Reasoning in Research

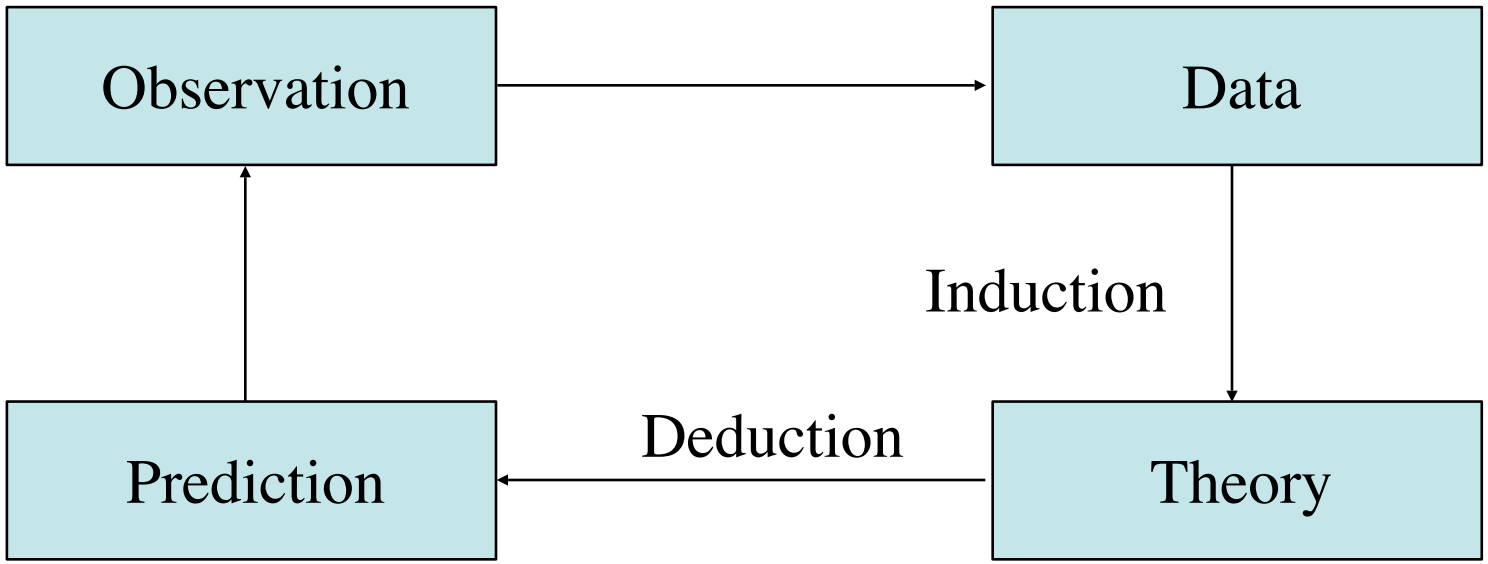
Inductive and Deductive Reasoning and the process of research

Hippocampal functioning

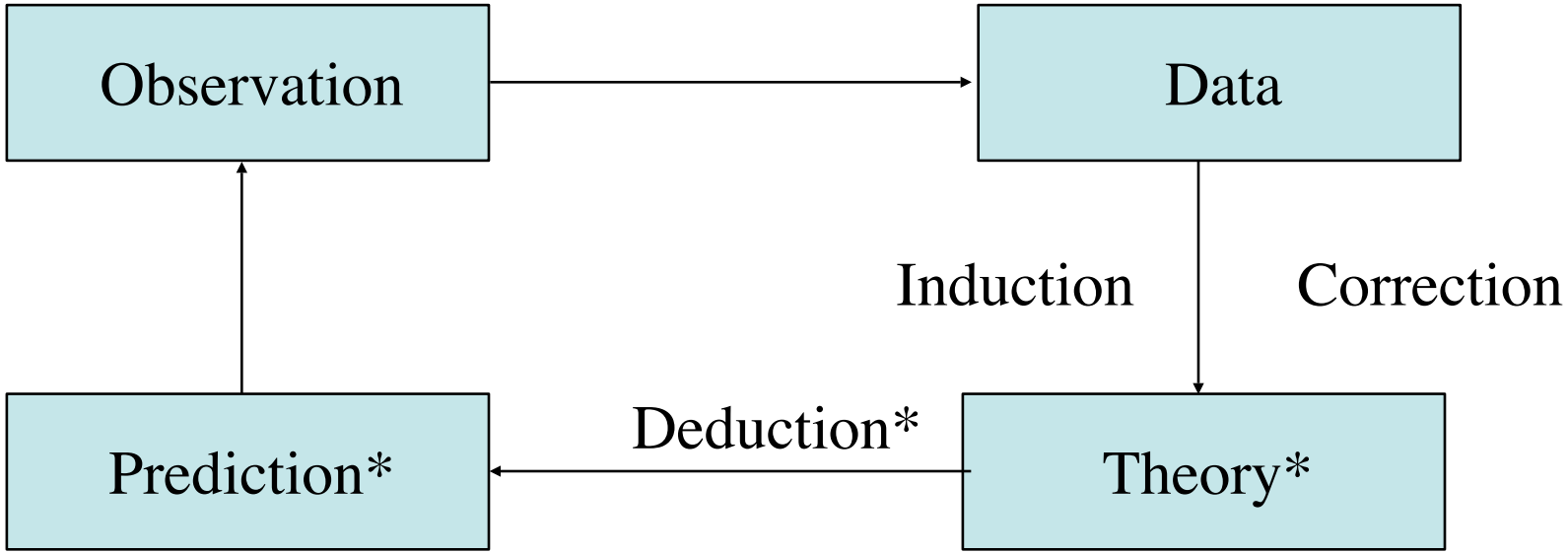
A certain investigator hypothesized that the hippocampus (a part of the brain) is related to complex thinking processes but not to simple thinking processes. He removed the hippocampus from a random sample of 20 rats. He had ten randomly selected rats learn a very simple maze and had ten randomly selected rats learn a very difficult and complex maze. The first group learned to run the maze without error within ten trials. It took the second group at least 30 trials to run the maze without error. Based upon these results, he concluded that his hypothesis had been confirmed -- rats without a hippocampus have more trouble learning a complex task than they do learning a simple task.

