

Exotic New Patterns of Synchronization

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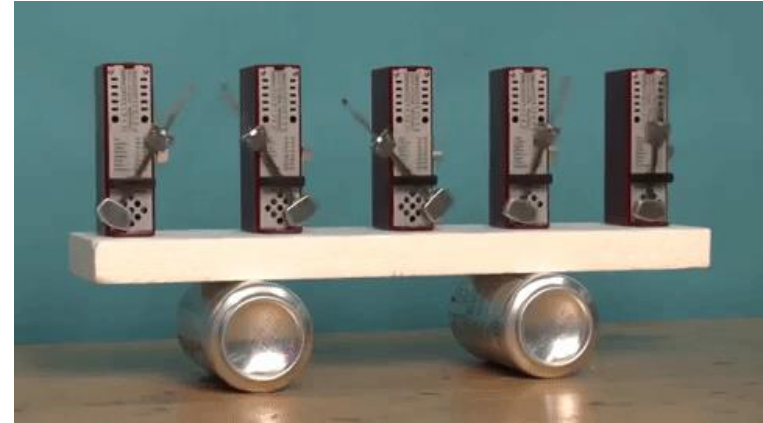
Presented by

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18th April 2019

Synchronization

- Two or more dynamical systems
- Adjust some of their properties
- To a common behavior
- Due to strong or weak coupling.



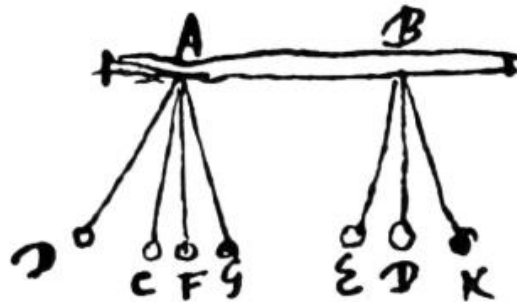
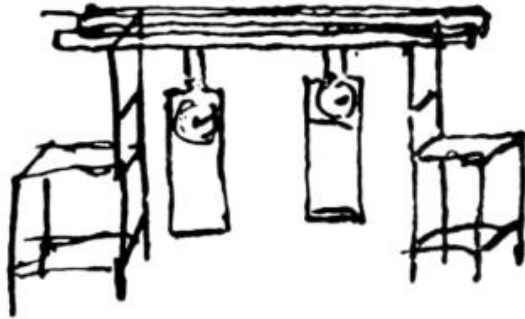
Synchronization in Nature



Male fireflies synchronizing their flashes

- Fireflies sync their flashes
- Crickets sing in sync
- Neurons in our brain fire in sync
- Pacemaker cell sync up their beat

Exploring Synchronization: An Early Experiment



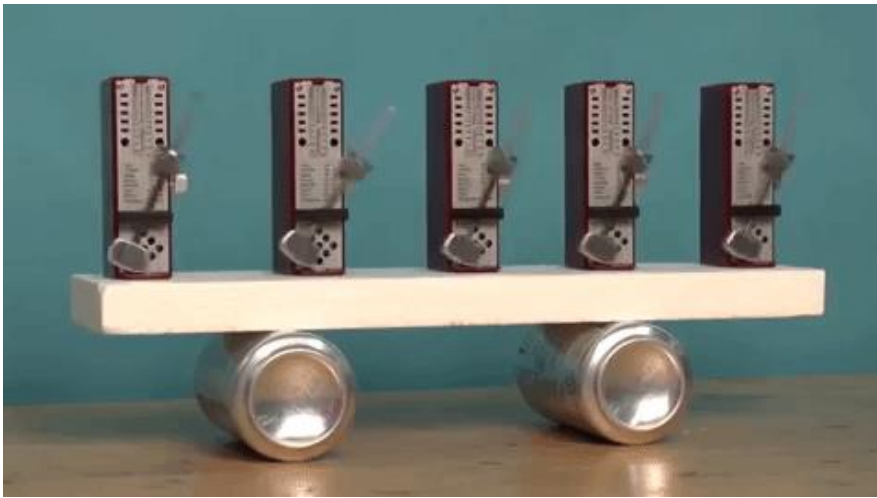
- The pendulums swung in unison.
- They go towards each other and then away.
- Reason: They exerted force on each other via the wall.
- They sync to attain their most “stable” and “relaxed” state.

