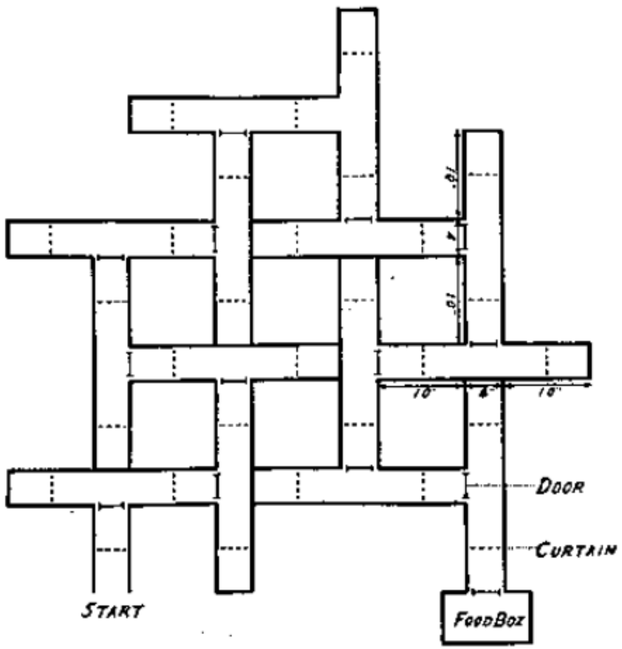
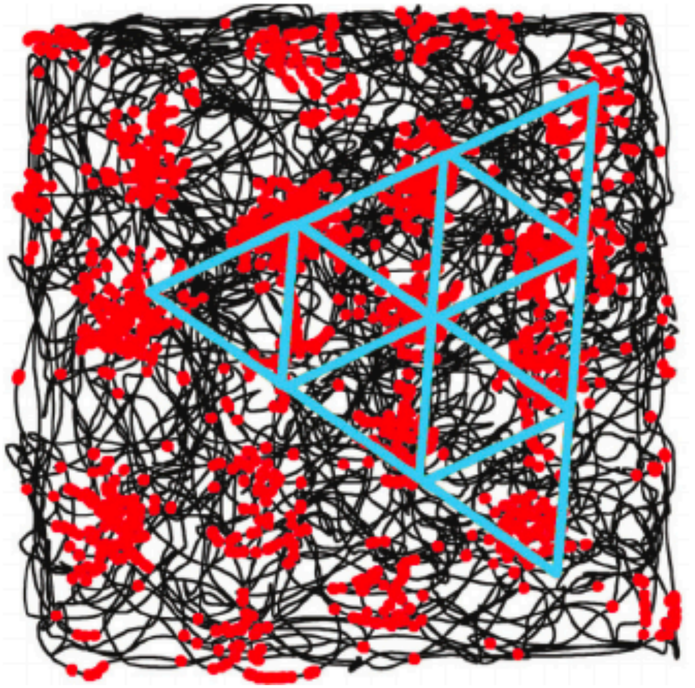


Plan of maze
14-Unit T-Alley Maze

FIG. 1

(From M. H. Elliott, The effect of change of reward on the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 1928, **4**, p. 20.)

Introduction to Cognitive Maps



Cognitive Maps Seminar (KOG)
Wednesdays from 16:00 - 18:00

Charley Wu, Philipp Schwartenbeck, Noémi Éltető

https://hmc-lab.com/Cogmaps.html

Overview

- Contact information and office hours
- Course organization: Seminar format
- Schedule
- Grading

Course & Contact Info


Charley


Philipp


Noémi

Instructors
Dr. Charley Wu (charley.wu@uni-tuebingen.de)
Dr. Philipp Schwartenbeck (philipp.schwartenbeck@tuebingen.mpg.de)

Teaching Assistant
Noémi Éltető (noemi.elteto@tuebingen.mpg.de)

General information
Location**: 4th floor seminar room, AI building, Maria-von-Linden-Str. 6, D-72076 Tübingen**
Class time: **Wednesdays 16:00-18:00**
Office Hours: Charley (Fridays 14:00-15:00) across the hall
Course website: https://hmc-lab.com/Cogmaps.html

Course organization - Seminar format

Oct. 19 - Nov. 30th: **Instructor led sessions** covering foundational topics

- Student responsibilities:
  - Read papers
  - Submit questions by end of Tuesday prior to the class (Nov 16th and onwards)
  - Show up to class and participate in discussion

Dec. 7 - Feb. 8th: **Student led presentations**

- Each week a student or group will present a paper of their choice
- Other students should:
  - Read papers
  - Submit questions by end of Tuesday prior to the class
  - Show up to class and participate in discussion

https://hmc-lab.com/Cogmaps.html

Schedule (instructor led sessions)

Date	Host	Topic	Required Readings
19. Oct 2022	Charley	Introduction to cognitive maps	Tolman, E. C. (1948). **Cognitive maps in rats and men.** Psychological review, 55(4), 189.
26. Oct 2022	Philipp	What is a cognitive map? An overview of modern neuroscientific discoveries	Epstein, R. A., Patai, E. Z., Julian, J. B., & Spiers, H. J. (2017). **The cognitive map in humans: spatial navigation and beyond**. Nature neuroscience, 20(11), 1504-1513.
2. Nov 2022	Charley	Introduction to Reinforcement Learning	Niv, Y. (2009). **Reinforcement learning in the brain**. *Journal of Mathematical Psychology*, *53*(3), 139–154. [Section 1 only] Dolan, R. J., & Dayan, P. (2013). **Goals and habits in the brain**. *Neuron*, *80*(2), 312–325
9. Nov 2022	Philipp	Neuroscience of RL	Lee, D., Seo, H., & Jung, M. W. (2012). **Neural basis of reinforcement learning and decision making**. Annual review of neuroscience, 35, 287.
16. Nov 2022	Nir Moneta (MPI Berlin)	Cognitive maps beyond spatial stimuli	Doeller, C. F., Barry, C., & Burgess, N. (2010). **Evidence for grid cells in a human memory network**. Nature, 463(7281), 657-661.
23. Nov 2022	Noémi	From Maps to Behavior and Back again	Stachenfeld, K. L., Botvinick, M. M., & Gershman, S. J. (2017). **The hippocampus as a predictive map.** Nature neuroscience, 20(11), 1643-1653.
30. Nov 2022	Georgy Antonov (MPI BC)	Linking memory and navigation	Eichenbaum, H. (2017). **On the integration of space, time, and memory.** Neuron, 95(5), 1007-1018.

https://hmc-lab.com/Cogmaps.html

Schedule (student led sessions)

Date	Host	Topic	Required Readings
7. Dec 2022	Charley	Student led presentation 1	
14. Dec 2022	Philipp	Student led presentation 2	
11. Jan 2023	Charley	Student led presentation 3	
18. Jan 2023	Charley	Student led presentation 4	
25. Jan 2023	Charley	Student led presentation 5	
1. Feb 2023	Charley	Student led presentation 6	
8. Feb 2023	Charley	Student led presentation 7	

Recommended papers

Topic	Paper link	Notes	Student(s) interested	Student presenter(s) (finalize by 16. Nov)
Cognitive maps for abstraction and values				
Bellmund, J. L., Gärdenfors, P., Moser, E. I., & Doeller, C. F. (2018). **Navigating cognition: Spatial codes for human thinking.** Science, 362(6415).	https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2632857/Bellmund.pdf?sequence=4	Overivew of spatial coding in different domains		
Schuck NW, Cai MB, Wilson RC, Niv Y. **Human Orbitofrontal Cortex Represents a Cognitive Map of State Space.** Neuron. 2016	https://reader.elsevier.com/reader/sd/pii/S0896627316305116?token=EEC9D92E3691CAB43CB09B75CA95094B	Cognitive maps in **decision making**		
Knudsen, E. B., & Wallis, J. D. (2021). **Hippocampal neurons construct a map of an abstract value space**. Cell, 184(18), 4640-4650.	https://www.sciencedirect.com/science/article/pii/S0092867421008369	Hippocampal neurons construct a map of an abstract value space		
Garvert, M, Dolan, R.J. and Behrens T.E.J. (2017) **A map of abstract relational knowledge in the human hippocampal–entorhinal cortex**. elife, 6.	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5407855/	Neurological evidence for learning hidd relational structure based on sequential presentation of visual stimuli		
The neural substrate of cognitive maps				
Buzsáki G, Tingley D. **Space and Time: The Hippocampus as a Sequence Generator**. Trends Cogn Sci. 2018;22(10):853-869. doi:10.1016/j.tics.2018.07.006	https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6166479/	Discussion of whether the hippocampus distinguishes between spatial and temporal modalities		
Brunec, I. K., & Momennejad, I. (2022). Predictive representations in hippocampal and prefrontal hierarchies. Journal of Neuroscience, 42(2), 299-312.	https://www.jneurosci.org/content/jneuro/42/2/299.full.pdf	Extending the SR to describe generalization across different timescales		
Jingfeng Zhou, Marlian Montesinos-Cartagena, Andrew M. Wikenheiser, Matthew P.H. Gardner, Yael Niv, Geoffrey Schoenbaum (2019), **Complementary Task Structure Representations in Hippocampus and Orbitofrontal Cortex during an Odor Sequence Task**. Current Biology	https://www.sciencedirect.com/science/article/pii/S0960982219310905			
Zhou, Jia, Montesinos-Cartagena, Gardner, Zong & Schoenbaum (Nature 2020) **Evolving schema representations in orbitofrontal ensembles during learning**	https://www.nature.com/articles/s41586-020-03061-2			
Nieh EH, Schottdorf M, Freeman NW, Low RJ, Lewallen S, Koay SA, Pinto L, Gauthier JL, Brody CD, Tank DW. **Geometry of abstract learned knowledge in the hippocampus.** Nature. 2021 [or both but they make a similar point]	https://www.nature.com/articles/s41586-021-03652-7.pdf	impressive neuro evidence for factorised/ conjunctive code		
Computational models of the hippocampal formation - How are maps formed?				
He, Q., Liu, J. L., Eschapasse, L., Beveridge, E. H., & Brown, T. I. (2022). **A comparison of reinforcement learning models of human spatial navigation.** Scientific Reports, 12(1), 1-11.	https://www.nature.com/articles/s41598-022-18245-1	Humans exhibit a blend of model-free and model-based navigation		
Pouncy, T., Tsividis, P., & Gershman, S.J. (2021). **What is the model in model-based planning?** Cognitive Science, 45, e12928.	https://gershmanlab.com/pubs/Pouncy21.pdf			
Linda Q. Yu *, Seongmin A. Park *, Sarah C. Sweigart, Erie D. Boorman, Matthew R. Nassar (2021). **Do grid codes afford generalization and flexible decision-making?** arxiv	https://arxiv.org/pdf/2106.16219.pdf	Nice review on SR vs. graph-based representations		
	https://proceedings.neurips.cc/paper/2019/hash/6e7d5d259ba7bf56ed70939c4e621f44	Overview of spatial coding for a variety of different		

Grading

- [**Required**] Attendance of at least 80% of sessions
- [**30% of grade**] Submit 1 engaging discussion question prior to every paper session (16. November onwards).
- [**70% of grade**] Give one presentation (90-minute session with discussion) on a relevant paper of your choice. This can be completed on your own or in a group of 2-3 students, depending on the size of the class
  - For list of recommended papers, see syllabus
  - Additional papers can also be picked, but please discuss first with us

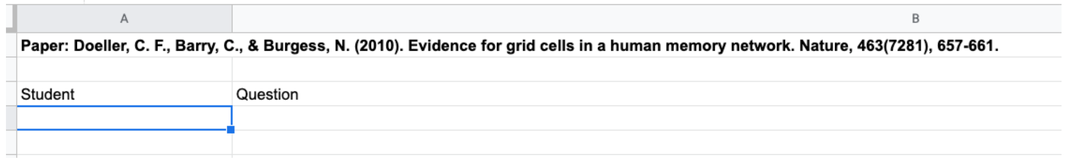
How to submit discussion questions

Step 1. Click link from course website

General Information

Location: 4th floor seminar room, AI building, Maria-von-Linden-Str. 6, D-72076 Tübingen
Class time: Wednesdays 16:00-18:00
Office Hours: Charley (Fridays 14:00-15:00)
Link to submit discussion questions (starting Nov 16th)
List of recommended papers for student-led presentations

Step 2. Enter info in spreadsheet



* make sure to select the tab for correct session

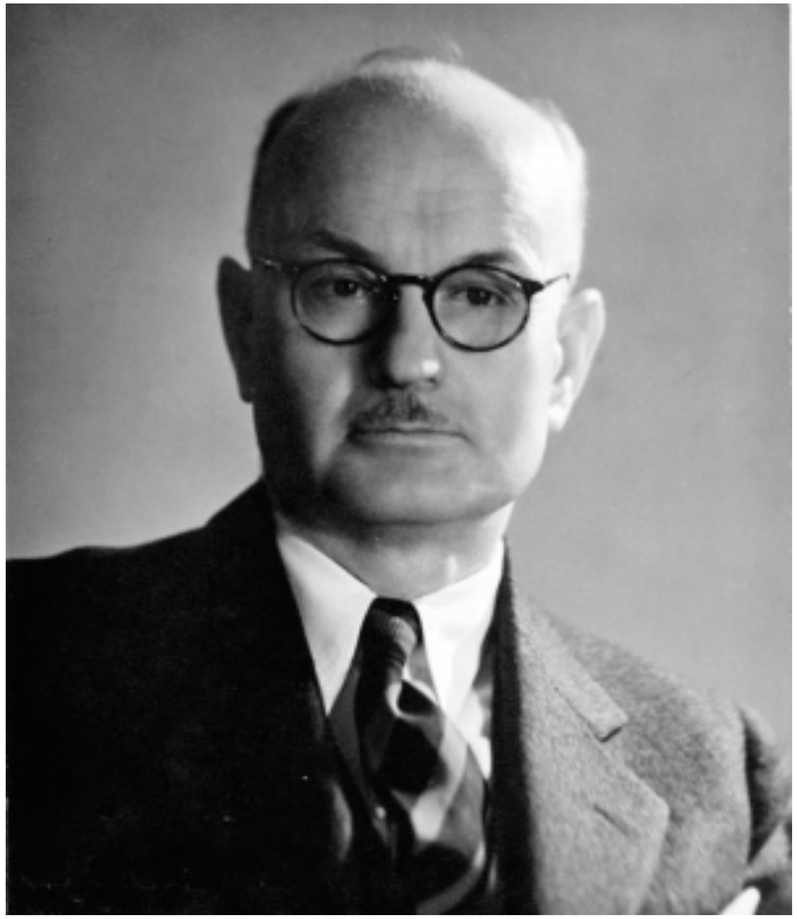
The first 4 sessions, me and Philipp will provide some examples of good discussion questions.

