Georg-August-
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CRATOS

DPZ
German Primate Center
Leibniz-Institut für Primatenforschung

Cortical hand movement prosthetics

Hans Scherberger

Neural Horizons:
Future Panorama within Brain-Machine Intefaces
Feb 19, 2025

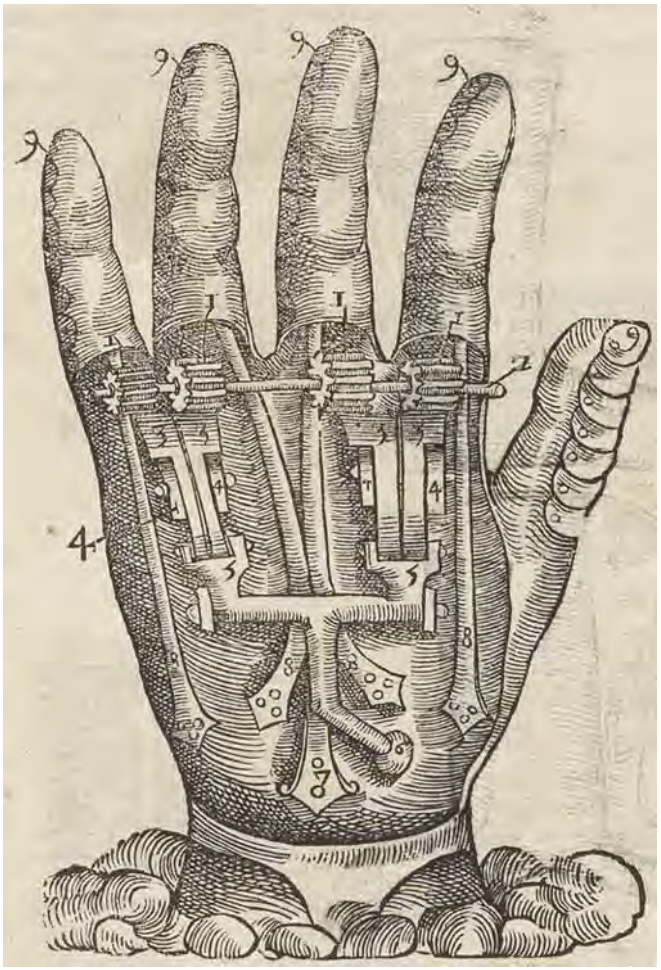
Leibniz
Leibniz-Gemeinschaft

Prosthetics

Jason Isaacs' Captain Hook (2003)

- Replacement of lost limbs
- Usually prostheses can only partial replace lost function
- Functional enhancement ?

Ambroise Paré's prosthetic hand (1575)

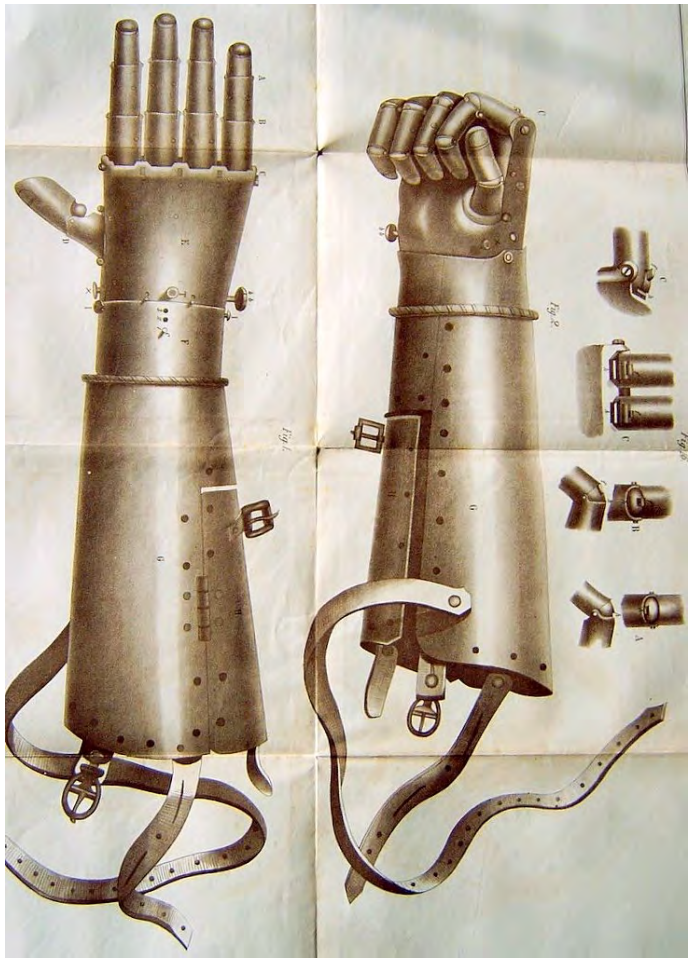


Ambroise Paré (1510–1590)
French Barber-Surgeon
"Je le pansai, Dieu le guérit"
("I bandaged him and God healed him")

'Le Petit Lorrain' prosthetic hand.
In: Les oeuvres d'Ambroise Paré 1575

www.nlm.nih.gov/exhibition/historicalanatomies/home.html

The iron hand of Goetz of Berlichingen (1504)



- Museum:

Götzenburg Castle

(Jagsthausen)

Muscle-driven arm prostheses (~1915)

- Ferdinand Sauerbruch and
- Aurel Stodola, ETH Zürich

Myoelectric hand (after ~1945)

Myographic electrodes

(Otto Bock, Germany)

Electric hand prosthesis

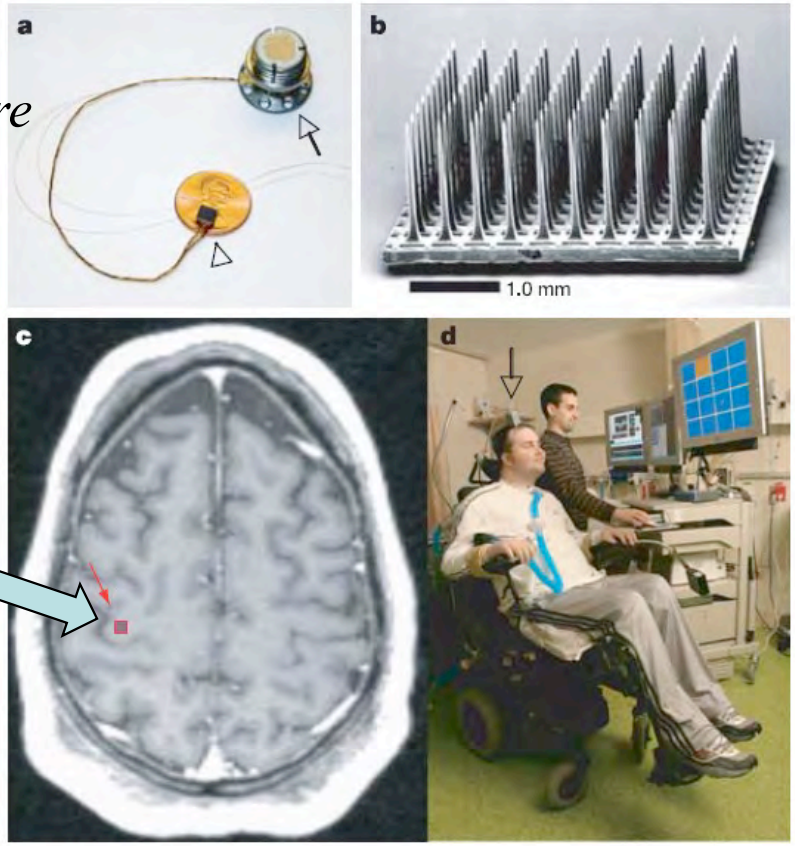
Robotic hands

(Shadow Dexterous Hand)

