SIPF
Società Italiana di Psicofisiologia e Neuroscienze Cognitive

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Effects of gamma tACS in language processing

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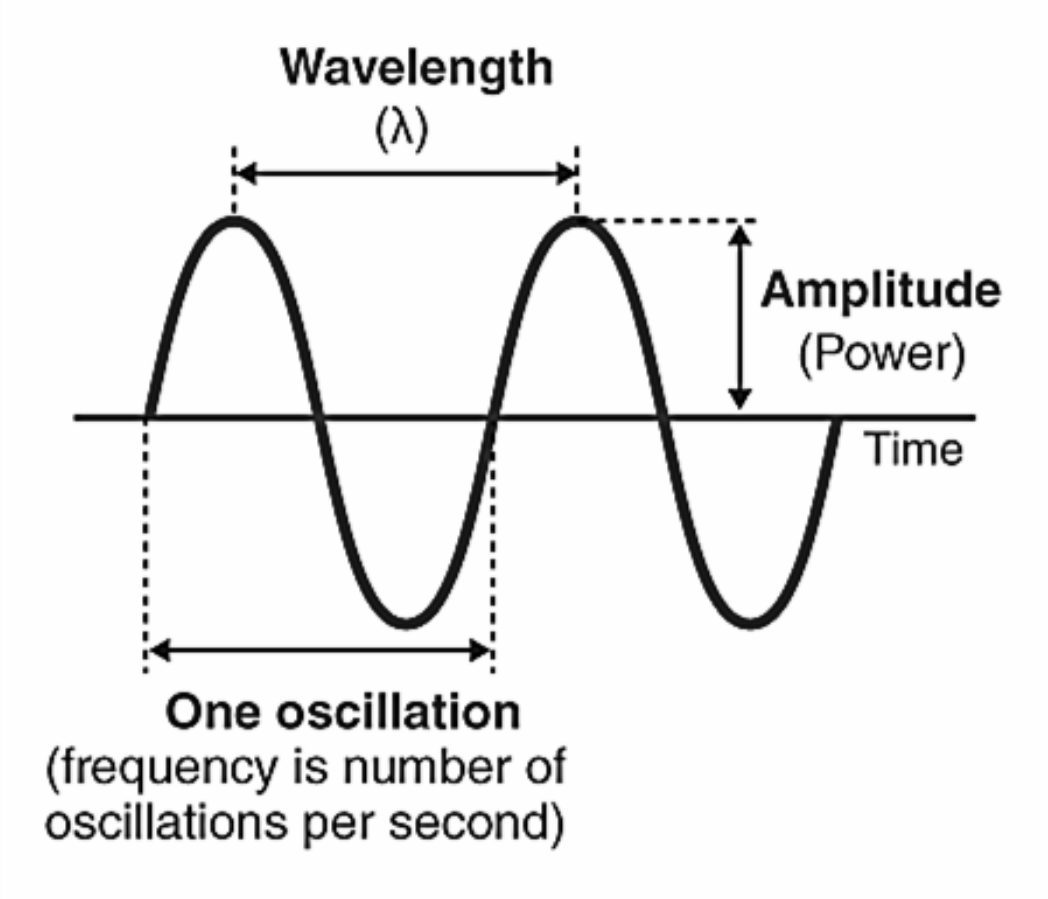
Oscillatory Activity



Oscillatory activity is generated by **neurons that fire synchronously** at a rate close to the frequency of the network oscillation

This activity is fundamental to **information transfer** and **temporal organization** of neural activity patterns in large-scale brain networks

Oscillatory fluctuations across time are representative of the **dynamic interplay** between different cell types in various cortical and subcortical circuits (Buzsaki, 2006)

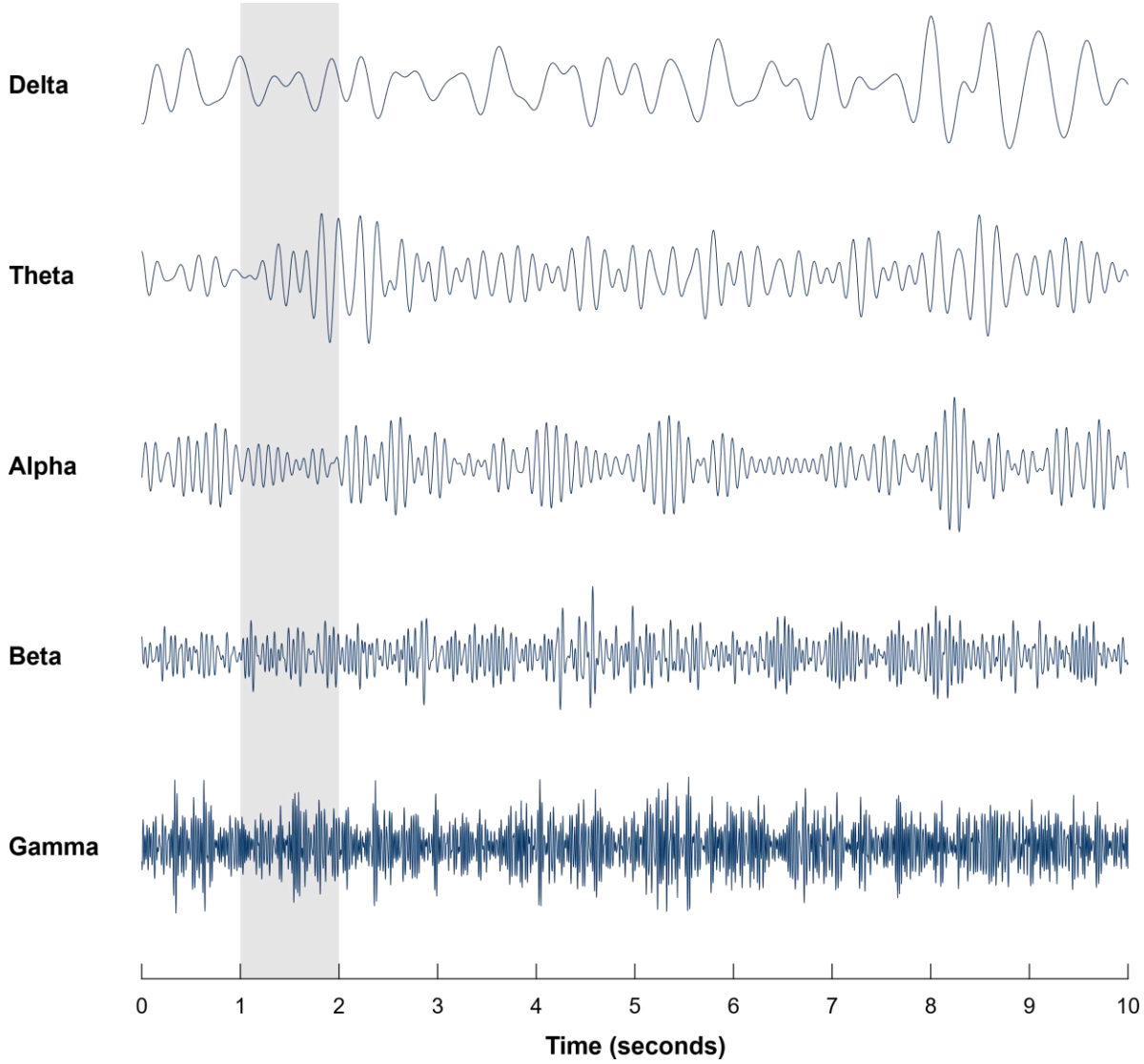
Excitatory and inhibitory neuronal activity that occurs within brain circuits operates at several **distinct time scales**, and their dynamic interactions contribute to **different frequencies of oscillations**.