• A pair of pendulum hanging from wall

Exploring Synchronization: New Patterns

Global Synchronization:

A population of oscillators all do the same thing.



Chimera State:

Some oscillate in sync, some drift incoherently.



Synchronization in Network

- Not all oscillators are connected to each other. Has some specific set of connection.
- Better model for real world systems: Brain and Internet.

Cluster Sync: The network breaks up into clusters of oscillators that sync.

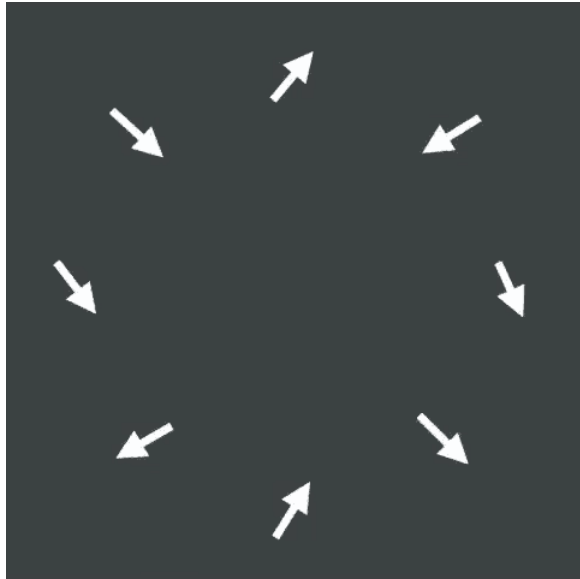
Synchronization in Network (II)

Remote Sync: Oscillators not directly linked sync up as a cluster, but oscillators in between behave differently.

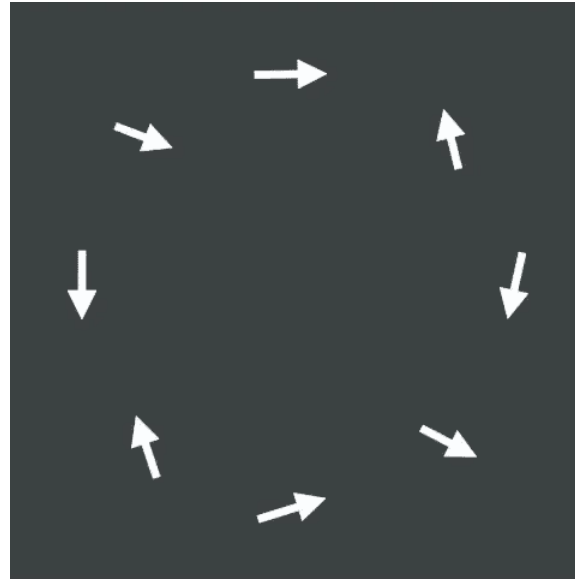
- Scientists have observed remote sync with "Chimera" state.
- Relevant for neuronal information processing.

Chaotic Sync: Individually unpredictable oscillators sync and evolve together.

