Alpha Power as a Constituent of Agency and Creativity: Looking at a Pilot Piano Turn-Taking Improvisation Duet.

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EEG, alpha, electroencephalography, neural oscillation, improvisation

I. Abstract

Creativity in the human brain has been linked to certain neural oscillations. Specifically, alpha power is correlated to creative ideation, among other factors. This study uses a piano duet paradigm to examine the relationship between musical improvisation and alpha power. Alpha power in respect to social interaction and joint action was also analyzed. Using a dual EEG setup pianists played a 6-measure duet. There were four different types of trial. In the first, both players played the score. In the second, one played the score and the other improvised. In the third the players switched their roles from the second version. In the fourth, both players improvised. Less alpha power was generated when the partner was playing the score, while an increase in alpha power was found when partner was doing improvisation. The second significant finding was more ERS overall when a follower instead of a leader, except in improvisation conditions. From this pilot study we saw that alpha power was increased during improvisation, and when the pianist was a leader. Alpha power seemed to be increased by creative ideation and environments where pianists could direct attention inwards rather than focusing on variables such as time and trial initiation.

II. Introduction

Certain portions of the human brain show intrinsic rhythmic oscillations. These neural oscillations provide excellent markers for brain dynamics. Unlike neural ERPs which are only found in response to a specific stimuli, neural oscillations are constantly reflecting the environmental state of a brain. Oscillations are categorized by their frequency band. In this study we focused on the alpha band. One of the most studied neural oscillations, alpha can be broken down into two subcategories. The first, lower alpha, can be described with an 8 - 10 Hz frequency and is most commonly found in posterior regions of the brain (Hari and Salmelin, 1997). Lower alpha is connected to general task demands such as attentional processes. In different states of alertness, vigilance, or arousal alpha is either amplified or suppressed. In contrast, upper alpha activity (~10 - 12 Hz) has been more closely connected to specific task requirements (Fink and Benedek, 2014). Hari et al, 1997 further reported alpha oscillations being suppressed during and after visual stimulation, during the visualization of an image, or in memory-related imagery. This event-related desynchronization (ERD) contrasts to event-related synchronization (ERS) where alpha power increases with multiple other processes such as semantic memory, creative ideation, voluntary movement and perception, social interaction, and empathy.

Alpha is a versatile wave which has been studied deeply because of its prominence in not only being affected by internal processes, but also external stimuli. Fink et al, 2014 reported a relationship between alpha ERS and semantic memory processes. This has been thought to reflect a state of reduced active information processing in the underlying neural networks before and during semantic priming and stimulation. This agrees with Rominger, Papousek, Weiss, et al, 2018 who reported alpha ERS reflected the inhibition of external stimuli, activation of internal information, and shielding of working memory processes. Alpha oscillations appear to reflect a direction of attention towards internal processes. These two studies provide more evidence for the use of the alpha neural oscillation as a neuromarker for creative ideation. In relation to this study alpha power will be a neuromarker for creative ideation during improvisation on a piano with a possible interaction with semantic priming of a score condition (ERS).

First found by Martindale and Hines, 1975 and later by Martindale and Hasenfus 1978, individuals instructed to perform an internalized creative ideation task such as to think of a story appear to exhibit more alpha band power. More recently, Rominger et al, 2018 reported an increase in alpha power at bilateral frontal and right posterior cortical sites when completing a task requiring creative ideation. This study also provided more evidence for ERS of upper alpha as a marker for inhibition of external stimuli and shielding of working memory. Furthermore, fMRI studies have shown activation in the pre-supplementary motor cortex, medial prefrontal cortex, inferior frontal gyrus, dorsolateral prefrontal cortex, and dorsal premotor cortex during musical improvisation. Studies also show that the default mode network (DMN), or our “instinctual” network, is important during improvisation – though it is still debated whether this system is responsible for alpha ERS or ERD (Beaty 2015). This could have a correlation to the ERS found with top-down control; essentially during improvisation the brain starts to run on instinct instead of processed reaction.

Alpha band oscillations have been shown to desynchronize during social interaction. (Babiloni 2011; Gallese et al., 2004; Rizzolatti and Craighero, 2004; Rizzolatti et al., 2006). Higher emotional empathy (as rated by a STAI test) between musicians in an ensemble shows a positive correlation with alpha band strength (Babiloni, Buffo, Marzano, et al., 2012). Furthermore, this effect appears to be enhanced when observing one’s own actions (Babiloni 2011).

