Neural Correlates of Face-Name Recognition using Simultaneous Eye-Tracking and ERP

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OBJECTIVE

- The face-name (FN) encoding paradigm has been previously established to show reliable bilateral medial temporal activity in functional magnetic resonance imaging (fMRI) studies, is sensitive to age- and Alzheimer's disease (AD)-related memory impairment, and correlates with previously established behavioral and neuropsychological measures of episodic memory.
- While behavioral studies and neuropsychological evaluations provide information about cognitive ability, event related brain potentials (ERPs) allow us to investigate the neurophysiological basis of cognition and are more sensitive than fMRI in revealing the temporal dynamics of neural activity associated with a specific cognitive task.
- Specifically, ERPs can accurately identify the onset, duration, and interaction of independent cognitive processes that support memory encoding and retrieval.
- Eye-Tracking (ET) provides another physiological measure of cognition, and ET measures have been shown to correlate with mnemonic processes. We sought to use multiple behavioral and physiological measures to characterize FN performance in healthy young adults.

METHODS

Participants and Design

- Sixteen healthy younger adults (ages 18-39) underwent neuropsychological assessments, followed by performance of a Face-Name (FN) memory paradigm with simultaneous EEG recording and eye-tracking **(Table 1).**

- During the study phase, participants viewed 40 different FN pairs, of which 20 were repeated 4 times (4R) and 20 were only presented (1R). During the test phase, subjects were presented with 80 FN pairs (40 old, 40 new) and asked to make a new/old judgment and high/low confidence rating in their choice.

Table 1. Participant demographics and neuropsychological performance.

Variable	Mean or N	SD or %
Age	27.4	5.7
Years Education	15.9	2.2
Gender		
Male	7	44%
Female	9	56%
Race		
Black	1	6%
White	13	81%
Asian	2	13%
MoCA	29	.9
MoCA 5-word recall	4.6	.7
Free and Cued SRT, Free Recall	38	3.8
Free and Cued SRT, Total Recall	47.9	.3
Digit Span, Longest Forward	7	1.4
Digit Span, Longest Backward	6	1.4
Digit Symbol Coding	96	10.7
Matrix Reasoning	21	2.9
Trails A, seconds	20	5.9
Trails B, seconds	39	10.6
AMNART EVIQ	125	4.8
Letter Fluency (F + S)	37	8.5
Semantic Fluency (Animals + Vegetables)	41	12.0
Grooved Pegboard Dominant, seconds	63	6.7
Grooved Pegboard Non-Dominant, seconds	70	15.7

Statistical Analysis

- **Behavioral results:** An effect of number of repeats of studied stimuli on the behavioral measure of accuracy during the test phase was investigated using one-way ANOVA and post-hoc tests.
- **Eye-tracking:** Effects of three types of probe (TOP), four times repeated stimuli (4R) versus one time repeated stimuli (1R) and novel stimuli (N), accuracy on the physiological measures of total number of fixations and saccades, and mean duration of fixations and saccades during test period was investigated using Friedman test with post-hoc Wilcoxon signed ranks test.

- **ERP:** Traditional ERP analyses of selected time intervals was guided by previous work showing that the N400 old/new effect typically occurs between the 300 and 500 ms time interval over frontal electrode sites, the Parietal Cortex old/new effect typically occurs between the 500 and 800 ms time interval over parietal electrode sites, and the late frontal effect typically occurs between the 1000 and 1800 ms time interval. To examine the effects of TOP on recognition memory performance, old/new ERP waves (hits minus correct rejections) were used to generate topographic maps (Figure 1) and graphical contrasts of conditions (Figure 2). Mean amplitudes were calculated for the three time intervals of interest (300–500 ms, 500–800 ms, 1000–1800 ms) for all subjects. Three repeated measures ANOVAs and post-hoc contrasts were used to test for differences in study modality in each region of interest (ROI) at each time interval of interest.

RESULTS

Behavioral task performance:

- There was a main effect of TOP on response accuracy (F=12.4, p<0.001). Post-hoc tests indicated the expected ordering, with accuracy for 4R items > 1R items > Novel items.

ERP findings: Classic old/new effects were demonstrated **Figures 1 & 2**.

