Neuroscience in Freiburg
2022

Cognitive action control in rodents

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Optophysiology

Freiburg * May 13, 2022

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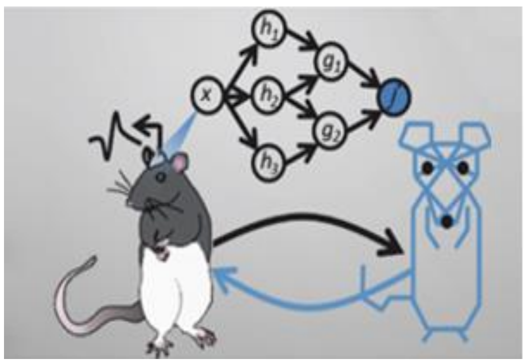
IMBIT

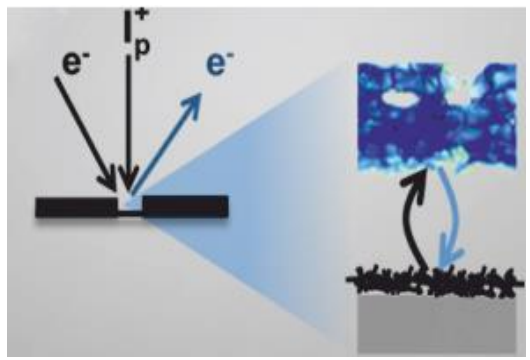
IMBIT Research program

NeuroCore



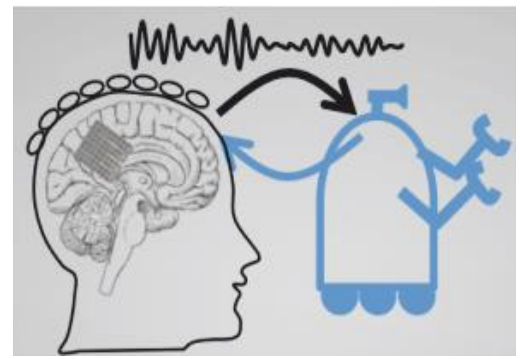
OptoRoboRat

NeuroProbes



Soft-FIB

NeuroBots



Machine-Brain-Interface

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OptoRoboRat Project

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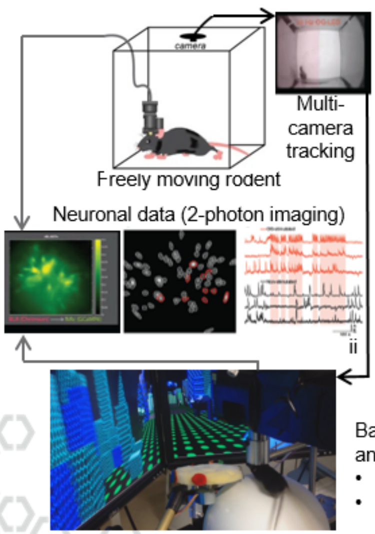
Intelligent Machine-Brain Interfacing Technology

OptoRat

optical imaging of neuronal activity combined with optogenetic stimulation

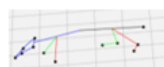


Head fixed rodent in virtual reality

Closed loop control of virtual environment

Behavioral tracking

Reconstructing complex movements in 3D

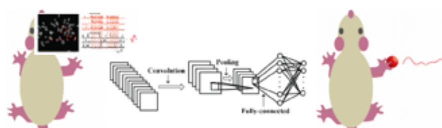


Based on decoding, simulations and RoboRat:

- Control virtual environment.
- Take out specific neurons via 2P targeted holographic optogenetic inhibition and observe behavioral outcomes.

Neuronal Decoding

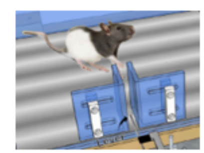
predict movements based on neuronal activity, extract knowledge about the ole of individual neurons via backpropagation

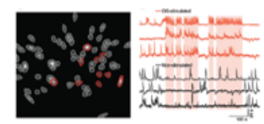


Extract behavioral patterns.
Take out specific "neurons/layers" and observe behavioral outcomes.

Computer simulated rat

simulate behavior based on neuronal data; compare learning rules in silico and in vivo





Take out specific neurons and observe behavioral outcomes.

RoboRat

apply biological control agorithms in a robotic scenario

Take out specific "control parts" and observe outcome.

Julian Ammer

Florian Steenbergen

Brice de la Crompe

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Functional heterogeneity in the rat prefrontal cortex supports correctly timed responses

Dr. Stefanie Hardung

Zoe Jäckel

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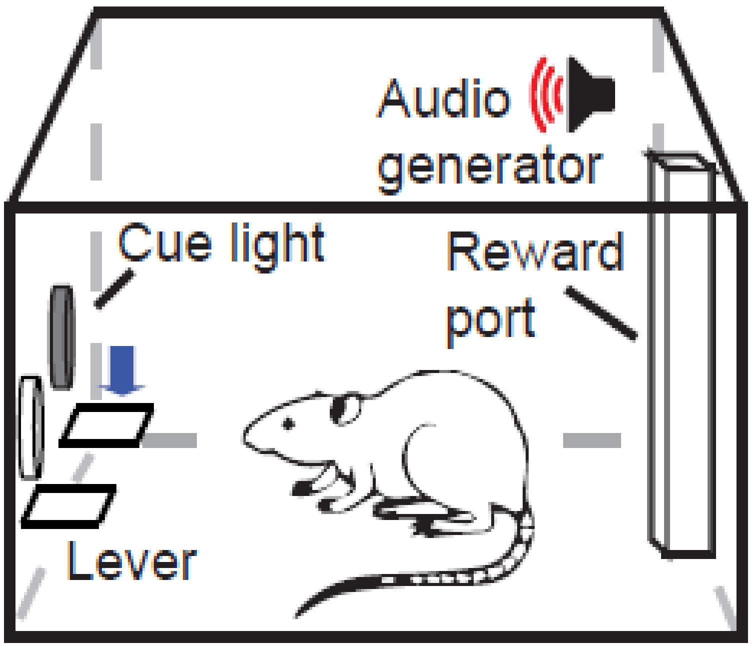
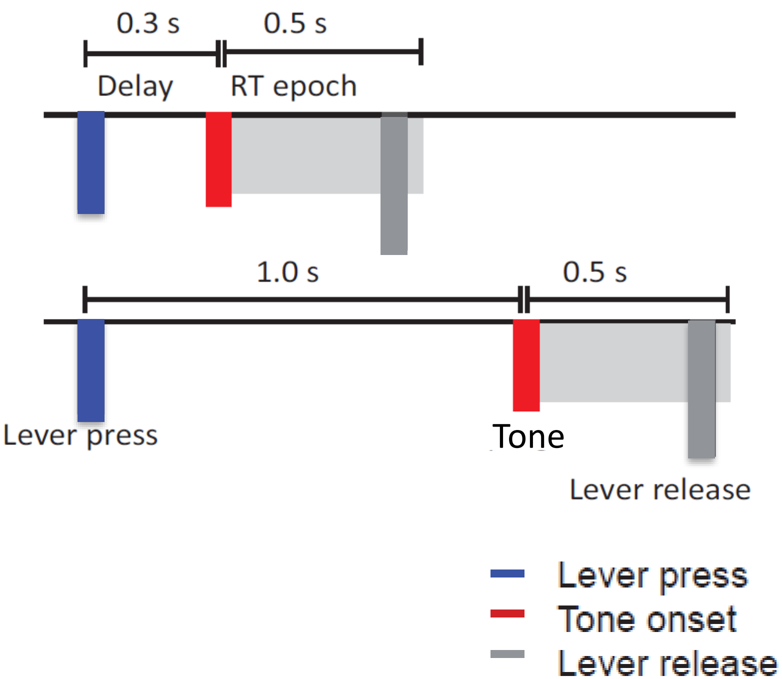
Our approach: A response preparation/inhibition task





Hardung, …, Diester, ***Current Biology*** (2017)

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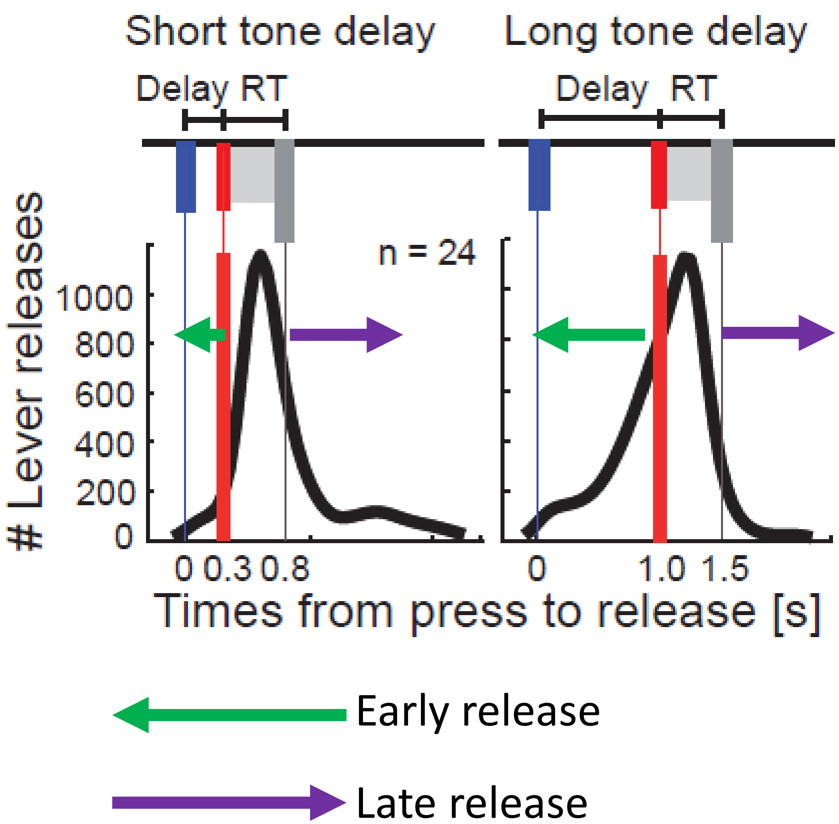
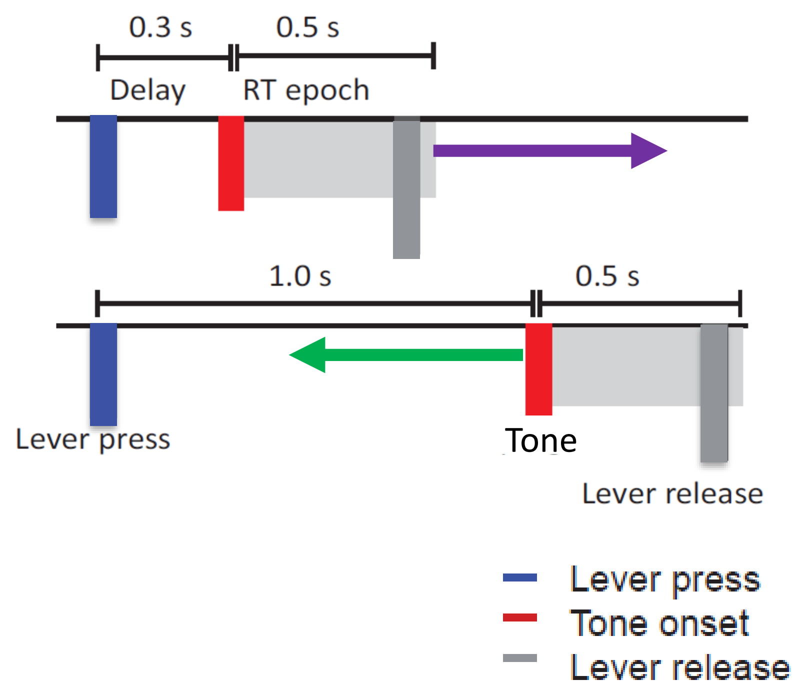
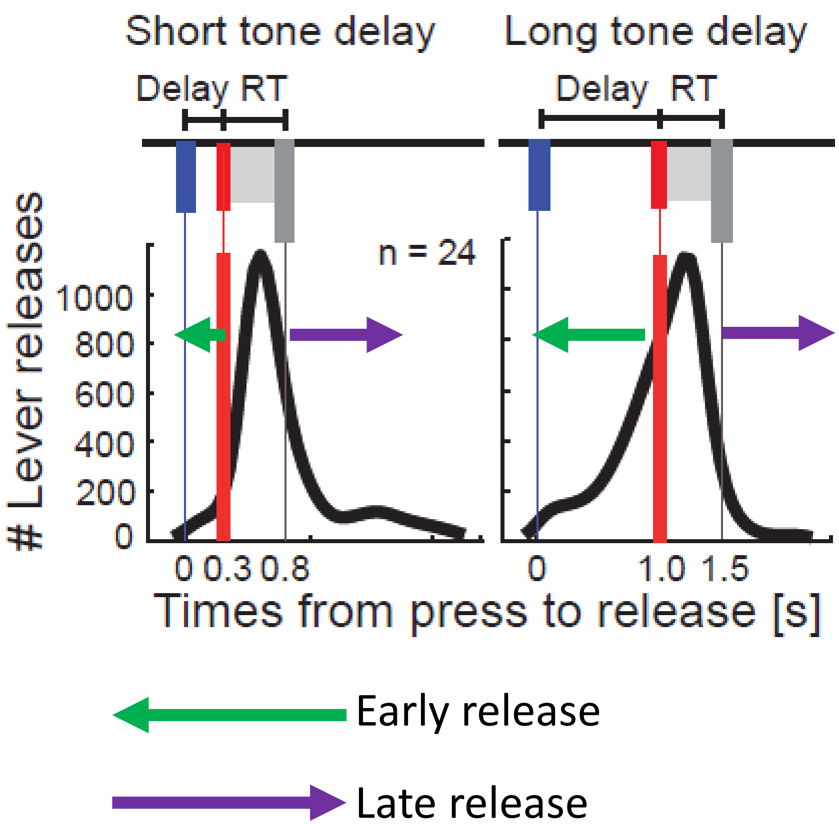
Two error types: early and late respones

