Memory in DFT

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What is memory?

- The influence of past experience on present perception, action, or thought

Time scale and types of memory

- working memory
- short term memory
- long term memory
- semantic memory/skill learning

Working memory

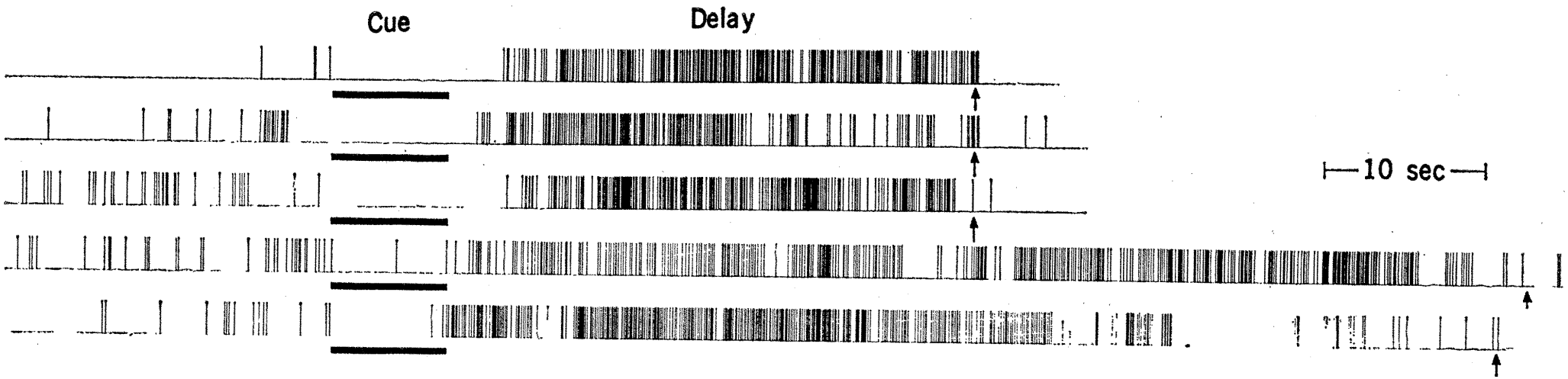
- perceptual, mental, or motor states that are immediately available to ongoing neural processes…
- arise on the time scale of perceiving, thinking, and acting…
- have strong capacity limits… 4 to 7 "items"
- are part of processing

Working memory

- standard neural interpretation: activation induced by stimulation (a detection decision) is sustained once that input is removed

Sustained activation

- monkey in a delayed response task
- neural recording from pre-frontal cortex

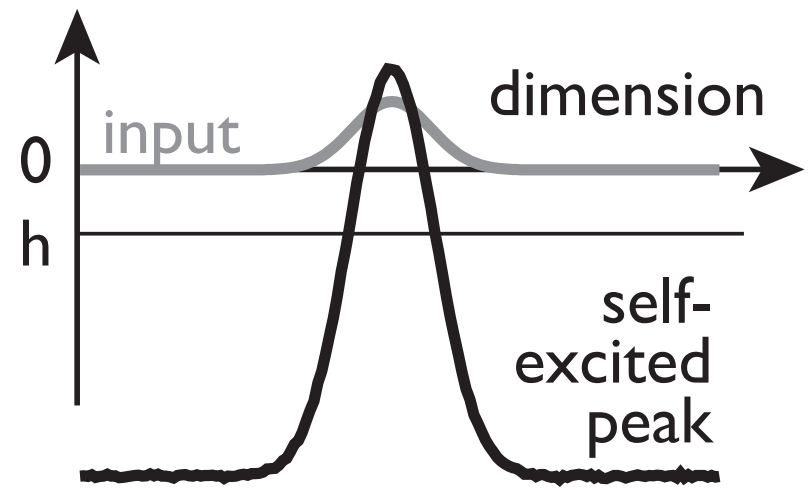


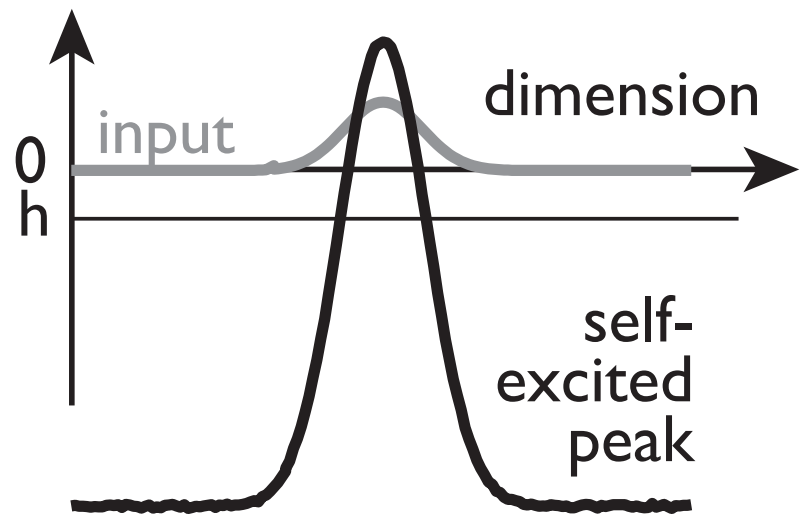
[Fuster 1971]

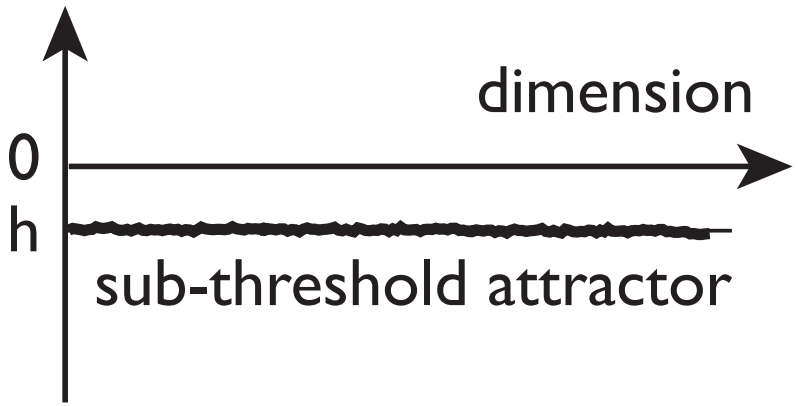
Working memory

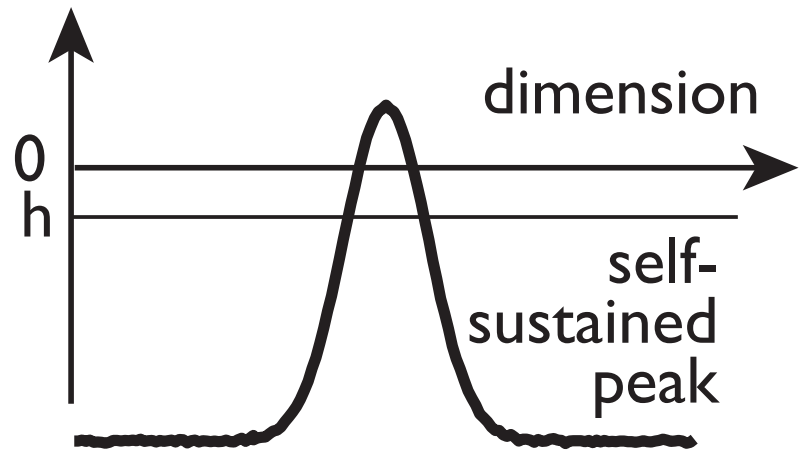
- a huge behavioral and neural literature
- with ongoing debates: resource allocation, re-activation of working memory etc

