Decoding frequency-specific tACS modulation of fMRI network connectivity

Tibor Auer[1], Romy Lorenz[2,3], Ines Violante[1]

1. School of Psychology, Faculty of Health and Medical Sciences, University of Surrey, Guildford, Surrey, United Kingdom
2. Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
3. MRC Cognition and Brain Sciences Unit, Cambridge, Cambridgeshire, United Kingdom

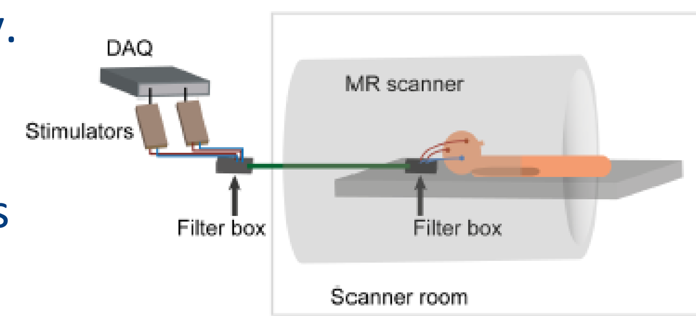
Introduction

Paradigm shift

Recent studies emphasize connectivity rather than regional specificity.
Cognition emerges from coordinated interplay between brain regions.
↓
Modulating functional connectivity could shape cognitive functions.

Transcranial Alternating Current Stimulation (tACS)

tACS can modulate functional connectivity.
tACS shows a dependency on trait- and state-related factors
The choice of tACS stimulation parameters to modulate specific functional connectivities is not trivial.

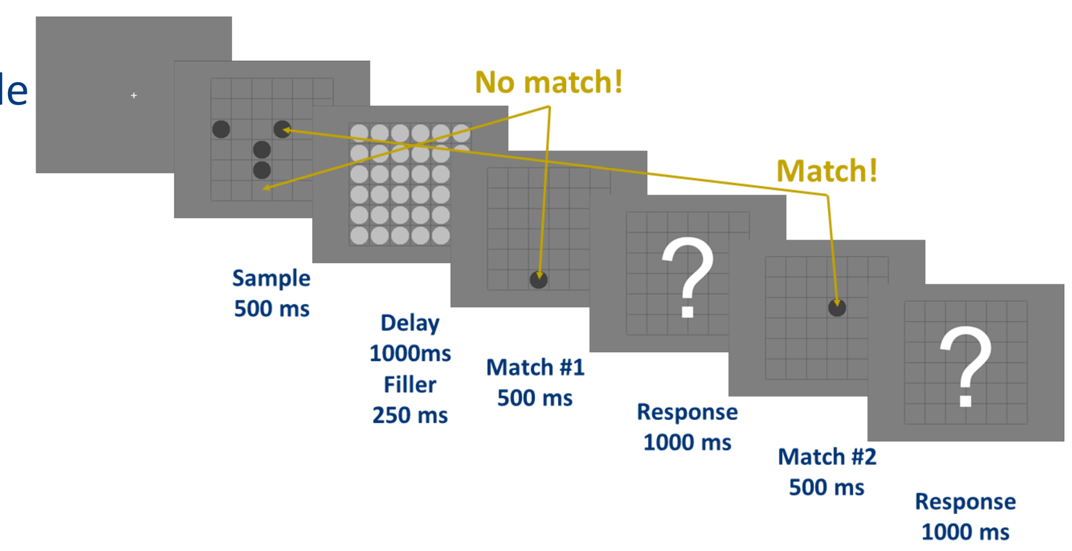


Questions

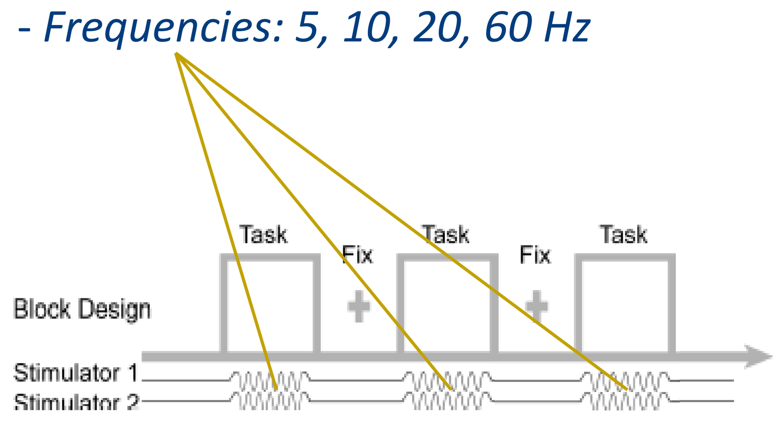
Does different stimulation frequencies impact brain dynamics differently?
Can this variability be measured using imaging approaches that can verify the effects of stimulation?

