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

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Introduction

Alpha oscillations

- **Alpha oscillations (alpha):** 8-13 Hz frequency band of scalp-recorded EEG signal, classified by location: occipital *alpha,* central *mu,* temporal *tau*
- **Event-related desynchronization (ERD)** is alpha band suppression with sensory input, and followed by **Event-related synchronization (ERS)**, or rebound, for repeating stimuli

Alpha oscillations and joint action

- **Joint action** is the anticipation of others' future actions to coordinate one's own movements, and requires shared representations of a goal.
- ERD/S can be evoked 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

- Musicians plan and execute very quick movements in real-time, especially during ensemble improvisation, which provides 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 investigate alpha ERD/S, engagement, and creativity during a joint action task involving both reading of a score and improvisation with factors of melody (Score vs. Improv), partner similarity (We vs. Me), and role (Leader vs. Follower).

- **When both partners are improvising**, they are more engaged with each other as they must listen for the unexpected melodies of their partner, which could appear as **stronger ERD**. This may be **stronger 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.

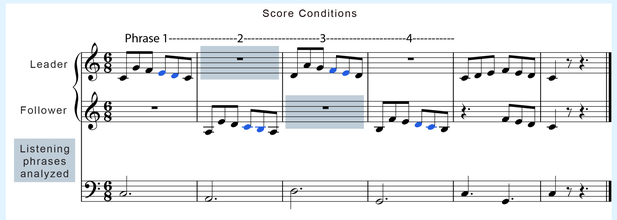
Methods

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 (eigth 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

- 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 stimulation delivered via two speakers.

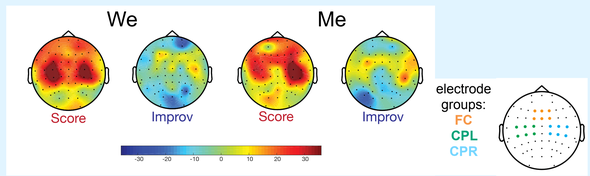
Data analysis

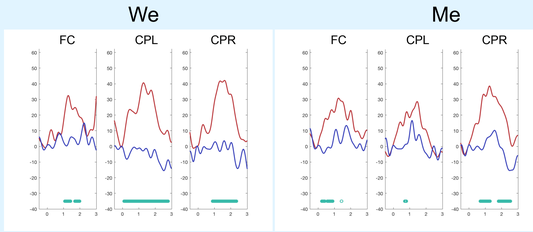
1. EEG epochs (-1500 msec - 4000 msec) for 2nd and 3rd phrase, chosen due to task similarity before and after
2. Time-frequency representations (TFRs) of epochs computed with a Morlet Wavelet decomposition with 31 logarithmically-spaced bins from 1 to 60 Hz. Normalized as ERD/S using Brainstorm functions.
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

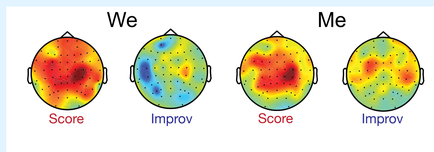
Alpha power reflects task creativity and partner engagement: Alpha ERS larger for score conditions compared to improvisation conditions ($p < .001$), with apparent right lateralization. This suggests that while pianists play the score, they are less engaged with their partner than while improvising.

Phrase 2

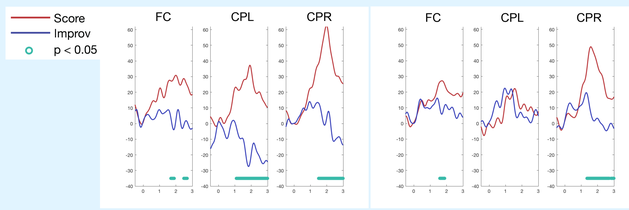




Phrase 3



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

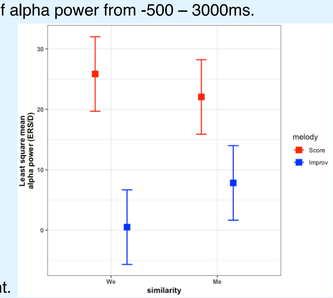


Time series plots of alpha power from -500 – 3000ms.

Two way interaction between *similarity* and *melody*: 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 results in overall lower alpha power than the score condition, the effect is modulated by the similarity of the partners' tasks.

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.



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

Conclusions

- During musical duet performance, partners require **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.

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