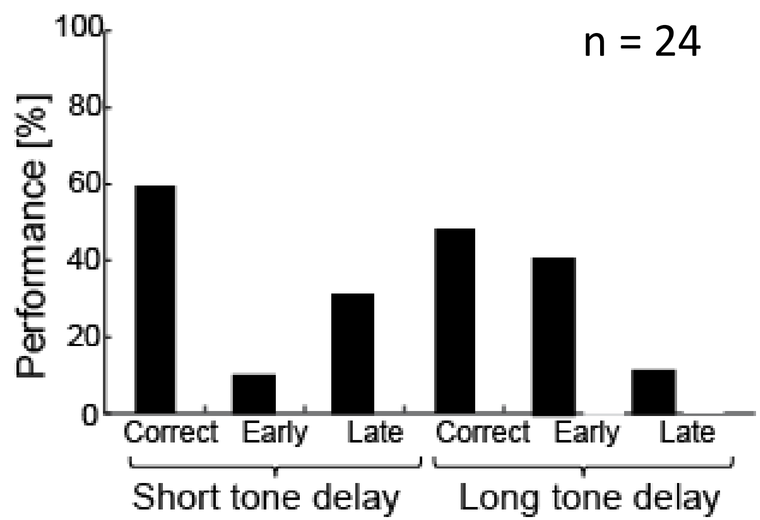




Hardung, …, Diester, ***Current Biology*** (2017)

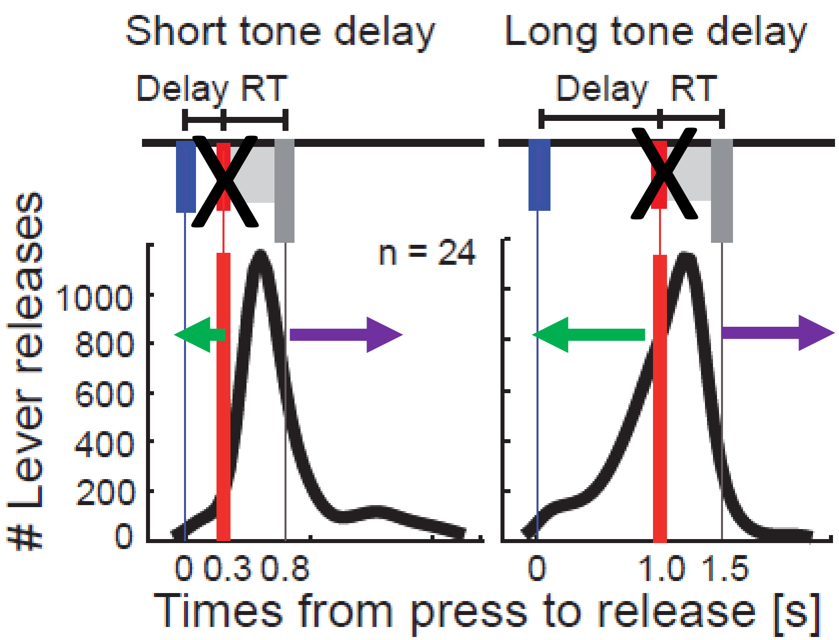
Two error types: early and late respones

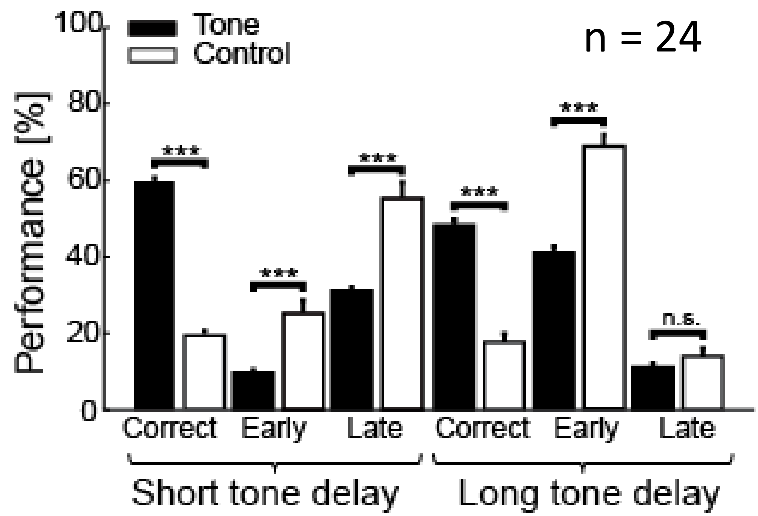




Hardung, …, Diester, ***Current Biology*** (2017)

The no tone control



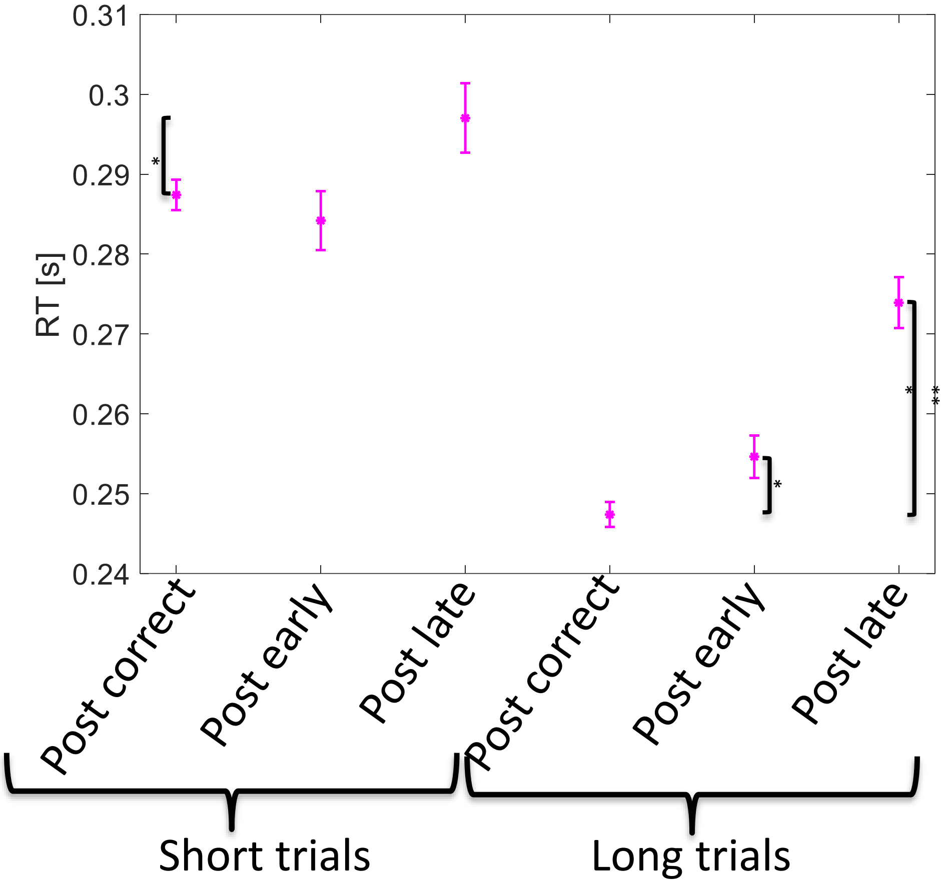


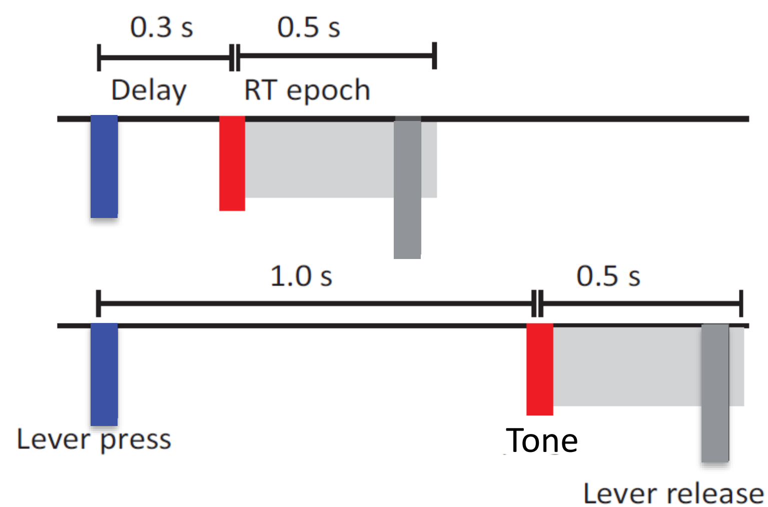
Early release

Late release

Hardung, …, Diester, ***Current Biology*** (2017)

Post error slowing





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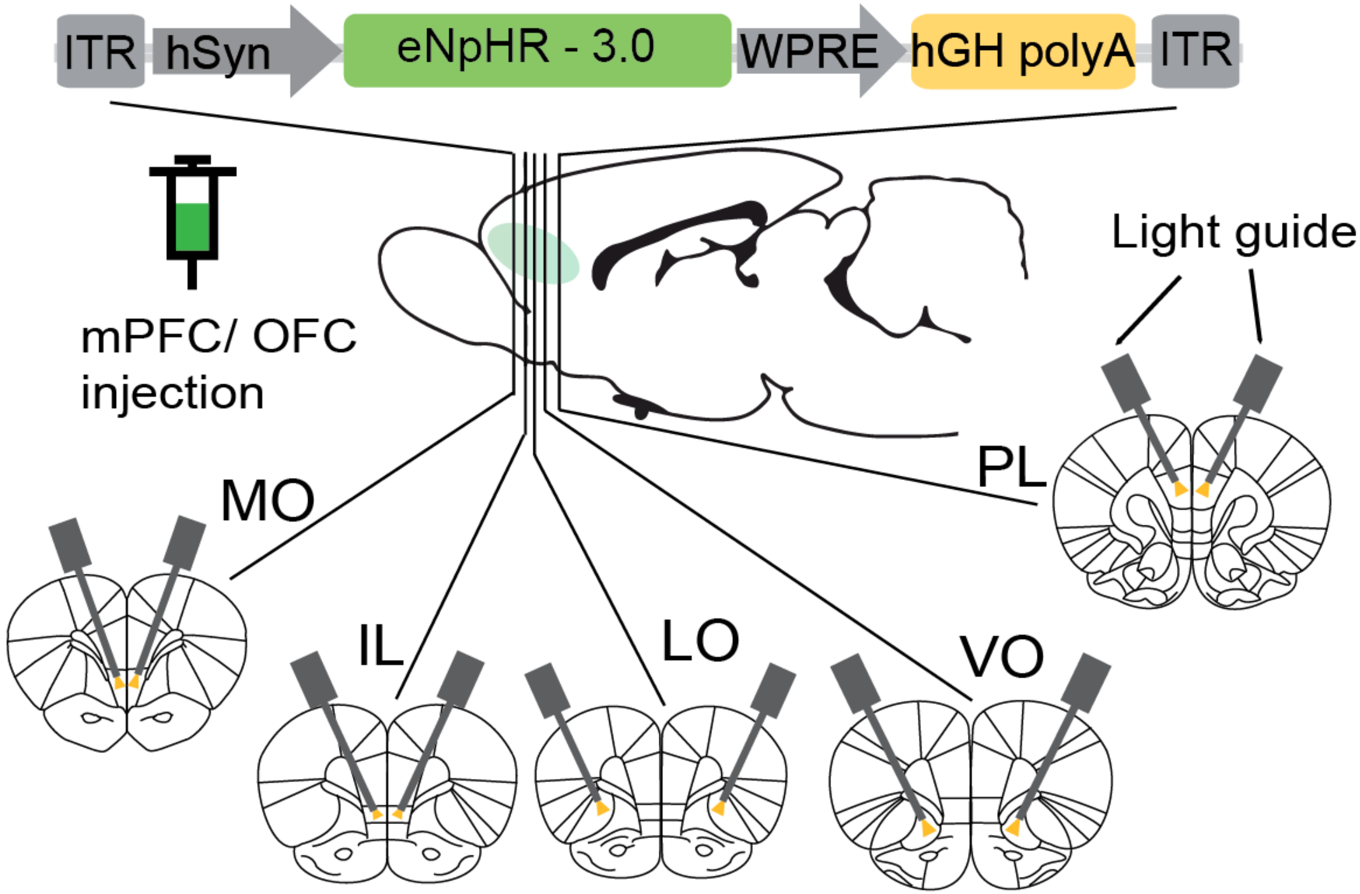
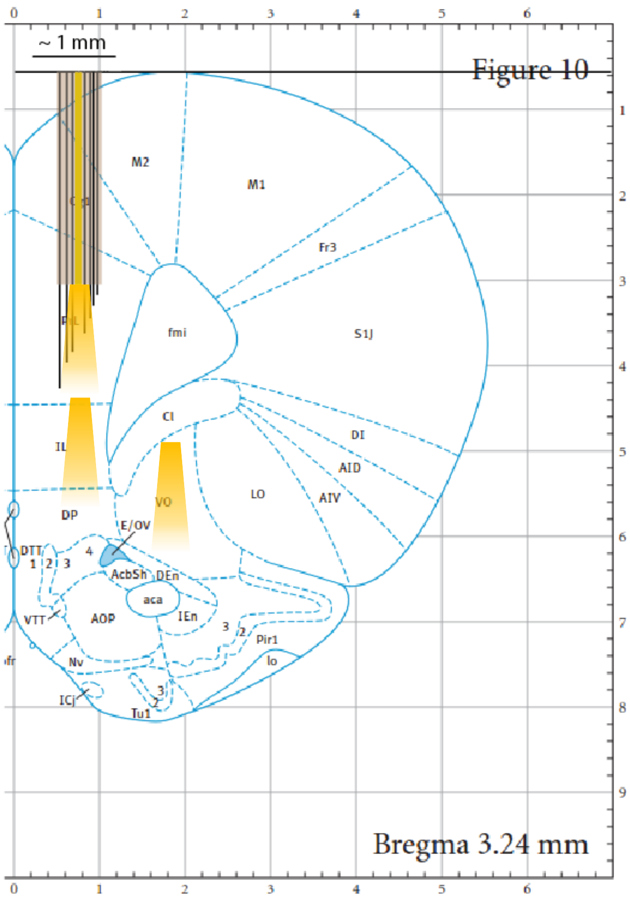
Optogenetic manipulations