Human brain-machine interface

Implantierbare Elektroden

Elektroden-matrix

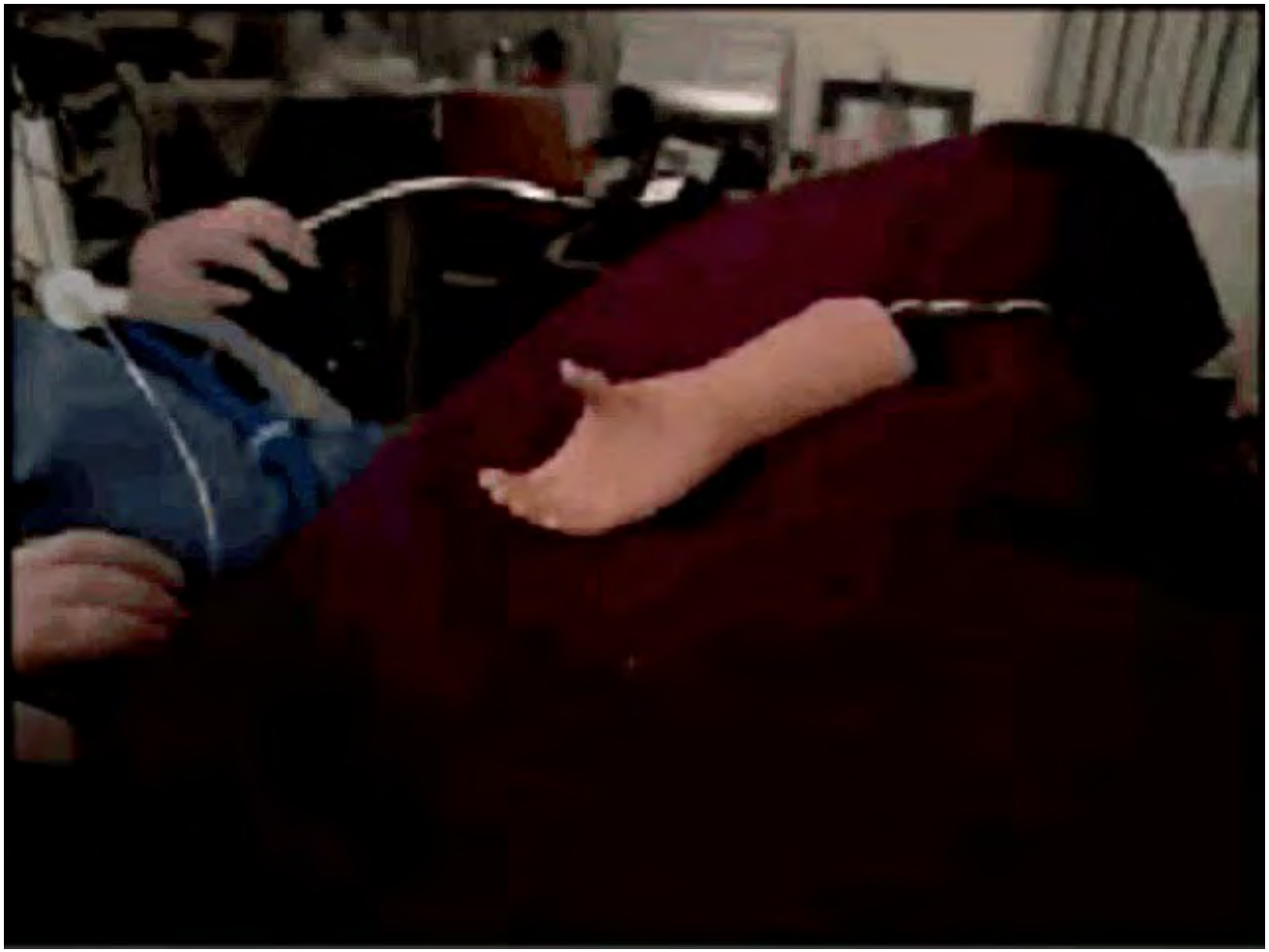


Implantierte Elektroden

Patient im Experiment

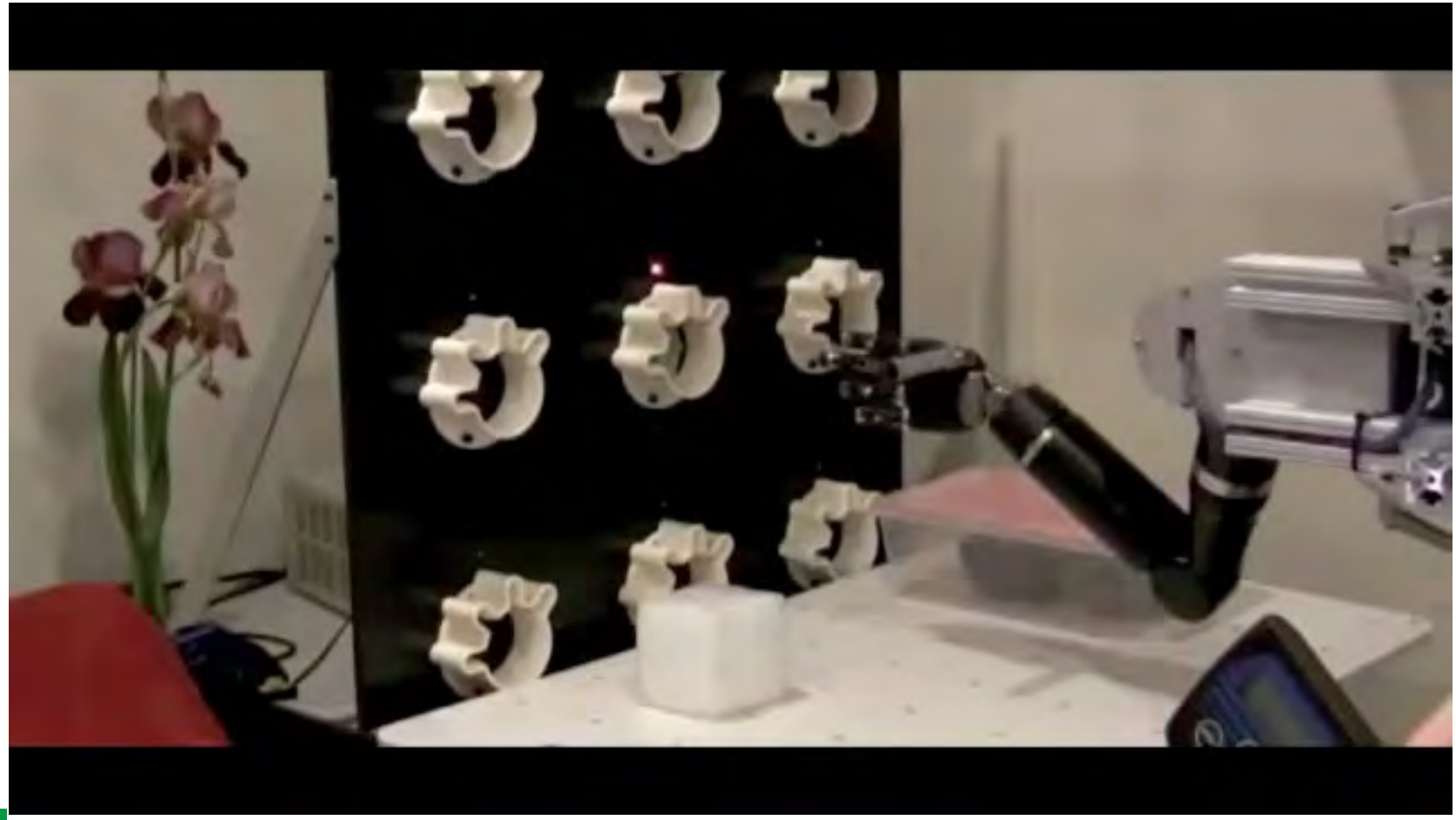
(Hochberg et al, Nature 2006)