Oscillatory Activity

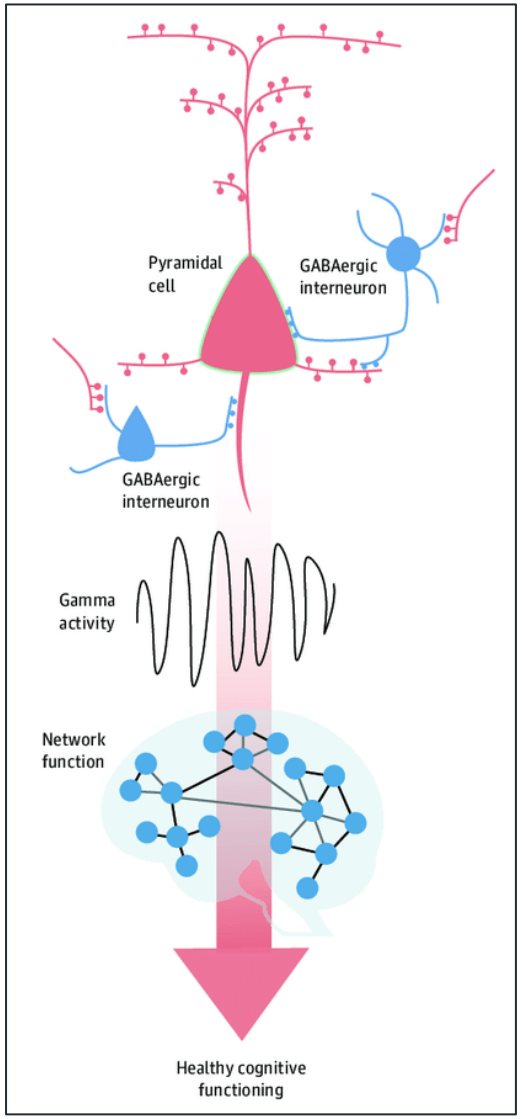
Oscillatory activity can be recorded using electroencephalography (**EEG**) or magnetoencephalografy (**MEG**)

Oscillatory frequencies, ordered from slowest to fastest, include:

- **Delta** (~0.5–4 Hz)
- **Theta** (~4–8 Hz)
- **Alpha** (~8–12 Hz)
- **Beta** (~12–30 Hz)
- **Gamma (~30–120 Hz)**



Gamma-Band Activity



McCutcheon et al. (2019), *JAMA Psychiatry*

Gamma-band activity refers to cortical oscillations primarily generated from the interaction between fast-spiking gamma-aminobutyric acid **(GABA)-ergic inhibitory interneurons**, and **excitatory pyramidal cells**.

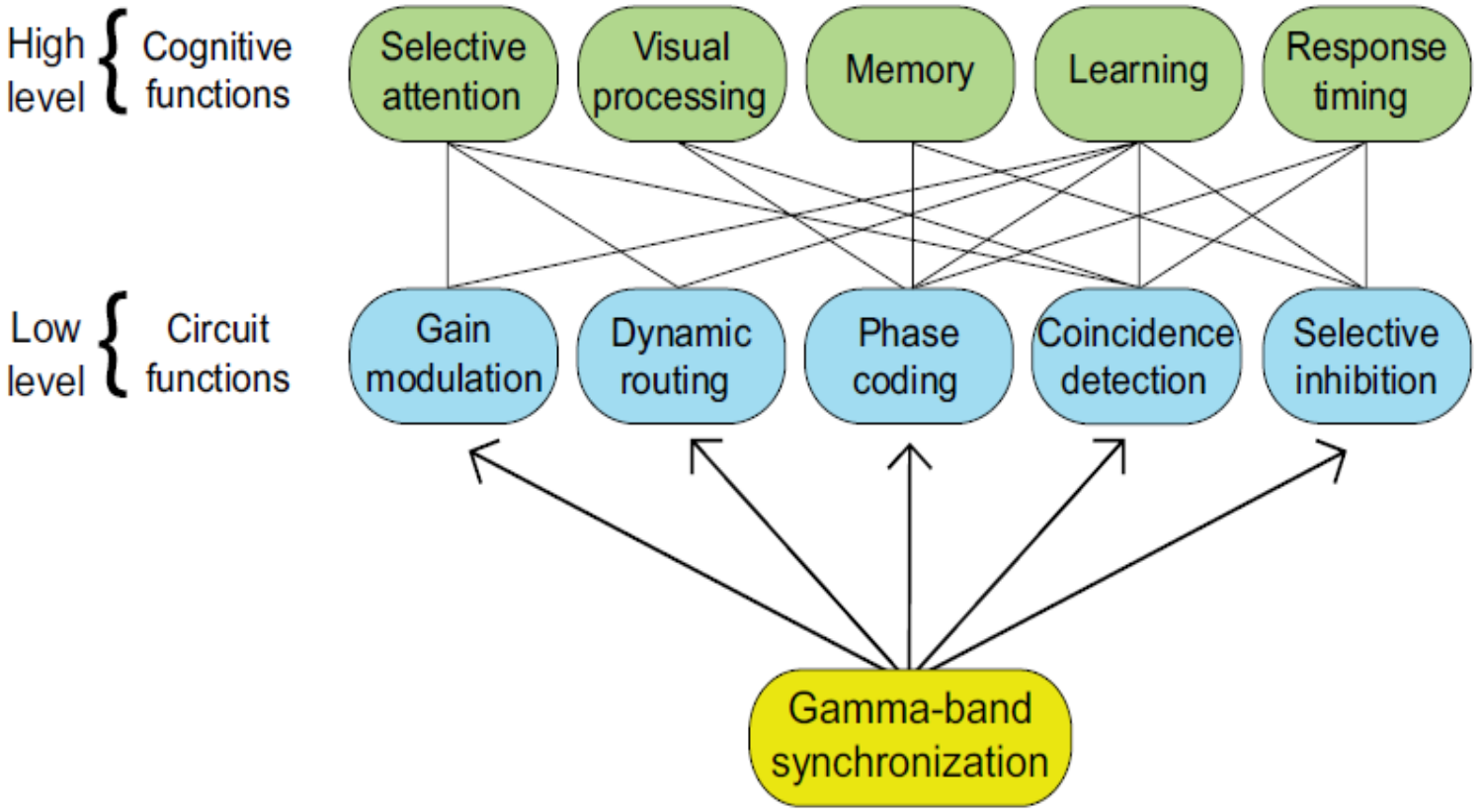
The gamma band range is conventionally divided into **slow (30/50 Hz)** and **fast (55/120 Hz)** oscillations.

Gamma-Band Activity

Gamma oscillations can be associated with several **low-level** and **high-level** functions in **circuit computations**.

At a **higher level**, gamma oscillations are linked to **cognitive functions**, but their specific role depends on the brain region where gamma has been found.