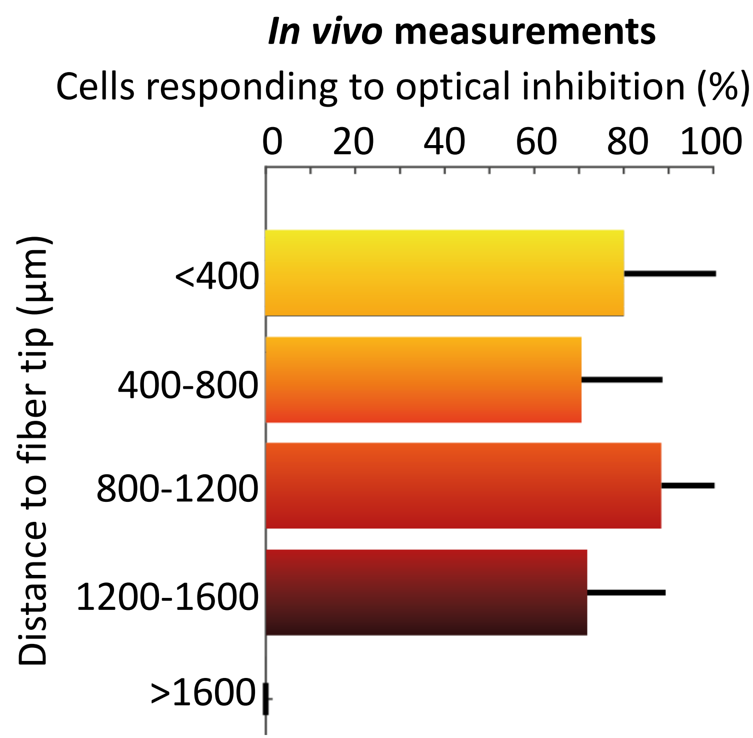
What is the causal impact of the PFC subsection in the task?



Hardung, …, Diester, ***Current Biology*** (2017)

Recording the effective spread of optical inhibition





Hardung, …, Diester, ***Current Biology*** (2017)

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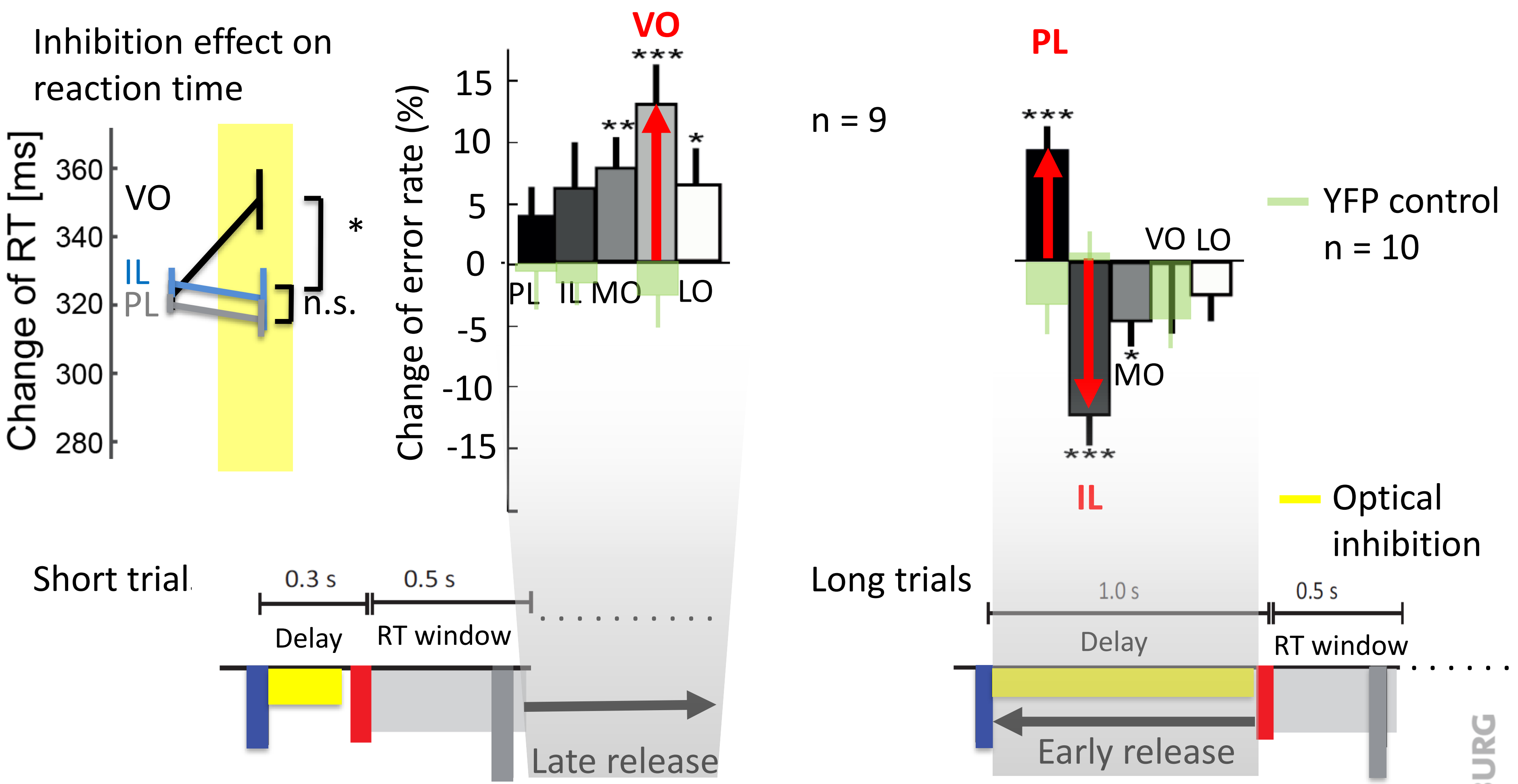
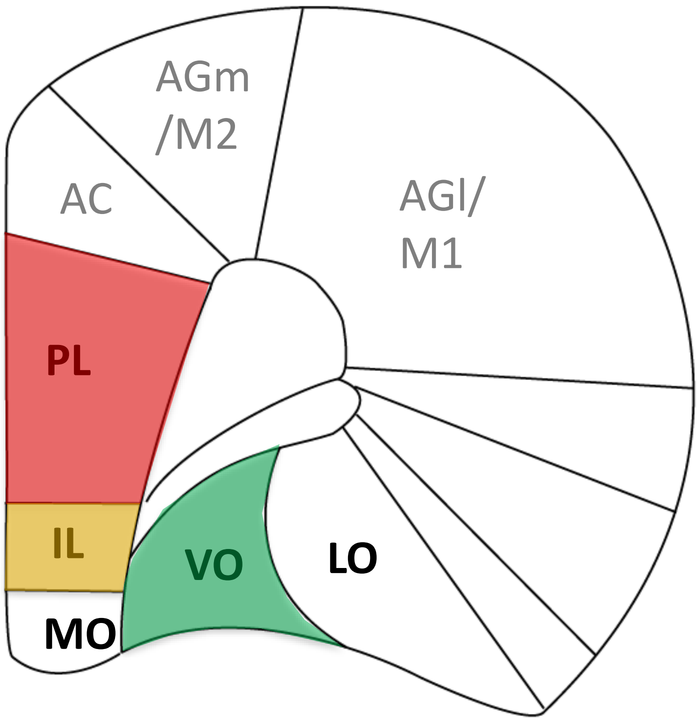
Effect of optical inhibition on behavior



Hardung, …, Diester, ***Current Biology*** (2017)

The traffic light in the PFC



PL suppresses the urge to act

IL enhances the urge to act

VO influences the reaction to the tone

Hardung, …, Diester, ***Current Biology*** (2017)

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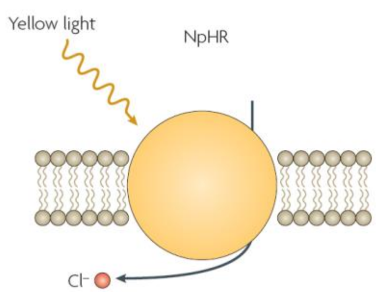
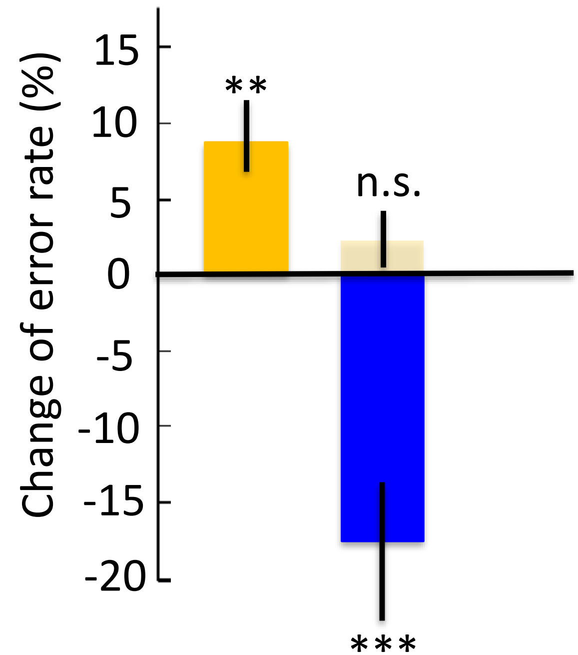
PL plays are very clear role in this task

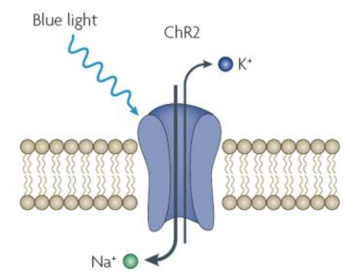
PL inhibition versus excitation have opposing effects

