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Representing as compressing.

Bridging the biological and artificial perceptual systems: a case for information-based explanations in cognitive science

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Overview/recap

1. Motivations
2. Compression in cognition?
3. Trouble with information?
4. From information to representation
5. Structural similarity and infomorphism - tbd.

Main motivations

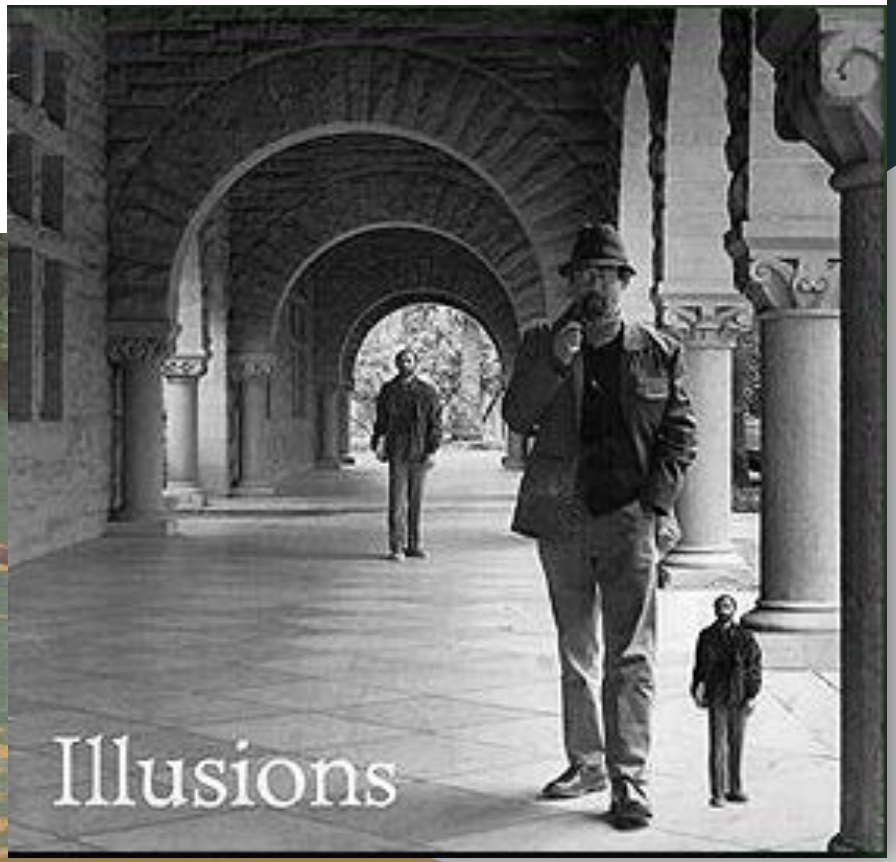
- Real simple.
- Analysis of information-talk (and according tools) for explaining perceptual processes
  - ➢ It’s widely used anyway! Let’s delve deeper under the platitude.
- Assessment of its promise as a currency in which both artificial and biological cognition can be cashed out. Successful comparisons and cognitive cartography?
- Tackling the question: can information-processing result in representation?

Compression in cognition?

