

Neural alpha oscillations during turn-taking piano duet index creative thinking and engagement to the partner's action

Barbara Nerness, Noah Fram, Kunwoo Kim, Aditya Chander, Cara Turnbull, Elena Georgieva, Sebastian James, Matthew Wright, Takako Fujioka
Center for Computer Research in Music and Acoustics (CCRMA), Department of Music, Stanford University, USA

Introduction

Alpha oscillations and modulation

- **Alpha oscillations** (8-13 Hz frequency band) in scalp-recorded EEG signal, classified by location: occipital *alpha*, central *mu*, temporal *tau*
- **Event-related desynchronization (ERD)** refers to suppression of oscillatory power compared to the baseline; alpha ERD is associated with movement and sensory stimulus processing
- **Event-related synchronization (ERS)** refers to the power increase; alpha ERS is associated with rebound after ERD, or processing for repeating stimuli

Alpha oscillations and joint action

- **Joint action** requires anticipation of others' future actions to coordinate one's own movements, as well as shared representations of a goal.
- Alpha ERD/S are found from imagining [1] or observing [2] a familiar task.
- Alpha power positively related to amount of creative ideation in a task [3] or inwardly directed attention [4].
- Larger mu ERD during both execution and observation has been correlated with higher scores of perspective-taking, a part of cognitive empathy [5].

Alpha oscillations in musical improvisation

- Musical improvisation in ensemble requires real-time planning and execution of actions as well as adaptation of musical goals, thus providing a unique lens to study joint action in a creative task.
- Musical improvisation elicits right parietal ERD in musicians, but not non-musicians [6].
- Musicians engaged in improvisation show greater ERS than when reading a score if they have improvisation training, but not otherwise [7].

Present Study & Hypotheses

- The current study investigates alpha ERD/S during piano duet involving factors of melody (Score vs. Improv), task similarity (We vs. Me), and role (Leader vs. Follower).
- **When both pianists are improvising**, they are likely more engaged with each other. Thus listening to each other's improvisation could result in **stronger ERD than a score**.
- Further, this difference may be **enhanced when partners share the same task** (i.e. similarity of We)
- In contrast, since **improvisation** is a more creative task, it **could elicit larger ERS than the score during playing, which carries over** into the subsequent listening phrase.

