Learning

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What is learning?

- a very broad concept, not nearly as well defined as we might think

neuroscience

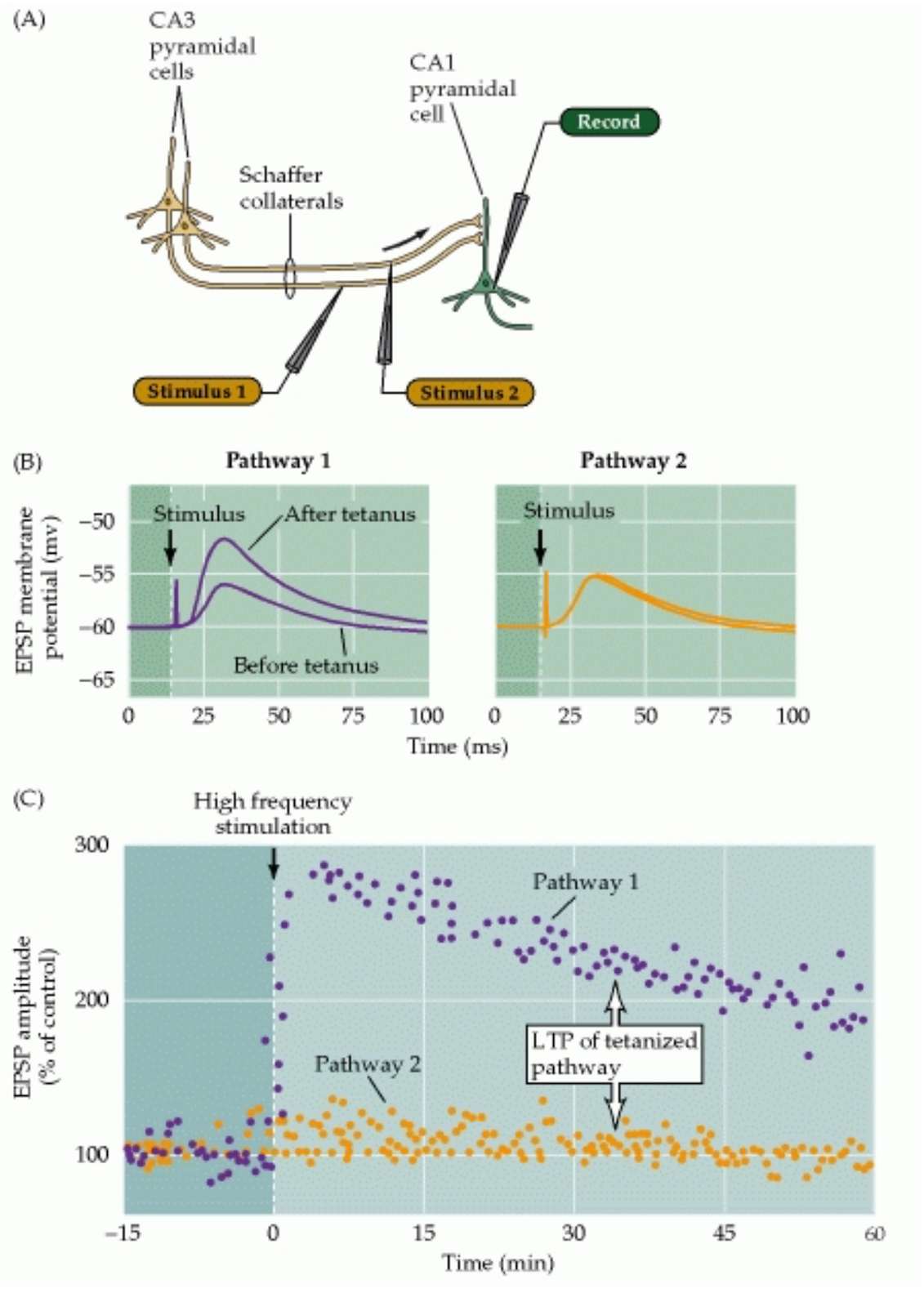
- definition: learning as the capacity of physiological neural networks to change their function over time, dependent on the history of stimulation/activation
- learning mechanisms are in the foreground
- concept of learning overlaps with that of psychology

synaptic plasticity: long term potentiation

- excitatory synapses are strengthened when the presynaptic and the postsynaptic neuron fire within small time window
  - easily established when stimulation by presynaptic cell is intense
  - (less clear at physiological rates)
  - readily observed in slices from hippocampus

Long-term potentiation

- experimental paradigm
- (here: Hippocampus)



Neuroscience. 2nd edition.
Purves D, Augustine GJ, Fitzpatrick D, et al., editors.
Sunderland (MA): Sinauer Associates; 2001.