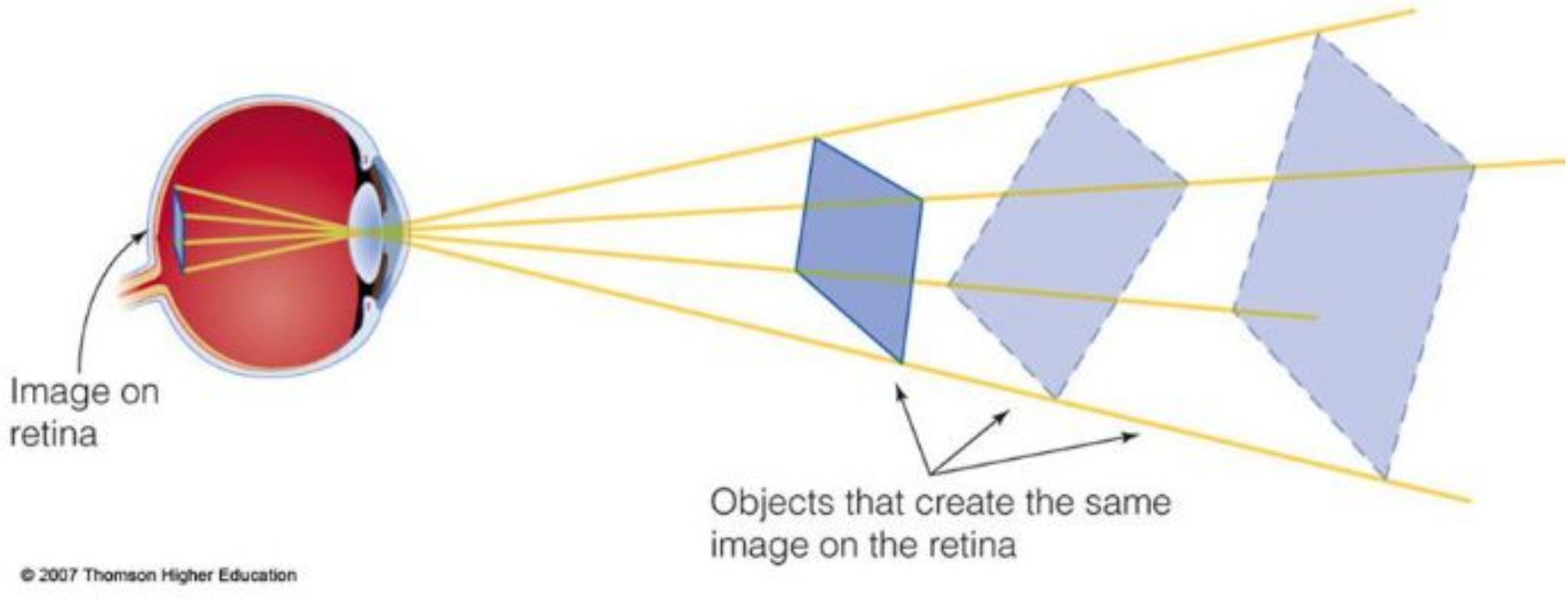
- Wilkenfeld's (2019) idea of understanding as 'maximizing output-to-scaffolding-ratio
- Conceptualizes the idea of generalizing-generative nature of cognition (Buckner 2018)
- Structure enables compression. Perception thrives on regularities (-> Natural Scene Statistics; Hyvarinen et al. 2009)
  - **Constructivist** (Helmholtzian; Rock 1983) vs. **ecological** (Gibsonian; Orlandi 2014) perception
- **Regularity=redundancy=predictability**
- Postulates of compression in semantic pointers theory (Eliasmith 2011, Blouw et al. 2015)

Where does the question come from?

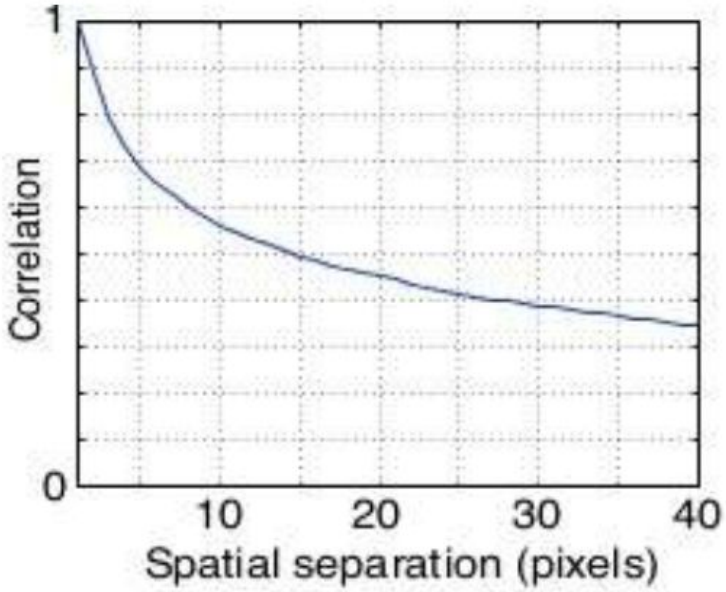
- Ambiguity (underdetermination) of stimuli - e.g. size-constancy
- Assumptions? Inference? Knowledge? The temptation of constructivism