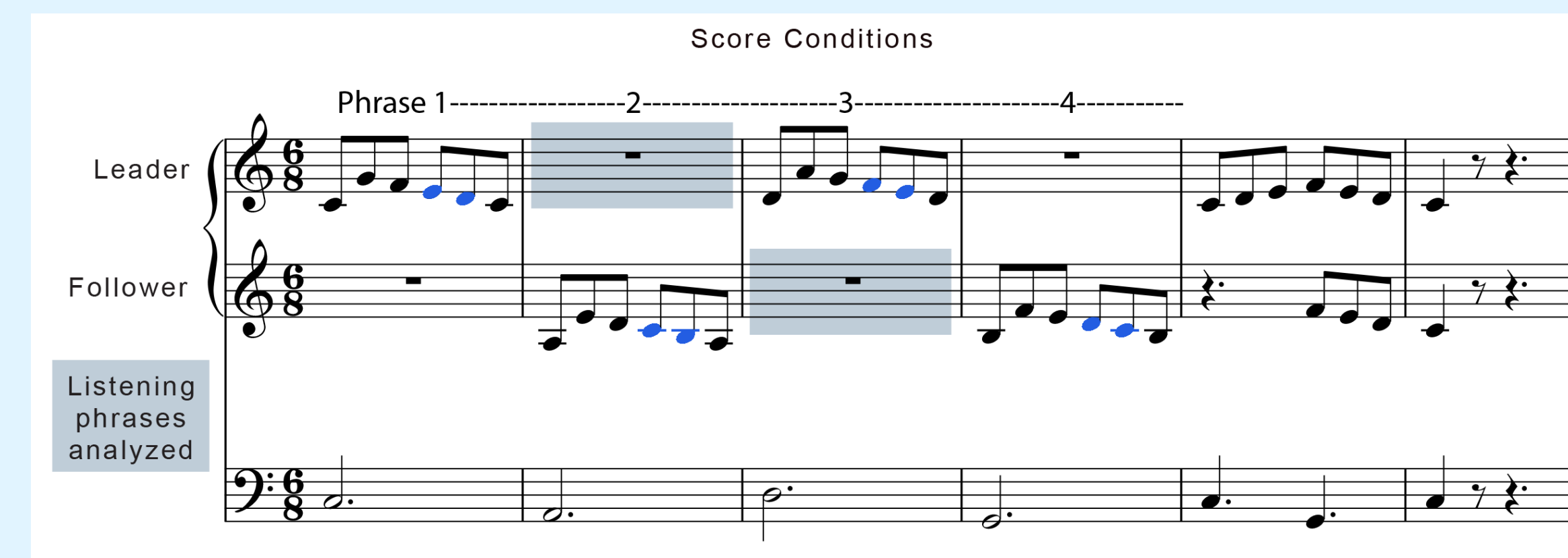
Methods

Participants

- 24 musicians (13 females; 1 ambidextrous, rest right-handed)
- Age (years): M = 26.3, SD = 4.7
- Piano training (years): M = 14.6, SD = 4.8

Stimuli

- A 31-note melody for *Score*. Players alternated first 4 bars.
- Altered pitch feedback occurred for 4th or 5th notes of each 6-note group to study another EEG component (shown in blue on the score). One deviant occurred per player per trial. Measures with deviant notes not included in this analysis.
- Trials began with 3 metronome beats (eighth note = 500 ms IOI)
- Two **melody** conditions: partners played the *score* as written, or *improvised* notes using the same rhythm as the score, resulting in 4 possible combinations per pair.
- Two **similarity** conditions: partners played the same melody condition (*We*), or different melody conditions (*Me*).



Procedure and Apparatus

- Two pianists faced each other. Each played a separate keyboard.
- 24 blocks per pianist; 1 block ≈ 18 trials with no errors (~8 min)
- Errors could be due to timing (+/-125ms from the 500ms IOI), or a wrong note during *score* conditions.
- Block order chosen before the study and rotated one place for the next set of participants. Pairs switched roles after completing a Super-block.
- Neuroscan SymAmpRT whole-head with a 64-channel EEG QuikCap for each participant.
- Sound from both keyboards were delivered via two loudspeakers.

Data analysis

1. EEG epochs (-1500 ms - 4000 ms) for 2nd and 3rd phrase, chosen due to task similarity before and after
2. Time-frequency representations (TFRs) of epochs computed with a Morlet Wavelet decomposition with 31 logarithmically-spaced bins from 1 to 60 Hz. Normalized as ERD/S using Brainstorm functions.
3. Alpha-band ERD/S computed by averaging frequency bins from 8-13 Hz, from 500 - 2000 ms in the phrase
4. Trials with channels exceeding ±150µV discarded.
5. Baseline: 80 msec before start of each phrase.
6. Three-way repeated measures ANOVAs with factors of *similarity*, *melody*, and *electrode group*