DFT: Working memory emerges from the memory instability









Time scale and types of memory

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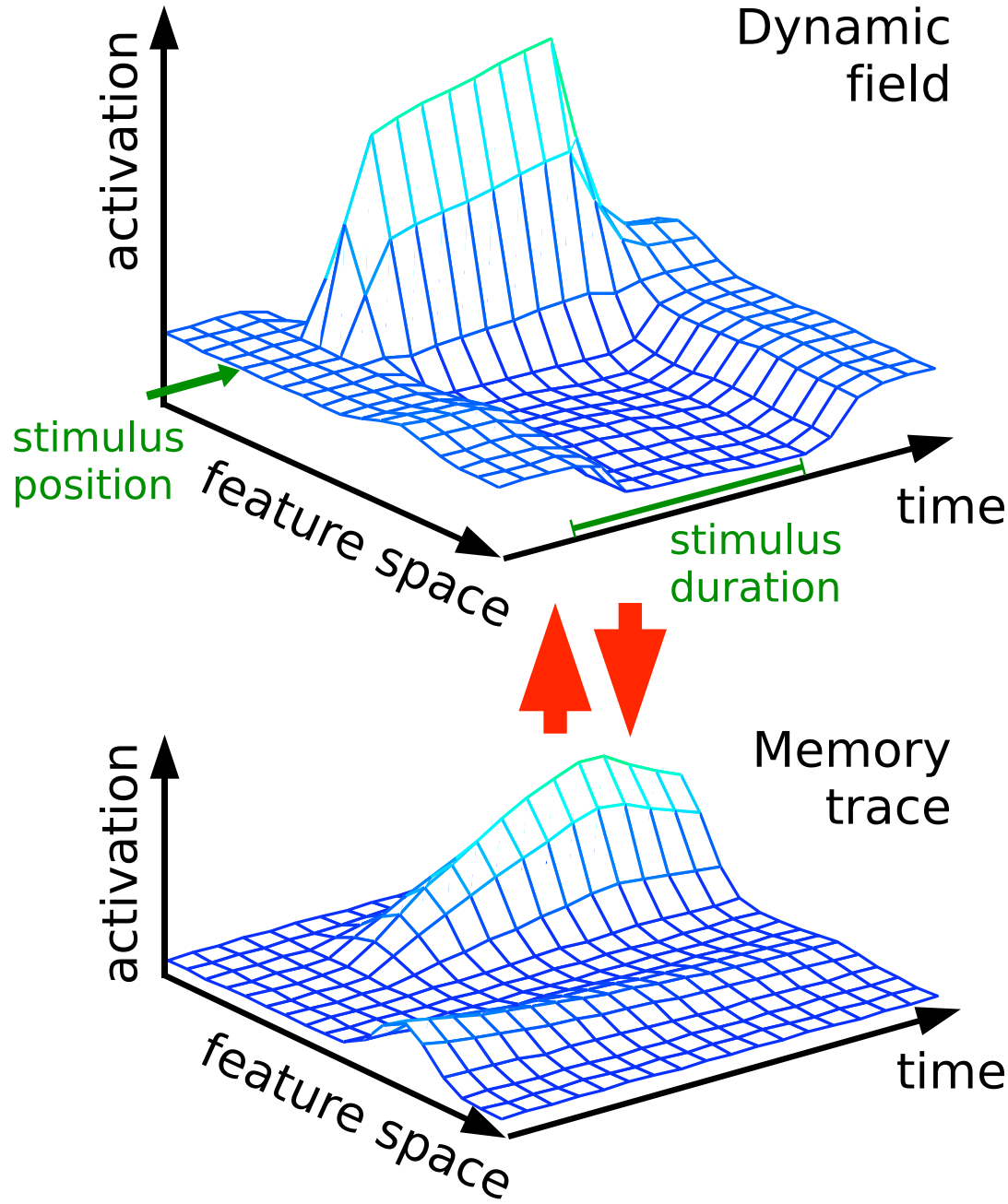
STM/LTM

- defined by the need/capacity to “recall” the memory…
  - cued recall
  - free recall
- it’s neural foundation is still actively researched
  - Hippocampus plays a role

DFT: the memory trace

- postulate that peaks of activation lay down a memory trace
- that conversely pre-activates the field

