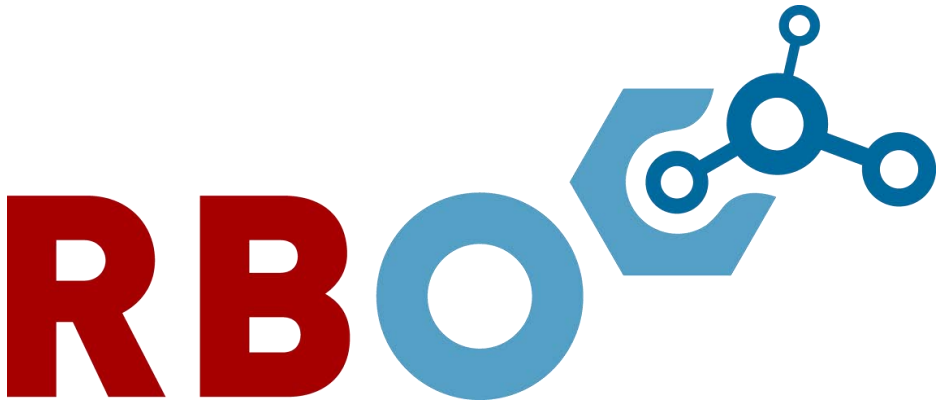


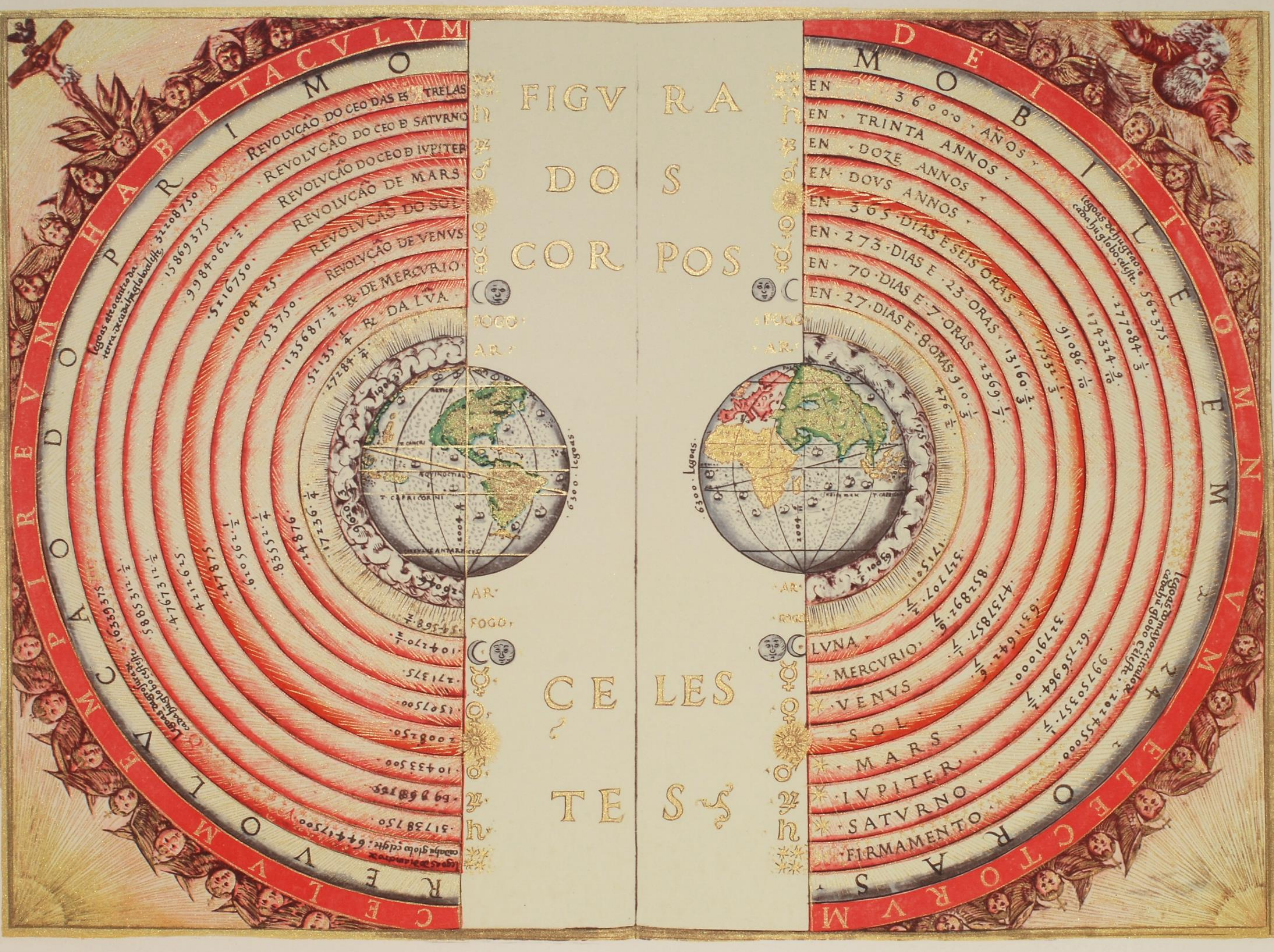
Mobile Manipulation:

Why Are Humans So Much Better? And How Can We Change That?

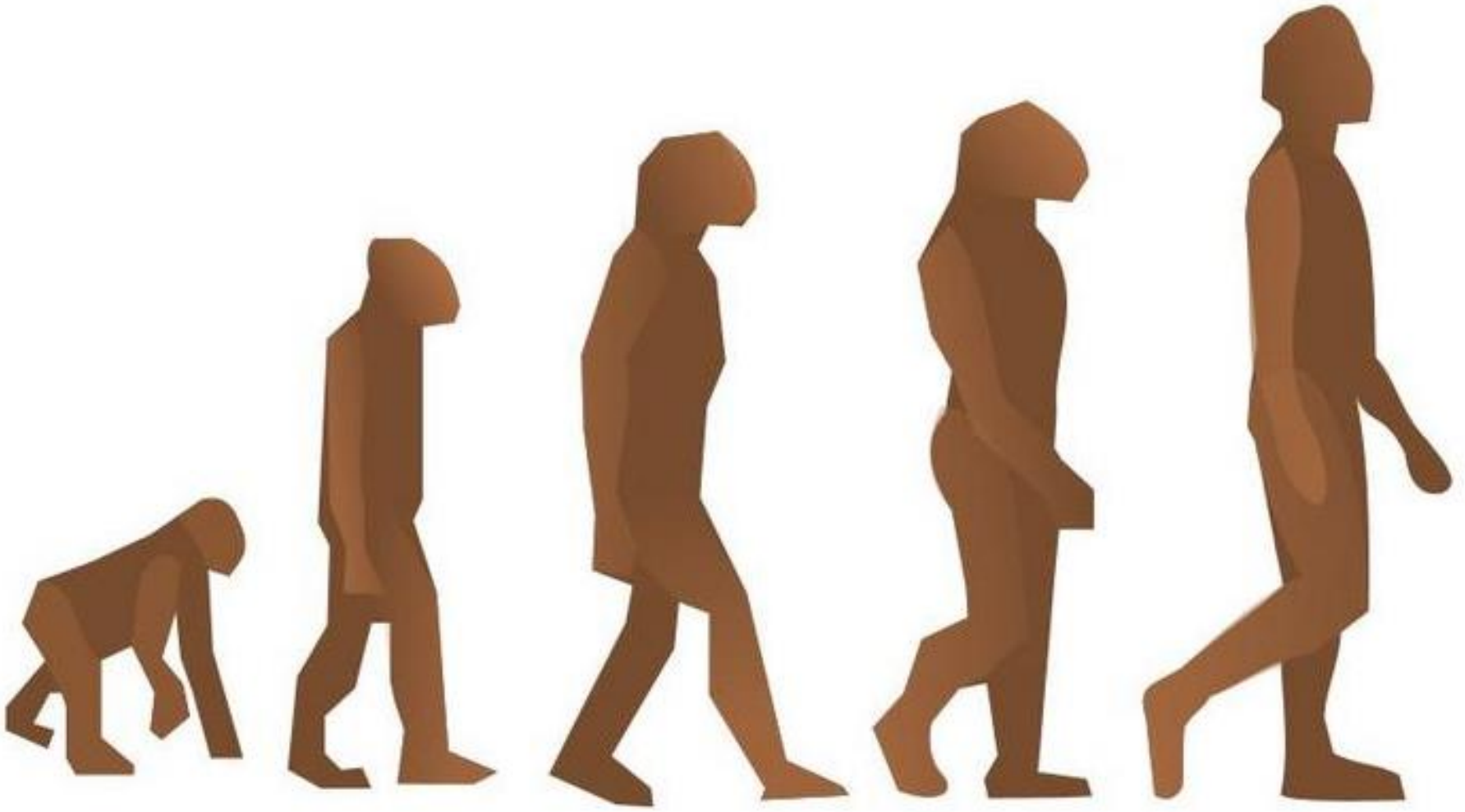
Oliver Brock
Robotics and Biology Laboratory

Alexander von Humboldt
Stiftung/Foundation

Technische Universität Berlin

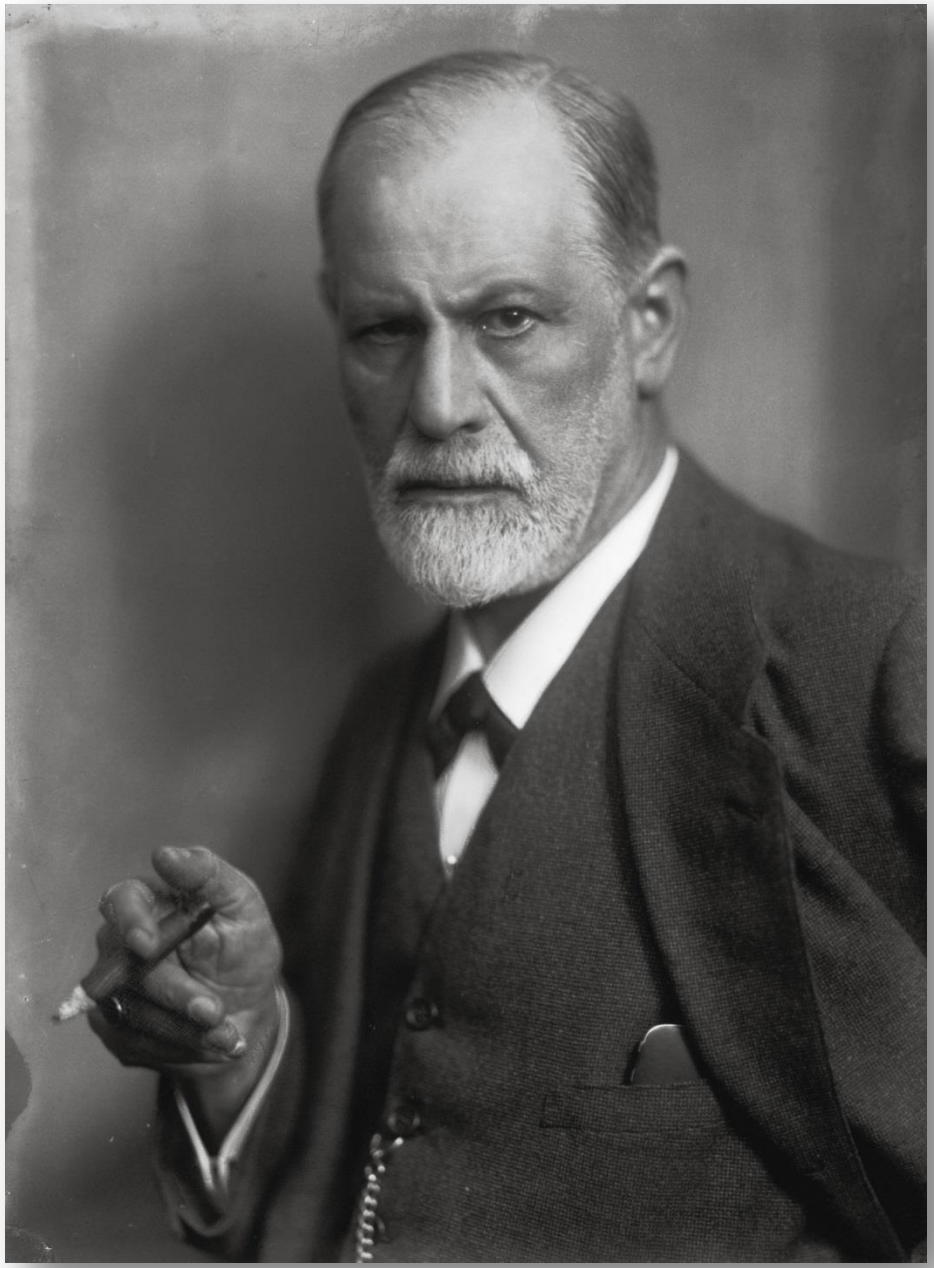


FIGVRA DOS CORPOS CELESTES
REVOLVÇÃO DO CEO DAS ESTRELAS
REVOLVÇÃO DO CEO DE SATVRNO
REVOLVÇÃO DO CEO D IVPITER
REVOLVÇÃO DE MARS
REVOLVÇÃO DO SOL
REVOLVÇÃO DE VENVS
REVOLVÇÃO DE MERCVRIO
R. DA LVA
EN 36000 AÑOS
EN TRINTA ANNOS
EN DOZE ANNOS
EN DOVS ANNOS
EN 365 DIAS
EN 273 DIAS E SEIS ORAS
EN 70 DIAS E 23 ORAS
EN 27 DIAS E 7 ORAS
FOGO
AR
LVNA
MERCVRIO
VENVS
SOL
MARS
IVPITER
SATVRNO
FIRMAMENTO