Human Neuroprosthetic



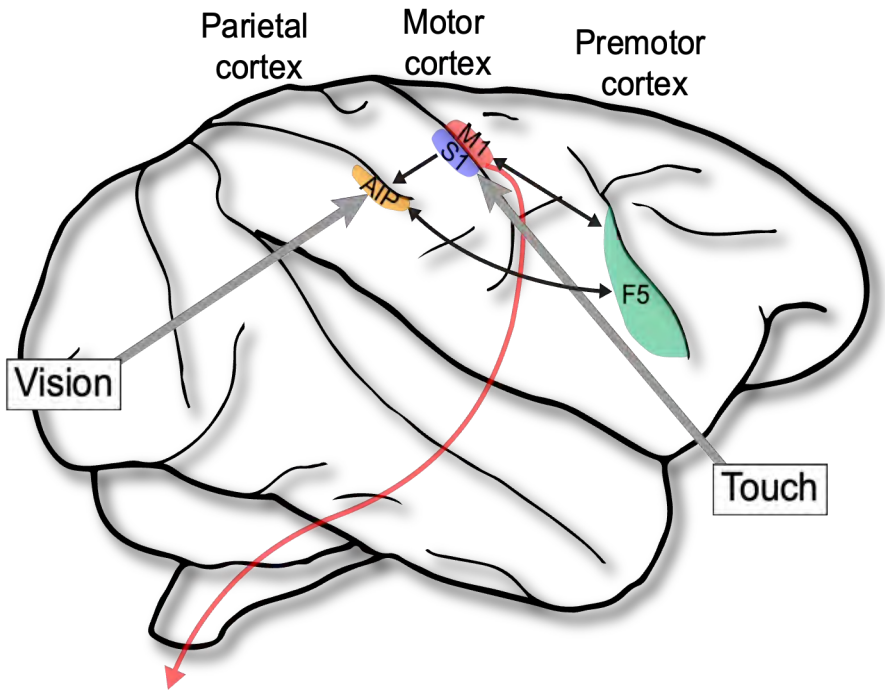
(Hochberg et al, Nature 2006)

Human Neuroprostheses



(Collinger et al, Lancet 2013)

The cortical grasping circuit



Anterior Intra-parietal Area (AIP)

- Selective for shape and orientation of objects to be grasped

Ventral Premotor Cortex Hand Area (F5)

- Selective for type of grip required to grasp objects

Motor Cortex Hand Area (M1)

- Strongest modulation during active movement
- Direct cortico-spinal projections

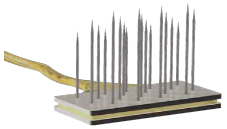
Somatosensory Cortex (S1)

- Selective for hand touch and force

Population coding of grasping movements

Stefan Schaffelhofer

Understanding **multidimensional processes** requires **a neural population approach!**



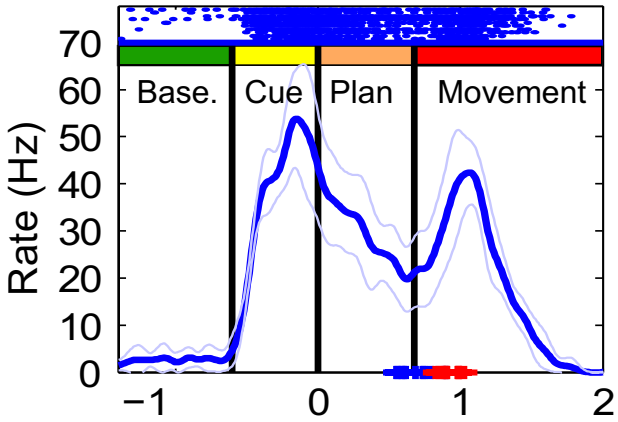
- Testing of many objects
- Monitoring of kinematics
- Recording of many neurons

Primate behavioral training

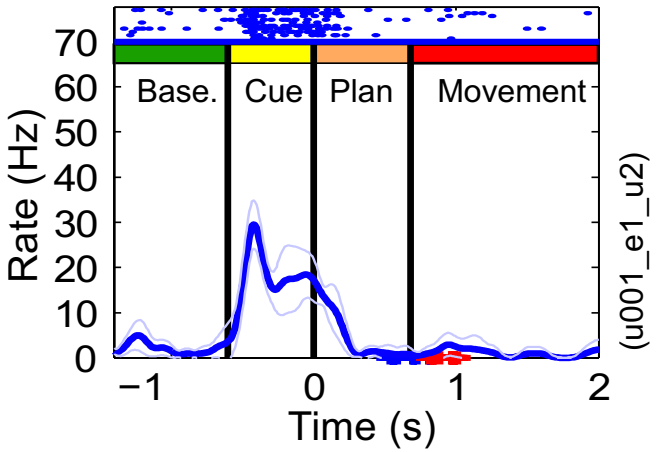
Monkey grasping task

Grip type coding in a single neuron (AIP)

Precision grip

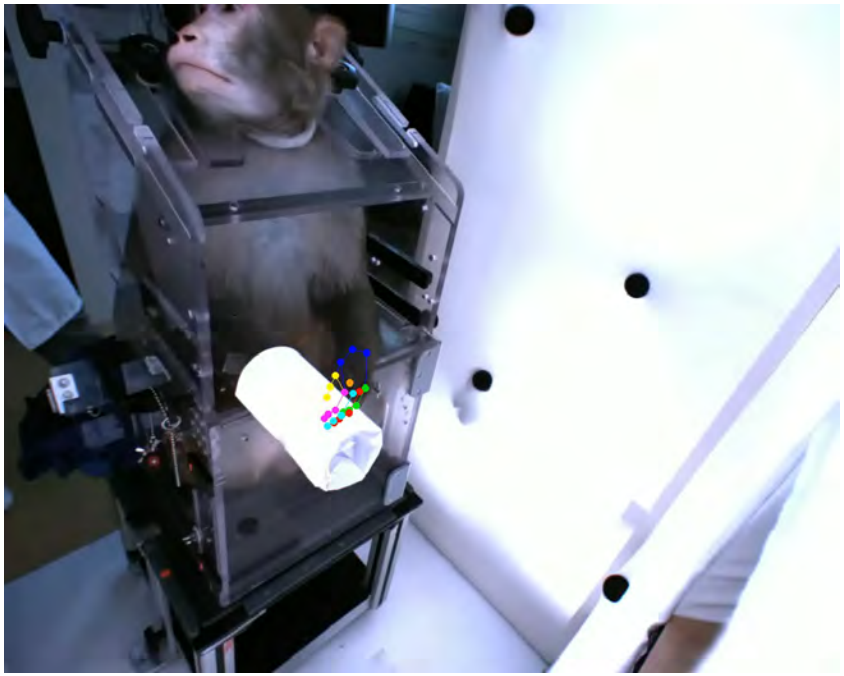


Power grip



(Baumann et al, J Neurosci 2009; Fluet et al, J Neurosci 2010)