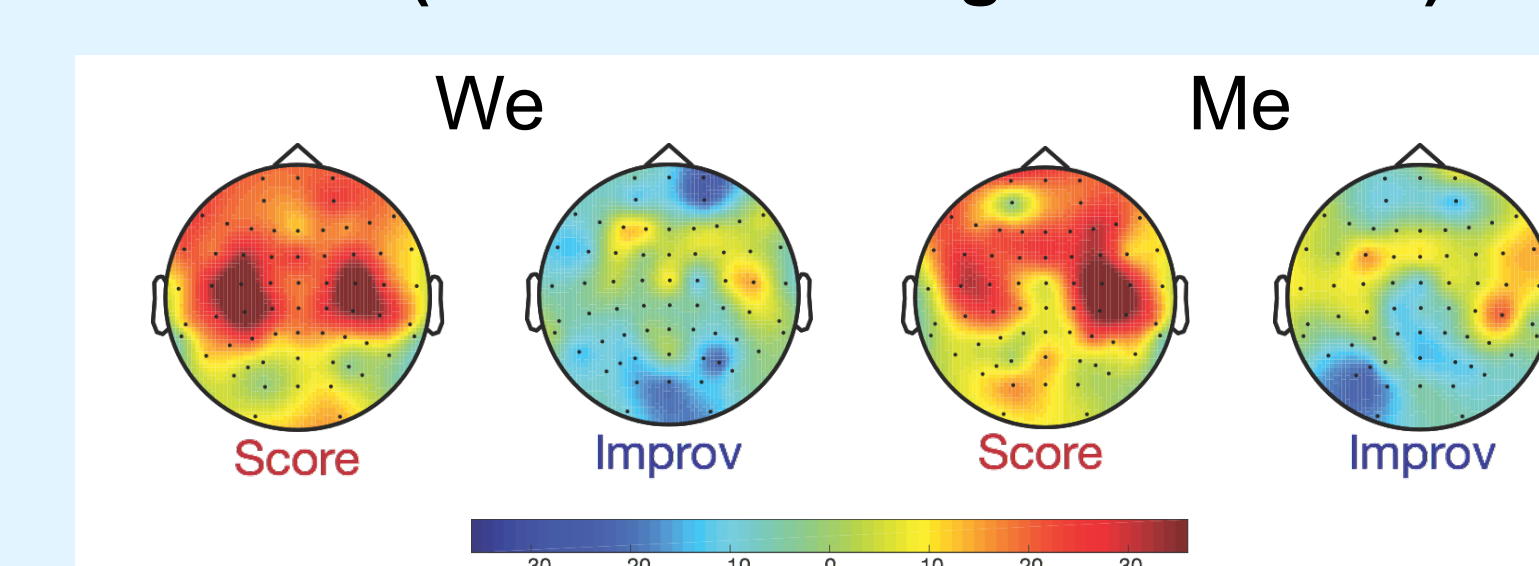
Results

Alpha power during listening to the partner reflects task creativity and partner engagement:

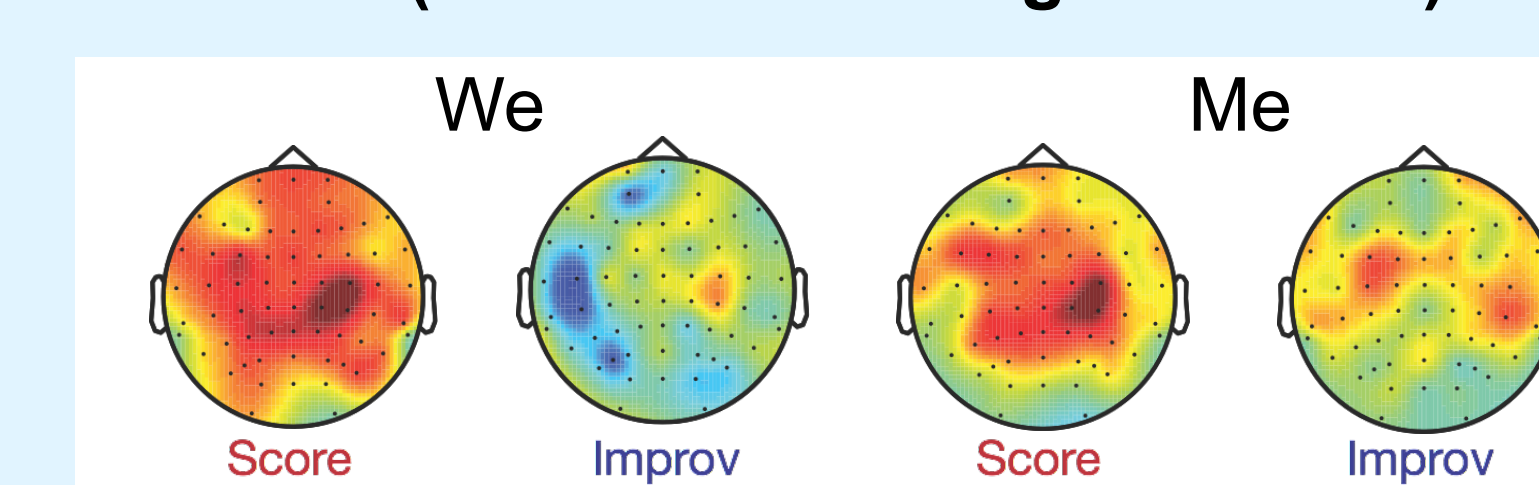
Alpha ERS was larger for score conditions compared to improvisation conditions ($p < .001$).