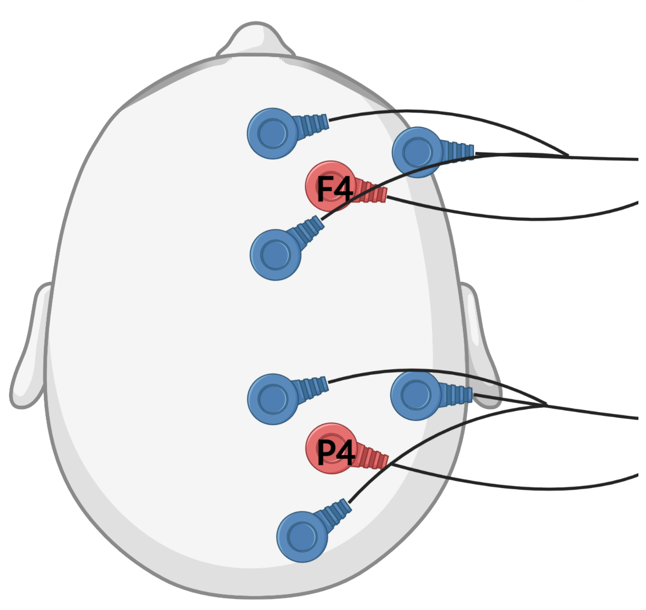
Methods

Cognitive task:
Repetitive Match-to-Sample (spatial working memory)



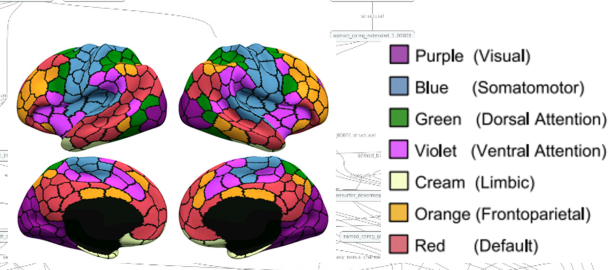
HD-tACS
- Dual-channel (F4, P4)
- Intensity: <=1 mA per channel
- *Frequencies: 5, 10, 20, 60 Hz*



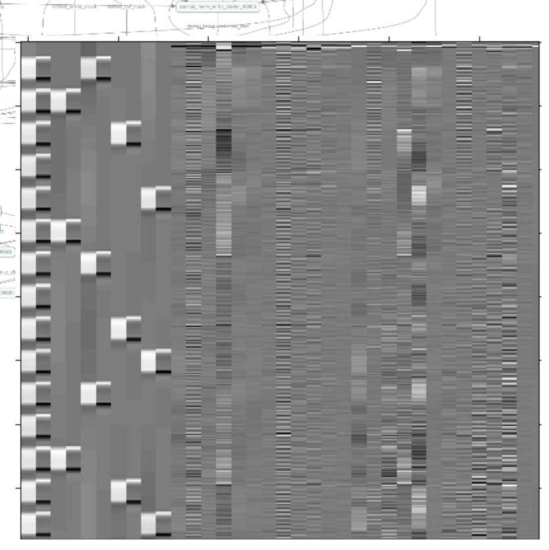


fMRI
- Siemens TIM Trio 3T
- MB-EPI, 1.8 s TR
- 2.5 mm iso, full-brain coverage

Data processing and analysis
- Framework: automatic analysis 5.8
- Tools: SPM12, CONN (connectivity), TDT (multivariate)
- Atlas:
  - Schaefer
  - 7 networks
  - 100 parcellations



Modelling
- Activation
  - Task-evoked response
  - Stimulation as additive effect (each frequency)
  - Extended modelling of motion
- Connectivity: ROI-ROI gPPI
- Multivariate: SVM, L1 regularisation, LOO CV
  - Voxels within 7 bihemispheric networks
  - ROIs within 7 bihemispheric networks
  - ROI-ROI connectivity within 7 bihemispheric networks



Highlights

Framework to investigate the frequency-specificity of the tACS modulation, the prequisite for optimisation of the stimulation.