Gamma oscillations do not subserve a single, universal function but rather a **multitude of high-level functions**

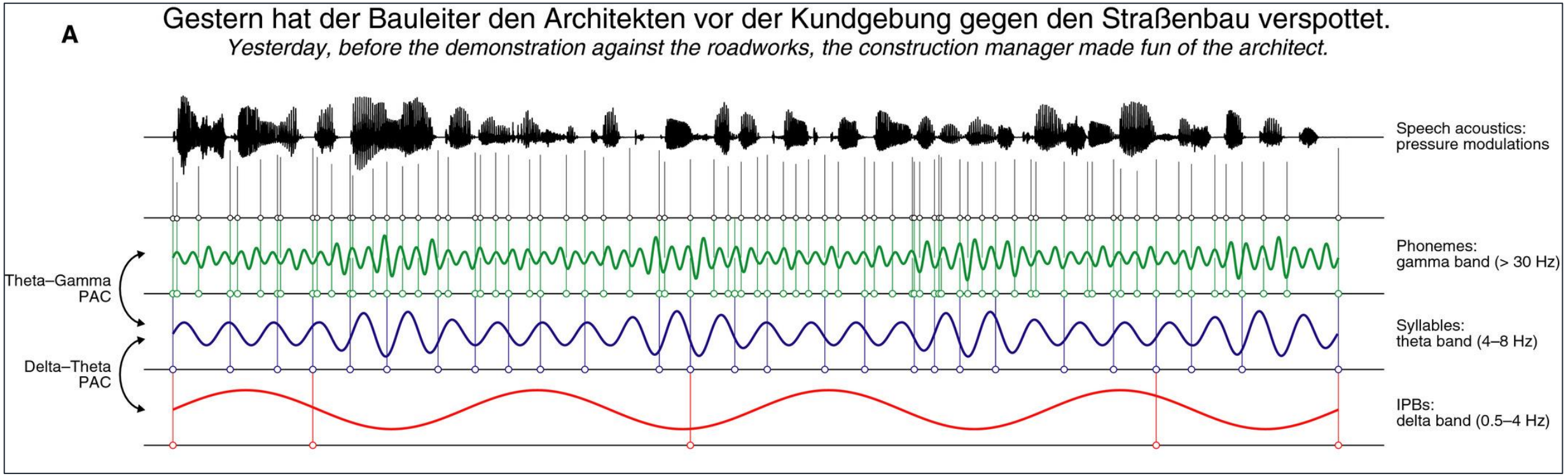


Murphy (2015), *Front Psychol*

Speech processing

Neural oscillations support **speech processing**

Speech processing is the set of neural processes enabling the **segmentation** and **identification** of more or less discrete **phonological units** in the acoustic spectrum, which encode to-be-communicated meaning.



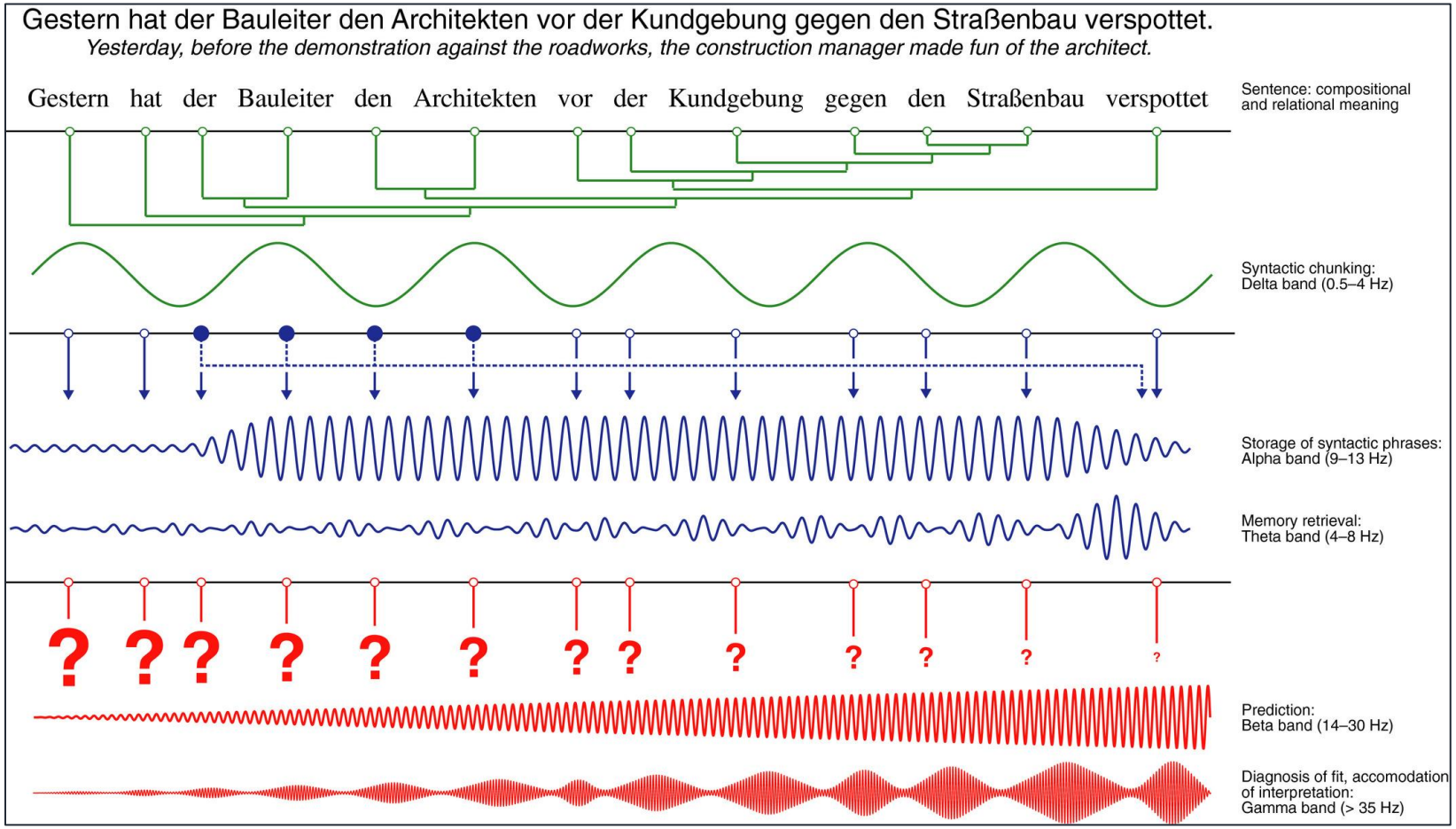
Meyer (2017), *Eur J Neurol*

Language comprehension

Neural oscillations support **language comprehension**.

Language comprehension describes the **decoding of the meaning of words** and combinations of words, such as phrases and sentences.

Two processing streams are involved in language comprehension:
- **Syntactic Processing Stream**
- **Predictive Processing Stream**

