Bernstein Focus: Neurotechnology Frankfurt

Self-generated off-line memory reprocessing in a hierarchical recurrent neural network

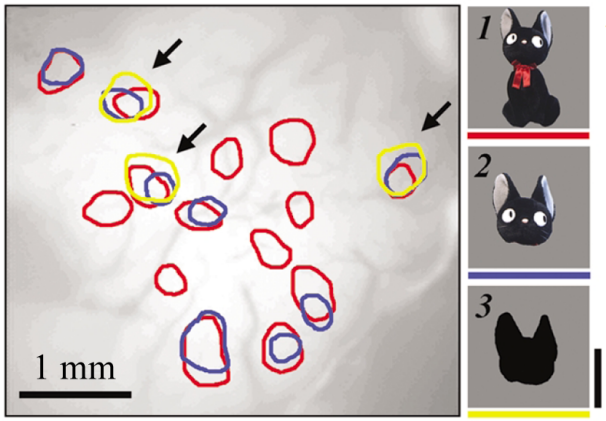
Boosting recognition performance in absence of external stimuli

Jenia Jitsev

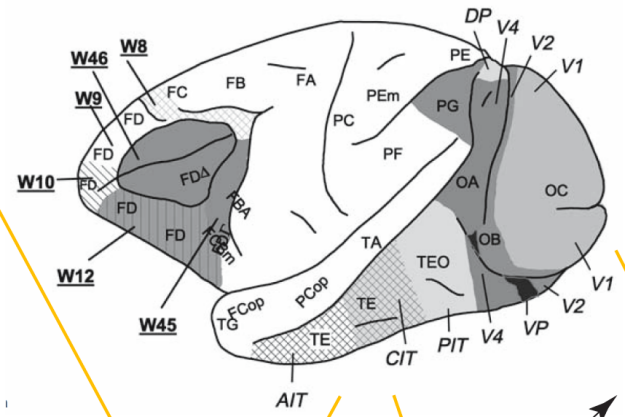
Max-Planck-Institute for Neurological Research, Cologne, Germany

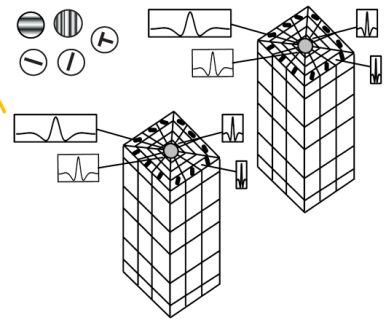
MAX PLANCK INSTITUTE
FOR NEUROLOGICAL RESEARCH
COLOGNE

Memory network in the visual cortex

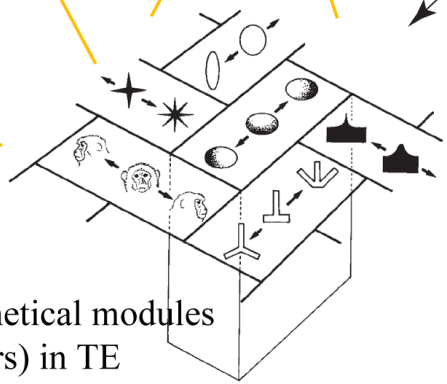


Cluster responses in dorsal TE, macaque
(via optical instrinsic imaging)





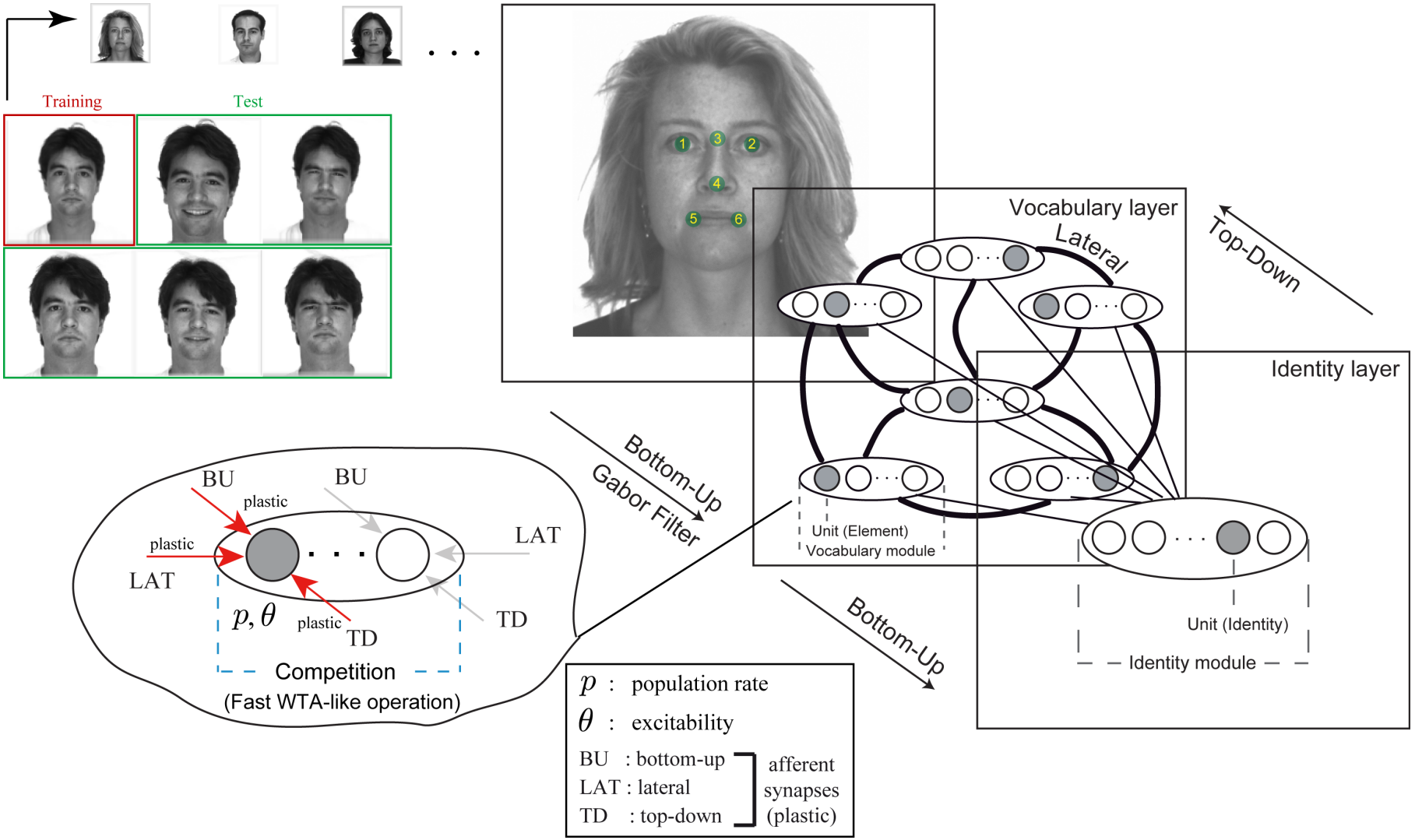
Hypothetical modules
(clusters) in V1



Hypothetical modules
(clusters) in TE

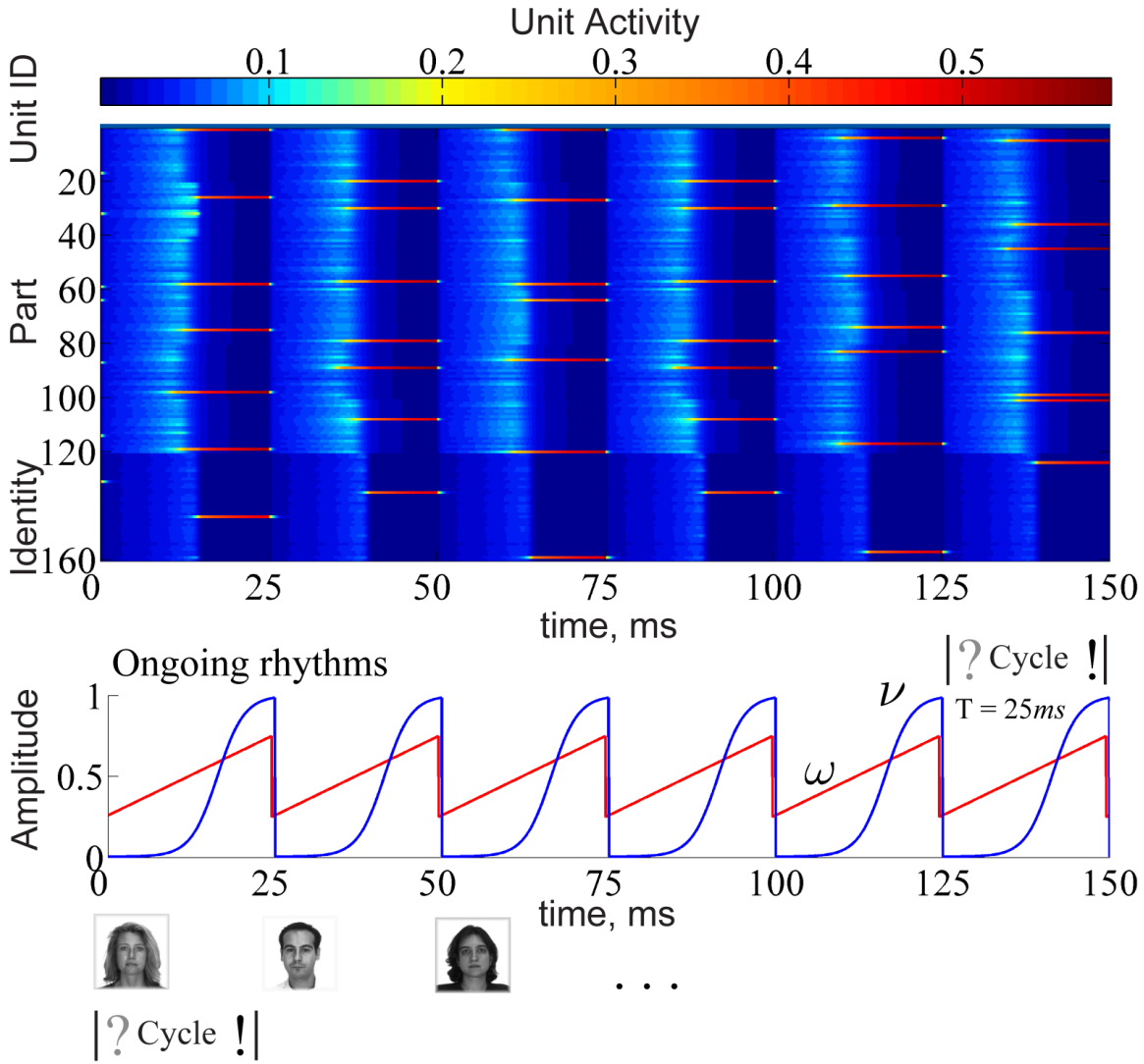
DeValois, 1990; Tanaka, 1996, 2003; Tsunoda et al., 2001

Unsupervised learning of compositional object identity

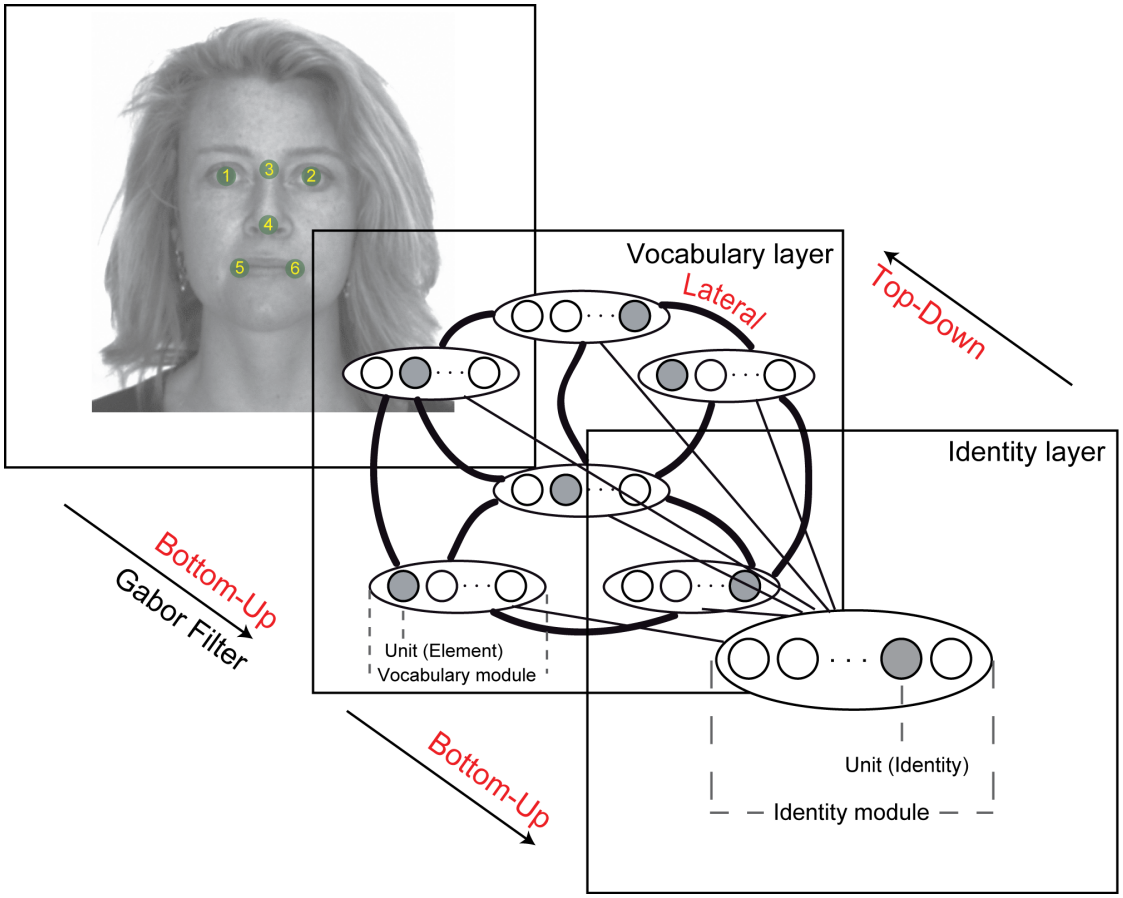


Jitsev and von der Malsburg, 2009; Jitsev, 2010

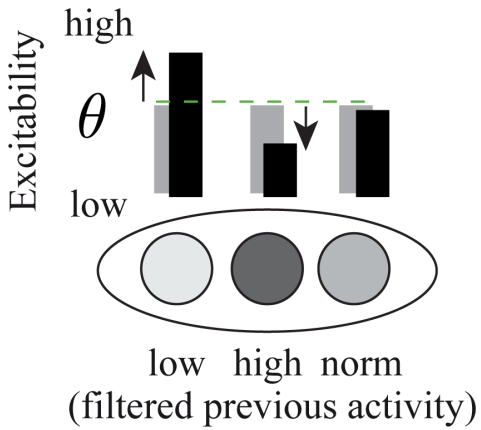
Network activity dynamics and competitive learning



Excitability regulation and memory trace formation

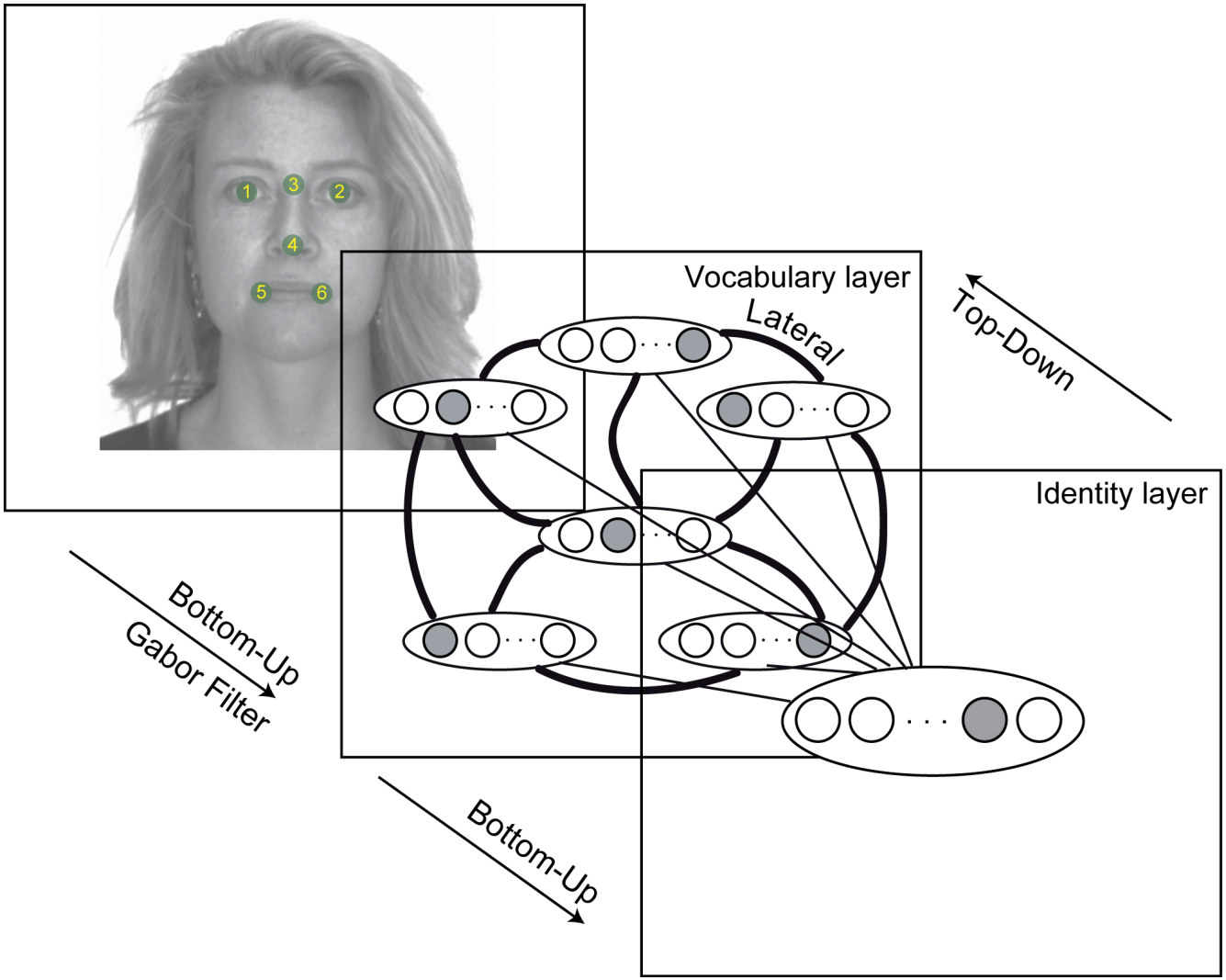


Intrinsic plasticity

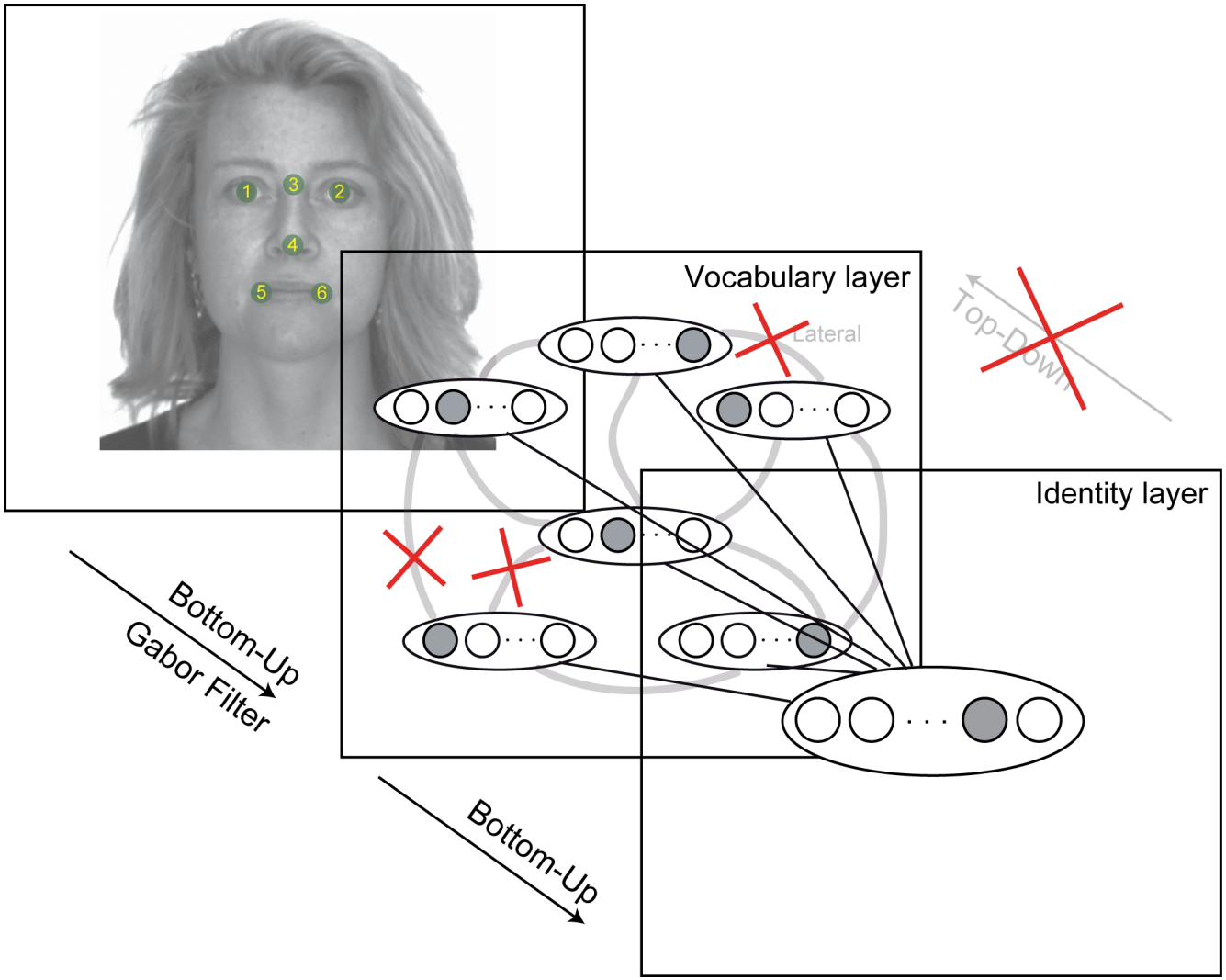


$$\underbrace{\frac{d\theta}{dt} = \tau_\theta^{-1}(p_{aim} - \langle p \rangle)}_{\text{Adaptive excitability}}, \quad \underbrace{\langle p \rangle = \frac{1}{T}\int_t^{t+T} p(t)dt}_{\text{Average activity in a cycle}}, \quad \underbrace{p_{aim} = \frac{1}{n}}_{\text{Target activity}}$$

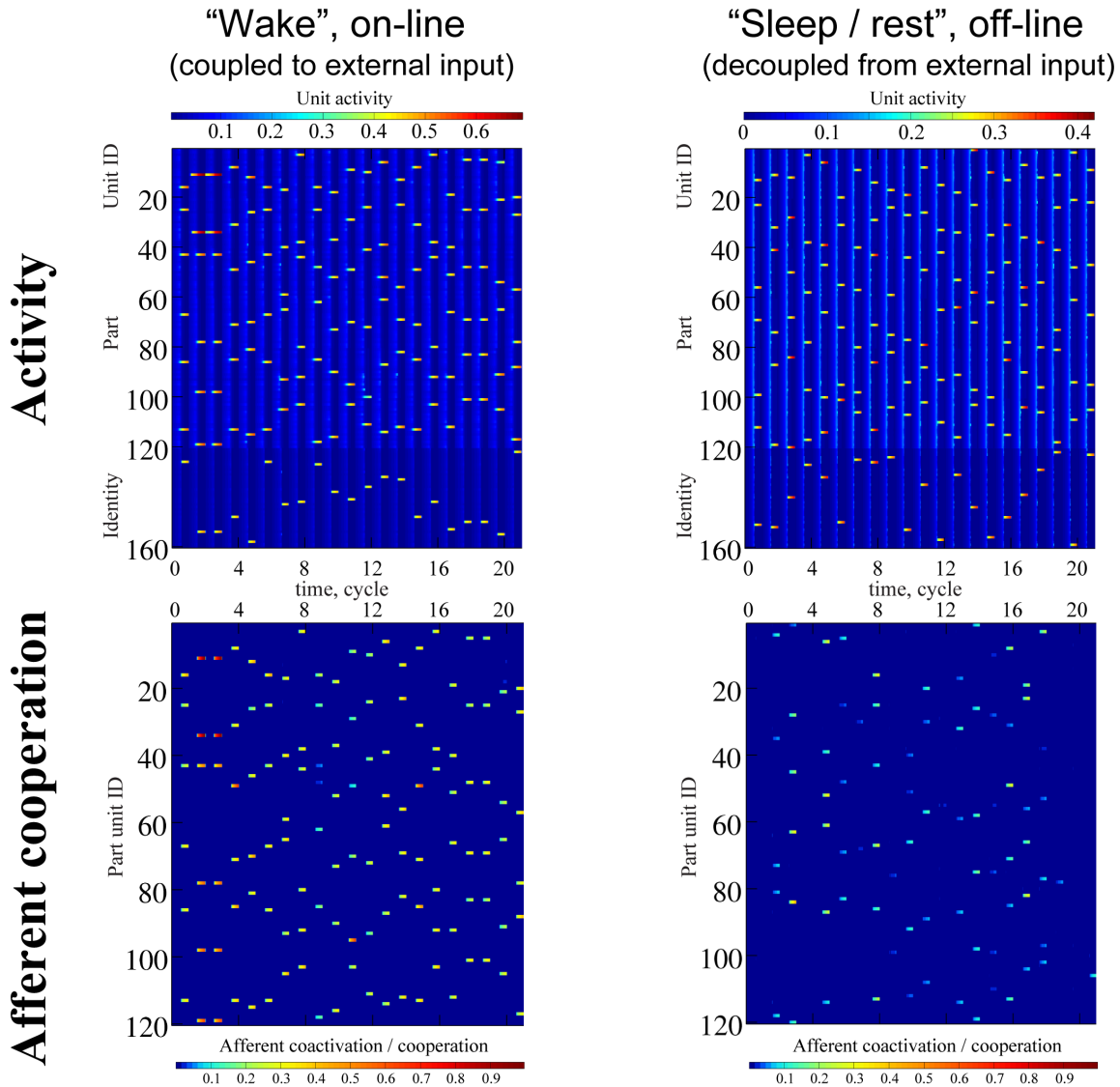
Fully recurrent and purely feed-forward configuration



Fully recurrent and purely feed-forward configuration



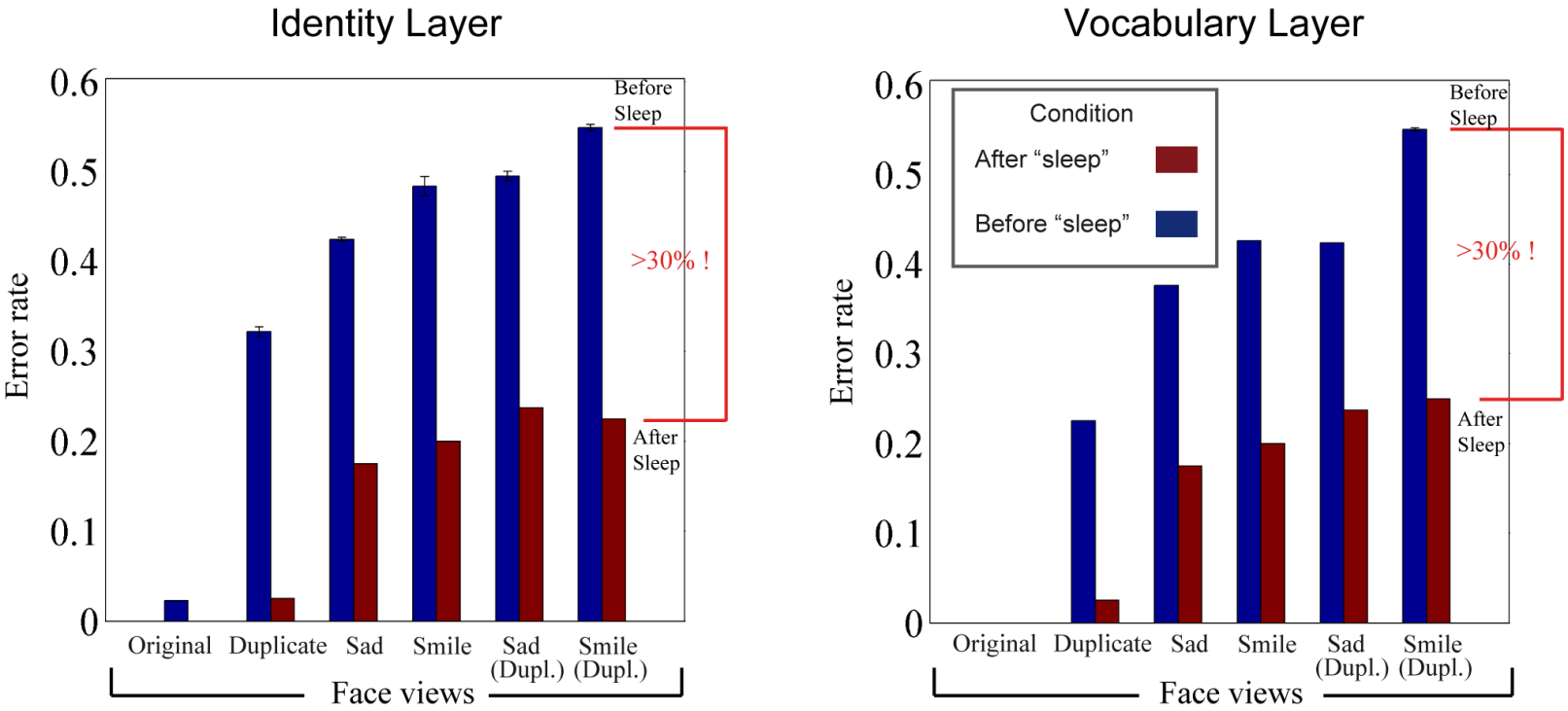
Stimulus induced and self-generated activity



Jitsev and von der Malsburg, 2010; Jitsev, 2010

Generalization boost after the off-line regime

Identity error before and after "sleep"

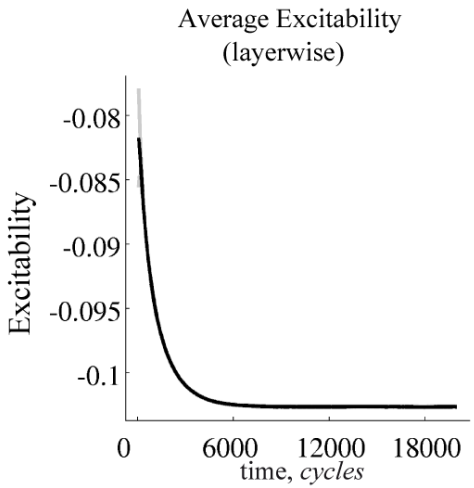


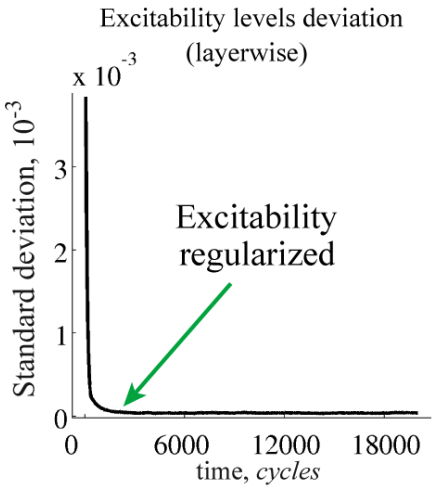
Improving recognition function via off-line reprocessing

- The positive effect does **not** require synapse-specific plasticity
- The effect is stronger on the novel views not presented before
  → Off-line reprocessing boosts the ability to generalize

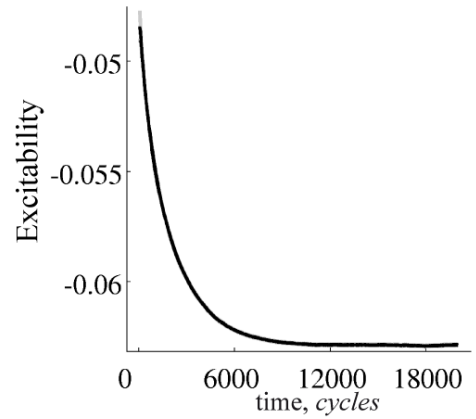
Intrinsic excitability regulation in the "sleep" state

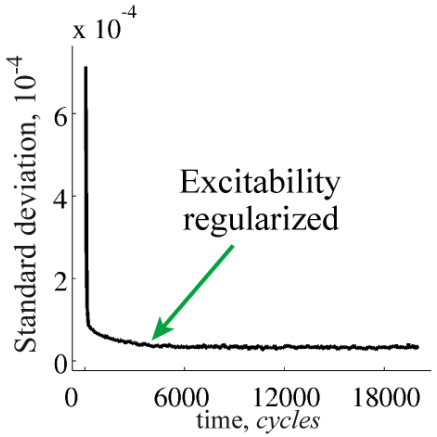
Vocabulary layer



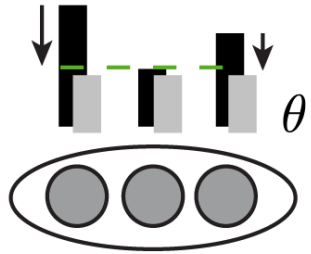


Identity layer

