The prehistory of cognitive science

Introduction to Cognitive Science

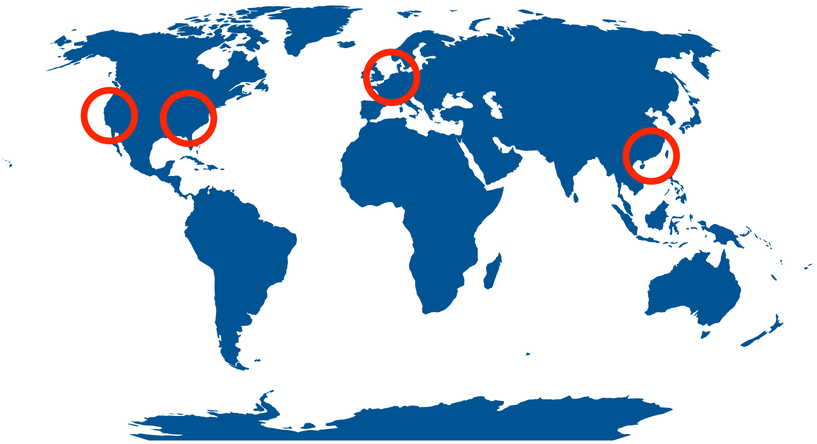
dr. ir. Roy de Kleijn
Tuesday, 10 February 2025

Universiteit Leiden

Course introduction

Who am I?

- Roy de Kleijn (The Hague, Netherlands)
- Background in **computer science** and **cognitive psychology.**
  - M.Sc. in **Computer Science** (Georgia Tech)
  - M.Sc. in **Cognitive Neuroscience** (Leiden/ Stanford)
  - Ph.D. at Leiden University
- **Assistant professor** at Leiden University and Chinese University of Hong Kong.



The *Introduction to Cognitive Science* team

Roy de Kleijn

Samarth Varma

Steven Miletić

Date	JLB	Topic	Lecturer
Friday, 7 February, 2025		**No lecture**	
Tuesday, 11 February, 2025	1	The prehistory of cognitive science	de Kleijn
Friday, 21 February, 2025	2	The discipline matures: Three milestones	de Kleijn
Friday, 28 February, 2025	3	The turn to the brain	Varma
Friday, 7 March, 2025	9	Strategies for brain mapping	Varma
Friday, 14 March, 2025		Instructions on essay writing	Varma
Friday, 21 March, 2025	16	Emotions	Varma
Friday, 28 March, 2025		**No lecture**	
Friday, 4 April, 2025	7	Bayesianism in cognitive science	de Kleijn
Friday, 11 April, 2025	6 and 8	Dynamical systems and Modules and architectures	Miletić
Friday, 18 April, 2025		**No lecture**	
Friday, 25 April, 2025	5	Neural networks and distributed processing	Miletić
Friday, 2 May, 2025	10	Models of language learning	Miletić
Friday, 9 May, 2025	15	The cognitive science of consciousness	Miletić
Friday, 16 May, 2025		Q&A	all
Monday, 16 June, 2025		Final exam	
Monday, 7 July, 2025		Re-sit	

What are these lectures for?

- When the textbook is particularly difficult, the lectures may **focus on the textbook**.
- In other cases, lectures can **discuss related topics**.

The essay

- Write a ~4,000 word essay on a topic of your choice related to cognitive science.
- Propose a topic before **Friday, 4 April 2025**.
- Essay deadline **Friday, 9 May 2025**.
- Essay counts for 30% of final grade.

The final exam

- Final exam will consist of 50 multiple choice questions about the textbook and lectures.
- Exam date **Monday, 16 June 2025**.
- Do not forget to register!
- Exam counts for 70% of final grade.

The end of behaviorism

What is behaviorism?

The end of behaviorism

- In order for the new science of psychology to become a true science, it should concern itself **only with observable behavior**.
- Speculating about cognition or other unobservable phenomena is unscientific.
- “Psychology is the **science of behavior**.”

What is behaviorism?

The end of behaviorism

- Two main assumptions of behaviorism:
    1. All learning is the result of **conditioning**.
    2. Conditioning depends on **association** and **reinforcement**.
- But what exactly is conditioning?

Classical conditioning

Principles of classical conditioning

The end of behaviorism

- **Reflex:** simple, automatic stimulus-response sequence mediated by the nervous system.
  - Eye blink reflex
  - Knee jerk reflex
  - Startle response

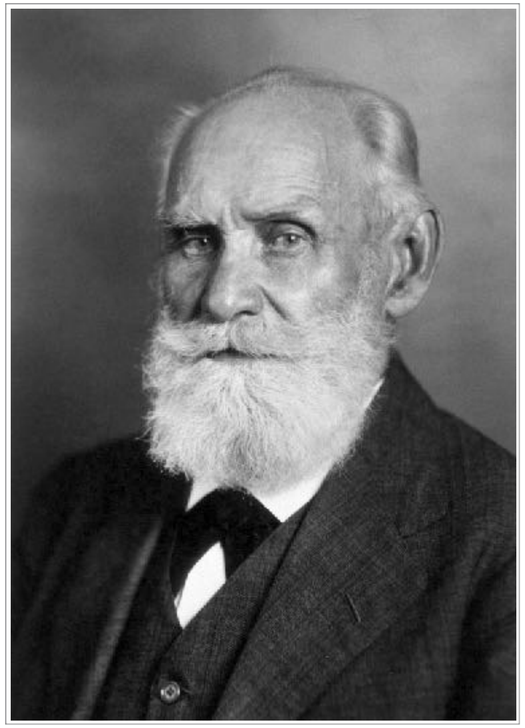
Principles of classical conditioning

The end of behaviorism

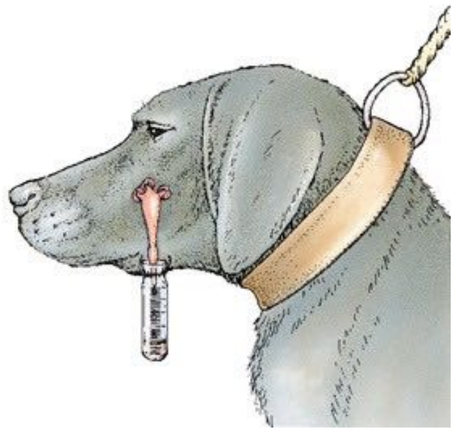
- The strength of some reflexes decreases due to **habituation**.
- Habituation **weakens** the stimulus–response connection.
- How can we **create** a stimulus–response connection?

Pavlov: the father of conditioning

The end of behaviorism

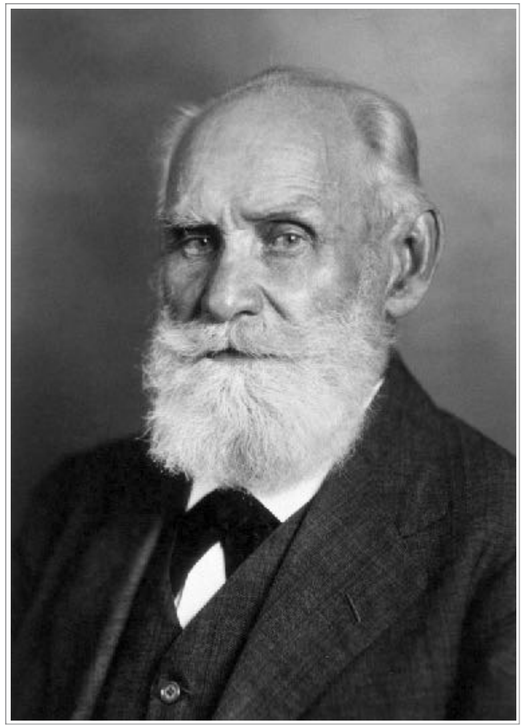


- Research on salivation reflex in dogs.
  - Food presented → salivation
  - Pavlov found that type of food affected composition of saliva (Nobel Prize 1904)
- Problem: dogs started to salivate as soon as the assistant bringing the food opened the door.
- Therefore **new association:** door opens → salivation

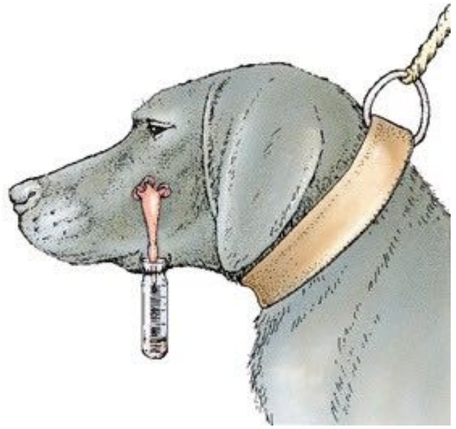


Pavlov: the father of conditioning

The end of behaviorism



- This was an unwanted source of errors.
- However, Pavlov shifted his research interest to this new phenomenon.



