Collaborative Tasks & Intersubject Correlation: A Naturalistic Hyperscanning Paradigm Using AR Tangram & Muse EEG

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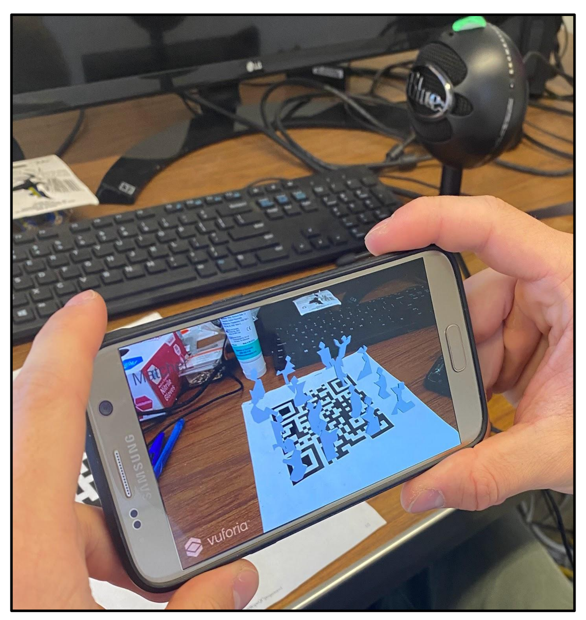
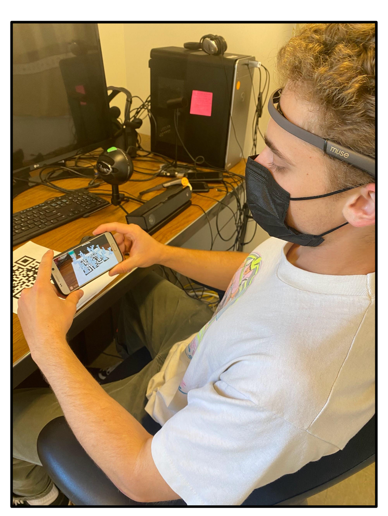
Background

- **Interactional synchrony**:
  - Is the mirroring of actions or facial expressions during social interactions
  - Plays a significant role in social interactions between humans[1-6]
  - Neural responses also synchronize during social interaction (inter-brain synchrony)[6]
  - Hyperscanning techniques are commonly used to study inter-brain synchrony while participants complete a joint interactive task[7-10]
- **Does inter-brain synchrony explain task performance?**
  - Preliminary results suggest yes[6]
  - Although most of these efforts are focused on how inter-brain synchrony shapes understanding rather than collaborative task performance[10-11]
- **Our project addresses this gap using a naturalistic collaborative task:**
  - Tangram matching tasks measure collaboration, coordination, and mutual understanding[12]
  - AR Tangram can be deployed on consumer-grade mobile devices; neural responses can be quickly and affordably measured using Muse EEG
- **We expect that:**
  - **Tangram performance (correct shape matches) increases across trials**
  - **Increased inter-brain synchrony explains Tangram performance**

Stimulus

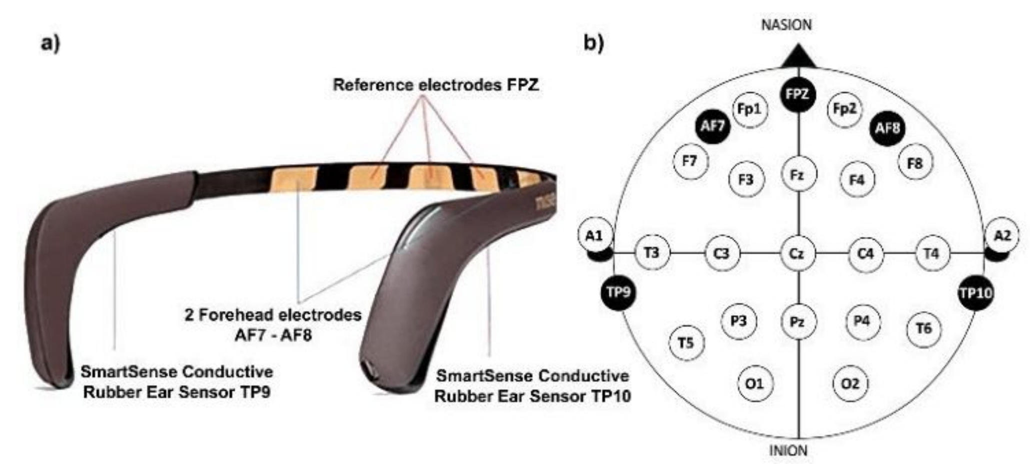
- Components of the AR Tangram task:
  - Novel participant pairs communicate to match novel geometric figures/tangrams
  - One participant (Director), describes a focal tangram
  - The other participant (Matcher) attempts to identify the described figure
- Independent variables include:
  - Session number (n = 3 sessions)
  - Time to complete task per session
  - Inter-brain synchrony (measured using pairwise intersubject correlation; ISC) at each electrode site
- Dependent measures:
  - Number of correctly matched tangrams