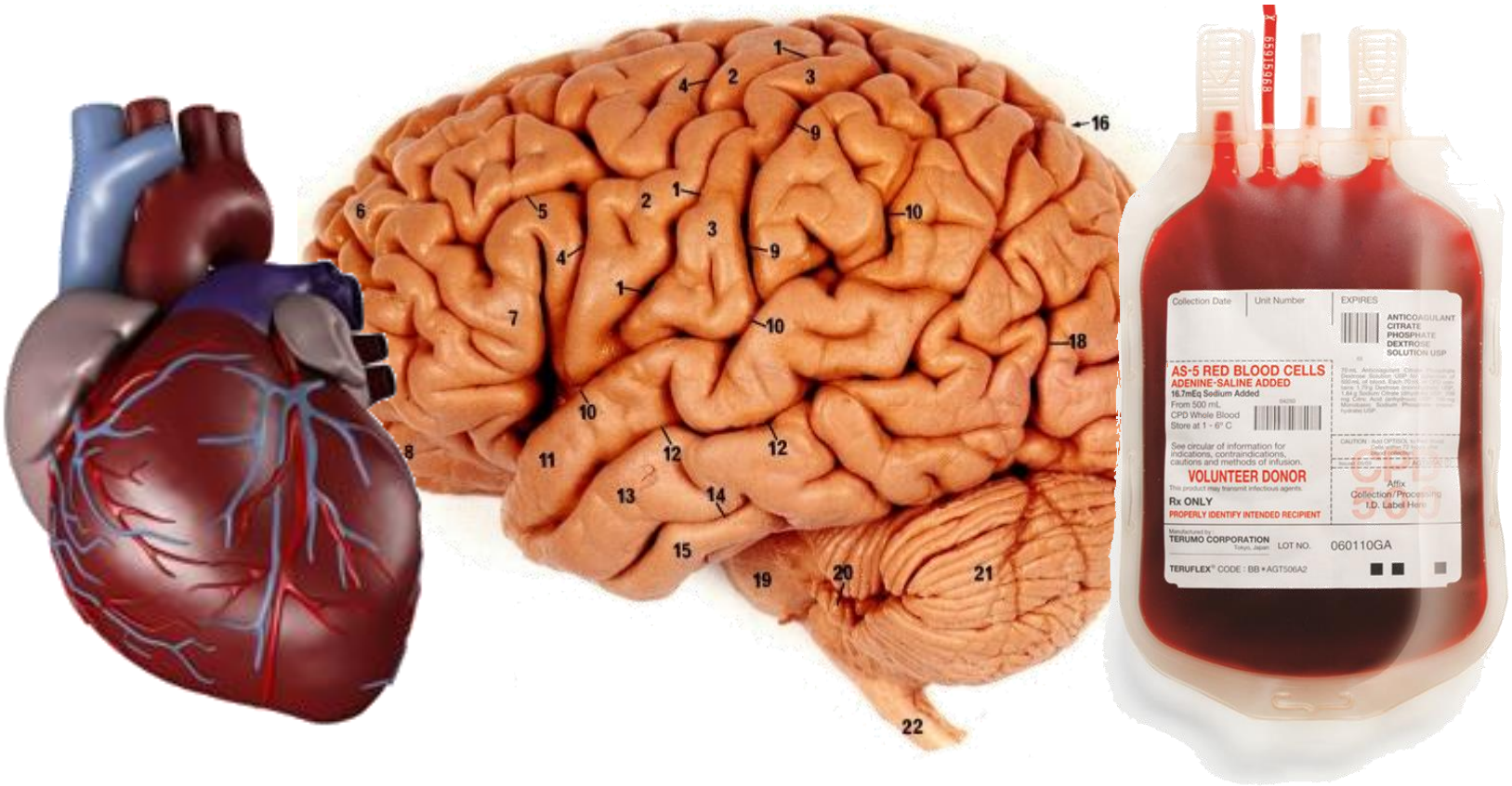


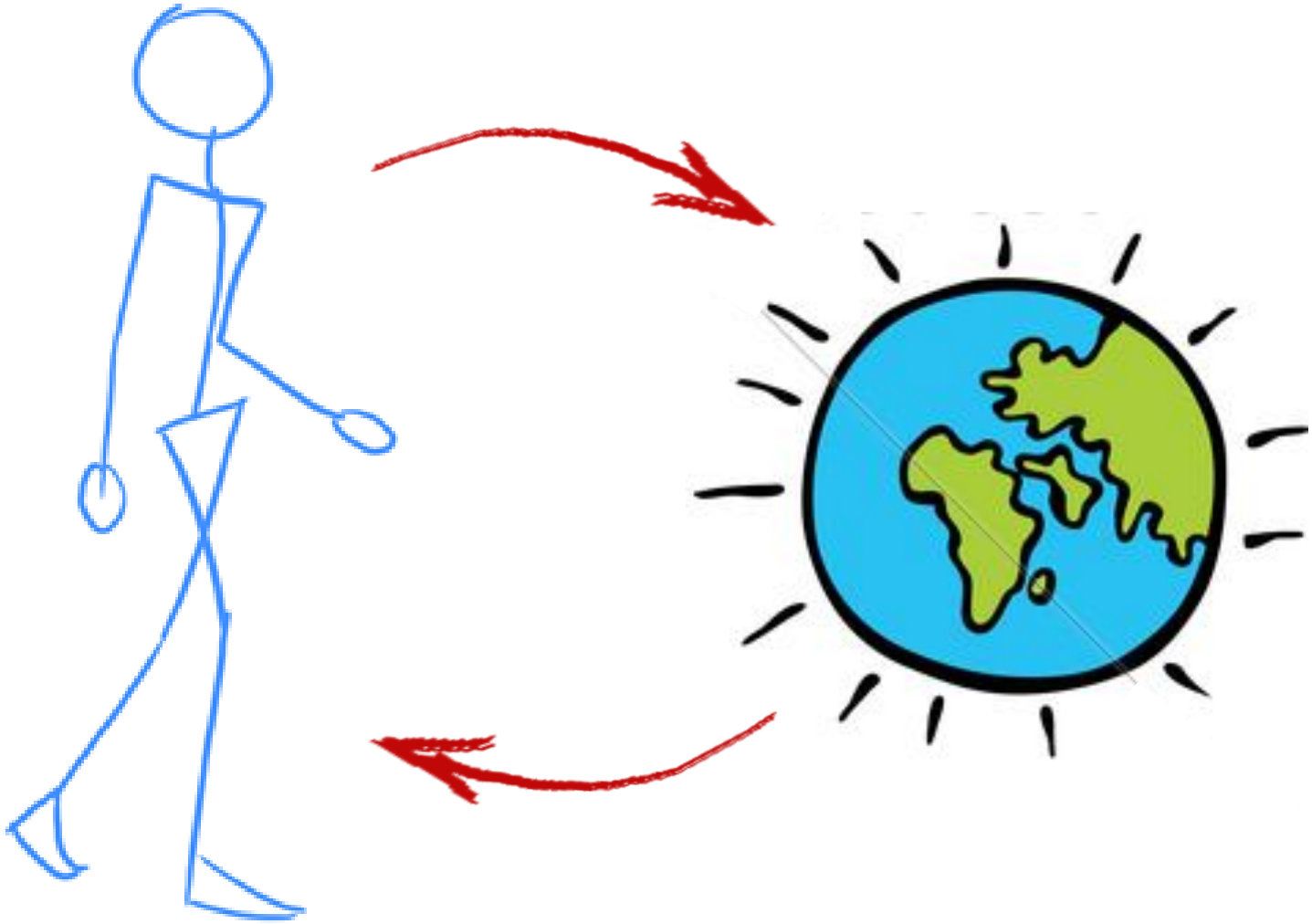
RBO

berlin



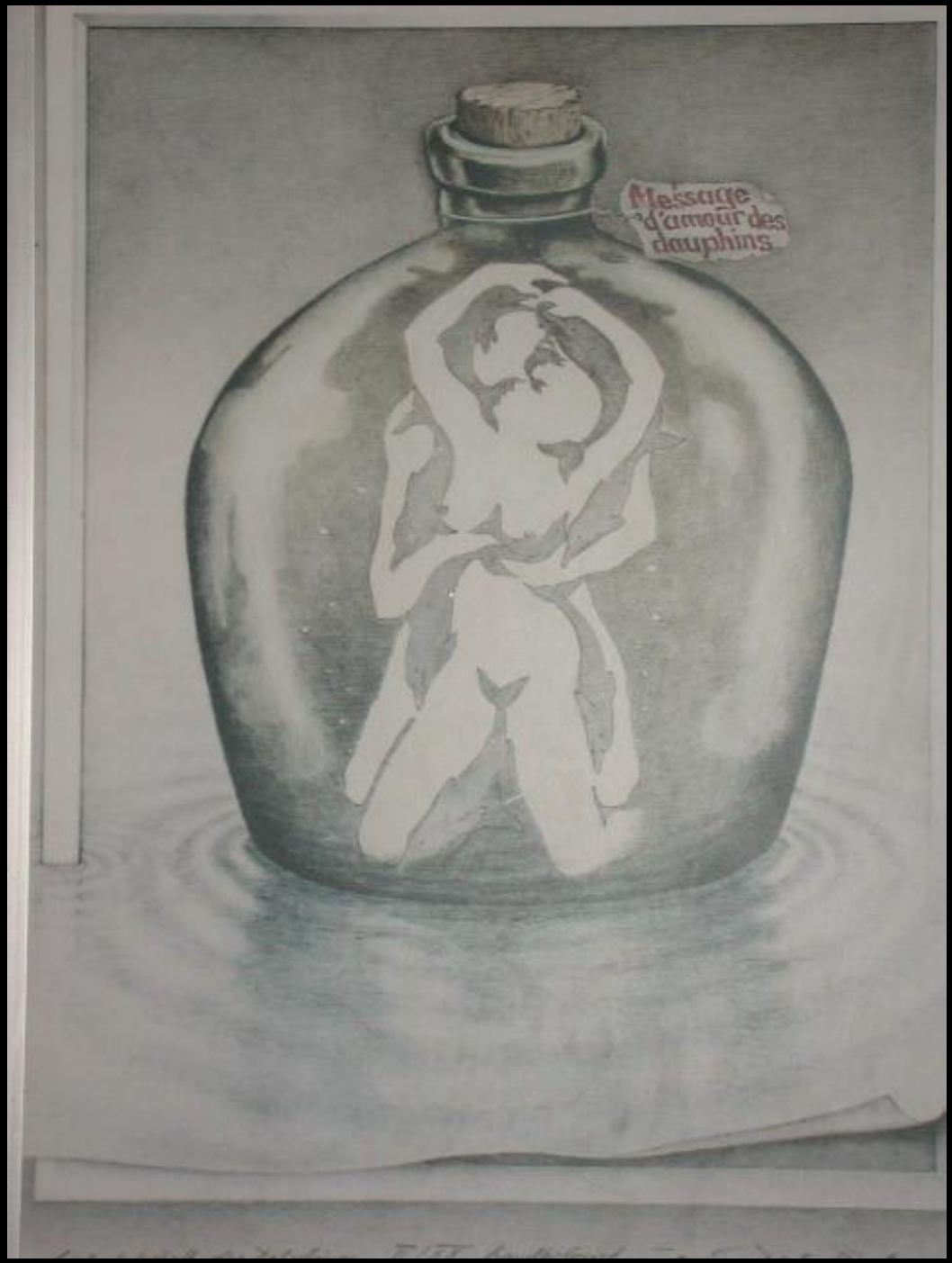
Intelligence

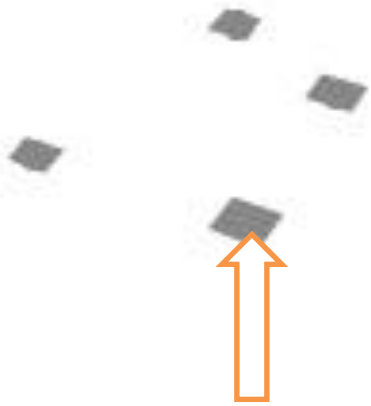


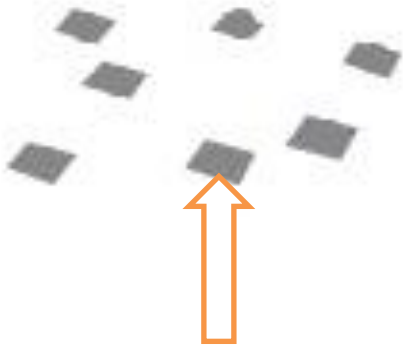


RBO

berlin


Message
d'amour des
dauphins

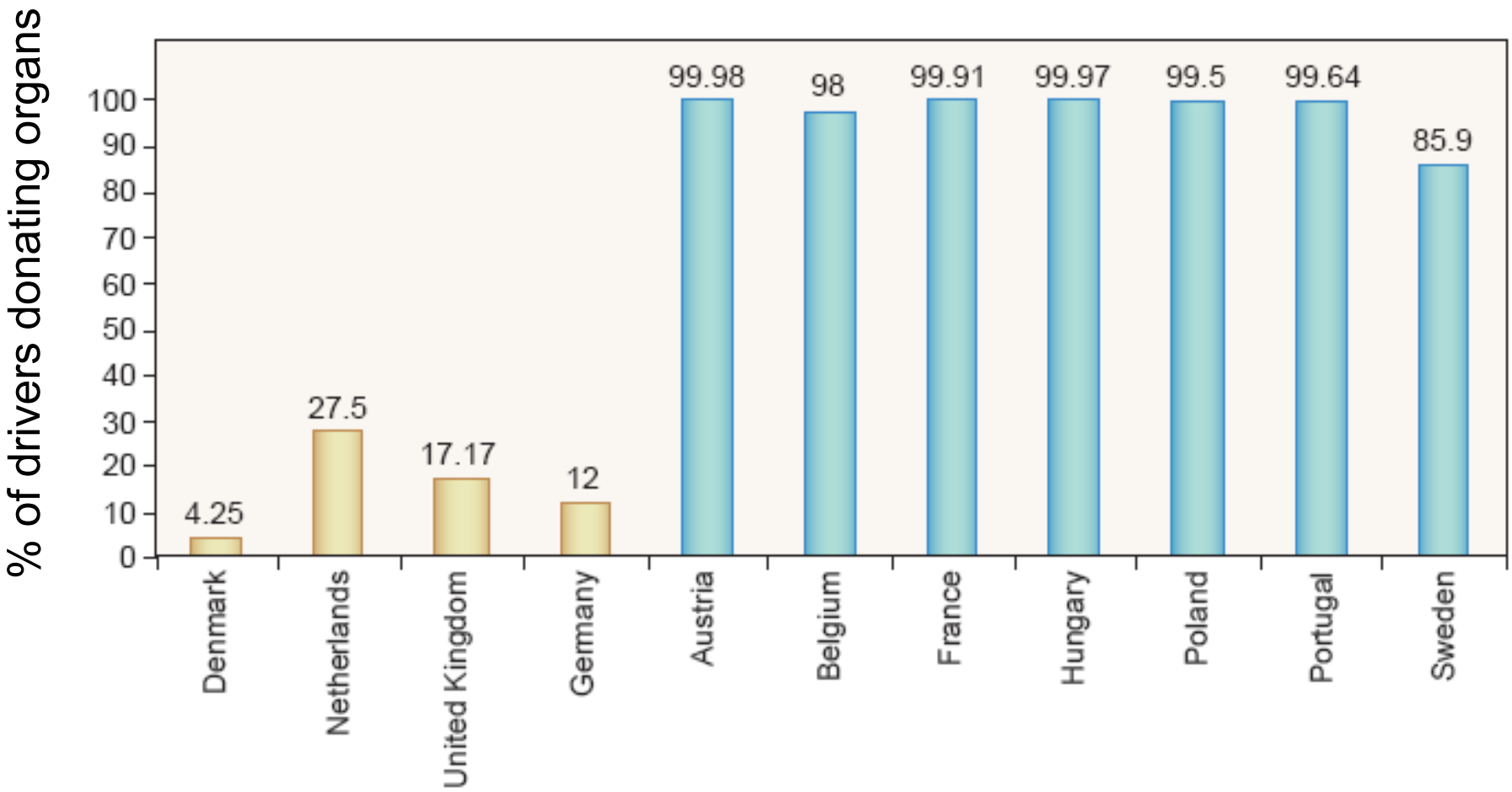




RBO

berlin

Organ Donations

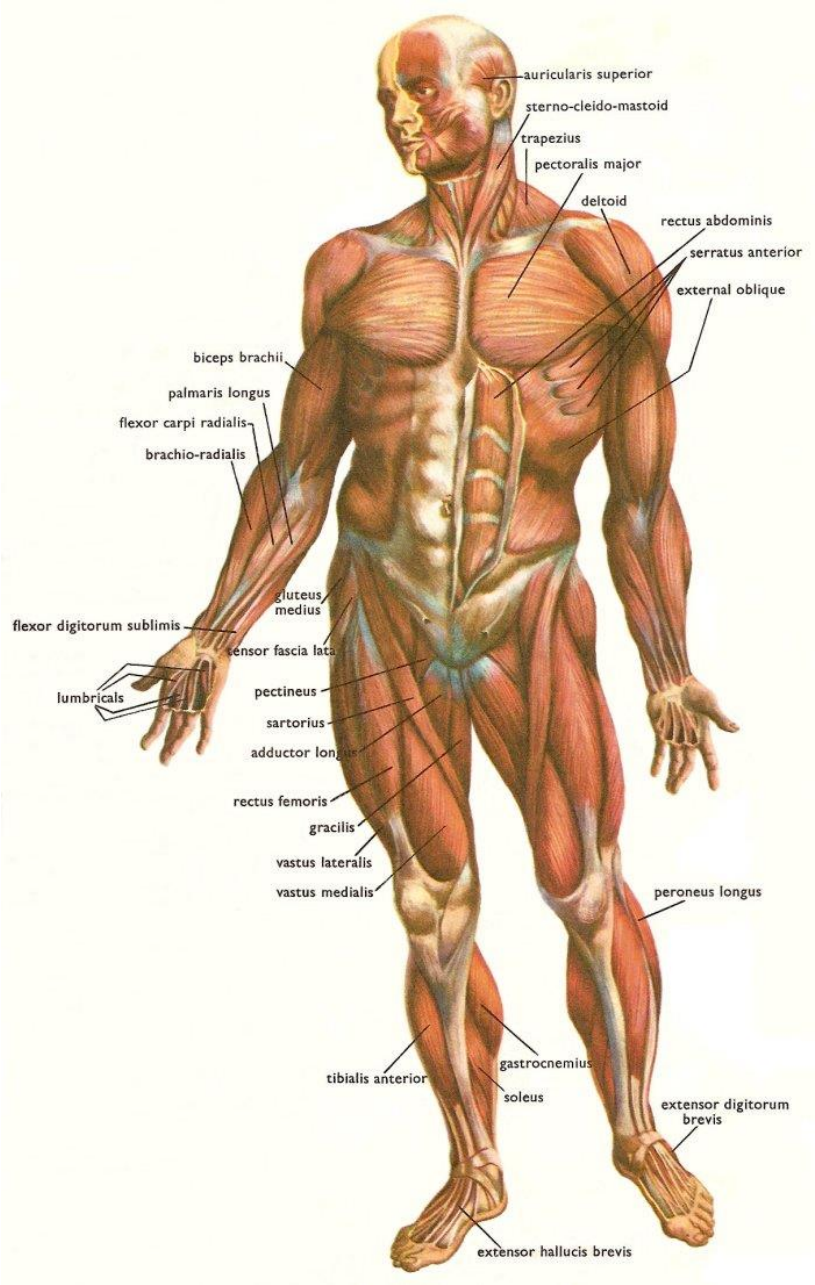


Johnson & Goldstein (2003)

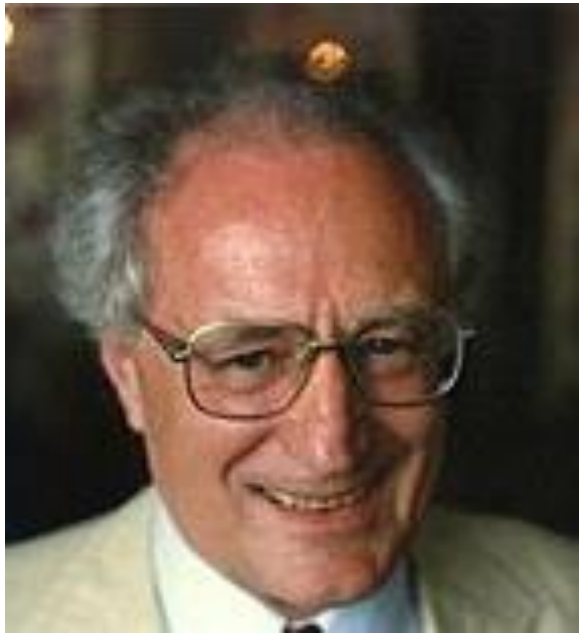
Johnson & Goldstein (2003)

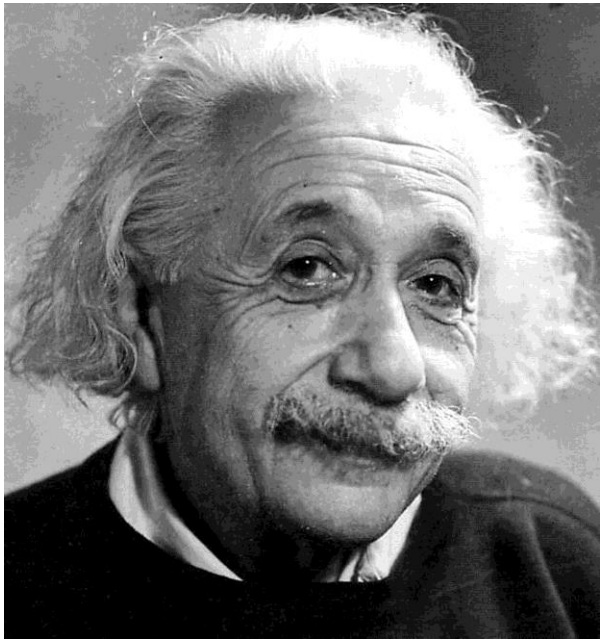
Opt-in

Opt-out


auricularis superior
sterno-cleido-mastoid
trapezius
pectoralis major
deltoid
rectus abdominis