synaptic plasticity: long term potentiation… issues

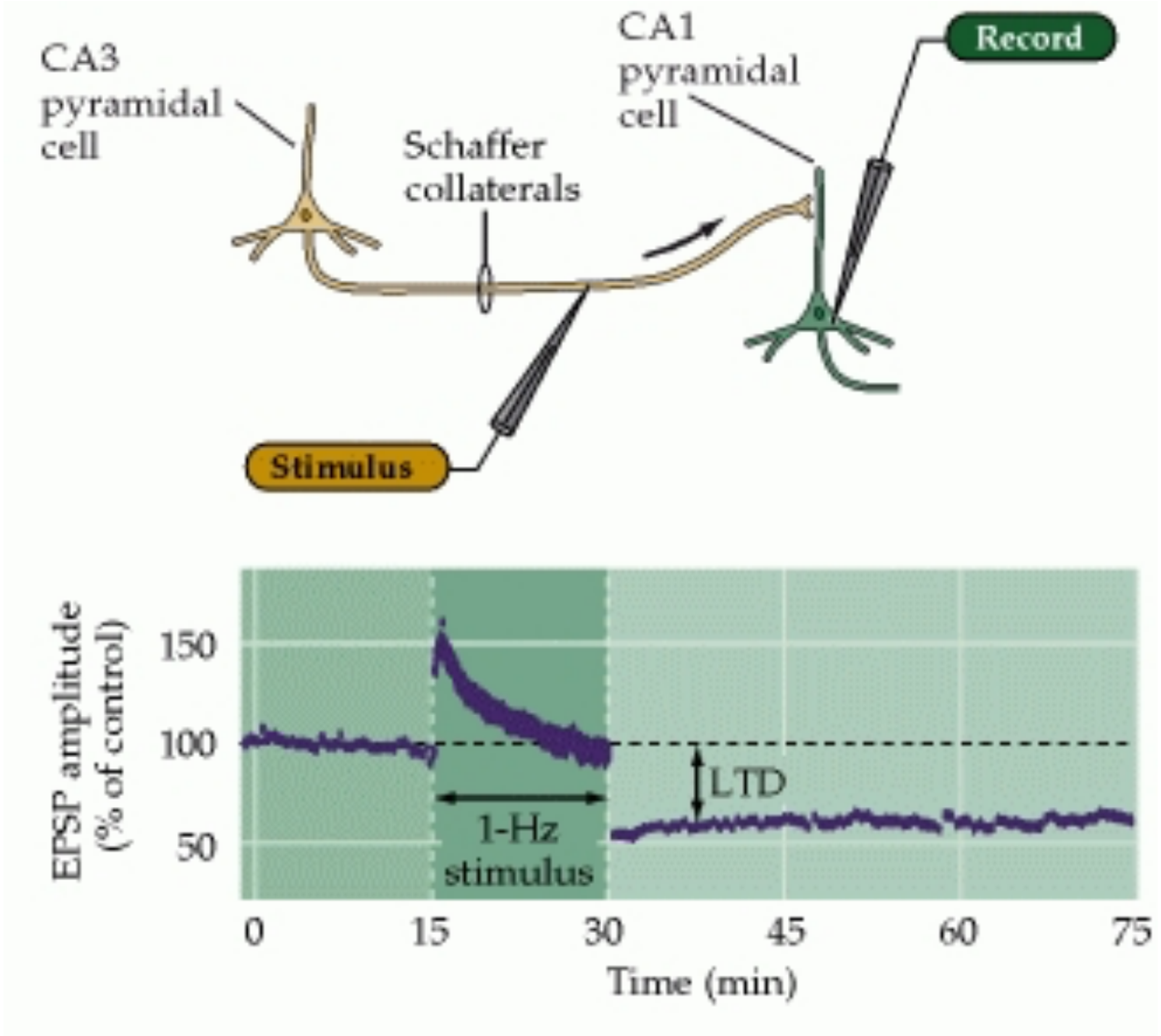
- problem of retrograde signaling
- link to behavioral learning recent and thin

synaptic plasticity: long term depression:

- excitatory synapses are weakened with the presynaptic neuron fires at a low frequency
- very broadly observed in CNS

Long-term depression

- low-frequency firing of pre-synaptic neuron that does not induce post-synaptic firing => LTD



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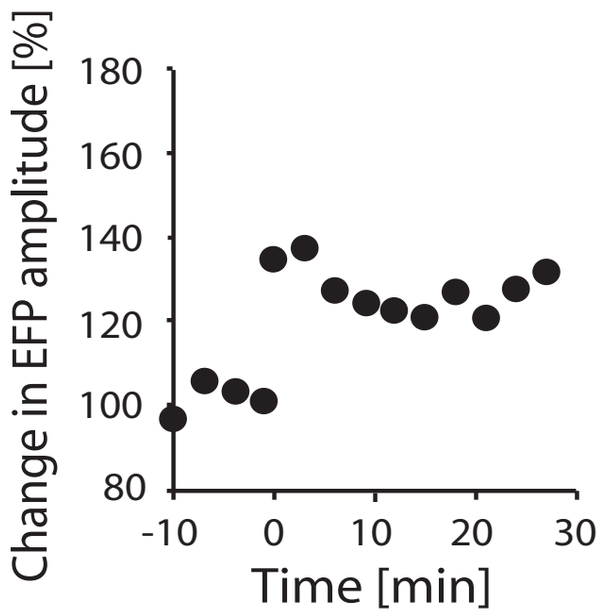
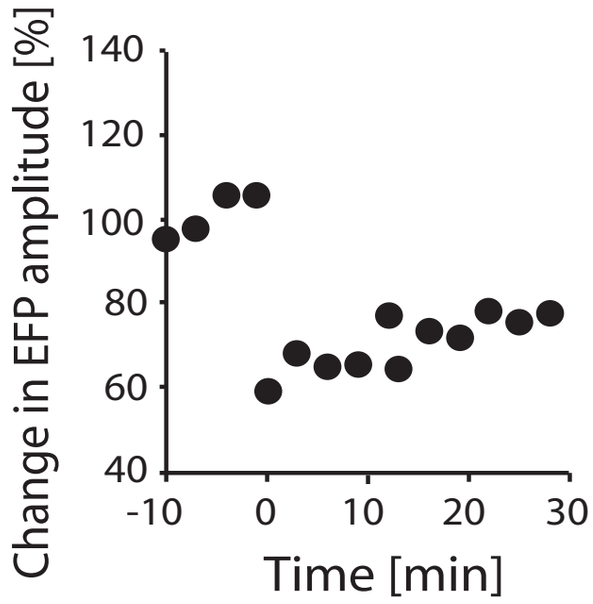
LTP/LTD