Criticize this experiment. Do the conclusions follow from the data? Why or why not? Do these results tell us anything about the role of the hippocampus in learning?

Reasoning in Research



Reasoning in Research
an iterative process



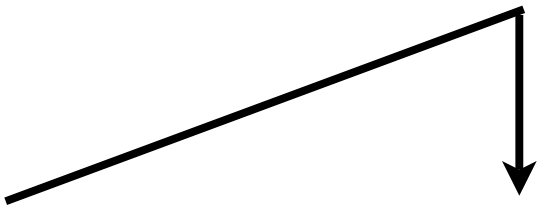
Observations

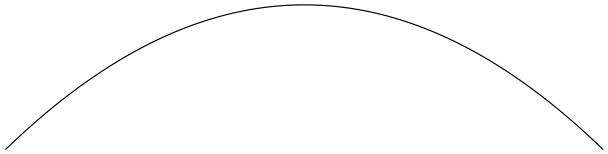
- Basis of science is systematic observation
- Describe phenomena as they occur, not as we think they should occur
  - Aristotle described flight of arrow as due to impetus for flight. When the impetus was used up, the arrow fell to the ground.
  - Newton observed the flight of an arrow, the fall of an apple, and inferred the motion of the planets. Arrows path is parabolic.

Two descriptions of motion

Based upon theory, not observation

Observation led to theory





Aristotle - theory of motion

Newton - description

Observations

- What is meaningful to observe?
  - About thirty years ago there was much talk that geologists ought only to observe and not theorise; and I well remember some one saying that at this rate a man might as well go into a gravel-pit and count the pebbles and describe the colours. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service!

C. Darwin to Henry Fawcett, 18 Sept 1861

http://www.darwinproject.ac.uk/entry-3257)

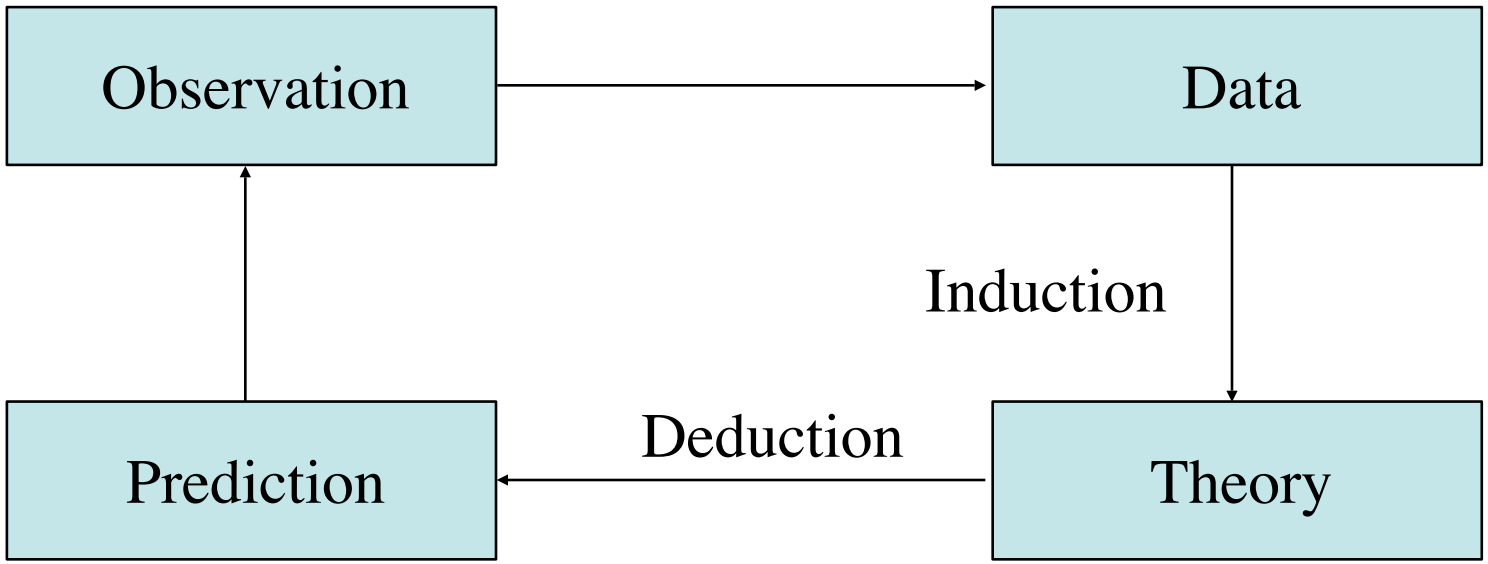
What to observe?

- Darwin and the voyage of the Beagle
  - when visiting the Galapagos, he observed birds, iguanas, tortoises and thought they were ugly and stupid (they were not afraid of humans)
  - only later did he realize he had observed many different species of mockingbirds, finches and iguana and that they differed as a function of which island they came from and where on the islands they were collected

What do we observe when we meet someone?

- Height, weight, age, gender, clothing, hair color, hair length, walking style, language, speech speed, ...
- What do we observe when we describe where someone is: location, time of day, weather, inside, outside, classroom, dorm, home, street, shop, ...
- What kinds of behaviors do we observe?
  - ...
- What else to observe?

Reasoning in Research



Reasoning in Research

Consider the following sequence of numbers that are following a certain rule

2 4 8 X Y

What is the rule?

Create a hypothesis for the rule (Write it down)

Test the hypothesis by predicting X

Is it confirmed?

Does this mean that you know the rule?

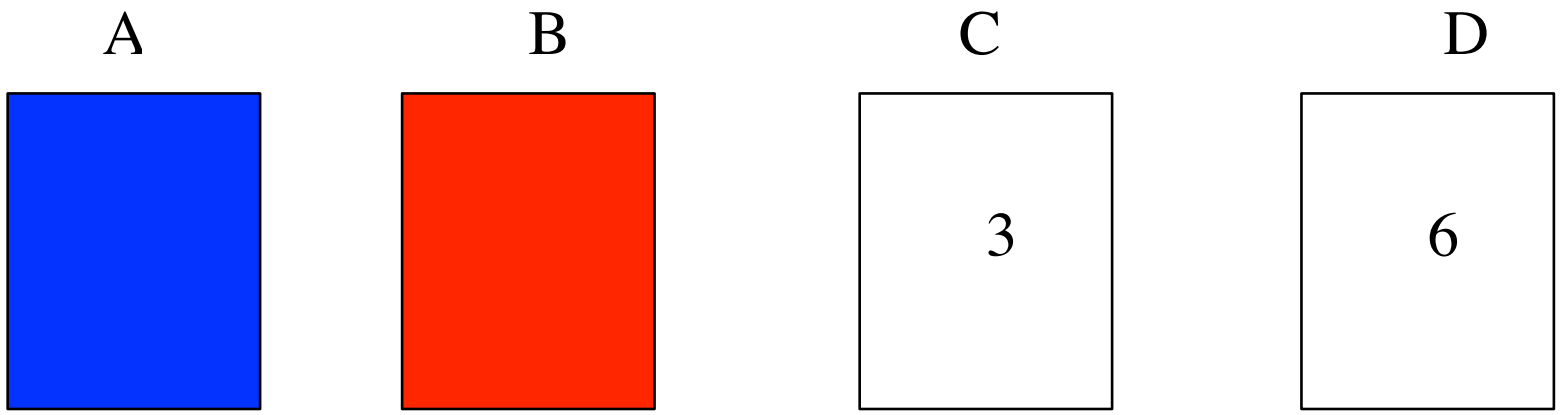
Test it again (Predict Y)

Reasoning in Research

- 2 4 8 X Y Z
- What was the rule that you had?
- One rule (the one used to generate the numbers) was ... (redacted)
  There are, of course, many rules compatible with this general rule.
- Need to do tests that are not confirmations of rule but rather challenge the rule.
- Avoid the confirmation bias -- seek to disconfirm

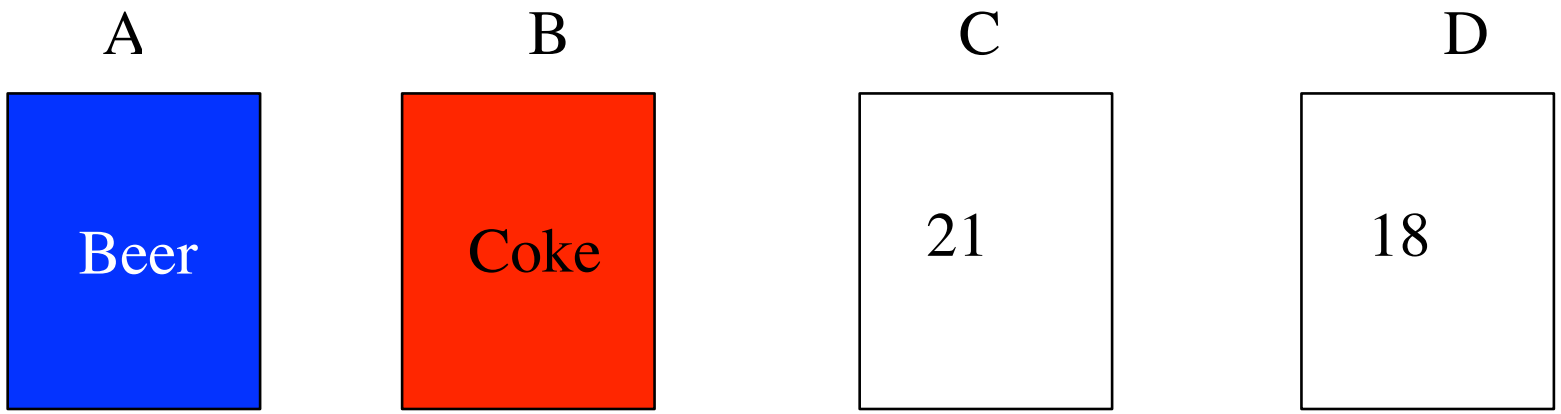
Reasoning in Research

- Consider the rule:
  - Cards are Blue or Red on one side and have numbers on the other side
  - All blue cards have an odd number on the other side
- Which of the following cards must you turn over to test this rule:



Reasoning in Research

- Consider the rule:
  - Some students are 18, some are 21, some are drinking beer, some coke.
  - You must be 21 to drink beer
- Which of the following students must you test to see if they are following this rule



Reasoning in research

- In both cases (blue -> Odd; drinking->21), the rule may be tested by affirming the antecedent and denying the consequent
  - Affirm the antecedent Blue -> Odd
  - Deny the consequent not odd -> not Blue
- Abstract cases typically are harder to deal with than concrete and familiar cases
- (Sometimes useful to convert abstract case into an analogous familiar case)

Principles of Logical Reasoning
P -> Q or if P, then Q

- Appropriate logical deductions
  - Affirm the Antecedent: P -> Q (modus ponens)
  - Deny the Consequent: not Q -> Not P (modus tollens)
- Incorrect logical deductions
  - Deny the antecedent: Not P -> Not Q
  - Affirm the consequent: Q -> P

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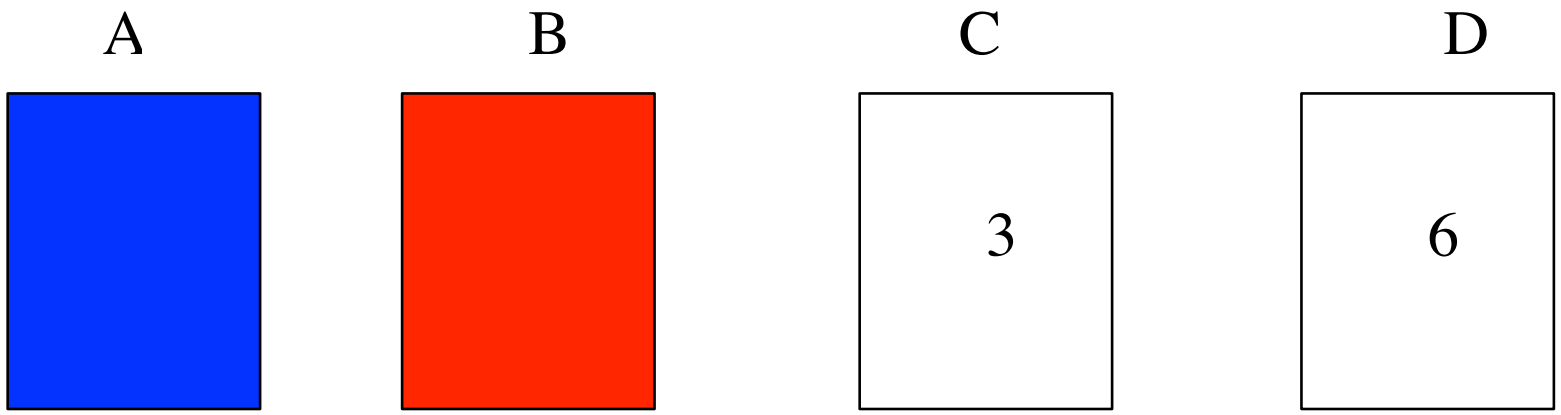

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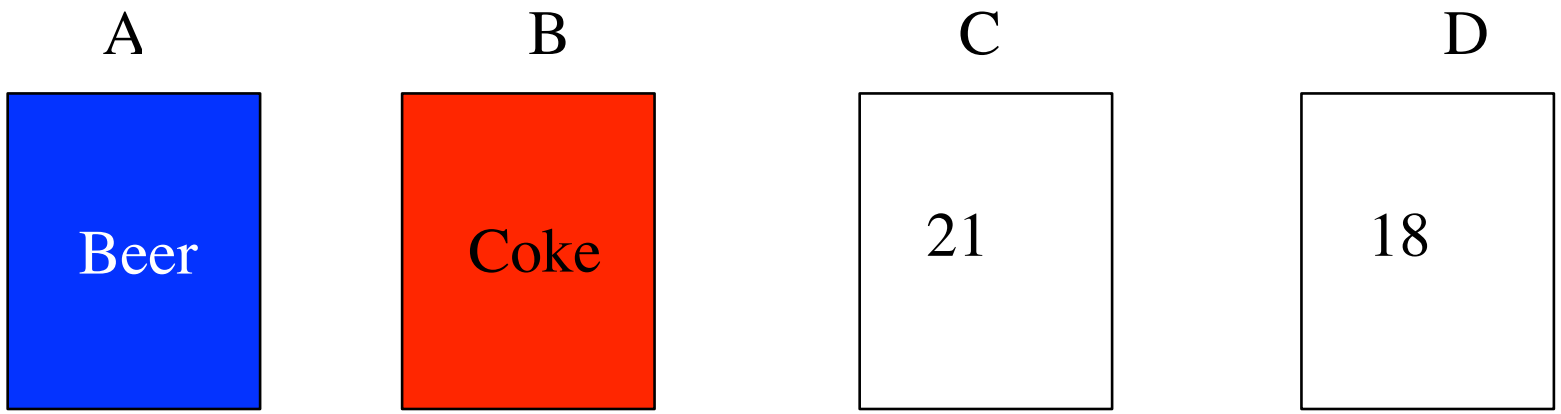


Classic logical syllogisms

- All men are mortal, Socrates is a man, therefore Socrates is mortal (yes)
- All men are mortal, Raja is mortal, therefore Raja is a man (no)
- Truth tables as way of analyzing logical argument.

Truth tables as aid to reasoning

- If A then B, examine A (modus Ponens)

Premise A => B	Observe A	Predict B	Observe B	Conclusion A => B
	T	T	T	T
	T	T	F	F
	F	?	T	?
	F	?	F	?

Truth tables as aid to reasoning

- Consider If A then B, examine not B (modus tollens)

Premise A => B	Observe B	Predict A	Observe A	Conclusion A => B
	T	?	T	?
	T	?	F	?
	F	F	T	F
	F	F	F	T

Truth tables as aid to reasoning

- If drinking then must be 21 (modus Ponens)

Premise if drinking must be 21	Observe Beer	Predict Age	Observe age = 21	Conclusion Beer => 21
	T	21	T	T
	T	21	F	F
	F	?	T	?
	F	?	F	?