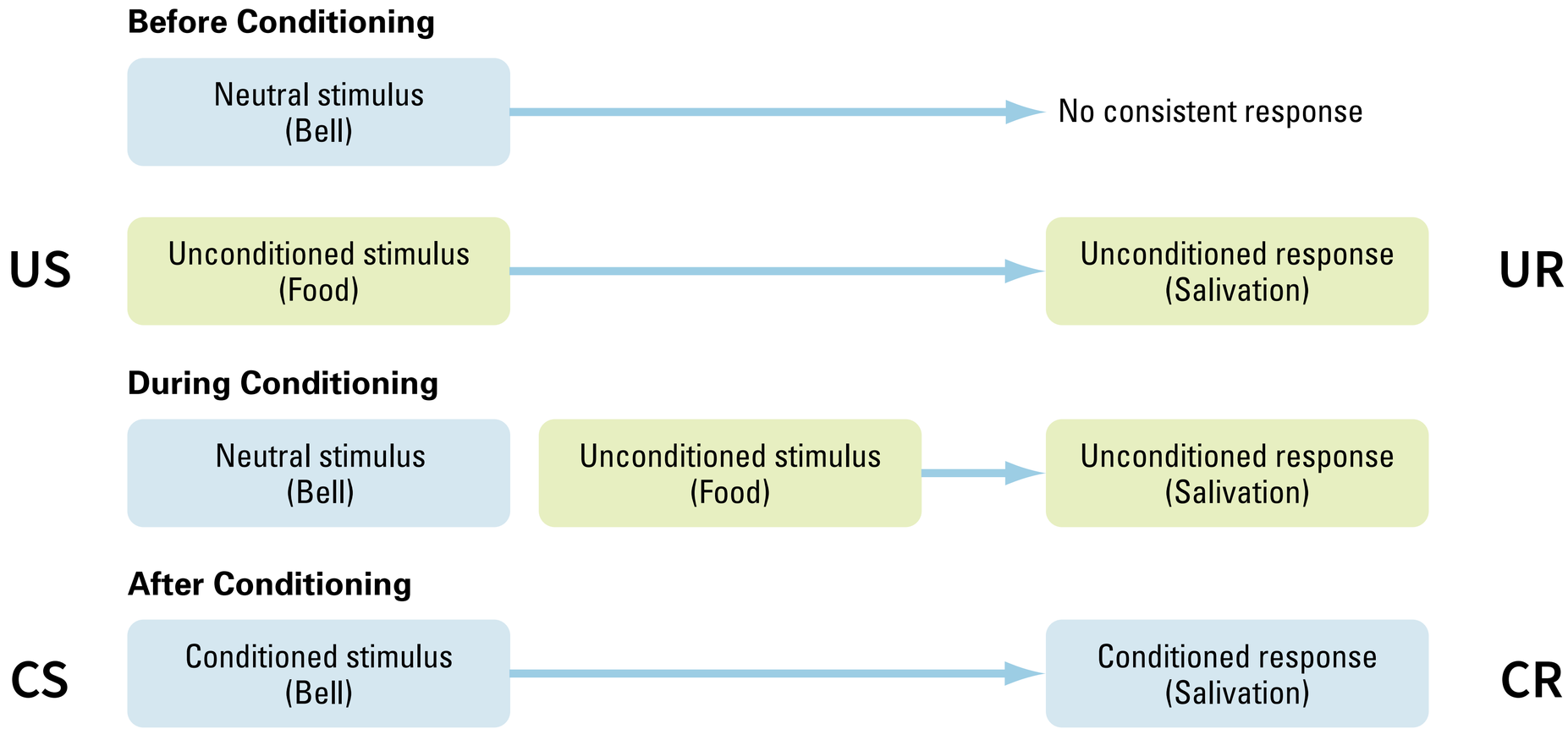
Classical conditioning

The end of behaviorism

- Just before giving food, Pavlov **sounded a bell.**
- After several repetitions, dogs started to salivate when they heard the bell, **even without food.**
- A **new stimulus–response connection** had therefore been created.

Classical conditioning

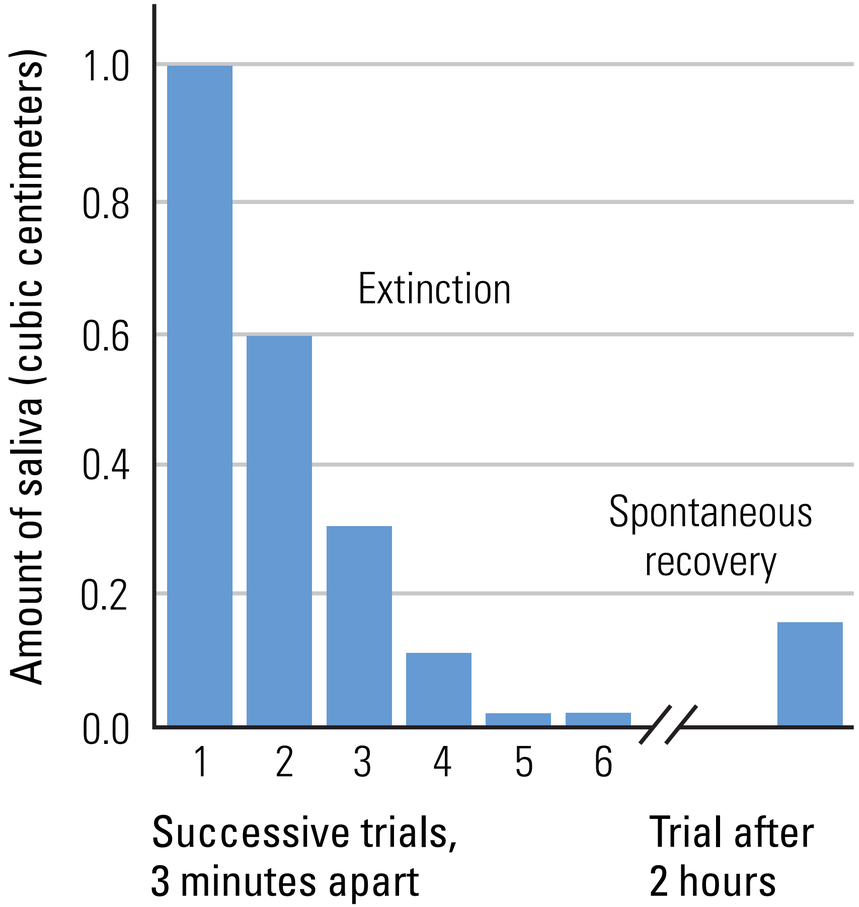
The end of behaviorism



Classical conditioning: extinction

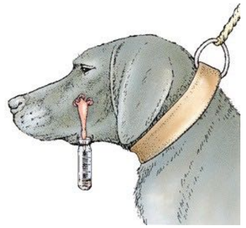
The end of behaviorism

- How long does this new stimulus–response connection remain, **in the absence** of the US?
- Strength of the stimulus–response connection becomes weaker: **extinction**
- **Spontaneous recovery:** the reflex has not been lost, but is possibly inhibited.



Classical conditioning: phenomena

- Generalization
- Training: 
- Test:
  -  = 20 mL
  -  = 18 mL
  -  = 18 mL



- Dog also salivates to higher and lower tones.

- Discrimination
- Training:  
- Test:
  -  = 20 mL
  -  = 0 mL
  -  = 20 mL

- Dog therefore senses difference between  and  !

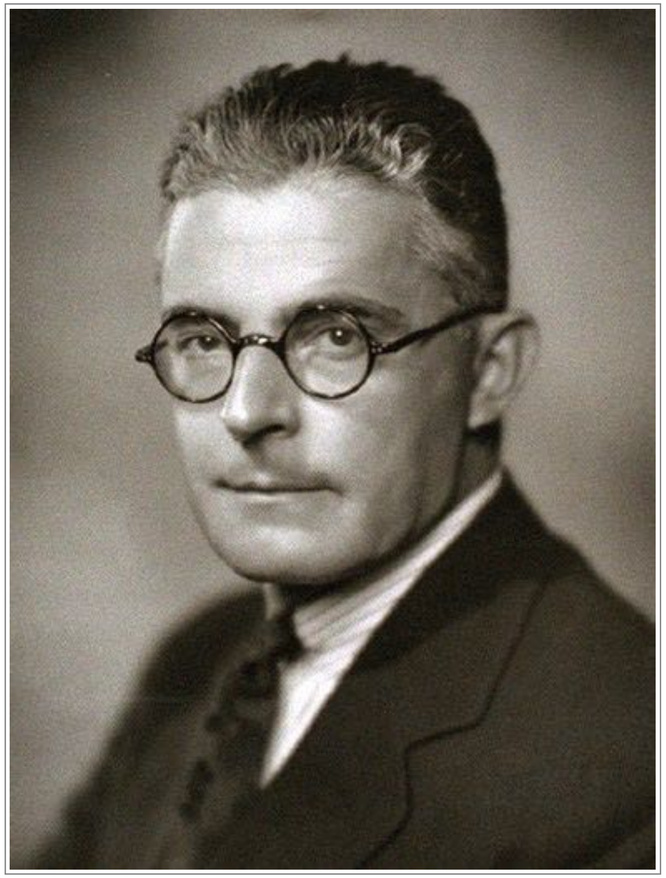
Classical conditioning: generalization

The end of behaviorism

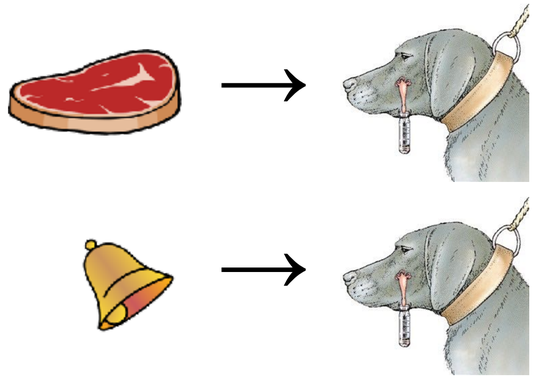
- This raised new questions: how similar must a stimulus be to the CS in order to elicit a CR?
- **Not only physical properties** are important (brightness, tone level, color).
- Volkova (1953):
  - Children conditioned to words **good** and **bad.**
  - “The children are playing nicely together.”
  - “The Fascists destroyed many cities.”

Classical conditioning: mechanisms

The end of behaviorism



- What exactly happens in classical conditioning?
- Watson: the creation of a simple stimulus–response connection



Classical conditioning: mechanisms

The end of behaviorism

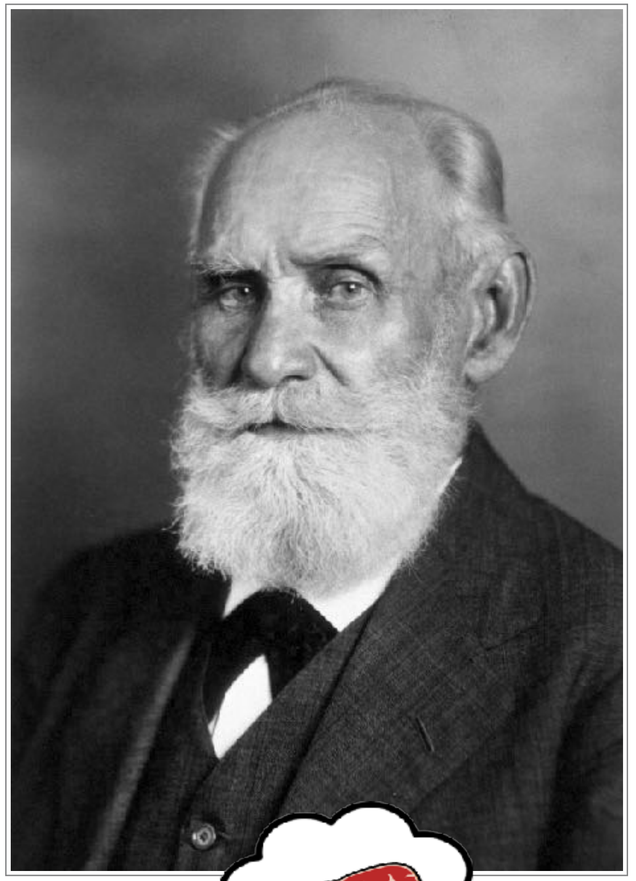
- So far, so good. Thus far, everything was **behaviorist** in nature.
- No mental concepts are used, only what is observable: association between stimulus and response.
- But the **cracks in behaviorism** were beginning to show.

“Defining psychology as the science of behavior was like defining physics as the science of meter reading.”

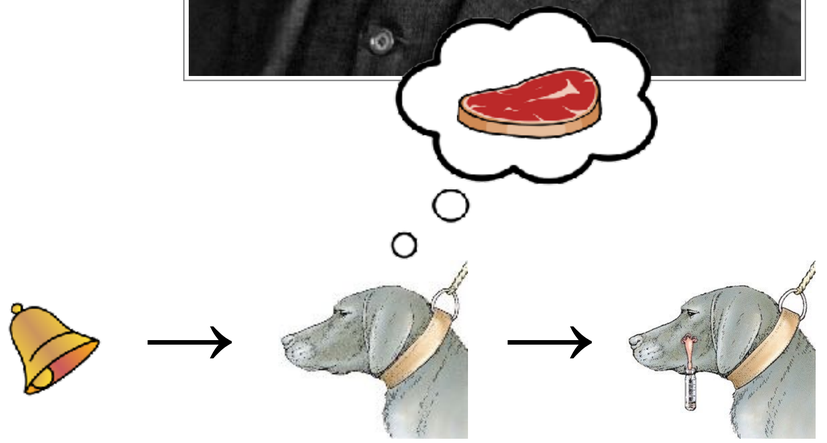
—Noam Chomsky

Classical conditioning: mechanisms

The end of behaviorism



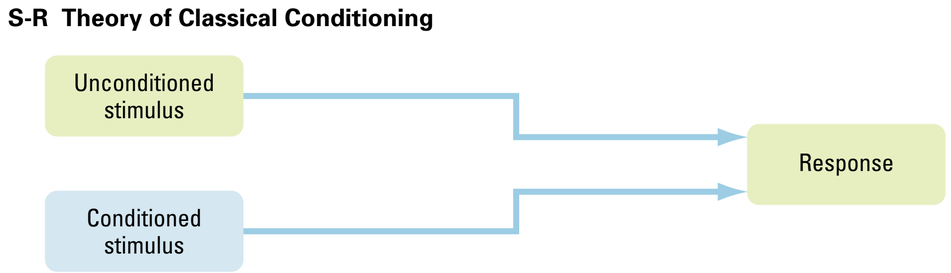
- What exactly happens in classical conditioning?
- Cognitive psychology:
  - It is useful to use **mental concepts** in explanations of behavior, e.g. ***expectation.***
  - Pavlov: creating a stimulus–stimulus connection.

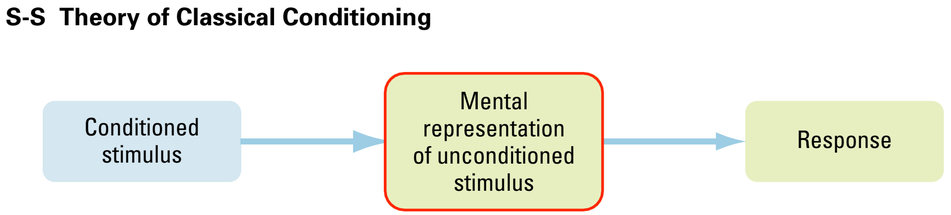


Classical conditioning: mechanisms

The end of behaviorism

- What exactly happens in classical conditioning?
- Behaviorism: creating simple **stimulus–response** connection
  - sound → salivation
- Cognitivism: a **stimulus–stimulus** connection is created
  - sound → mental representation of food → salivation





Classical conditioning: mechanisms

The end of behaviorism

- We therefore now have two theories, one of which uses **non-observable processes.**
- Behaviorists: it is therefore **not possible** to investigate this scientifically.
- Cognitivists: but it is possible! Non-observable processes can be investigated by **looking at their effects** and the **predictions that follow** from them!
- How might we be able to test these theories (S–R vs. S–S)? Which is correct?

Classical conditioning: S–R vs. S–S

The end of behaviorism

- Rescorla (1973) devised a clever habituation experiment.
- Rats display a *freezing response* to a loud sound.
- He conditioned a group of rats by pairing a light with the sound; the rats therefore now also displayed a freezing response to the light.
- He then **habituated** half of the group of rats to the loud sound until they no longer displayed a freezing response to the sound.
- What happens now when the light flashes?

Classical conditioning: S–R vs. S–S

The end of behaviorism

- What happens now when the light flashes?
- Behaviorists (S–R): the habituated rats will **still display a freezing response** to the light, because a **direct S–R connection was created** between the light and freezing.
- Cognitivists (S–S): the habituated rats will **no longer show a freezing response** to the light. The light activates the representation of the loud sound, which has been habituated and therefore no longer elicits a response.

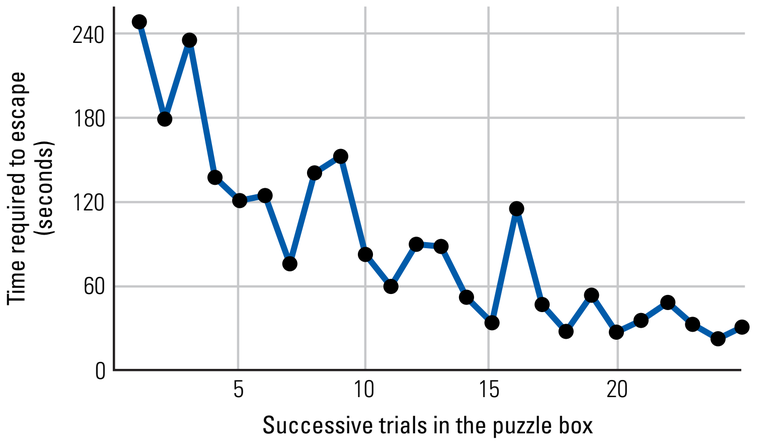
Operant conditioning

also known as

Reinforcement learning

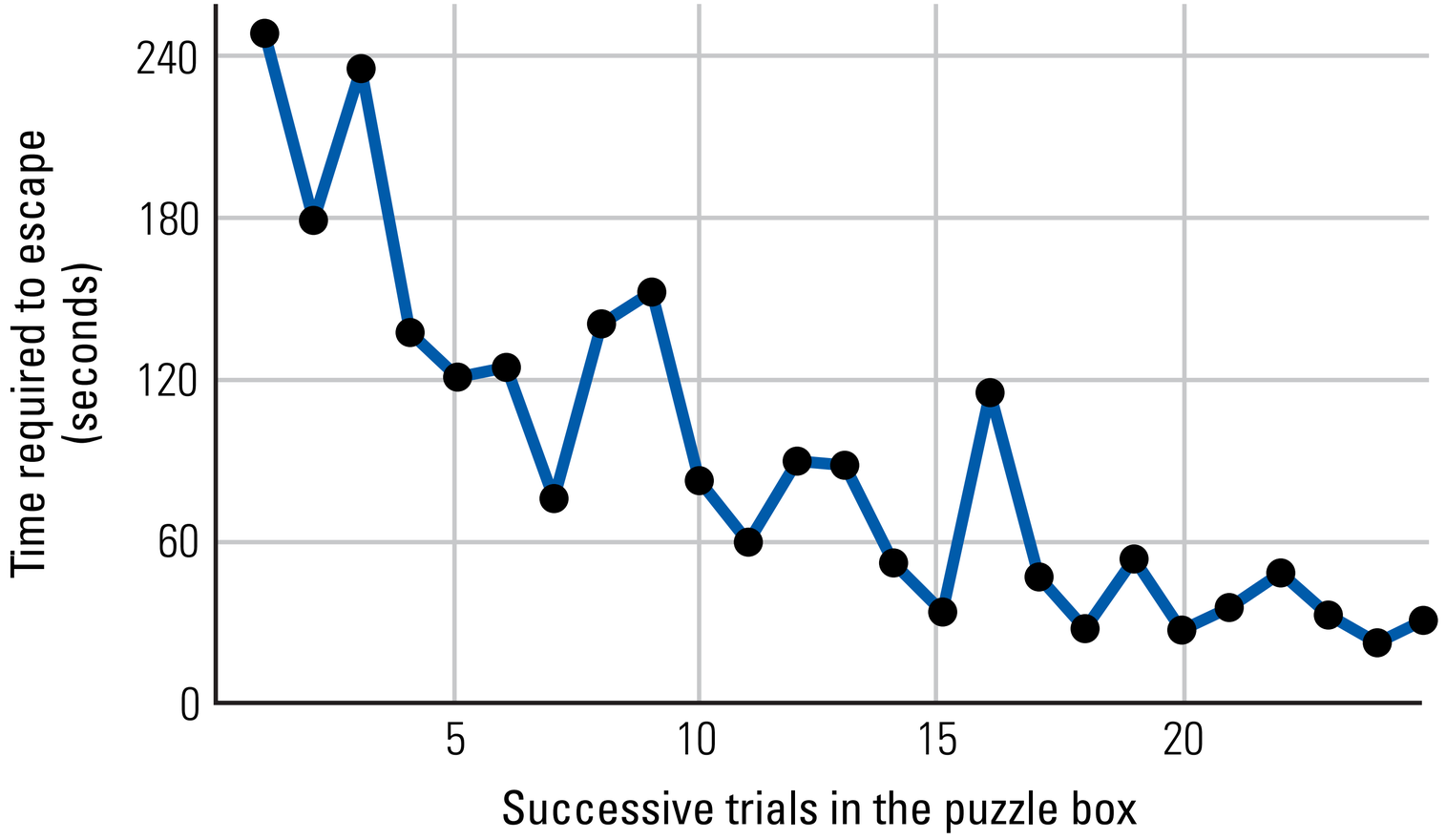
Basic principles of operant conditioning

- Classical conditioning: **reflexive** behavior (blinking, etc.)
- Operant conditioning: **self-initiated** behavior
- Thorndike's puzzle box:
  - cat scratches at floor
  - cat meows
  - cat pushes against wall
  - cat presses lever → door opens → food!



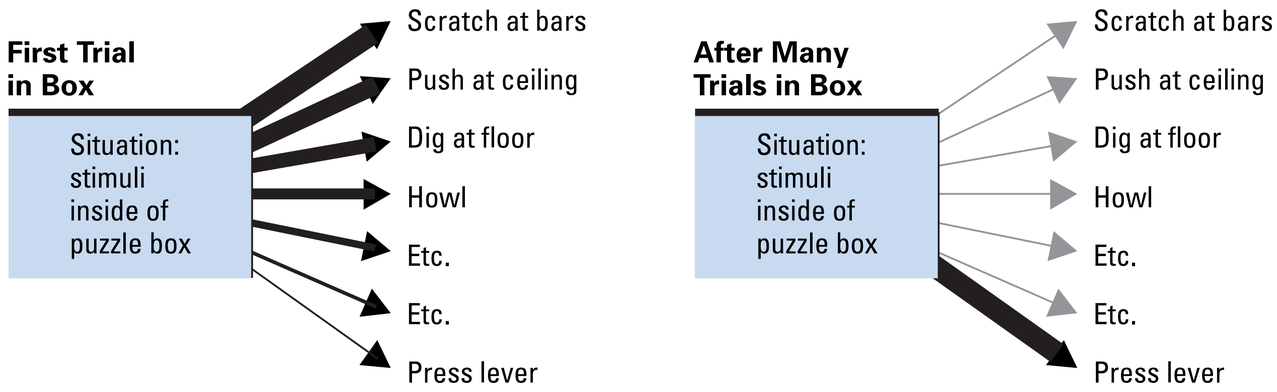
Basic principles of operant conditioning

Basic principles of operant conditioning



Thorndike’s law of effect

- Operant responses that produce a **satisfying effect** in a particular situation become **more likely** to occur again in that situation.
- Operant responses that produce a **discomforting effect** in a particular situation become **less likely** to occur again in that situation.

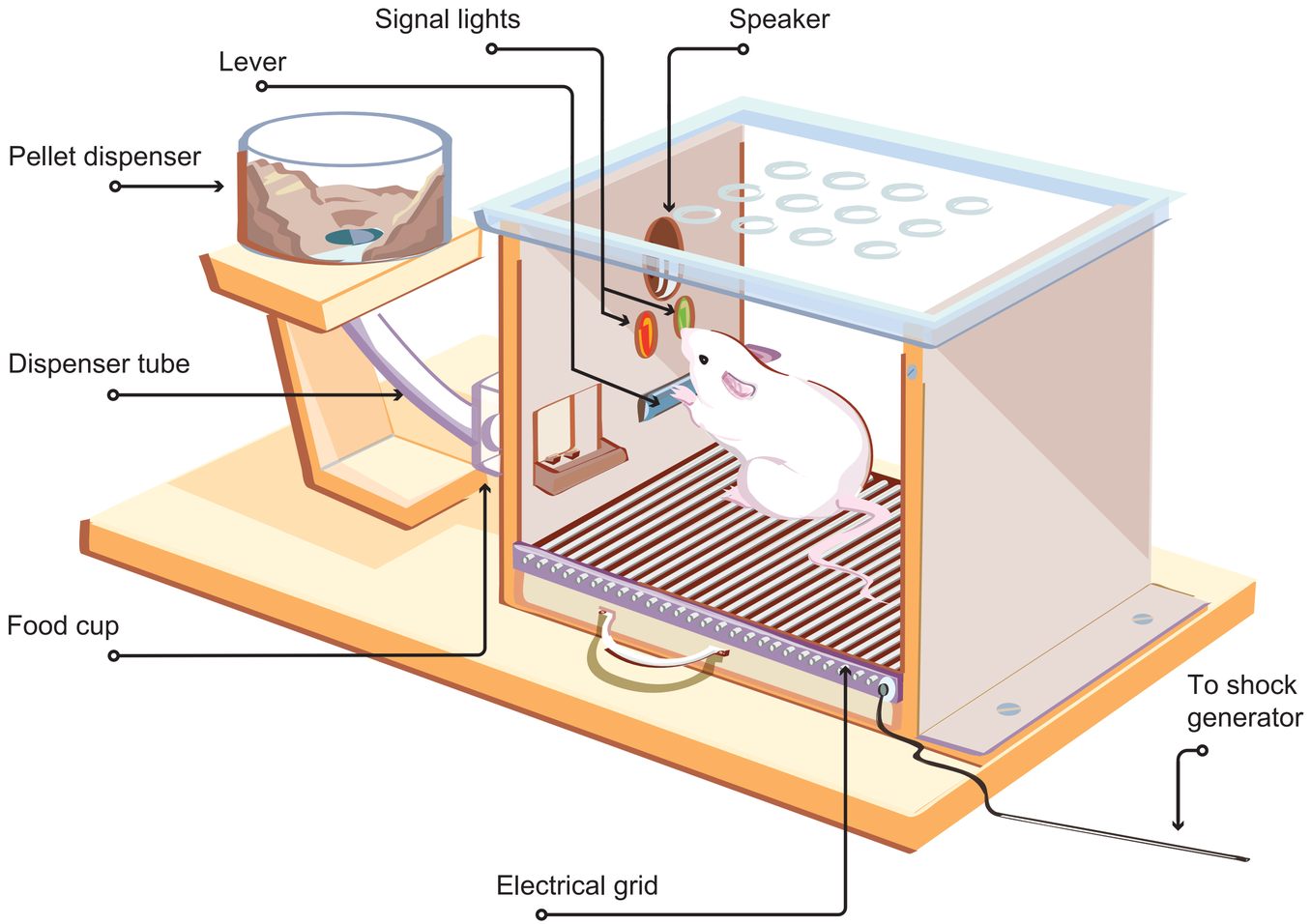


B. F. Skinner

- Skinner made a much more convenient apparatus than Thorndike’s puzzle box.
- In his ***Skinner box*** the animal stays in the box, and can therefore produce more than one operant response.