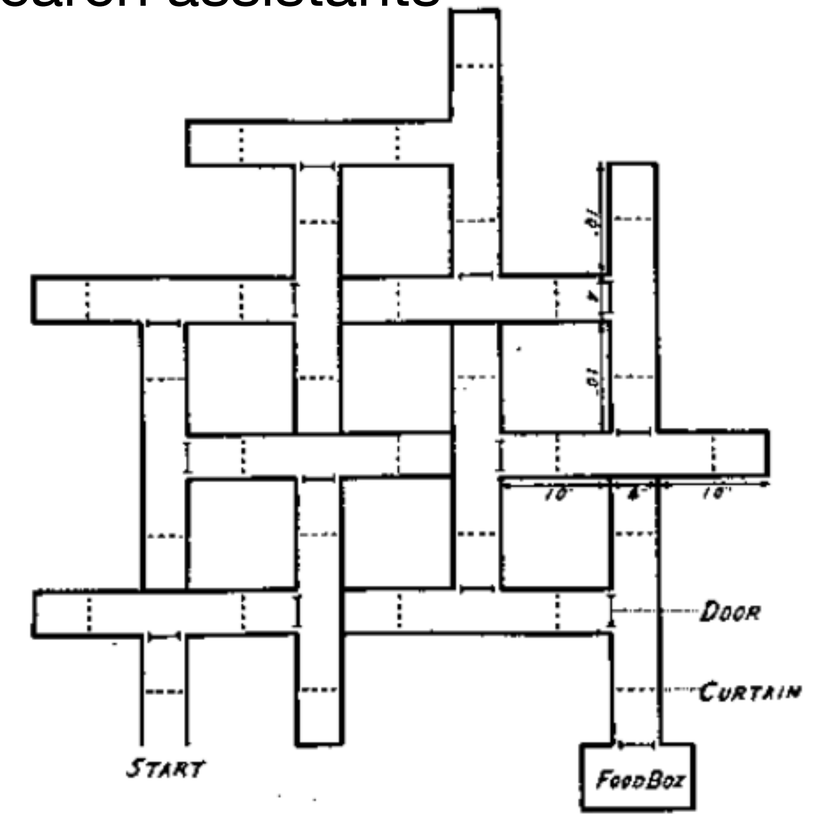
In general, good discussion questions should demonstrate comprehension of the material and go beyond (e.g., combining ideas across topics or reasoning about how to apply principles in new settings)

5 minute break

Cognitive Maps in Rats and Men

Edward Tolman
& uncredited graduate students/underpaid research assistants
Psychological Review, 1948





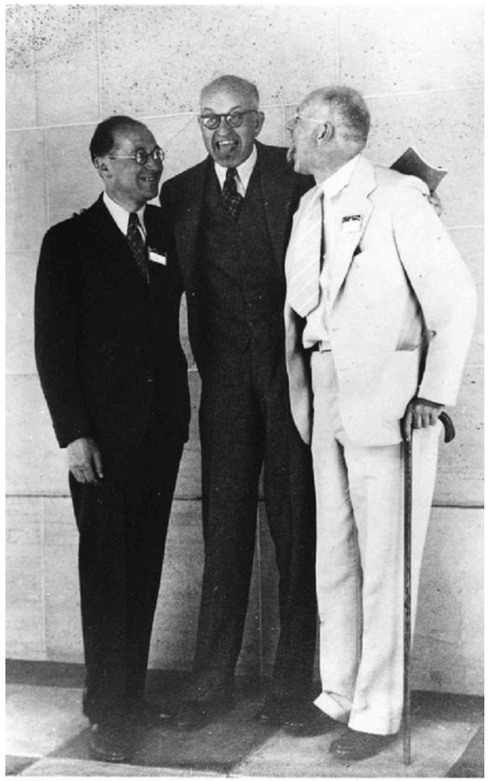
Plan of maze
14-Unit T-Alley Maze

FIG. 1

(From M. H. Elliott, The effect of change of reward on the maze performance of rats. *Univ. Calif. Publ. Psychol.*, 1928, **4**, p. 20.)

Edward Tolman (1886 - 1959)

- Raised by an adament Quaker mother
- Studied at MIT, Harvard, and Giessen
- Inspired by Gestalt psychologists like Kurt Koffka and Kurt Lewin
- Coined "***Purposive Behaviorism***"
  - Behavior needs to be studied in the context of the purpose or goals of behavior
- In contrast to other **behaviorists** at the time, Tolman believed in latent learning and the need to talk about hidden mental states in how we make decisions



Lewin, Tolman, & Hull

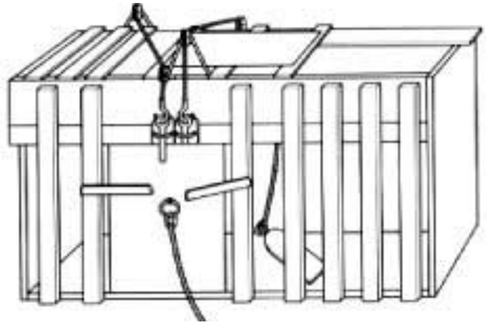
Behaviorism

- [*noun* Psychology.] An approach to understanding the behavior of humans and animals
  - Generally tries to focus on outward observable behavior rather than hidden inner mental states
- **Methodological Behaviorism** (Watson):
  - Only public events can be objectively observed and studied scientifically
  - Thoughts and feelings exist, but cannot be the target of scientific study
- **Radical Behaviorism** (Skinner)
  - Internal processes are also the target of scientific study
  - But they are fully controlled by environmental variables just as environmental variables control behavior

John B. Watson

B.F. Skinner

A brief timeline of early research on learning

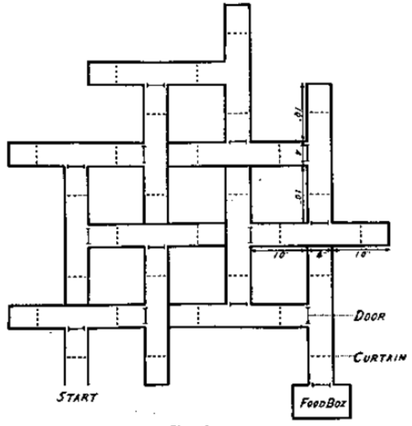


Pavlov (1927)

Tolman (1948)

Thorndike (1898)

Skinner (1938)



Plan of maze
14-Unit T-Alley Maze

FIG. 1

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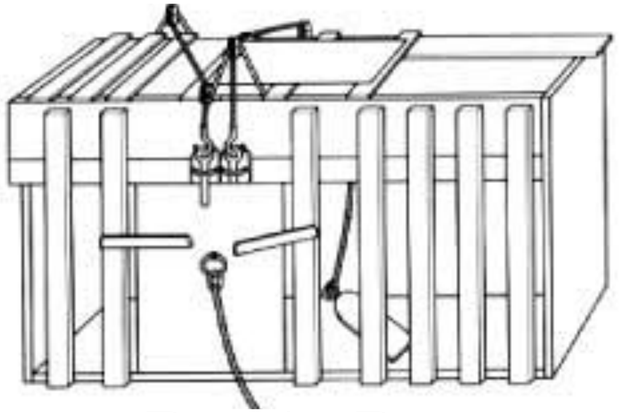
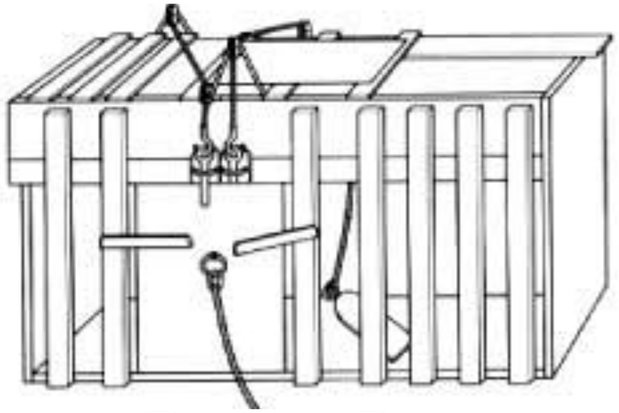
Thorndike’s (1898) Law of Effect



Puzzle Box

Thorndike’s (1898) Law of Effect

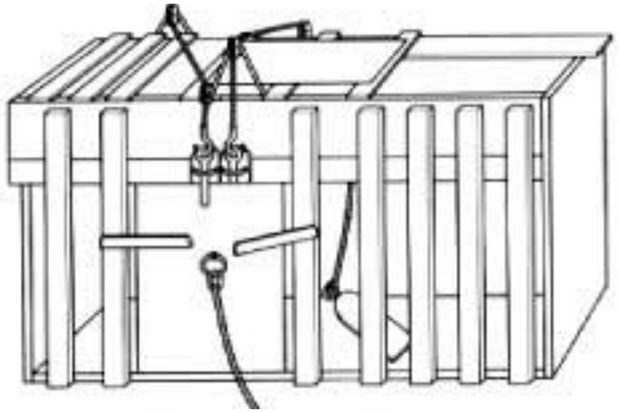
Cat



Puzzle Box

Thorndike’s (1898) Law of Effect

Cat

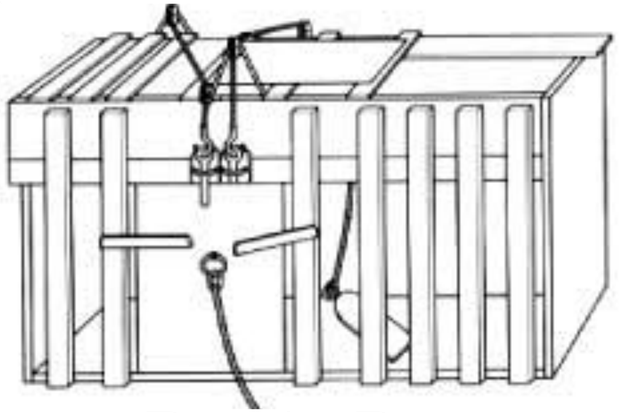


Puzzle Box

Time to escape

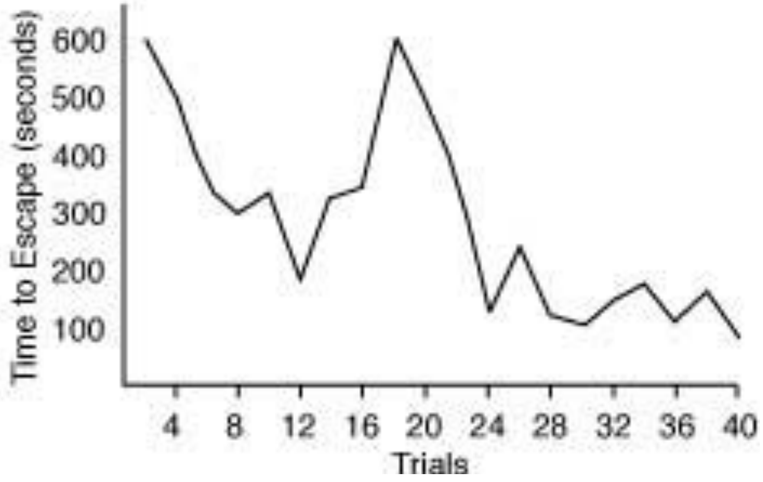
Thorndike's (1898) Law of Effect

Cat



Puzzle Box

Time to escape

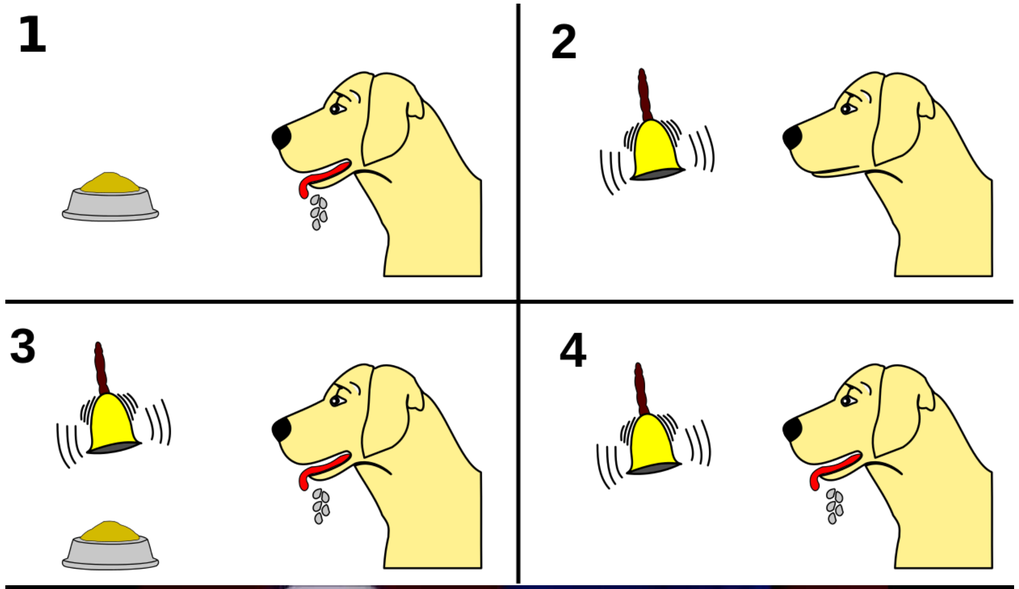


Actions associated with satisfaction are strengthened, while those associated with discomfort become weakened.