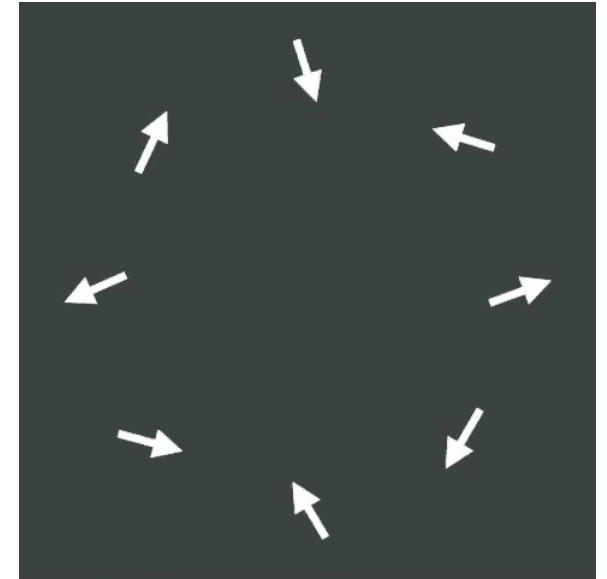
Synchronization: Experiments using NEM



Splay State



Traveling wave state



Noise driven chimera

Why Study Synchronization

A major motivation: Our human brain is a network of neurons acting in a combination of synchrony as well as synchrony.

- How human brain works?
- Functionality and interaction of different parts
- Brain disease: Similarities between the destabilization of chimera states and epileptic seizure.



Inter-Brain Synchronization during Social Interaction

Dumas G, et al. (2010)
PLoS One Journal

Interactional Synchrony

- When two people talk
 - Volume and pitch come in to balance
 - Speech rate and latency equalizes

