Electrophysiological Correlates of Theory of Mind
Caitlin M. Hudac & Dennis L. Molfese
University of Nebraska-Lincoln

1. Theory of Mind
One particularly complex aspect of social cognition called theory of mind (ToM) involves the ability to make inferences about the mental states of others called. Neuroimaging studies of adults have implicated the posterior superior temporal sulcus (pSTS; Vander Wyk et al., 2009), temporo-parietal junction (TPJ; Saxe & Kanwisher, 2005), and medial pre-frontal cortex (mPFC; Mitchell, Banay, & Macar, 2005) during ToM tasks, such as belief reasoning. Recent event-related potentials (ERPs) studies report late slow-wave components over left frontal regions that correspond to belief-state processing (Li, Melzoff, & Wellman, 2009). However, many ToM tasks require participants to make explicit responses about another person’s mental state.

This study explores elements of ToM using a non-verbal auditory ERP (AERP) probe paradigm to explore neural structures underlying emotion processing and violation-of-expectation. The AERP generates a P100 component that can differentiate electrophysiological correlates for different conditions, based upon emotion, congruence, and at different timepoints of the reach selection. In addition, late slow-wave components are expected during ToM processing.

2. Methods
Stimulus Design:
Participants: 10 adults (5 females, age 19-30, mean age = 22.4 years).
Video stimuli from Vander Wyk et al. (2009).
- An actress regards one of two cups with an emotional expression (2: Happy, Disgust).
- She proceeds to pick up regarded cup or ignored cup.

Trial combinations (16 of each):
- Happy: Congruent: Selects regarded cup
- Happy: Incongruent: Selects ignored cup
- Disgust: Congruent: Selects ignored cup
- Disgust: Incongruent: Selects regarded cup

Preprocessing of EEG data:
- Filtered at 0.3 - 30 Hz
- Averaged into 9 bilateral surface clusters: orbital, temporal, frontal, para-sagittal, central, parietal, occipital
- Auditory event-related potentials (AERP) Probe:
- Collected on EGI 256-channel EEG system
- AERP time-locked to 1500 Hz tone
- Stimuli presented using EPrime 2.0

Analysis Strategy:
PCA/ANOVA computed separately for (a) Expression AERP and (b) Reach AERPs. Source estimation using NeuroStation 4.4. GeSource 2.0. Differences were computed for Reach AERPs using independent samples T-test.

3. Expression Results
Principal Components Analysis (PCA):
5 Temporal factors accounted for 77.1% of the variance.

Analysis of Variance (ANOVA):
Region (9) x Hemisphere (2: Left, Right) x Emotion (2: Disgust, Happy)

There was a significant difference between the Disgust and Happy expressions at the P100 component and a late negative component.
Scalp topographies illustrate bilateral positivity across frontal electrodes for Happy trials. This positive is prominent across left frontal electrodes for the Disgust trials.

4. Discussion
The late negative potential (584-800 ms post-stimulus) differentiating between expressions indicates that emotional processing is ongoing.

Similarly, another late factor (564-800 ms) has a main effect for emotion during Reach AERP. There is more late negativity following a Disgust than Happy expression. Source estimation indicates a network of brain regions associated with emotional processing, memory encoding, and reasoning are likely sources.

Although there was no main effect of congruence, the P100 component highlighted a 3-way interaction. Congruent trials have a larger positive peak and engage the fusiform gyrus. This may suggest additional face processing during these trials. Incongruent trials engaged the vmPFC and DACC, implicated in reasoning and cognitive processing. Unlike predictions, the pSTS, TPJ, and mPFC were not engaged more during incongruent trials.

There is a decrease in amplitude for Reach 2 at the P100 component (584-844 ms). The insula, often associated with emotional experience, is more engaged during Reach 1, suggesting emotion processing as the actor selects a cup initially. The engagement of the parahippocampal gyrus during Reach 2 may suggest more memory encoding.

References: