Predictability as a generic principle
Why two different lines of research are one and the same.

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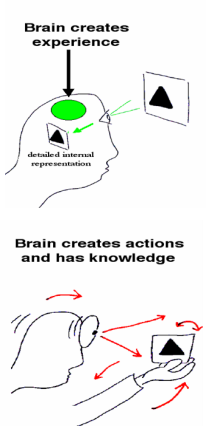
Understanding perception ...

Why do different sensory modalities have so different qualities?

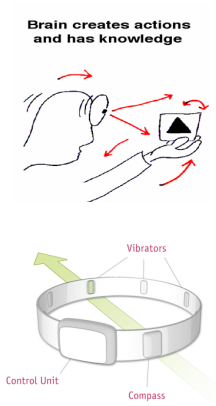


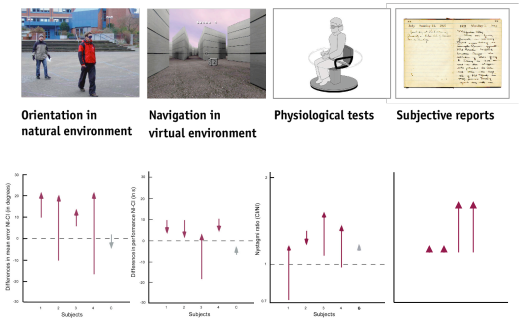
- No satisfying answer if we describe perception only as a representation of the world inside the brain.
- Information is processed in different areas of the brain, but the underlying hardware is the same.
- We have to relate directly perception to the world, i.e. to action. Sensory input changes as a function of motor actions.
- Every sensory modality has specific rules which govern those changes. This is the basis of sensory substitution (Bach-y-Rita, 1997) and called sensorimotor contingencies (O'Regan & Noe, 2001).
- A sensory modality is a mode of exploration mediated by distinctive sensorimotor contingencies.

... in the interaction with the environment.

Learning the 6th sense, feelSpace

Nagel et al. (2005) J Neur Eng
Schumann et al (in prep)



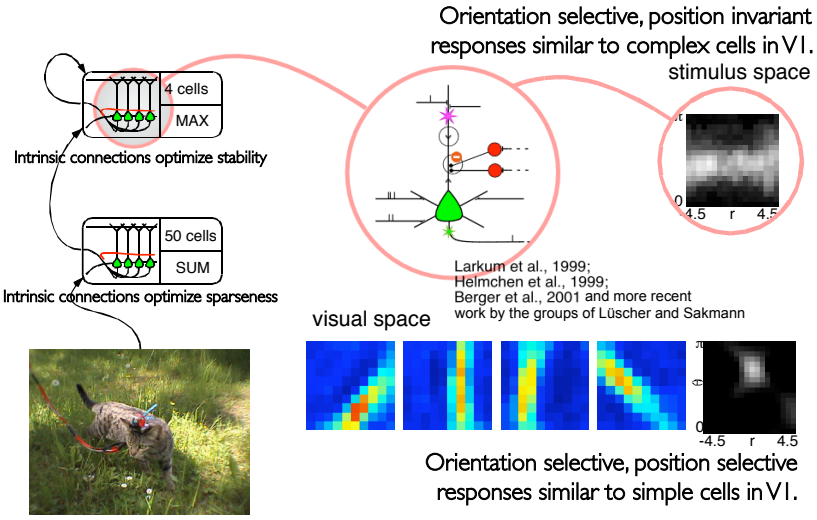


We do not have a recipe which guarantees a change in perception, but provide an example that where the quality of perception is subject to learning of sensory motor contingencies.

Proof of principle of modifying the quality of perception.

Learning the 2nd sense, i.e. vision

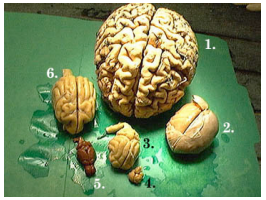
Einhäuser et al. (2002) Eur J Neurosci
Körding et al. (2004) J Neurophysiol
Kayser et al. (2004) Curr Opin Neurobiol



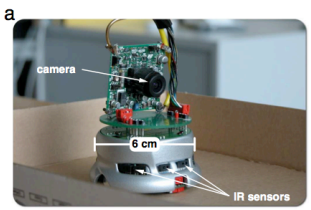
Optimal stability and sparseness leads to simple and complex cells

A general learning principle

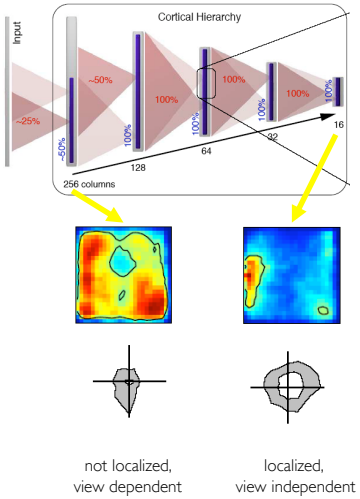
Wyss et al. (2006) PLoS



The cortical structure is rather homogeneous.



We investigate unsupervised learning in a behavioural context, but open loop control.



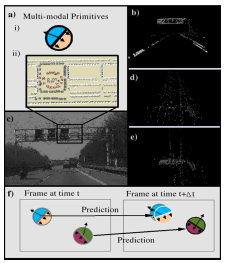
not localized, view dependent

localized, view independent

Optimizing stability in a hierarchical system leads to place fields. Non-trivial results are obtained for the auditory and tactile modality as well.

The more general learning principle: Predictability

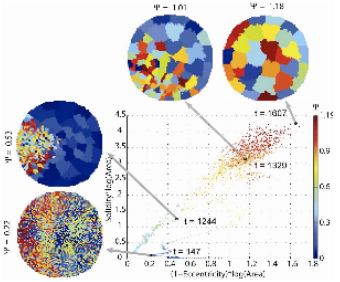
König & Krüger (2006) Biol. Cybern.
Weiller et al. (submitted)



$$\Psi_{\text{Decorr}} = -\frac{2}{n(n-1)} \sum_{i_1} \sum_{i_2 > i_1} \frac{\text{cov}_I(r_{i_1}, r_{i_2})^2}{\text{var}_I(r_{i_1}) \times \text{var}_I(r_{i_2})},$$

$$\Psi_{\text{Sparse}} \equiv -\frac{1}{n} \sum_i \left\langle \log\left(1 + \frac{r_i^2}{\langle r_i^2 \rangle}\right) \right\rangle.$$

$$\Psi_{\text{pred}} = \frac{1}{NN_p} \sum_{f(j)=i} \sum_i \frac{\text{cov}_I(p_{f(j)}(\vec{r}(t)), r_i(t+\Delta t))^2}{\text{var}_I(p_{f(j)}(\vec{r}(t))) \times \text{var}_I(r_i(t))}$$



Optimizing the predictability of sensory consequences of actions – this is learning a sensorimotor contingency (SMC) – leads to the emergence of place fields. This sensory representation is nearly as stable as when optimizing stability, but much better predictable.

Optimizing predictability in a behavioural context leads to place field, which are stable and predictable.

Not a conclusion, but a hypothesis

- Perceptual consciousness is based on sensorimotor contingencies (this has been claimed before).
- Sensory motor contingencies are equivalent to optimal predictability of sensory representations.
- Optimal predictability is not a unitary high-level process, but a pervasive property of hierarchical sensorimotor representations. It encompasses optimal stability and sparseness, two widely investigated principles of unsupervised learning.