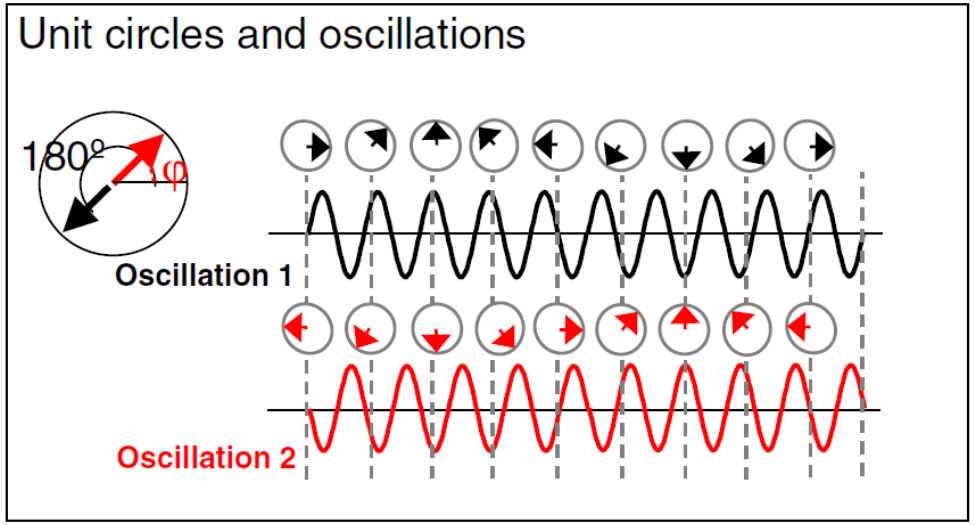


Meyer (2017), *Eur J Neurol*

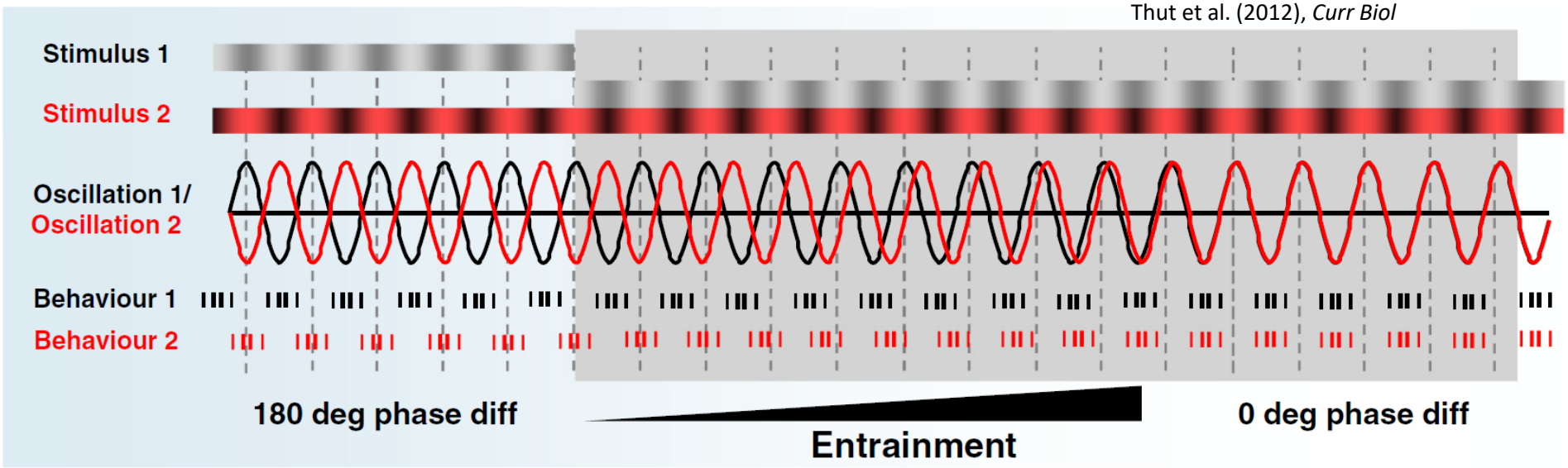
Transcranial alternating current stimulation (tACS)

tACS is a non-invasive neuromodulation technique that applies **sinusoidal electrical current** to the brain.

ENTRAINMENT: tACS can entrain ongoing brain oscillations activity and modulate brain areas in a frequency-dependent manner.



Thut et al. (2012), *Curr Biol*



Gamma tACS

Attention → **40 Hz gamma tACS facilitated endogenous attention**, but had no significant effect on exogenous attention, suggesting a critical role of low gamma in attentional disengagement and reorientation (Hopfinger et al., 2016).

Perception → The frequency range from 10 Hz to 40 Hz (Moliadze et al., 2010; Paulus, 2011) affects **phosphene interference**.

Motor Function → **Enhanced movement acceleration** and **velocity** were achieved with gamma band entrainment of the M1 (Moisa et al., 2016).

Higher Cognition → Alekseichuk et al. (2016) found **that spatial working memory depends on theta-gamma** cross-frequency coupling.

Gamma tACS

tACS may have a **strong therapeutic potential** by promoting gamma oscillations expression and plasticity

The application of gamma tACS in healthy individuals and neurological patients has been associated with **improved cognitive performance** (e.g., Alzheimer, Mild Cognitive Impairment)

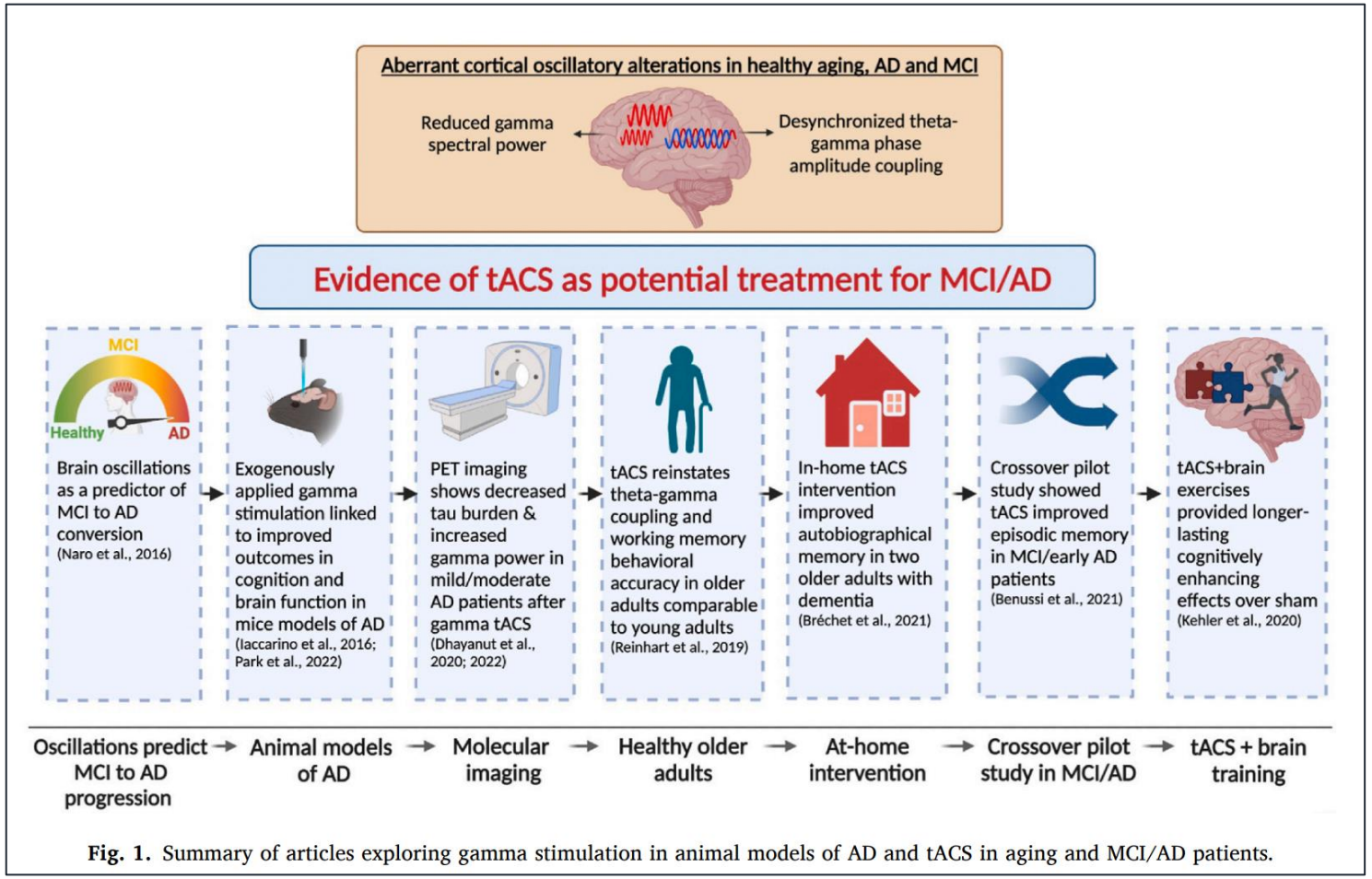
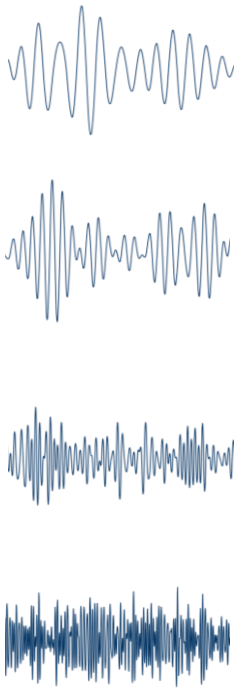


Fig. 1. Summary of articles exploring gamma stimulation in animal models of AD and tACS in aging and MCI/AD patients.