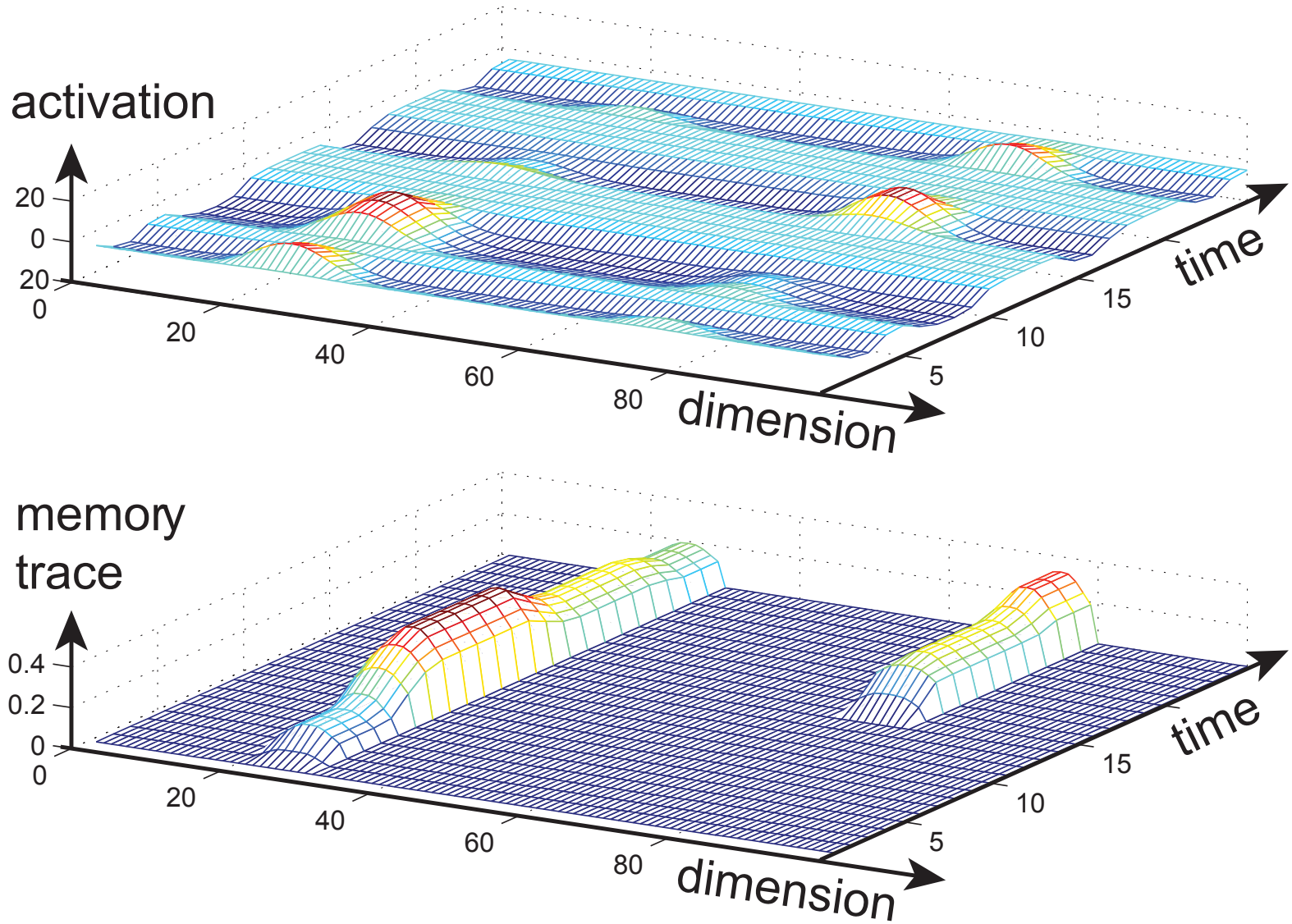


Mathematics of the memory trace

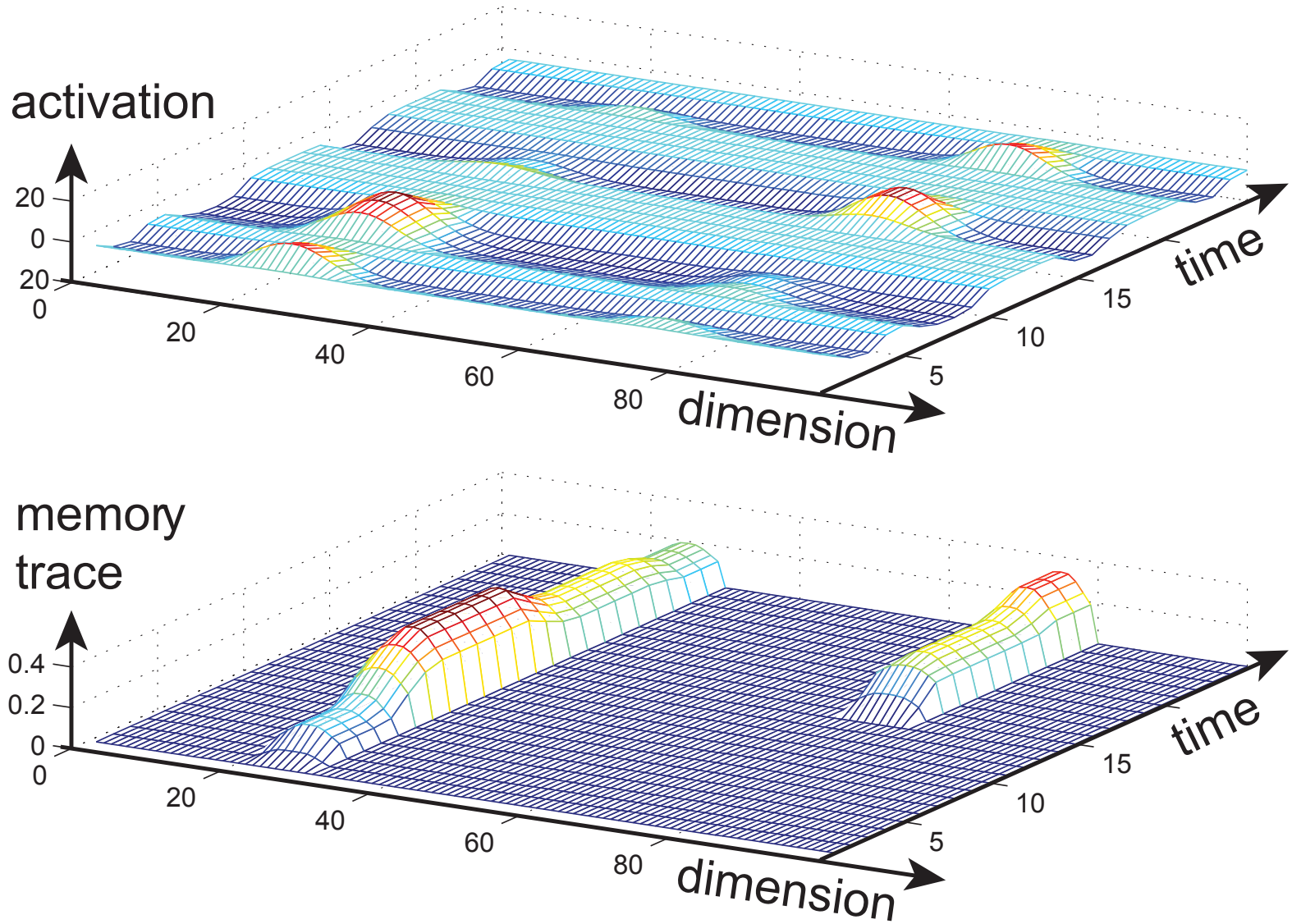
$$\begin{aligned}
\tau \dot{u}(x,t) &= -u(x,t) + h + S(x,t) + u_{\text{mem}}(x,t) \\
&+ \int dx'\ w(x-x')\ \sigma(u(x')) \\
\tau_{\text{mem}}\ \dot{u}_{\text{mem}}(x,t) &= -u_{\text{mem}}(x,t) \\
&+ \int dx'\ w_{\text{mem}}(x-x')\sigma(u(x',t))
\end{aligned}$$

- memory trace only evolves while activation is excited
- potentially different growth and decay rates