Classical and Operant Conditioning

Classical Condition (Pavlov, 1927)

Learning as the ***passive*** coupling of stimulus (bell ringing) and response (salivation), anticipating future rewards



Operant Condition (Skinner, 1938)

Skinner (1938): Learning as the ***active*** shaping of actions in response to rewards or punishments (not just stimuli)

Stimulus-Response (S-R) Learning

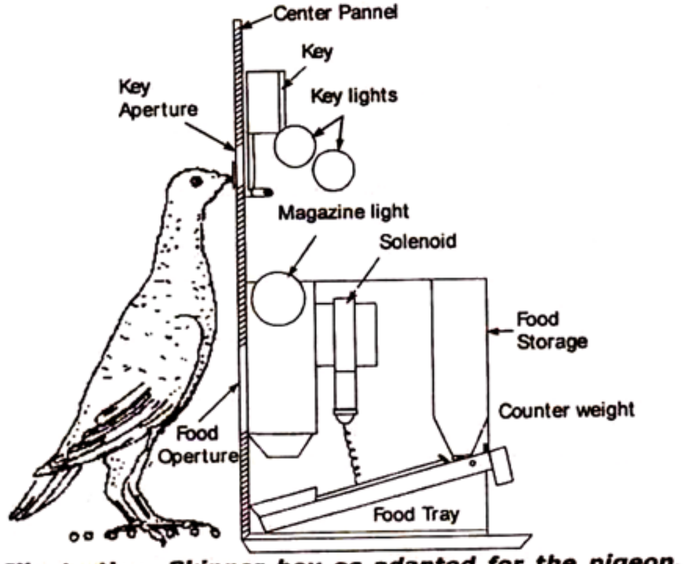
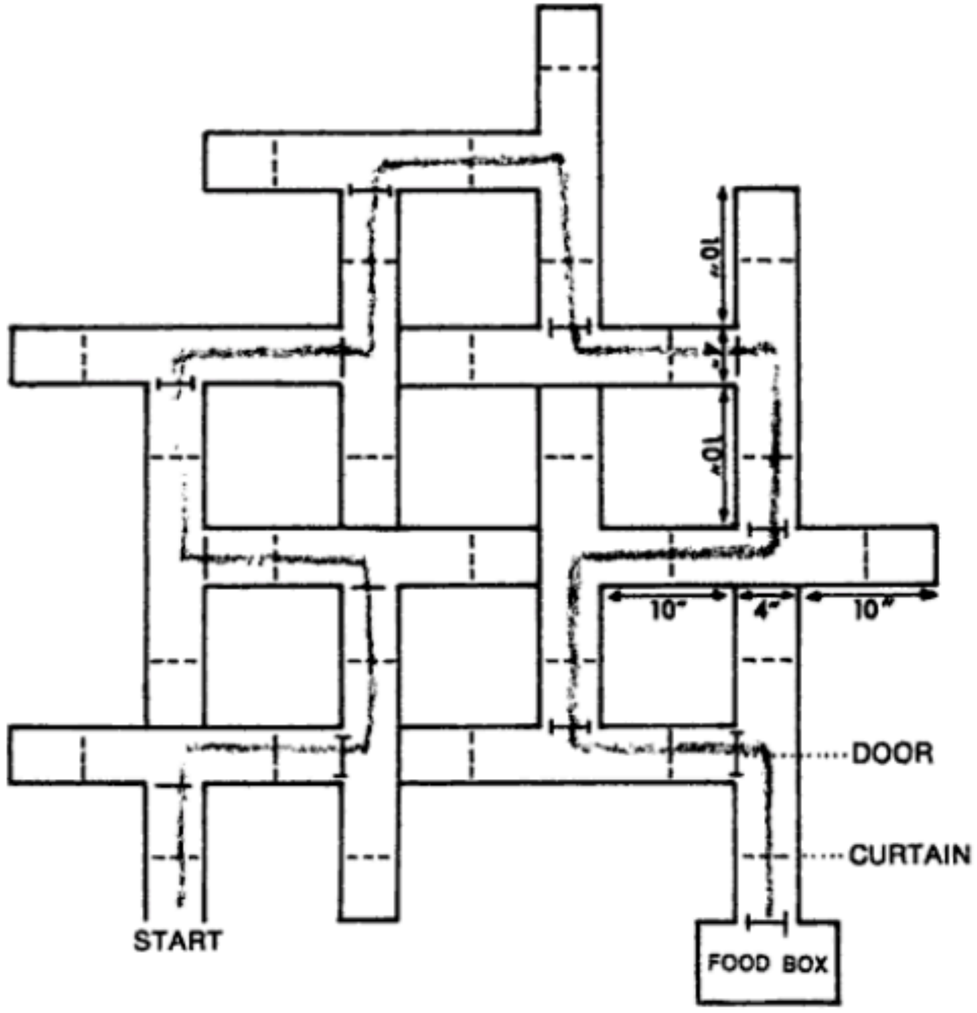


Illustration. Skinner box as adapted for the pigeon.

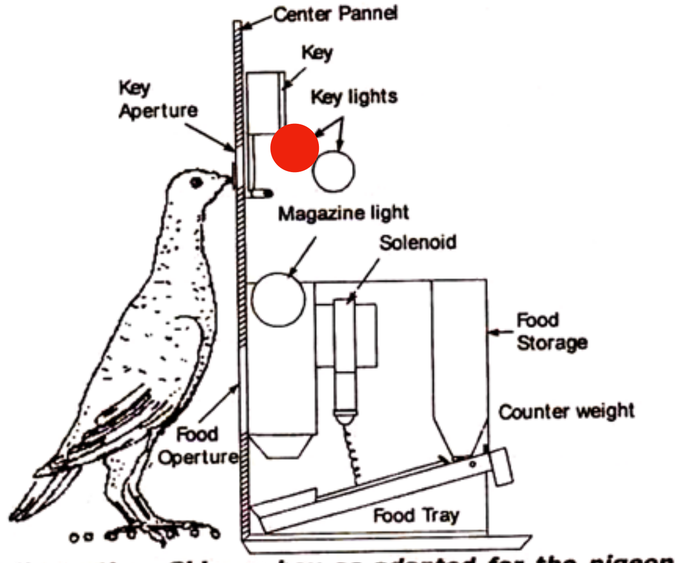
Thorndike, Pavlov, Skinner

Stimulus-Stimulus (S-S) Learning



Tolman

Stimulus-Response (S-R) Learning



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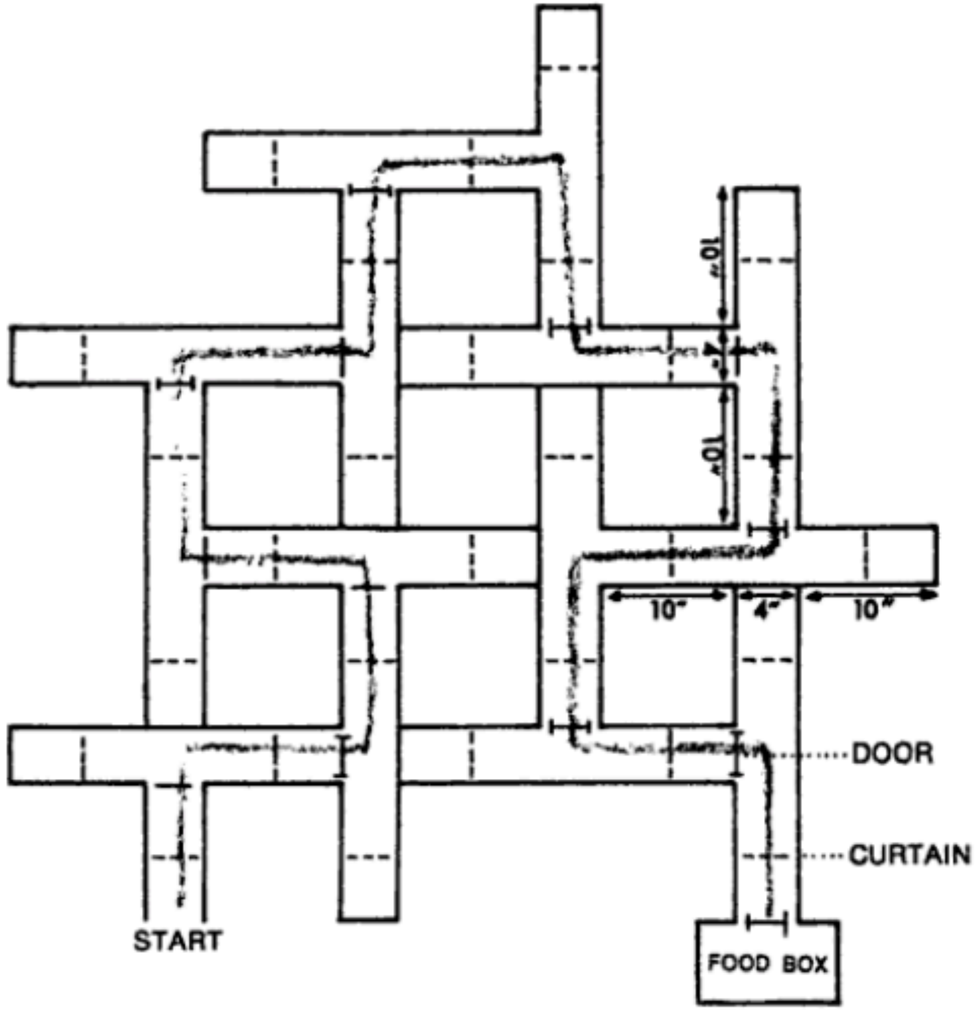

Tolman

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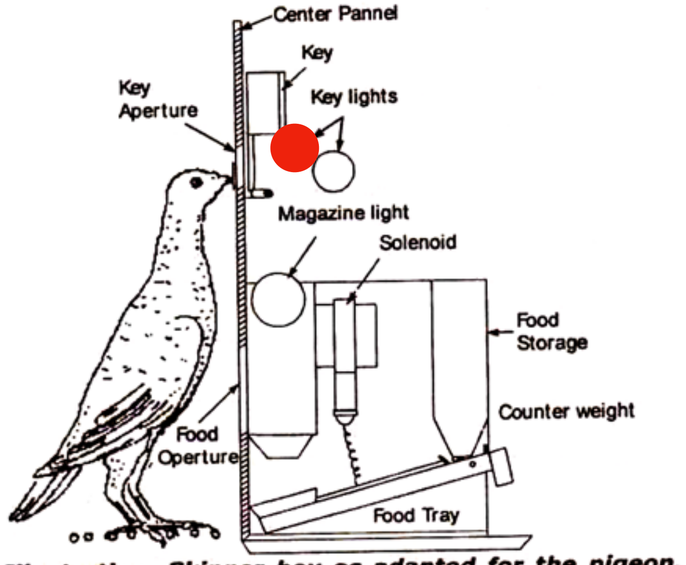

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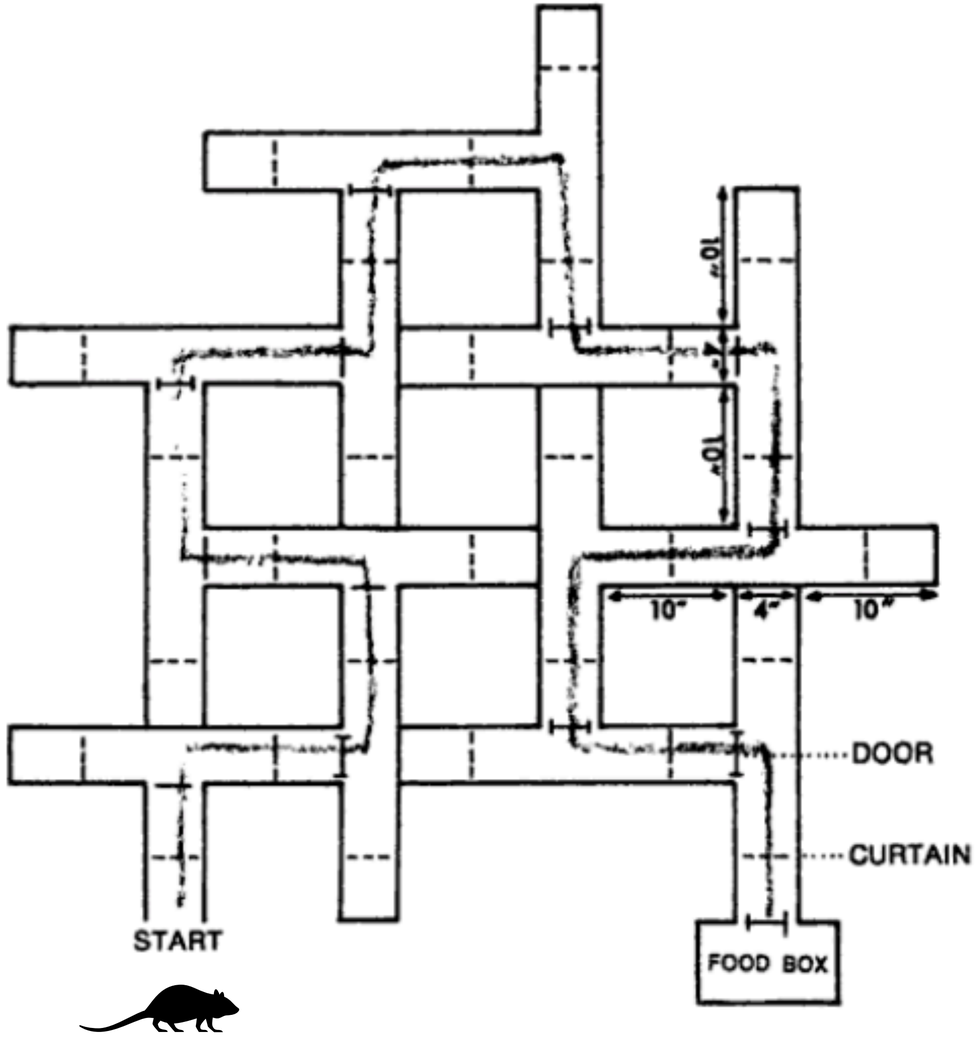
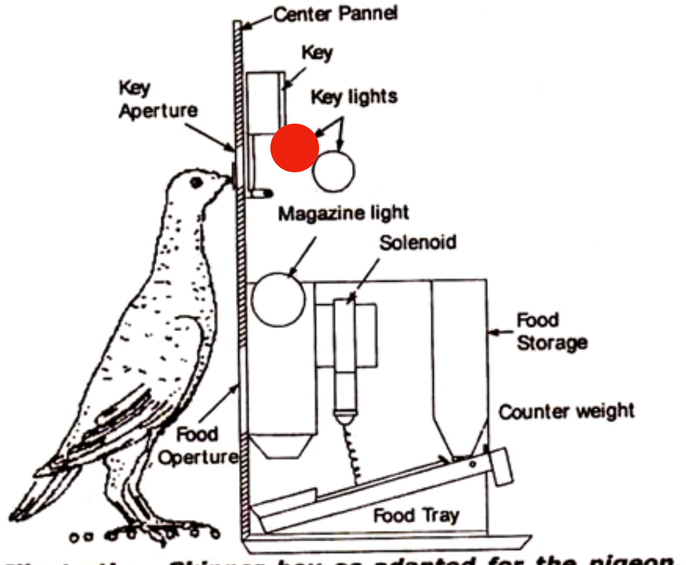
Thorndike, Pavlov, Skinner

Stimulus-Stimulus (S-S) Learning



Tolman

Stimulus-Response (S-R) Learning



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Thorndike, Pavlov, Skinner

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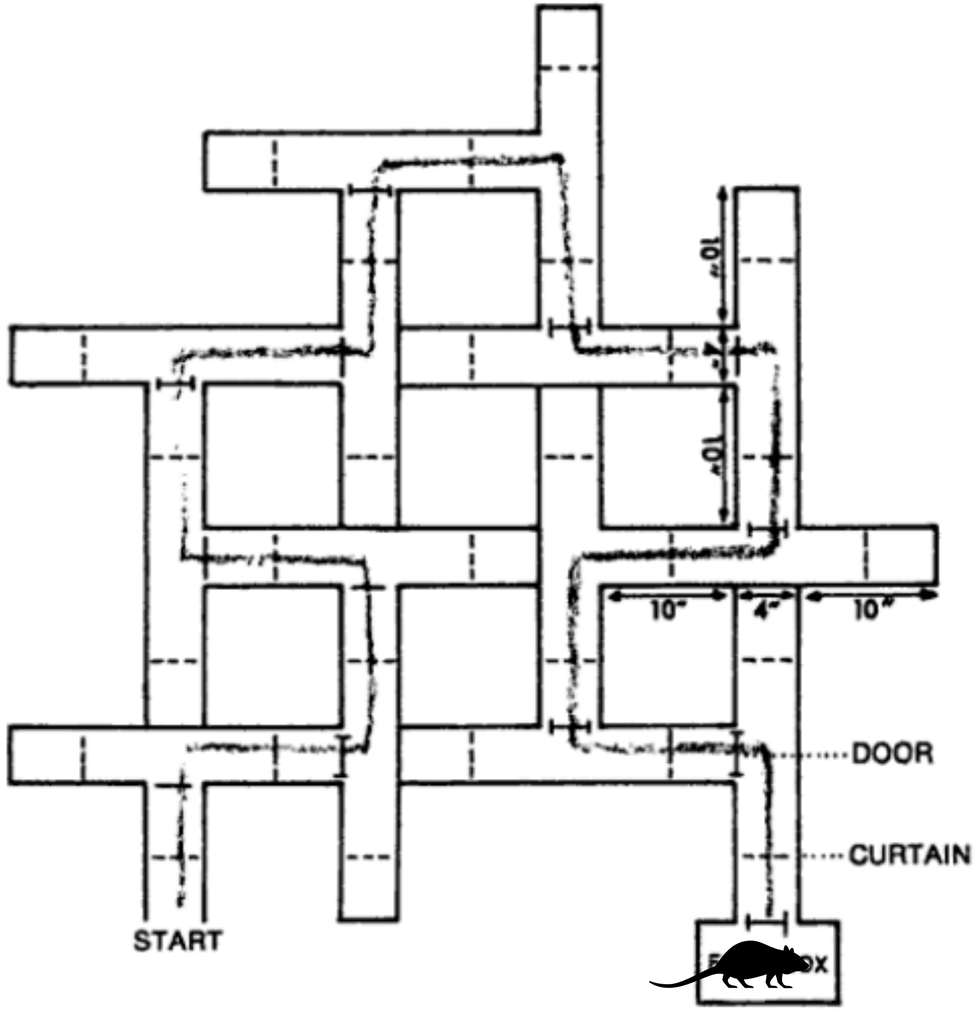