Nissim et al. (2023), Brain Stim

tACS

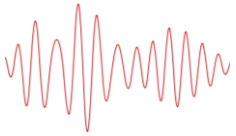
And Language?



tACS and Language

There are still **few studies** investigating the effects of tACS on language processing.

Theta



- 20’ at 6Hz, 1mA tACS on the left temporoparietal cortex during **implicit language learning** improves retrieval performance in older adults (Antonenko et al., 2016)

Alpha

- 20’ at 10Hz, 1mA tACS on bilateral posterior IFG (offline) facilitated **phonological response speed** and increased theta power during phonological decisions in young adults (Moliadze et al., 2019)
- 20’ at 10Hz, 1mA tACS on prefrontal cortex improved **phonemic fluency** in young adults (Sun et al., 2021)

Beta

- 15’ at 16.8 Hz, 1mA tACS on the left posterior IFG during a **phonological task** of two- or three-syllable words significantly impaired task accuracy relative to sham, without affecting response speed in young adults (Moliadze et al., 2021)

Gamma tACS and Language

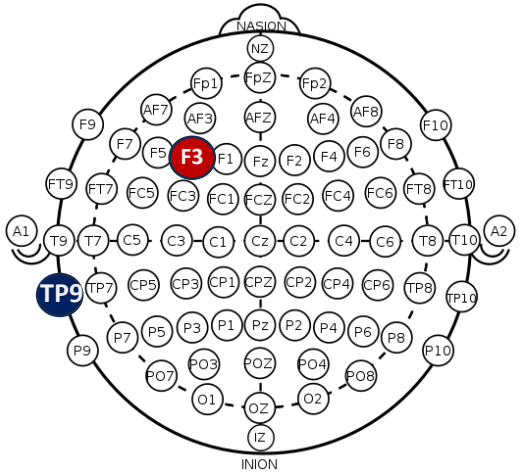
Author/Year	Aim	Sample/Design	Session	tACS Parameters	Site	Task	Results
Rufener et al. 2016a	To investigate the role of gamma tACS in speech perception.	36 healthy adults Between	Exp: 2 sessions - 7 days interval Control: 1 session	40 Hz (1mA – 18') 6 Hz (1mA – 18')	T7 - T8 bilateral auditory cortex	VOT phoneme categorization task	40 Hz tACS attenuated repetition-induced improvement in phoneme categorization
Rufener et al. 2016b	To compare the effects of tACS to modulate VOT processing	25 healthy young adults 20 healthy older adults Between	2 sessions- 6 days interval	40 Hz (1mA – 16') 6 Hz (1mA – 16')	T7 and T8 bilateral auditory cortex	VOT phoneme categorization task	40 Hz tACS diminished task accuracy in young adults. 40 Hz tACS increased precision in phoneme categorization in older aldults.

Gamma tACS and Language

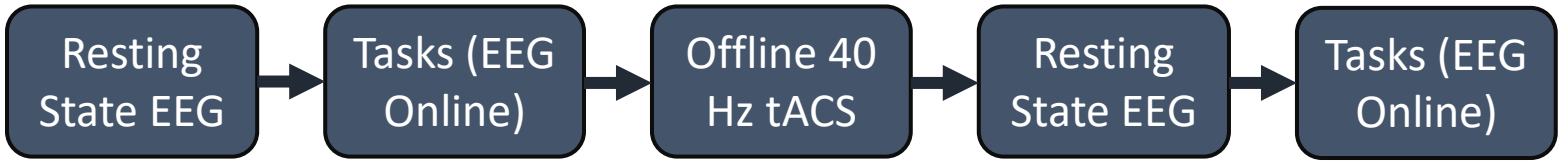
Author and year	Aim	Sample/Design	Session	Parameters	Site	Task	Results
Rufener et al. 2019	To investigate the effects of tACS/tES on phoneme processing in individuals with developmental dyslexia (DD)	Study 1: 19 adolescent DD Study 2: 15 adult DD Within	Study 1: 3 sessions - 7 days interval Study 2: 3 sessions - 7 days interval	Study 1: 40 Hz tACS (0.95mA - 20'), tRNS (1mA - 20') Study 2:40 Hz tACS (1.33 mA – 20'), tRNS (1.5 mA – 20')	Study 1: T7 and T8 bilateral auditory cortex Study 2: T7 and T8 bilateral auditory cortex	Study 1:VOT phoneme categorization task Study 2:VOT phoneme categorization task	Study 1: 40 Hz tACS improved phoneme categorization in adolescents with DD Study 2: 40 Hz tACS improved phoneme categorization in adults with DD
Marchesotti et al. 2020	To investigate the effects of HD-tACS on phonological processing and reading accuracy in individual with dislexia	Experimental group: 15 adults DD Control group: 15 healthy adults Between	4 sessions (1 language and cognitive assessment, 3 experimental days with 10 days interval combined with tACS)	30 Hz tACS (1.1 mA – 20'), 60 Hz tACS (1.2 mA), sham.	4 × 1 ring configuration at TTP7h, FTT9h, FCC5h, CPP5h, and TPP9h (left auditory cortex)	Pseudoword repetition Spoonerism Text reading	30 Hz tACS improved phonological processing and reading accuracy

Gamma tACS effects on syntactic processing and inhibitory control

- **Design**: randomized crossover within subject
- **Participants**: 30 young adults (20-35)
- **2 Sessions**, 7 days washout
- **Tasks**: Syntactic Violation and Stroop
- **Stimulation parameters**: offline 40Hz tACS (20', 2mA)