serratus anterior
external oblique
biceps brachii
palmaris longus
flexor carpi radialis
brachio-radialis
gluteus medius
flexor digitorum sublimis
tensor fascia lata
lumbricals
pectineus
sartorius
adductor longus
rectus femoris
gracilis
vastus lateralis
vastus medialis
peroneus longus
tibialis anterior
gastrocnemius
soleus
extensor digitorum brevis
extensor hallucis brevis

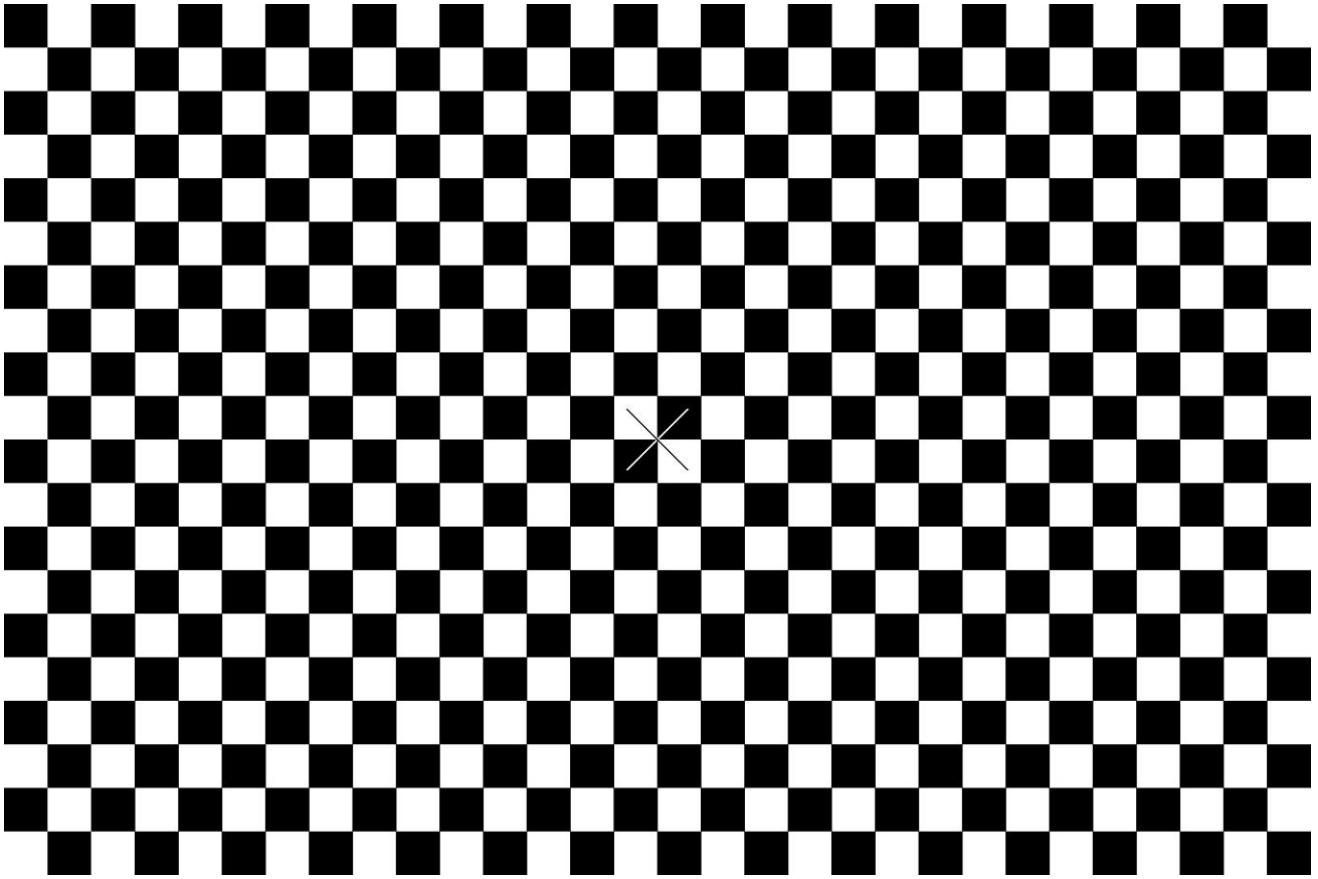
Bremermann's Limit





$$1.36 \times 10^{50} \text{ bits/(s kg)}$$

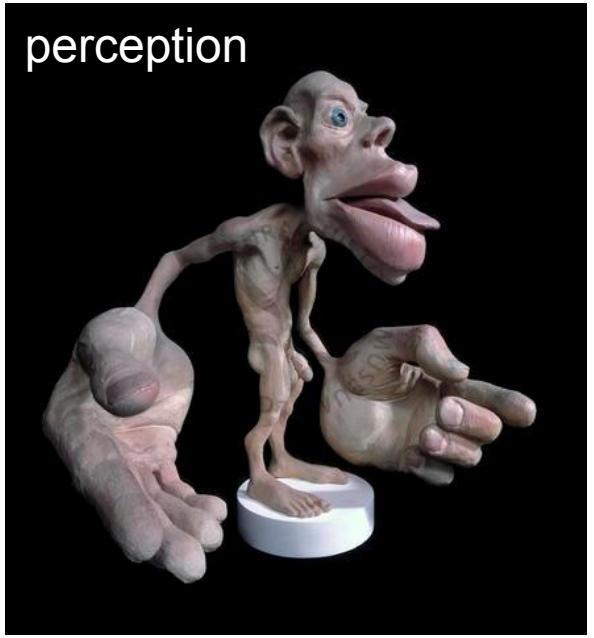
10^{75}ops/s



$$10^{200} \gg 10^{75}$$

$$600 \ll 300.000.000$$

Grasping



RBO


c|net


c|net

Julia Child (1912 – 2004)