Behaviour and activation show no/little frequency-specificity → not suitable for optimisation

Connectivity within and between the *Dorsal Attention* and the *Control* networks shows frequency-specific information which also relates to behaviour. → good candidate for optimisation

Results

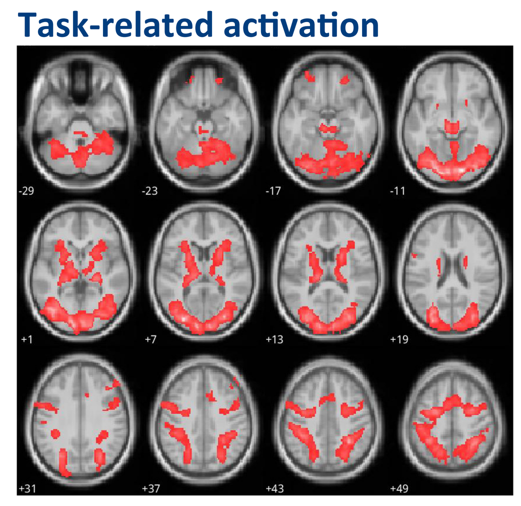
Behaviour

Strong effect of (re)match
- Increased reaction time
- Reduced accuracy and d-prime

Activation

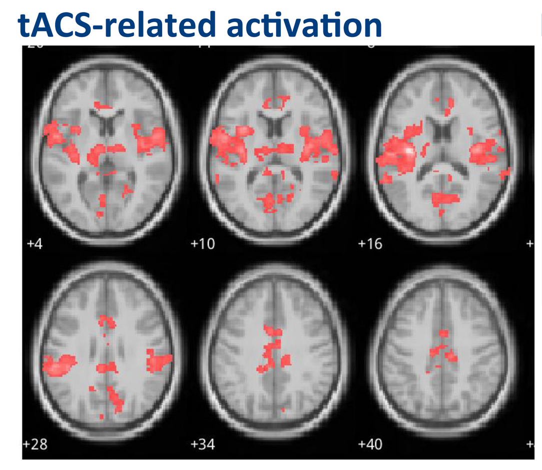
Univariate

Task-related activation



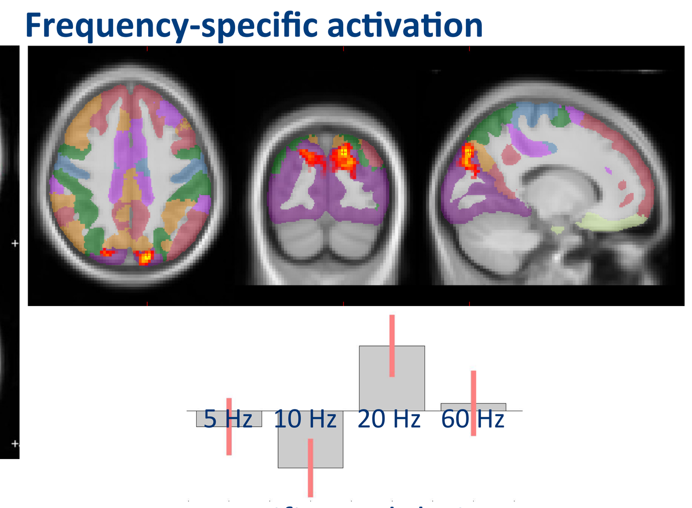
Salient, Control, and *Visual* networks

tACS-related activation



Salient, Limbic, and *Visual* networks

Frequency-specific activation



Frequency-specific modulation in the *Visual* network

Decoding
- Voxels within 7 bihemispheric networks: None
- ROIs within 7 bihemispheric networks: No multiclass

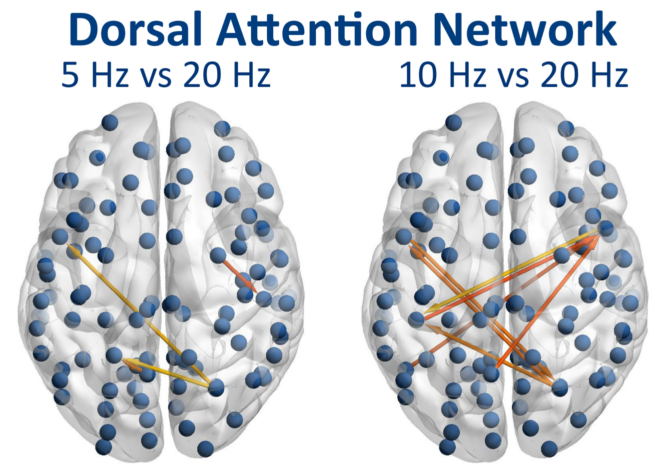
Connectivity

Decoding (ROI-ROI connectivity within 7 bihemispheric networks)