Alpha also appears to be present during movement. Crick 1984 first hypothesized that a relaxed but well-focused athlete would demonstrate large alpha amplitude before the accomplishment of a motor task. Individuals with more alpha activity at a resting state have been found to have better focus, balance, and fine motor capabilities (Del Percio et al., 2007, Cheron et al., 2016). During voluntary movements there also appears to be a bilateral frontal-parietal alpha ERD (Babiloni 1999, 2002, Pfurtscheller 1997, Cochin, 1998, Ulloa 2007). In this study we examine a paradigm with joint action and social psychology as the foundation. Alpha ERD appears to be stronger when two humans are completing a task together rather than a human with a computer partner. This effect was also enhanced in the human who was the leader of the joint action. Tognoli, Lagarde, DeGuzman, and Kelso 2007 reported ERD during action observation of another’s movement, especially if that movement was familiar to the observer.

This study used a melodic turn-taking piano improvisation duet where certain pitches were altered as deviant stimuli. Factors such as agency and leader versus follower were measured in their respect to alpha band power. Using a melody score, pianists in a duet alternative measures with one dubbed the “leader” and the other the “follower” Experimental design included the score being played by both pianists, one pianist, or neither, with the pianist(s) not playing the score freely improvising. This pilot was executed in an attempt to research if prominence of a relationship between alpha oscillatory power, musical improvisation, and joint action and perception.

III. Methods

A. Participants

In this pilot, 6 pianists were recruited which yielded 3 pairs of 2 pianists each. All pianists were right handed with a M (mean) age of 30.7 and SD (standard deviation) of 10.3 and a range of 23-51. The M years of musical experience in the sample was 23.8 and SD 10.3 with a range of 17-45. It is important to note that not all participants were natural pianists, but all participants had musical training.

B. Task & Apparatus

The experimental setup included 2 *Axiom 61-Key MIDI Keyboard*’s with *Max/MSP* to control the audio feedback and triggers. Participants each wore *Neuroscan 64-Channel Quik-Cap* electroencephalography (EEG) caps. The melody was composed in C-major with a compound meter time signature.

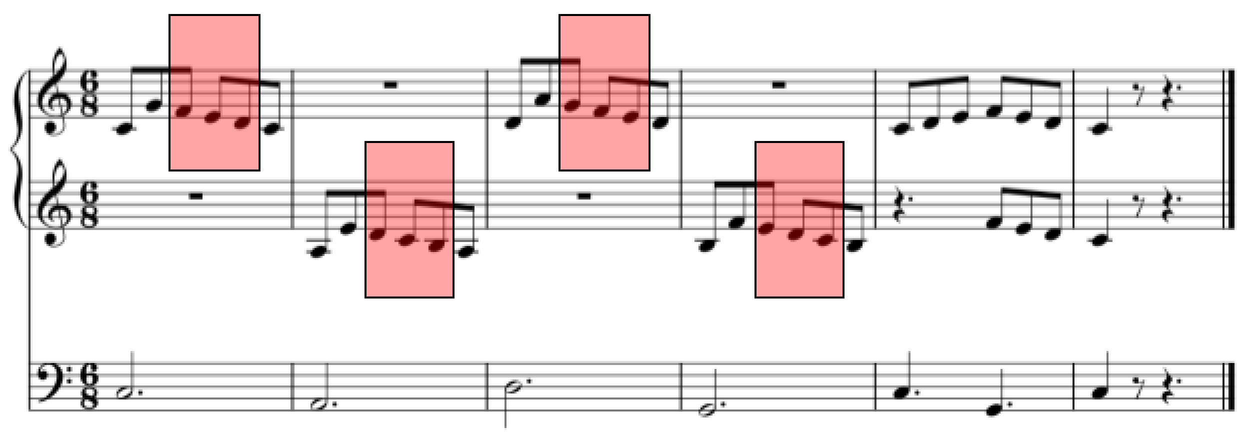


Figure 1: The score used in the study. Pianists alternated playing be measures. When a pianist was in an improvising condition, they would not play the score in their designated measure. Instead, they would improvise while keeping the same. The red regions are possibilities for deviant notes (+/- 4 scale tones). Each participant gets 1 deviant per trial (Bars: 1,2; 1,4; 2,3; 3,4).