Tolman

Tolman (1948): Different interpretations

"All students agree as to the facts. They disagree, however on theory and explanation"

- **S-R school**: learning consists of strenthening/weakening of S-R connections
  - subgroup a) more frequent responses are strengthened (Law of Exercise)
  - subgroup b) more rewarded responses are strengthened (Law of Effect)
- **S-S school**: in the course of learning, "*a field map of the environment gets established*"
  - Sampling of stimuli is not passive, but active and selective during learning w.r.t. to a goal or purpose
  - Rather than like a telephone exchange, stimuli are not just routed to associations, but used to construct some new (map-like) representation
  - The nature of these map-like representations (strip-like vs. broad) have consequences for generalization

Experiments

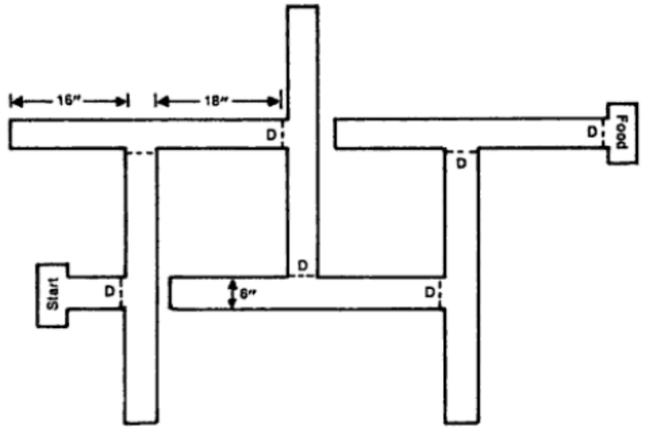
1. Latent Learning

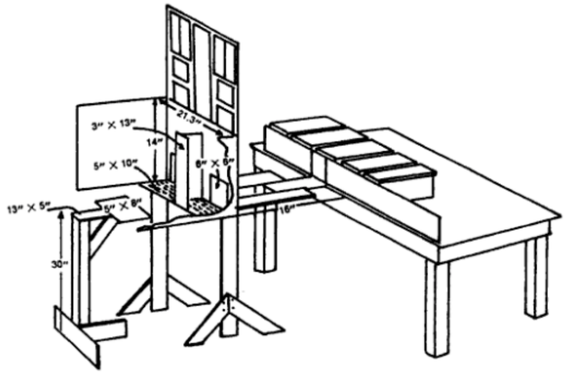
2. Vicarious trial and error

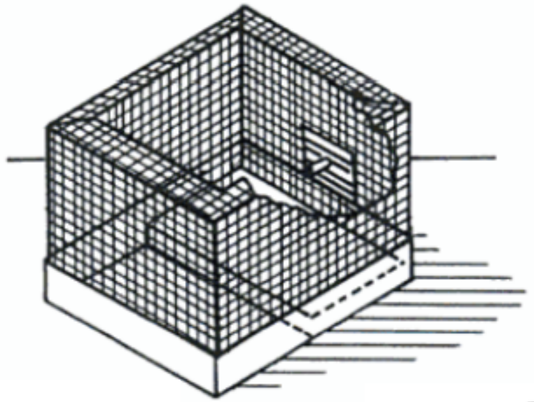
3. Searching for the stimulus

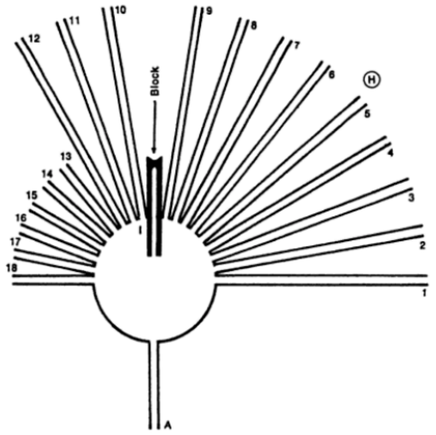
4. Hypotheses

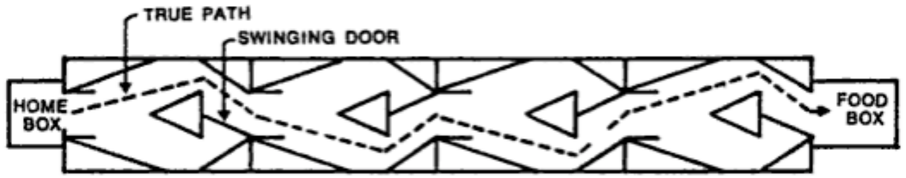
5. Spatial orientation





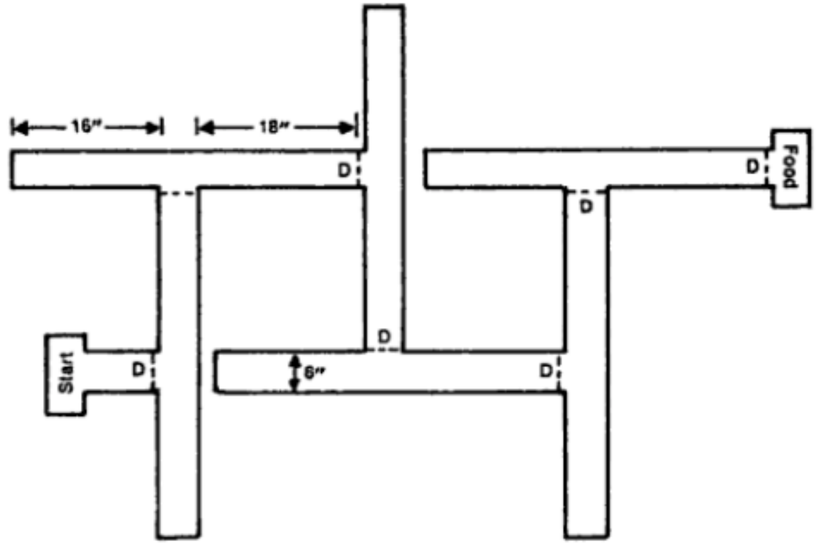


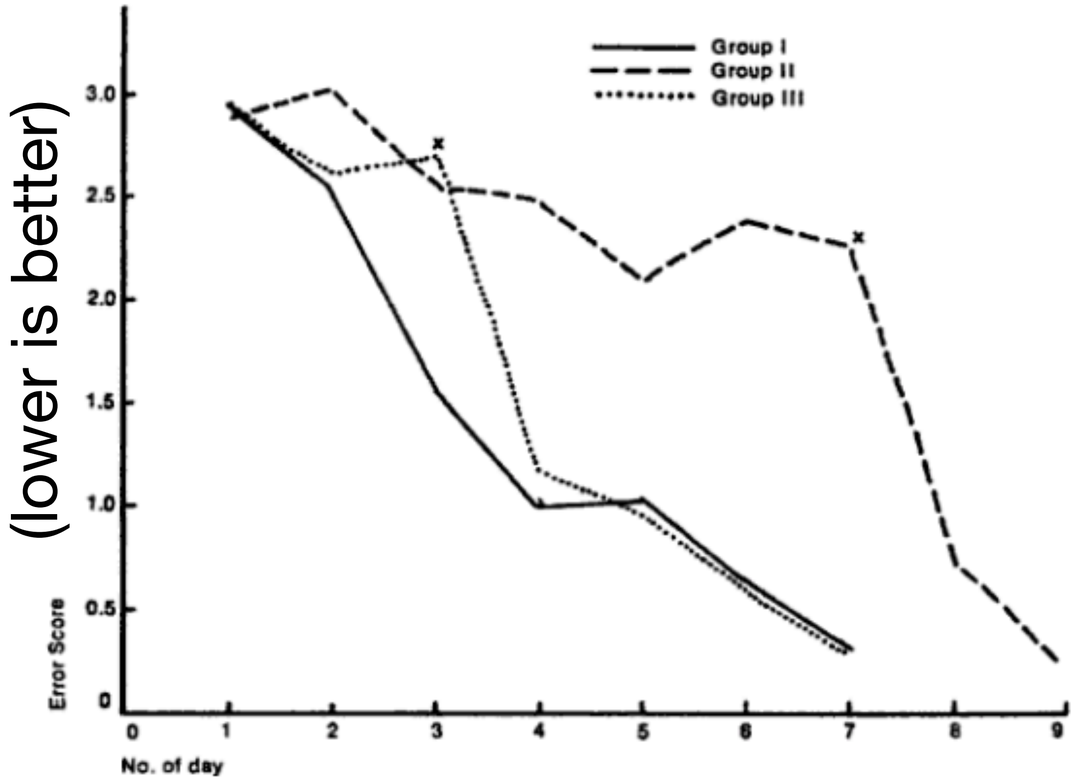




Latent Learning

- Blodgett (1929) Maze navigation task
  - **Group 1** [Control]: one trial a day with food in the goal box at the end
  - **Group 2** [Late food] No food in the maze for days 1-6, then food provided at the end on day 7
  - **Group 3** [Early food] … food added on day 3
- Learning curves dropped dramatically when food was added
  - This suggests latent learning prior to reward
  - “They had been building up a ‘map’”
  - Once the reward was added, they could use the map rather than starting from scratch





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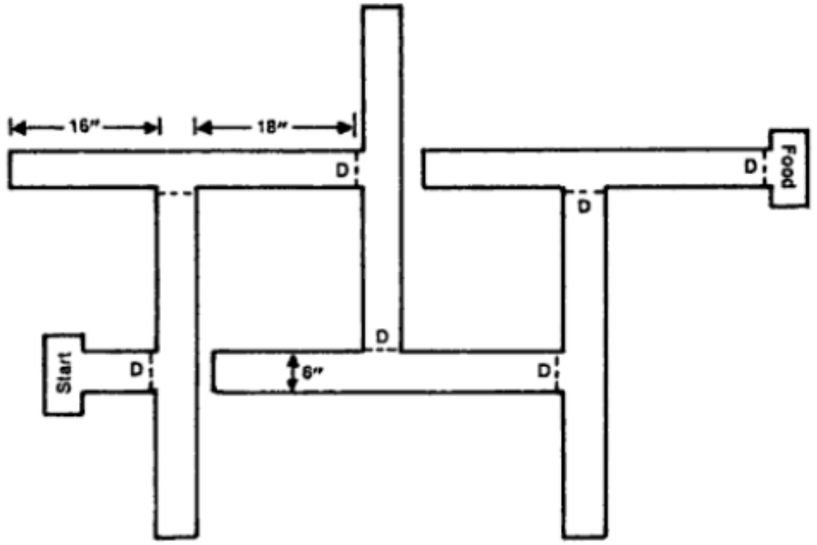
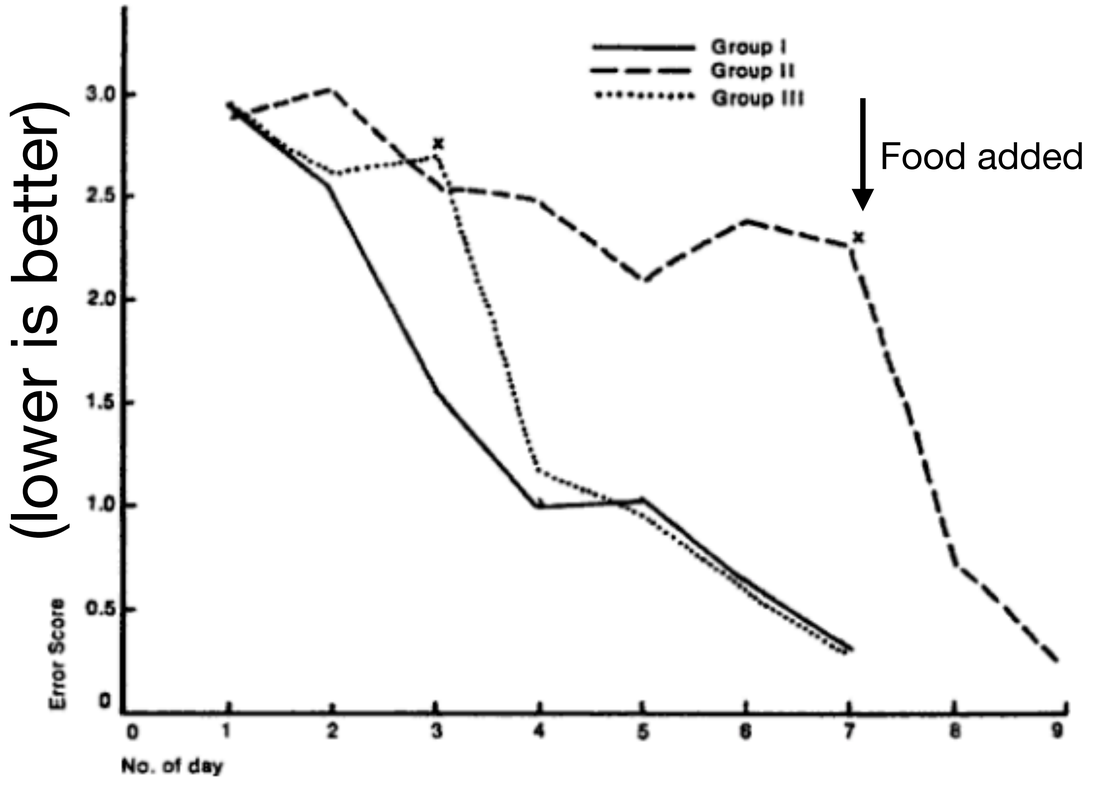
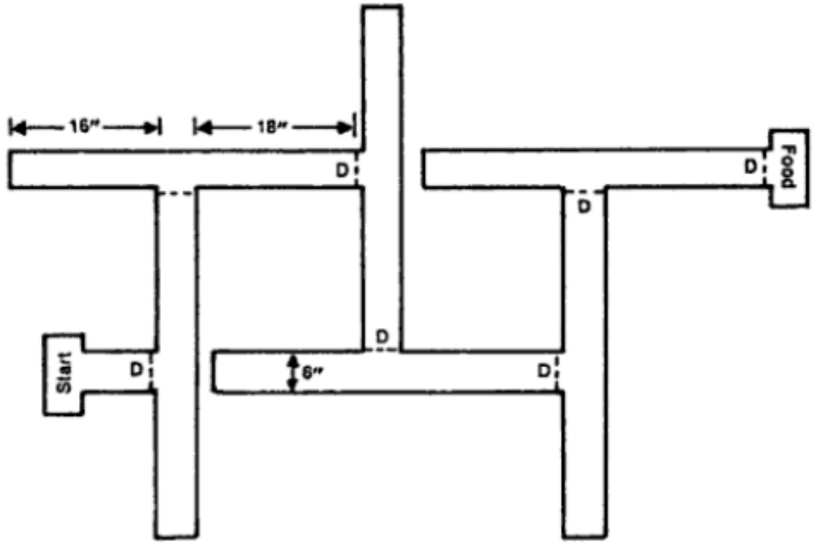
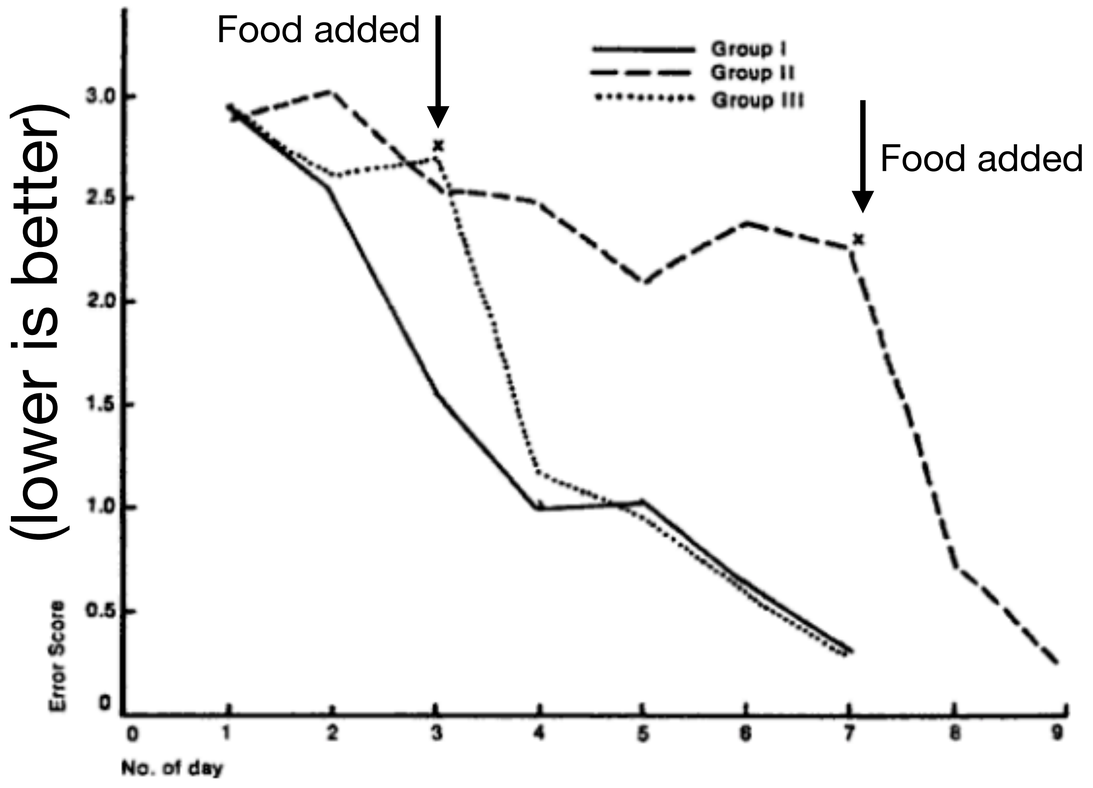