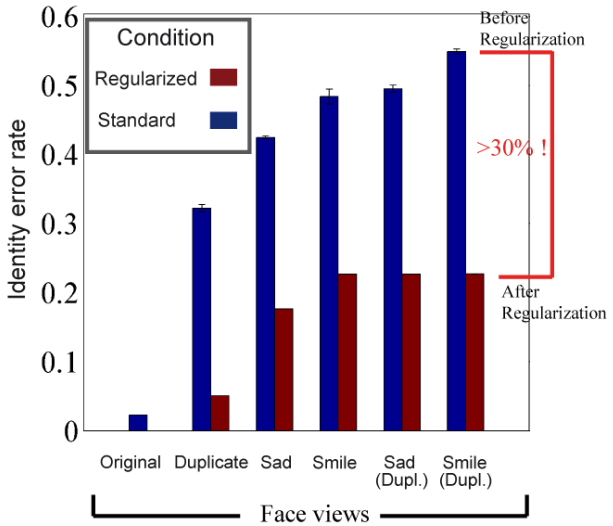




Excitability regularization

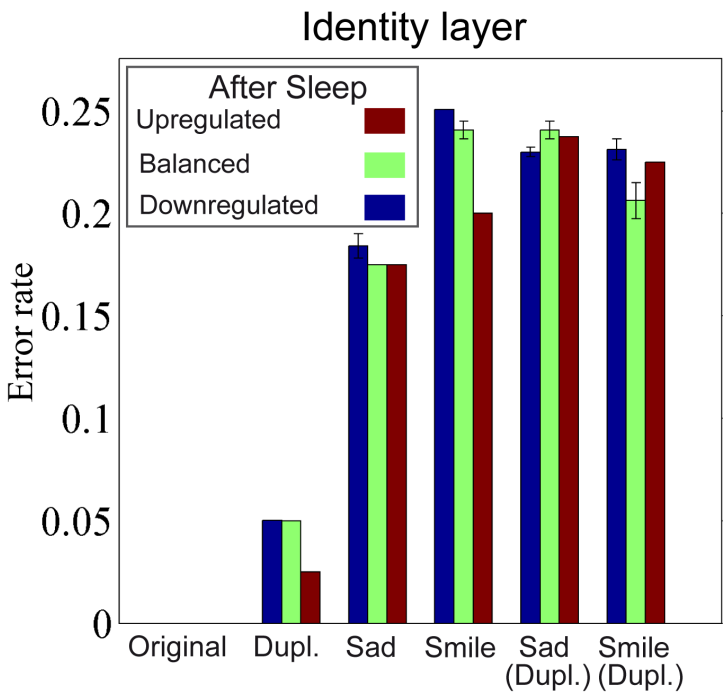


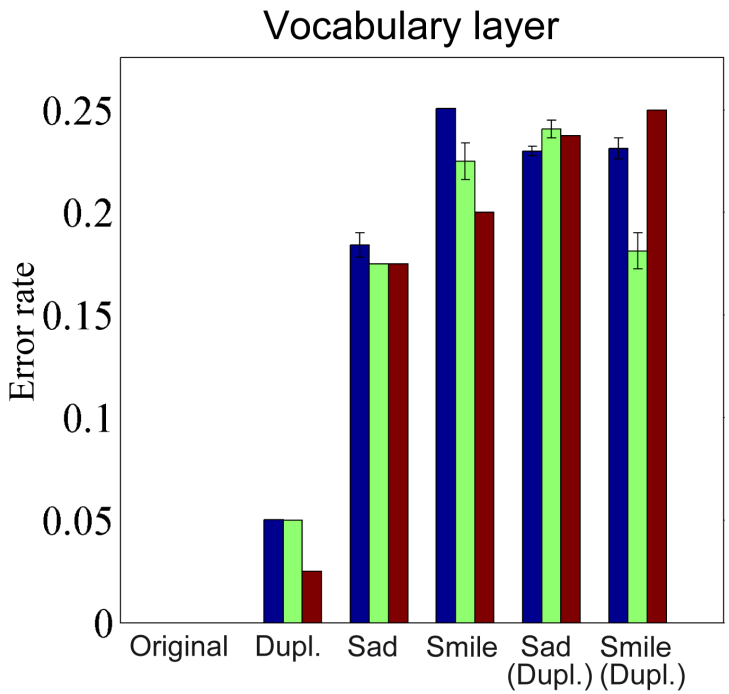
Manual regularization



Excitability equalization causes the positive effect

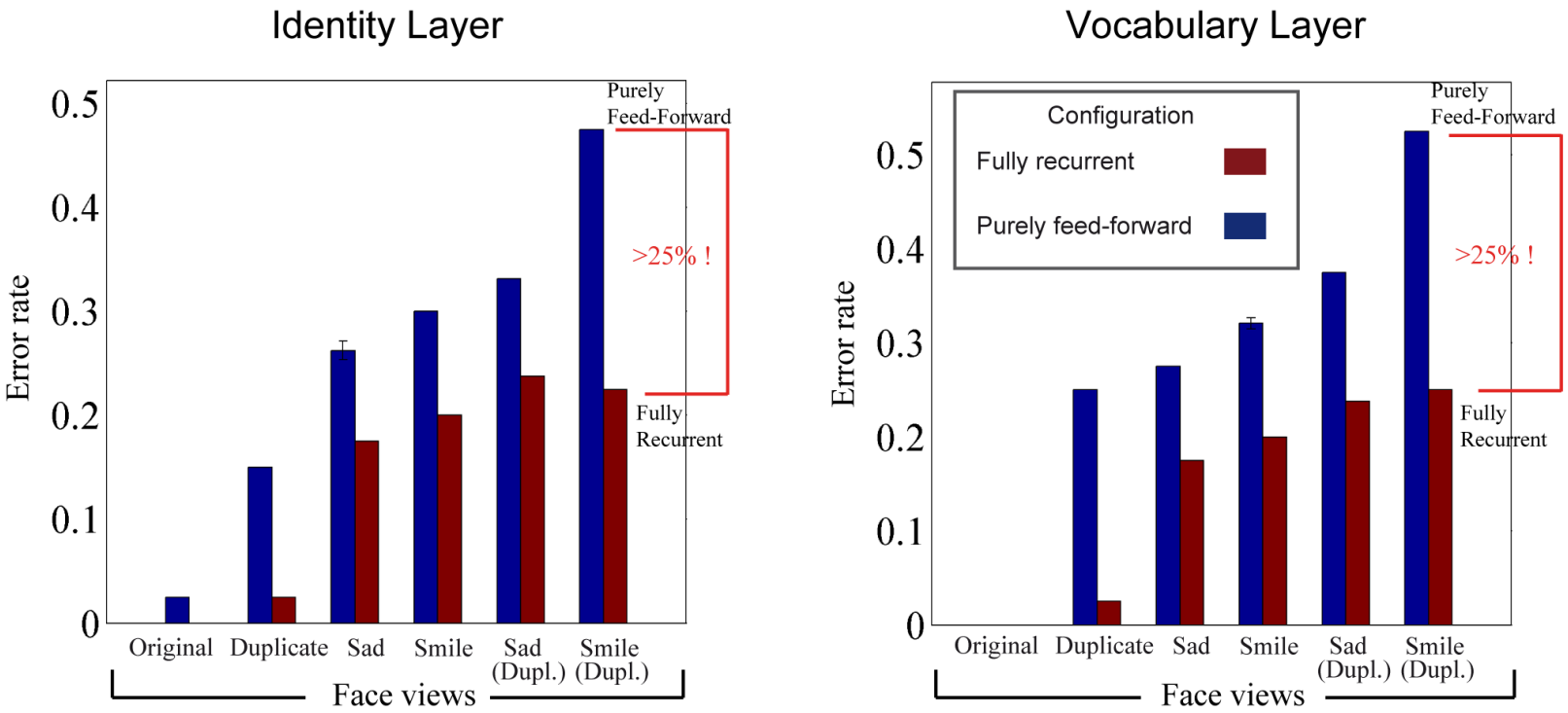
- Positive effect does not depend on direction of regulation





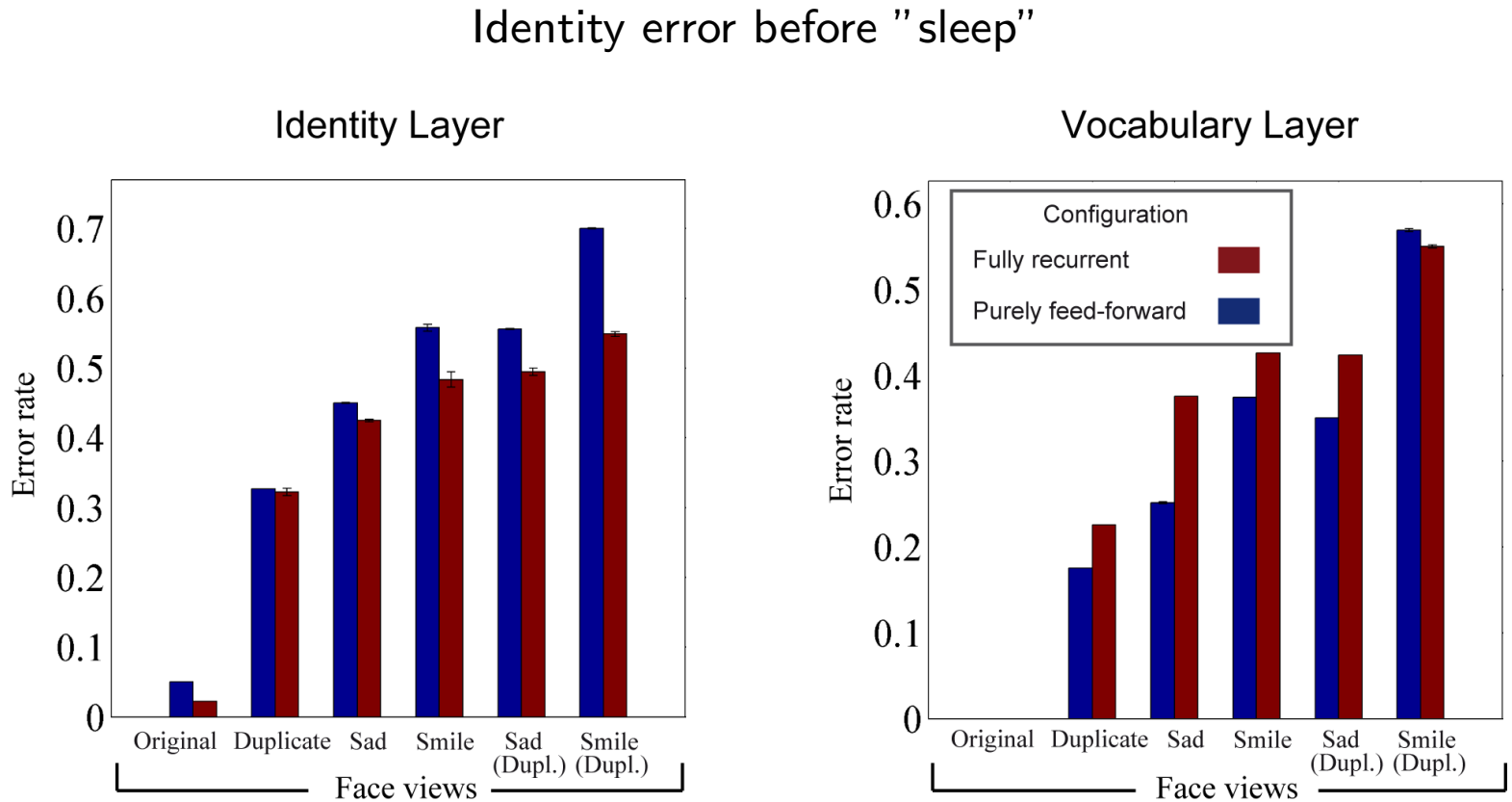
Off-line boost favors the fully recurrent configuration