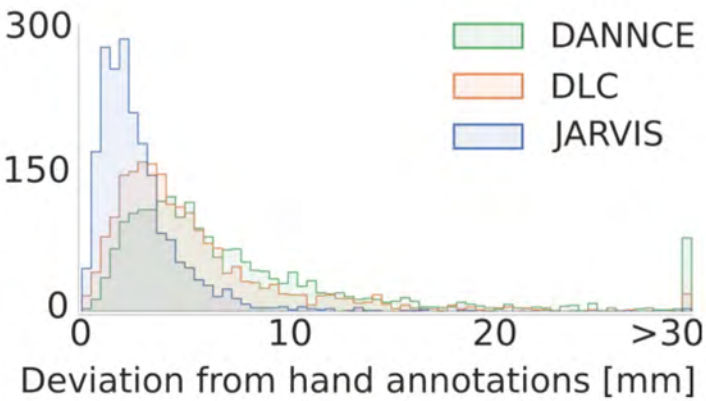
Jarvis: markerless hand motion tracking



Jarvis

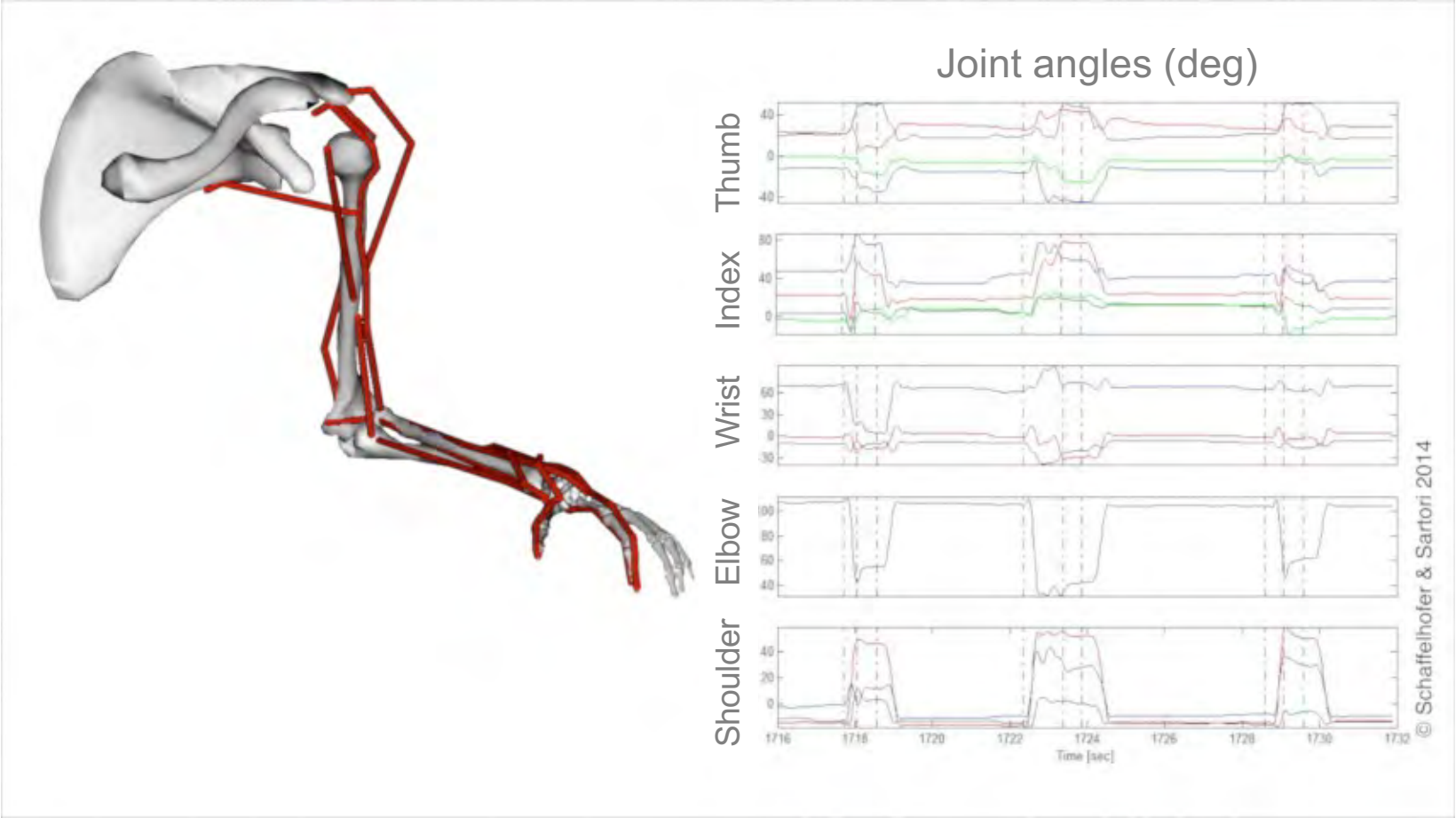
1. Acquisition tool
2. Annotation tool
3. Hybrid Net: 3D pose estimation

Comparision to other methods



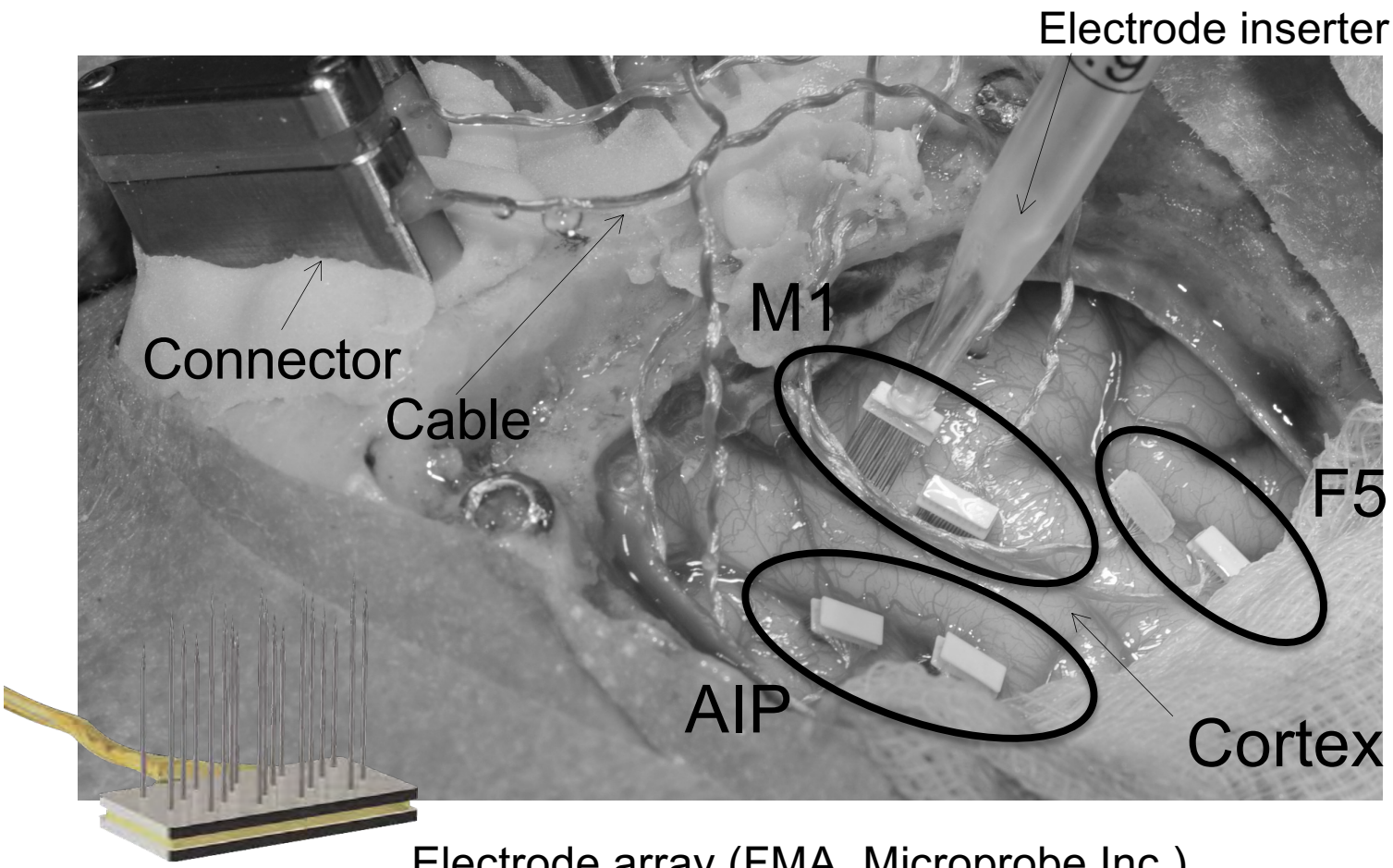
(Hüser et al. 2022: https://github.com/JARVIS-MoCap/JARVIS-MoCap)