A. Long term potentiation



B. Long term depression



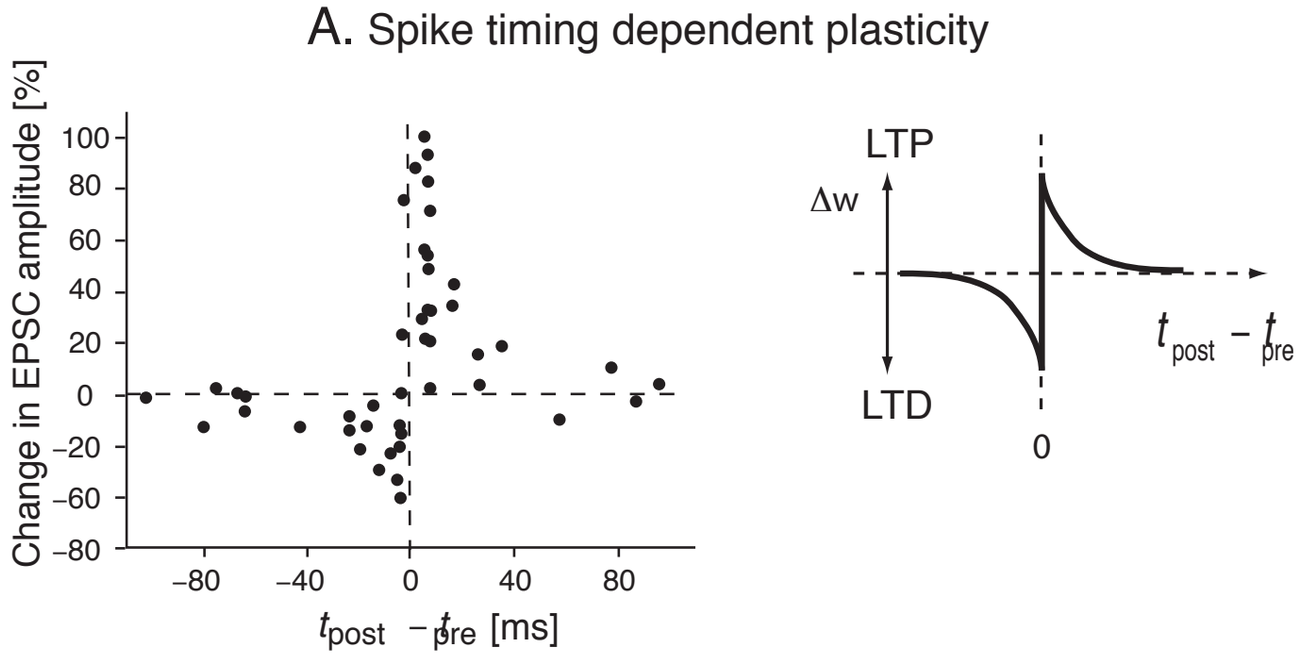
[from: Trappenberg: Fundamentals of Computational Neuroscience, Oxford, 2002]

synaptic plasticity: spike time dependent plasticity

- combines both weakening and strengthening synapses depending on the relative timing of presynaptic and postsynaptic spikes

STDP

- through intra-cellular recording/stimulation control the relative timing of pre and postsynaptic spikes
- => LTP for positive, LTD for negative delay



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psychology

- learning is perhaps the central theme of human psychology
- every single behavior is subject to learning
- a wide range of phenomena are considered forms of learning
- widest definition: learning is change of behavior over the longer run based on experience

habit formation

- perhaps the most basic and pervasive form of learning ... dating back to William James (1890)
- definition: behaviors facilitate themselves, lowering the threshold and sensory or cognitive demands to reactivate the same behavior
- examples:
  - drive along the same route, make the same dance move, select the same food
  - write the same thing, argue in the same way