As stated in Figure 1, each participant received one deviant note per trial. There were no deviants in measure 5 or 6. There were four different condition types: SS (both players play the score), IS (player one improvises, player two plays the score), SI (player one plays the score, player two improvises), and II (both players improvise). In all four condition types, both players played the score in bar 5. A computer monitor visible to both players displayed colors indicating the task of each player for that trial. The color green indicated that the player should improvise, while the color red indicated that the player should play the score. Half of the monitor displayed a color for player one, and the other half displayed the other for player two. Metronome lead-in was 500ms per note with an intensity of about 80 dB SPL. Tones were held at constant amplitude, and sounded for at least 375ms duration until onset of next note. The first note in each bar triggered a computer-generated bass note that continues for the rest of the bar. In each block, there were 4 practice trials followed by four subgroups of 12 trials each (4 practice + (4 subgroups * 12 trials) = 52 trials per block). Each subgroup contained exactly 1 of each condition type, and each block contained all four conditions. In each trial, one deviant (+- 4 in-key notes) sounded per person [Bars: 1,2; 1,4; 2,3; 3,4]. Bar 5 had no deviants. 1 block = 1.5 sec (first trial extra 3 metronome beats) + 52 trials x (0.5 sec * (31 notes + 3 metronome beats) + on average 2.0 sec inter-trial-interval)) = 989.5 seconds = ~16.5 minutes. There were four different variations of the order of the conditions within the block, and each block order was ran twice, with keyboard 1 on top and bottom lines (4 block orders * 2 times = 8 blocks total = ~132min = ~2.2hrs).

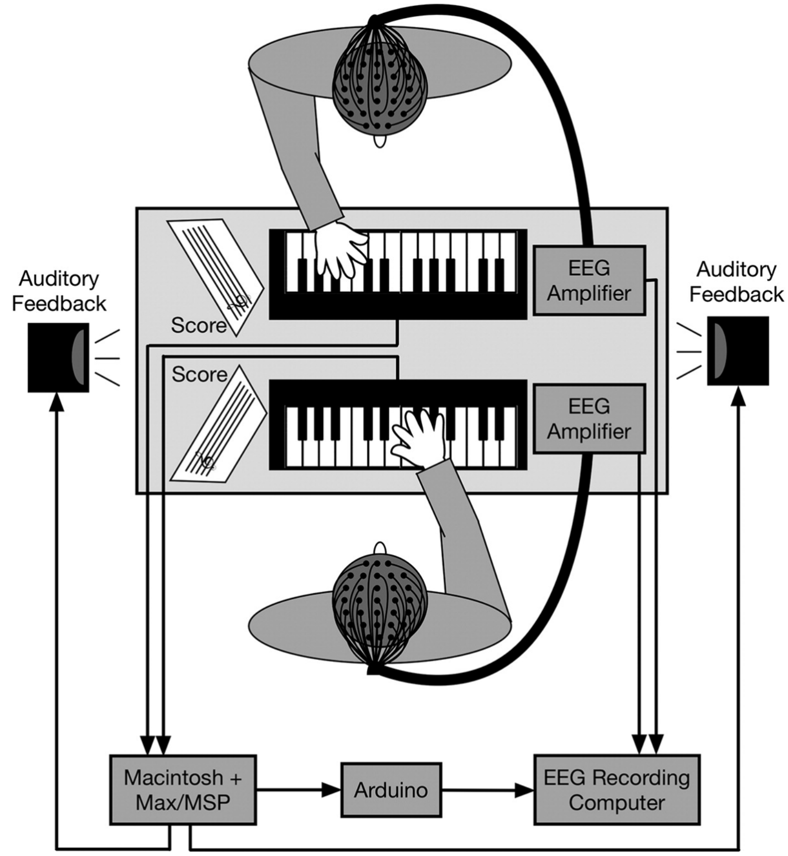


Figure 2: Task apparatus setup: Keyboards and participants were in a electrostatically and sound proof room. The rest of the equipment was outside of the room.

C. *EEG Equipment and Data Analysis*

EEG data was recorded from two Neuroscan 64-Channel Quik-Cap which fed into a dual-EEG Neuroscan SymAmpRT amplifier (Compumedics Neuroscan Inc.). The amplifier fed into a computer running Curry 7 for data collection (Compumedics Neuroscan Inc.). Max/MSP were used to record musical performances (including key press timing, velocity, and expected versus actual MIDI data). Horizontal EOG was recorded for each participant and electrode impedances were kept below 10 kΩ. Cz was used as a reference electrode. Eye artifacts and bad channels were removed using SSP source space projection (SSP) in the Brainstorm toolbox (Tadel, Baillet, Mosher, Pantazis, and Leahy 2011) in MATLAB (Mathworks Inc., Natick, MA). The data was epoched around each measure with a time window of -1.5 s to 4 s with a baseline of -80 ms to 0 ms for the Leader and 1420 ms to 1500 ms for the Follower. The epochs were averaged by condition: Self/Other, We/Me, Score/Improvise, and Standard/Deviant. A MATLAB script was run to isolate the alpha power and a 100 Hz low pass filter was applied to the line plots.