Unilateral **dlPFC** montage



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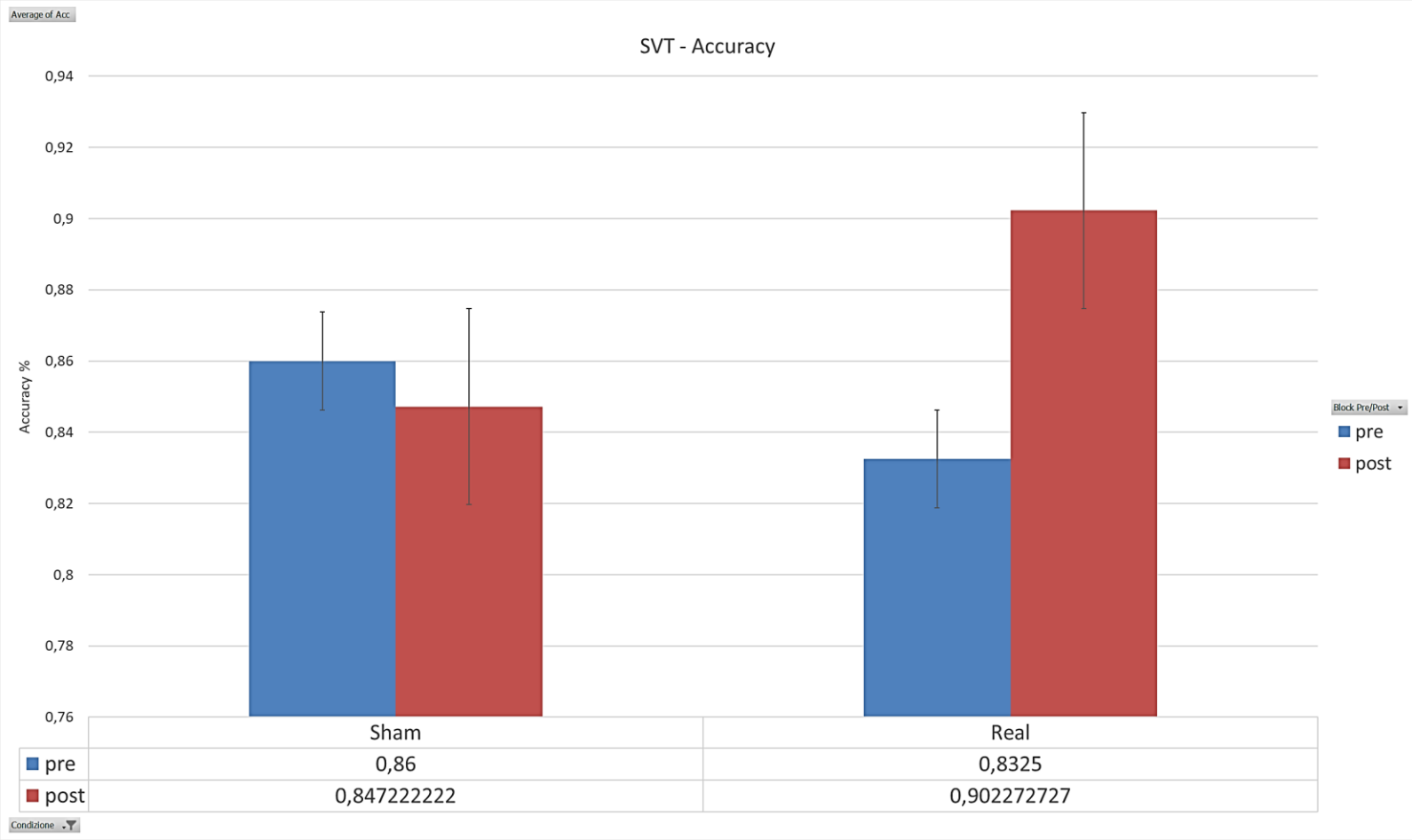
Partial Results (n=10) - Syntactic Violation Task

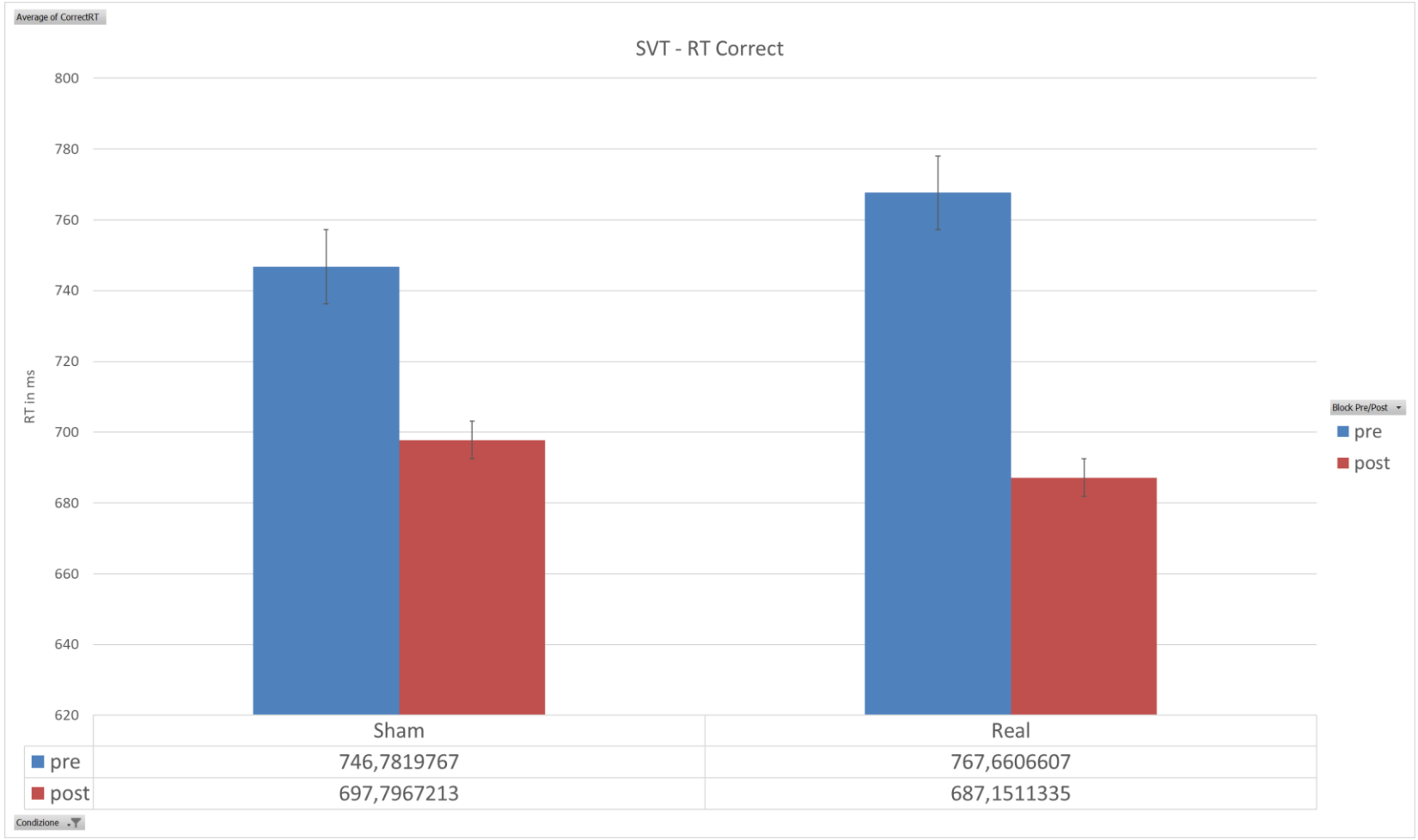
Accuracy (%)