Operant conditioning: Skinner box

- Operant response: press lever
- Reinforcer: food pellets
- Operant conditioning: press lever more often if this is followed by food.

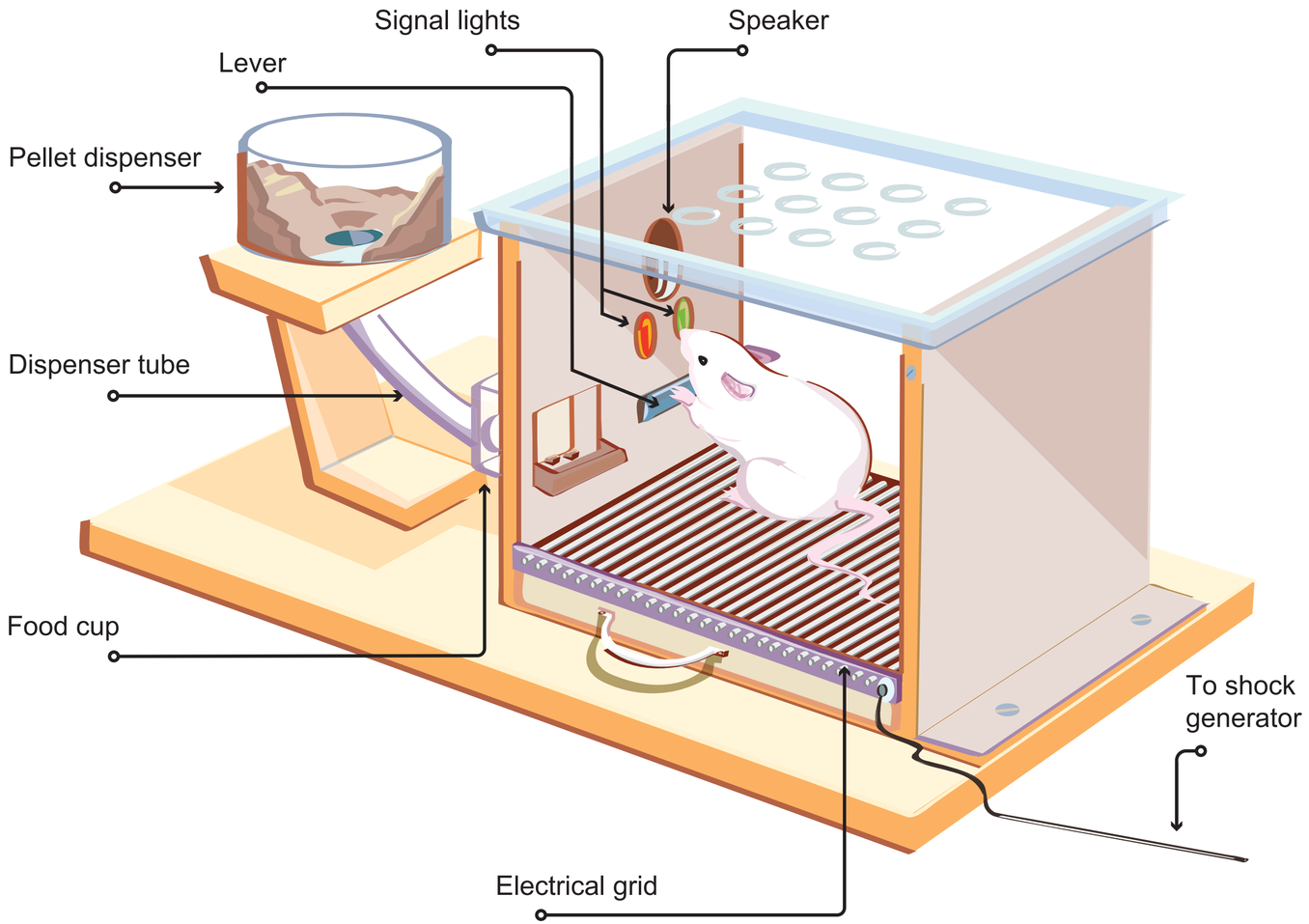


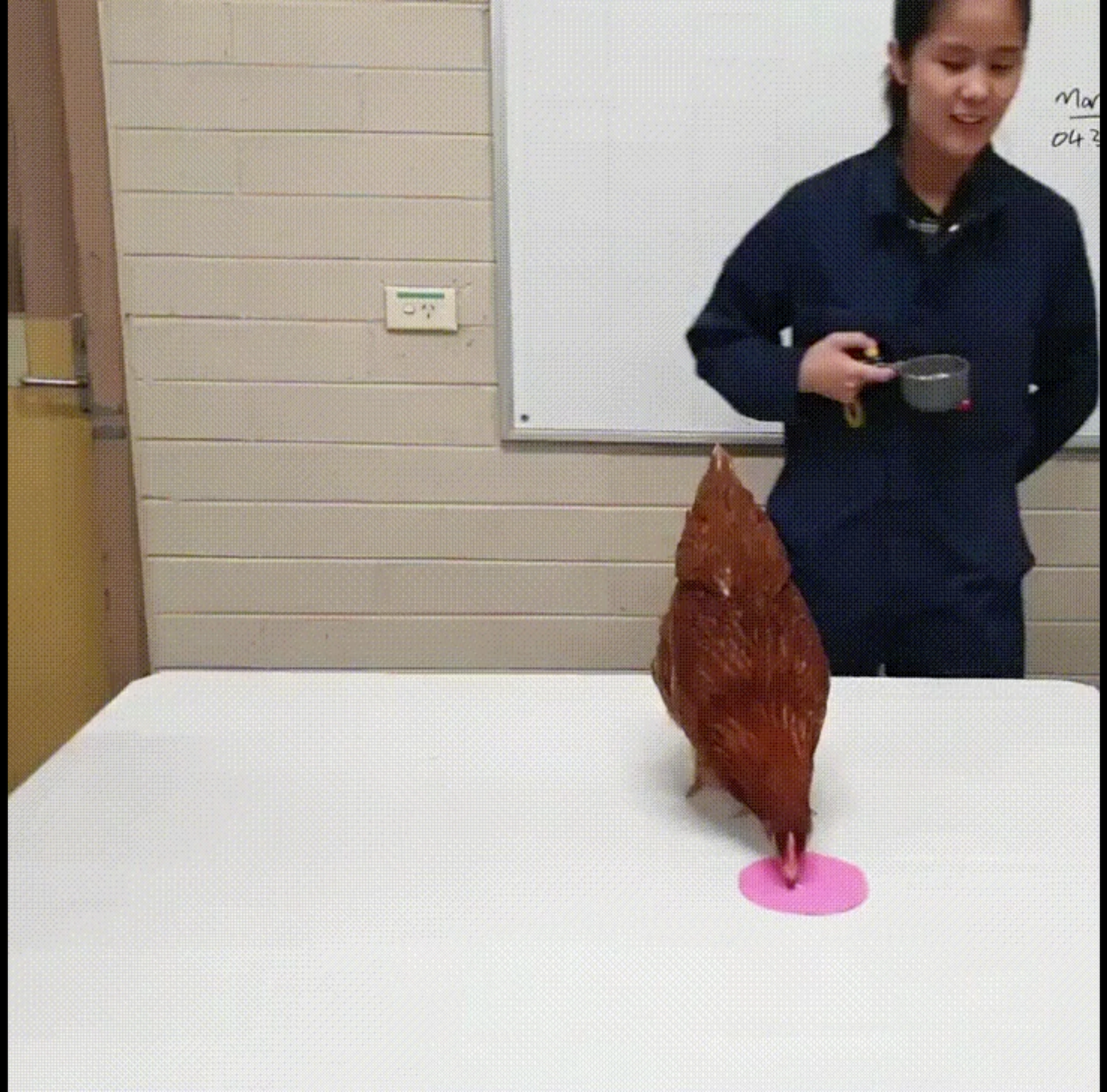
Operant conditioning: complex behavior

- **Shaping**: training of complex behavior by rewarding successive steps in that behavior.
  - First give a reward when dog enters the kitchen
  - Then a reward if your dog comes close to refrigerator
  - Then when it touches the refrigerator
  - Then when it scratches the refrigerator door…

