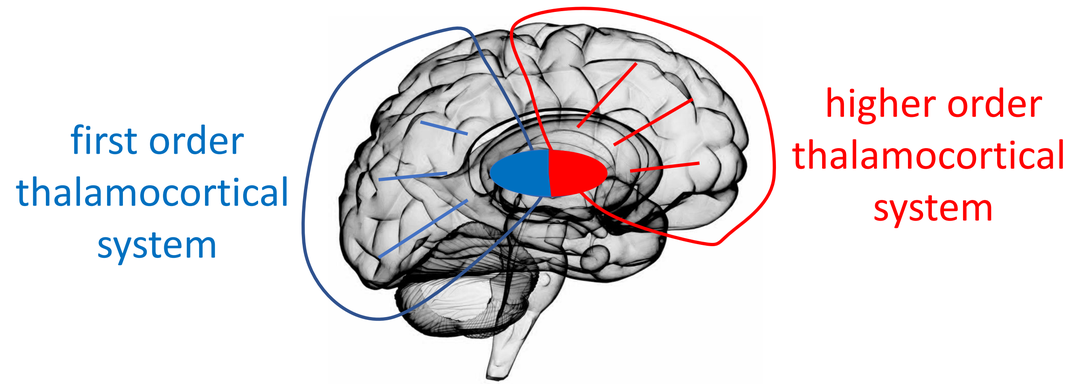
Intra-thalamic functional connectivity as a classifier for wakeful and anesthetized states in humans

J. ZIMMERMANN[1,2,4], R. NUTTALL[4], D. GOLKOWSKI[3],G. SCHNEIDER[4], A. RANFT[4], R. ILG[5], C. SORG[1,2,6] , A. WOHLSCHLAEGER[1,2]

[1]TUM-Neuroimaging Center, School of Medicine, Technical University Munich, Germany [2]Department of Neuroradiology, School of Medicine, Technical University Munich, Germany [3]Department of Neurology, School of Medicine, University of Heidelberg, Germany [4]Department of Anesthesiology and Intensive Care, School of Medicine, Technical University Munich, Germany [5]Department of Neurology, Asklepios Stadtklinik Bad Tölz, Germany [6]Department of Psychiatry, School of Medicine, Technical University Munich, Germany

BACKGROUND:

- Anesthesia relates to thalamocortical hyperpolarization
- Thalamocortical connectivity expresses itself via electrophysiological activity in the α range
- Thalamus is bi-partite: first order, higher order; connecting to different cortical regions



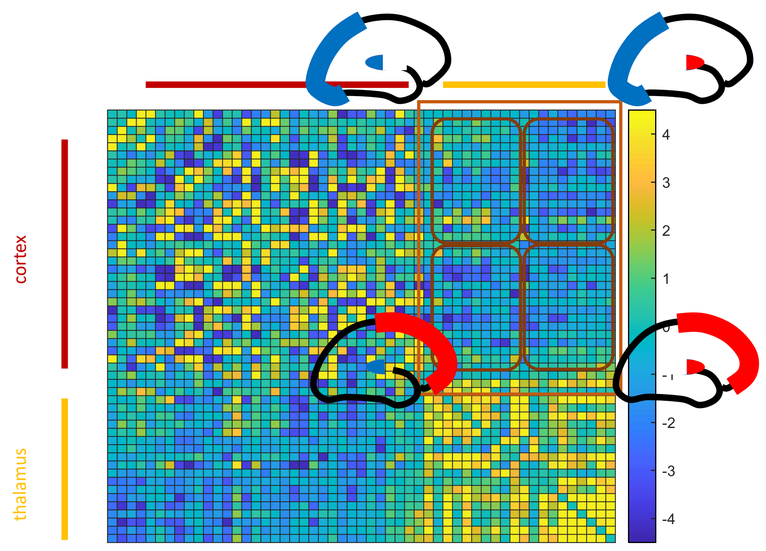
- Sevoflurane and propofol both act as a positive allosteric modulator of the $GABA_A$ receptor
- Models suggest qualitatively different impact of anesthetic onto the two distinct thalamocortical systems resulting in frequently observed anteriorization of α-power[1]
- During Sevoflurane and propofol anesthesia:

1. Does thalamocortical connectivity change between thalamic subregions and their respective cortical projection fields?
2. Is connectivity change related to state of consciousness or type of anesthetic?

