unique façade.
- During the delivery, the 4 stores that are not the target store are considered *non-target stores*.

Scalp EEG



- Scalp regions of interest:

  Left anterior superior (LAS), left anterior inferior (LAI), left posterior superior (LPS), left posterior inferior (LPI), right anterior superior (RAS), right anterior inferior (RAI), right posterior superior (RPS), right posterior inferior (RPI)
- 20 right-handed adults (ages 19 to 27; nine female)
- 129-channel 500-Hz EGI scalp EEG system
- 200 MΩ high-impedance amplifier
- Post-process EEG data
  - Eye artifact detection (EOG > 100 μV)
  - Manually inspect EEG for bad channels
  - Average rereference
  - Kurtosis threshold of 5

Viewing Landmarks

- Consider periods in which participants are goal-seeking; i.e., they have picked up a passenger and are searching for the *target store*.
- Set a *screen-area threshold* (0.35%) and minimum viewing length (2500 ms) to find when a landmark is "seen."
  - *Target-store events*: appear and stay on the screen until delivery is made
  - *Lure-store events*: seen on the way to the target, but target cannot be on the screen

0.35% of the screen is occupied by the store

(arrow added for the purpose of illustration)

ROI Analysis

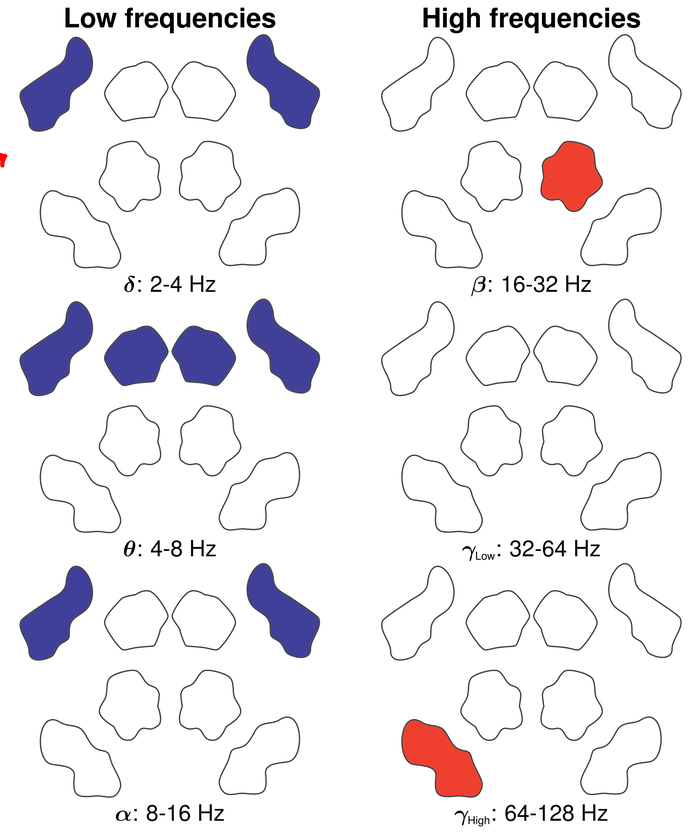
- Z-transform baseline:

  -600 to -100 ms before stimulus onset within each subject
- 2 (Target vs. Non-target) × 3 (time bins) repeated-measures ANOVA for each of six frequency bands in each ROI
  - Effects of time were small and did not interact with T vs. NT
- False discovery rate with $q = 0.05$ yields an adjusted significance threshold of $p = 0.0062$

Results: Targets vs. Non-targets

Significant differences in Z-transformed power

Red: greater power for targets; Blue: greater power for non-targets



Data Trends

- Lower frequencies (δ, θ, α)
  - Greater oscillatory power for non-targets than targets (though both decrease relative to baseline)
- Higher frequencies (β, γ)
  - Greater power for targets than non-targets

Discussion

- Even though we were working with relatively unconstrained events, we were able to distinguish between target and non-target stores on the basis of oscillations in the EEG signal.
- The differences in oscillatory power for target and non-target stores may reflect a general goal-related effect.
- Directionality of the difference in oscillatory power correlates with scalp topography.
- Lower power for targets than non-targets in low frequencies.
  - This is at odds with (Klimesch et al., 2000). It may be due to differential behavior when approaching target and non-target stores.

Next Steps

- Uncover more distinctive behaviors (e.g., rotation vs. linear movement) in targets and non-targets.
- Use eye-tracking technology to more precisely lock electrophysiological signals to visual events.

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