- Compared to correct rejections of novel FN pairs, hits for the 1R pairs were more positive at bifrontal electrode sites between 300 and 500 ms, reflecting enhanced familiarity (p<0.05). **(Figure 1.a)**
- In contrast, when compared to correct rejections of the novel FN pairs, hits for both the 4R and 1R items were more positive at superior parietal electrode sites between 500 and 800 ms, reflecting enhanced recollection (both p<0.05). **(Figures 1.a & 1.b)**
- Finally, the late frontal effect was seen when contrasting 1R hits versus novel correct rejections during the 1100-1300 ms interval, reflecting increased recruitment of frontal areas with increased task demands (p<0.05). Post-hoc contrasts of ROIs showed significant activity in right frontal regions, again consistent with the typical post-retrieval late frontal effects demonstrated in other memory paradigms. **(Figure 1.a)**

Figure 1. Scalp topography maps after subtraction of item type from each other (a).1R-N, (b). 4R-N, (c). 4R-1R. Topographies are presented in 50 ms averages going forward.
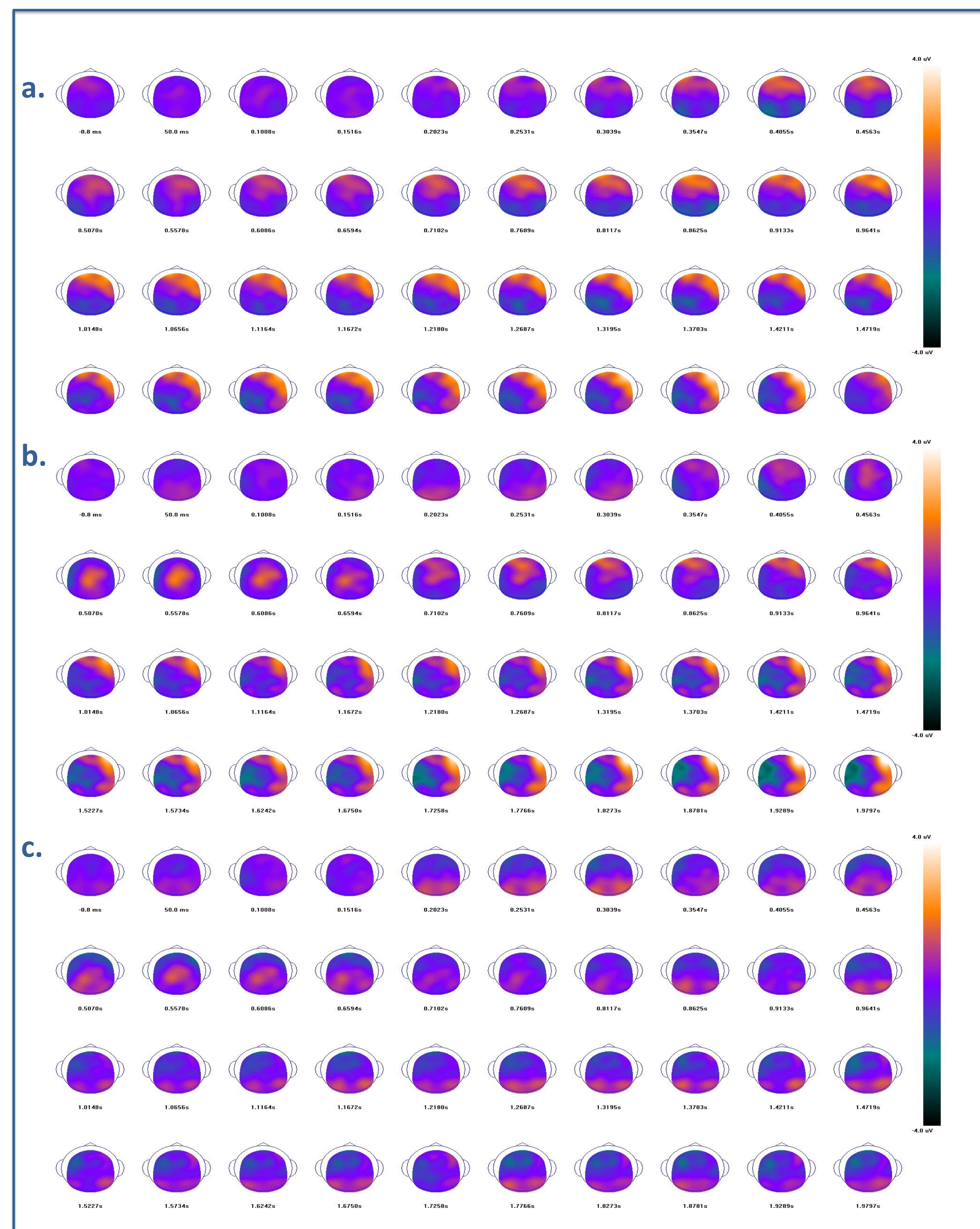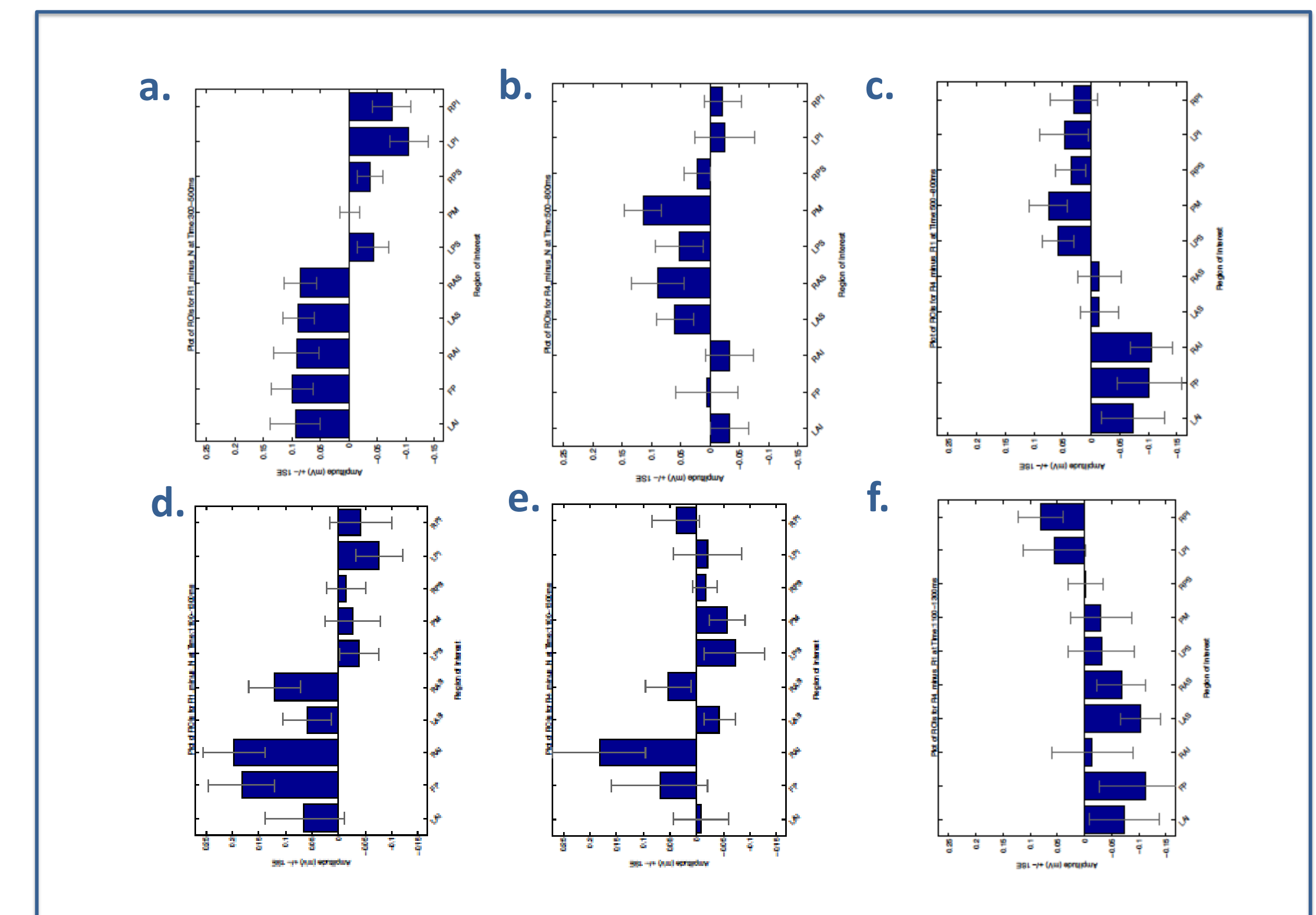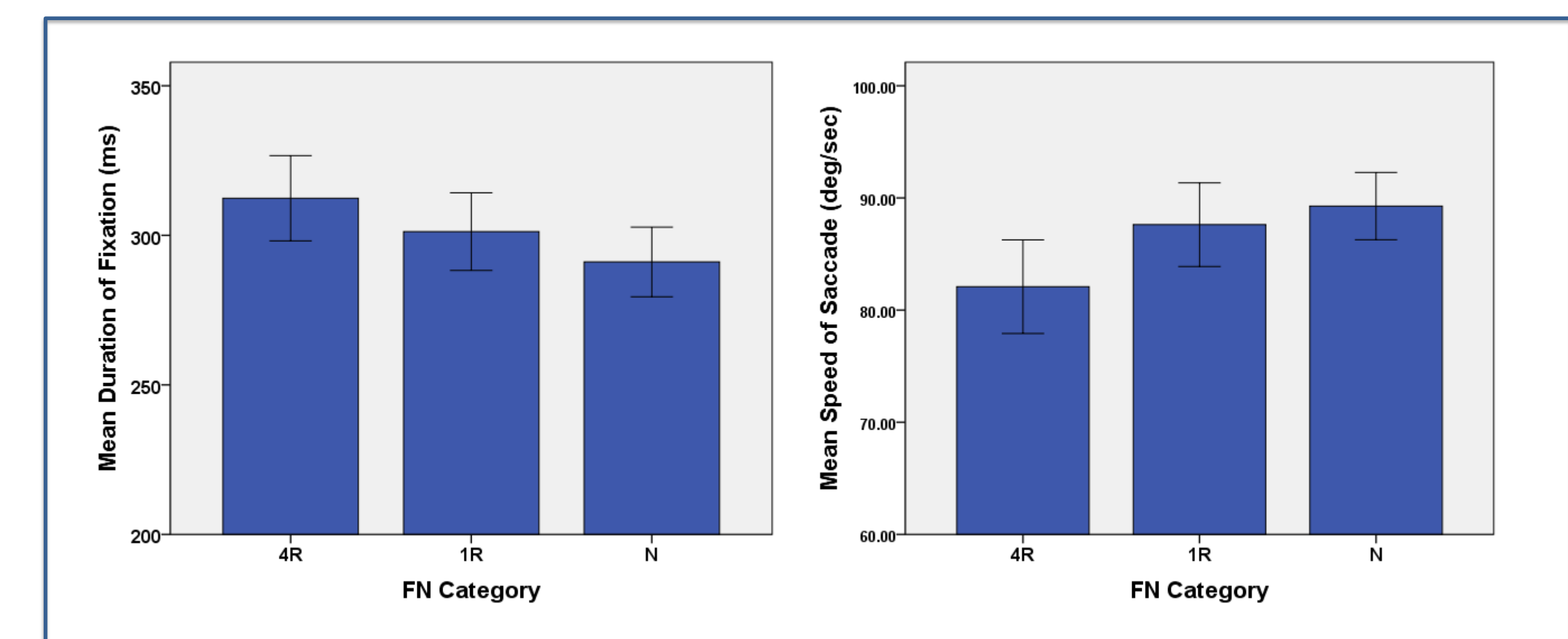