	Sham	Real
pre	0,86	0,8325
post	0,847222222	0,902272727

Partial Results (n=10) - Syntactic Violation Task

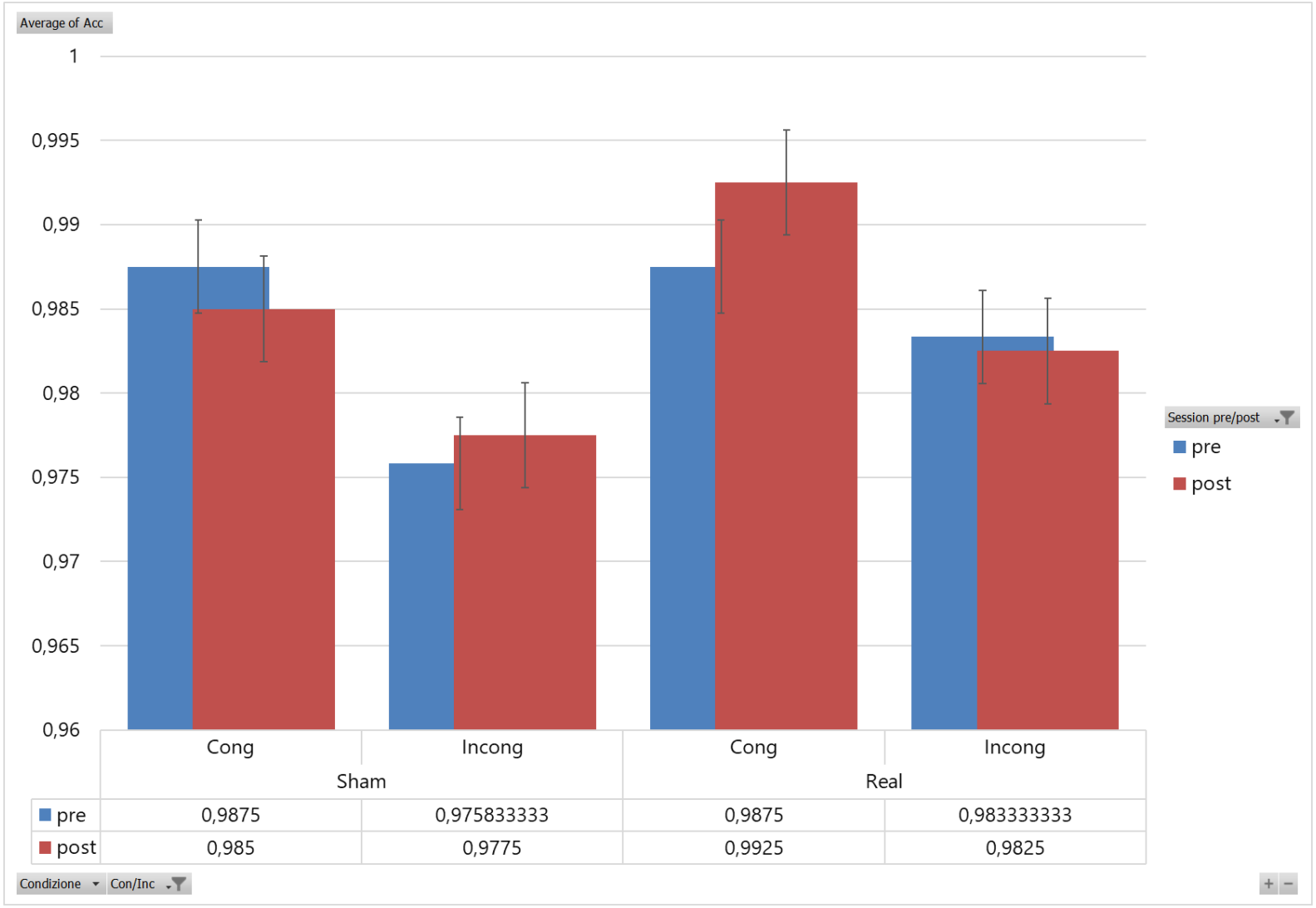
Reaction Time (ms)



	Sham	Real
pre	746,7819767	767,6606607
post	697,7967213	687,1511335

Partial Results (n=10) – Color-Word Stroop

Accuracy (%)



	Sham		Real	
	Cong	Incong	Cong	Incong
pre	0,9875	0,975833333	0,9875	0,983333333
post	0,985	0,9775	0,9925	0,9825

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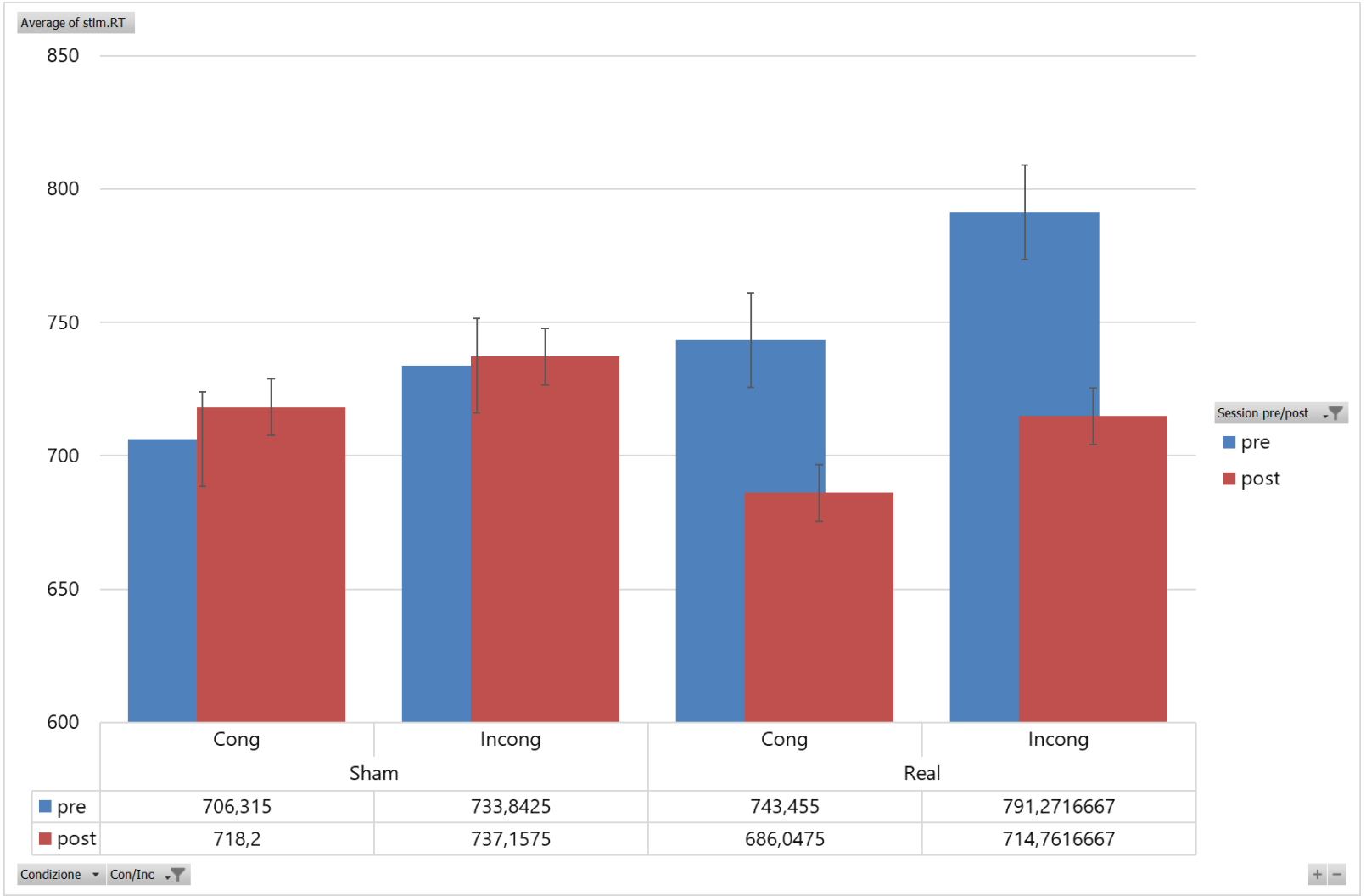
Partial Results (n=10) – Color-Word Stroop

Reaction Time (ms)



	Sham Cong	Sham Incong	Real Cong	Real Incong
pre	706,315	733,8425	743,455	791,2716667
post	718,2	737,1575	686,0475	714,7616667