Purpose



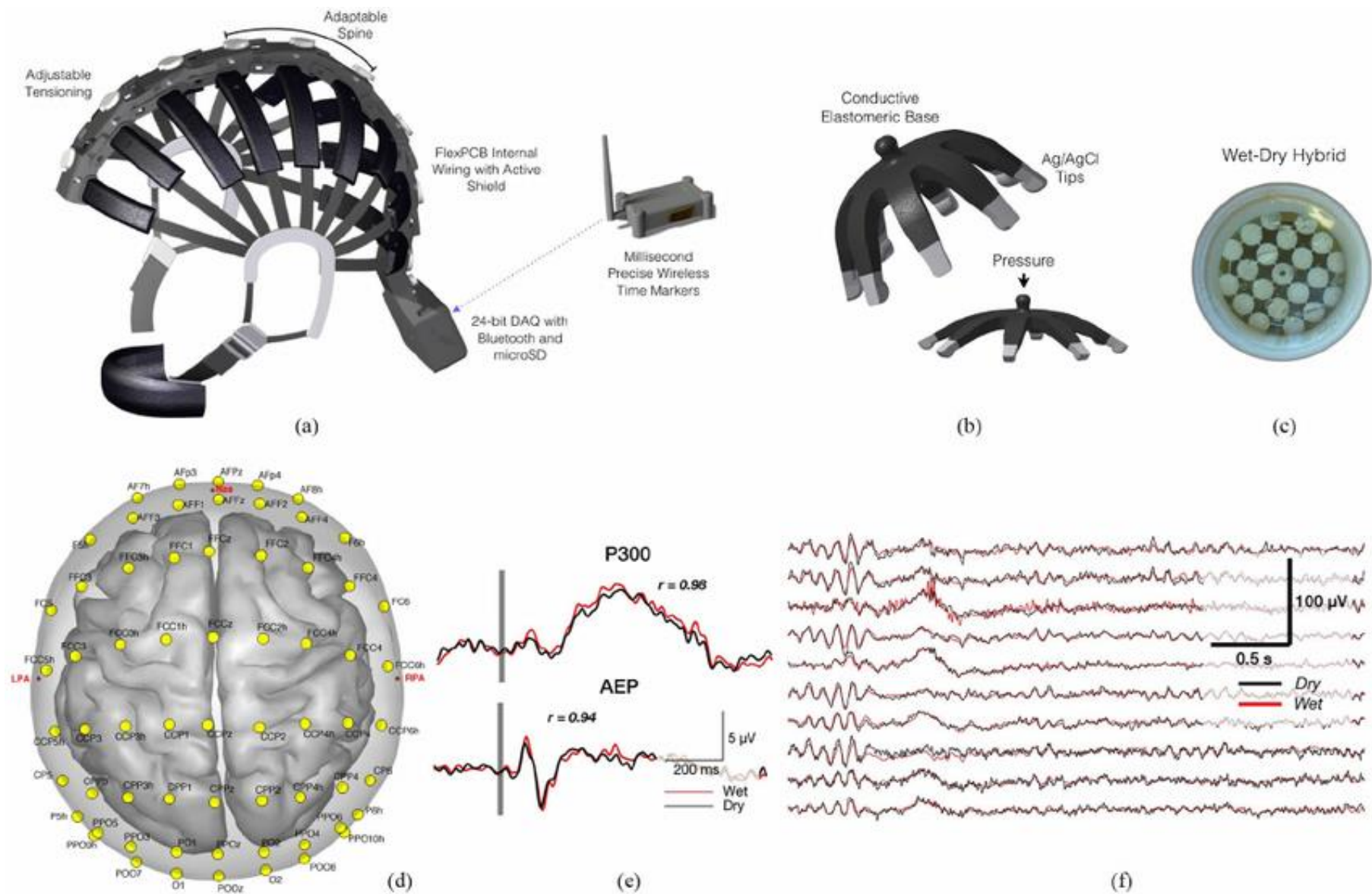
Experimental Setting



Two Tasks

Spontaneous
Imitation (SI)

Induced
Imitation (II)



Two Types of Data

Video Recordings

- Labeled by either of the following labels: Sync, NSync, Im, NIm

EEG Data

- PLV for each pair of electrodes b/w the two helmets
 - If $PLV = 1$; same phase
 - If $PLV = 0$; totally non synced

Results

Major Findings

- Interactional synchrony is a consequence of inter brain neural sync.
- **centroparietal** domains as the major functional hub during interactional synchrony
- Neural synchronization became asymmetrical in the higher frequency bands

Figures presented to back up those claims

- Overall time spend by all the subjects
- Comparison between different frequency bands
- PLV differences between sync and non-sync interactions