The memory trace reflects the history of decisions

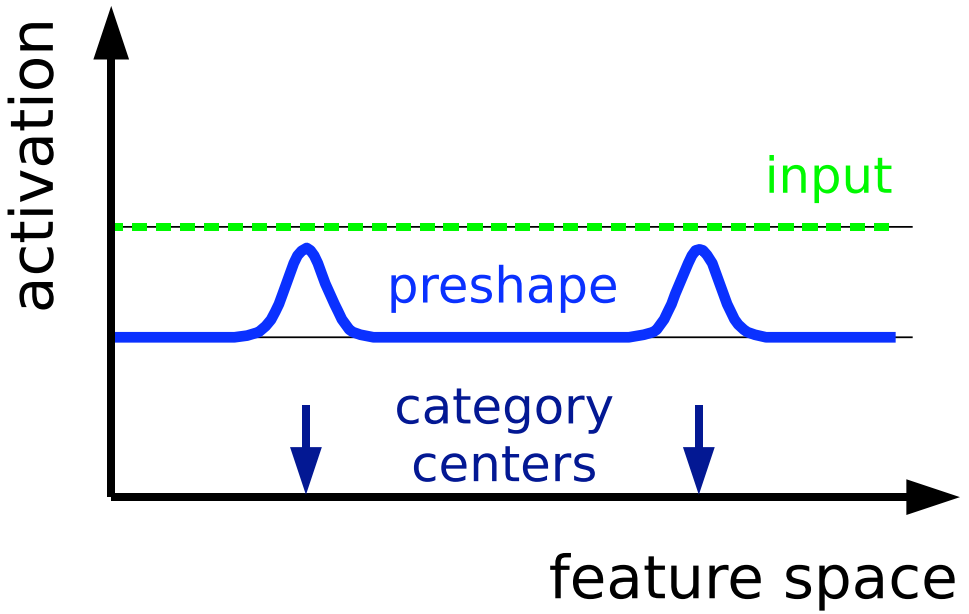


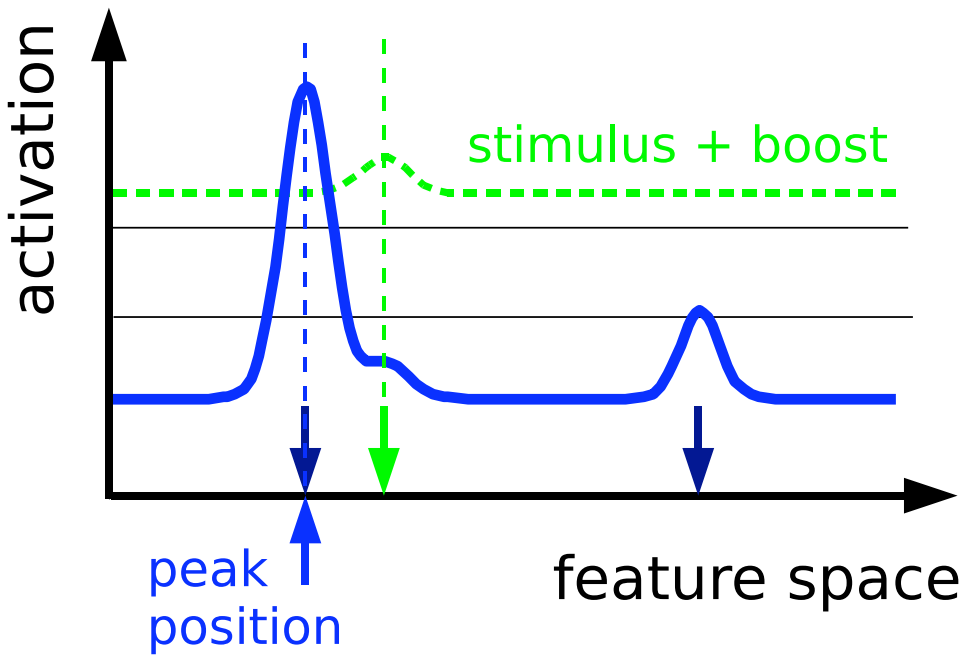
The memory trace suffers from interference



Cued recall: boost + localized input

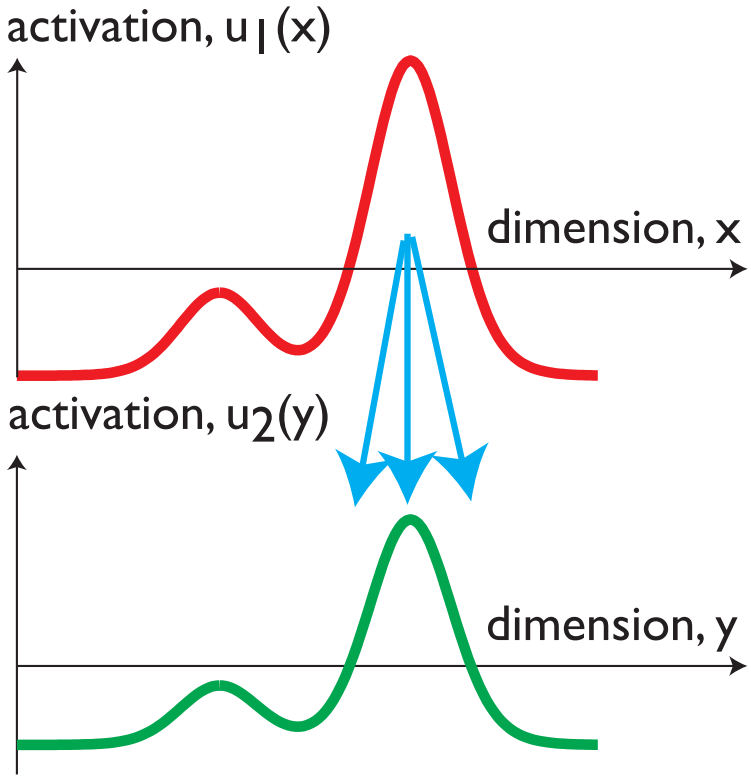
- re-creates a peak at the location at which the memory trace pre-activates=preshapes the field