Kinematic description of grasp actions



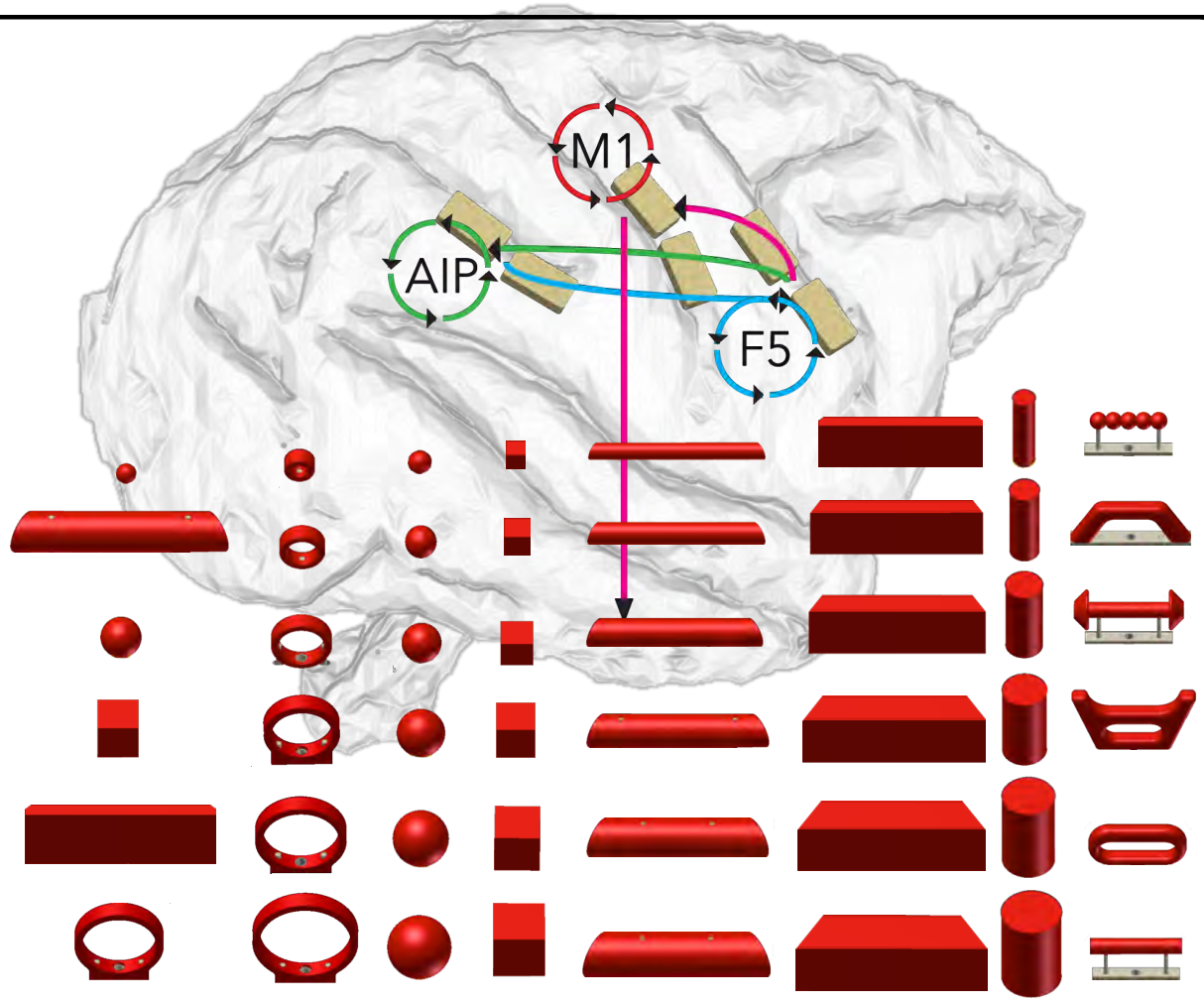
(Schaffelhofer, Sartori et al, TNSRE 2014)

Multi-electrode recordings (192 channels)



Electrode array (FMA, Microprobe Inc.)