Latent Learning

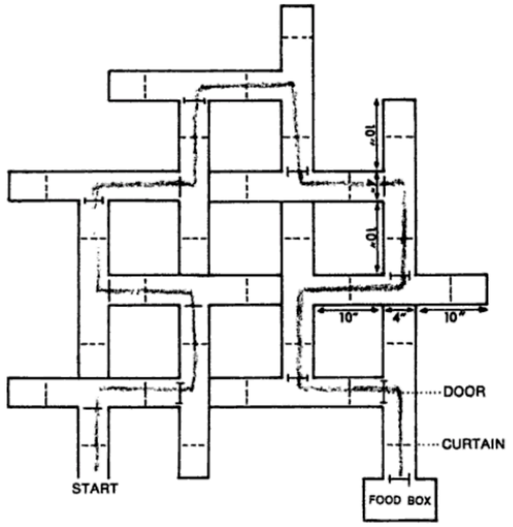
- Blodgett (1929) Maze navigation task
  - **Group 1** [Control]: one trial a day with food in the goal box at the end
  - **Group 2** [Late food] No food in the maze for days 1-6, then food provided at the end on day 7
  - **Group 3** [Early food] … food added on day 3
- Learning curves dropped dramatically when food was added
  - This suggests latent learning prior to reward
  - “They had been building up a ‘map’”
  - Once the reward was added, they could use the map rather than starting from scratch



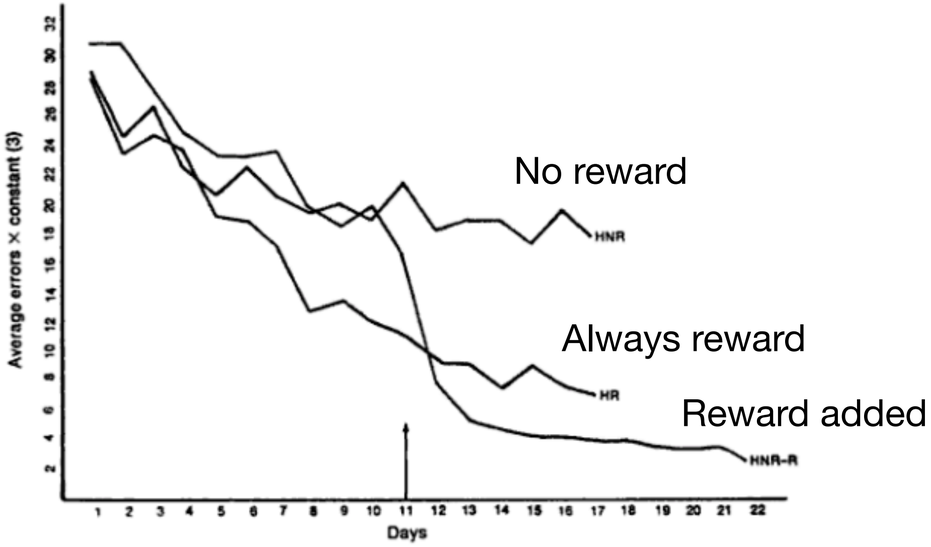


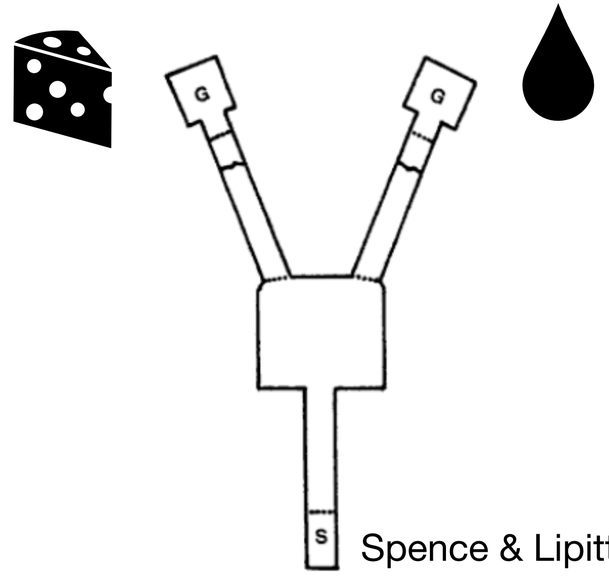
Latent Learning

- Tolman replicates with more complex environment (Tolman & Honzik, 1930)
- Y-maze (Spence & Lipitt, 1946)
  - Exposed to maze while satiated (food + thirst)
  - One group reintroduced when hungry goes left
  - Another group reintroduced when thirsty goes right



Tolman & Honzik (1930)



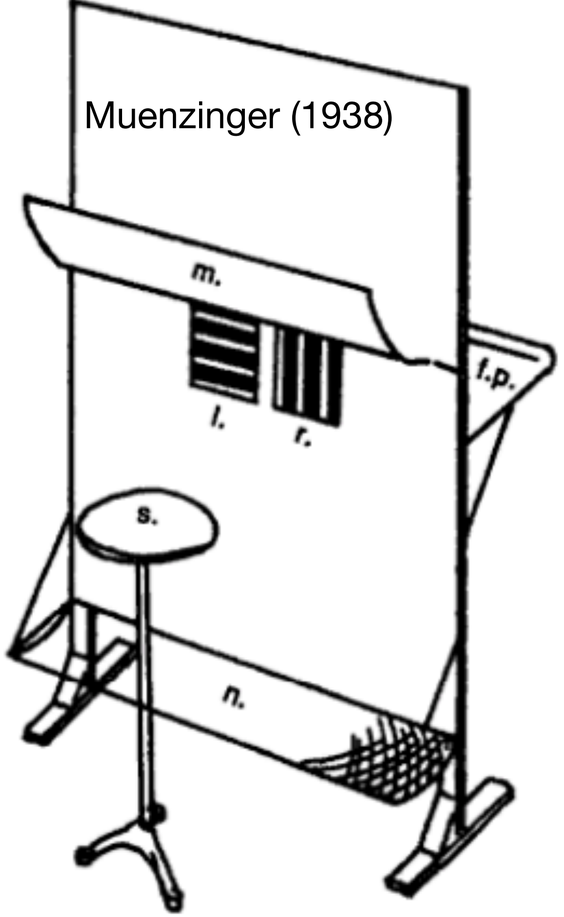


Spence & Lipitt (1946)

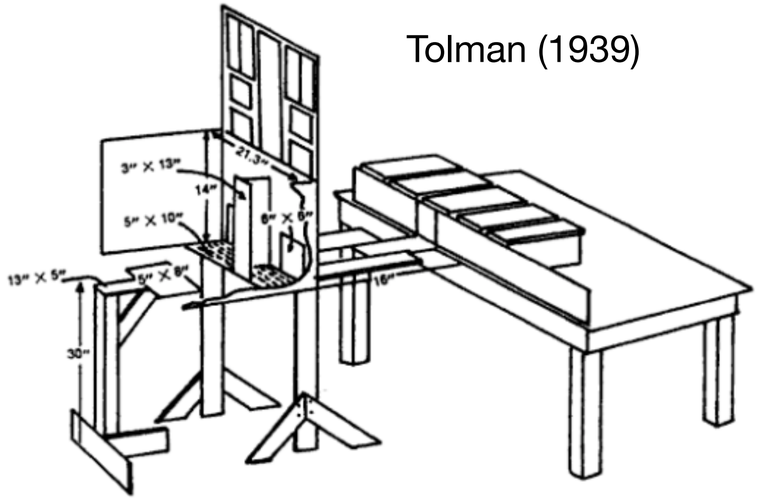
Vicarious Trial and Error (VTE)

- Animal put on jumping stand, facing two doors (l vs. r) with different visual properties (e.g., horizontal vs. vertical stripes)
  - One door is correct, the other incorrect
  - location is randomly swapped but visual features are predictive
  - If the animal jumps towards the correct door, it opens and reveals food on a platform behind
- VTE = hesitating, looking-back-and-forth behavior
- Tolman (1939) added landing platforms infront of the doors
  - When the choice was easy (black vs. white stimuli), the animals learned quicker and did more VTEing than for hard problems
  - After learning had been established, VTEs went down
  - Better learners also did more VTEing (Geier, LEvin & Tolman, 1941)

Muenzinger (1938)



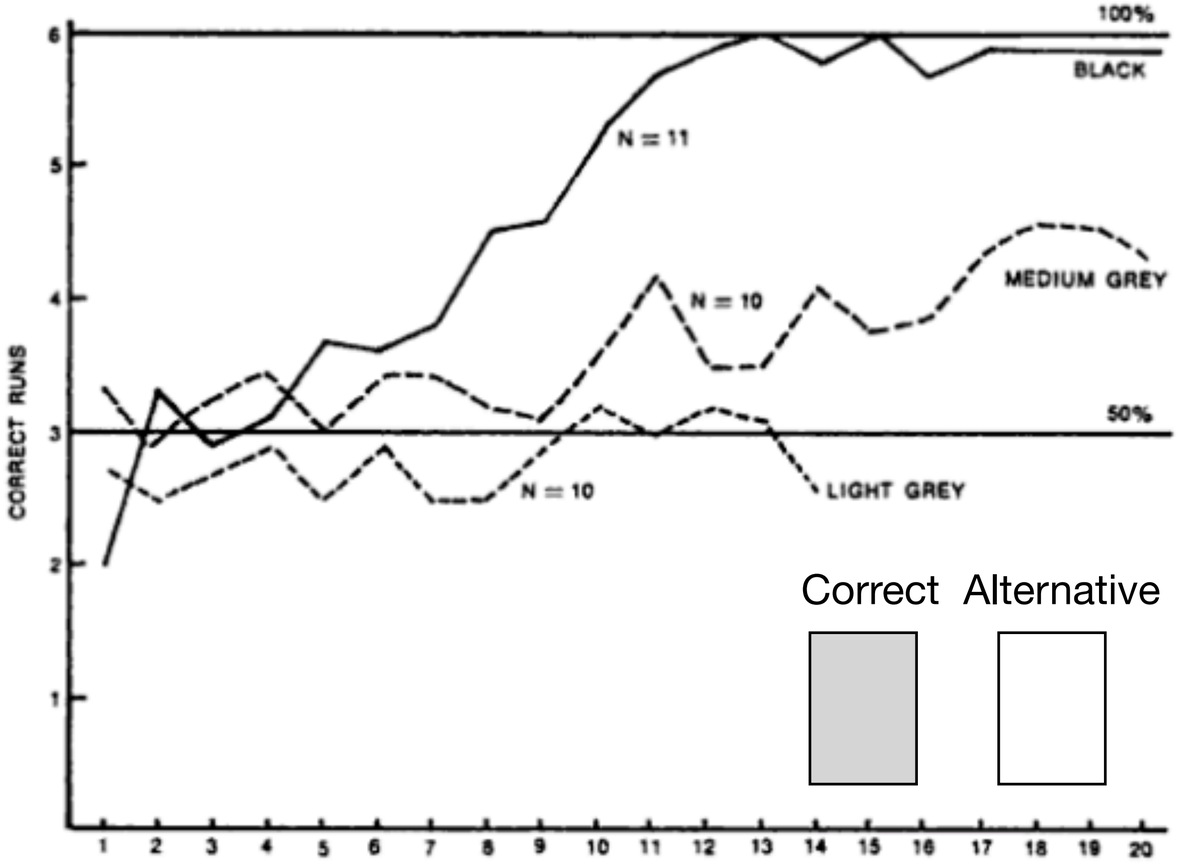
Tolman (1939)