Operant conditioning: discrimination

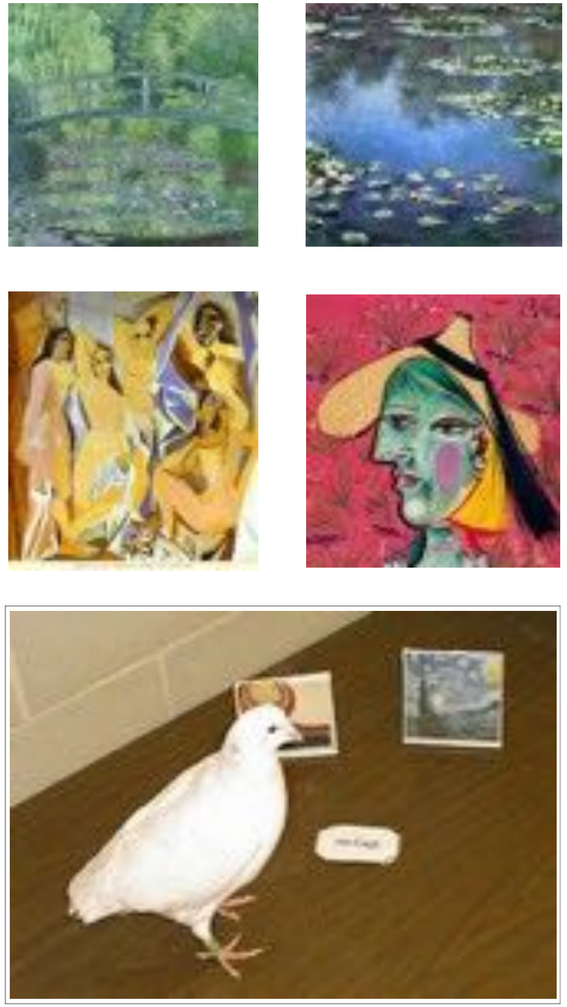
- Example: pressing the lever **only** results in food **if the light is on.**
- The light being on (discriminative stimulus) is a signal that response will be rewarded.
- Method to study sensory abilities in animals (and infants).





Operant conditioning: concept learning

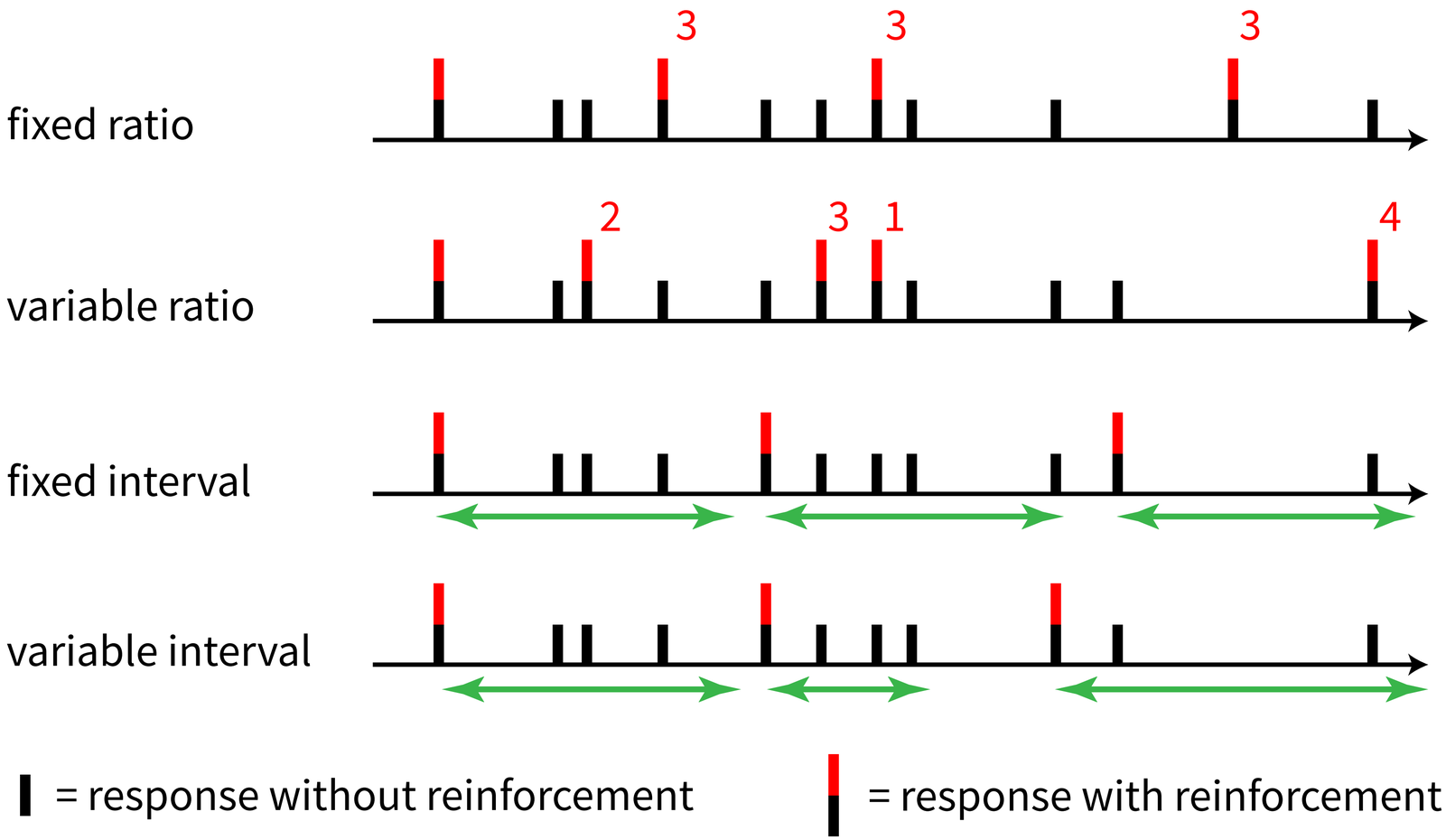
- Discrimination training
  - Food given for pecking on Monet paintings.
  - Food **not** given for pecking on Picasso paintings.
- Generalization?
  - Yes: Also peck on **other Monet paintings.**
  - Yes: Also peck on paintings by **other impressionists** (Cézanne, Renoir).
  - Category “impressionist paintings” formed.



Operant conditioning: partial reinforcement

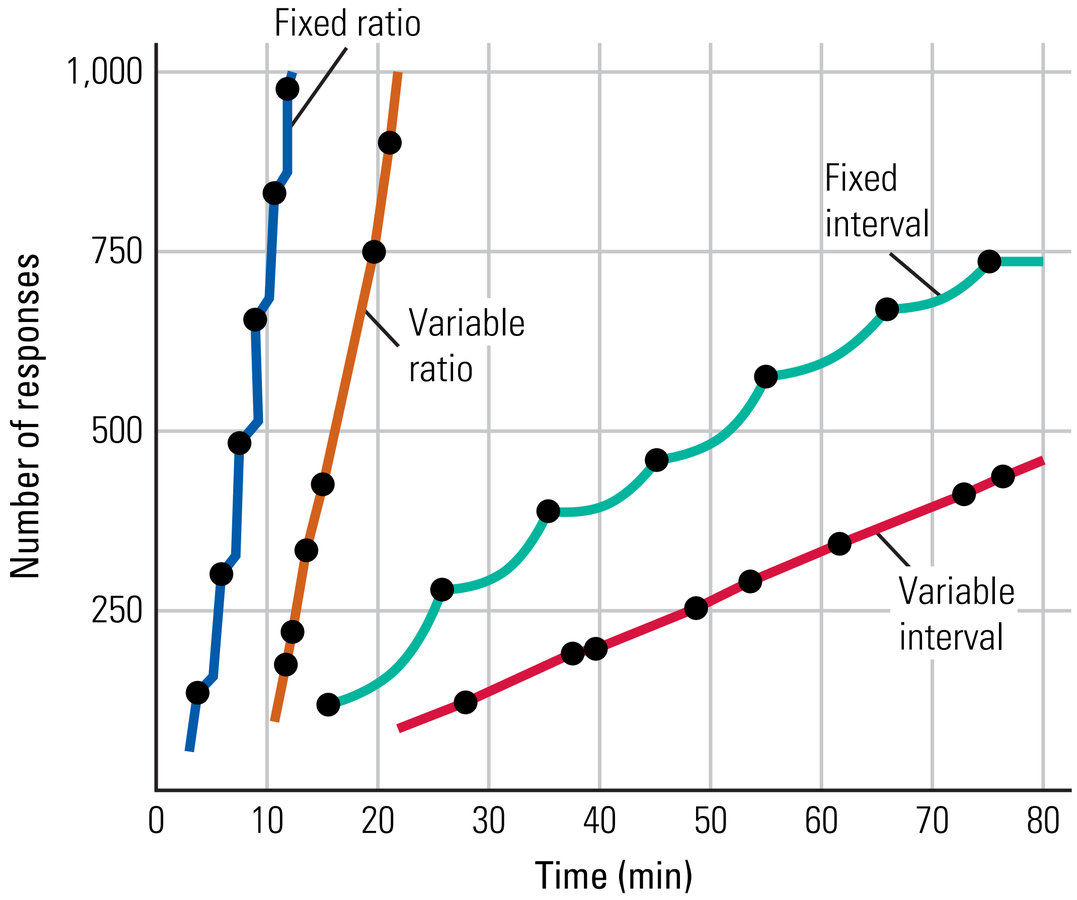
- We speak of continuous reinforcement if the desired response is **always** followed by a reinforcer.
- We speak of partial reinforcement if this relationship is not 1-to-1.
- Variable reinforcement is **very resistant to extinction.**

Operant conditioning: partial reinforcement



Operant conditioning: partial reinforcement

- Interval-based reinforcement leads to reduced response.
- This is because the reinforcement is **limited by time,** not by operant response.