METHODS:

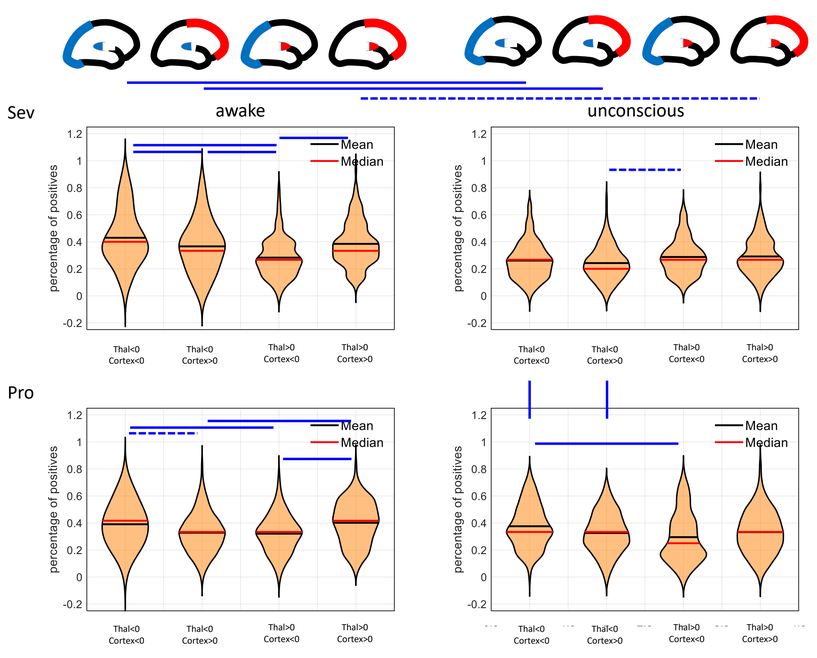
- rs-fMRI data from two studies in healthy males:
  - (i) with sevoflurane (**Sev**), 15 subjects[2],
  - (ii) propofol (**Pro**), 12 subjects[3]
- Preprocessing: Careful physiological artefact correction, slice-wise-movement correction; canonical pipeline; no smoothing
- Parcellation
  - Thalamus: Morel atlas[4] (12 thalamic nuclei),
  - Cortex: freesurfer[5]
- Subject-wise correlation matrices between thalamic and cortical parcels
- Z-scaling of correlation matrices
- Support vector machine (SVM) classification based on:
  - Intra-thalamic connectivities
  - Intra-cortical connectivities

RESULTS:



- **Fig.1 Z-transformed connectivity matrix (awake).** Connectivities within the thalamus (T) but also within the cortex (C) are higher than between them; **thalamocortical** connectivities posteriorC - posteriorT and anteriorC - anteriorT are higher than posterior - anteriorT and anteriorC - posteriorT

- In the awake state functional connectivity is higher within the two loop systems (higher order and first order) than across them (Fig. 1 & Fig. 2)
- Connectivities within the first order system reduce in Sev but not in Pro (Fig. 2)



- **Fig.2 Percentage of positive connections within systems and across.** Significant changes at $p < 0.05$ are indicated by blue lines

- SVM:

precision/%	cortex	thalamus
Sev	96.7	100.0
Pro	100.0	62.5

CONCLUSIONS:

- Sev and Pro have different effects on thalamocortical connectivity
- Sev: state of consciousness is reflected in intra-thalamic connectivity
- Pro: thalamocortical connectivity is left mostly unaltered

REFERENCES:

1. Weiner VS, Zhou DW, Kahali P, Stephen EP, Peterfreund RA, Aglio LS, Szabo MD, Eskandar EN, Salazar-Gomez AF, Sampson AL, Cash SS, Brown EN, Purdon PL. (2023) Propofol disrupts alpha dynamics in functionally distinct thalamocortical networks during loss of consciousness. PNAS 120(11):e2207831120. 2. Ranft, A., Golkowski, D., Kiel, T., Riedl, V., Kohl, P., Rohrer, G., Pientka, J., Berger, S., Thul, A., Maurer, M., Preibisch, C., Zimmer, C., Mashour, G. A., Kochs, E. F., Jordan, D., & Ilg, R. (2016). Neural Correlates of Sevoflurane-induced Unconsciousness Identified by Simultaneous Functional Magnetic Resonance Imaging and Electroencephalography. Anesthesiology, 125(5), 861-872. 3. Jordan, D., Ilg, R., Riedl, V., Schorer, A., Grimberg, S., Neufang, S., Omerovic, A., Berger, S., Untergehrer, G., Preibisch, C., Schulz, E., Schuster, T., Schroter, M., Spoormaker, V., Zimmer, C., Hemmer, B., Wohlschlager, A., Kochs, E. F., & Schneider, G. (2013). Simultaneous electroencephalographic and functional magnetic resonance imaging indicate impaired cortical top-down processing in association with anesthetic-induced unconsciousness. Anesthesiology, 119(5), 1031-1042. 4. Saranathan, M., Iglehart, C., Monti, M., Tourdias, T., & Rutt, B. (2021). In vivo high-resolution structural MRI-based atlas of human thalamic nuclei. Sci Data, 8(1), 275. 5. Fischl B. Automatically Parcellating the Human Cerebral Cortex. Cereb Cortex. 2004;14:11–22.

CONTACT: Juliana.zimmermann@tum.de, afra.wohlschlaeger@tum.de