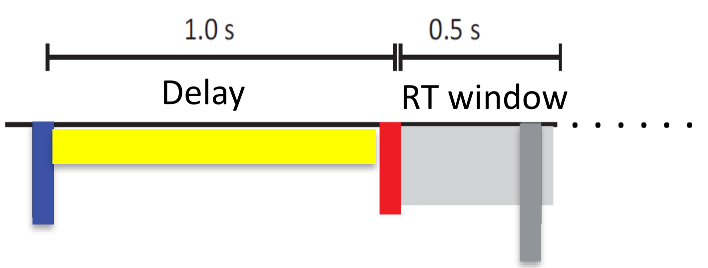
inhibition

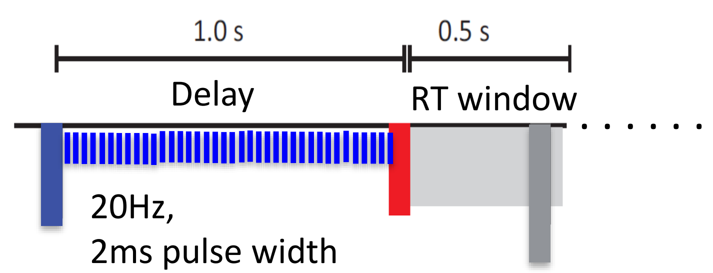




excitation



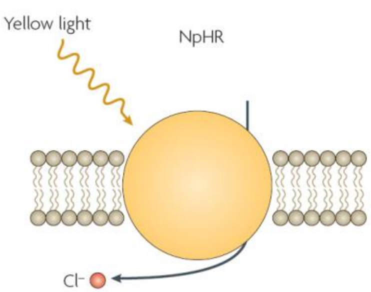


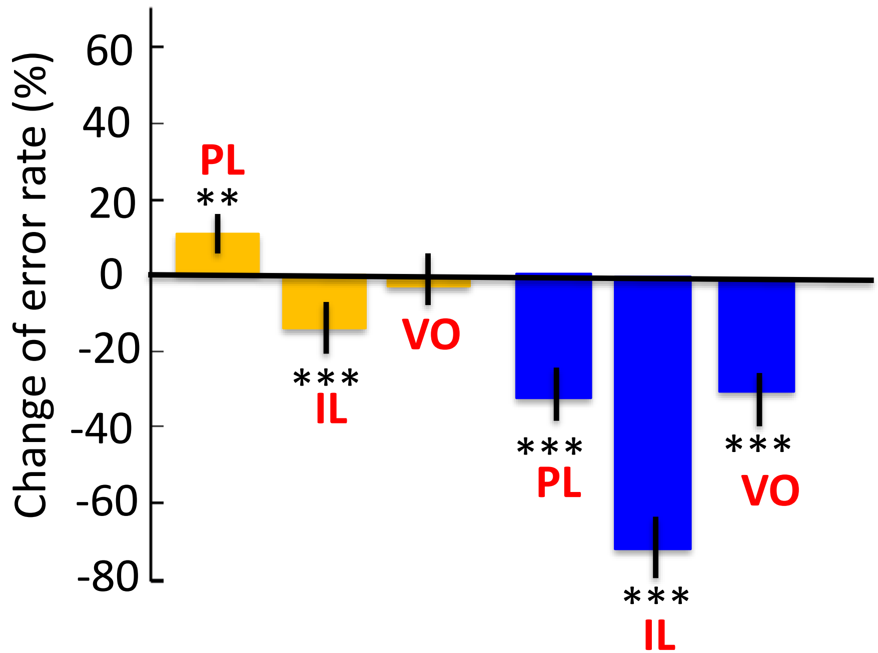


Zoe Jaeckel & Dominic Lau

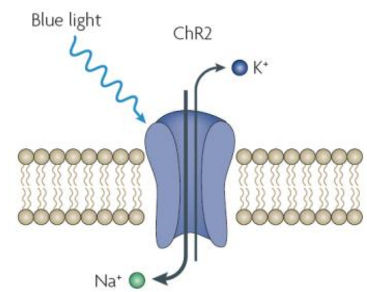
Optogenetic excitation results in similar effects in all three structures

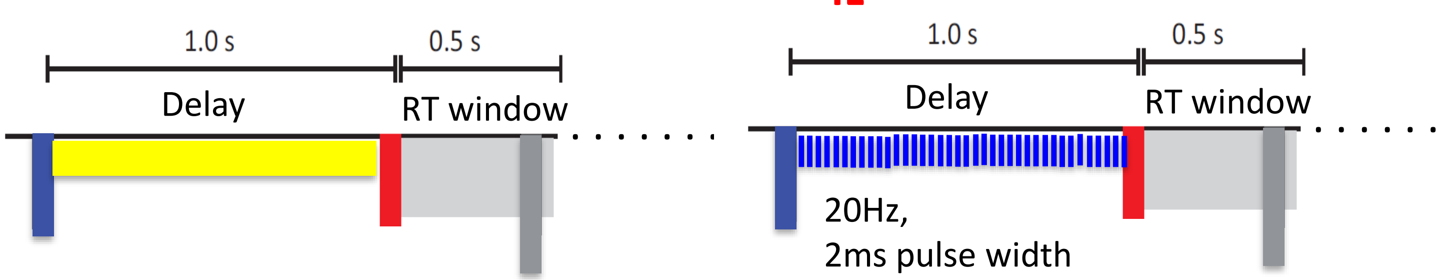
inhibition





excitation



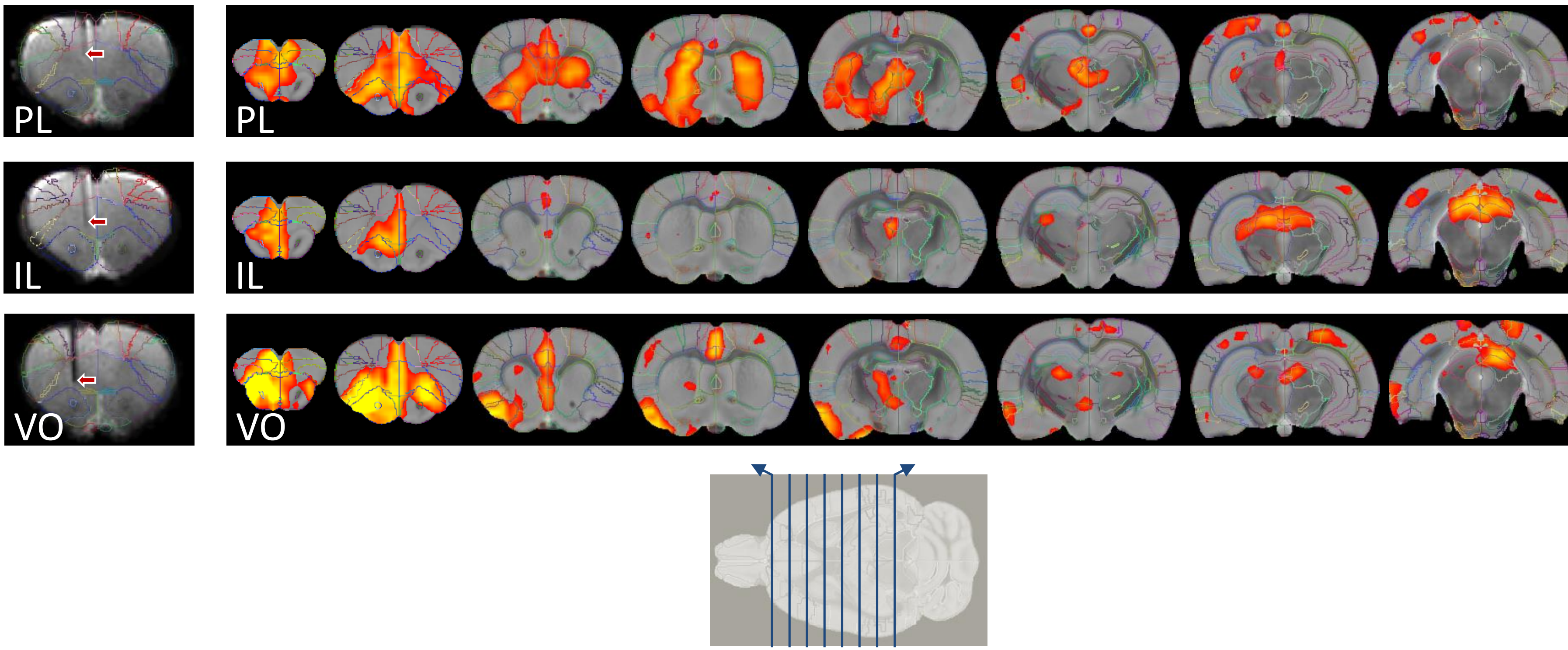


Zoe Jaeckel & Dominic Lau

Direct comparison of PL, IL , and VO stimulation

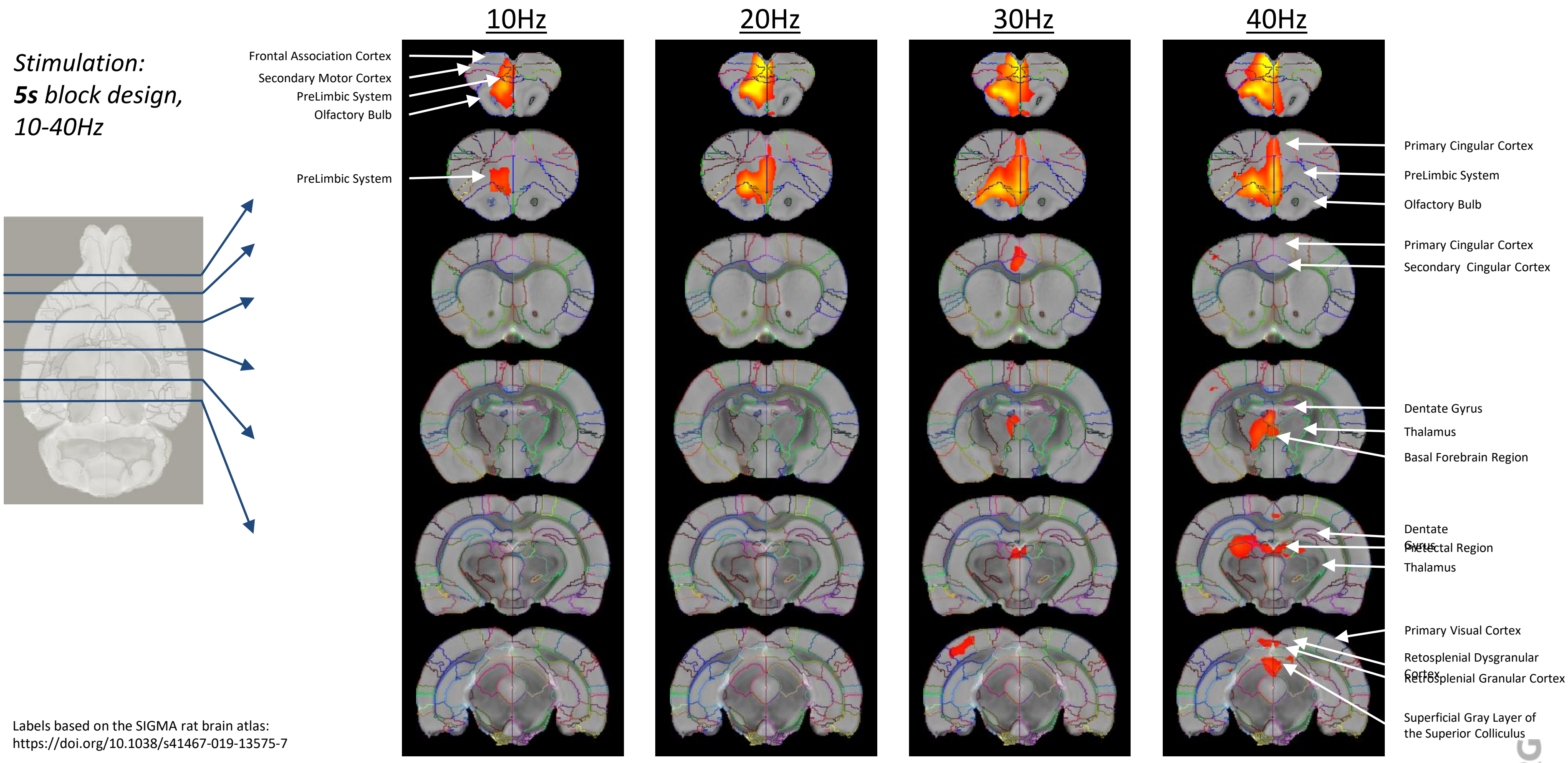
Fiber position

fMRI response at **30Hz** stimulation (**5s** block design)



Common response of PL, VO, IL stimulation

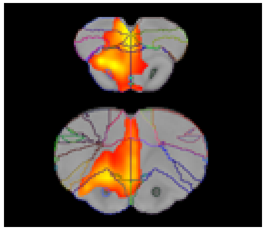
Stimulation:
***5s** block design,*
10-40Hz



Labels based on the SIGMA rat brain atlas:
https://doi.org/10.1038/s41467-019-13575-7

Take home message from opto-fMRI

- Optogenetic activation leads to far spread increase in neuronal activity with highly overlapping activation patterns
- We are currently running additional experiments including a PPI analysis



- Outlook: Establish correlation between behavior and network effect

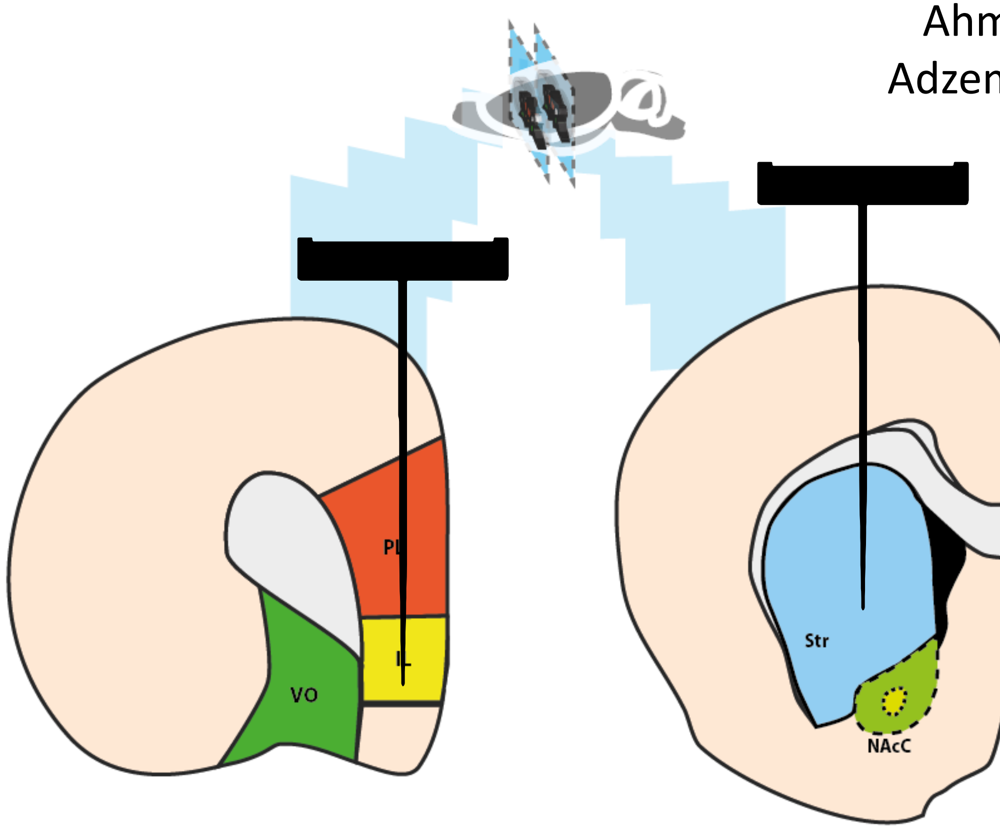
Optogenetic dissection of cortico-subcortical interactions during movement control in rodents