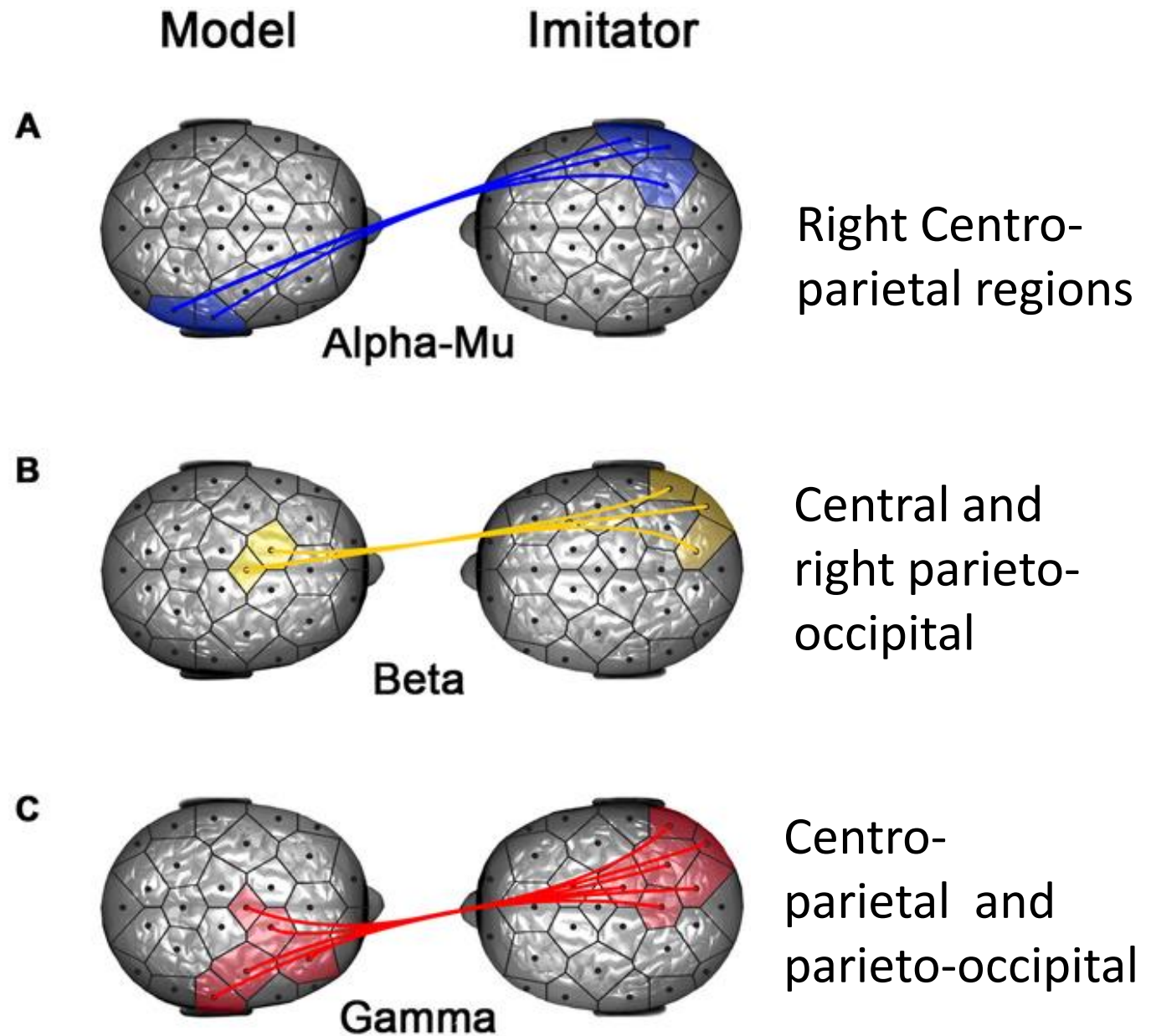


Mean (and SD) percent time spent synchronizing and/or imitating hand movement during spontaneous imitation condition.

	Imitation		Non-Imitation		Total	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Synchrony	51.27%	16.59%	26.66%	12.77%	77.93%	17.63%
Non-Synchrony	13.42%	13.62%	08.65%	05.56%	22.07%	17.63%
Total	64.69%	13.74%	35.31%	13.74%		

doi:10.1371/journal.pone.0012166.t002

Where is this synchrony coming from?