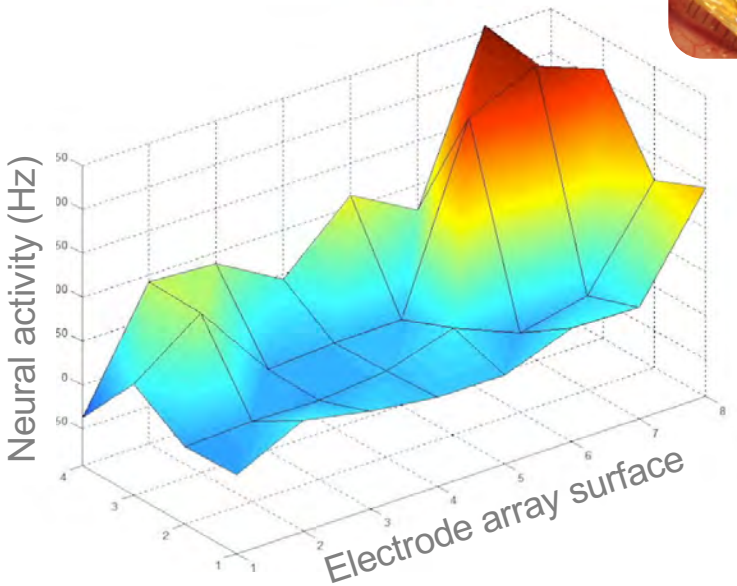
Cortical coding properties

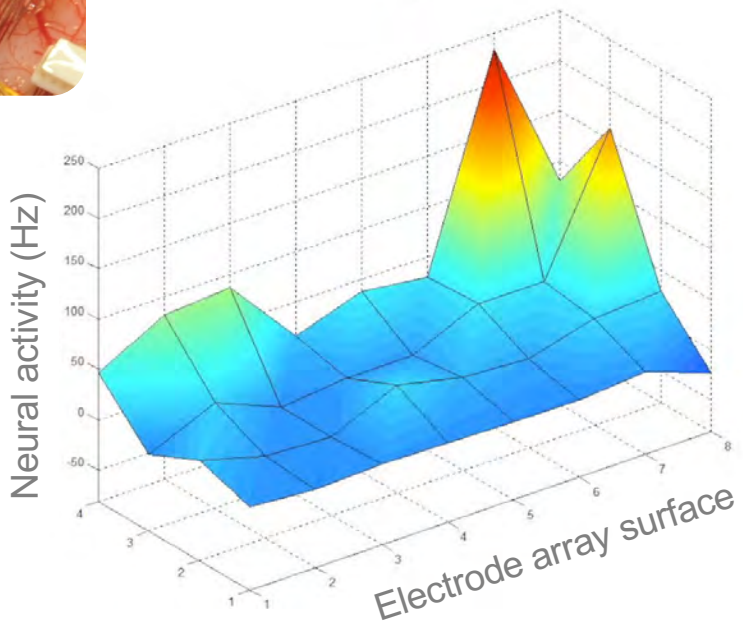


Neural population activity during grasping

Precision Grip

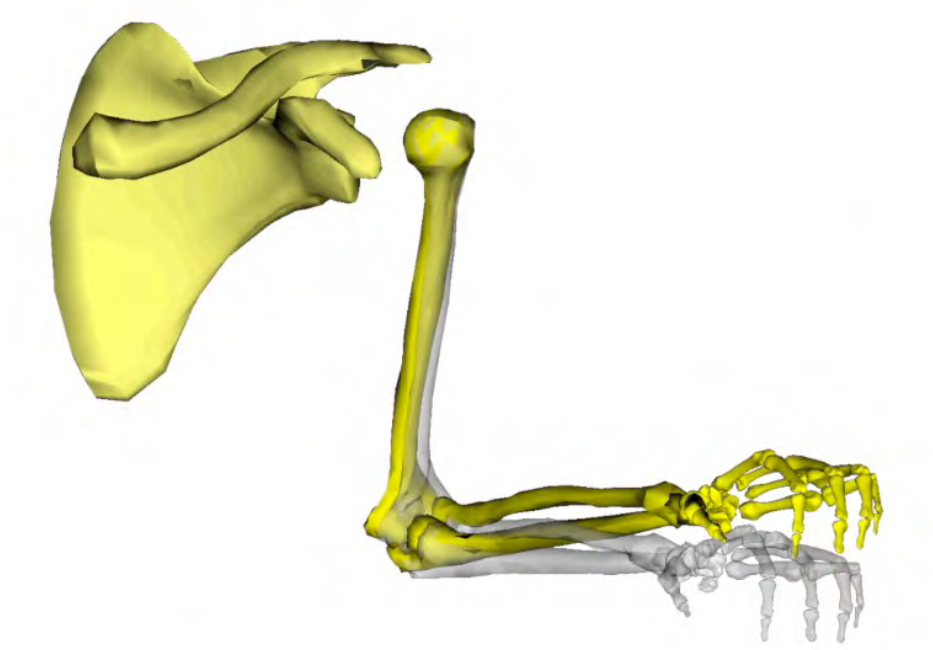
Power Grip





Continuous decoding of hand movements (offline)

Katharina Menz



- Decoding hand kinematics (27 dof) from population spiking activity
- using Kalman filter

Yellow: decoded kinematics

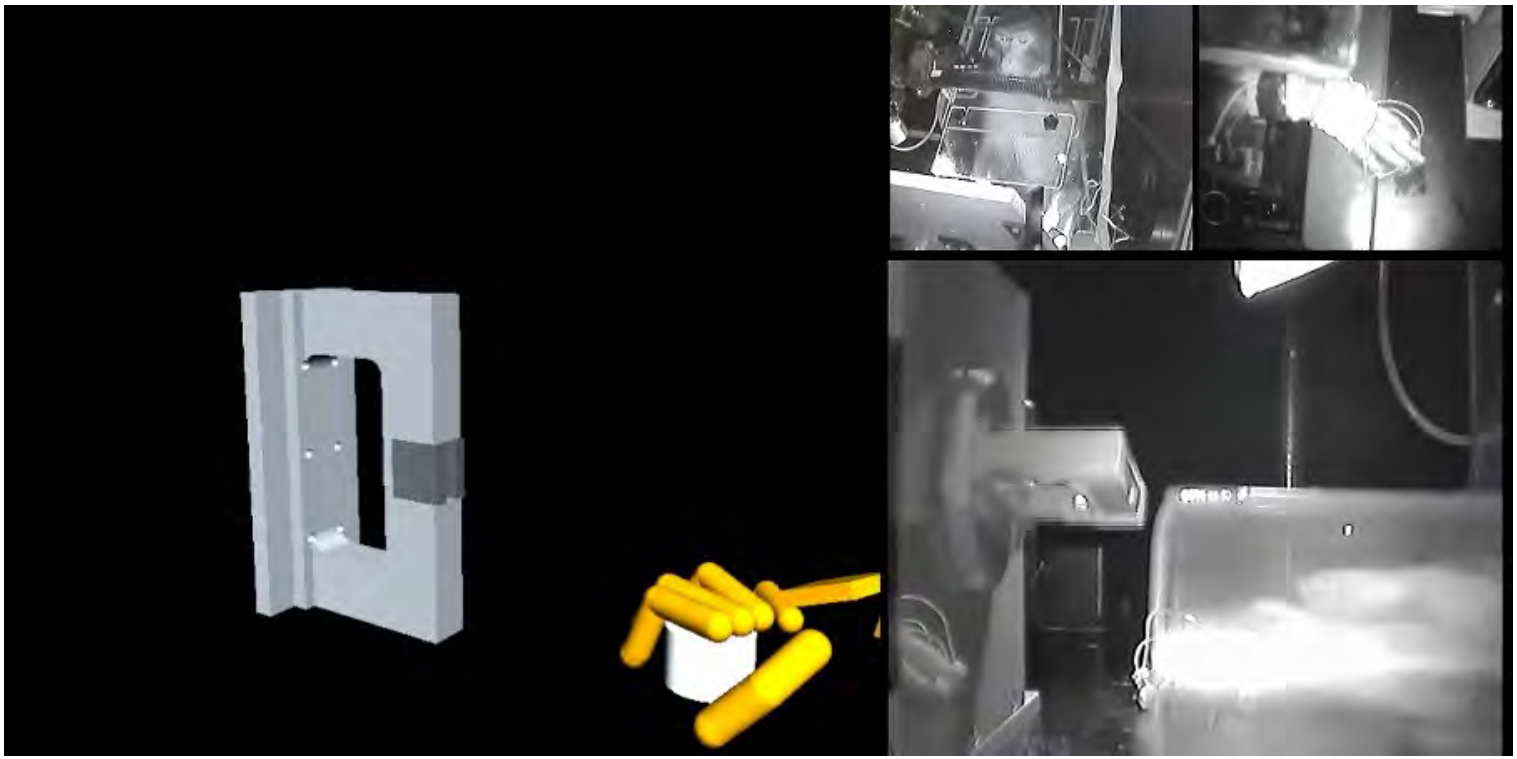
Grey: true kinematics

(Menz, Schaffelhofer et al., J Neural Eng 2015)