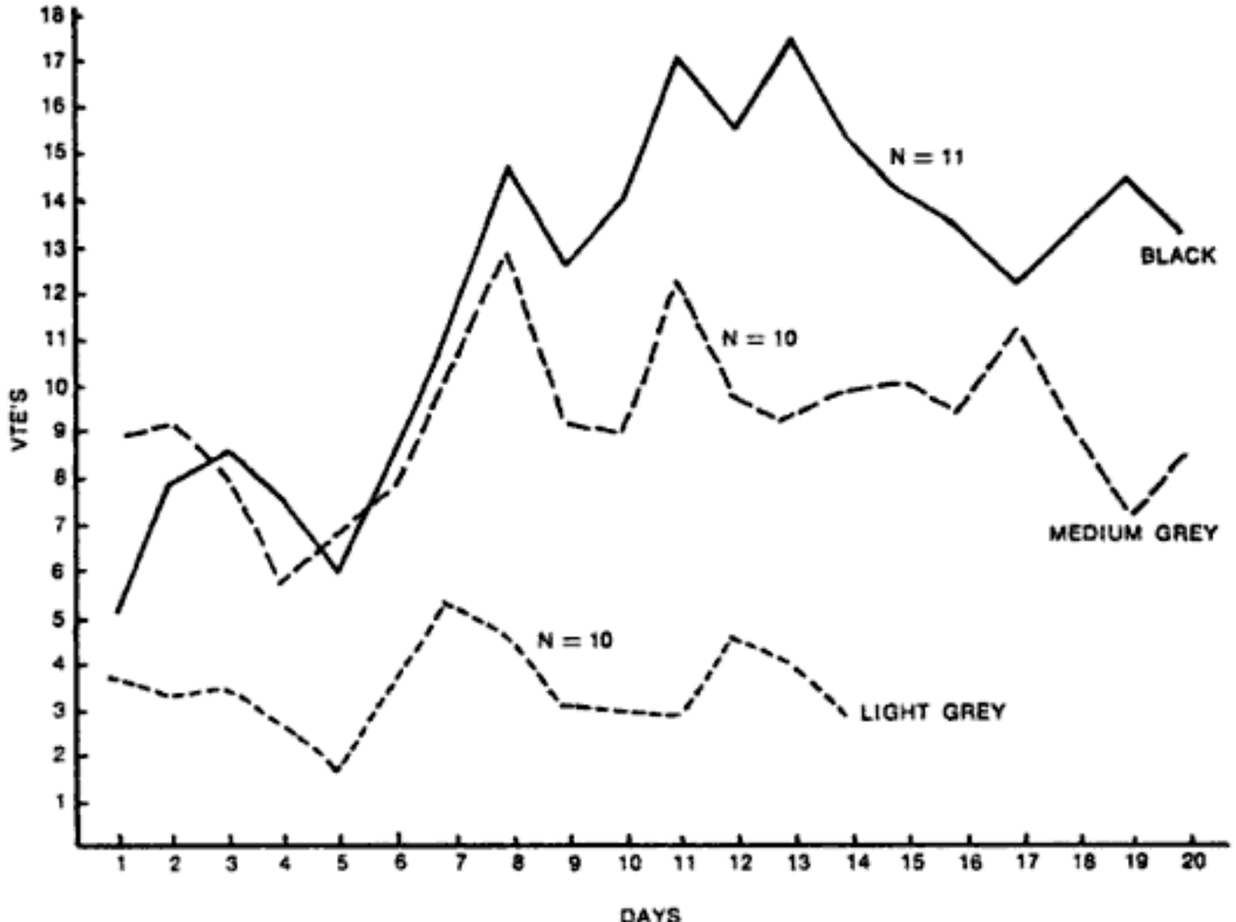



AVIOLI·P

Vicarious Trial and Error (VTE)

- Learning curves on the left, VTEs on the right: VTEs coincinde with the start of learning, and fade away
- Not just passive association of stimuli, but active selecting and comparison of stimuli





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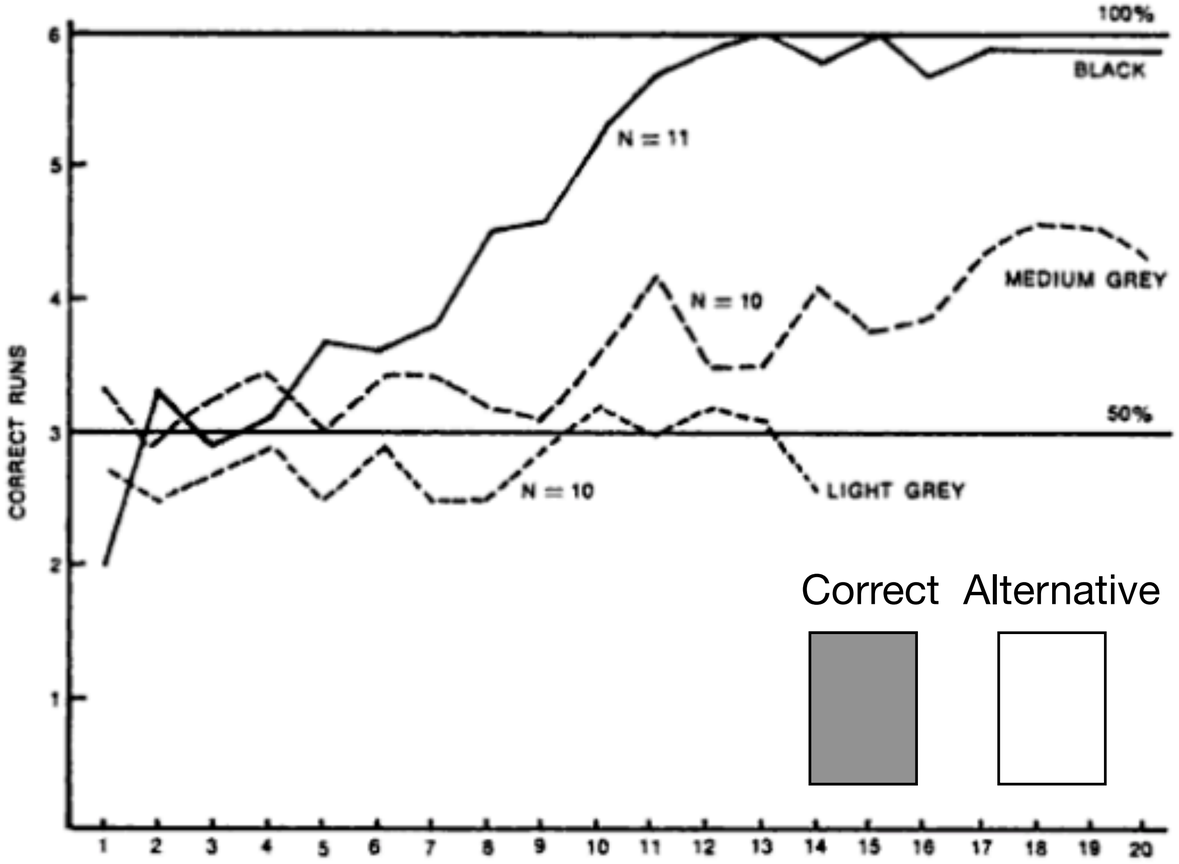

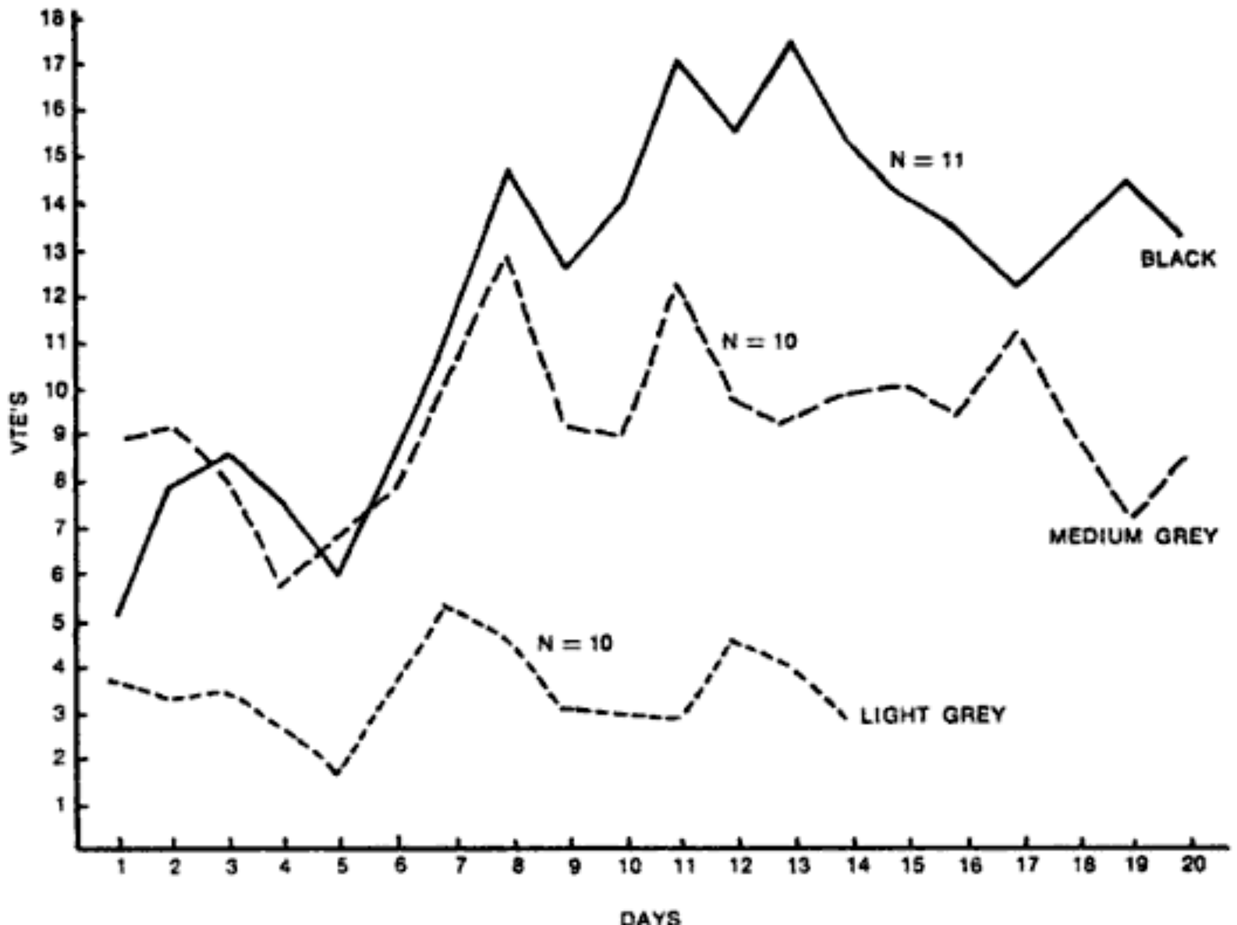

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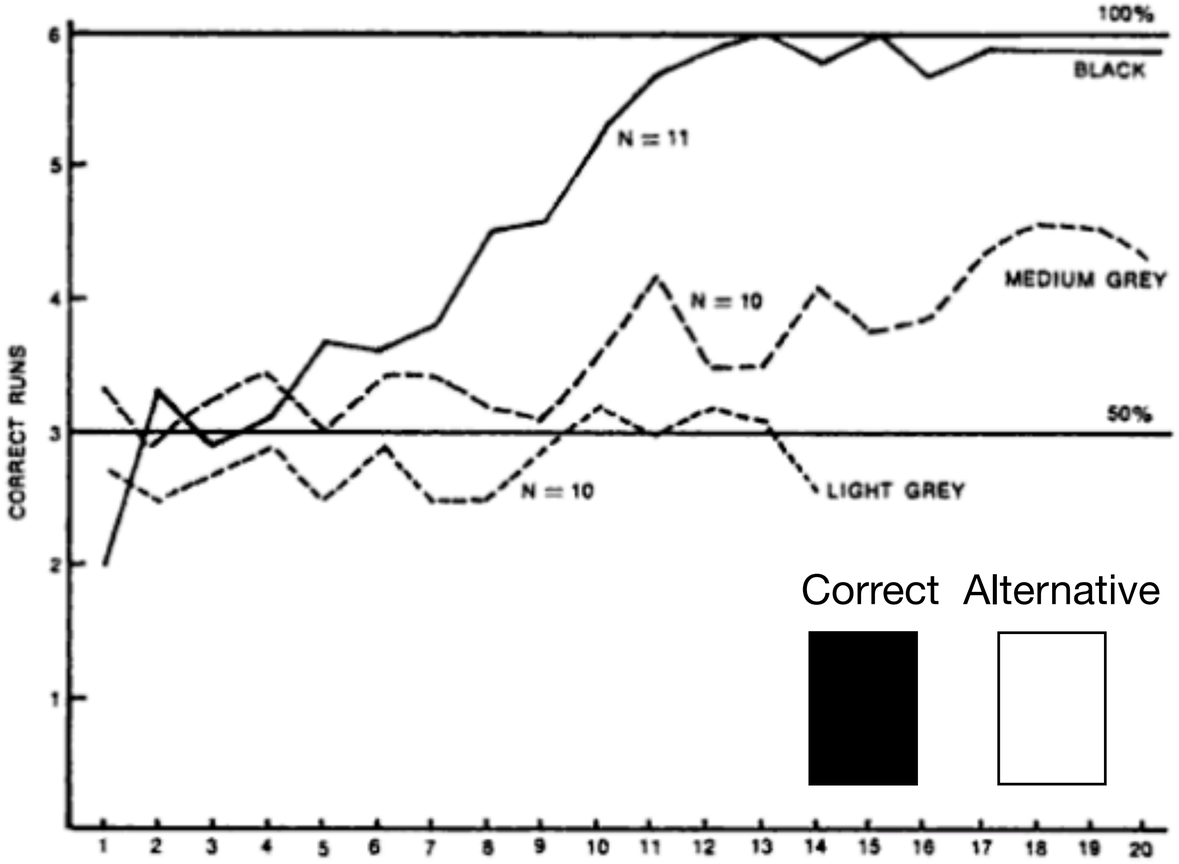
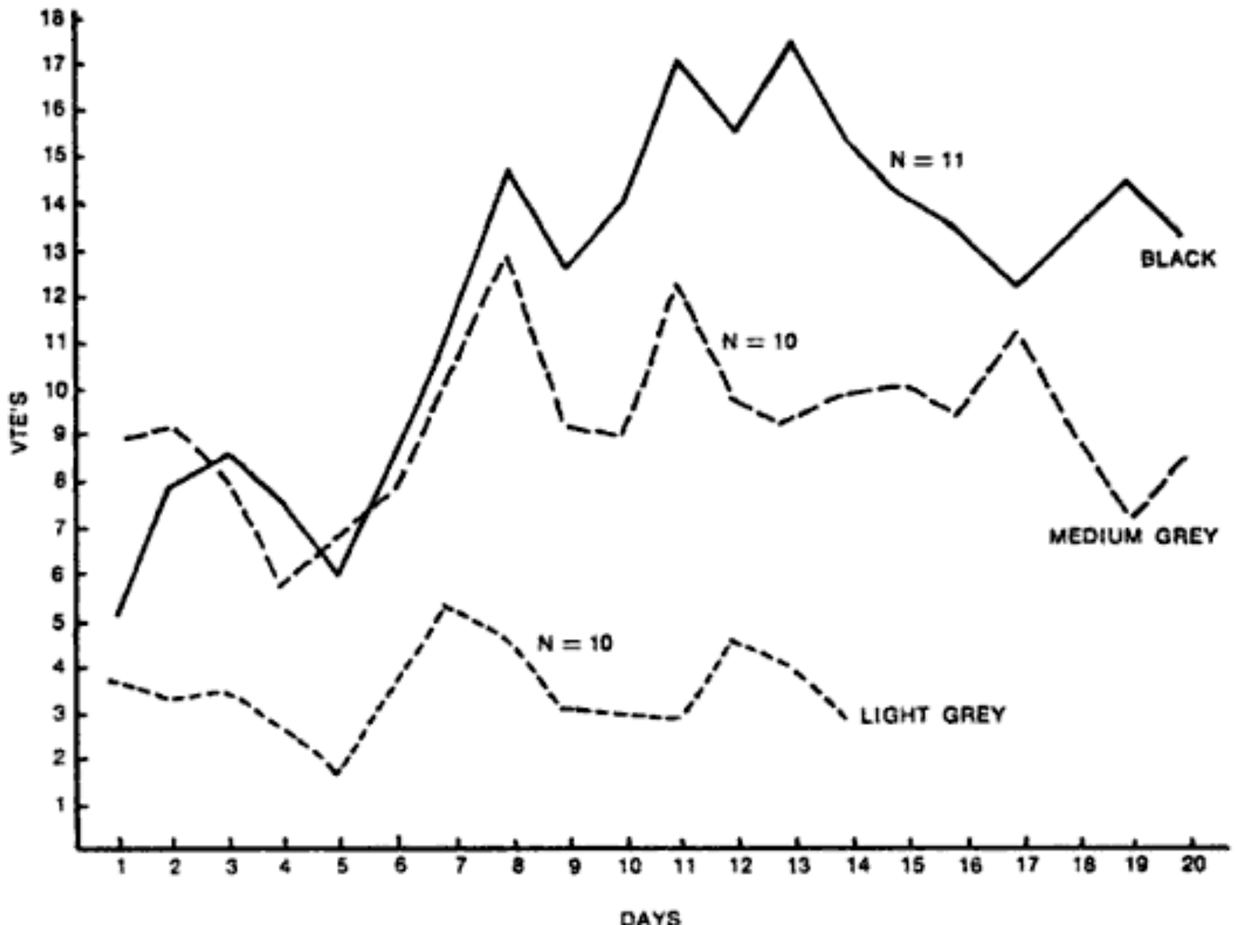
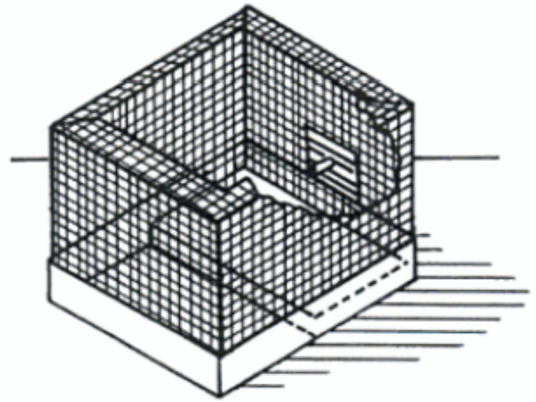