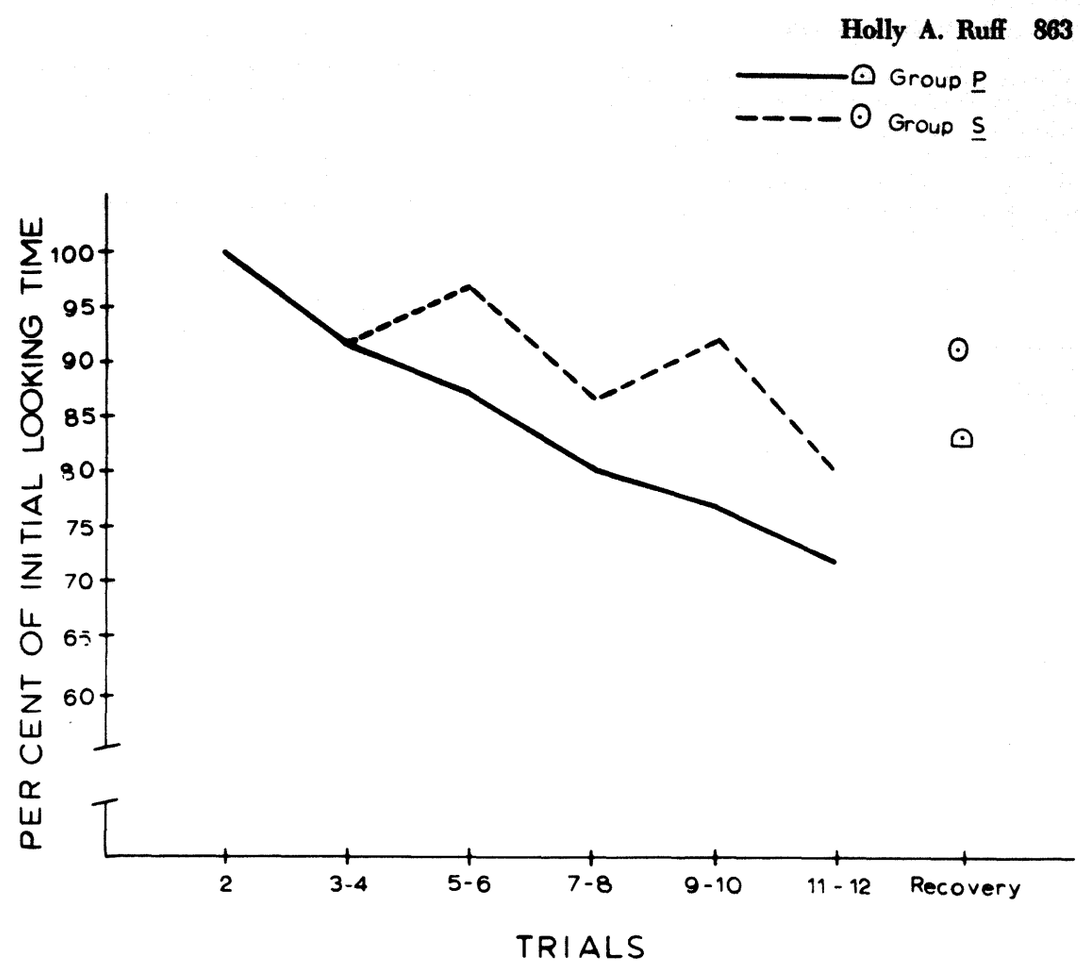
examples of habit formation

- learning behavioral routines, habitual stimulus-response associations, action patterns
- e.g., animals showing up at particular locations expecting food, cows showing up at particular spots expecting to be milked
- e.g., people developing routines in daily life, taking routine routes

habituation

- also a very basic, pervasive form of learning
- definition: the opposite of habit formation: behaviors inhibit themselves, raising the threshold to activate the same behavior again

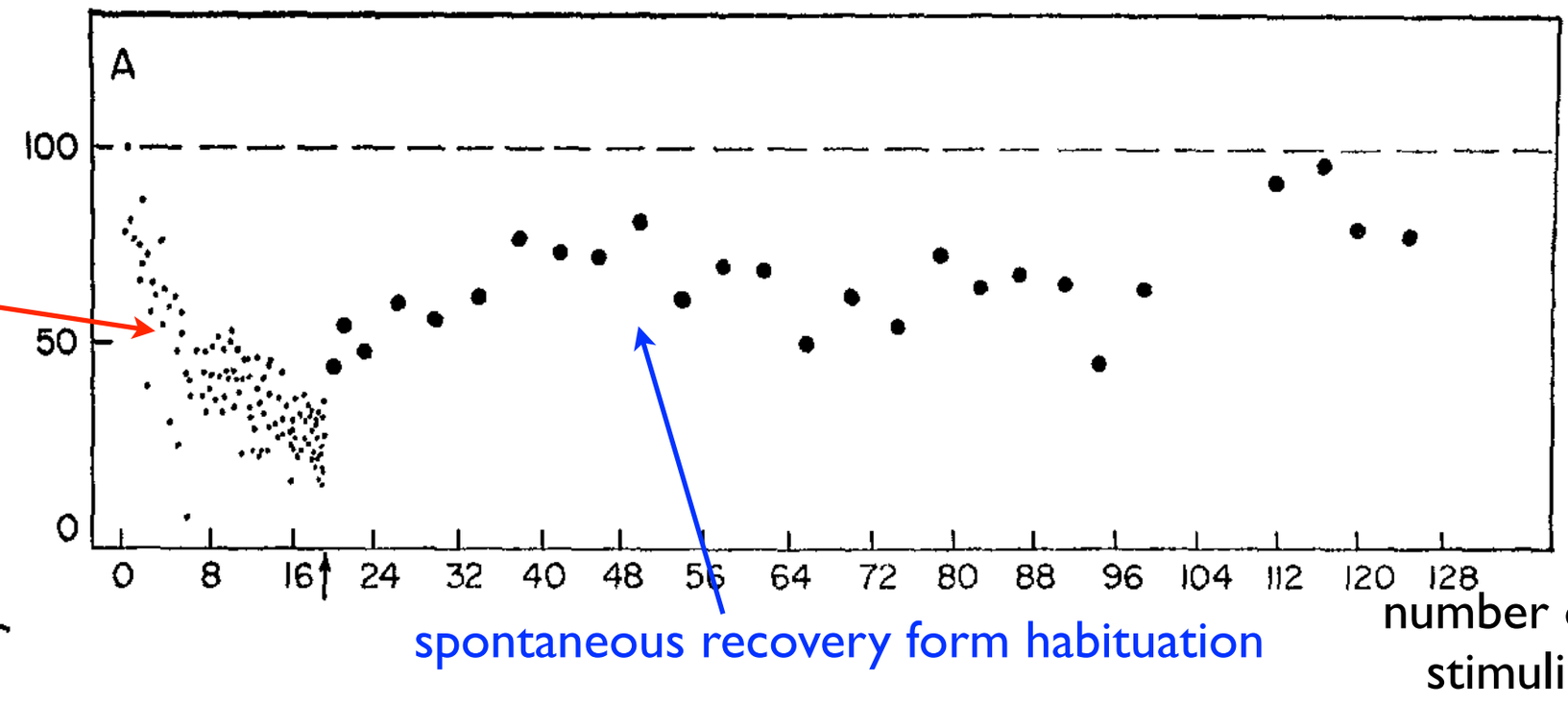
how much looking does a repeated stimulus elicit in a baby?