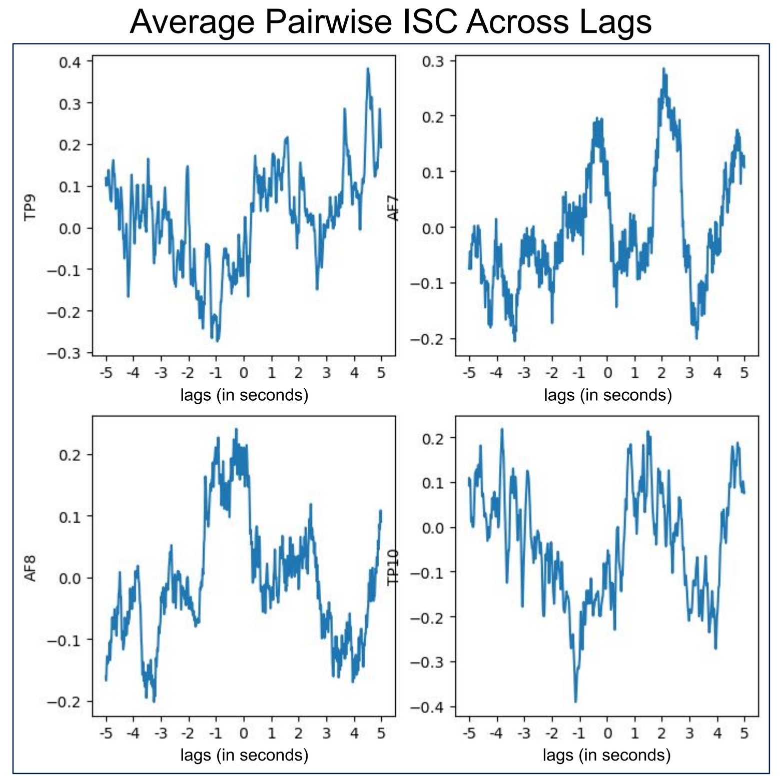


Methods

- Data were cleaned using the autoreject algorithm[13] with 1s epochs
- Data were included if more than 30% of epochs and 210s of time series survived autoreject
- Intersubject correlation (ISC) was calculated for each electrode for each session for each pair of participants (n = 71 pairs)