This suggests that while pianists play the score, they are less engaged with their partner than while improvising.

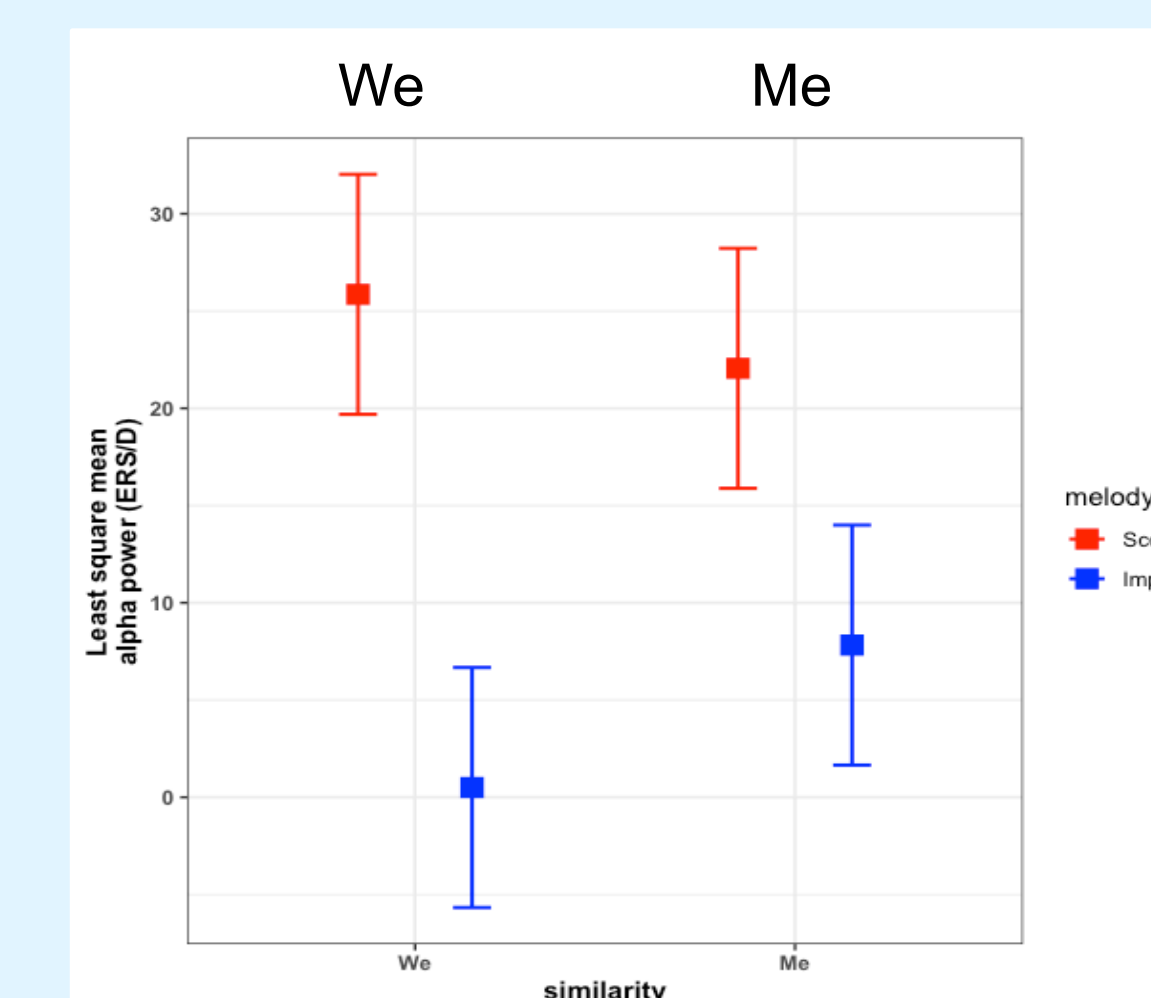
Phrase 2 (Leader listening to Follower)