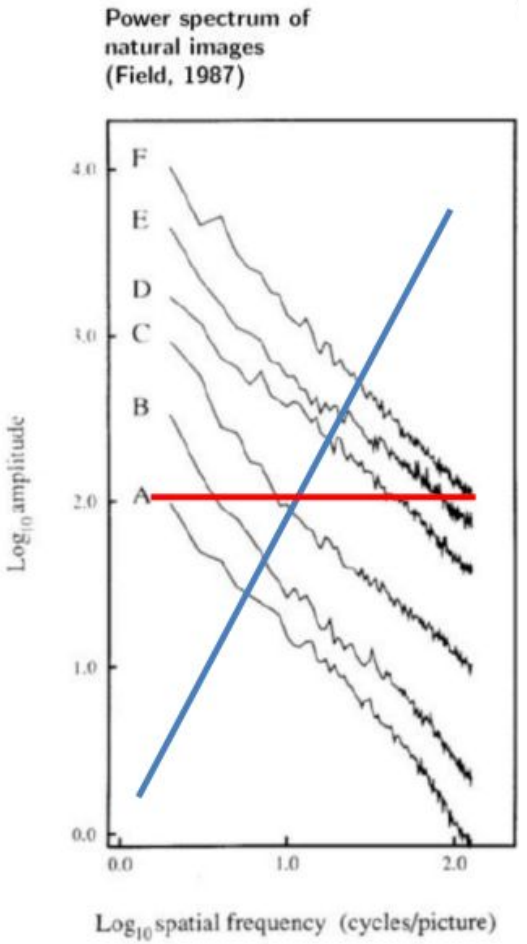


The inverse problem of perception

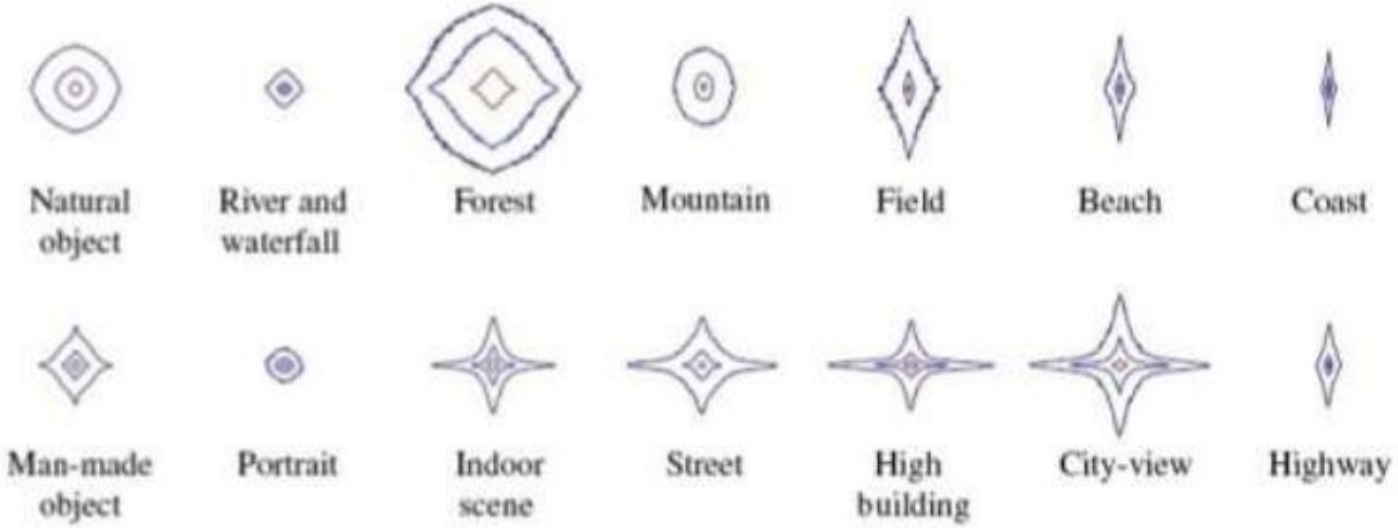


Auto-correlation in natural images





Scene categorization according to Natural Scene Statistics

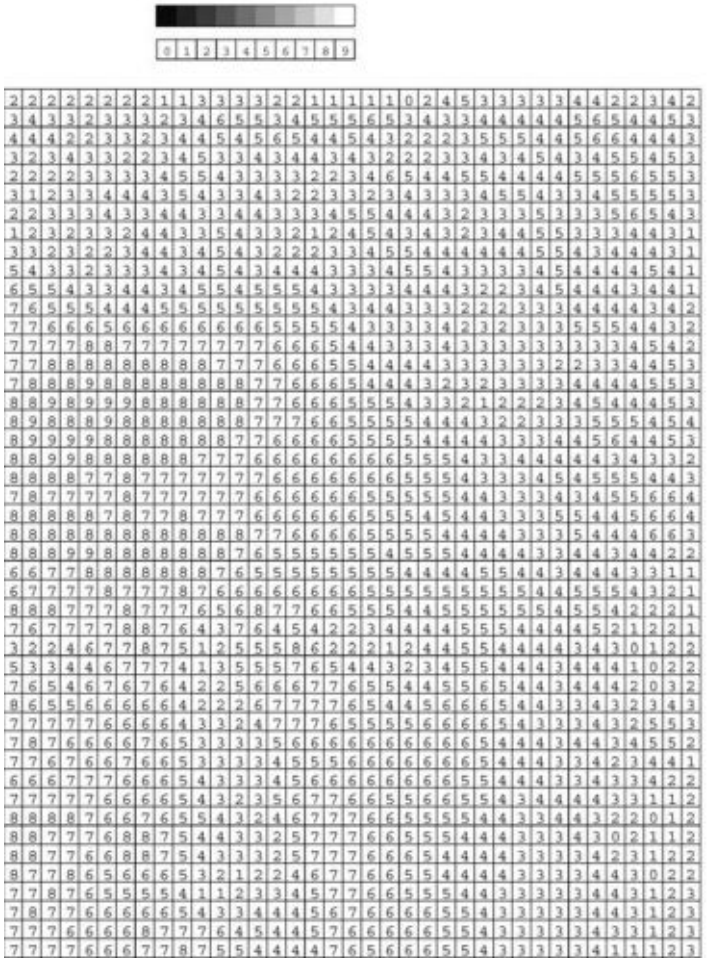


[Torralba and Oliva, 2003]

Putative problems with ‘information’

- The notion is a *free-for-all*
- Alternative frameworks: classical (Shannonian; 1948), algorithmic (Chaitin 1977), semantic, teleosemantic (Milikan 2005), transmission (Bergstrom & Rosvall 2008), thermodynamic (Colgate & Ziock 2010; **-> equivocation?**