Figure 2. Subtractions of averaged amplitudes (+/- 1 SE) during each of three time intervals of interest by item type in each of 10 ROIs.

Eye tracking:

- There was a main effect of TOP on the mean duration of eye fixations (p=0.01), with post-hoc tests showing fixations were longer in 4R condition in compare with both 1R and N conditions (p=0.02 and p=0.013 respectively). **(Figure 3)**
- There was no main effect of TOP on average pupil size was observed (p=0.14).
- There was a main effect of TOP on the mean duration and speed of saccades (both p <0.01), with post-hoc tests revealing longer saccades during 4R items relative to both 1R and N items (p < 0.01) and faster for Novel stimuli relative to the 4R condition (p=0.03). **(Figure 3)**

Figure 3. Average duration of fixation and speed of saccade by item type. Error bars represent -/+ 1 SE.

CONCLUSIONS

- Simultaneous EEG and eye-tracking was successfully combined in a FN memory paradigm.
- ERP results at retrieval of face-name pairs in this old/new memory paradigm are consistent with traditional old/new ERP effects; this finding supports paradigm validity and provides another potentially important noninvasive biomarker for an ecologically valid and sensitive task for detection of age- and AD-related memory impairment.
- Quantitative ET suggested positive associations between fixation duration and speed of saccade with repeated presentation of FN pairs.
- This preliminary study lays some of the foundation for combining neuropsychological assessments, quantitative ET and ERP with other imaging modalities, including structural and functional MRI, in hopes of better elucidating the essential spatiotemporal processes involved in normal memory, cognitive aging, and dementia.