Ahmed Adzemovic

Rat lever press training

Ephys recordings

Optogenetic modulation



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Optogenetic dissection of cortico-subcortical interactions during movement control in rodents

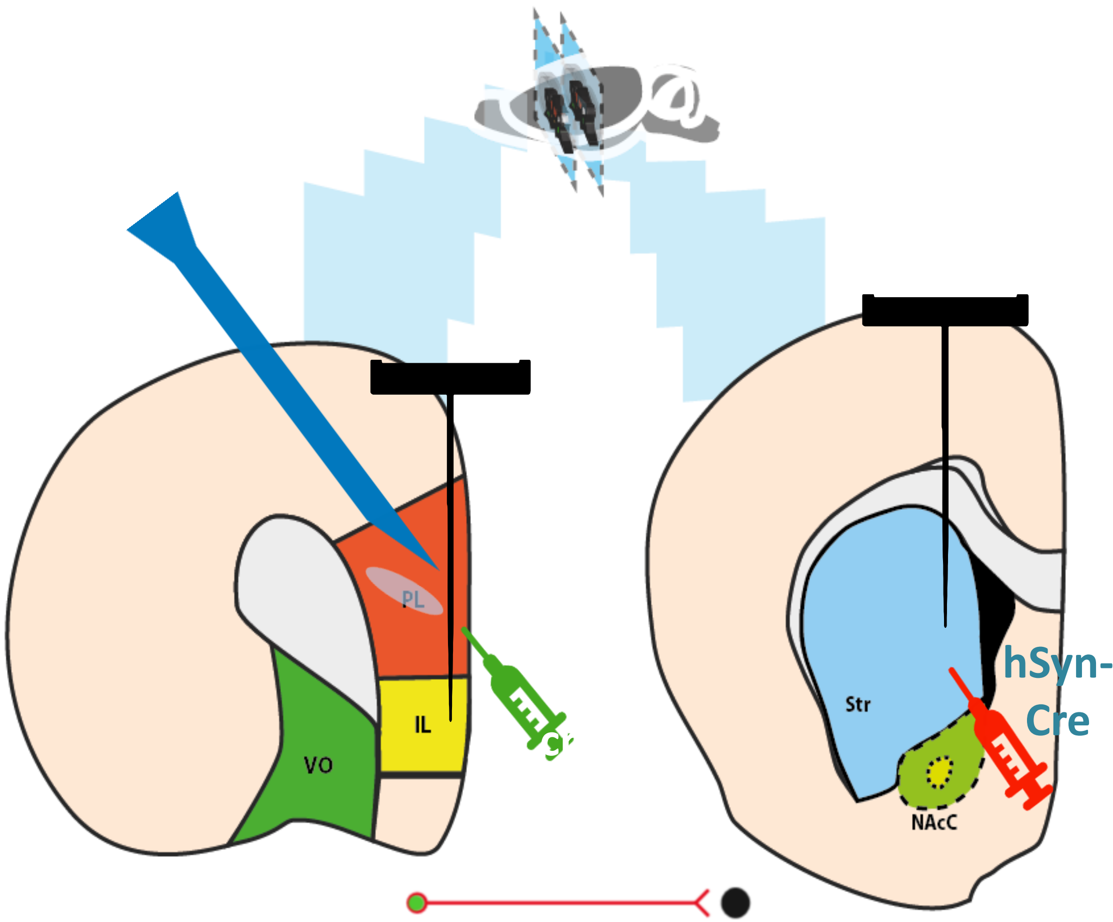
Rat lever press training

↓

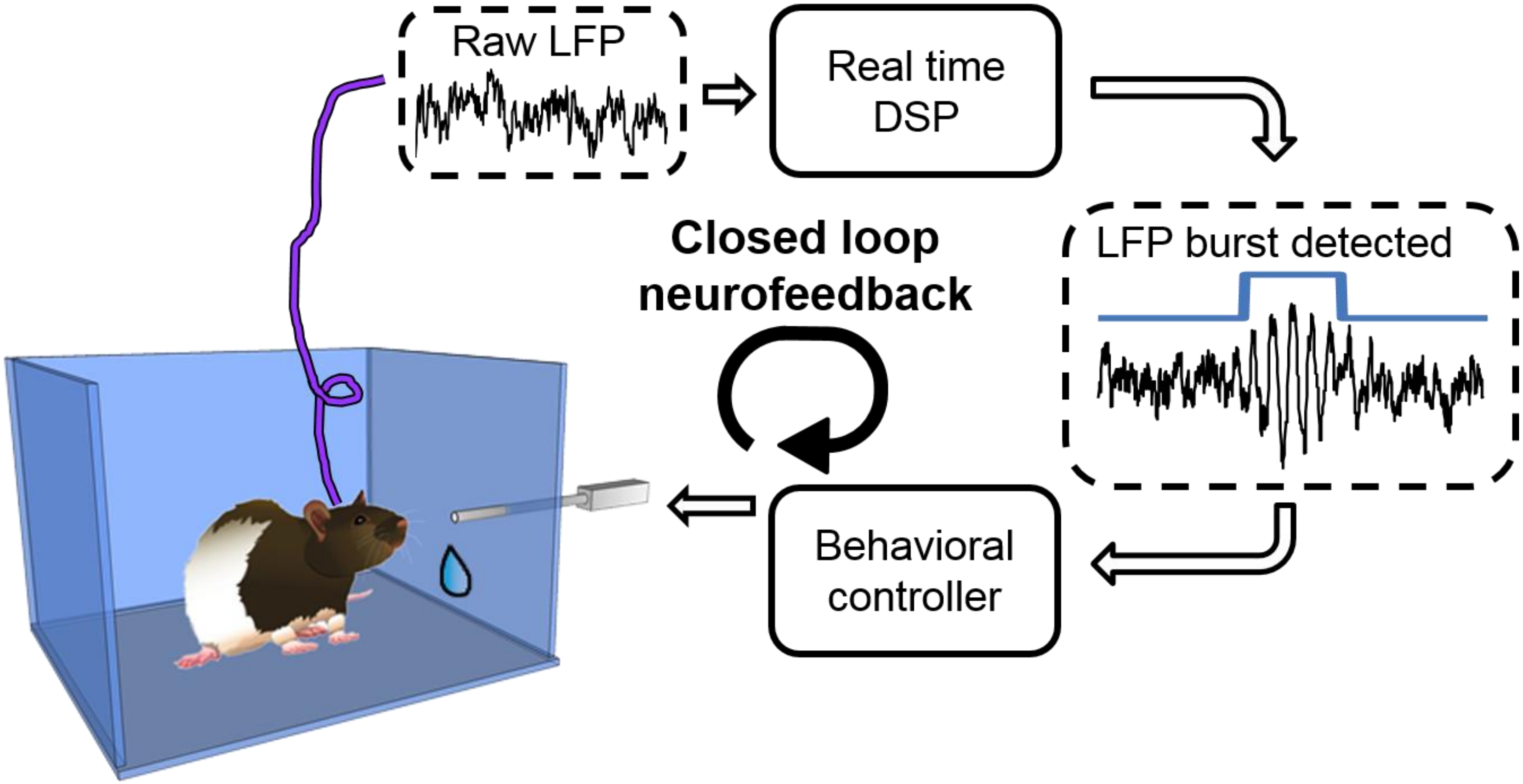
Ephys recordings

↓

Optogenetic modulation

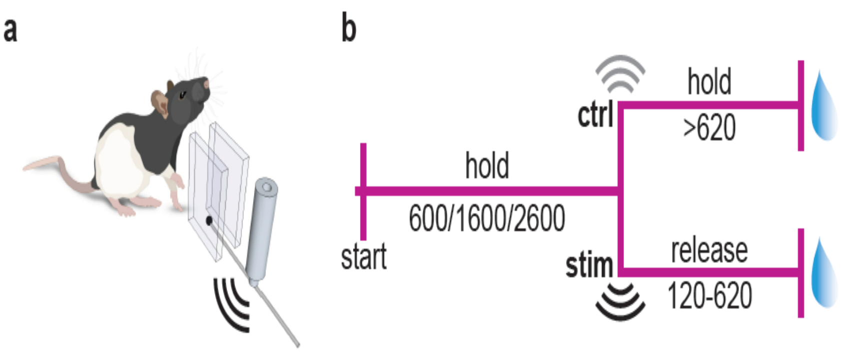


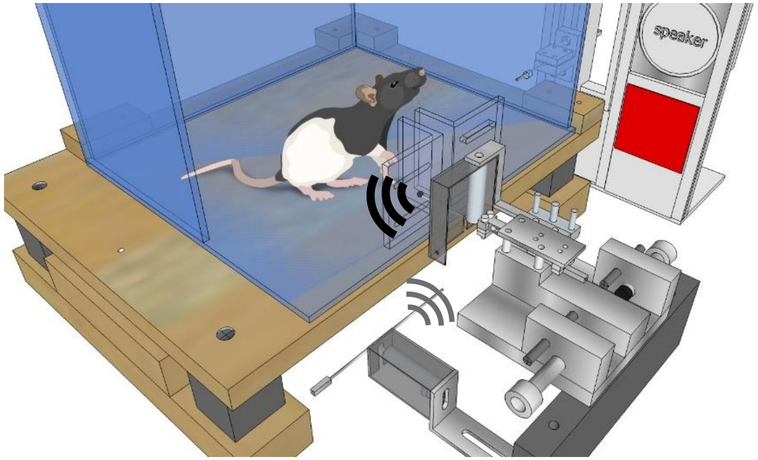
LFP-burst based real-time neurofeedback in rats



Karvat, …, Diester, ***Comm Biology*** (2020)

Influence on beta bursts on vibrotactile perception - the task





Karvat, …, Diester, ***PNAS*** (2021)

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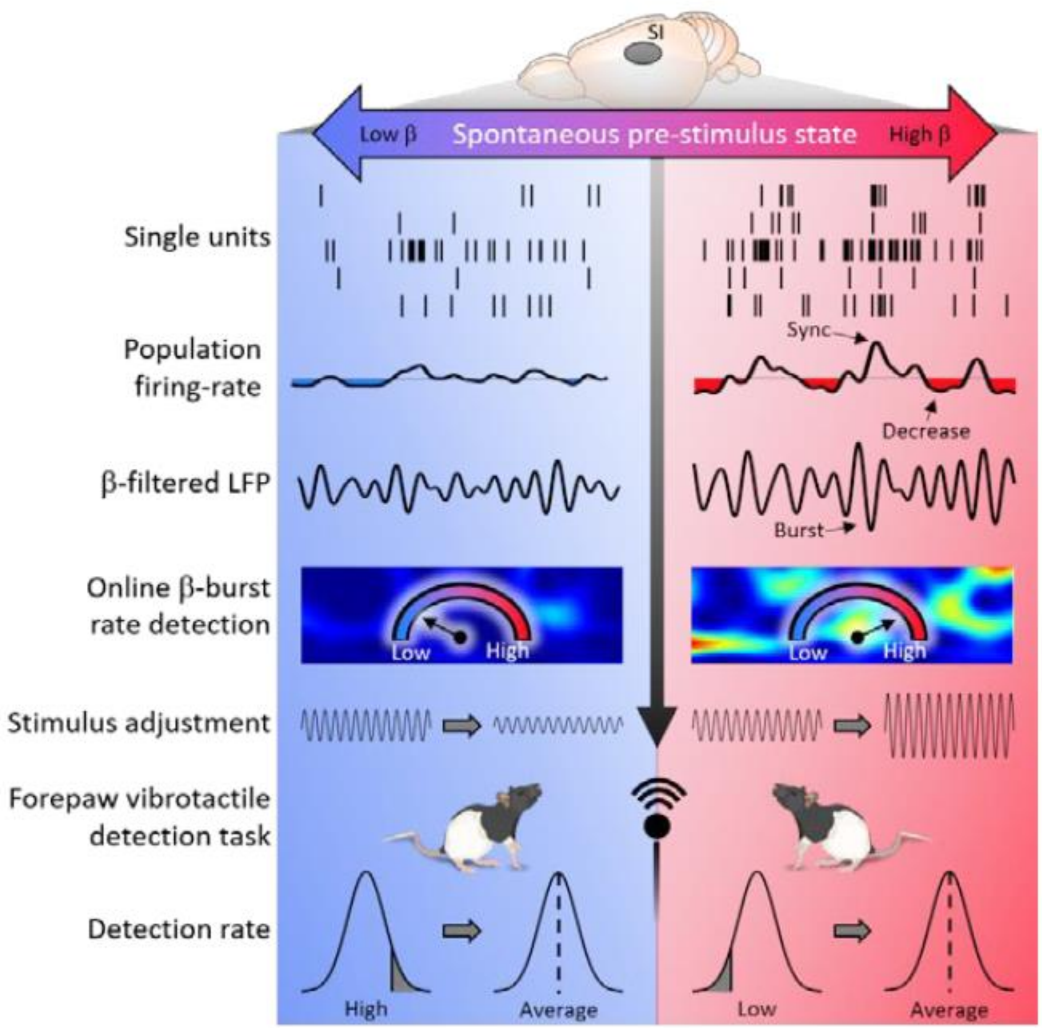
Beta indicates a dynamic state that competes with detection of external stimuli