- What about neural information?
  - *Hydraulic* metaphor (information-flow)
  - Receiver-relativity (Rathkopf 2017, 2018)
  - What’s a vehicle? (Timme & Lapish 2018)
- Format matters (Hyvarinen et al. 2009)
- Hard Problem of Content (Myin & Hutto 2017 -> Isaac 2019, Martinez, in press)
- Information-in-the-system vs information-about-the-system (Roskies, in press)
- Setting up the coding game (Skyrms 2010:35)

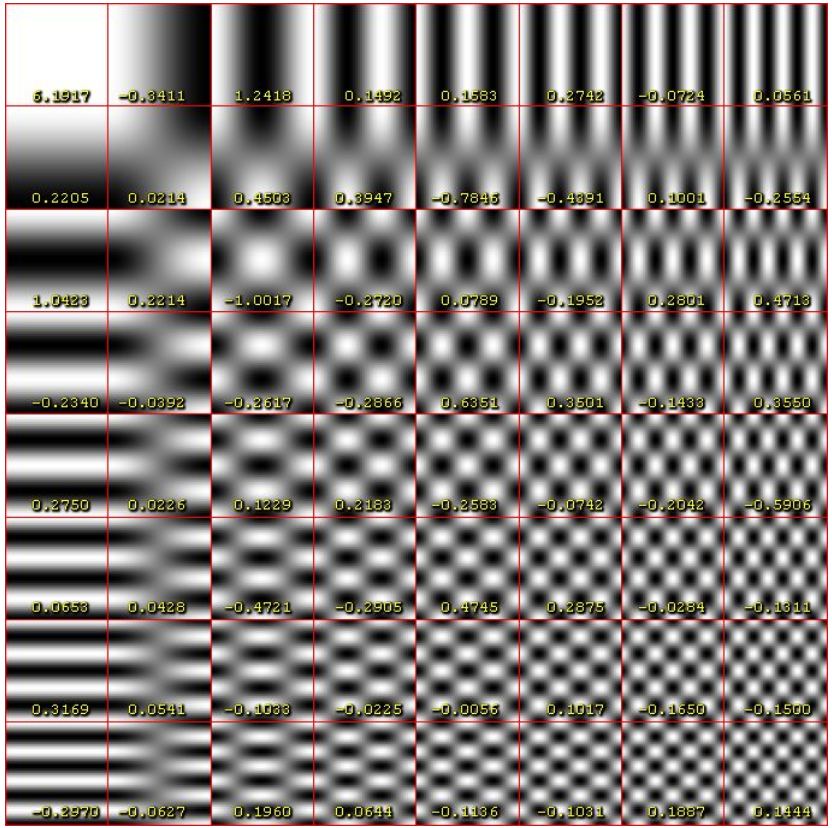
The invisible president - vehicle's important