Time course of channel P8

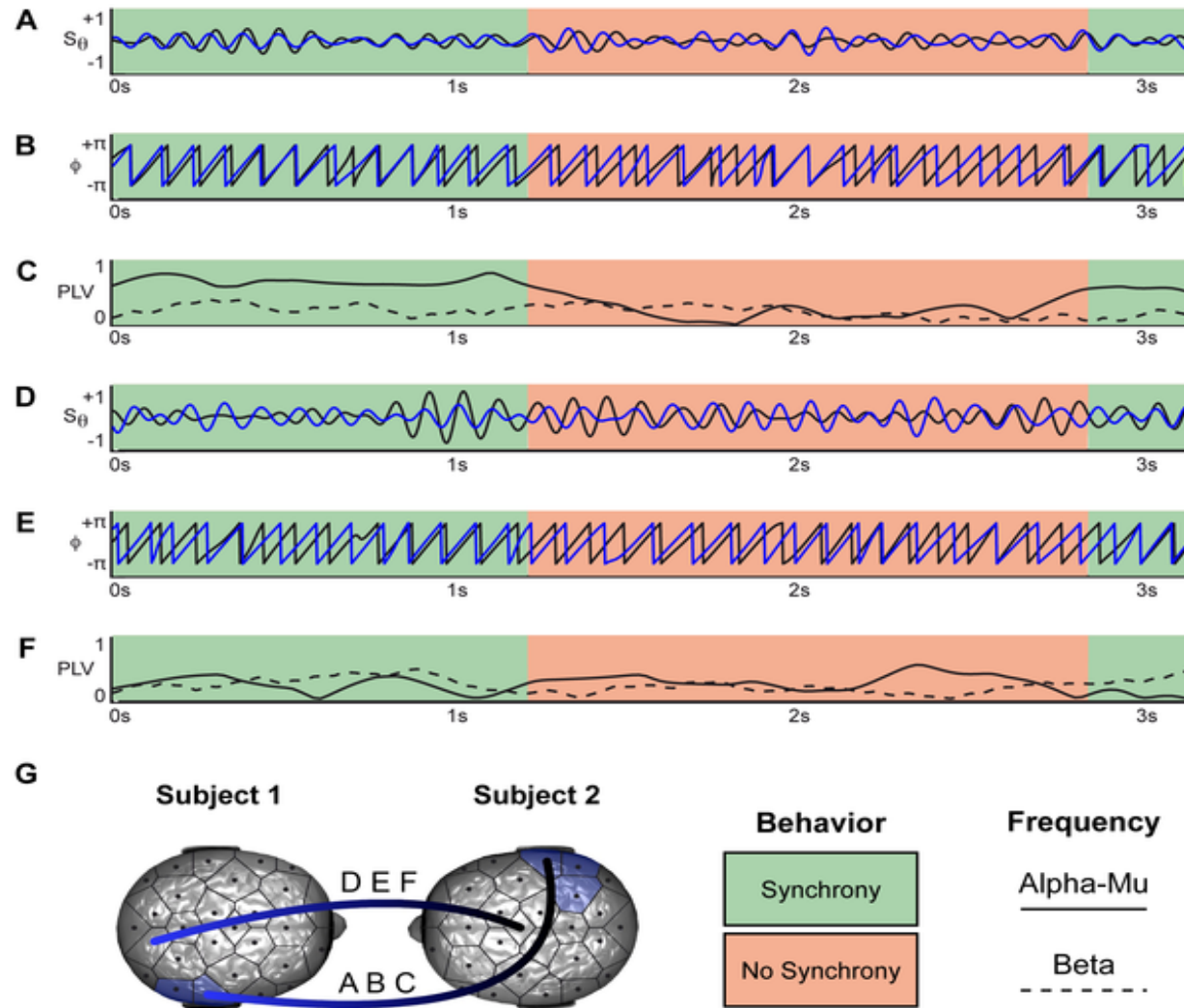
Phase

PLV for alpha-meu and beta band

Time course for channel PO2

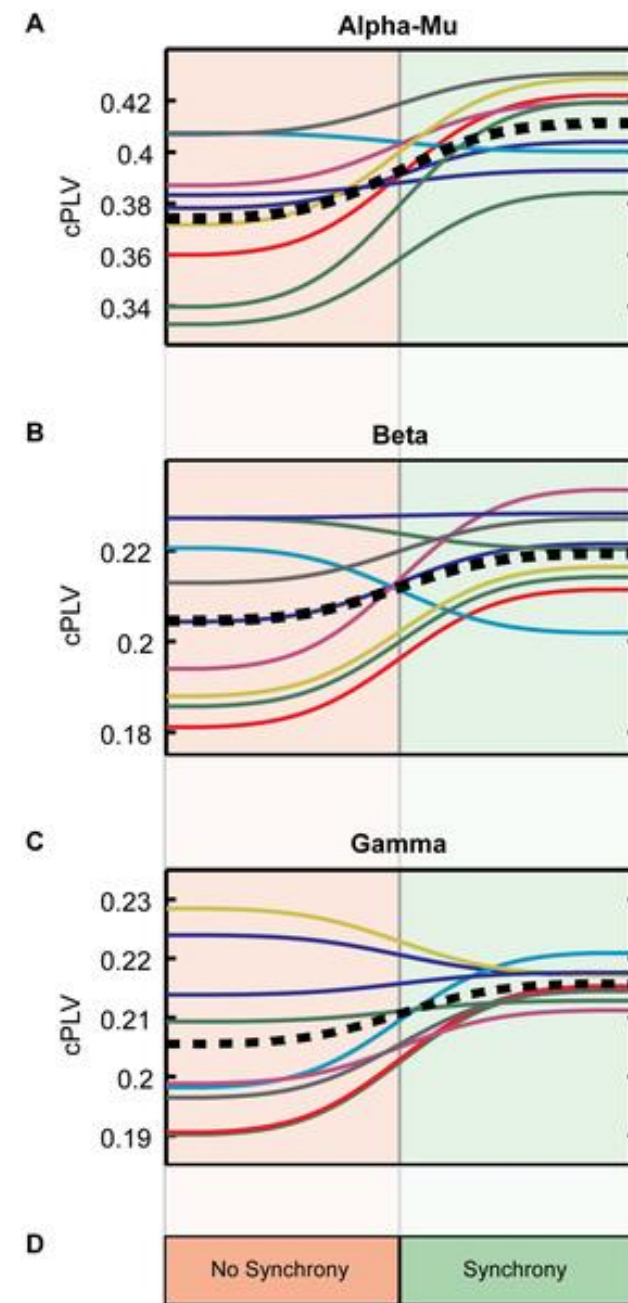
Phase

PLV for alpha-meu and beta band



Closely Looking into the parietal region: Correspondence between interactional synchrony and brain activities for two given channels (P8 & PO2)

Summary of relevant inter-subject synchronizations for all dyads according to interactional synchrony



32- pair of active electrodes

Discussion

- First study of dual-EEG activity
- Behavioral synchrony is a result of inter brain synchronization
- Evident to **centroparietal** regions as a functional hub of social interactions.
- Comparison between different frequency bands gives an impression of how brain synchronization evolves across different frequency ranges.