A Scene From

The French Chef - Julia Child

The Potato Show

Season 1, Episde 22, 1963

A Scene From

The French Chef - Julia Child

The Potato Show

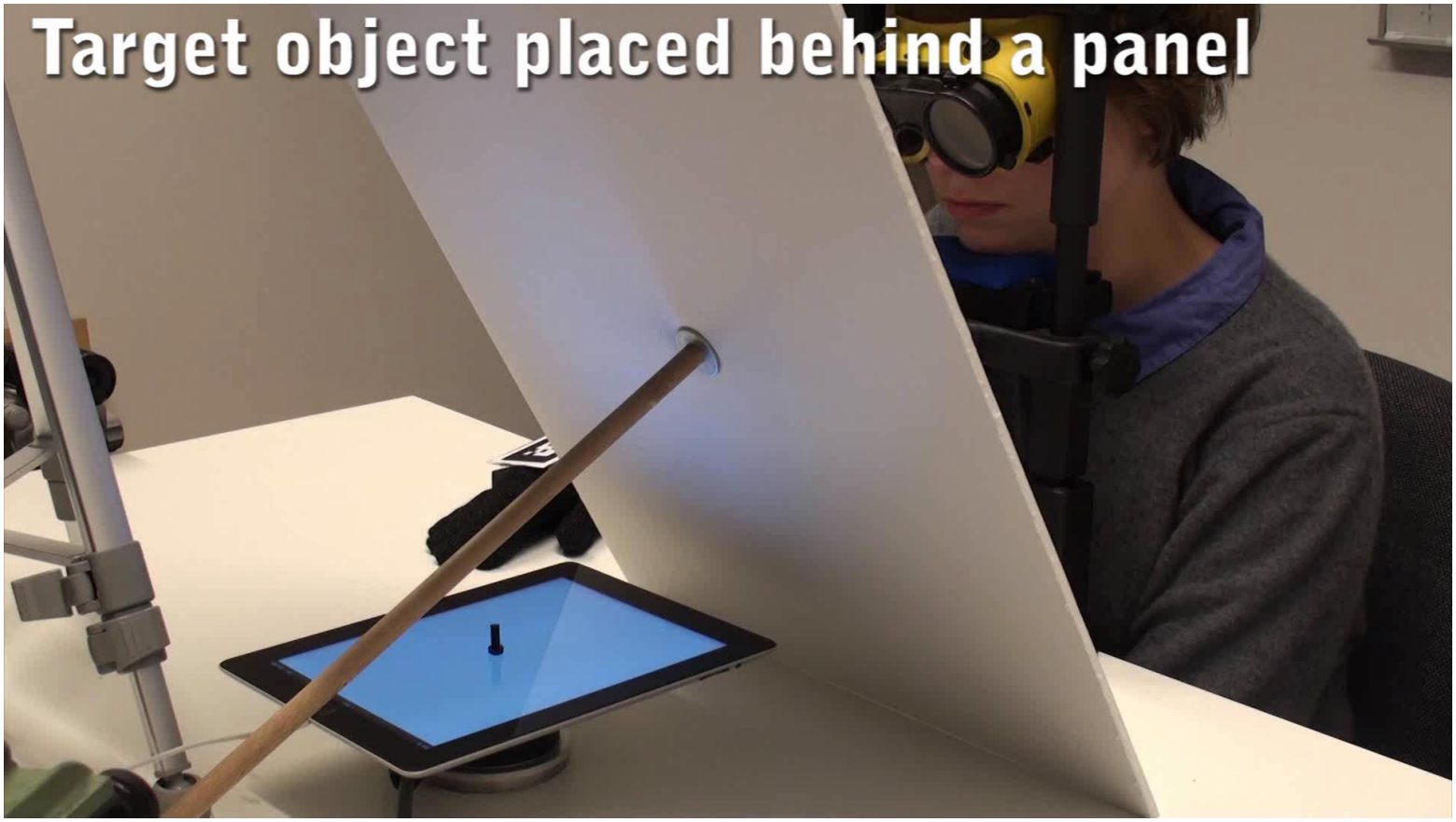
Season 1, Episde 22, 1963

Two Experimental Conditions

Control

Impaired

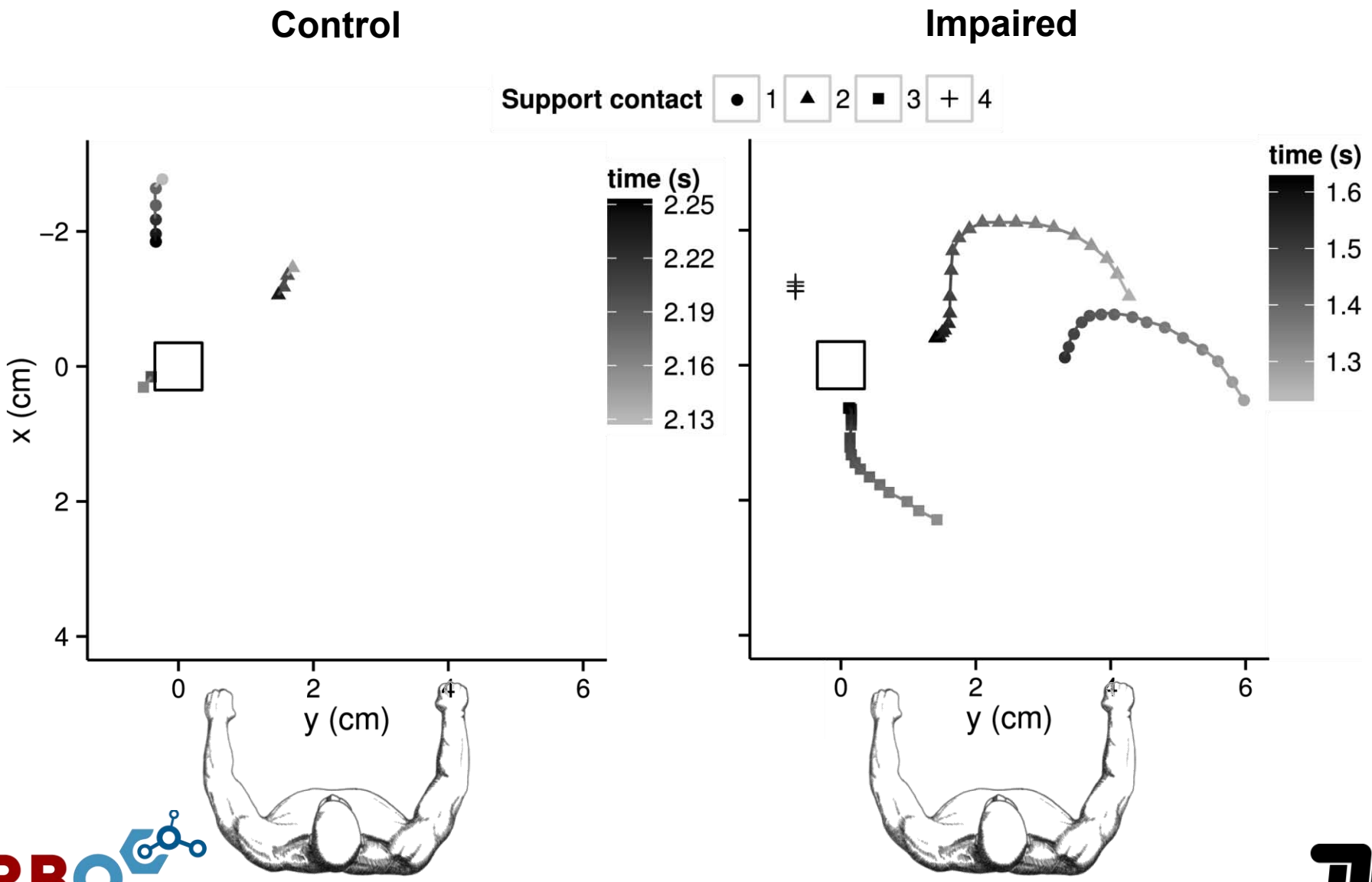
Human Grasping Strategies



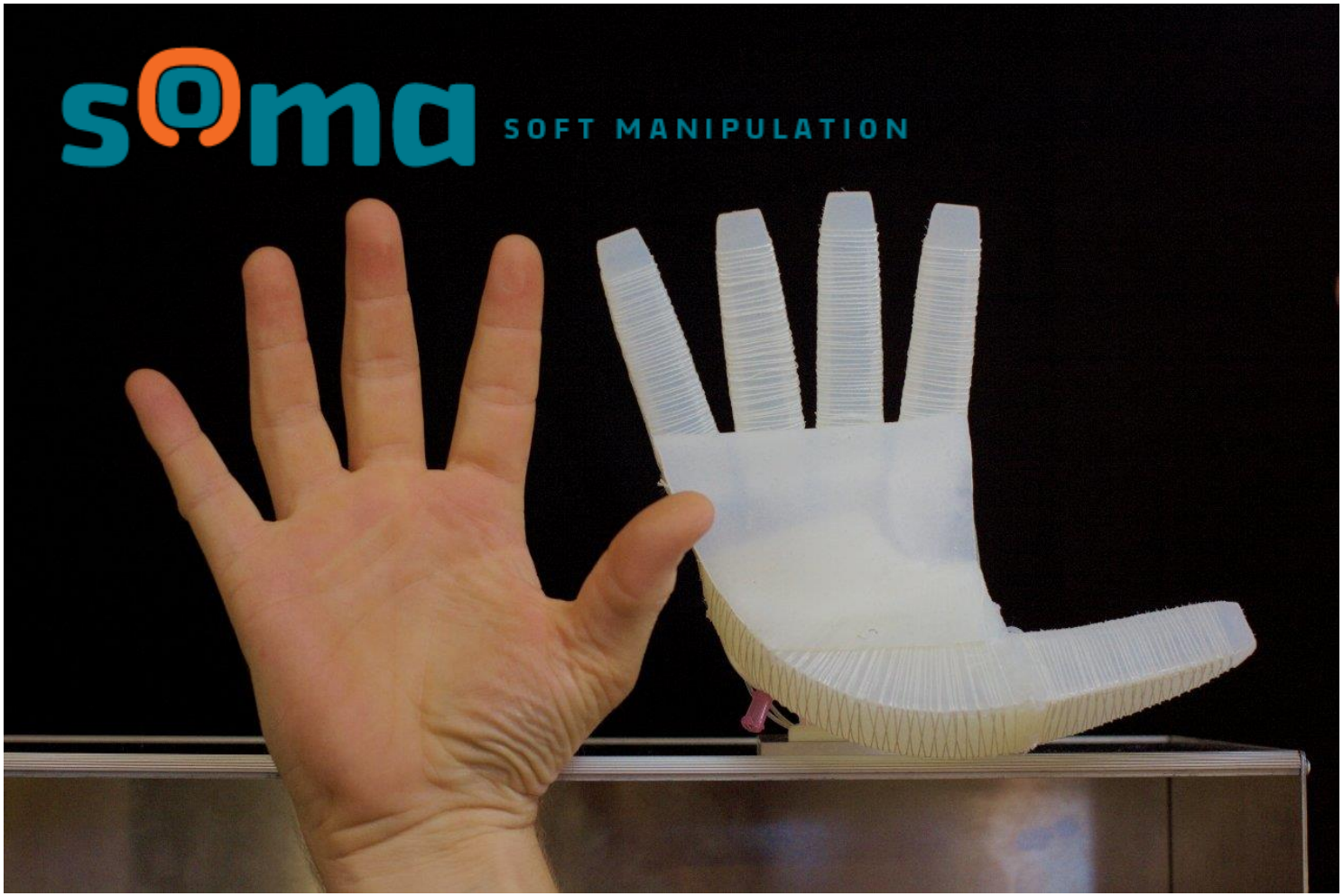
José Alvarez-Ruiz

Marianne Maertens
Modelling of Cognitive Processes

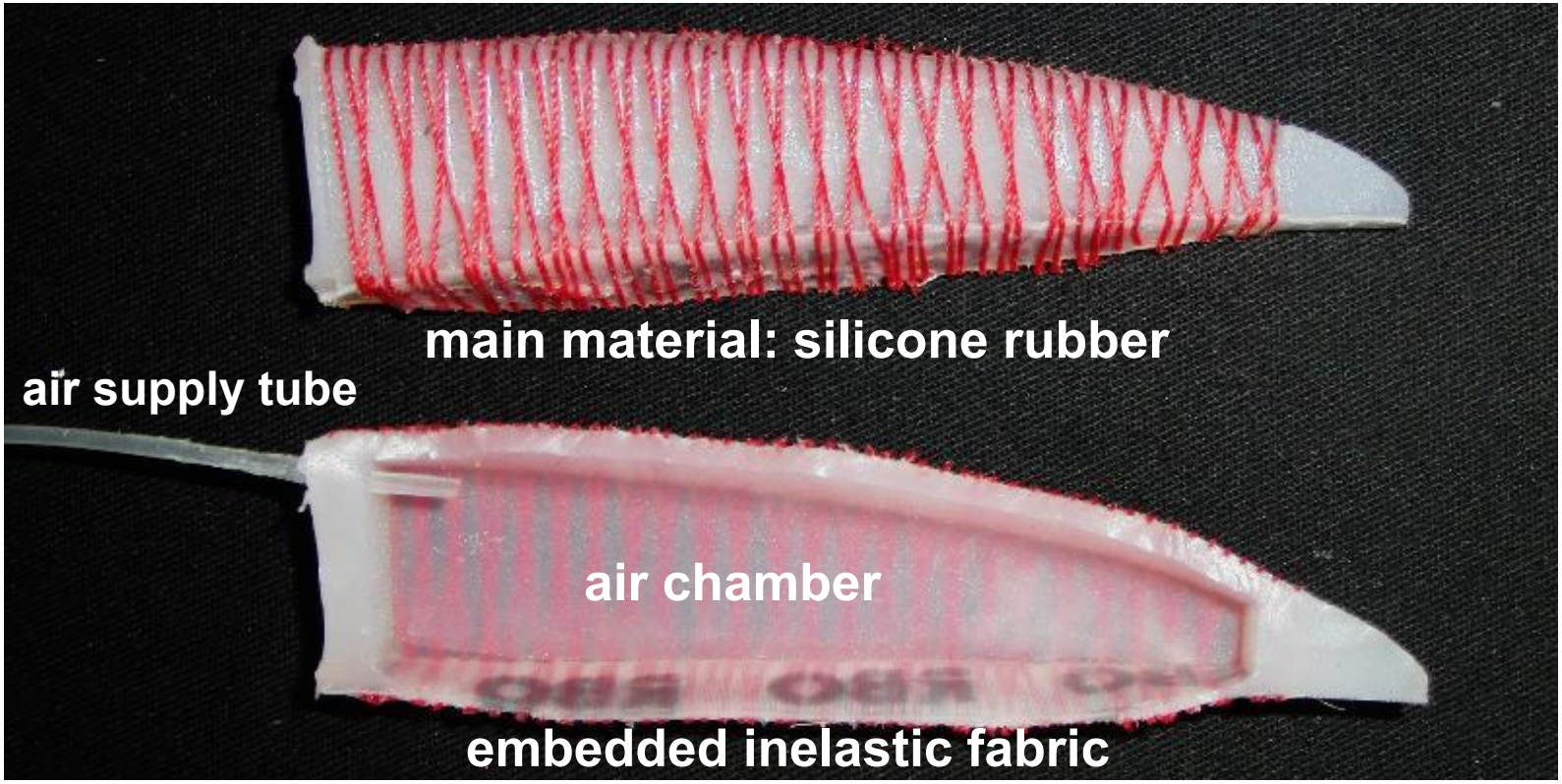
Traces of Support Contacts



RBO Anthropomorphic Hand

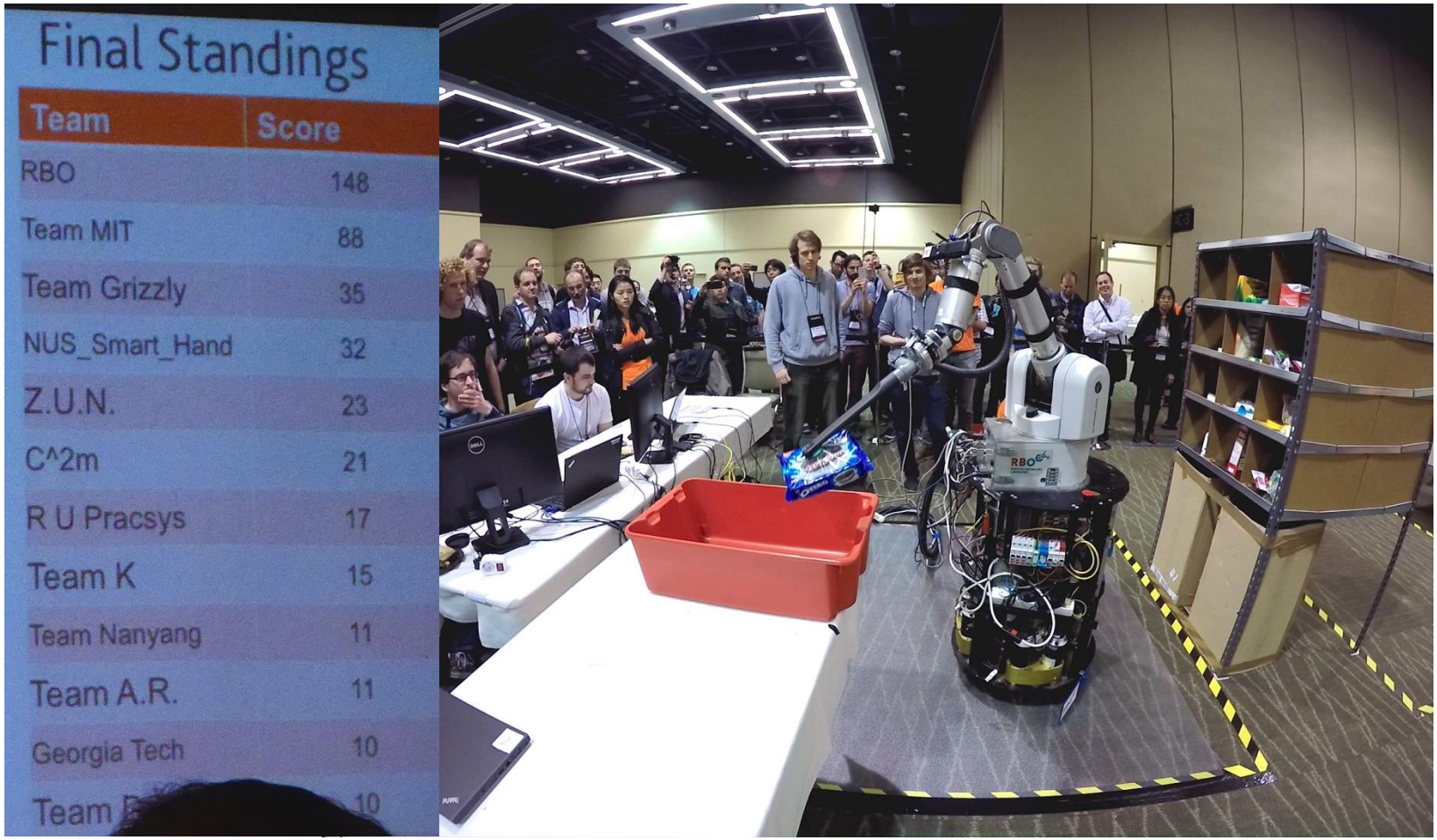