Realtime decoding of hand grasping

Andres Agudelo-Toro

- using monkey **hand kinematics**

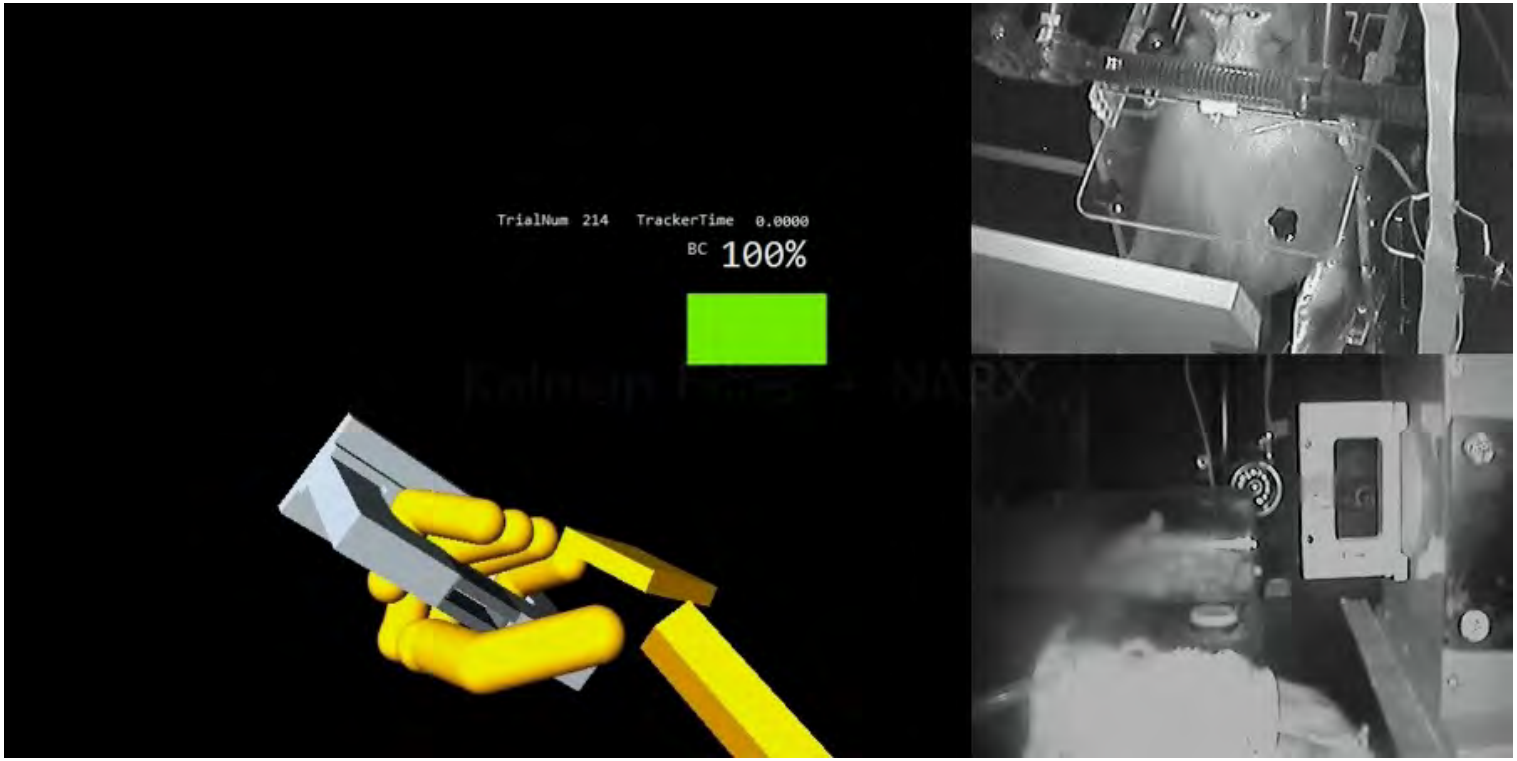


(Agudelo-Toro et al., Neuron 2024)

Realtime control of a robotic hand

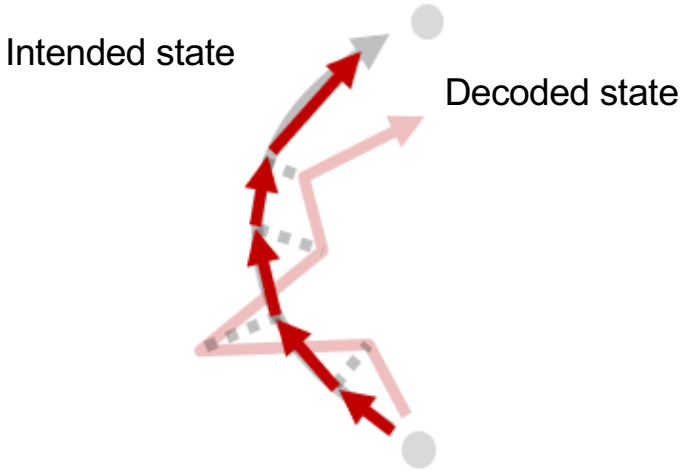
Andres Agudelo-Toro

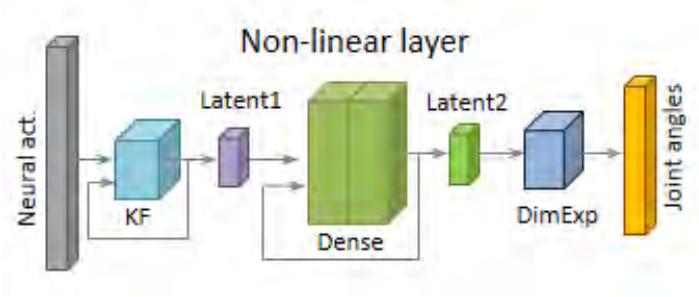
- using neural spiking activity



(Agudelo-Toro et al., Neuron 2024)

Latent State Transition Training (LSTT)





- Grasp decoding works better for position vs. velocity decoding
- LSTT: project decoded state to intended neuronal state
- LSTT extends well to novel conditions
- A hybrid decoder addition can further impove decoding performance

(Agudelo-Toro et al., Neuron 2024)