Karvat, , …, Diester, ***PNAS*** (2021)

Optogenetic dissection of cortico-subcortical interactions during movement control in rodents

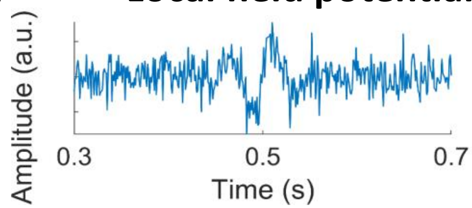
Rat lever press training

Ephys recordings

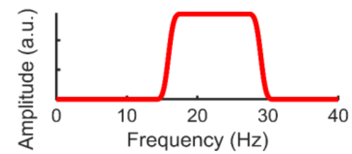
Optogenetic modulation

Neurofeedback

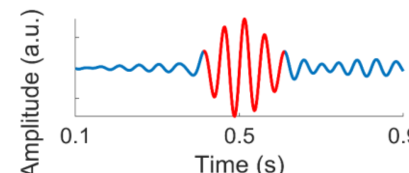
Local field potentials



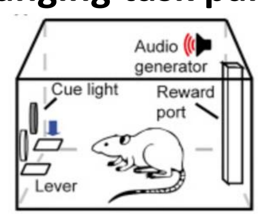
On-line beta band filter



Burst detection



Changing task parameters



3D pose estimation enables virtual head fixation in freely moving rats

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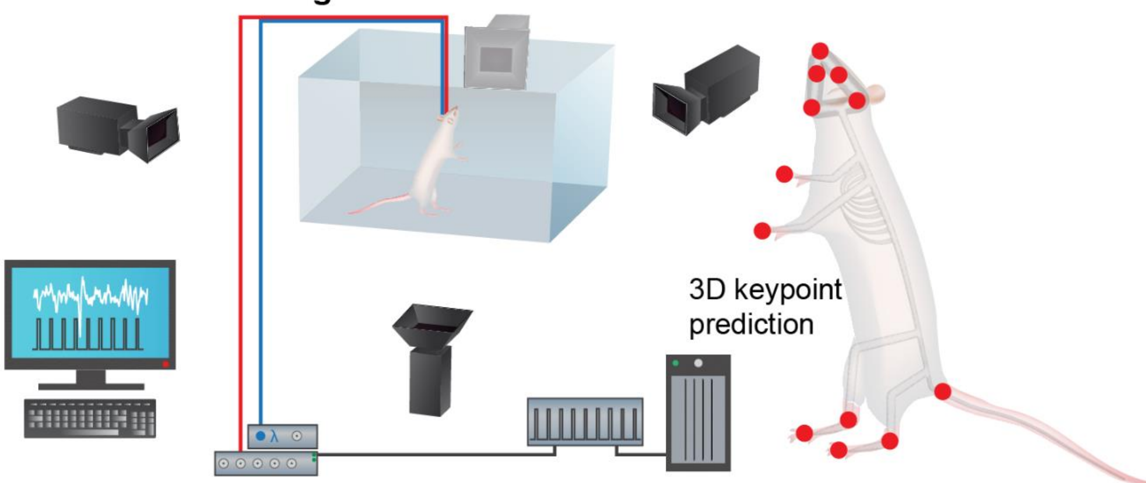
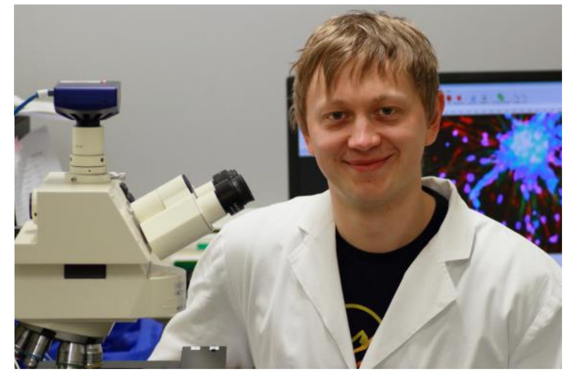
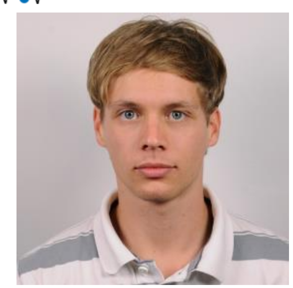
FreiPose 3D tracking





Artur Schneider
Optophysiology

Prof. Dr. Thomas Brox



Christian Zimmermann
[◉] Vision

3D tracking of movements

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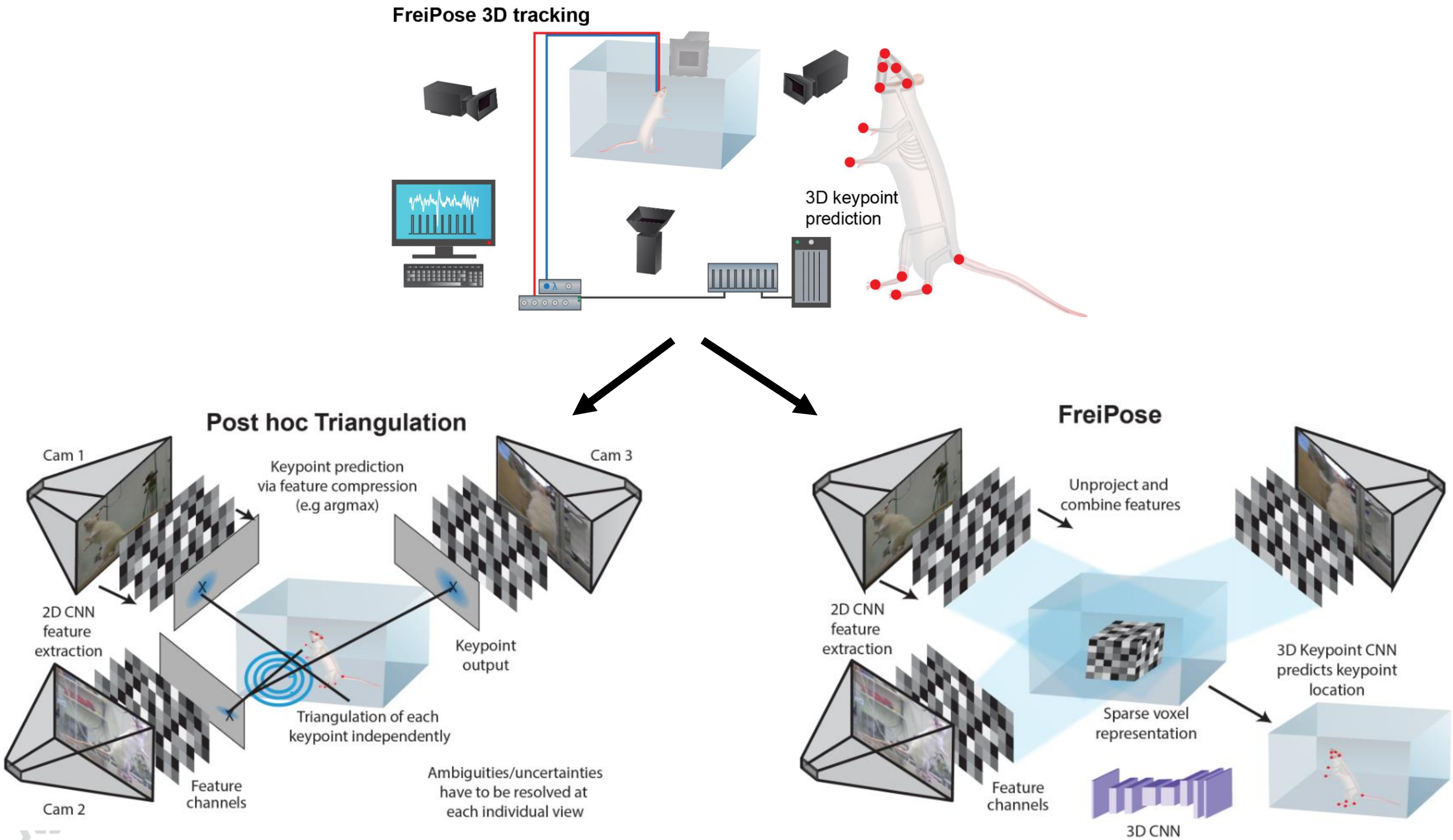

Schneider et al. (Neuron, in press)

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Neuronal tuning to paw trajectories

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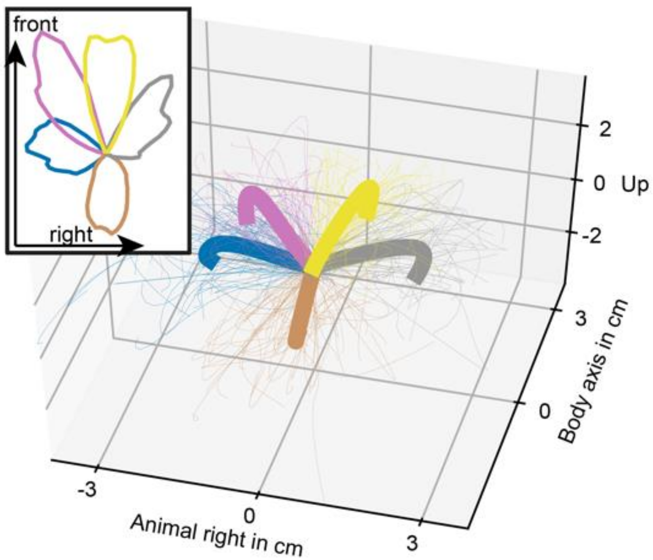

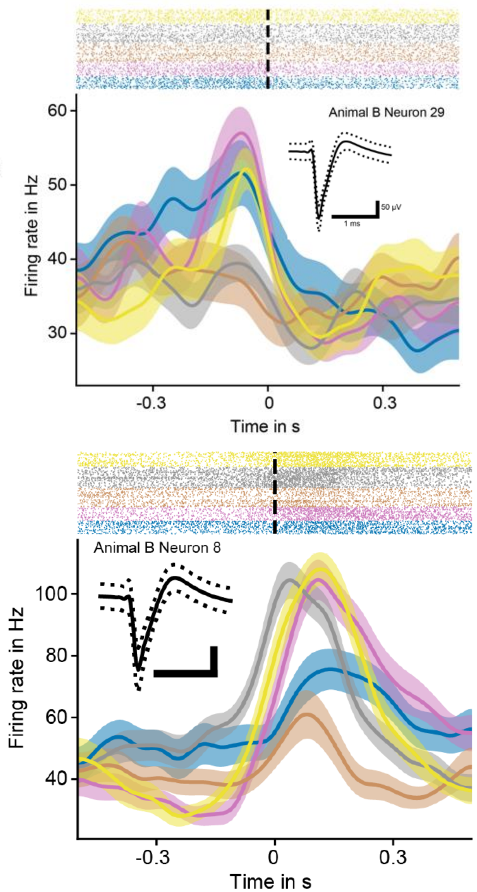

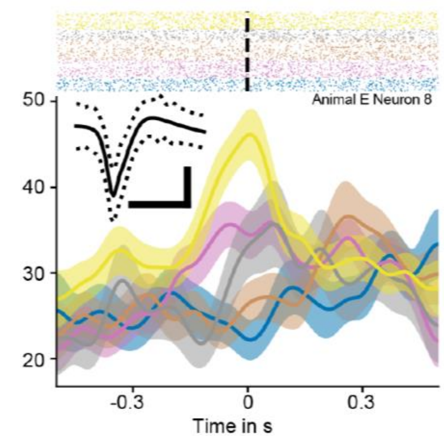

17.68% (29/164) paw tuned neurons (one-way ANOVA, Bonferroni-adjusted p< 0.05)

Schneider et al. (Neuron, in press)

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Virtual head-fixation unmasked a large fraction of paw-tuned neurons