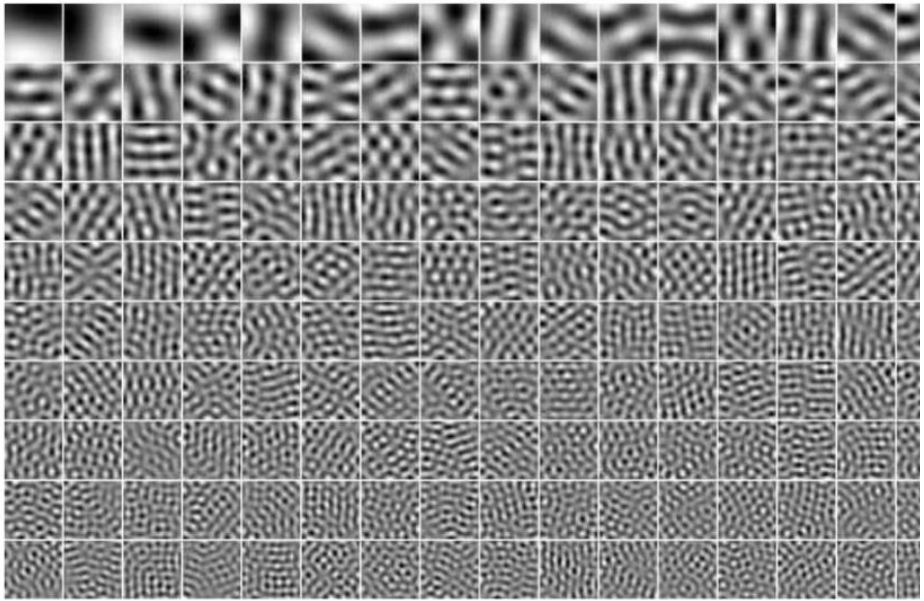
(Hyvaerinen et al. 2009:4-5)

Neuropsychological evidence

- Barlow's maxim of efficient coding (minimize the number of spikes to transmit signal)
  - Task-dependent
  - Level-dependent
  - Constraints
- Whitening and sparse coding
  - Artificial and biological (Field 1987, Ng 2015)
- Inter-frame compression? (Nortmann et al. 2013)