habituation

- habituation as a weakening of the link between stimulus and response

flex reflex at the hindleg is weakened after repeated skin stimulation in the decerebrate cat



Thomson, Spencer, 66

habituation

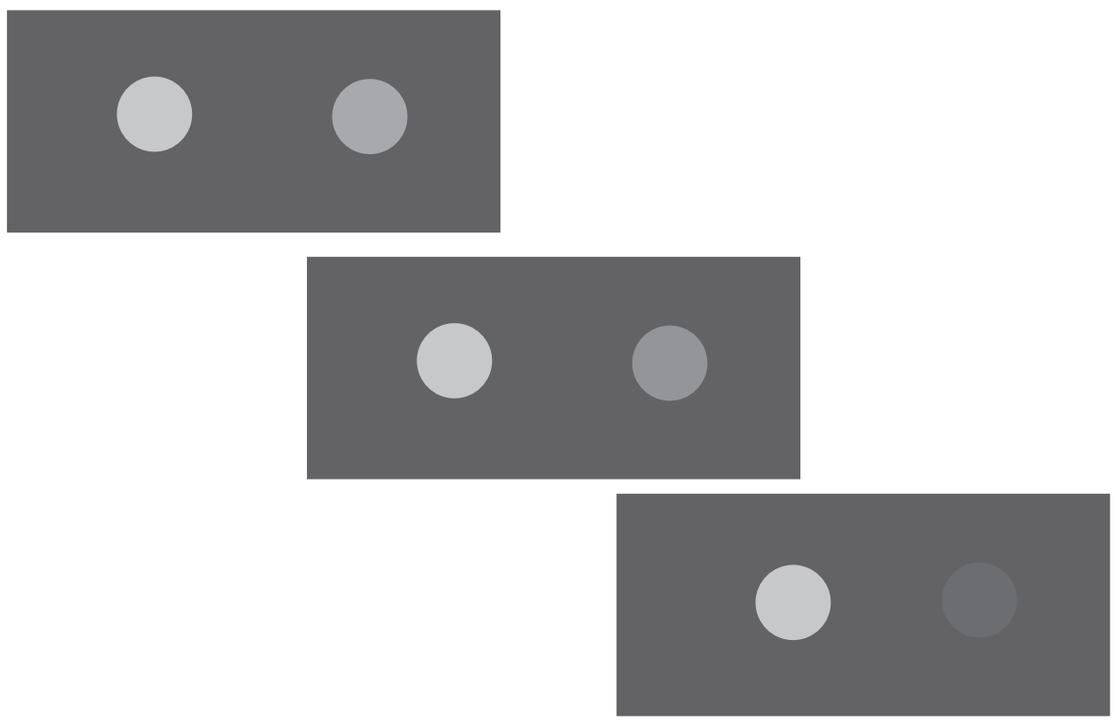
- the gill withdrawal reflex in Aplysia is on of the classical animal preparations to study this form of learning leading to the first Nobel price for learning (E Kandel)

selective adaptation

- a common form of habituation in the perceptual domain
- the perceptual threshold increases with the time a particular percept is being experienced