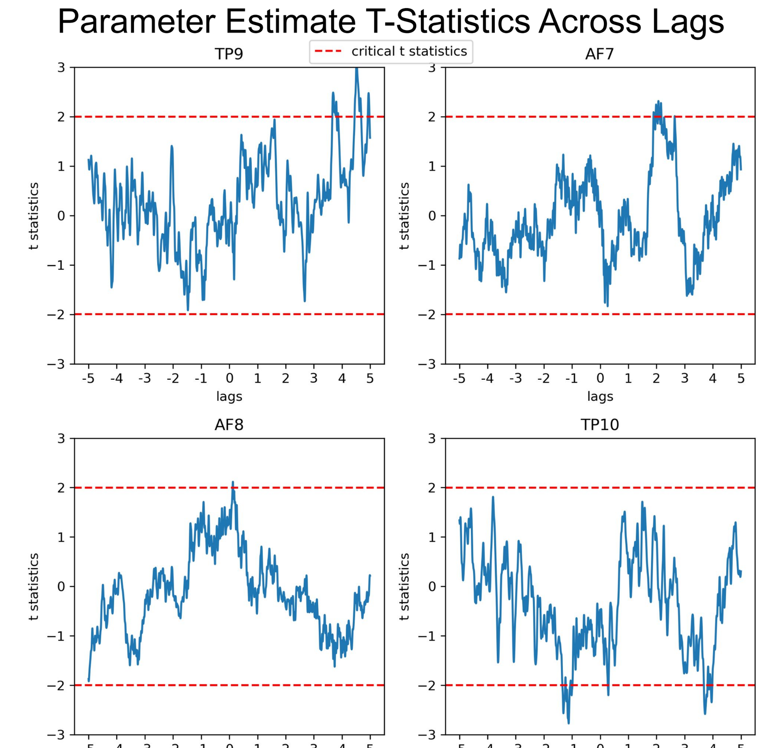


Results



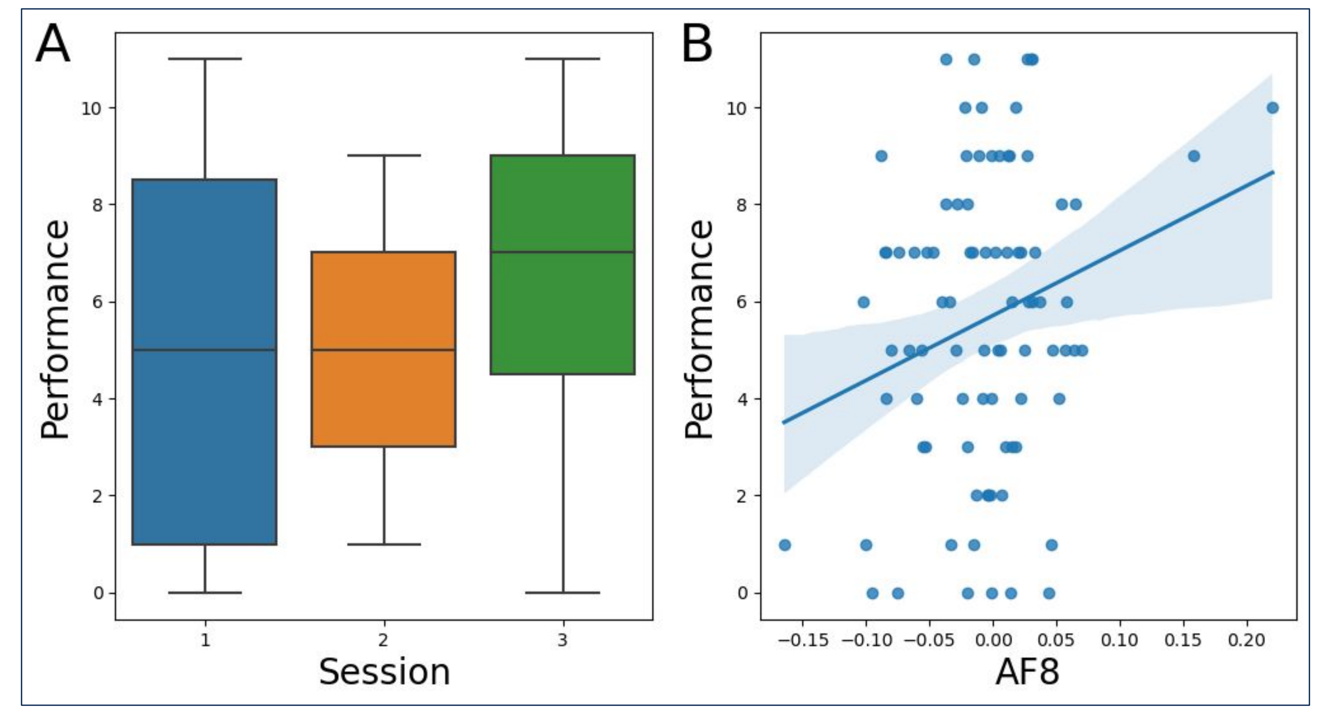
- As a data-driven first step, and consistent with prior research[11], we investigated ISCs across several lags
- Data sampled at 256 Hz
- Each datapoint encodes average ISC at each lag (n = 2,560 lags)
- Negative lag means "matcher" temporally precedes "director"
- Positive lag means "director" temporally precedes "matcher"
- Results show:
  - AF7: Peak ISC at +2s
  - AF8: Peak ISC at 0s
  - TP9: Peak ISC at +4.5s
  - TP10: Peak ISC at -1s

Results



- Following a multiverse logic[14], regression models were fit for each ISC lag
- Model IVs:
  - Pairwise ISC for each electrode, time spent on each session, session #
- Model DVs:
  - Task performance (correct matches)
- Critical *t-statistic* (indicating a significant result for a two-sided t-test with $p < .05$)
  - $t = 1.997$
- Results:
  - AF7: +2s, increased performance
  - AF8: 0s, increased performance
  - TP9: +4.5s, increased performance
  - TP10: -1s, decreased performance

Results



Discussion

- EEG-based hyperscanning + AR Tangram provides a naturalistic solution for studying behavioral and neural responses associated with:
  - Collaboration
  - Coordination
  - Mutual understanding
- Analyses show that increases in ISC are associated with increases in performance for AF7, AF8, and TP9 electrodes
- Consistent with earlier work showcasing that increased ISC is associated with:
  - Increased collaborative performance[6]
  - Increased comprehension[11]
  - Particularly in dorsolateral PFC[6] and auditory cortex[15]
- Next step:
  - Study 2, comparing novel participant pairs to friend participant pairs
- Important step in ***social*** cognitive neuroscience[16-17]
- Monitor this Project:
  - https://github.com/cogcommscience-lab/muse_artgram

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