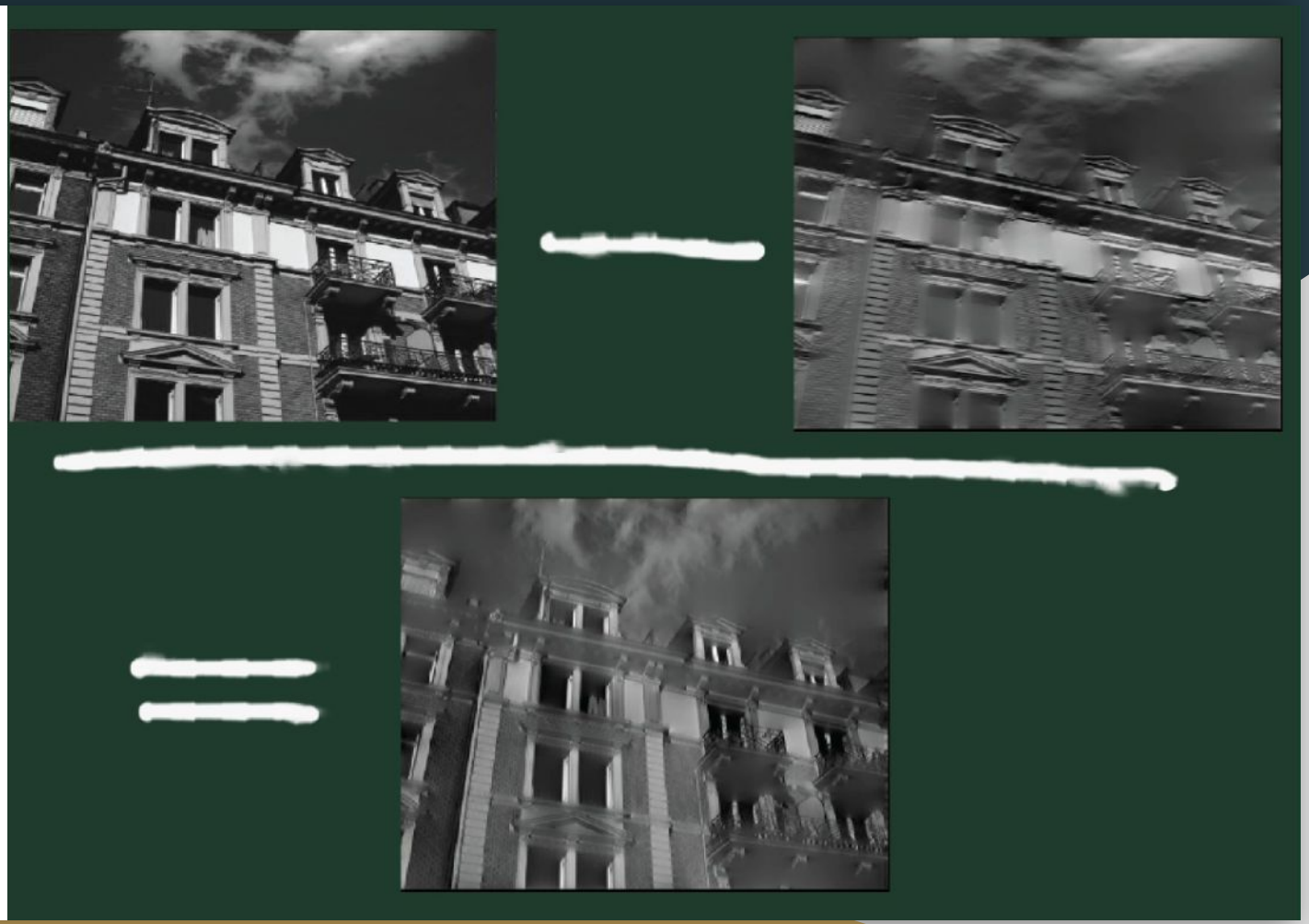


Discrete Cosine Transform (JPEG)



PCA Analysis Effect (Field, Olshausen 1995)

Inter-frame compression scheme? (Nortmann et al. 2013)