Operant conditioning: partial reinforcement

- Extinction is slowest with variable ratio reinforcement.
- This reinforcement schedule is used in e.g. slot machines.
- Very difficult to extinguish!

Cognition and computation

Is the brain Turing-complete?

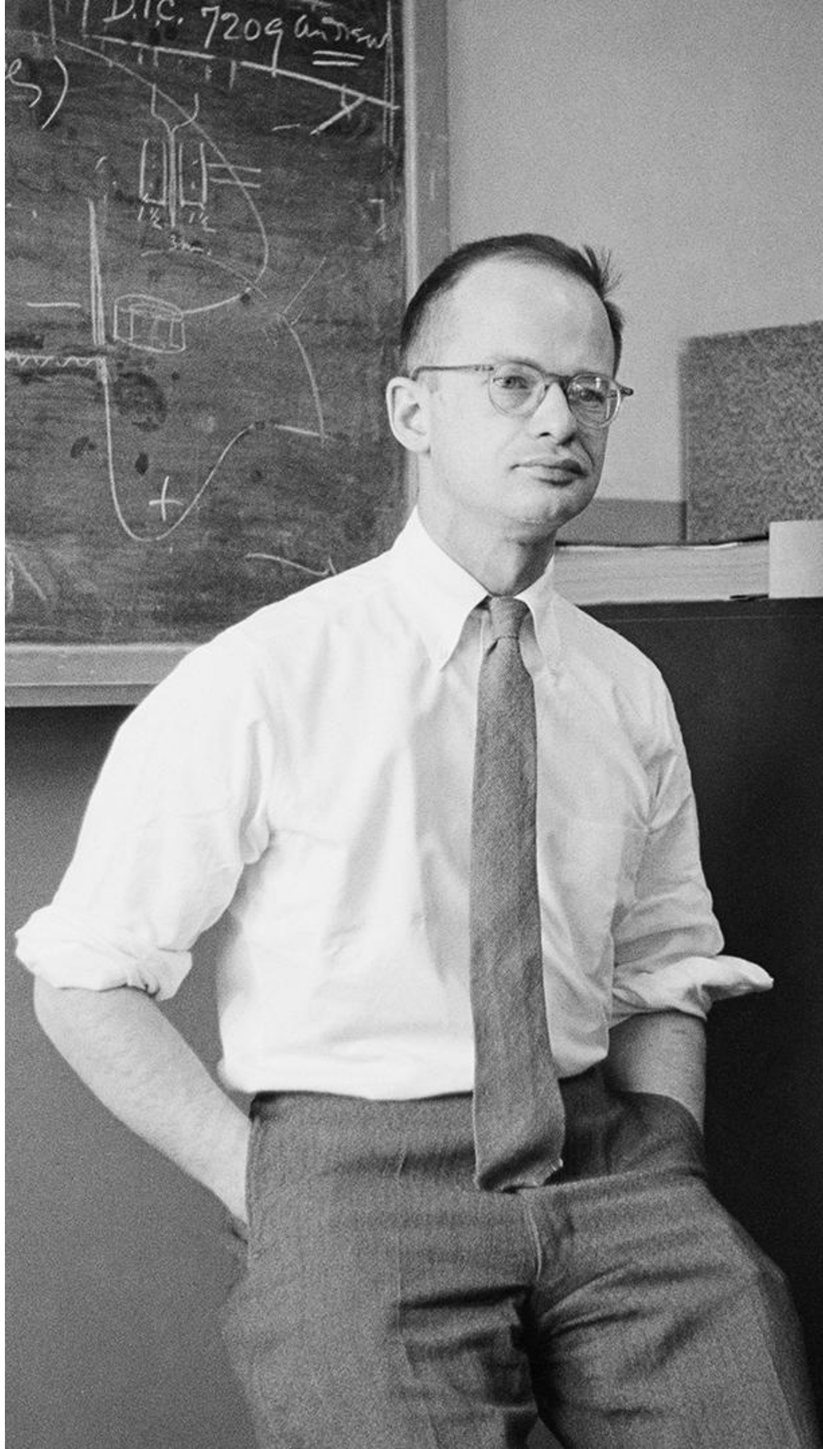
Cognition and computation

- If something can simulate a single-tape Turing machine, it is itself Turing-complete.
- Humans can do that (try it!), although perhaps not very efficiently.
- Therefore, **the human brain is Turing-complete.**

Computational power of neurons

Cognition and computation

- Warren McCulloch and Walter Pitts' three principles:
  1. Basic physiology
  2. Propositional logic
  3. Turing's theory of computation
- **Any computable function** can be computed by a network of neurons.
- **All logical operators** can be implemented by simple neural networks.



Processing limits of humans

Humans as information processors

- The mind contains **information channels**.
- Mean channel capacity is ~3 bits, or $2^3 \approx 7$ items.
- Miller (1956): the magical number 7 (± 2)
- Roughly independent of modality.

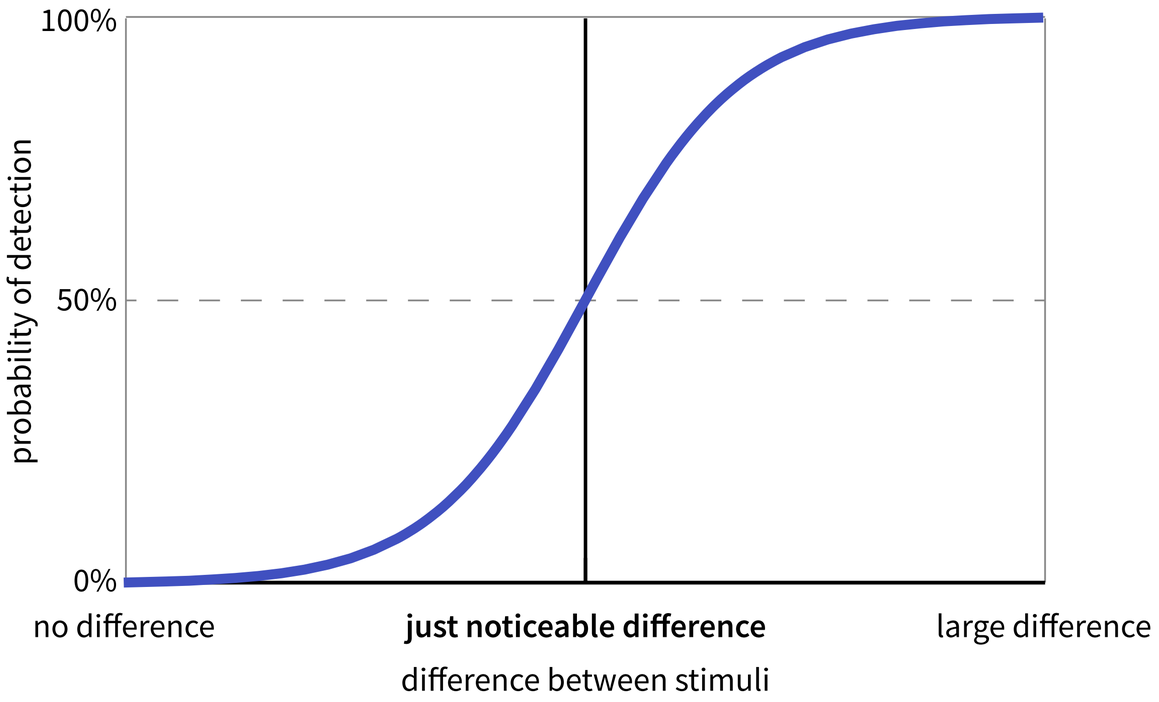
Processing limits of humans

Humans as information processors

- How do we measure this capacity?
  - Digit span task
  - Absolute judgment task

Psychophysics: threshold values

- Difference threshold: minimal difference in intensity between two stimuli at which a difference is detected.
- This is also called the **just noticeable difference** (jnd).
- Is there a relationship between absolute intensity of stimulus and jnd?
- Is 95 vs. 100 kg detected as easily as 10 vs. 15 kg?



