Dynamic Field Theory

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Recall from last lecture …
reaction time (RT) paradigm

imperative signal = go signal

response

RT

task set
time course of neural processing
observe the time course of neural processing behaviorally

[Favilla et al. 1989]
observe the time course of neural processing directly

[Graphs and charts showing population activation over time for complete, two-target, and three-target information, with time in milliseconds and number of targets on the axes.]
Memory instability

- Self-excited peak
- Sub-threshold attractor
- Self-sustained peak
“space ship” task probing spatial working memory

2000 ms  10 sec delay  Ready, Set, Go!

[Schutte, Spencer, JEP: HPP 2009]
Because (various, variable) induction processes that underlie performance on a single spatial recall trial. During the delay (various, variable) and other geometric biases. The simulations in Figure 3 demonstrate that the spatial precision parameters, the widths of the projections between the fields are weaker (relative to the adult model; Figure 3c). For instance, if the working memory peak were positioned very 40 degrees, 60 degrees, and 80 degrees relative to midline during the delay, that is, the maximal activity (various, variable) and the increase in plasma levels of various, variable parameters during the delay). Additionally, the reference parameter...
DFT account of repulsion: inhibitory interaction with peak representing landmark.

[Simmering, Schutte, Spencer: Brain Research, 2007]
Working memory as sustained peaks

implies metric drift of WM, which is a marginally stable state (one direction in which it is not asymptotically stable)

=> empirically real..
inhomogeneities from simplest from the memory trace

~ habit formation (?) William James: habit formation as the simplest form of learning

habituation: the memory trace for inhibition..
mathematics of the memory trace

\[ \tau \dot{u}(x, t) = -u(x, t) + h + S(x, t) + u_{\text{mem}}(x, t) \]
\[ + \int dx' \, w(x - x') \, \sigma(u(x')) \]

\[ \tau_{\text{mem}} \dot{u}_{\text{mem}}(x, t) = -u_{\text{mem}}(x, t) \]
\[ + \int dx' \, w_{\text{mem}}(x - x') \sigma(u(x', t)) \]

- memory trace only evolves while activation is excited
- potentially different growth and decay rates
memory trace reflects history of decisions formation
Piaget’s A not B paradigm: “out-of-sight -- out of mind”
Toyless variant of A not B task

[Smith, Thelen et al.: Psychological Review (1999)]
Toyless variant of A not B task reveals that A not B is essentially a decision task!

[Smith, Thelen et al.: Psychological Review (1999)]
A location

B location

activation field

Thelen, et al., BBS (2001)]

Dineva, Schöner, Dev. Science 2007]
Instabilities

- **detection**: forming and initiating a movement goal
- **selection**: making sensori-motor decisions
- **(learning): memory trace**
- **boost-driven detection**: initiating the action
- **memory instability**: old infants sustain during the delay, young infants do not
Instabilities

- detection: forming and initiating a movement goal
- selection: making sensori-motor decisions
- (learning: memory trace)
- boost-driven detection: initiating the action
- memory instability: old infants sustain during the delay, young infants do not

Diagram:
- activation field
- boost-induced detection
- movement parameter
- A and B points
- Boost label
- After the delay label
Instabilities

- detection: forming and initiating a movement goal
- selection: making sensori-motor decisions
- (learning: memory trace)
- boost-driven detection: initiating the action
- memory instability: old infants sustain during the delay, young infants do not
DFT of infant perseverative reaching

[Dinveva, Schöner, Dev. Science 2007]
DFT of infant perseverative reaching

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DFT of infant perseverative reaching

[Inveva, Schöner, Dev. Science 2007]
DFT of infant perseverative reaching

- In spontaneous errors, activation arises at B on an A trial
- Which leads to correct reaching on B trial

[Dinveva, Schöner, Dev. Science 2007]
DFT of infant perseverative reaching

that is because reaches to B on A trials leave memory trace at B

[Dinveva, Schöner, Dev. Science 2007]
DFT is a neural process model that makes the decisions in each individual trial, by amplifying small differences into a macroscopic stable state and that’s how decisions leave traces, have consequences.
Decisions have consequences

- A spontaneous error doubles probability to make the spontaneous error again

Figure 7. Estimates from experiment (solid lines) and DFT simulations (broken lines) of the rate of spontaneous errors across A-trials (black lines). The grey lines show the conditional probability that a reach again goes to B on a given A-trial given that the first spontaneous reach to B has just occurred on the previous trial.

Figure 8. Estimates from infant experiments (solid line) and DFT simulations (broken line) for the probability to make exactly n spontaneous errors as a function of n. According to this hypothesis, the overall rate of spontaneous errors reflects the distribution of the side bias across babies and is, therefore, constant across A-trials. This hypothesis predicts that the conditional probability of repeating a spontaneous error after a previous error should be high (close to one in the limit case of completely deterministic decisions). In fact, this limit case predicts that babies with a bias to B should repeat spontaneous errors across the entire A-trials phase of the paradigm. This prediction is tested in Figure 8 showing the probability that an infant/simulation makes exactly n spontaneous errors as a function of n (Equation (3)). The deterministic account predicts that this probability should have a U-shape: Some infants should systematically make no spontaneous errors, while the biased babies should make a large number of spontaneous errors. Intermediate numbers of spontaneous errors should not be frequent, as these reflect stochastic decision making. The data clearly refute this hypothesis. The monotonic decrease of the probability of n spontaneous errors with the number n is consistent with a stochastic contribution to sensorimotor decision making.

[Dineva, Schöner: Connection Science 2018]
Conclusions

- action, perception, and embodied cognition takes place in continuous spaces. peaks = units of representation are attractors of the neural dynamics

- neural fields link neural representations to these continua

- stable activation peaks are the units of neural representation

- peaks arise and disappear through instabilities through which elementary cognitive functions (e.g. detection, selection, memory) emerge
The conceptual framework of DFT

DST/DFT

human factors models

Naturalistic experiment

DFT models for experiment: account for experimental results

Laboratory experiment neural behavioral

Robotic demonstrations of DST/DFT models

robotic demonstrations of experimental results

DST/DFT approaches to technical autonomous robotics