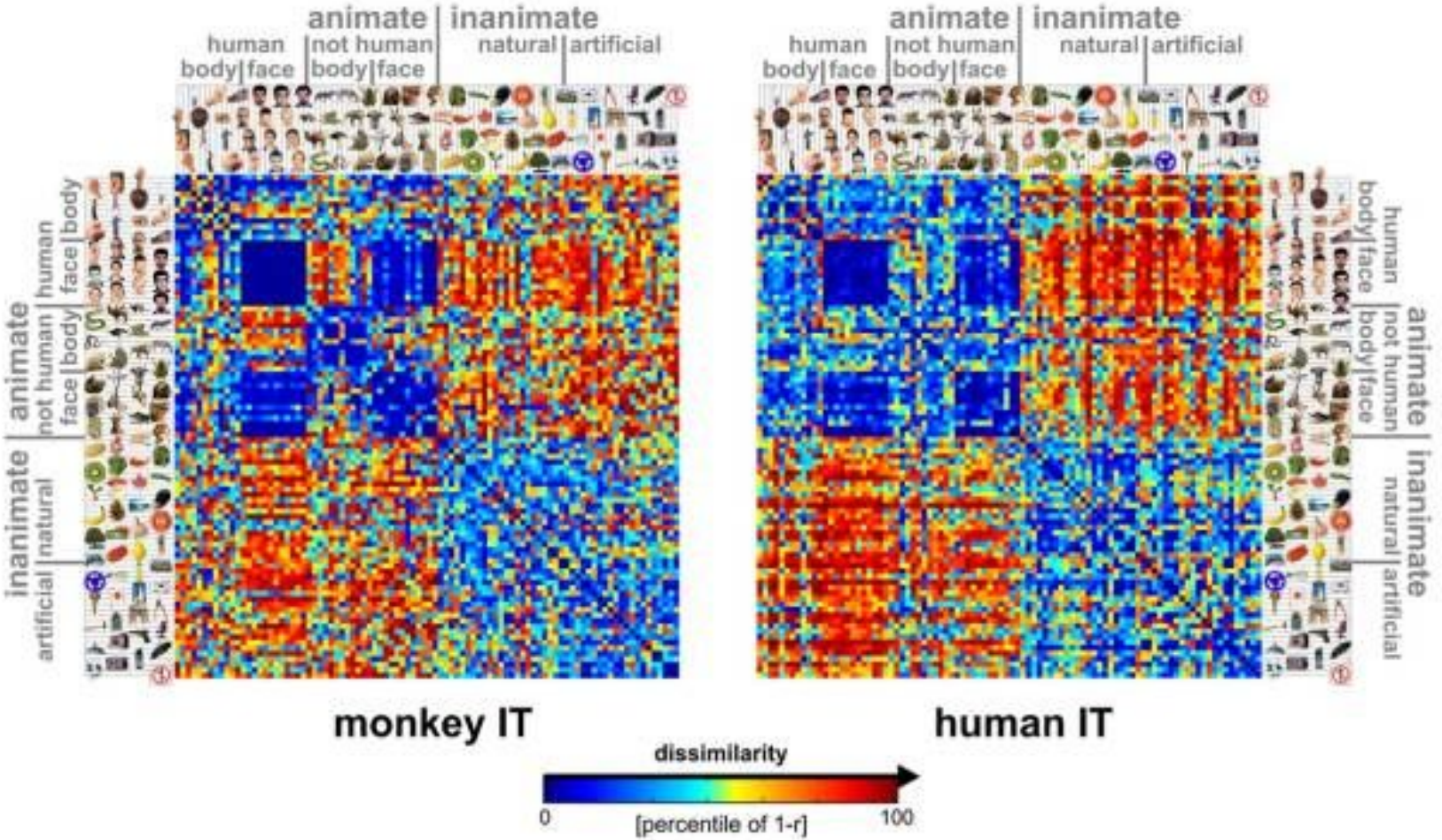


Representations

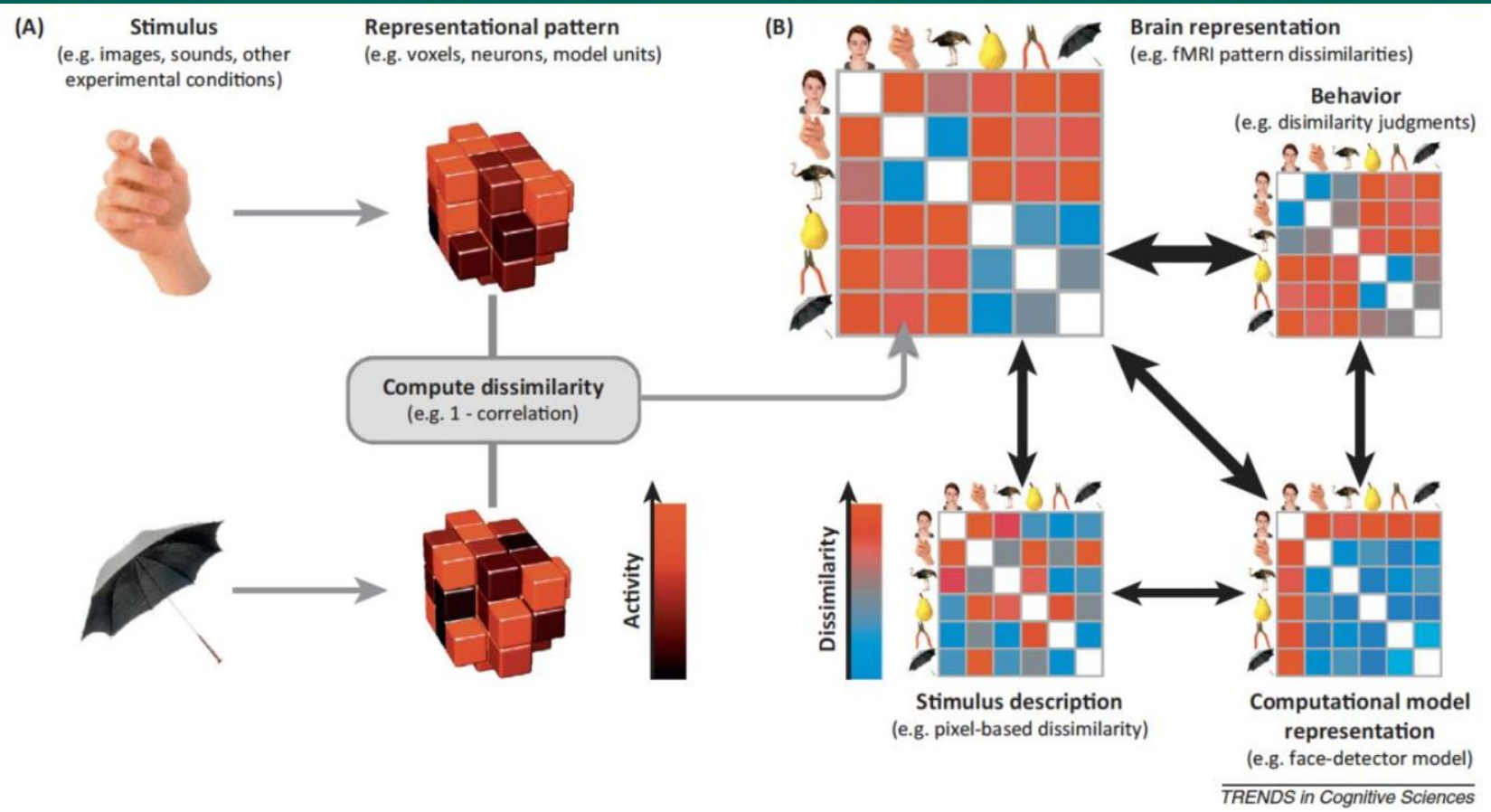
- Stand-in relations
- Semantic content (indicative, imperative)
- Functional role, realized in the virtue of that (Ramsey 2007)
- Similarity to what's represented (Cummins 2015)
- No representation without misrepresentation (Dennett 1988)
- Information is cheap, representation is to be cherished (Orlandi 2014)
- Absence of stimuli, decouplability, portability? (Clark 2013)
- Taxonomy? (s-representations, p-representations, r-…and more?)
- Causally relevant

New tools

- Representation similarity analysis (Kriegeskorte et al. 2008, 2015; &Kievit 2013)
- Observable and manipulable neural representations (Piccinini & Thomson 2018)
- Deep learning -> deep image synthesis (Bashivan et al. 2019) , building blocks of interpretability (Olah et al. 2018); ‘compressed representations’
- Reciprocal predictive power (Haxby et al 2001; Tong et al. 2005)
- Incepting percepts (Schalk et al. 2017)



Kriegeskorte et al. 2008



(Kriegeskorte & Kievit 2013)

Incepting percepts

https://www.youtube.com/watch?v=x7pWlnZJHVE

Schalk et al. 2017: Facephenes and rainbows: Causal evidence for functional and anatomical specificity of face and color processing in the human brain, PNAS November 14, 2017 114 (46) 12285-12290; https://doi.org/10.1073/pnas.1713447114

Success in similarity(?)

- Taking advantage of the structure of the informational make-up of the environment (encoding biases)
- Escaping the curse of dimensionality through ‘computational swindle’ (Poldrack, in press)
- The contravariance principle - only very few information-processors can succeed (Cao & Yamins, in press)
- Learning as arriving at more adequate, compressed representations (-> Schmidhuber’s lab)
- Cue structural similarity and infomorphisms? (Barwise & Seligman 1997; Gładziejewski & Miłkowski 2017)