Truth tables as aid to reasoning

- If drinking then 21, observe not 21 (modus tollens)

Premise if drinking must be 21	Observe Age = 21	Predict Beer	Observe Beer	Conclusion beer => 21
	T	?	T	?
	T	?	F	?
	F	F	T	F
	F	F	F	T

Reasoning in Research

- Karl Popper and the testability of theory
  - The hallmark of science is the testability of theory
  - Non-testable theories are not science
  - "it must be possible for all empirical scientific systems to be refuted by experience"
  - Theories are not shown to be correct, they are shown to be incorrect
- Science is the process of asking questions that have answers (Rep. Rush Holt)

J. Platt and Strong Inference

(Science, 1964)

- 4 signs of strong science
  - Devising alternative hypotheses;
  - Devising a crucial experiment (or several of them), with alternative possible outcomes, each of which will, as nearly is possible, exclude one or more of the hypotheses;
  - Carrying out the experiment so as to get a clean result;
  - Recycling the procedure, making subhypotheses or sequential hypotheses to refine the possibilities that remain, and so on.

Strong inference

- A theory which cannot be mortally endangered cannot be alive. (Rushton, as cited by Platt)
- "The problems of how enzymes are induced, of how proteins are synthesized, of how antibodies are formed, are closer to solution than is generally believed. If you do stupid experiments, and finish one a year, it can take 50 years. But if you stop doing experiments for a little while and *think* how proteins can possibly be synthesized, there are only about 5 different ways, not 50! And it will take only a few experiments to distinguish these." (Szilzard, as cited by Platt)

Platt and Strong Inference

"I will mention one severe but useful private test - a touchstone of strong inference - that removes the necessity for third-person criticism, because it is a test that anyone can learn to carry with him for use as needed. It is our old friend the Baconian "exclusion," but I call it "The Question." Obviously it should be applied as much to one's own thinking as to others'. It consists of asking in your own mind, on hearing any scientific explanation or theory put forward, "But sir, what experiment could *dis* prove your hypothesis?"; or, on hearing a scientific experiment described, "But sir, what hypothesis does your experiment *dis* prove?" Platt, *Science*, 1964

Sherlock Holmes and Theory

- "By the method of exclusion, I had arrived at this result, for no other hypothesis would meet the facts" [*A Study in Scarlet* , pt. 2, ch. 7]
- "when you have eliminated the impossible, whatever remains, however improbable, must be the truth" [*The Sign of Four* , ch. 6]

- (From Soshichi Uchii, Sherlock Holmes and Probabilistic Induction. http://www.bun.kyoto-u.ac.jp/~suchii/holmes_1.html

Sherlock Holmes and Theory

- “Most people, if you describe a train of events to them, will tell you what the result would be. They can put those events together in their minds, and argue from them that something will come to pass. There are few people, however, who, if told them a result, would be able to evolve from their own inner consciousness what the steps were which led up to that result. This power is what I mean when I talk of reasoning backward, or analytically." [*A Study in Scarlet* , pt.2, ch.7]

The problem of knowing the answer

- Everything is certain if you know how it turns out.
  - Easy to explain why something happened if you know that it did happen.
  - But this ease leads to false confidence of understanding.
- It is predicting what will happen in the future that is difficult.

Reasoning in Research

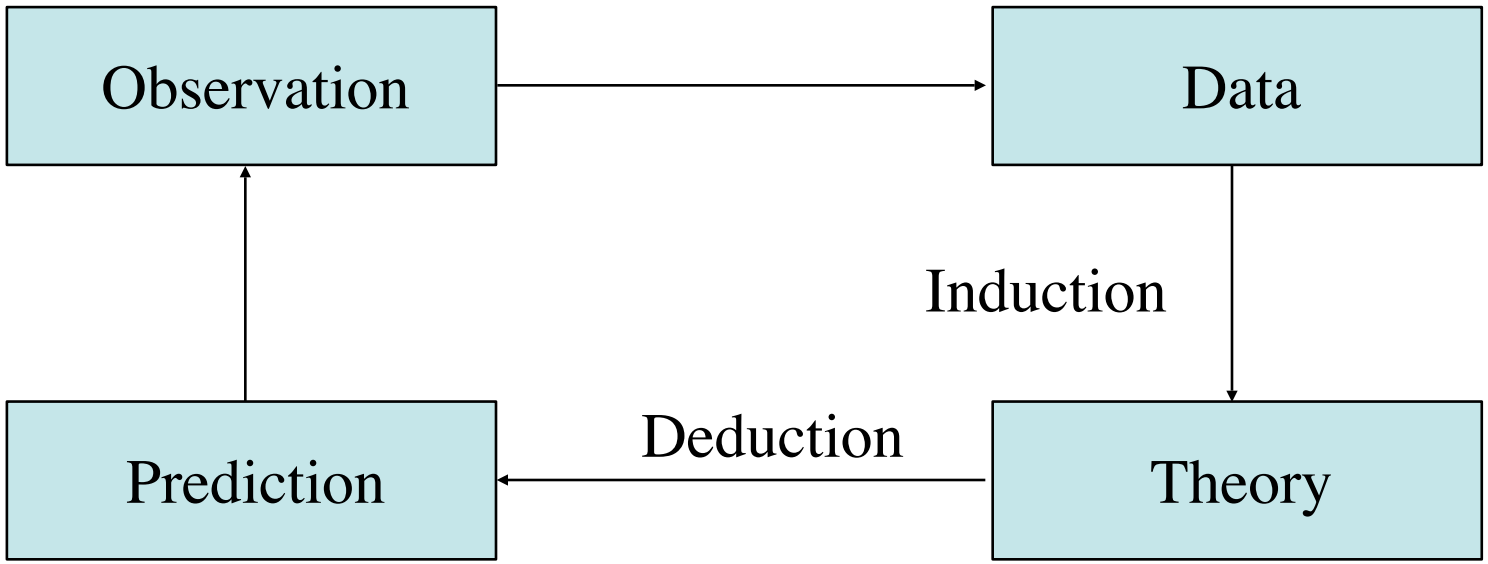
Observe, Induce, Deduce, Predict, Observe