IV. Results

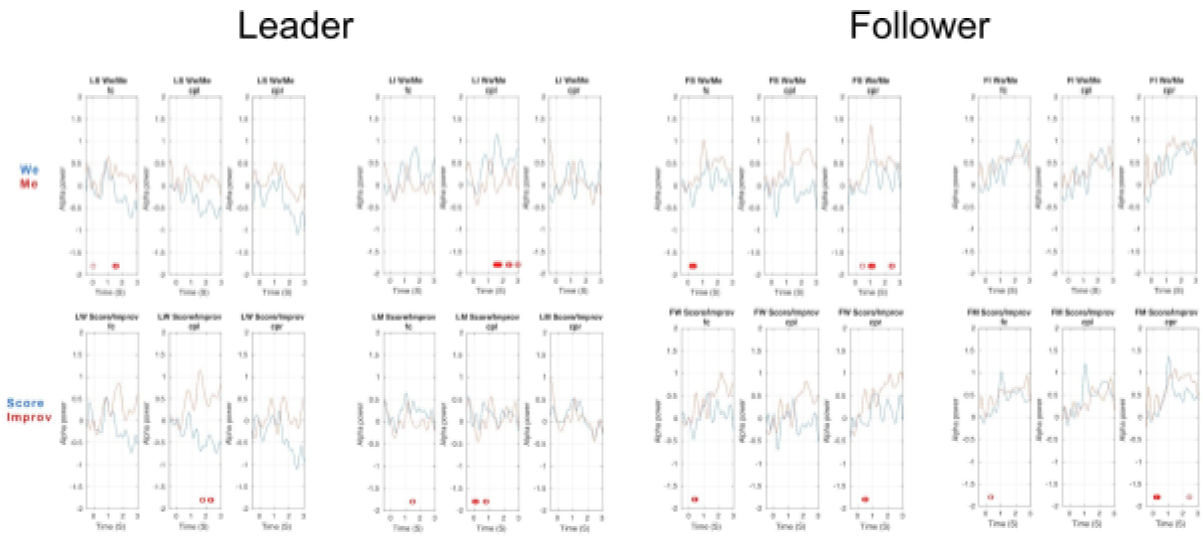


Figure 3: Alpha power line plot for different conditions as a function of Leader/Follower.

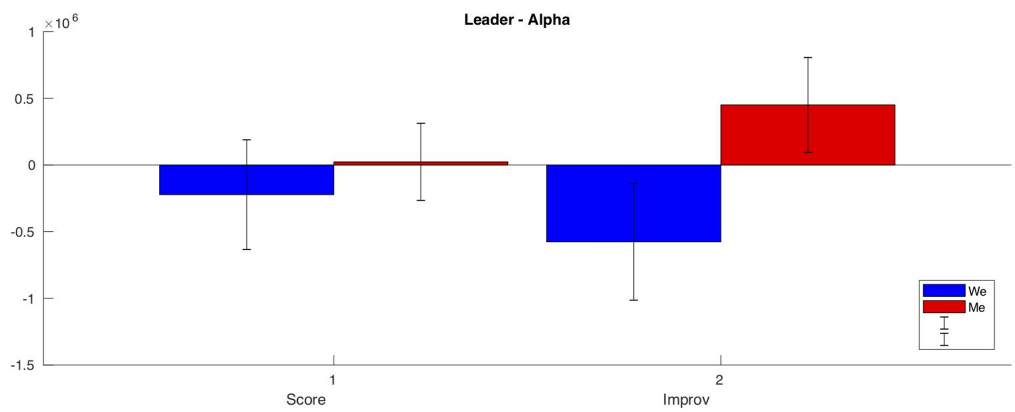


Figure 4: Leader (1485-1515ms) 30ms time window around 1500ms to capture ERD & focus on start of unison part at 1500ms.