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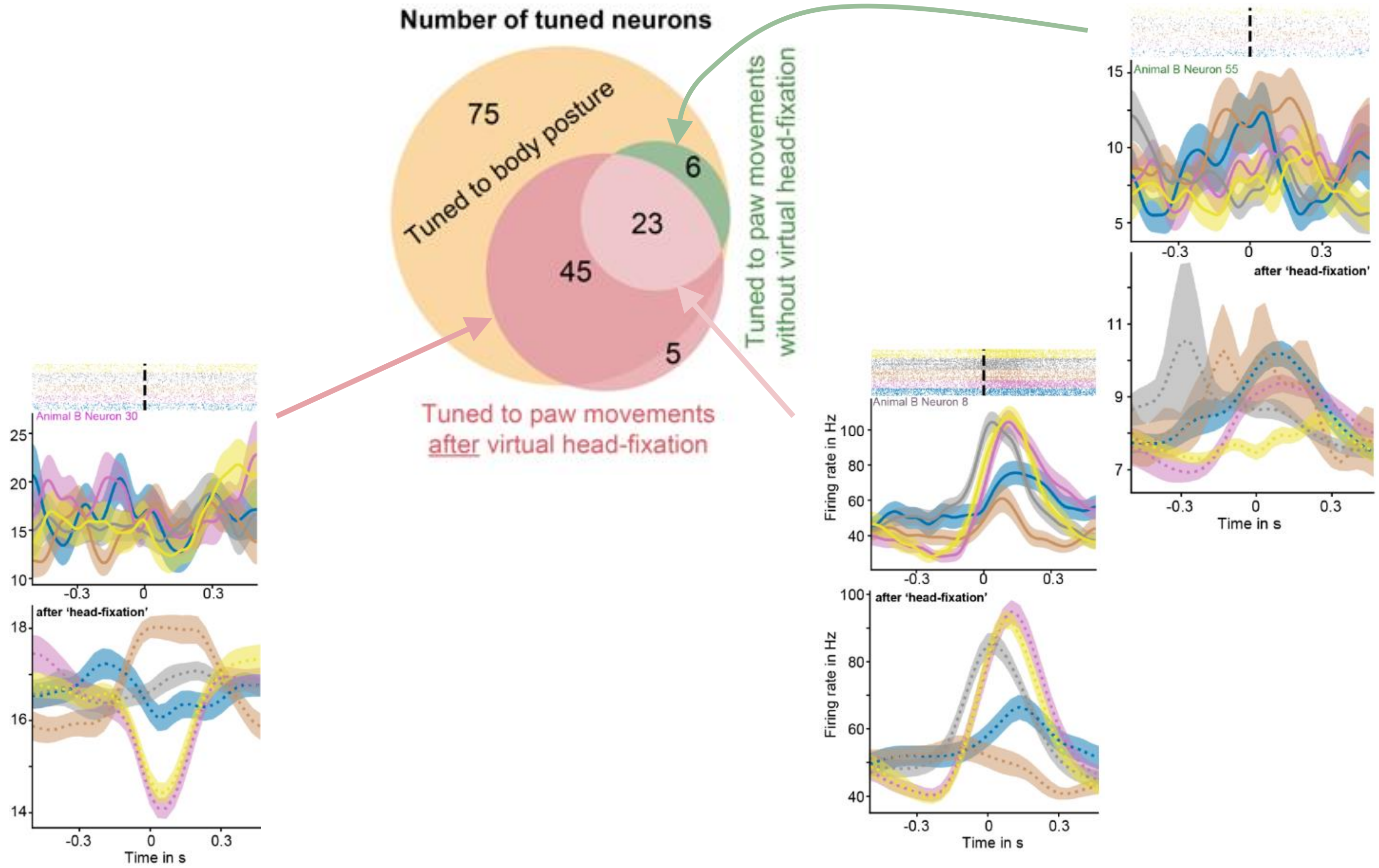

Schneider et al. (Neuron, in press)

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Outlook: Dynamic foraging task

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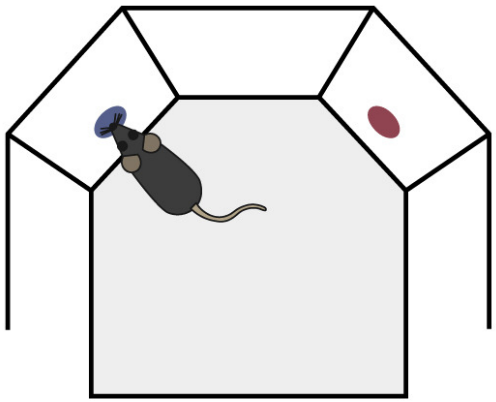

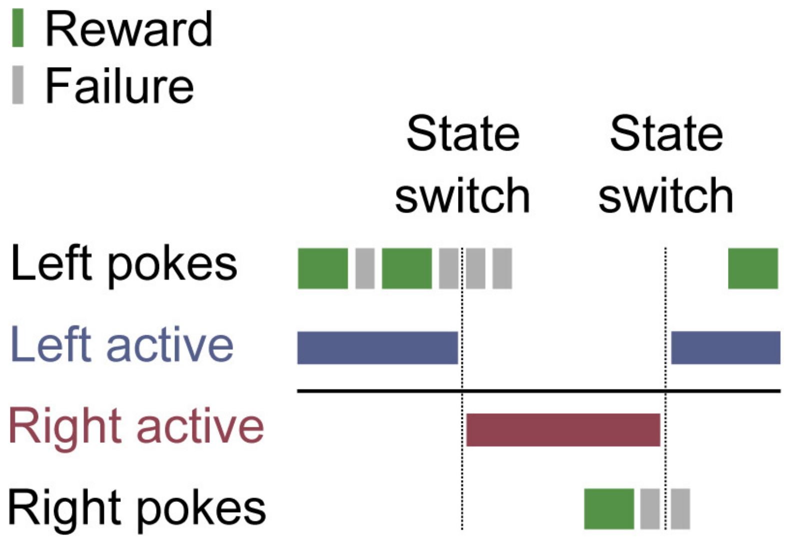

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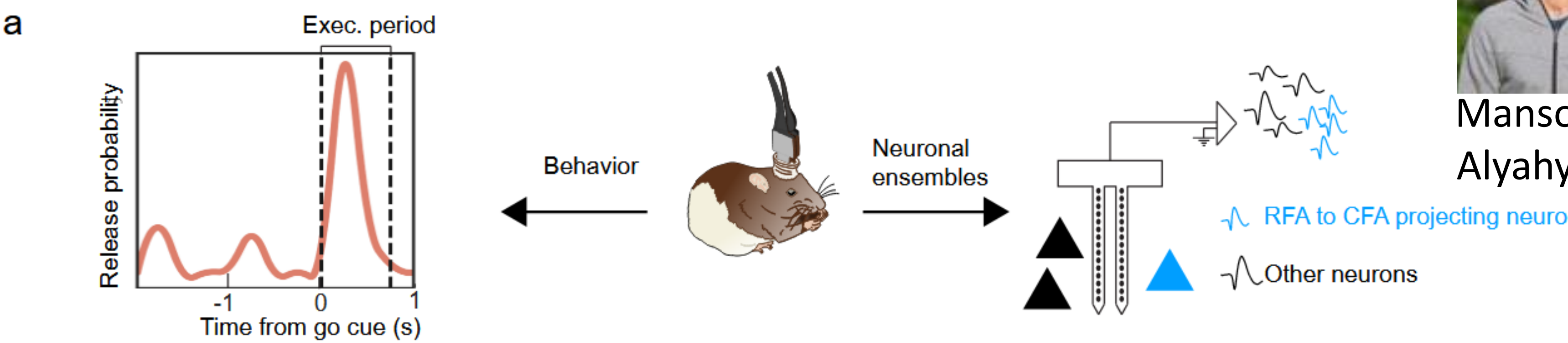
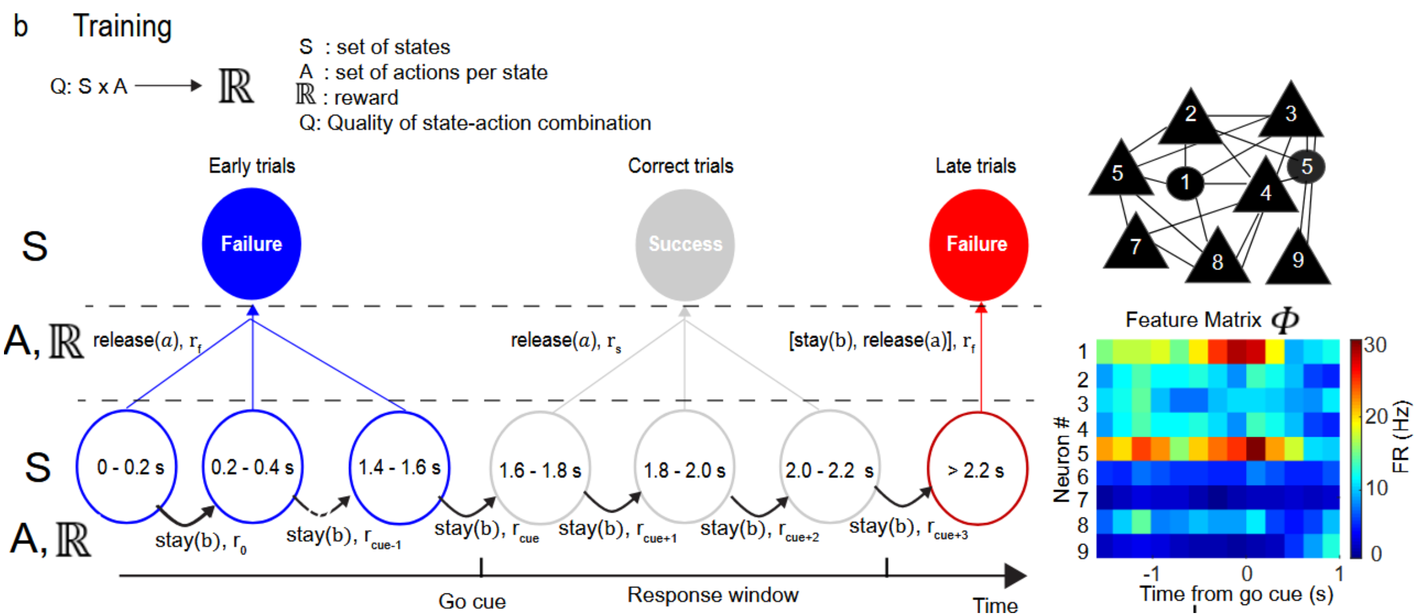
Reinforcement learning to extract individual strategies & link behavior to neuronal activity