Disconfirm, don't confirm

Prune the tree of alternative explanations

Be modest about the strength of your explanations

Reasoning in Research



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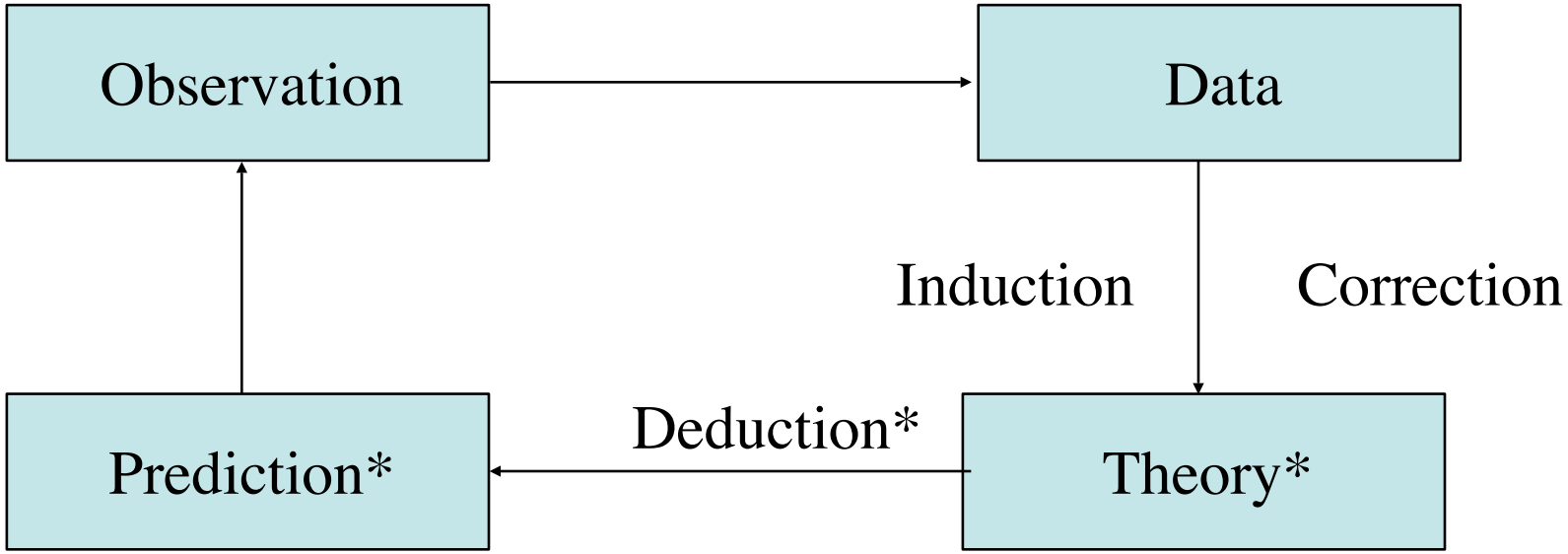


Review of statistical concepts

- 205.wk.2.meansvariances.stats

Reasoning in research

- The example of Madsen and McGaugh (1961)
- The pitting of two theoretical explanations for the same phenomena
- Meta question:
  - What is memory and how is it stored
  - Historical studies on memory consolidation had shown temporal effects of Electroconvulsive Shock on memory

Madsen and McGaugh

- Prior work on ECS and memory consolidation (Duncan)
  - retrograde amnesia -- loss of memory for an event immediately prior to a trauma.
  - Avoidance learning followed by ECS
    - Box with two compartments
      - brightly lit but safe compartment
      - unlit compartment with gridded and electrified floor
    - Animals learn to avoid the gridded side
  - ECS applied various times after learning trials

Duncan, 1949

TABLE 1

Mean numbers of anticipatory responses, all groups

Data based on animals that completed the experiment

GROUP	n	N	MEAN	σM
20 sec.....	12	11	2.54	.85
40 sec.....	12	7	5.85	1.02
60 sec.....	12	9	8.00	.77
4 min.....	12	9	9.11	1.66
15 min.....	12	10	10.20	.79
1 hr.....	6	6	12.33	.68
4 hr.....	6	6	12.16	1.36
14 hr.....	18	15	12.66	.68
Control.....	18	18	12.00	.53

n — number of animals at the beginning of the experiment.
N — number of animals that completed the experiment.