adaptation phase

test phase



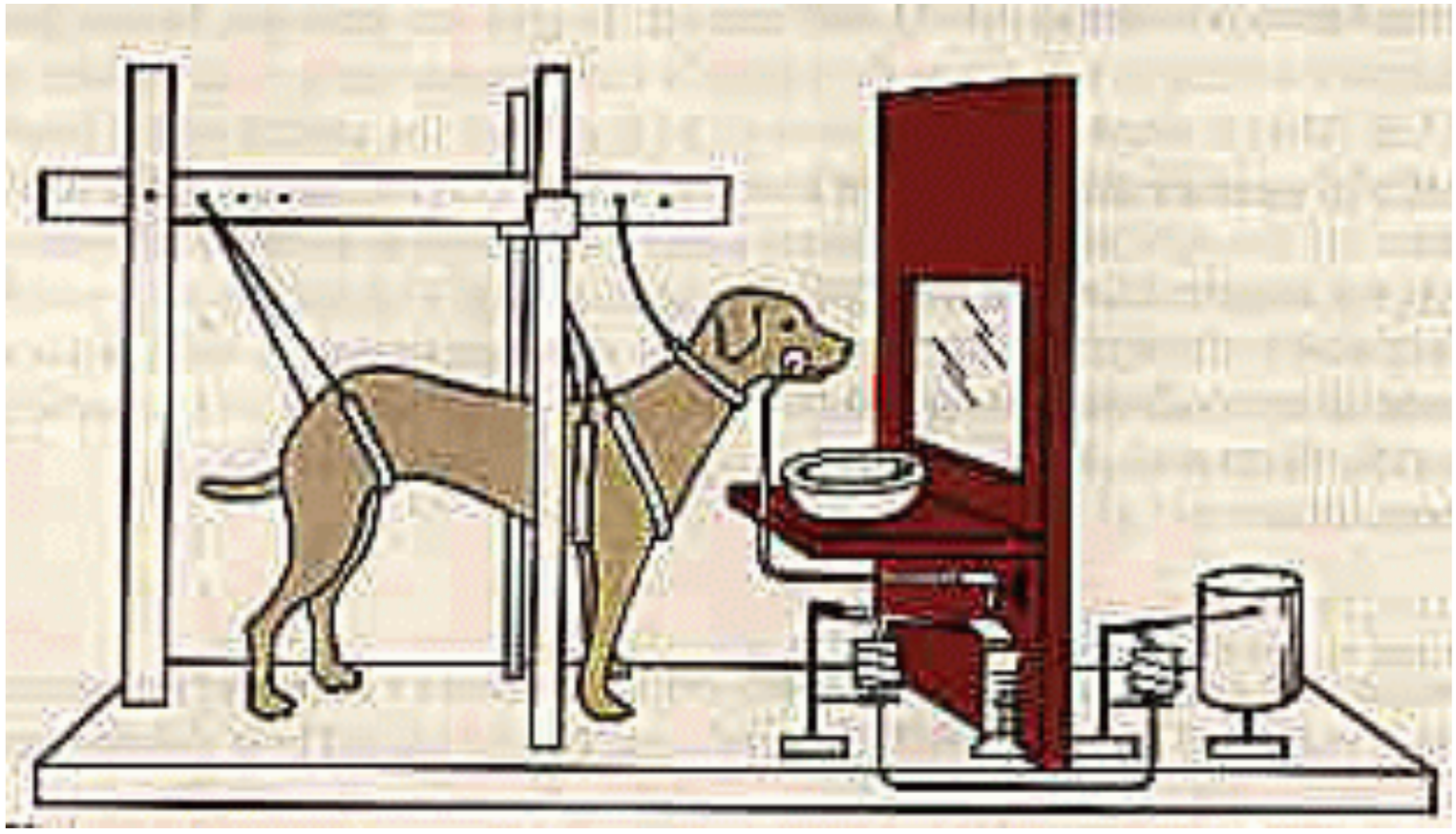
=> determine relative contrast threshold

classical (or respondent) conditioning

- associating new stimuli with an response by pairing the stimulus with a pre-existing stimulus response link
  - unconditioned stimulus (UCS): the stimulus of the pre-existing stimulus-response link
  - conditioned stimulus (CS): the new stimulus

examples of classical conditioning (CC)

- classical example: Pavlov's dog



examples of classical conditioning (CC)

- modern (neuroscience) laboratory example: eye-blink conditioning
  - an air-puff applied to the eye (unconditioned stimulus) elicits a blink (response)
  - if the air-puff is frequently paired with a new (conditioned) stimulus, e.g., a bell, a tone, a light etc, then this conditioned stimulus alone is capable of eliciting the response

classical (or respondent) conditioning

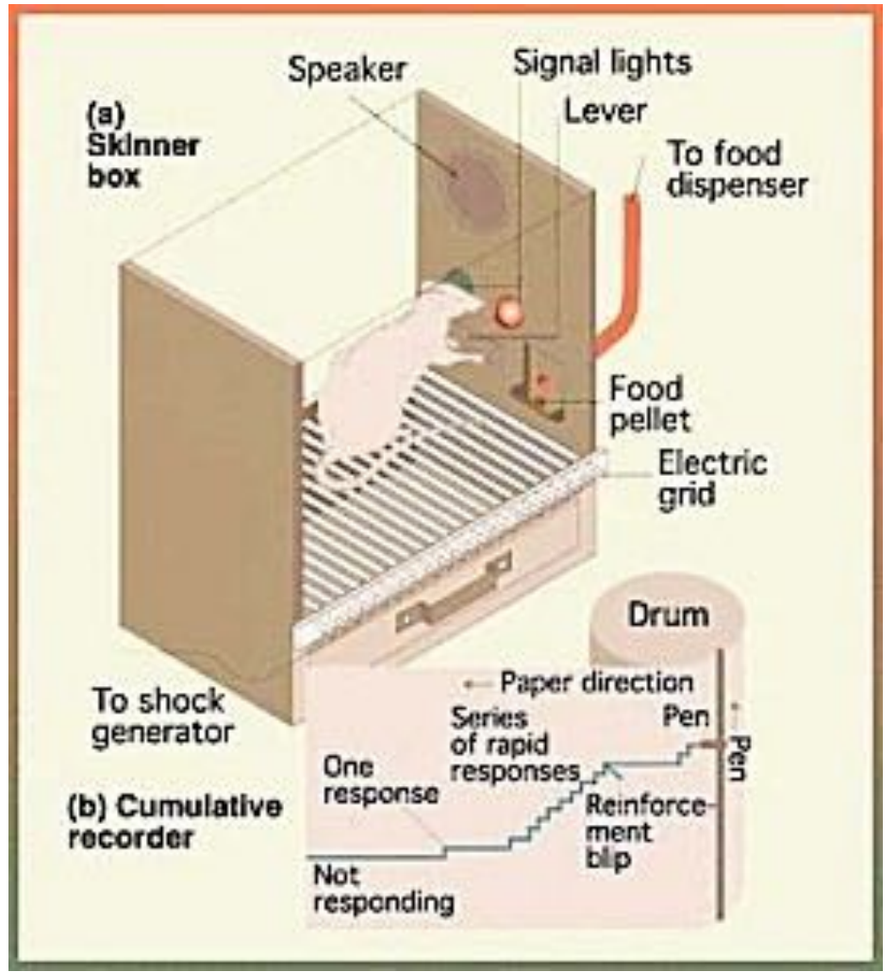
- a long history of detailed study
  - the time contingencies of CC
    - e.g., much easier/faster to associate a stimulus (CS) that precedes the UCS ("predicts" the UCS) than to associate a stimulus that arrives after the UCS ("backward conditioning)
  - dependence on award schedule, on history of reward/ stimulation, etc.
- together with instrument/operant conditioning the basis for learning theory and the starting point of behaviorism