A two-way ANOVA was ran on the alpha power for Leader and Follower data at the unison onset. The variables examined were *Partner (We/Me)* and *Melody (Score/Improv).* For the leader data, a two-way interaction approaching significance between *Melody (Score/Improvisation)* and *Partner (We/Me)* was found in the time window 1500 - 1530 ms ($F(1, 5) = 6.57$, $p = 0.0412$). In the *Score* condition, "We" ($M = -0.37$) yielded more ERD than in the "Me" ($M = 0.31$) interaction ($p < 0.001$). In the topomaps in *Figure 6* further show this effect where the *Self Score* and *Partner Score* in the *Leader* condition shows a slight ERD which is not present in the *Self Score* and *Partner Improv* condition. Furthermore, *Figure 3* shows similar ERS for both "Me" and "We" in the *Leader/Score* condition at 1000ms which diverges and we see larger ERD for "We" than "Me" at unison onset (1500-1530 ms).

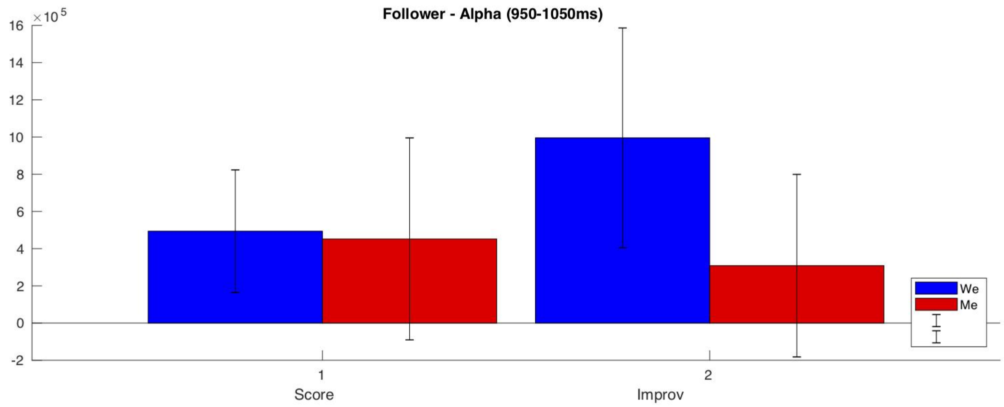


Figure 5: Follower (950-1050 ms) 100ms time window around 1000ms to capture ERS for unison & because there was a less clear peak

In the improvisation condition, “We” (M = 0.74) gives significantly more ERS than “Me” (M = -0.055, p = 0.011). This can be seen in *Figure 6* in the *Leader/We/Improv* condition by the strong alpha ERS compared to the more bland topomap in “Me”. In the line plot for this interaction in *Figure 3* there is strong ERS for “We” at 1000 ms to the unison onset, whereas “Me” is flat, agreeing with the ANOVA result and topomap.

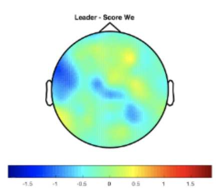
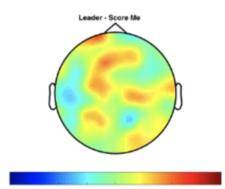
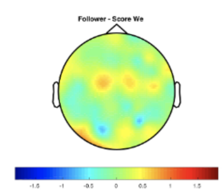
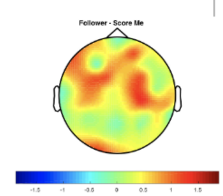
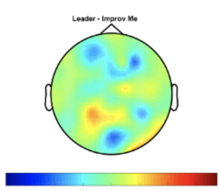
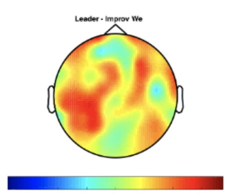
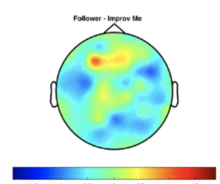
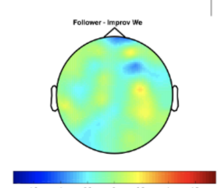
	Leader		Follower	
	Partner Score	Partner Improv	Partner Score	Partner Improv
Self Score				
Self Impro				

Figure 6: Topomaps for Alpha power at unison onset (in 5th measure) for Leader/Follower (1500 - 1530 ms).

When a two-way ANOVA with *Partner (Me/We)* and *Melody (Score/Improv)* was run in the Follower data in the time window 1500-1530 ms, no results close to significant were found. This same ANOVA was also run on the time window 950-1050 ms for Follower and 1485-1515 ms for Leader. Similar conclusions were found for the Leader data with slightly weaker alpha power, however. The Follower data yielded a main effect for *Partner (Me/We)* approaching significance $F(1, 5) = 4.49$, $p = 0.0875$. For “We” ($M = 0.37$), the alpha power was significantly lower than for “Me” ($M = 0.86$). When the window was readjusted, however, this result was no longer significant.