Stable memory in DFT: Hebbian learning

- Hebbian learning of projections
  - among fields
  - forward from sensory input to fields
- interaction leads to localized rather than distributed representations (SOM)

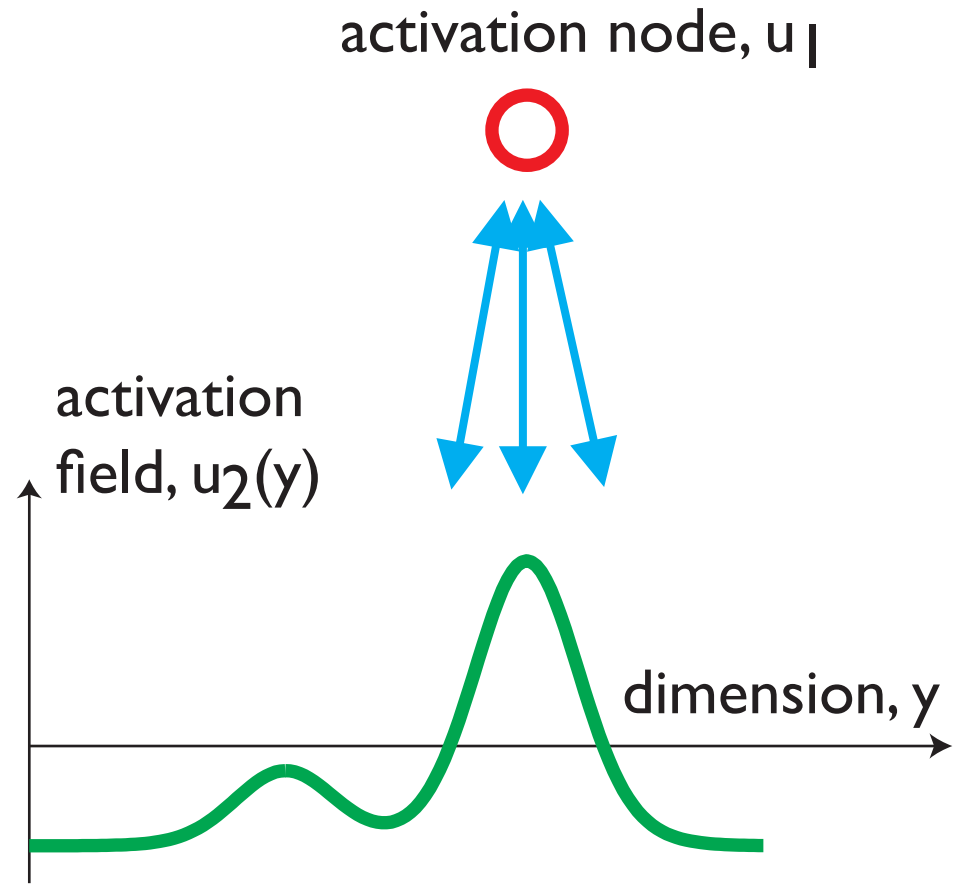


$$\tau \dot{W}(x, y, t) = \epsilon(t)\Big(- W(x, y, t) + f(u_1(x, t)) \times f(u_2(y, t))\Big)$$

[Sandamirskaya, Frontiers Neurosci 2014]

Hebbian learning

- learning reciprocal connections between zero-dimensional nodes and fields
- => grounded concepts
- analogous to the output layer of DNN
- => ensembles of such nodes coupled inhibitorily form the basis for conceptual thinking…



Cued recall

- with ridge/slice input in joint representations of different feature dimensions
- => module on higher-dimensional fields and binding

Memory trace ~ first-order Hebbian learning

- increases local resting level at activated locations
- ~ the bias input in NN
- boost-driven detection instability amplifies small bias => important role in DFT