PneuFlex Actuators




x4

Amazon Picking Challenge: Results



Final Standings

Team	Score
RBO	148
Team MIT	88
Team Grizzly	35
NUS_Smart_Hand	32
Z.U.N.	23
C^2m	21
R U Pracsys	17
Team K	15
Team Nanyang	11
Team A.R.	11
Georgia Tech	10
Team [illegible]	10

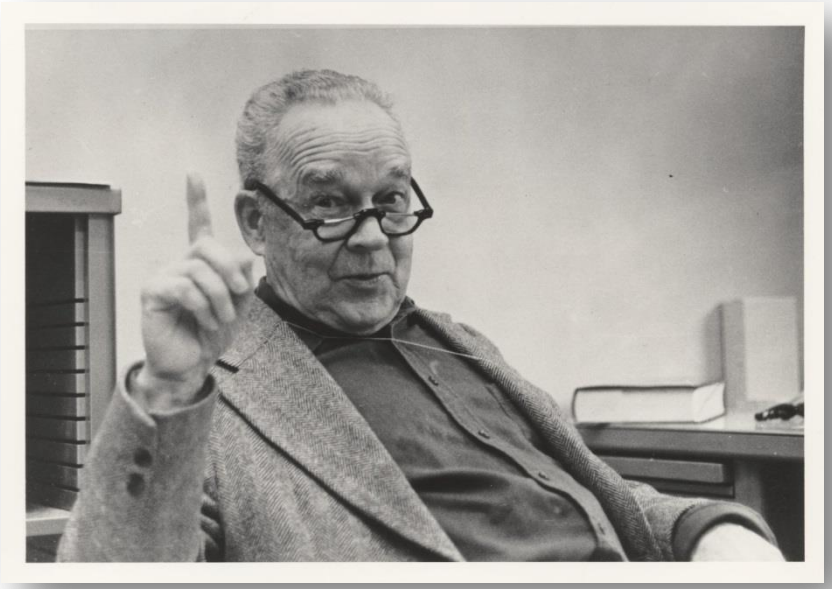
Why Are Humans So Much Better?

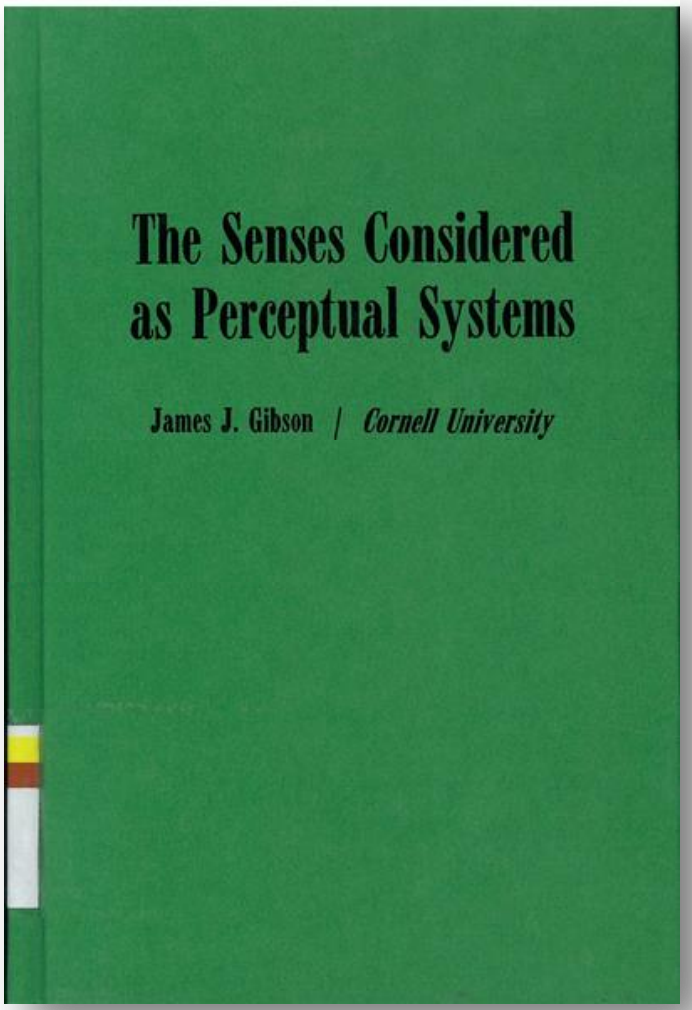
They let the body solve the problem!

Why Are Humans So Much Better?

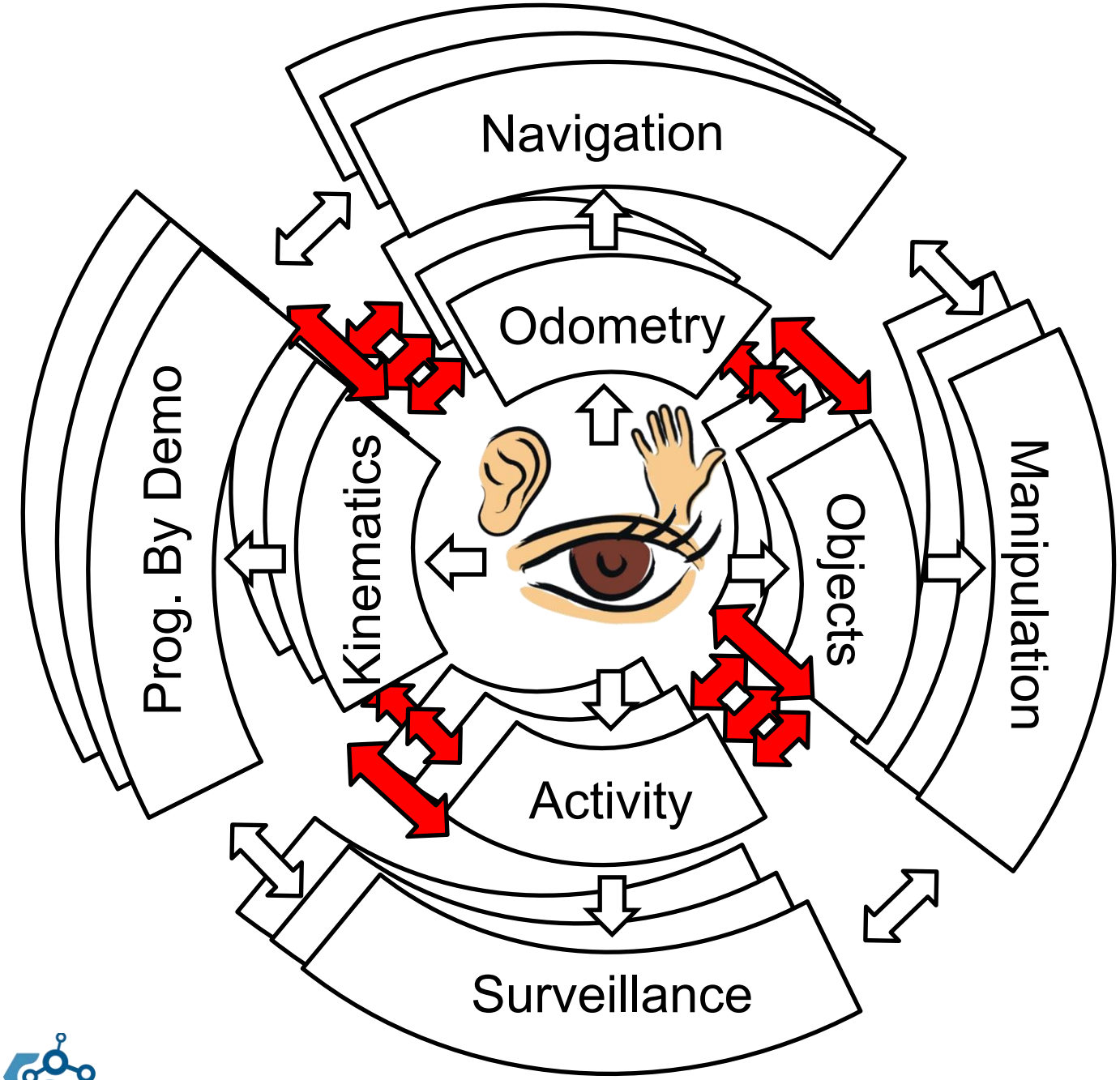
They are optimized for behavior!
(as are all biological systems)

James J. Gibson (1904–1979) Eleanor J. Gibson (1910–2002)