[CITATION] One trial learning: a study of the avoidance behavior of the rat
BB Hudson - 1947 - University of California, Berkeley Paperpile
☆ Cite Cited by 4 Related articles Import into BibTeX

Searching for the stimulus



- (Hudson, 1947) Cage with visual pattern on the end, with a mounted food cup
  - when the rat touched the cup, it received a shock
  - one shock was enough to learn strong avoidance of the visual pattern
- The animal only began searching around *after* the shock to see what it was that caused the shock
  - Hudson created a new experiment that turned off the lights after the shock
  - No avoidance of the stimuli was learned
- More evidence that building up a cognitive map is an active process

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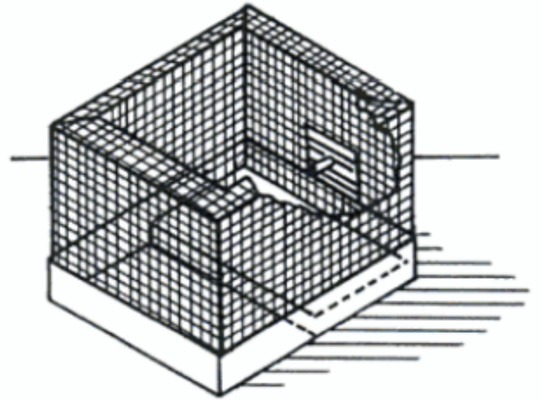

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Human analogue

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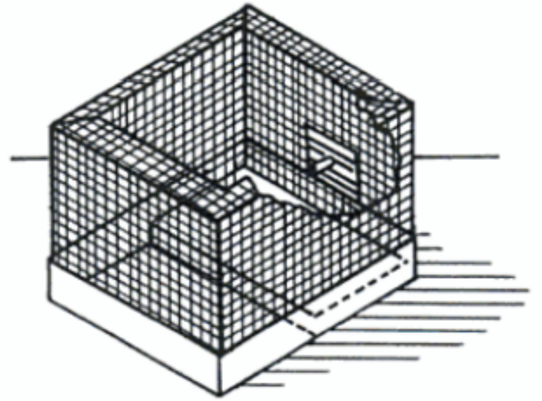

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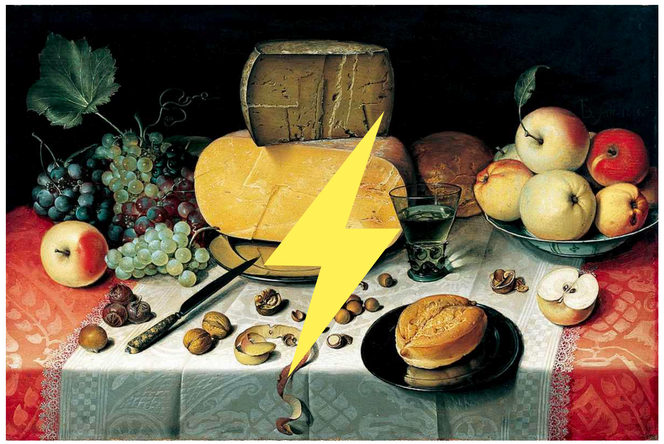
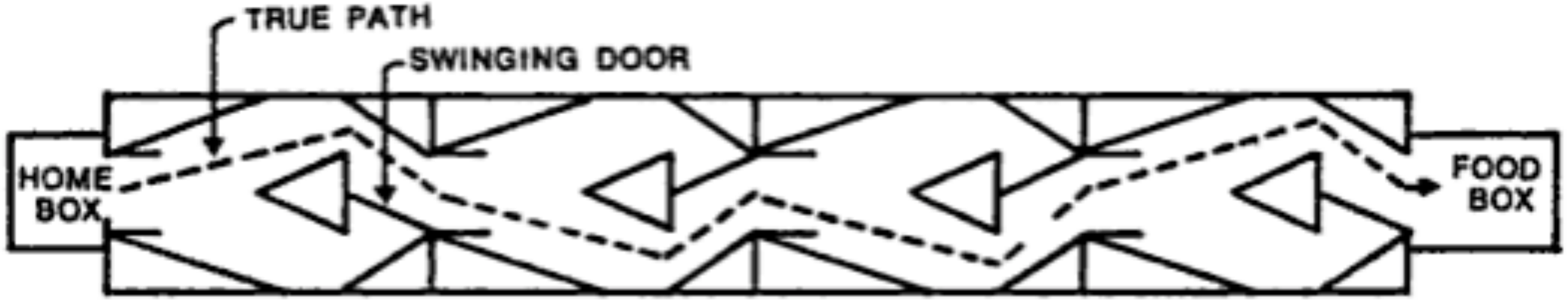


Hypotheses

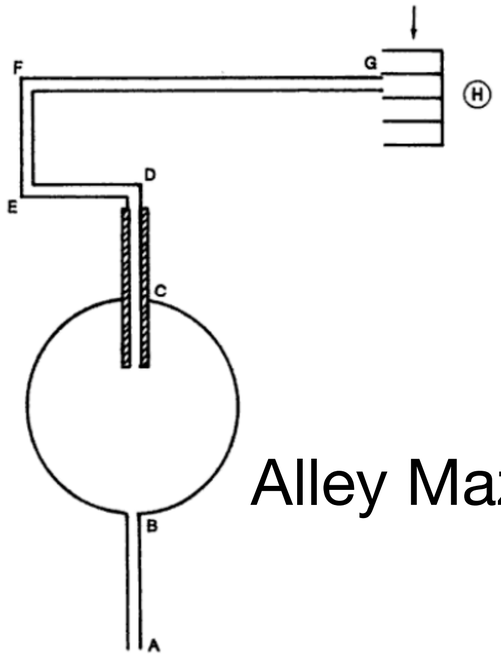
- Four compartment discrimination box with $2^4 = 16$ possible combinations
- Rats explored systematically:
  - e.g., choosing all right-handed doors, and then giving up to try all left-handed doors
  - Krech called these persistent and systematically above-chance types of choices “hypotheses”



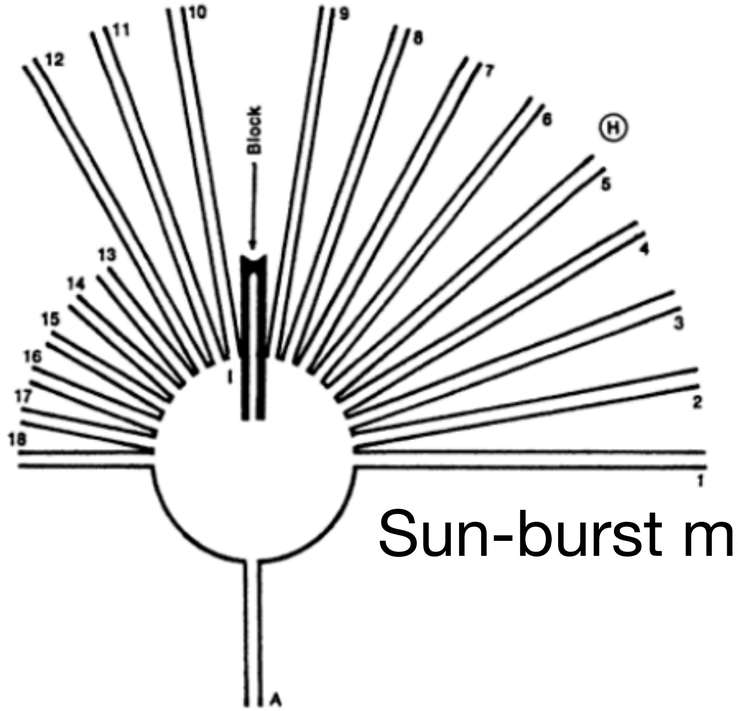
Tolman, Ritchie, & Kalish (1946)

Spatial Orientation

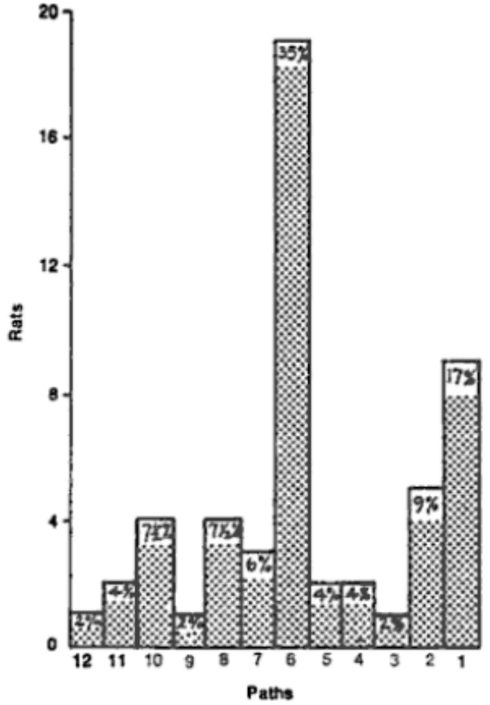
- 3 trials of alley maze task, where H was a light shining from G-F
- Afterwards, rats transferred to sun-burst maze
  - Initially tried the C-D move, but found it blocked
  - Returned to circle and prefered the radiating path in the same direction as the original food location



Alley Maze



Sun-burst maze



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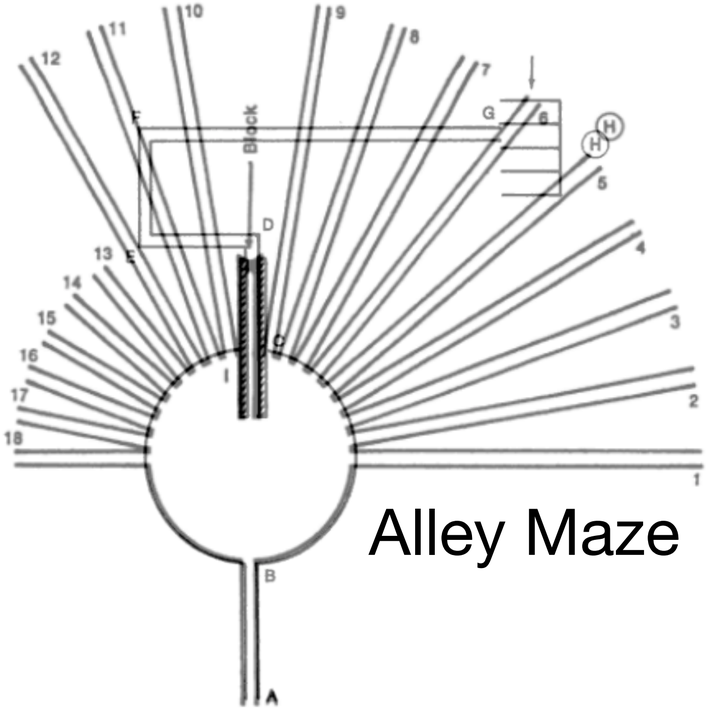