instrumental (or operant) conditioning

- learning new stimulus-response associations, including possibly quite complex ones, as the result of both exploration and reward

examples of instrumental conditioning (IC)

- e.g., rats learning to press lever for food, then learning to do so only in the presence of certain stimuli (reward based)
- e.g., rats learning to avert shock by not approach food when certain stimuli a present (punishment based)



instrumental (or operant) conditioning

- the basis of Reinforcement Learning as a theoretical paradigm (RL)
- very influential historically in behaviorism, which sought to account for almost any skill on the basis of operant conditioning

instrumental conditioning

- shaping: although a pre-existing SR association is not needed, in practice pre-existing habits or goals must be exploited to shape behavior into a graded discovery of the contingency

- much informal knowledge about animal behavior is hidden/ contained in shaping procedures

- shaping illustrates that associations are NOT arbitrary: some things are easier to achieve than others in instrumental conditioning

associative learning

rote learning

- e.g., the learning of arbitrary lists of words or lists of associations
  - experimentally probed by free recall vs. cued recall (cued is easier)
- historically, the most typical human learning paradigm that was looked at with the methods of reinforcement learning
  - maybe because it is artificial and boring enough to turn of many of the most interesting forms of learning?
- much schooling is based on this...

sequence learning

- with origins in rote learning, but learning of sequences, e.g., telephone numbers...
- but contain an aspect that is really different from rote learning.. there are two aspects here:
  - what's in the sequence?
  - in which serial order are those items?

example of sequence learning

- e.g., in a movement tracking task
  - a portion of the track repeats many times
  - while other portions do not repeat:
  - performance becomes better on repeated part, not on unpredictable portions
  - even though participant is not aware of the regularity (Pew, 1974)

example of sequence learning

- e.g., in serial reaction time task
  - making saccadic eye movements to targets that show up in new places in different frames in the presence of distractors
  - a predictable sequence of targets leads to more shortening of reaction times than an unpredictable sequence, again independent of awareness of sequence...
  - and even amnesiacs show this improvement across sessions, although each day they come to a session they think this is the first time they ever did this task...