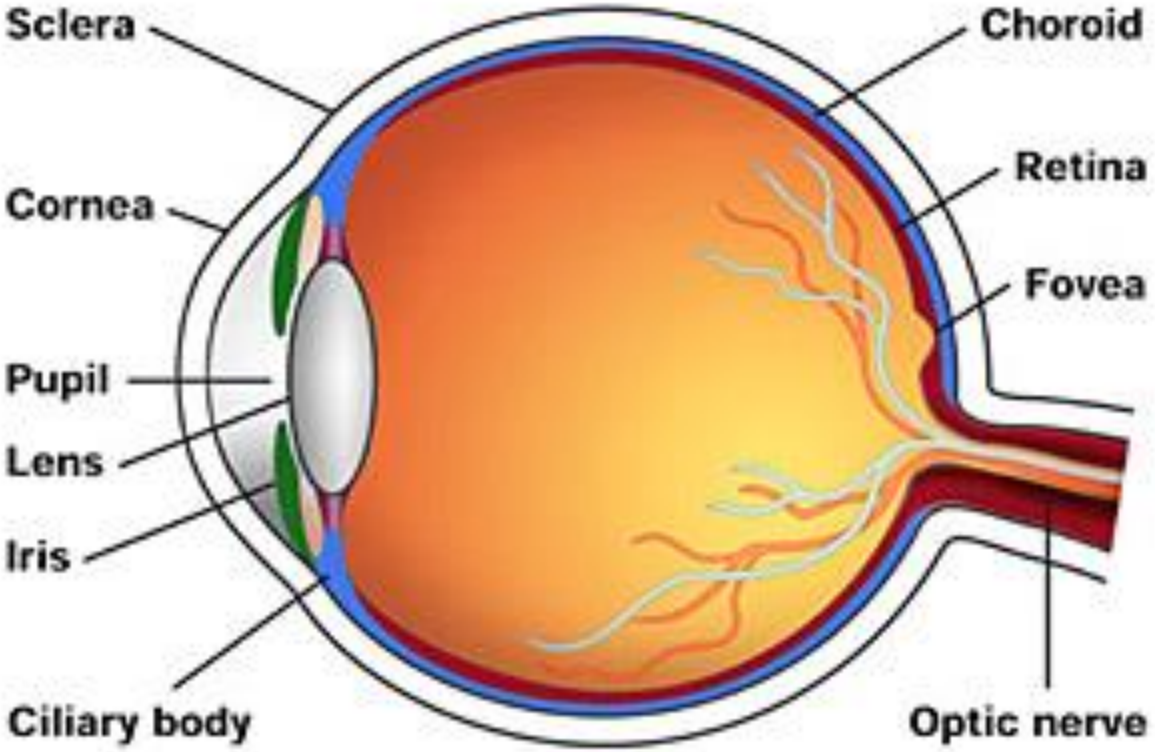




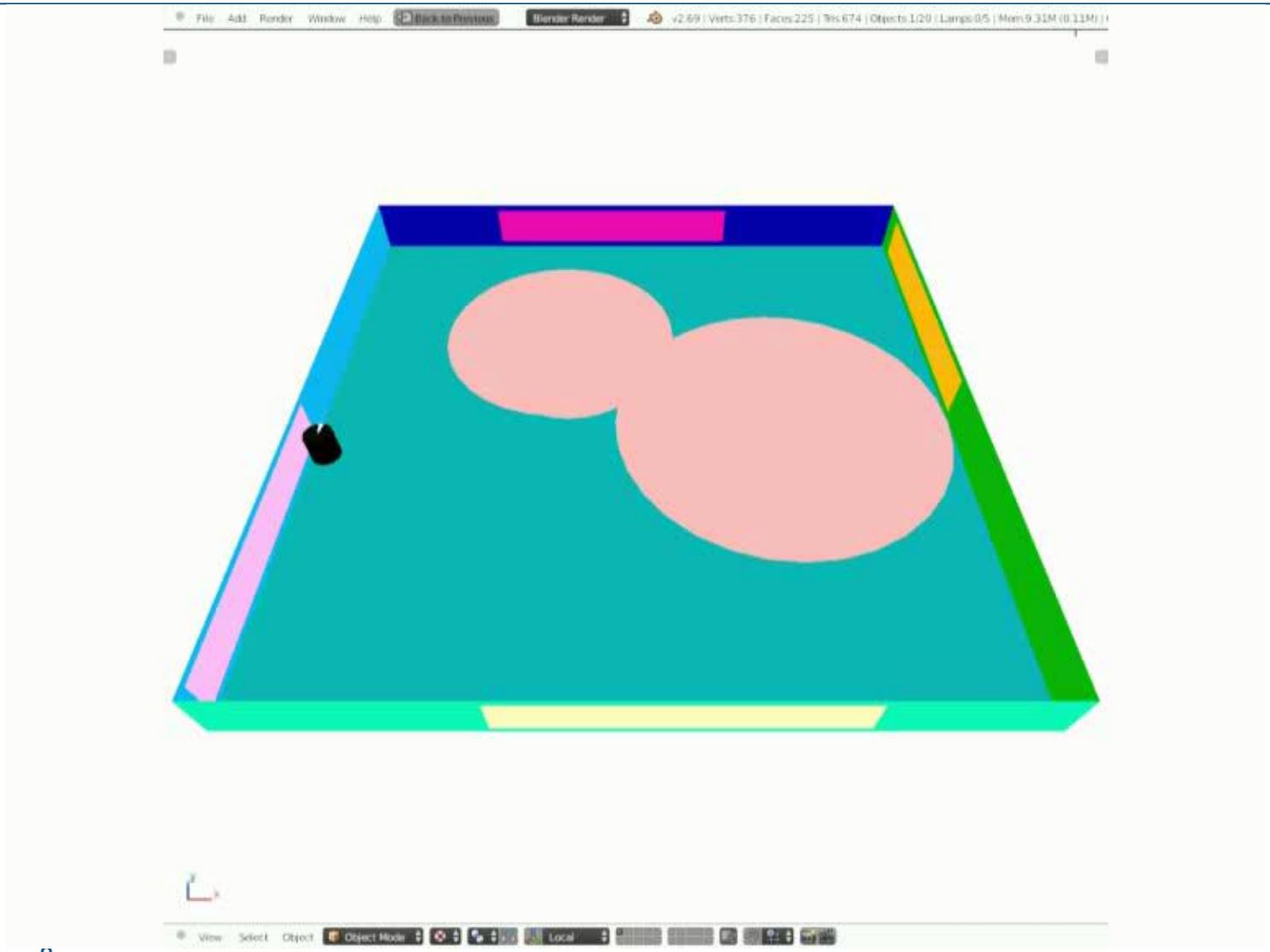
1966


Navigation
Odometry
Prog. By Demo
Kinematics
Objects
Manipulation
Activity
Surveillance

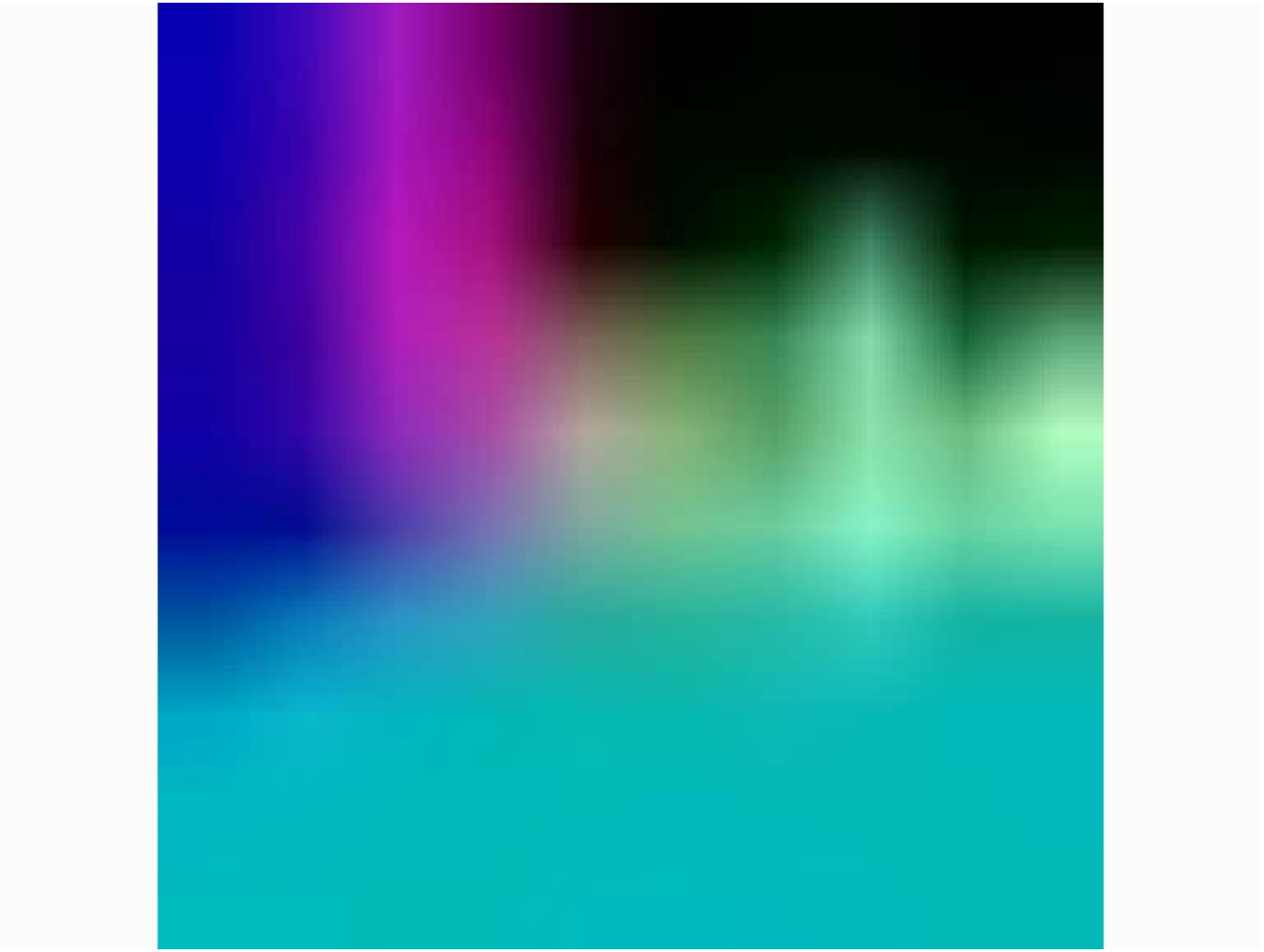
“Learning to See (Sense)”

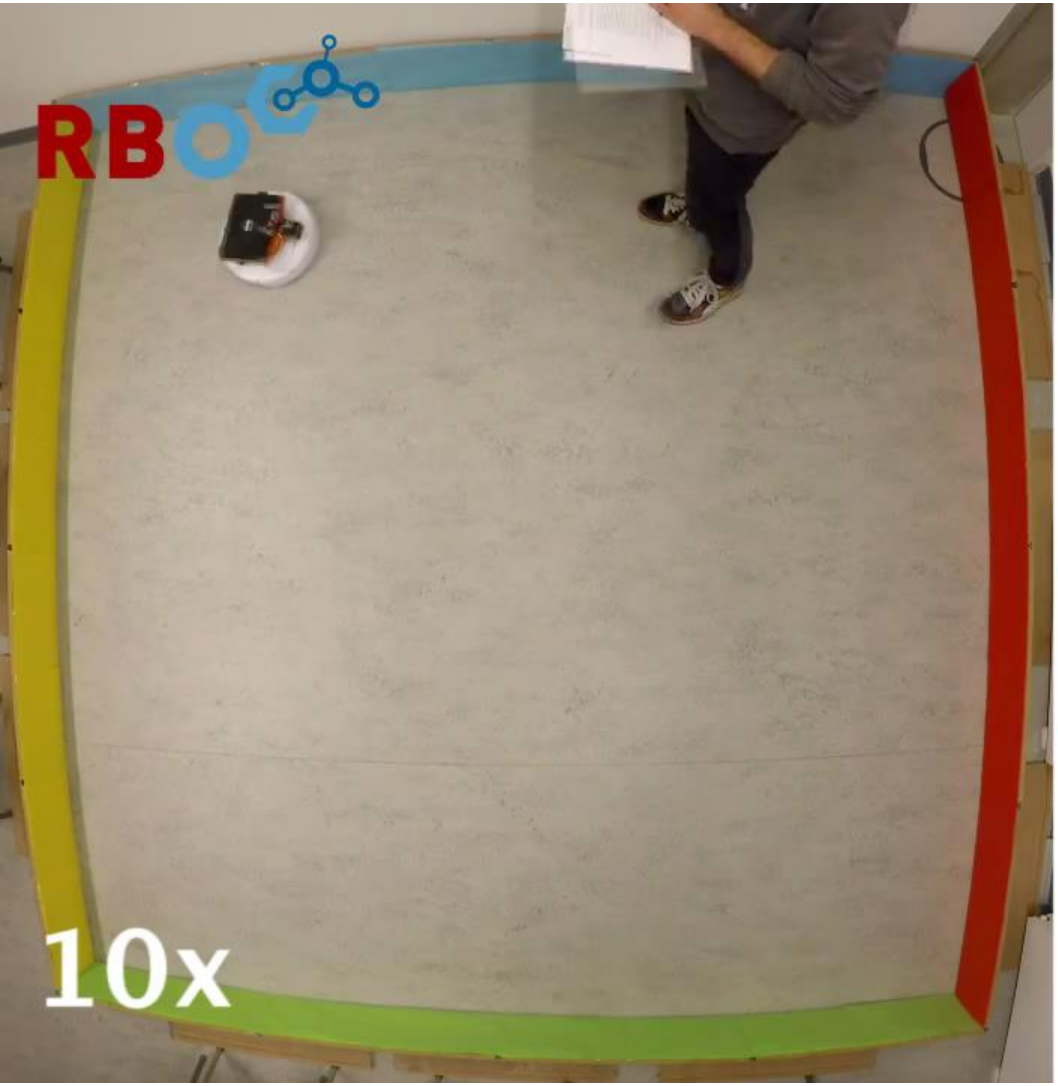


Learning to See With Distractions



Moving With Distractions (Robot's View)





Robot's perspective:

Reward:

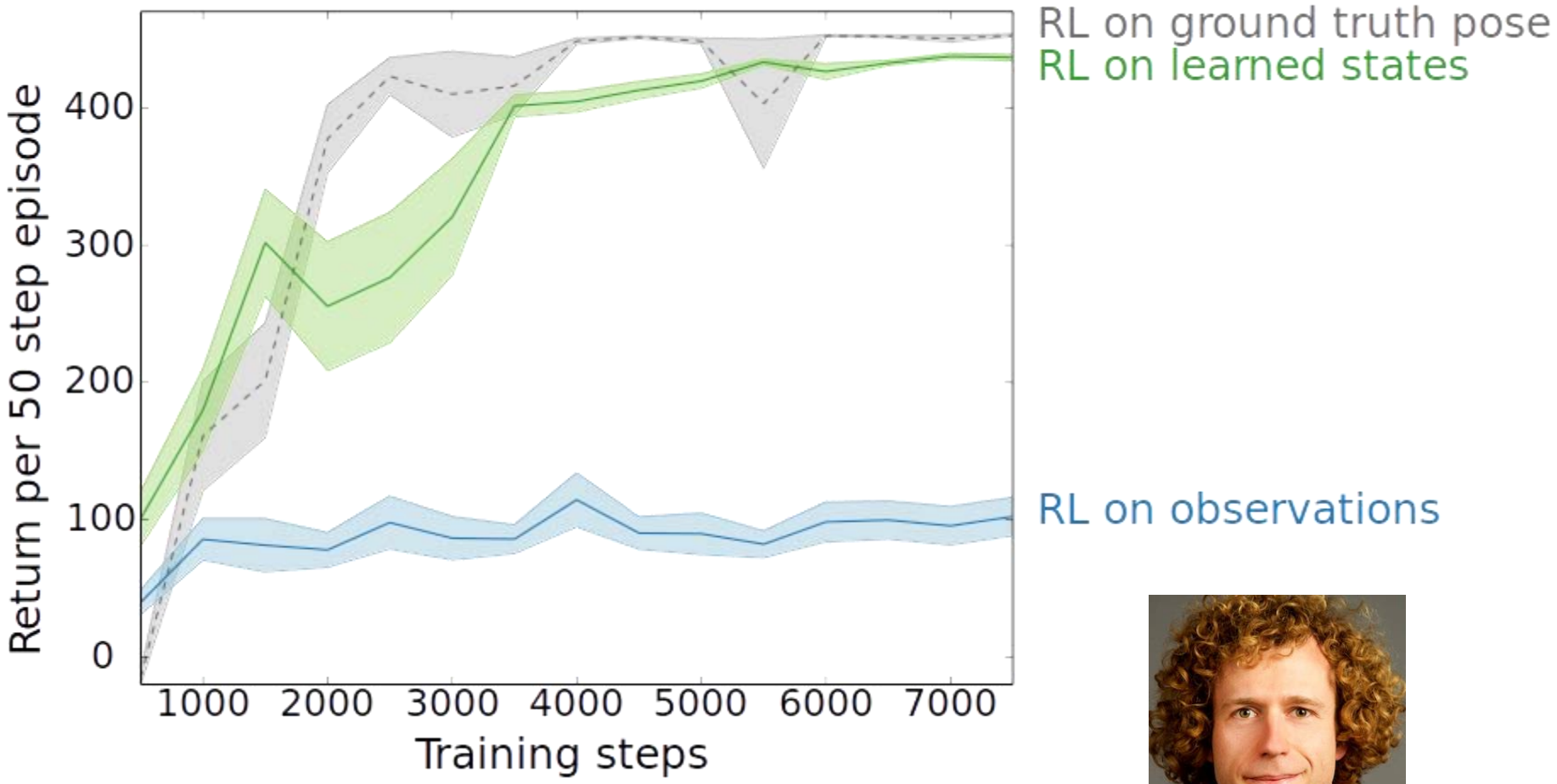
Observation:

Action:

RBO

berlin

Did the Robot „Learn to See“?



Rico Jonschkowski

Five Robotic Priors

Simplicity

Only a small number of world properties are relevant.

$$L_{\text{temporal coherence}}(D, \hat{\phi}) = \mathbf{E}\left[\|\Delta \hat{s}_t\|^2\right]$$

Task-relevant properties of the world change gradually.

$$L_{\text{causality}}(D, \hat{\phi}) = \mathbf{E}\left[e^{-\|\hat{s}_{t_2} - \hat{s}_{t_1}\|} \;\middle|\; a_{t_1} = a_{t_2}, r_{t_1} \neq r_{t_2}\right]$$

The task-relevant properties together with the action determine the reward.

$$L_{\text{proportionality}}(D, \hat{\phi}) = \mathbf{E}\left[(\|\Delta \hat{s}_{t_2}\| - \|\Delta \hat{s}_{t_1}\|)^2 \;\middle|\; a_{t_1} = a_{t_2}\right]$$

The amount of change in task-relevant properties resulting from an action is proportional to the magnitude of the action.

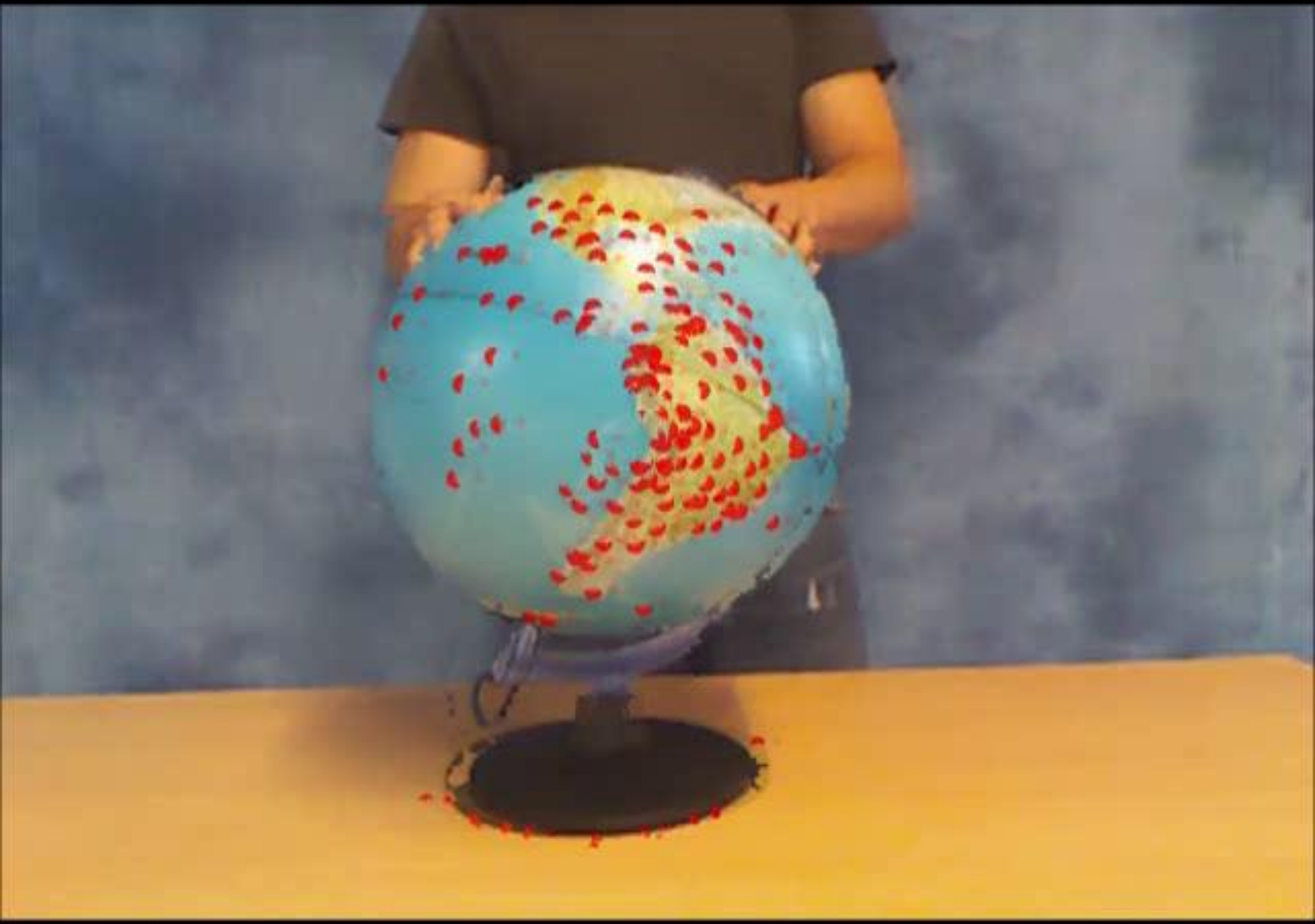
$$L_{\text{repeat.}}(D, \hat{\phi}) = \mathbf{E}\left[e^{-\|\hat{s}_{t_2} - \hat{s}_{t_1}\|}\|\Delta \hat{s}_{t_2} - \Delta \hat{s}_{t_1}\|^2 \;\middle|\; a_{t_1} = a_{t_2}\right]$$

The task-relevant properties and the action together determine the resulting change in these properties.

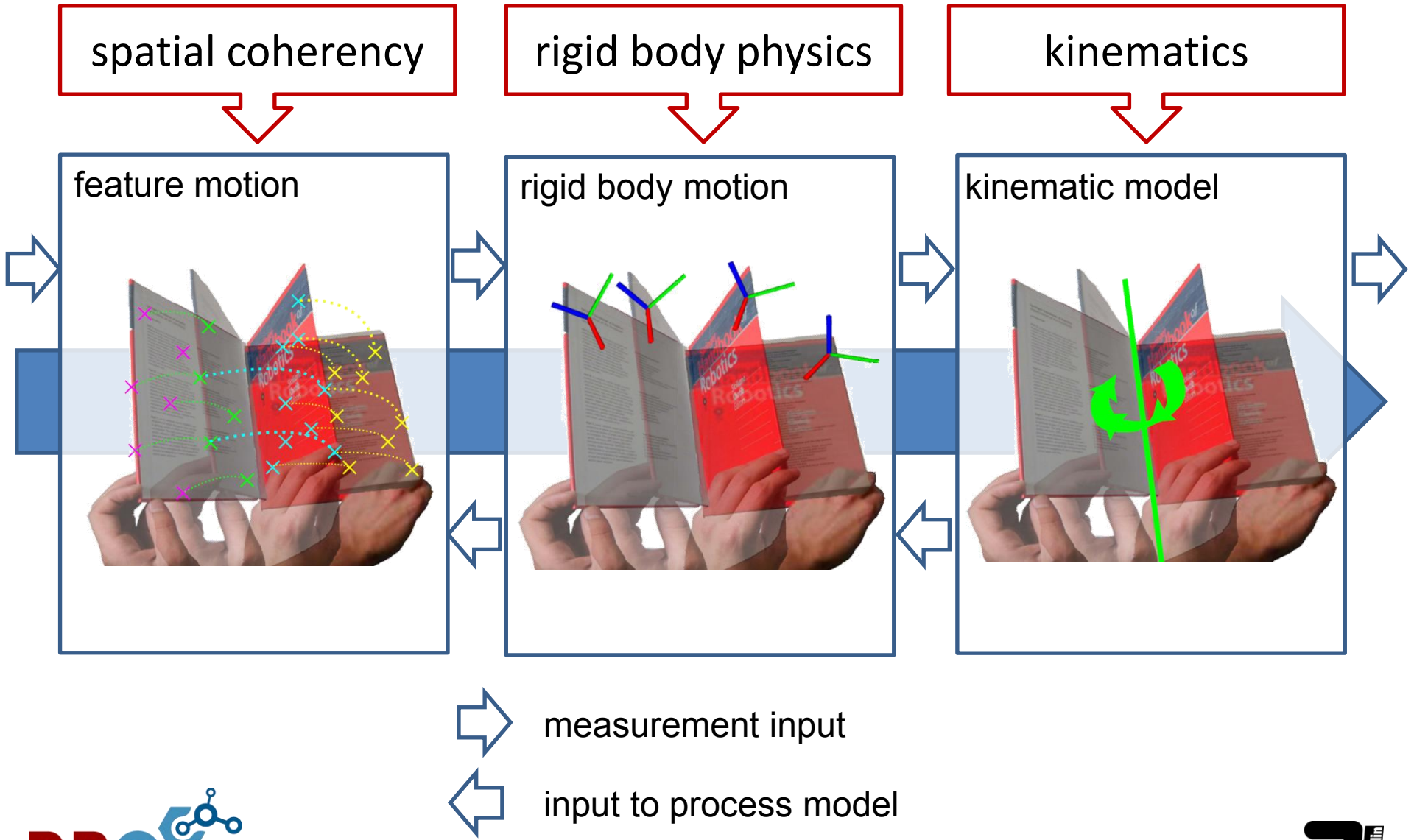
Why Are Humans So Much Better?

They had evolution program task-relevant dimensionality reduction into the nervous system!