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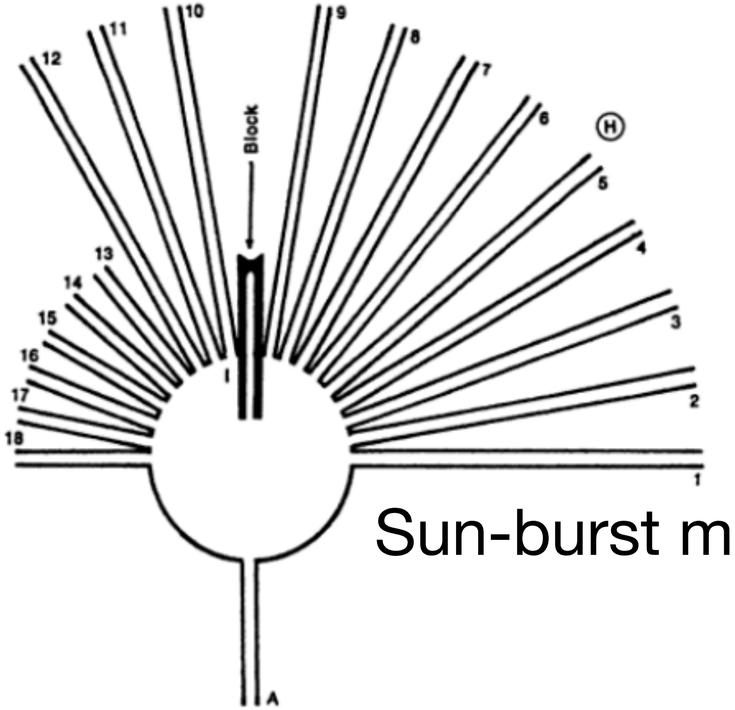

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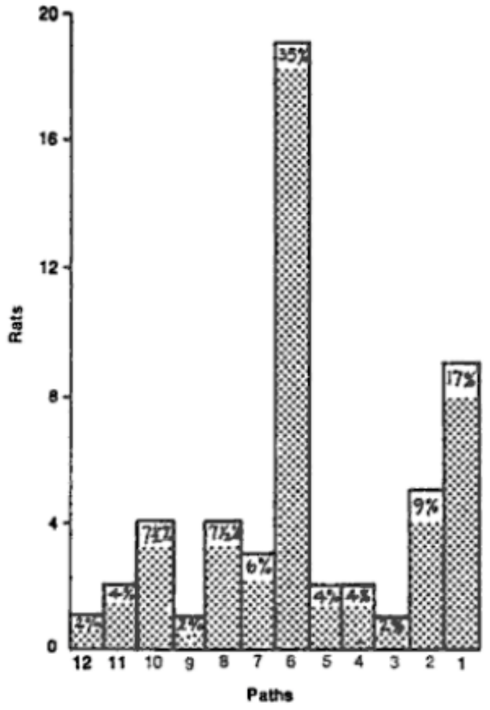
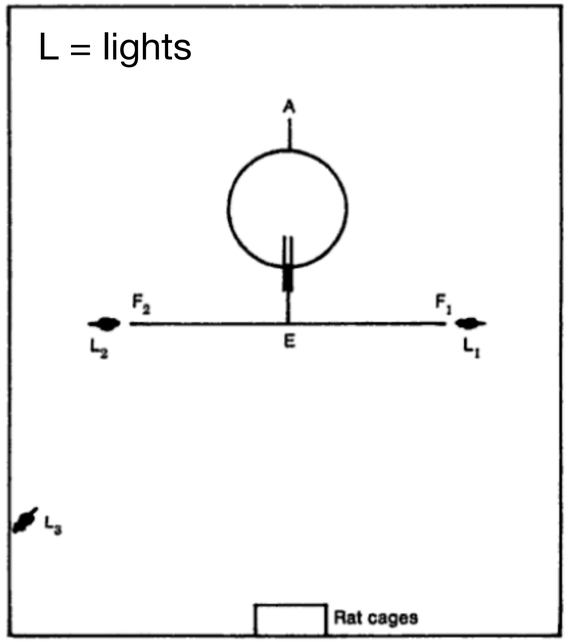


Ritchie (n.d.)

Spatial Orientation

- Rats were trained to find food at either F_1 or F_2, starting from position A
- After 7 days, the starting location and table top were rotated 180 deg
- Tried to run down central alley, but it was blocked
- Majority did not choose path where original food was located, but which ran perpendicular to the corresponding side of the rooms

Old



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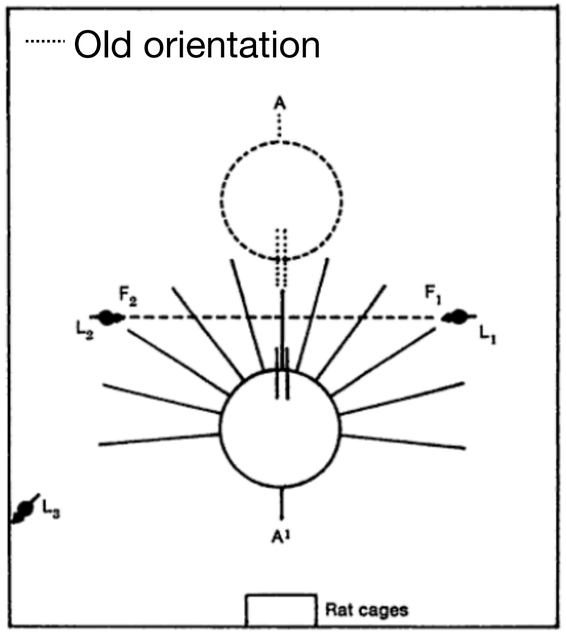

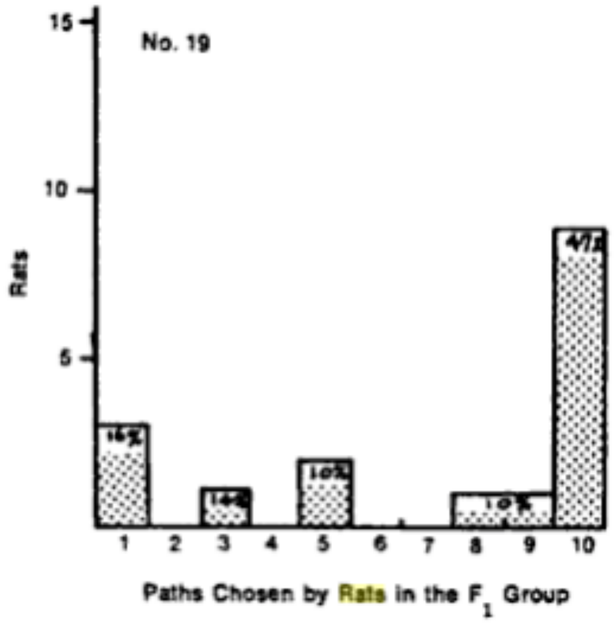

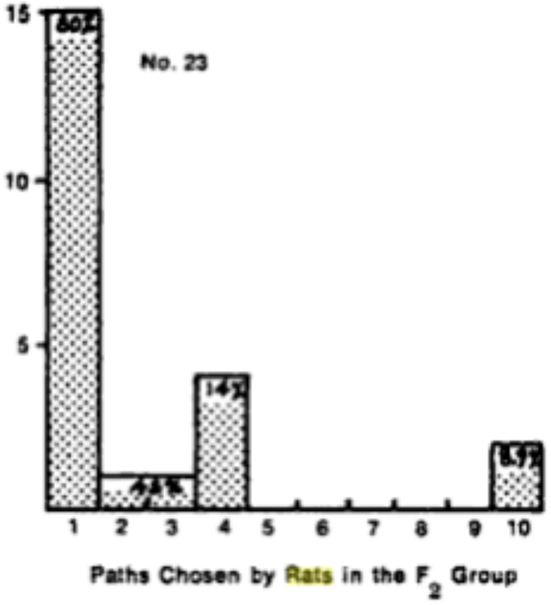

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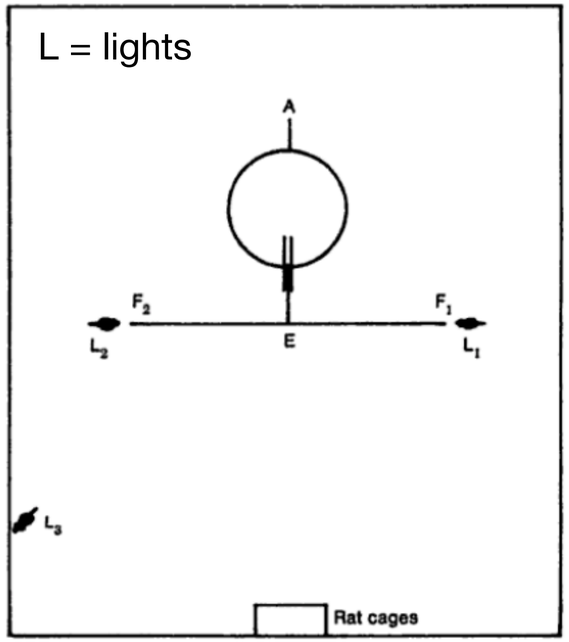

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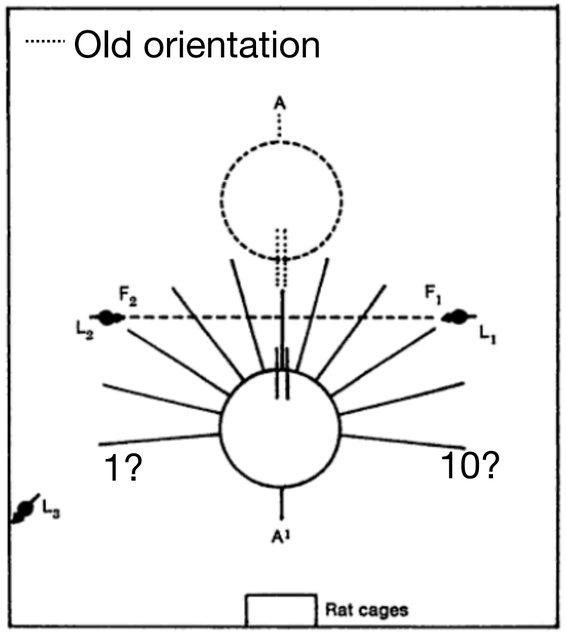

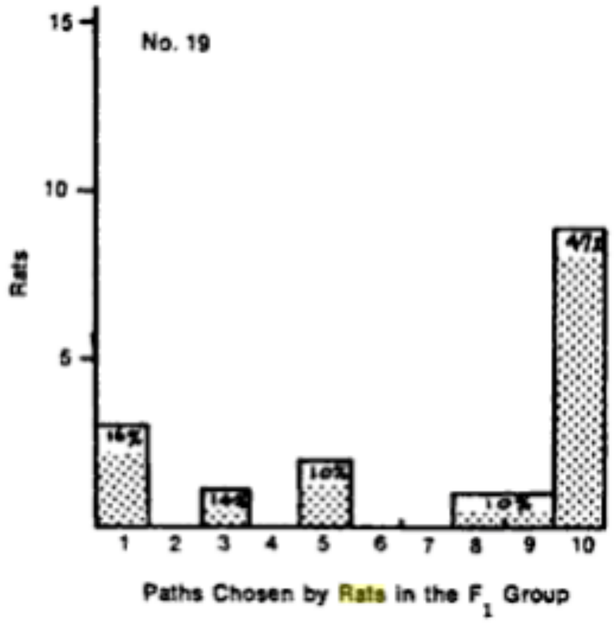

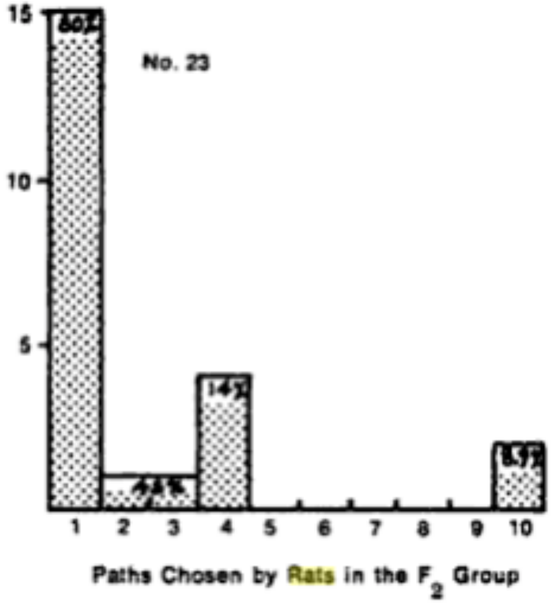

Conclusions

Conclusions

“The poor Southern whites, who take it out on the Negroes, are displacing their aggressions from the landlords, the southern economic system, the northern capitalists, or wherever the true cause of their frustration may lie, onto a mere convenient outgroup. The physicists on the Faculty who criticize the humanities, or we psychologists who criticize all the other departments, or the University as a whole which criticizes the Secondary School system or, vice versa, the Secondary School system which criticizes the University-or, on a still larger and far more dangerous scene-we Americans who criticize the Russians and the Russians who criticize us, are also engaging, at least in part, in nothing more than such irrational displacements of our aggressions onto outgroups.”

Tolman's world view

- The nature of the maps we learn shape how we generalize
  - "*the narrower and more strip-like the original map, the less will it carry over successfully to the new problem; whereas, the wider and the more comprehensive it was, the more adequately it will serve in the new set-up*"
- What conditions favor learning a narrow strip-map vs. a broad comprehensive map?
  - narrow maps induced by :

    1) damaged brains

    2) impoverished environments

    3) overdose of repetition

    4) too strongly motivational/frustrating conditions

Maladaptive psychopathologies

- **Regression** to childlike behavior

  "*take an example, the overprotected middle-aged woman (reported a couple of years ago in Time Magazine) who, after losing her husband, regressed (much to the distress of her growing daughters) into dressing in too youthful a fashion and into competing for their beaux and then finally into behaving like a child requiring continuous care, would be an illustration of regression.*"

- **Fixation** on various addictive behaviors

  "*If rats are too strongly motivated in their original learning, they find it very difficult to relearn when the original path is no longer correct*"

- **Displacement** of agression towards outgroups

  "*The individual comes no longer to distinguish the true locus of the cause of his frustration. The poor Southern whites, who take it out on the Negroes, are displacing their aggressions from the landlords, the southern economic system, the northern capitalists, or wherever the true cause of their frustration may lie, onto a mere convenient outgroup. …. [physicists vs. humanities, psychologists vs. all other depts., university vs. secondary school, americans vs. russians]… nothing more than such irrational displacements of our aggressions onto outgroups*"

What is the solution?

*"We must, in short, subject our children and ourselves … to the optimal conditions of moderate motivation and of an absence of unnecessary frustrations…. I cannot predict whether or not we will be able, or be allowed, to do this; but I **can** say that, only insofar as we **are** able and **are** allowed, have we cause for hope.*

Discussion questions

- How convinced are you by Tolman's interpretation of the experiments? What experiment could you design to strengthen his claims about map-like representations?

- How different is the current landscape of cognitive science? To what extent can we study internal mental states?

- What do you think about Tolman's conclusions? What can his research on rats actually inform us about clinical or social psychology?

https://hmc-lab.com/Cogmaps.html

Next week

Read next week's paper

It's ok if there are a lot of new concepts

Philipp will give a *gentle* introduction to how modern neuroscience has progressed since Tolman

You still have until **Nov 16th** before you need to be submitting discussion questions in advance

The cognitive map in humans: spatial navigation and beyond

Russell A Epstein[1], Eva Zita Patai[2], Joshua B Julian[1] & Hugo J Spiers[2]