Criticisms

- Very small dataset
- All participants are from same age cohort (mean = 24.5). So, a synchrony in social interactions is already expected.

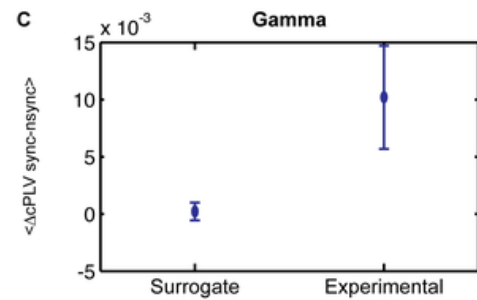
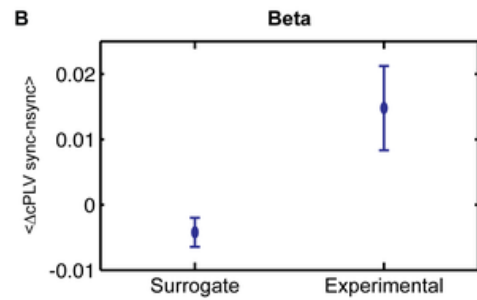
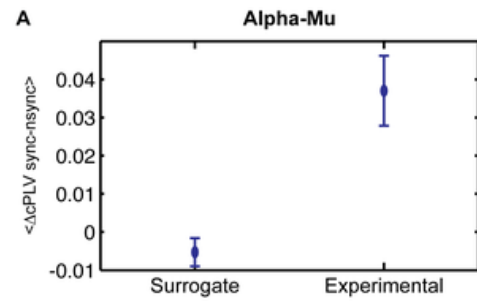


Thank You!

Questions?

Why this synchronization is important?

- A key mechanism for information integration
- Temporal binding
- Information propagation inside the brain
- Prediction
- Patient-control group differences.



Averaged inter-subject clustered PLV (cPLV) difference between synchronous and non-synchronous interactions (Sync - NSync) compared for experimental and surrogate behavioral analysis.

Bars represent standard errors.