Phrase 3 (Follower listening to Leader)



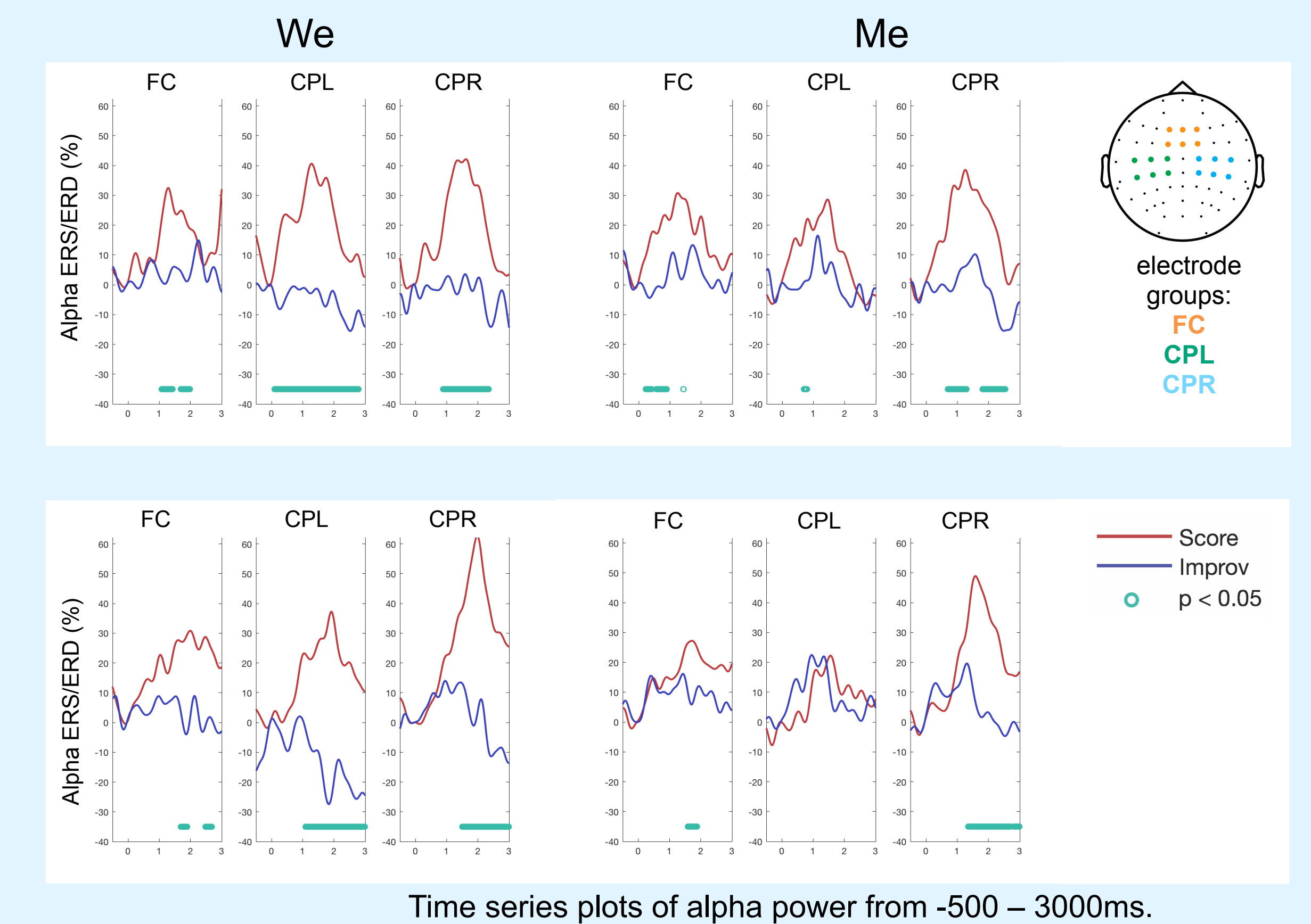
Average alpha power (ERS/D) topographies for phrase 2 and 3, by *similarity* (We/Me) and *melody* (Score/Improv).