Psychophysics: threshold values

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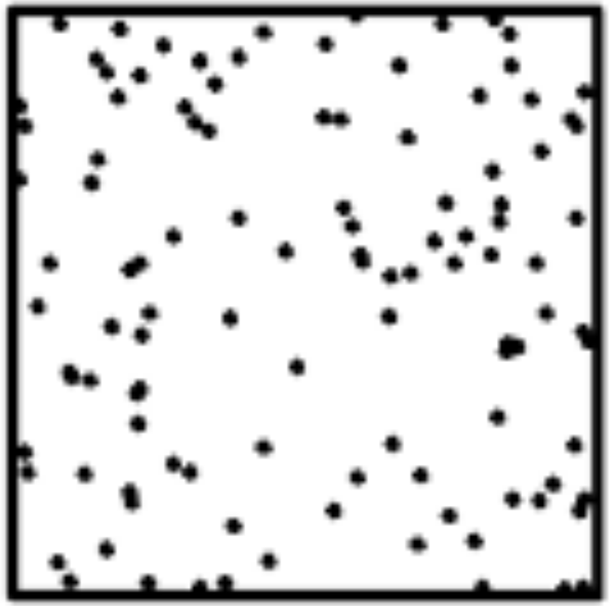

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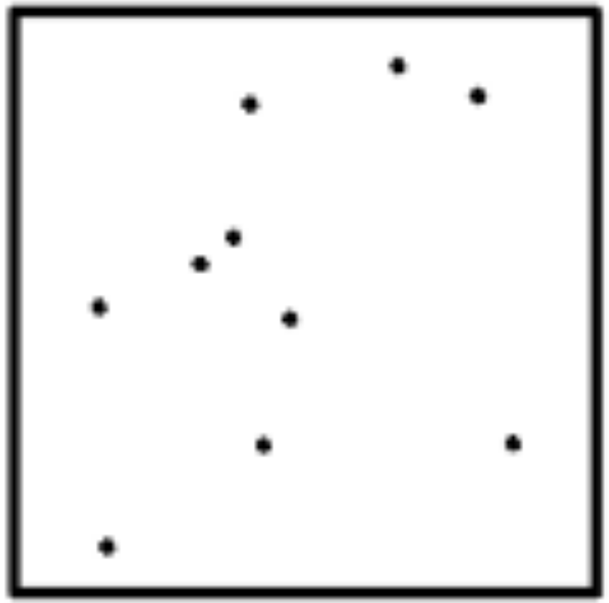
Psychophysics: threshold values



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Psychophysics: Weber's law

- There is a **linear relationship** between the jnd and the absolute intensity (magnitude) of a stimulus.
- jnd = kM
  - k is domain-dependent.
  - k = 0.03 for detection of weight (change of ~3%)
  - k = 0.01 for detection of length
  - k = 0.25 for detection of sound frequency in mice
  - etc…

Reducing information load

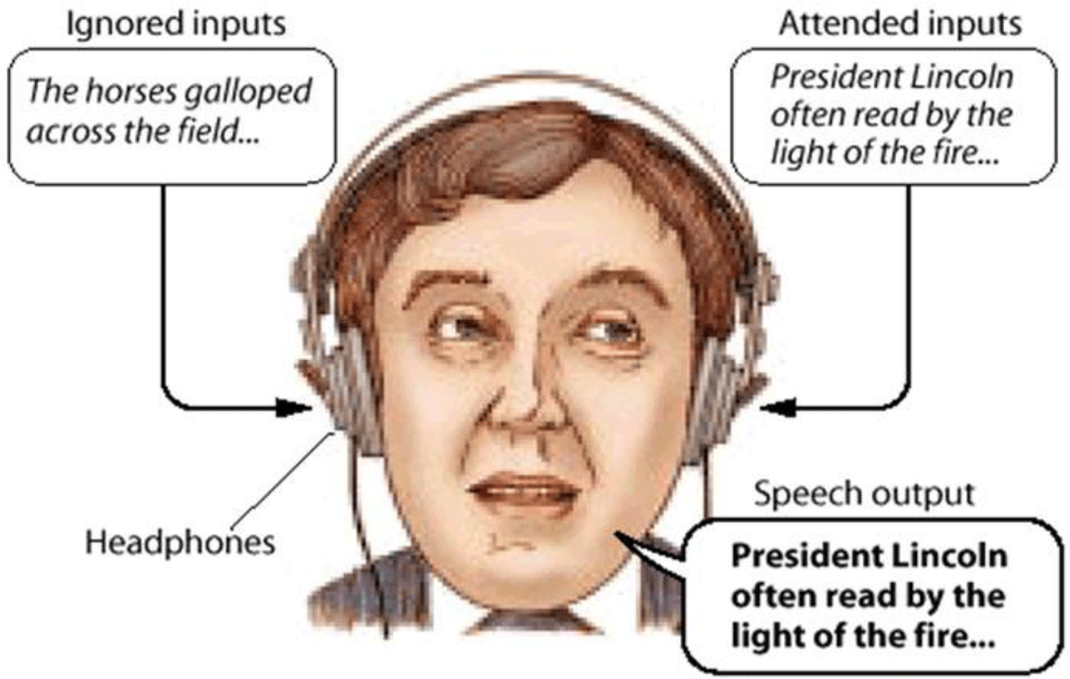
Reducing information load: attention

- We can reduce channel information load by “turning off” certain channels.
- We call this **attention**.

Cherry: dichotic listening task

Channel capacity limitations

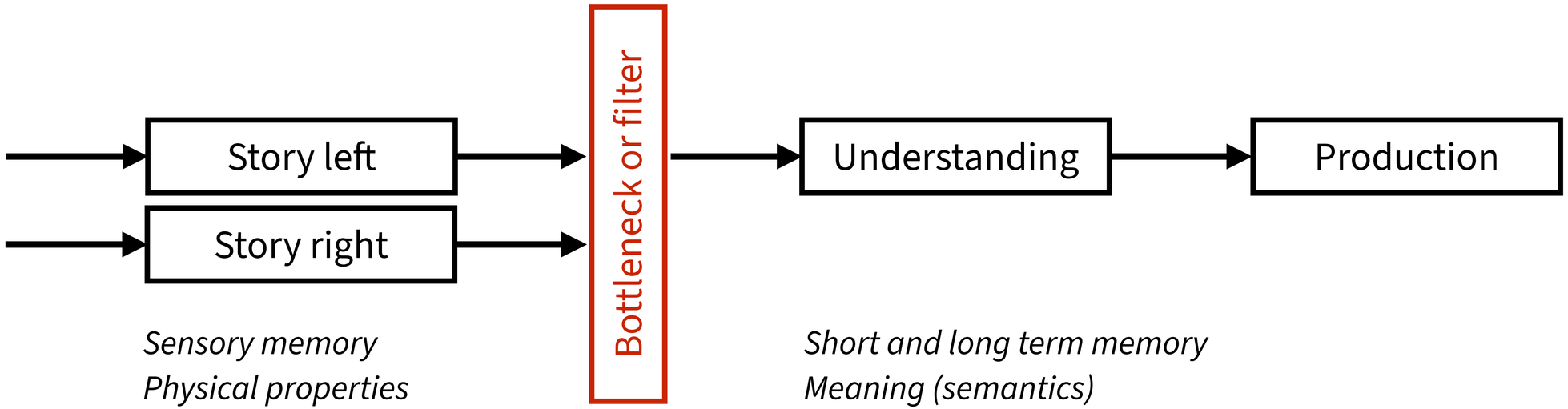
- **Shadowing**: read back a story from one ear as it arrives.
- Participants are virtually **unable to tell anything** about the content of the ignored story presented to the right ear.



Cherry: dichotic listening task

Channel capacity limitations

- Participants do notice a change in voice pitch (male-female). They also notice sudden tones.
- Broadbent: filter model, **early selection.**
- Ignored information is filtered **in an early stage.**



Some arguments against early selection

Channel capacity limitations

1. Breakthrough (Moray, 1959): some information (such as your own name) “breaks through”
   - This is only possible if you **do process the information** in the ignored story.
2. Switching (Treisman, 1960): the shadowed story is followed when it is switched to the other ear.
   - This is only possible if you process the information of the ignored story.

Some arguments against early selection

Channel capacity limitations

3. Unconscious fear response (Corteen & Wood, 1972): conditioned fear response in ignored ear (PARIS-LONDON-CAIRO)
    - Fear response (GSR) when new city is presented in ignored ear. So: meaning (ROME = city) is activated.

Alternatives to early selection

Channel capacity limitations

1. Late selection (Deutsch & Deutsch)
   - Meaning of all stimuli (target and distractors) is processed. But the ignored message (D) is **quickly forgotten.**
2. Attenuation (Treisman)
   - Information to be ignored (D) is **attenuated.**
   - Very important information (such as your name) is **spared.**
3. Capacity explanation (Load theory, Lavie)
   - The amount of processing of distractor D depends on the **capacity required to process** target T.
   - An easier main task **leaves more capacity** to process distractors.

End of lecture

Next week: three milestones of cognitive science

- Do not forget to register in Brightspace.
- Work on the Exercises in JLB!