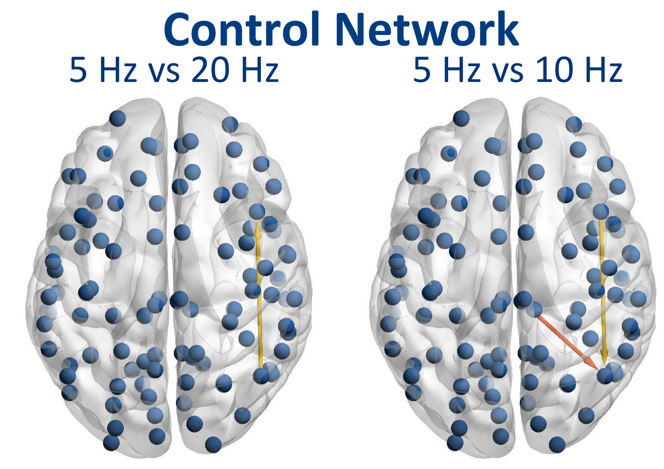
	multiclass	STIM10-STIM5	STIM20-STIM5	STIM5-STIM60	STIM10-STIM20	STIM10-STIM60	STIM20-STIM60
DorsAttn	**0.000312207**	0.25363128	**0.049948742**	0.290884146	**0.02511452**	0.160292771	0.100031808
Cont	**4.32413E-06**	0.176420617	**0.049948742**	0.303730892	**0.022695455**	0.189957161	0.102512472

Feature analysis (parwise comparison corrected for multiple tests)

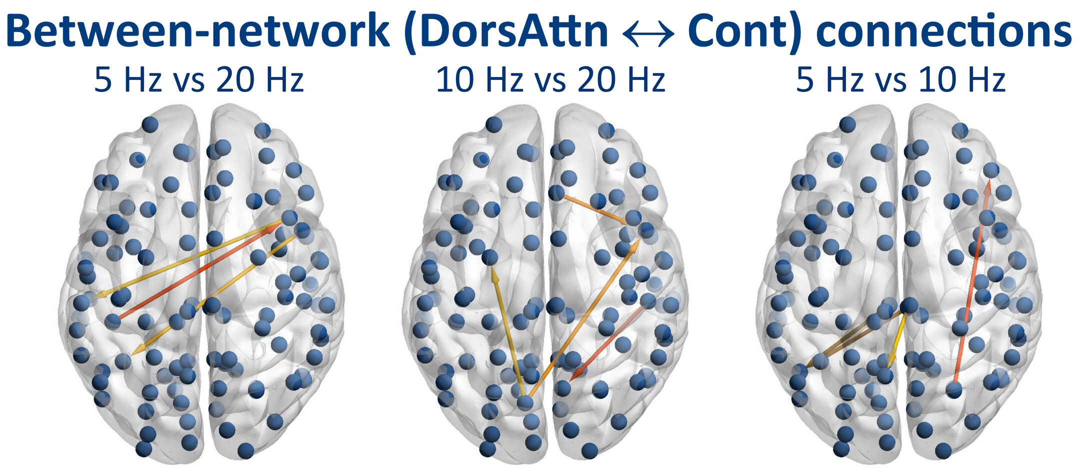
Dorsal Attention Network



Control Network



Between-network (DorsAttn ↔ Cont) connections



Correlation with behaviour
- 5 Hz vs 10 Hz network (*Control* and *DorsAttn ↔ Cont*):
  - Frequency-specific modulation (10 Hz) explains slower response for match #1
- 5 Hz vs 20 Hz network (*DorsAttn*, *Control* and *DorsAttn ↔ Cont*):
  - Frequency-specific modulation (20 Hz) explains slower response for match #1
- 10 Hz vs 20 Hz network (*DorsAttn*, *DorsAttn ↔ Cont*):
  - Frequency-specific modulation (20 Hz) explains faster response for match #2

References

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