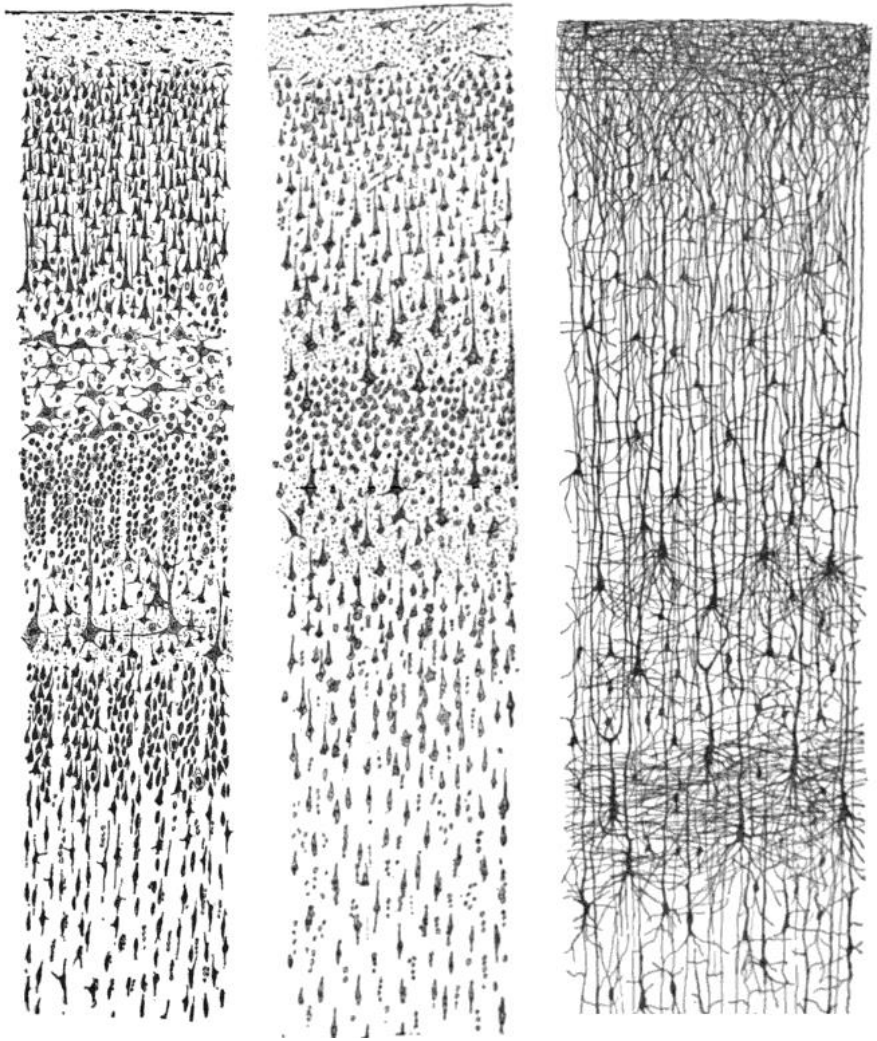
Roberto Martín Martín

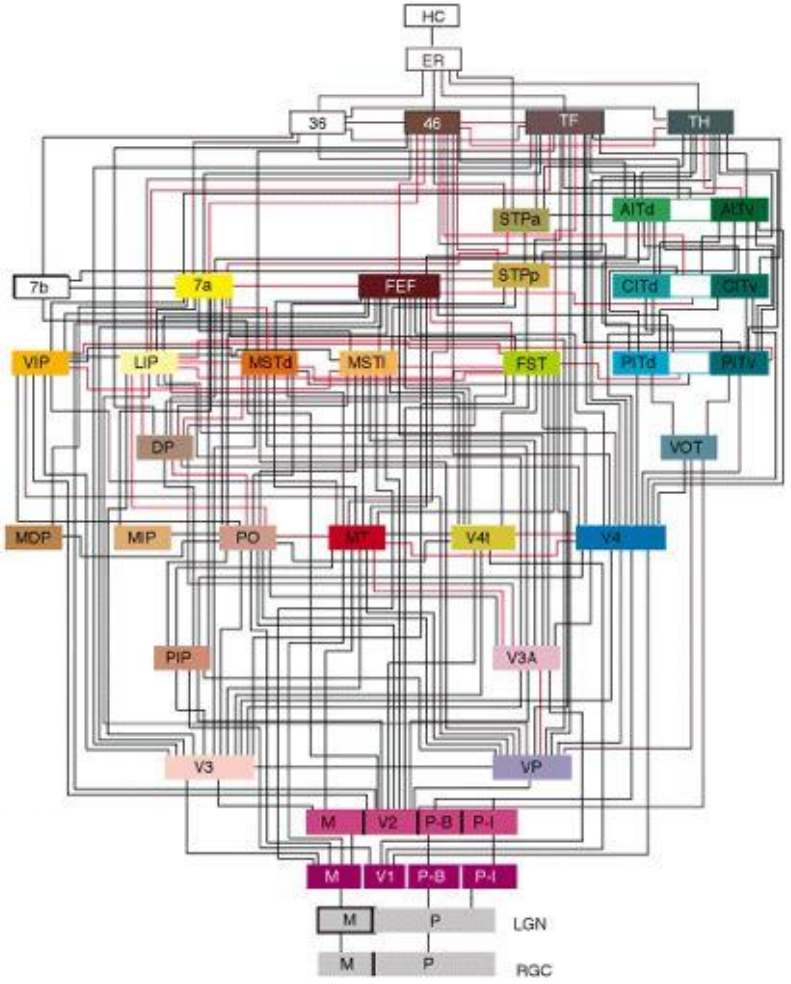


Online IP: Three Recursive Estimation Problems



Layers of the Cortex / Connectivity of Visual Cortex





Why Are Humans So Much Better?

They interpret **multiple** sensor streams
at once, **hierarchically**,
taking into account what they “know”
about the world at each step!

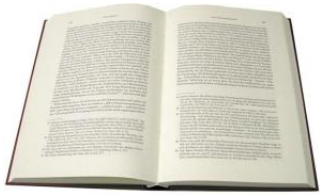
Understanding Regularities in the World







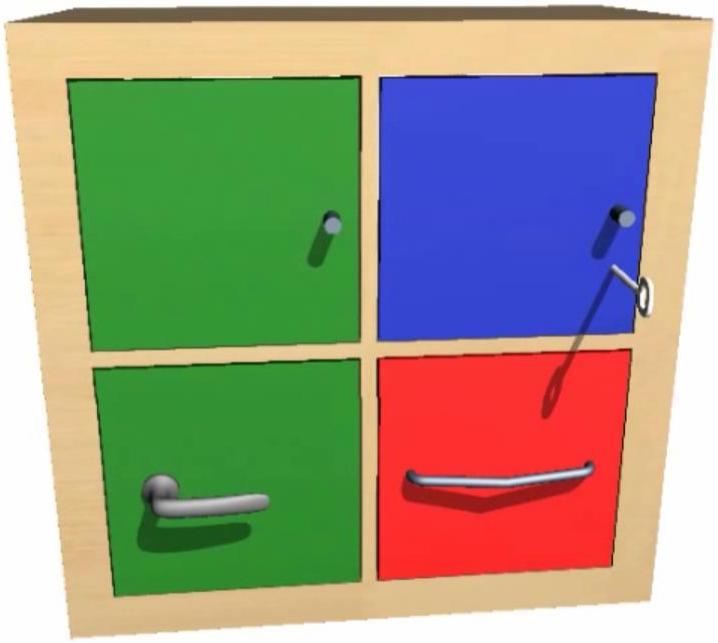


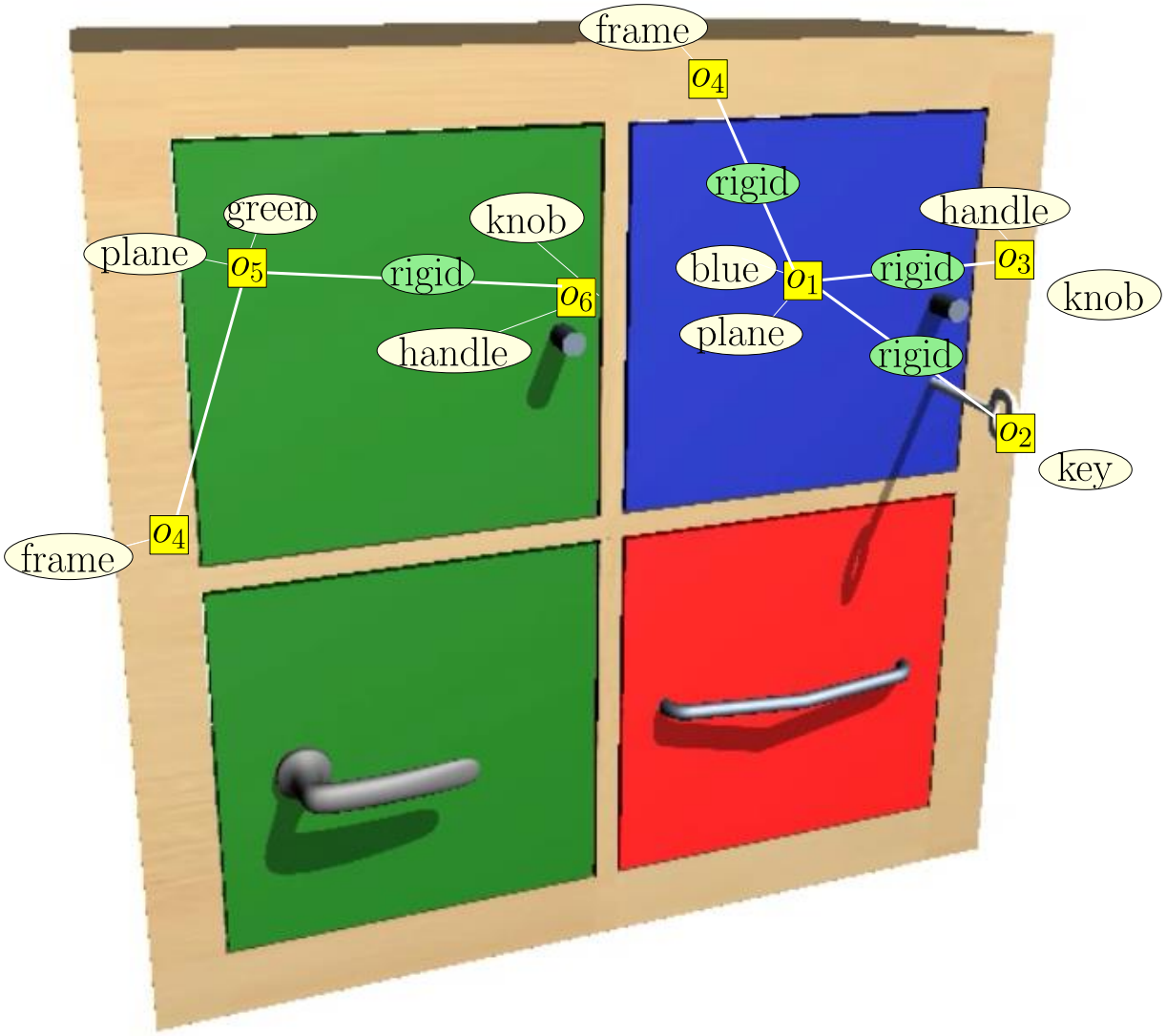

[Kemp 09] [Sturm, Stachniss, Burgard 08] [Yan, Pollefeys 06]

Learning About Furniture World

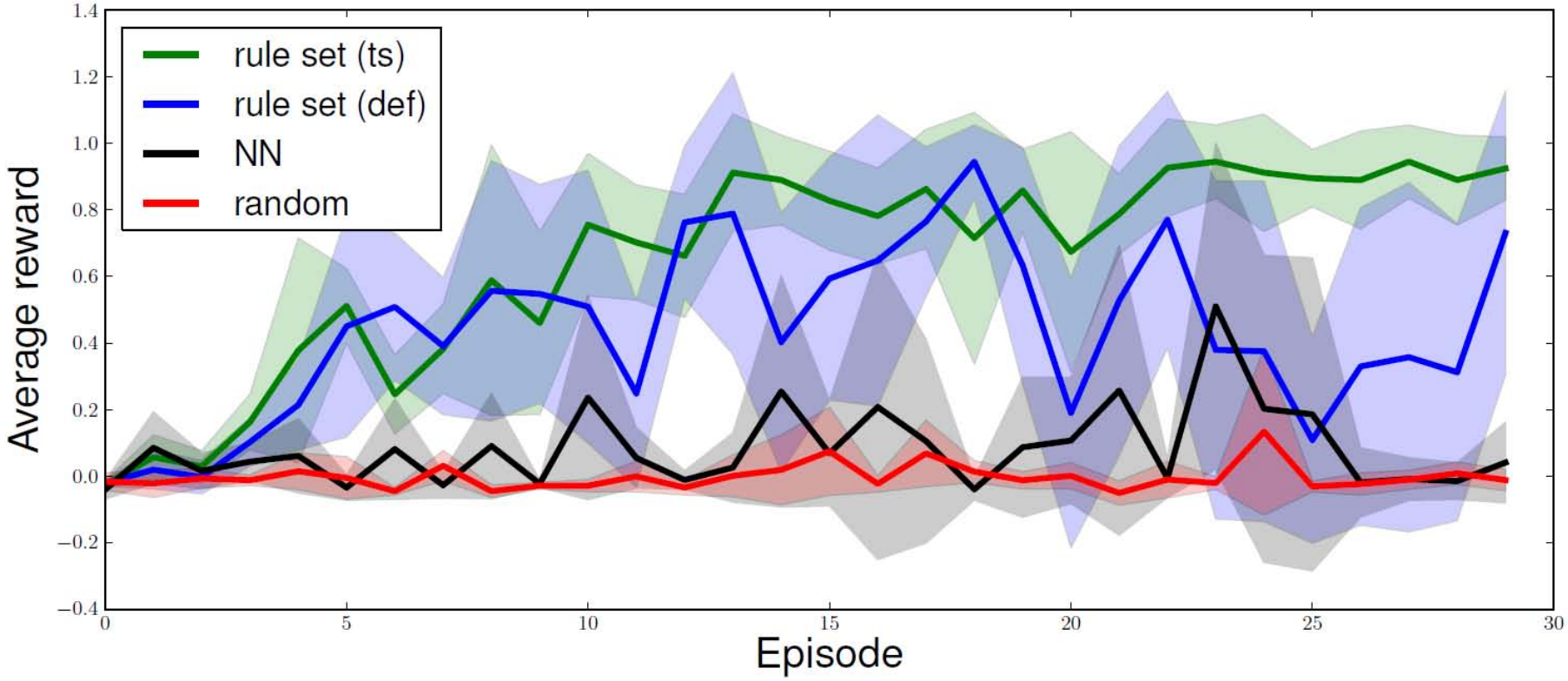
The robot interacts with an environment containing kinematic regularities.



A Relational Representation



Learning Performance



Sebastian Höfer

Why Are Humans So Much Better?

They have society, education, the environment, and “survival” to tell them a lot about what is important.

Robotics and Biology Laboratory @ TUB

Understanding Intelligence by Building Robots?