memory formation

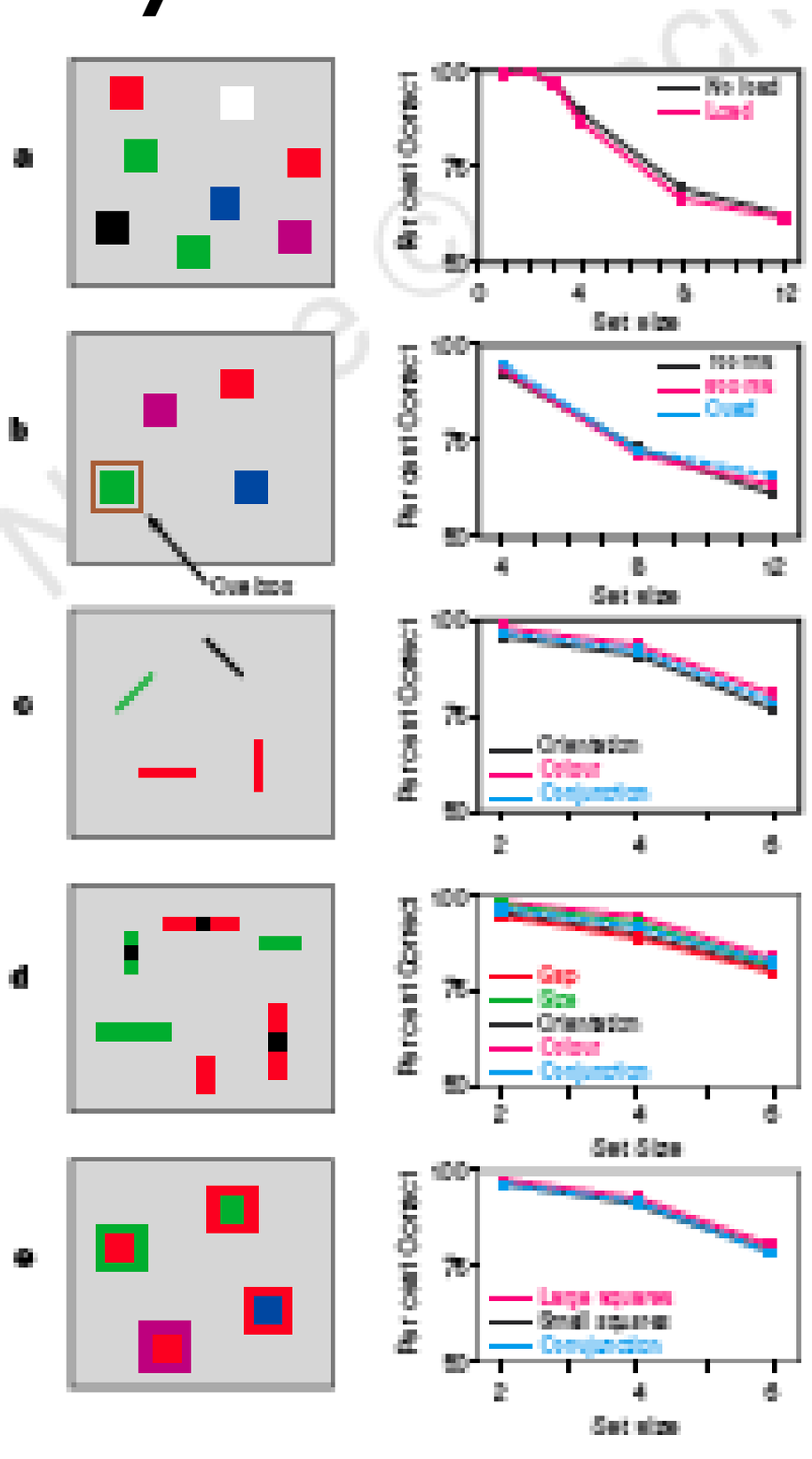
working memory

- short term... subject to interference and capacity limits
- e.g., phonological: speech is structured in time, so that to understand a sentence you need to keep recent sounds and words in mind...
  - phonological loop
  - has capacity limits

working memory

- e.g., visual working memory
  - probes: change detection, free recall
  - limited capacity
  - object based

Luck, Vogel, 1997



working memory

- e.g., motor memory
  - remembering a limb position, reproducing a movement that had been done previously
  - works even if initial position is changed
  - works even when proprioception is eliminated (e.g., through a block)

working memory

- working memory is fundamental to our sense of reality
- perception as a form of memory: scene representation
- e.g., change blindness

demonstration of change blindness

Credit: RA Rensink http://www.usd.edu/psyc301/Rensink.htm

LTM: long term memory

- less subject to interference and capacity limitation...
- traditionally thought to require longer processes of acquisition, with practice, rehearsal etc. => rote learning
- but single shot learning also leads to impressive retention!

long-term memory from single views

- Andrew Hollingworth, Univ. of Iowa:
- participants look at 10 locations in a scene, doing this for as many as 300 scenes

http://www.psychology.uiowa.edu/faculty/hollingworth/

long-term memory from single views

- later (days or weeks later) they must do change detection tasks on
  - the identity of objects
  - and poses of objects

http://www.psychology.uiowa.edu/faculty/hollingworth/

long-term memory from single views

- very good performance!

http://www.psychology.uiowa.edu/faculty/hollingworth/

skill learning

learning motor skills

- e.g., learning to walk
- e.g., learning to ski, to surf, to play the piano, ...
- requires (a lot of) practice, effort, motivation
- requires sensory feedback
- does not necessarily require instruction

learning cognitive skills

- e.g.,. learning Morse code
- e.g., learning to read and write
- e.g., learning a foreign language
- e.g., learning mathematics
- e.g., learning to write novels
- requires likewise a lot of effort, motivation, practice
- may not require instruction (although usually given)

perceptual learning

- learning to discriminate
  - e.g., learning to tell male from female chicklets
  - e.g., learning to categorize shapes
  - e.g., learning to discriminate the phonemes of a language
- sometimes is relatively effortless (e.g., learning to recognize music), although influenced by tasks and improved by effort (e.g., learning sounds of a foreign language)

learning categories, words, concepts

- development: acquiring language (and concepts) is clearly learning rather than maturation
- children learn words at an amazing rate, but actually need substantial experience for each word… they learn all the time…
  - they generalize, initially too much, then differentiate
- (many other aspects of development are also experience dependent
  - e.g., the concept of transparency depends on experience
  - e.g., motor experience drives skill

learning categories, words, concepts

- learning concepts
  - e.g., furniture.. do curtains belong to that category? how about a clock? is a clock a typical piece of furniture (no because it may also be a part of clothing (wrist watch) and part of a building (church clock)...
  - in other words: learning a concept also involves learning a lot of inner structure of the network of concepts
- in experiment: learning new categories affects discrimination
  - better across category boundaries than within (Goldstone)

social learning: rich but hard to grasp

- learning is social situations involves
  - teaching
  - imitation
  - peer learning
  - scaffolding
- which affects
  - motivation, reward
  - exploration
  - enabling learning to obtain sensory feedback

=> Learning in DFT

- memory trace
- inhibitory memory trace
- dynamic Hebb…

Conclusion

- learning as a different, if overlapping concept in different disciplines
  - psychology
  - neuroscience
  - applied mathematics

applied mathematics

- machine learning
  - acquiring the capacity to classify, regress, or estimate from examples
- neuronal network learning
  - often used in that sense of machine learning, using neural networks as the substrate