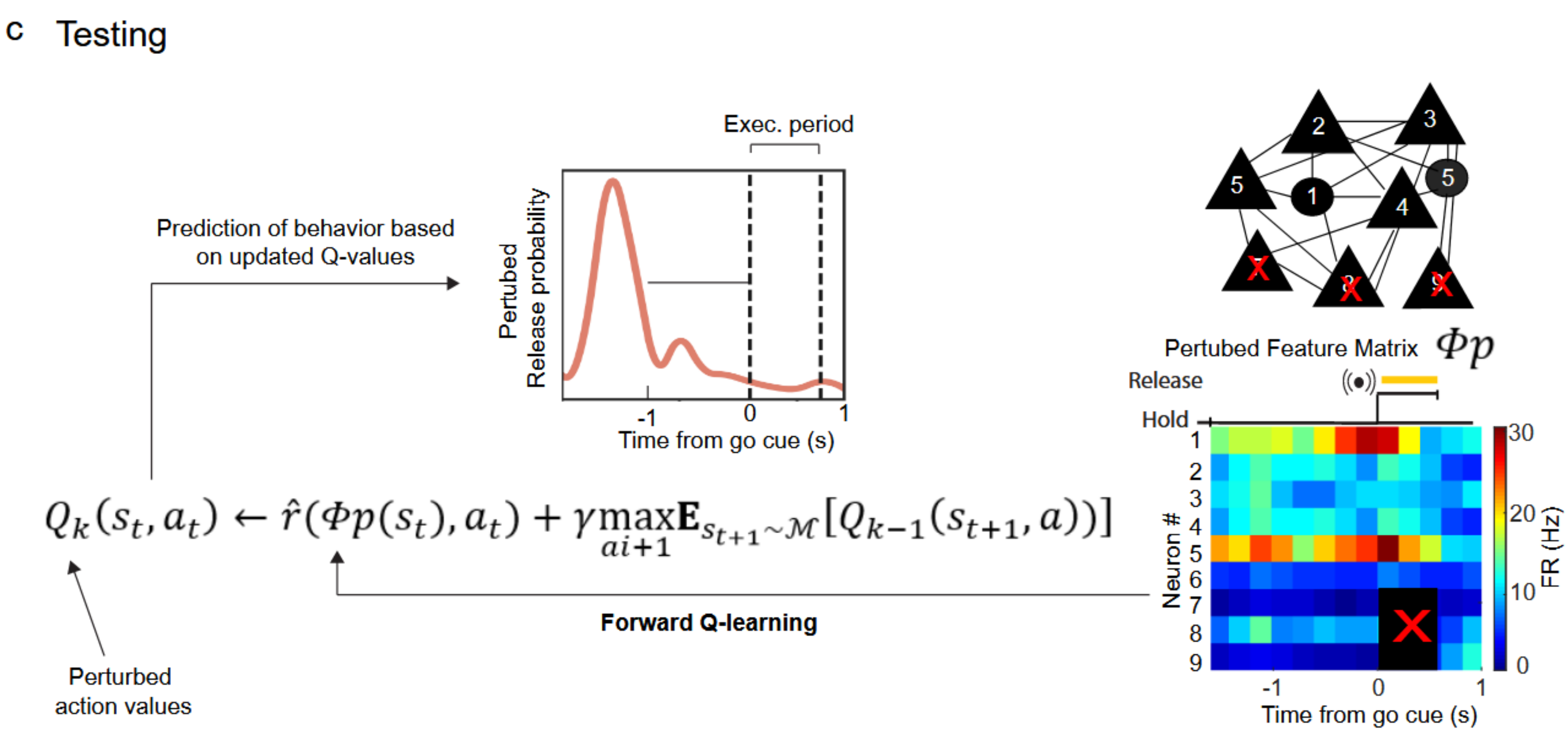


Mansour Alyahyay

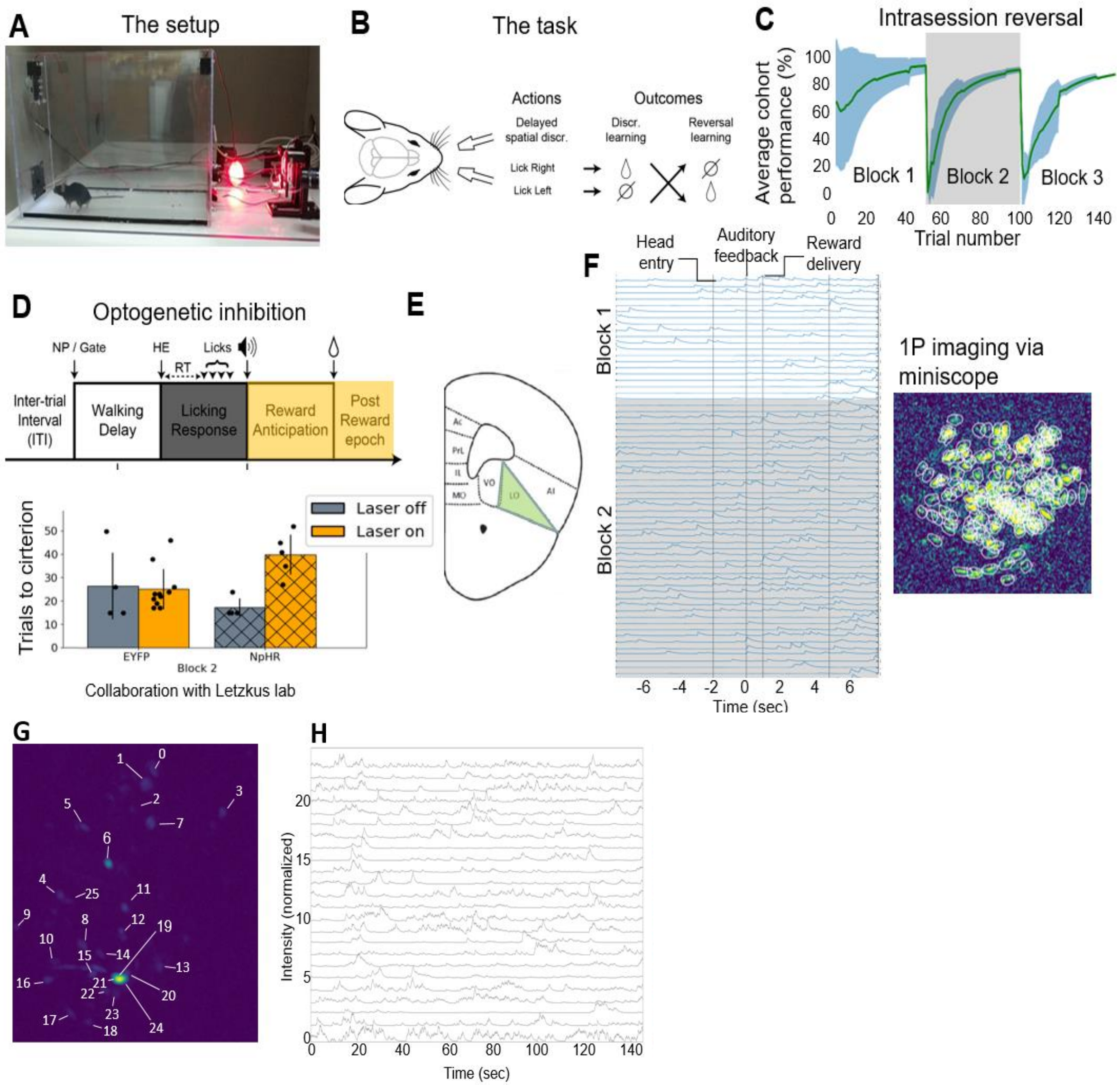


Prof. Dr. Joschka Bödecker

Reinforcement learning to extract individual strategies & link behavior to neuronal activity



The role of OFC and motor cortex in reversal learning



Megan Schneck

Brice de la Crompe

In vitro slice work: Combination of patch-clamping and 2-Photon-Calcium-Imaging

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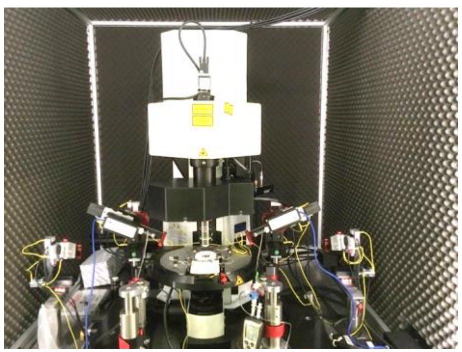
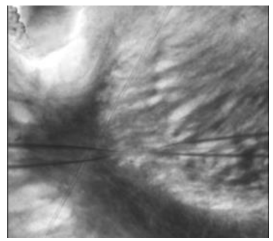
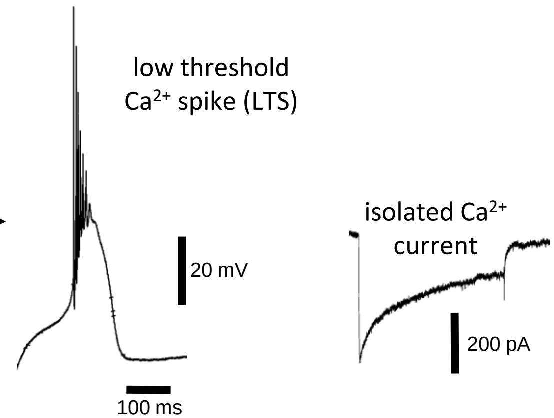
Subgroup Cellular Neurophysiology

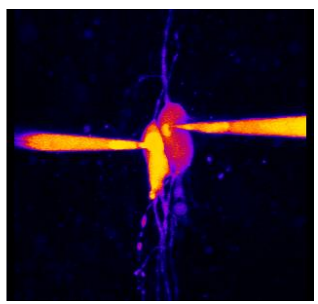


Brain slice

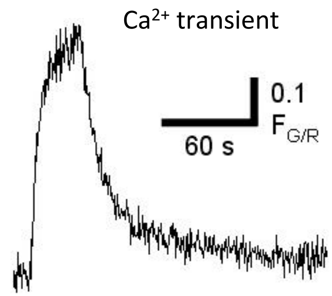




Cellular electrophysiological responses



Imaging



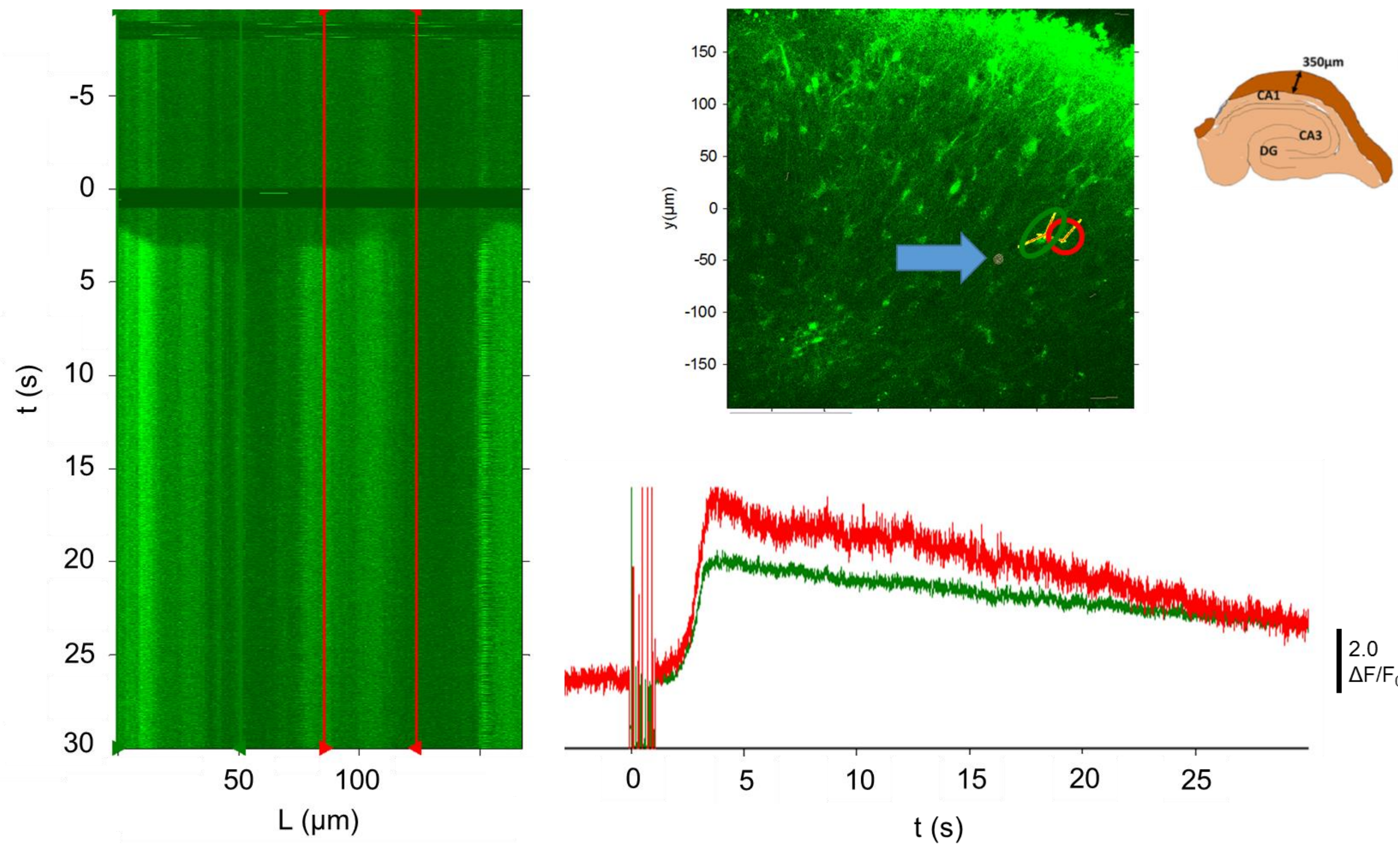
Cellular Ca^{2+} responses

Philippe Coulon

Ashlyn Creamer

Optogenetically stimulated Ca2+-transients in organotypical brain slice cultures

IMBIT //
Intelligent Machine-Brain Interfacing Technology



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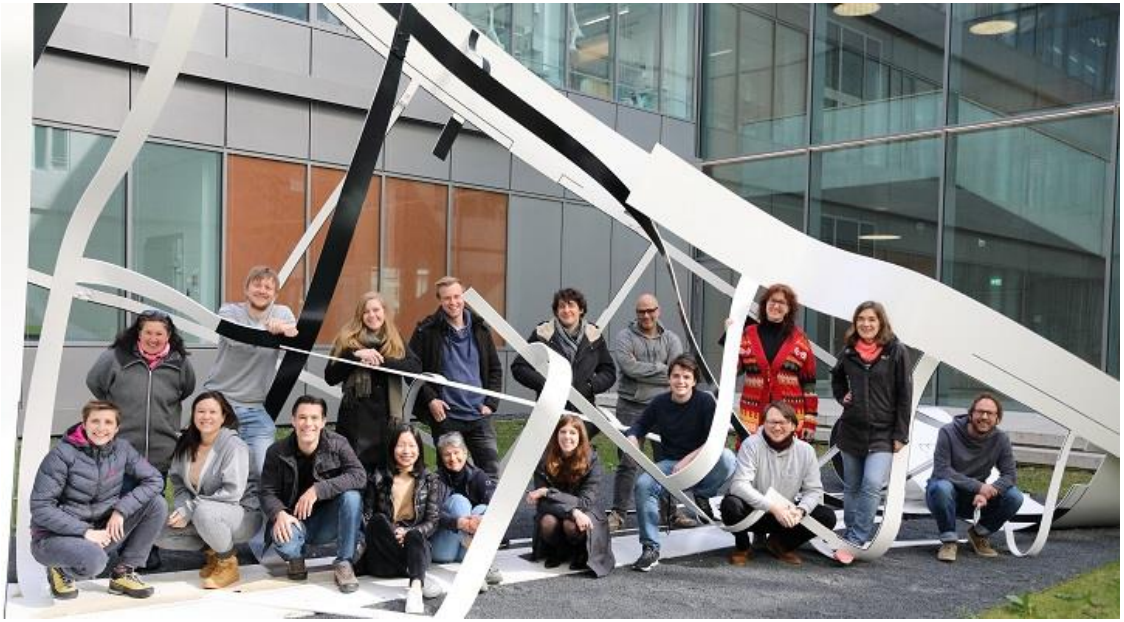
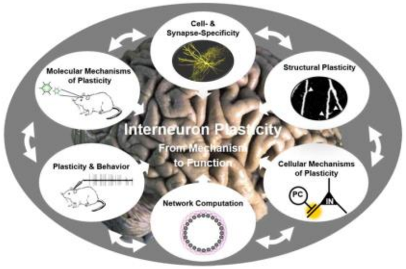
Acknowledgements



// BrainLinks BrainTools
acting thoughts

Resolving prefrontal flexibility

DFG
FOR 5159, Resolving Prefrontal Flexibility



FOR 2143, Interneuron plasticity

Bernstein Award in Computational Neuroscience Ilka Diester

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