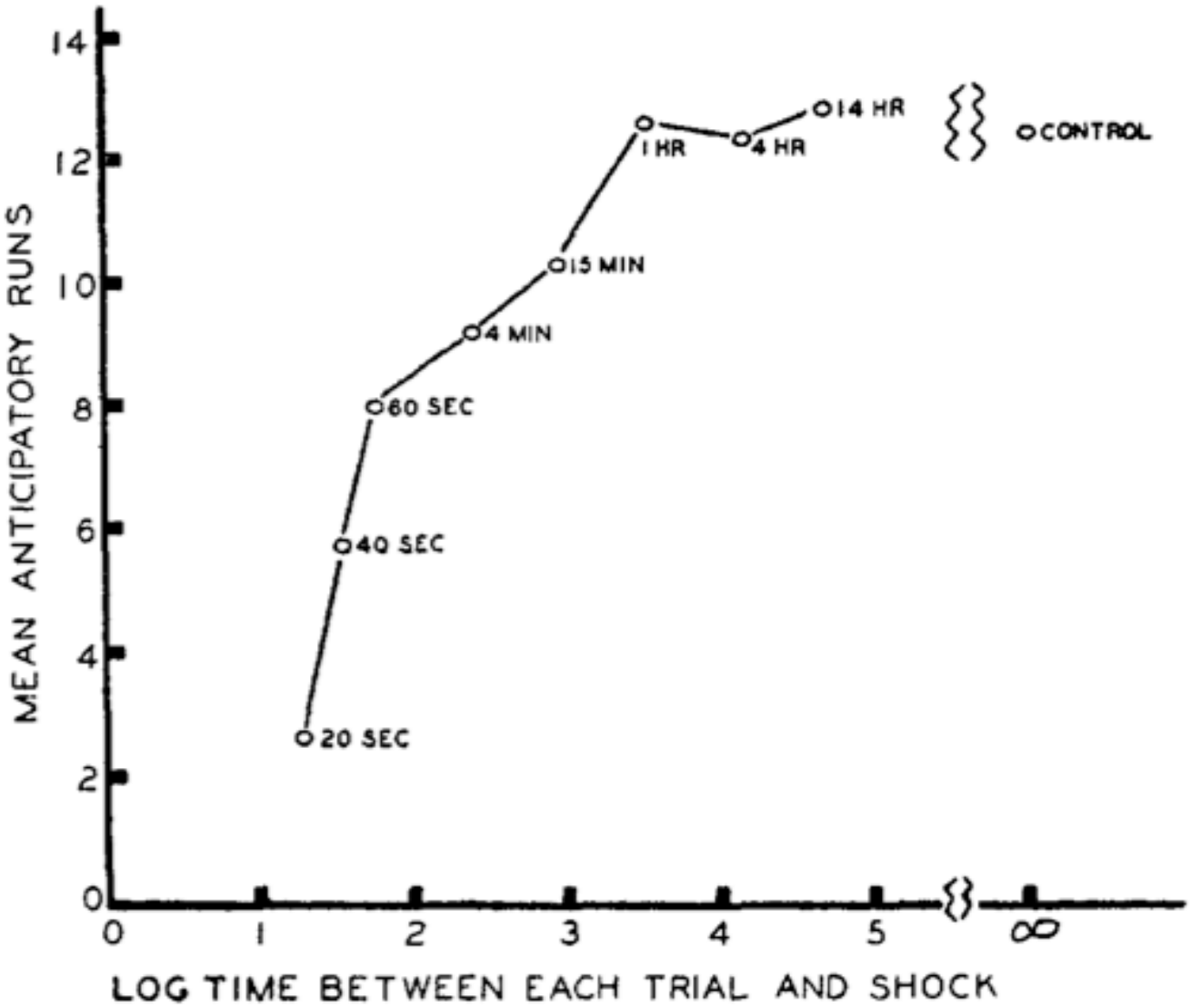


FIGURE 1. MEAN ANTICIPATORY RUNS FOR ALL 18 TRIALS AS A FUNCTION OF THE TRIAL-ELECTROSHOCK INTERVAL EXPRESSED IN LOGS

Different points on the curve represent different groups

Learning curves Duncan, 1949

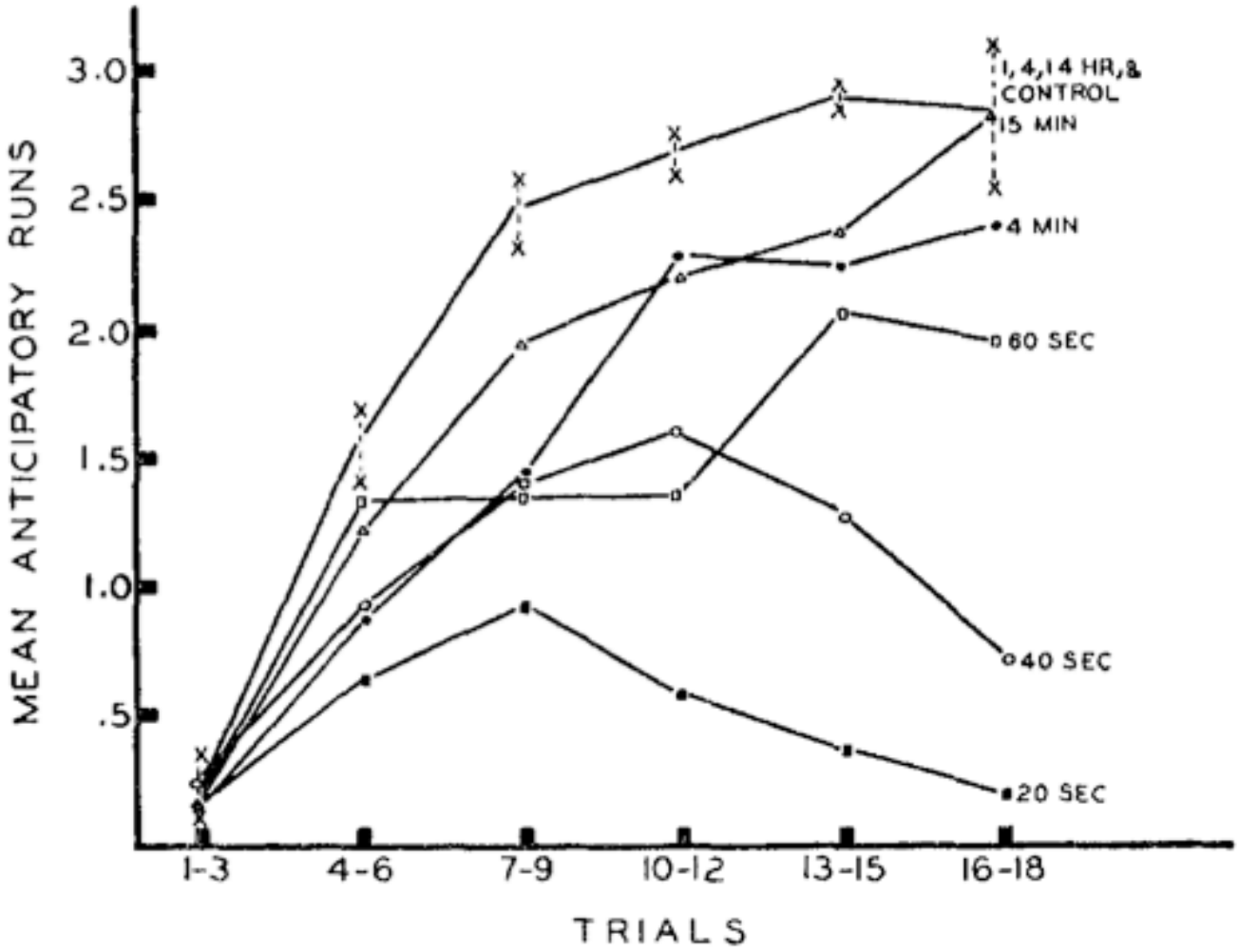


FIGURE 2. LEARNING CURVES FOR ALL 9 GROUPS

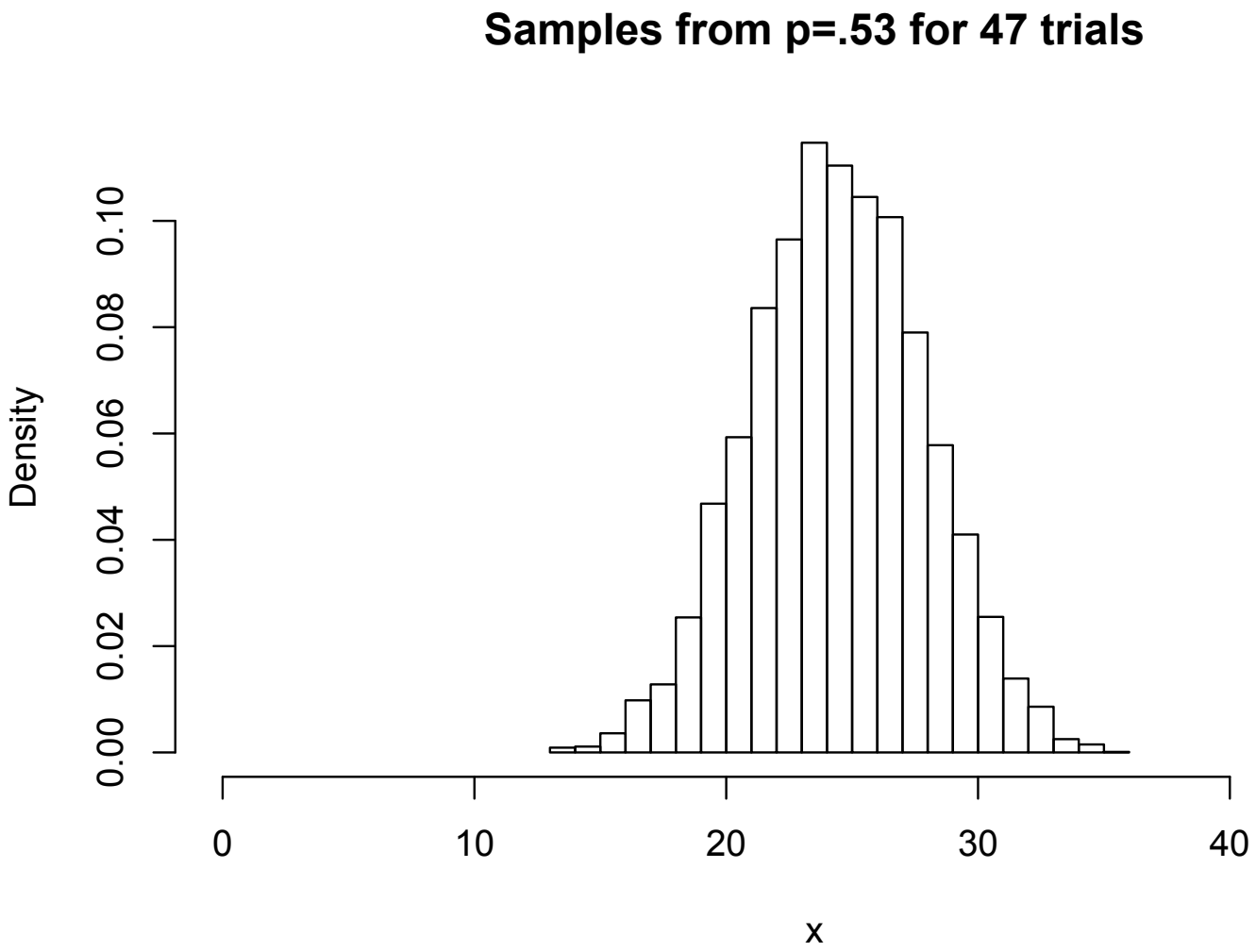
But is this effect fear or retrograde amnesia

- Madsen and McGaugh chose a task that fear and amnesia made opposite predictions
- Step down avoidance
  - stand on a plate, shocked if step off the plate
  - experimental rats received ECS 5 seconds after stepping off the plate, controls did not
- Learning would lead to not stepping off plate
- Fear would lead to not stepping off plate
- Amnesia would inhibit learning

Madsen and McGaugh

Strain	Control		Experimental	
	Avoid	Not Avoid	Avoid	Not Avoid
S1	11	17	1	22
S2	15	6	7	17
Total	26	23	8	39

Statistical analysis by the binomial distribution



Madsen and McGaugh

- ECS impairs memory, not by inducing fear
- Subsequent work by McGaugh has been tracking the storage process of memory.
- What circuits and neuro-transmitters facilitate and hinder the storage of memory.