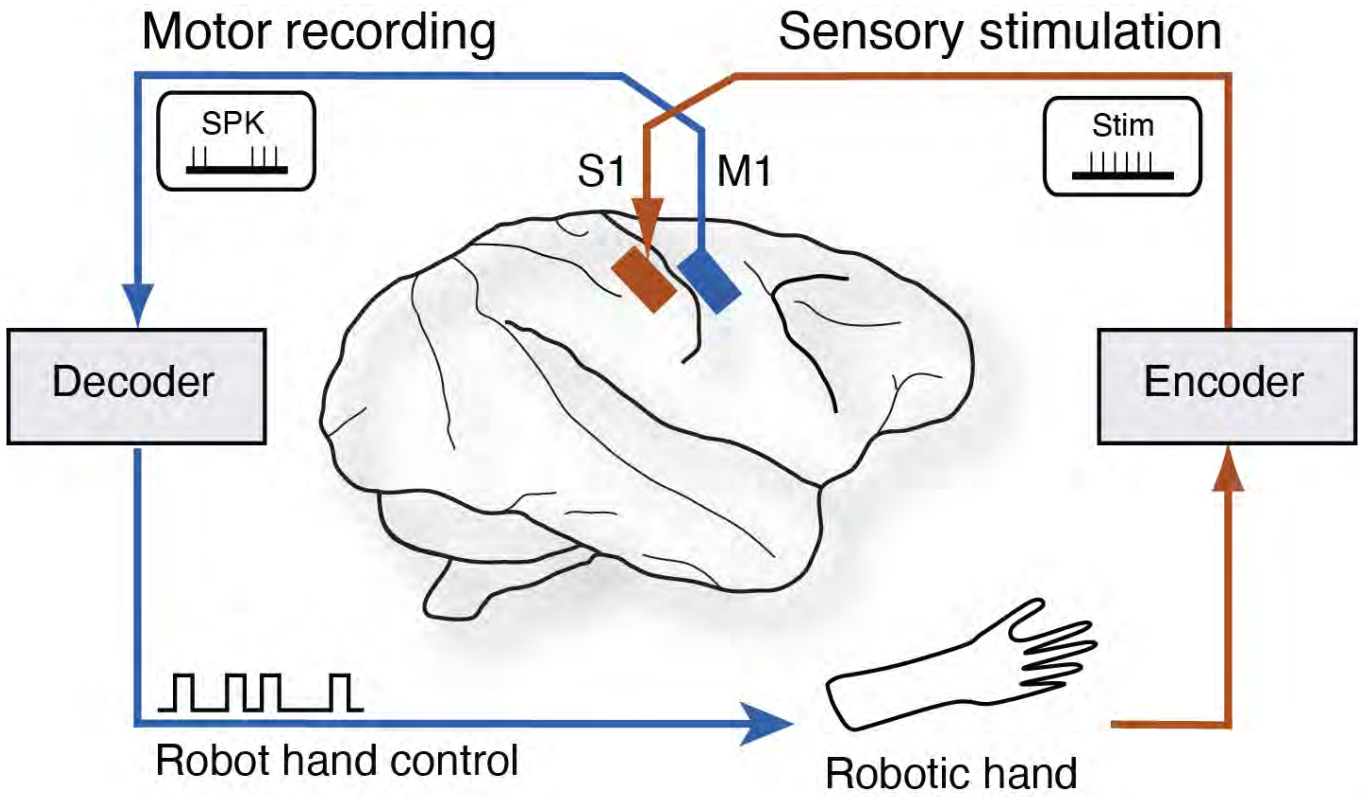
Finger sensation is important for dexterous movements

Normal finger sensation

Fingers numbed

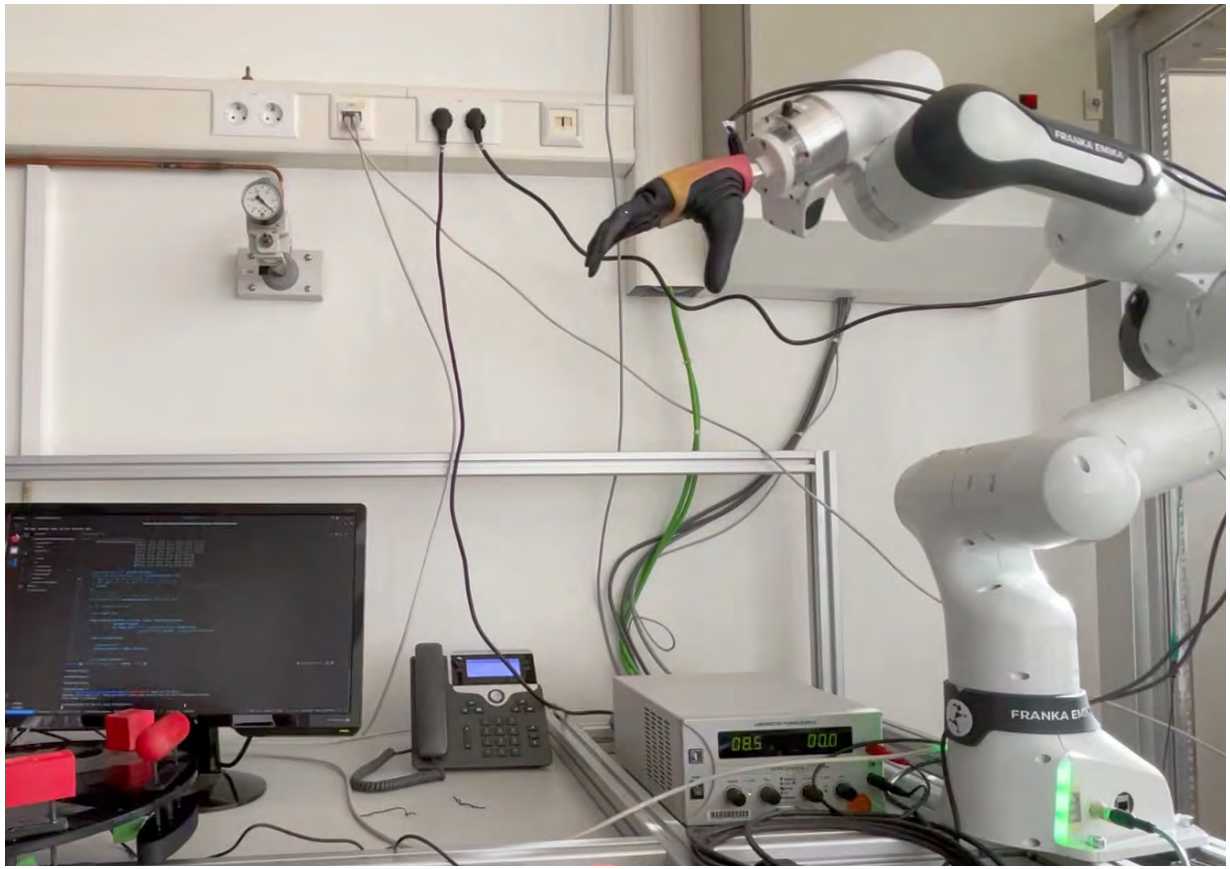
Johansson, et al. (uploaded: 2011, January 8th). *Johansson testing*. Retrieved from: https://www.youtube.com/watch?v=0LfJ3M3Kn80

Grasp decoding & sensory feedback



Next steps: realtime decoding for robotic hand control

Hunaid Hameed



Realtime control of

- robot arm (Franka Emika)
- anthropomorphic hand (Prensilia)

Robot hand can provide

- touch and
- proprioceptive feedback

Summary

1. Cortical areas contribute differently to hand motor control
   - **AIP** represents predominantly **object information**
   - **F5** encodes best **grip type intentions**
   - **M1** represents most accurately **movement execution**
2. Population activity from the grasping network
   - can be used to decode **grip types** and **hand kinematics**
3. Sensory feedback from the hand is necessary for dexterous control
   - **Tactil and proprioceptive signals** from a robotic hand can fed to sensory cortex via electrical microstimulation

Thank you!

Neurobiology Lab, German Primate Center, Göttingen, Germany

- Alireza Fathian
- **Andres Agudelo-Toro**
- Benjamin Dann
- **Hunaid Hameed**
- Jan Churan
- Jannik Luff
- Judith Hampe
- Kerstin Zaft
- Matthias Dörge
- Natalie Bobb
- Nicolas Zdun
- Roberta Nocerino
- Sabine Borchert
- TianWei Wang

Support

- DFG (SFB, RU, …)
- BMBF (CogNetDyn)
- EU (B-CRATOS, In2PB)
- Leibniz Foundation (Pakt)
- Ministry of Lower Saxony

Lab alumni

- Alexandra Wellner
- Anne-Dominique Gindrat
- Ben Townsend
- Daniela Buchwald
- Erk Subasi
- James Goodman
- Jeroen Buil
- Jonathan Michaels
- **Katharina Menz**
- Marie-Christine Fluet
- Markus Baumann
- Rijk in 't Veld
- Sebastian Lehmann
- Stefan Greulich
- **Stefan Schaffelhofer**
- Steve Suway
- Swathi Sheshadri
- Timo Hüser
- Tomke Schoss