V. Discussion

This pilot study looked at the effect on alpha band oscillations of improvising in a piano duet with a human partner. Each partner had an opportunity to lead the duet and be a follower. When either a follower or a leader, improvisation on the keyboard showed more alpha, as expected from previously studied literature (Martindale et al., 1975; Rominger et al., 2018; Beaty 2015). When a leader, however, there appears to be less alpha power across all conditions except in *Improv We*. Rominger et al 2018 and Hari et al 1997 hypothesized that alpha ERS displayed shielding of working memory and external stimuli in favor of internal action. Being a leader in this paradigm could present a sense of urgency to keep time and initiate each sequence so not to disqualify the trial. When listening to a partner improvise while one was playing the score there was more alpha ERD than in the *Score We* condition. This could be a stimulatory effect from hearing improvisation. This could be an effect similar to that found in Babiloni et al 2012 where musicians watching a performance showed alpha ERS. Ultimately there appeared to be more creative freedom while both pianists were improvising.

The *Score We* condition for leader yielded a slight ERD. As no creativity was necessarily needed for this condition, this is to be expected during social interaction where alpha is suppressed (Babiloni 2011; Gallese et al., 2004; Rizzolatti and Craighero, 2004; Rizzolatti et al., 2006). While in the *Improv* condition there was alpha wave stimulation from creative ideation, in the *Score* condition participants were simply required to read music. In some cases improvisation could be completed in a manner of joint action, but this is more likely when reading a score; both pianists are privy to their “instructions” to complete the task. This could have led to ERD from social interaction, joint action, and action perception, all previously supported by literature (Babiloni 1999, 2002, Pfurtscheller 1997, Cochin, 1998, Ulloa 2007, Tognoli 2007).

In the follower paradigm we see less alpha power in frontal scalp regions during *Improv We*, but considerably more alpha ERS in parieto-occipital regions compared to *Improv Me* (reference *Figure 3 and Figure 6*). In *Figure 5* and *Figure 6* we can see more alpha power when the partner is improvising. *Figure 4* and *Figure 5* show the alpha power in the original time window – 950-1050 ms for Follower and 1485-1515 ms for Leader. We can see more ERS is general while a leader. This could suggest an extended sense of creativity while initiating a trial whereas a follower relies more on social interaction and joint action to react to the actions of the leader; these cause ERD.

Previous literature looking at the relation of alpha power to creativity show alpha band ERS during tasks requiring creative ideation. Alpha oscillations have two sub-bands: lower alpha (8-10 Hz) and upper alpha (10-12 Hz). Lower alpha can be connected to general task demands and attentional processes while upper alpha is affected by specific tasks, such as creativity. Alpha power has been connected to multiple other processes such action perception, joint action, and social interaction. During action observation, especially when observing a familiar movement, there is alpha ERD. During social interaction and joint action there also appears to be alpha ERD. Voluntary movements have also been shown to suppress alpha.

In this pilot study, alpha power was studied in its relation to improvisation in a duet. Less alpha power was generated when the partner was playing the score, while an increase in alpha power was found when partner was doing improv. One possible explanation for this is that more attention is paid to the partner when they play the score compared to improvisation. Alpha ERS signals a direction of attention away from external stimuli and to internal processes. The increase in attention towards the partner could result in the alpha ERD. Another possible explanation is lower creative and motor inhibition when both players are improvising.

The second significant finding was more ERS overall when a follower instead of a leader, except in improvisation conditions. One possible explanation for this result is an increased sense of focus for the leader. As they are responsible for starting the trial and therefore, have less time between trials, the increase in focus could suppress alpha because in inhibitions of top-down control. A second explanation for the exception in ERS in the follower paradigm is the increase in creative freedom for the leader as they are starting a trial instead of reacting to the actions of their partner. A confounding variable here could occur when both players are improving. In that condition fluidity of both players improvising decreases social awareness as attention is directed inwards, and the sense of a leader/follower role is diminished.

There were possible variables in the pilot, such as the number of pianists, musical ability, and block order. For further study into this area we suggest recruiting more pianists, and using different scores with some similar and dissimilar melodies to test the effect of melodic structure on alpha.

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