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 and joint action in music

•**Alpha oscillations (alpha):** 8-13 Hz frequency band of scalp-recorded electroencephalography (EEG) signal, classified according to location: occipital *alpha,* central *mu,* temporal *tau*

•**Event-related desynchronization (ERD):** the suppression of alpha, mu, or tau with sensory input in the corresponding domain (visual, motor/tactile, or auditory)

•**Event-related synchronization (ERS):** rebound of alpha, mu, or tau following ERD

•**Joint action**: involves anticipation of the future actions of others in order to coordinate one's own movements. Requires shared representations of a goal, a hallmark of musical performance in ensembles.

Alpha oscillations in context

•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, an important part of cognitive empathy [5].

Alpha oscillations in music ensemble tasks

•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 in non-musicians [6].

•Musicians engaged in improvisation show greater ERS than when reading a score if they have improvisation training, but not otherwise [7].

•The current study investigate alpha ERD/ERS, 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 or Follower).

Hypotheses and Expected Outcomes

•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.

•Furthermore, this may be stronger when partners share the same task (i.e. similarity of We)

•On the other hand, 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.

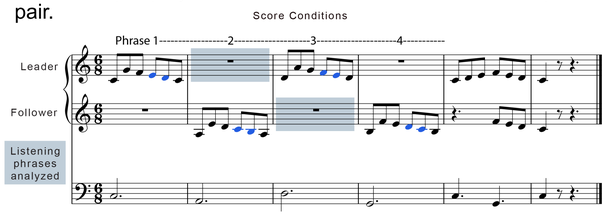
Methods

Participants

1.Twenty-four musicians (13 females, 1 ambidextrous, the rest right-handed).
2.Age (years): M = 26.3, SD =4.7
3.Piano training (years): M = 14.6, SD = 4.8.

Stimuli

1.Four 31-note melodies. Players alternated first 4 bars.
2.Deviant notes (altered pitch feedback) occurred during 4th or 5th notes of each 6-note group in order to study another distinct EEG component (shown in blue on the score). Only one deviant occurred for each player in a whole trial. Measures with deviant notes not included in this analysis.
3.Trials began with 3 metronome beats (500 msec IOI for eighth note)
4.Two melody conditions: partners played the *score* as written, or *improvised* notes using the same rhythm as the score. Two conditions per player resulted in 4 possible combinations per pair.



Procedure and Apparatus

1.24 blocks per pianist; 1 block ≈ 18 trials with no errors (~8 minutes)
2.Errors could be due to timing (+-125ms from the 500ms IOI), or a wrong note during *score* conditions.
3.Block order was chosen before the study and rotated one place for the next set of participants (i.e. they started on Block 2 instead of Block 1). Pairs switched roles after completing a Super-block.
4.Neuroscan SymAmpRT whole-head with a 64-channel EEG QuikCap for each participant.
5.Sound stimulation delivered via two speakers.

Data analysis

1.EEG epochs (-1500 msec - 4000 msec) for the first four phrases
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/ERS computed by averaging frequency bins from 8-13 Hz
4.Trials with channels exceeding ±150μV discarded.
5.Baseline: 80 msec before start of each phrase.
6.Data were band-pass filtered (1-100Hz) in visualization; statistics (ANOVAs) performed on non-filtered data.

Results

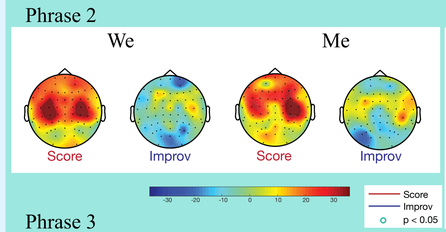
1. Phrase 2 and 3 chosen due to the similarity before and after for each partner.
2. Alpha power averaged from 500-2000 msec in the 2nd and 3rd phrase
3. **Listening** phrases separated from **Playing** phrases; only Listening phrase 2 and 3 included in this analysis
4. Three-way repeated measures ANOVAs with factors of:
   1. Similarity [We/Me]
   2. Melody [Score/ Improv]
   3. Electrode Group [FC/CPR/CPL]

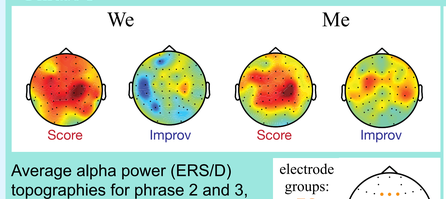
- Similarity conditions:
  - **We**: participants *both improvise* or *both play score*
  - **Me**: *one participant* plays *score* while the *other improvises*

Conditions in a Super-block		
	Role	
Block	*Leader*	*Follower*
1	Score	Improvise
2	Score	Score
3	Improvise	Score
4	Improvise	Improvise

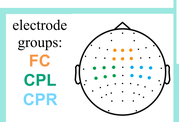
Conditions in each block for each partner. Leader and Follower switch after completing the 4 blocks, called a Super-block.

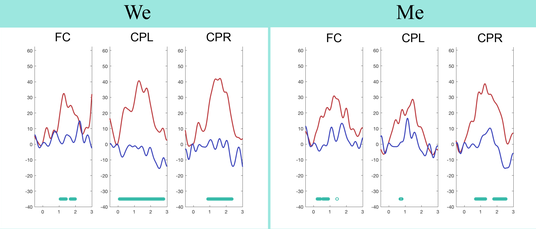
Alpha power reflects task creativity and partner engagement: Alpha ERS larger for score conditions compared to improvisation conditions ($p < .001$), with apparent right lateralization. This suggests that while pianists play the score, they are less engaged with their partner than while improvising.

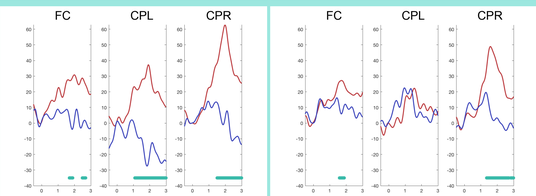




Average alpha power (ERS/D) topographies for phrase 2 and 3, by *similarity* (We/Me) and *melody* (Score/Improv).







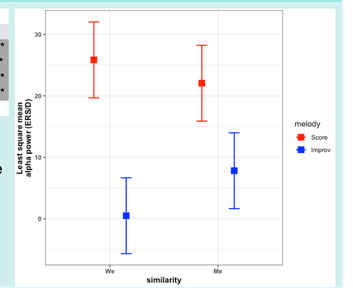
Time series plots of alpha power from -500 – 3000ms for phrase 2 and 3 separated by *similarity*, *melody*, and *electrode group*. Blue lines indicate Score, and red lines indicate Improv.

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.

	p
We:Improv-Me:Improv	0.1551938
Me:Score-Me:Improv	0.0003074 ***
We:Score-Me:Improv	0.0000020 ***
Me:Score-We:Improv	0.0000000 ***
We:Score-Me:Improv	0.0000000 ***
We:Score-Me:Score	0.6962341

Post-hoc results from the 2 way interaction between similarity and melody, above (*** = p<0.001).

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



Conclusions

1. During a musical duet performance, partners attend less to each other when listening to their partner play familiar material, such as the score.

2. While listening to a partner improvise, partners are more externally focused, suggesting higher levels of engagement and empathy with each other.

3. Task creativity and amount of shared goal both modulate engagement between musical partners while listening to each other, reflecting the complex coordination involved in ensemble performance.

4. Right-lateralization of alpha power could be due to reduced left hemisphere response since all players used their right hand.

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