Alpha ERS reduction for improvisation interacts with similarity:

2-way interaction is significant ($p < .001$) only when melodic conditions differ. Reduced ERS for improvisation conditions compared to score conditions ($p < .001$). This suggests that although improvisation reduces alpha power compared to the score listening, the effect is stronger if the partners' tasks are more similar.

Plot showing least squares mean alpha power and 95% confidence interval for similarity and melody conditions at right.



Condition Difference	p
We:Improv-Me:Improv	NS
Me:Score-Me:Improv	< .001
We:Score-Me:Improv	< .001
Me:Score-We:Improv	< .001
We:Score-We:Improv	< .001
We:Score-Me:Score	NS

Post-hoc results (Tukey) from 2 way interaction between similarity and melody.

Conclusions

- During piano duet performance, partners need **fewer neural resources when listening to their partner play familiar material, such as the score**.
- Listening to **improvisation requires more neural resources**, since one's part depends on the previous partner's, and **could indicate higher levels of engagement and empathy** between partners.
- **Task creativity and amount of shared goal modulate neural resources** in musical partners while listening to each other, reflecting the complex coordination involved in ensemble performance.

References

1. Pfurtscheller, G., Stancak Jr., A., & Neuper, C. (1996). Post-movement beta synchronization. A correlate of an idling motor area? *Electroencephalography and clinical Neurophysiology*, 98, 281-293
2. Cannon, E. N., Yoo, K. H., Vanderwert, R. E., Ferrari, P. F., Woodward, A. L., & Fox, N. A. (2014). Action Experience, More than Observation, Influences Mu Rhythm Desynchronization. *PLOS ONE*, 9(3), e92002
3. Fink, A. & Benedek, M. (2014). EEG alpha power and creative ideation. *Neuroscience & Biobehavioral Reviews*, 44, 111-123
4. Cooper, N. R., Croft, R. J., Dominey, S. J. J., Burgess, A. P., & Gruzeliier, J. H., (2003). Paradox lost? Exploring the role of alpha oscillations during externally vs. internally directed attention and the implications for idling and inhibition hypotheses. *International Journal of Psychophysiology*, 47, 65-74
5. Woodruff, C. C., Martin, T., & Bilyk, N. (2011). Differences in self- and other-induced Mu suppression are correlated with empathic abilities. *Brain Research*, 69-76
6. Berkowitz, A. L. & Ansari, D., (2010). Expertise-related deactivation of the right temporoparietal junction during musical improvisation. *NeuroImage*, 49, 712-719
7. Lopata, J. A., Nowicki, E. A. & Joannisse, M. F. (2017). Creativity as a distinct trainable mental state: An EEG study of musical improvisation. *Neuropsychologia*, 99, 246-258

contact: bnerness@ccrma.stanford.edu

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