Identity error after "sleep"



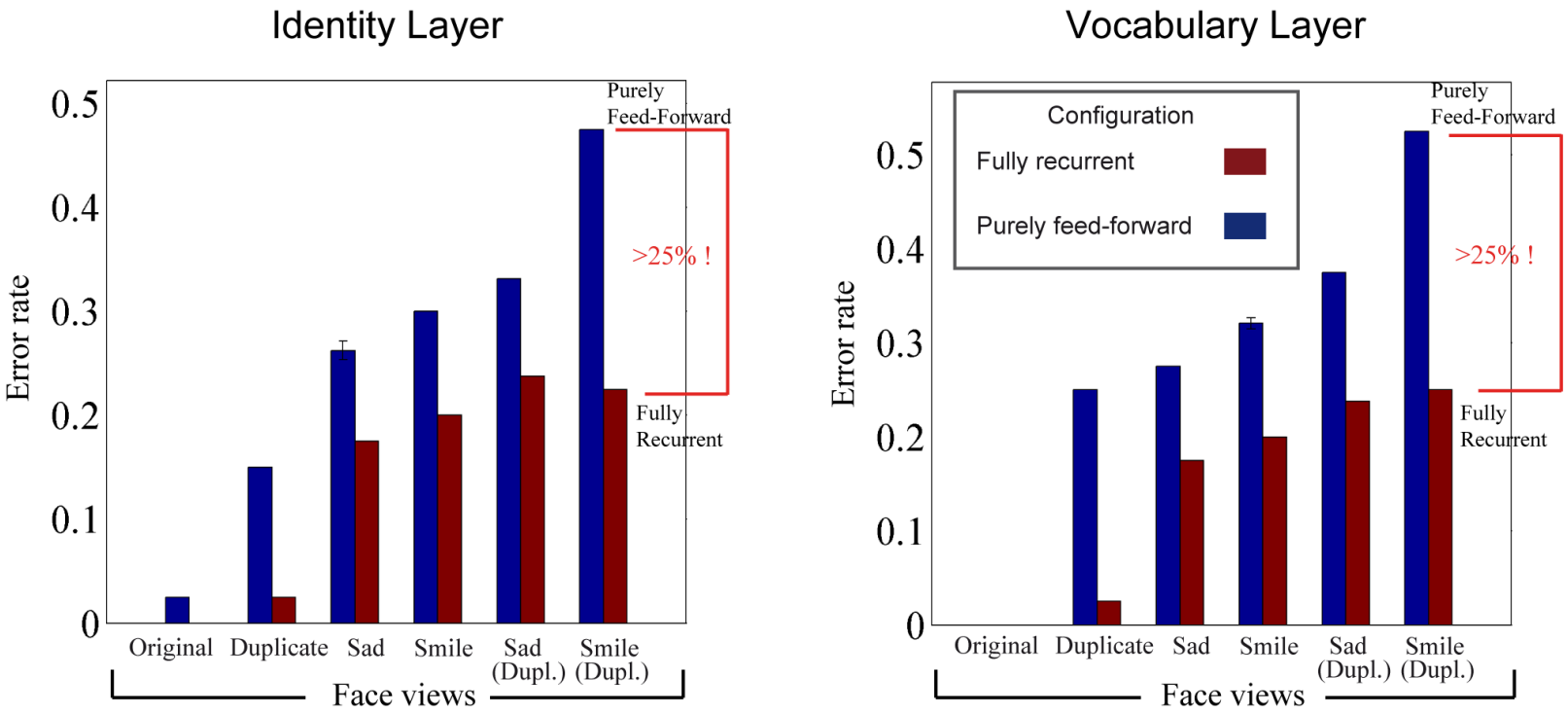
Off-line boost favors the fully recurrent configuration

Identity error before "sleep"



Off-line boost favors the fully recurrent configuration

Identity error after "sleep"



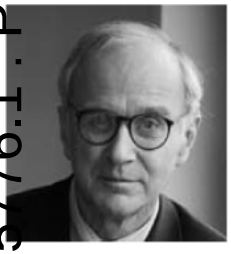
Résume

Improving recurrent neuronal network via off-line reprocessing

- Self-generated reprocessing in absence of external stimuli
- Strong boost in recognition performance after the off-line regime for the data not shown before
- The positive effect entirely mediated by synapse-unspecific excitability regulation
- Off-line boost favors fully recurrent architecture over purely feed-forward one

FIAS Frankfurt Institute for Advanced Studies

FIAS neuro-branch


Christoph von der Malsburg


Wolf Singer


Jochen Triesch


Thomas Burwick


Yasuomi D. Sato
Kyushu Institute of Technology
(KYUTECH, Japan)


Jörg Lücke


Urs Bergmann


Jörg Bornschein


Christian Keck


Nikolai Axmacher
University Bonn,
Clinics for Epileptology,
Cortical Oscillations Group
Bonn, Germany

Bernstein Focus: Neurotechnology Frankfurt

Supported by BMBF within the Bernstein Focus: Neurotechnology, Grant 01GQ0840, in frame of Bernstein network.

DFG

Bundesministerium für Bildung und Forschung

Clinical Research Unit 219

MAX PLANCK INSTITUTE FOR NEUROLOGICAL RESEARCH COLOGNE