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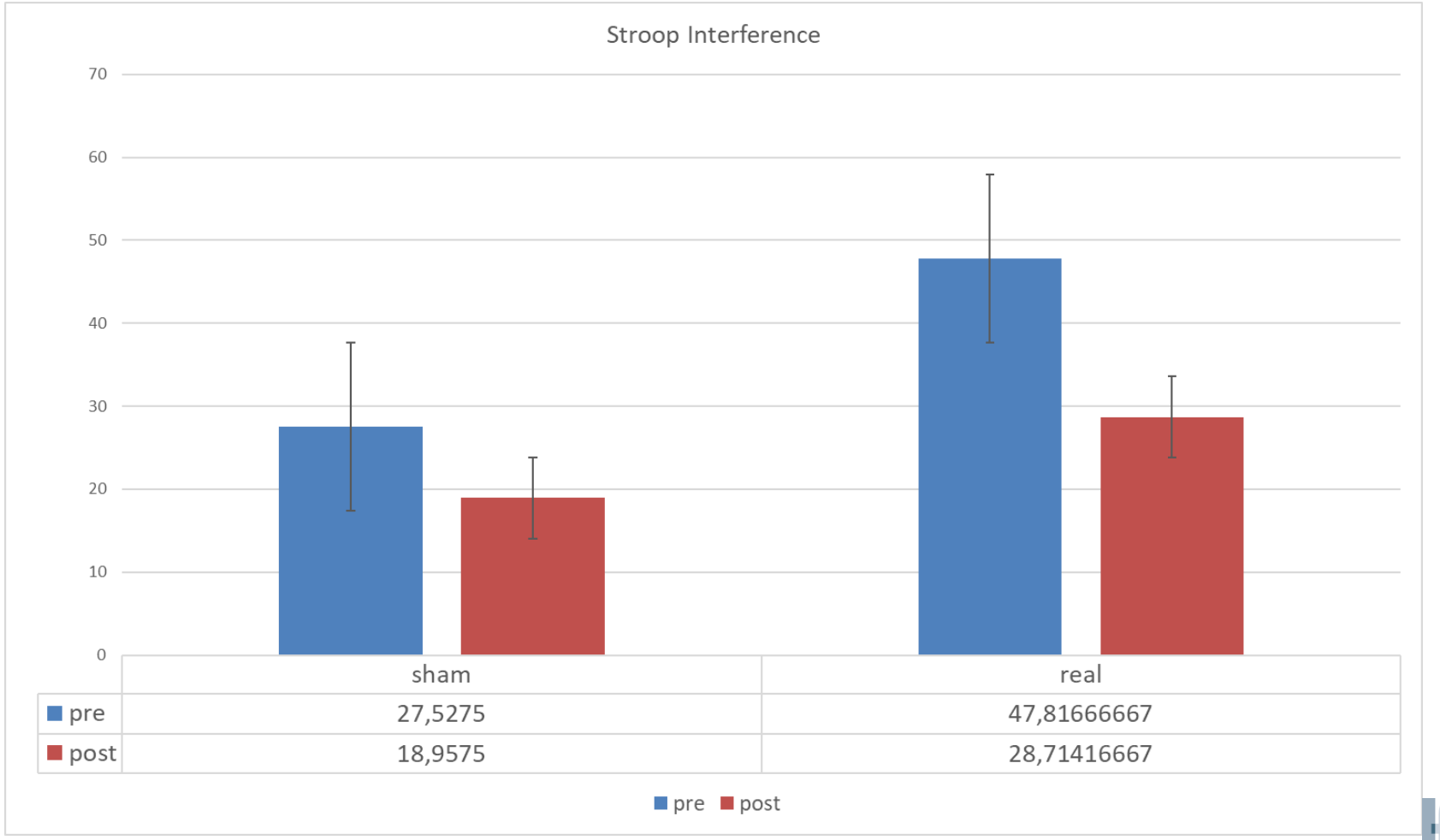
Partial Results (n=10) - Stroop Interference

Incongruent-congruent (ms)



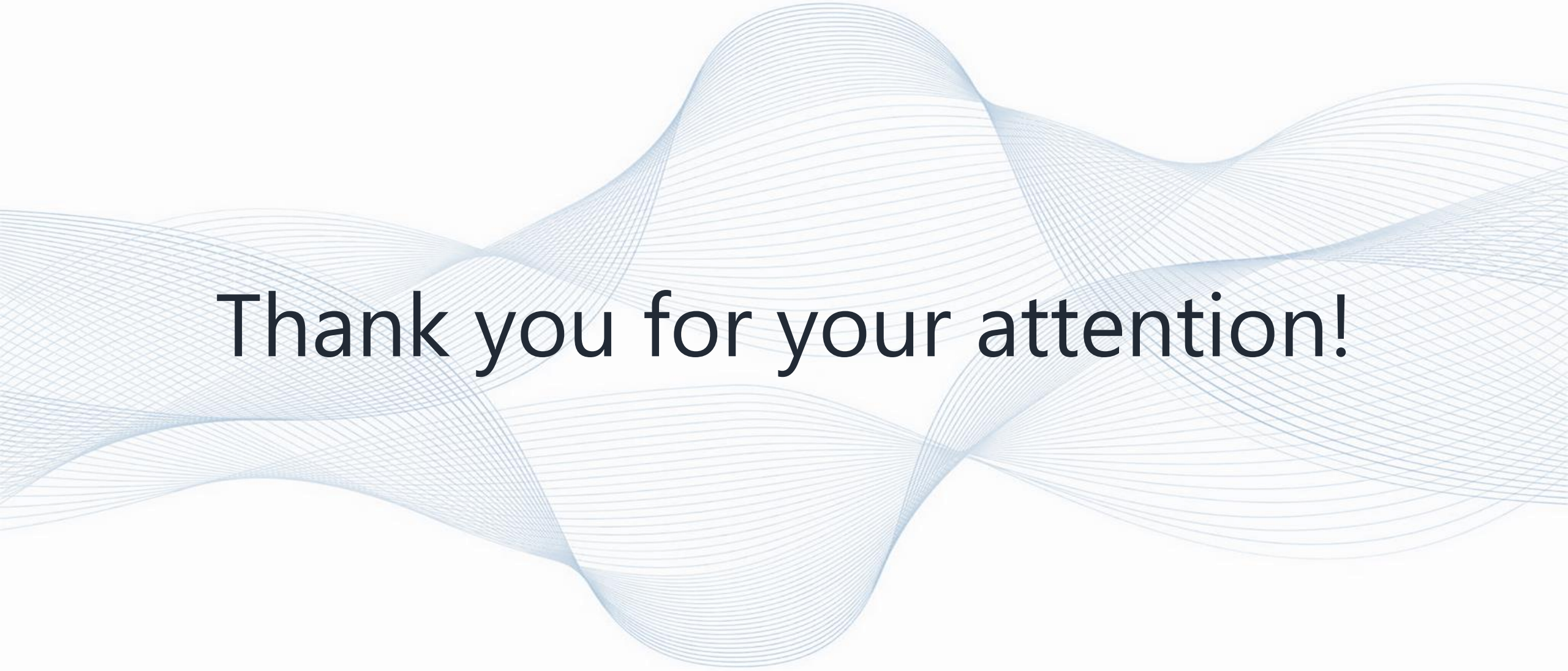
Concluding Remarks

Our partial findings show:

- A possible involvement of gamma tACS in the syntactic violation task in terms of accuracy and reaction times
- A possible effect of gamma tACS in inhibitory control in terms of reaction times

It would be interesting to investigate the effects of tACS by considering:

- Patients with language impairment, such as post-stroke aphasia
- Different linguistic tasks (e.g., semantic violation, verb and noun naming, picture naming)
- Different areas devoted to language processing (e.g., Broca's Area, Wernicke's Area)
- Different stimulation parameters (frequency, intensity, duration, electrode size, control conditions)
- Comprehensive analysis involving MRI, EEG and behavioral data


Thank you for your attention!

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