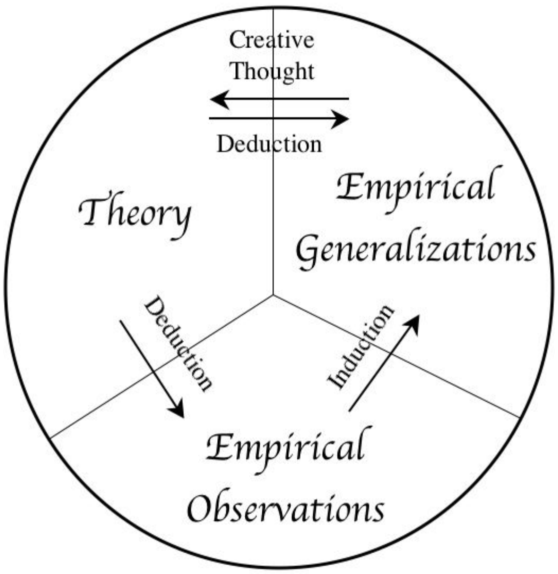
Science, Theories, Models and Data
Psych 465A
Lawrence Ward

1. The Mandala of Science (Michael Ovenden and Lawrence Ward)

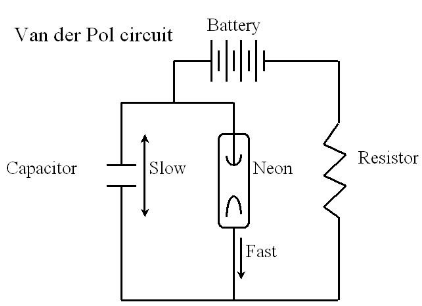


1.1 Empirical observations: lab experiments (manipulate a variable, e.g. rate of presentation of memory items), natural experiments (nature manipulates, e.g. lesion in hippocampus vs normal), systematic observations (count number of times eye witness testimony is accepted without question in different kinds of law cases).

1.11 Can be generalized to "all experiments, etc. that are conceptually similar and also do not depart significantly in method or subject population). This is also an empirical question.

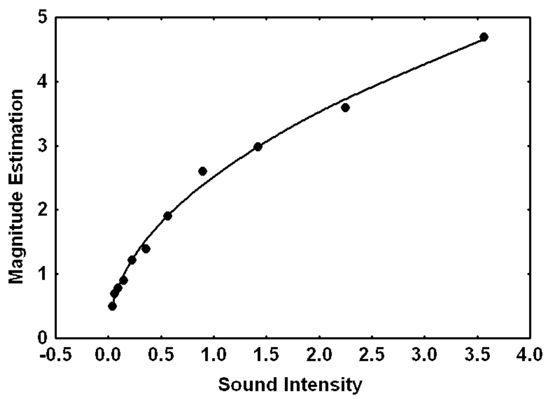
1.2 Empirical generalizations: usually achieved on the basis of many experiments, observations, etc. Ideally quantitative since that allows greatest power, but that is seldom possible in psychology.

1.21 Example from physics: Ohm's Law: $E=IR$, where E is electromotive force (measured in volts after Volterra), I is current (measured in amps after Ampere), and R is resistance (measured in ohms after Ohm). Works for all electrical circuits, e.g.,



Note this circuit was the first to produce chaos!

1.22 Example from psychology: Stevens's Power Law, $R=aI^m$, where R is the average magnitude estimation or other psychophysical judgment, I is the stimulus intensity in physical units, a is a measurement constant, and m is an exponent that differs across sensory modalities. This describes the relationship between stimulus intensity and subjective sensation magnitude for all stimulus modalities and several different psychophysical judgment paradigms. Based on several hundred experiments by many tens of researchers. For example, magnitude estimations of loudness give the following data and the corresponding equation is $R=aI^{0.6}$.



1.3 Theory: a theory is a set of definitions of concepts, elementary propositions (axioms) about the properties of those concepts, and a set of derived propositions (predictions) about those same concepts. Theories can be formal (e.g., mathematical) or informal (e.g., verbal, flow diagrams). Either formal logic (e.g., Boolean algebra) or everday reasoning is used to derive propositions from axioms.

1.31 Example from physics: Newton's mechanics (formal)

1. Definitions: measured quantities, e.g., space (x, y, z), time (t), mass (m)

2. Newton's First Law (Axiom) of Motion: A body remains at rest or in uniform motion in a straight line unless acted on by a force (i.e., sum of forces in any direction at a particular time t on a body in equilibrium is 0: $\Sigma F_x=0$, $\Sigma F_y=0$).

3. Newton's Second Law of Motion: $\Sigma F = ma = m(d^2x/dt^2]$ where F is represented as a vector sum (i.e. mathematics of vector calculus, invented by Newton and Liebniz, is also assumed).

4. Newton's Third Law of Motion: To every action there is an equal and opposite reaction, i.e., whenever a force is exerted upon an object to change its motion, there is also, at the same time, an equal force exerted in the opposite direction.

5. See any physics book for many derived propositions; example are orbital mechanics, falling bodies (gravity), shot arrows and thrown rocks.

1.32 Example from physics: Einstein's theory of special relativity (formal)

1. Definitions: *relative* space (x, y, z) and time (t)

2. Principle of Relativity: all inertial systems moving relative to one another nonetheless observe the same (simplest) physical laws.

3. Principle of constancy of speed of light: The speed of light in all

inertial systems has the same value, *c*, when measured in the same way.

4. Derived propositions: time and space contraction, mass increases with speed, $E=mc^2$!

1.33 Example from physics: Quantum electrodynamics (QED, formal)

1. Definitions: space (*x, y, z*), time (*t*), electron, photon, energy as in quantum mechanics (wave/particle duality)

2.Axiom 1: Electrons move in space/time (see diagram at end)

3. Axiom 2: Photons move in space/time

4. Axiom 3: Electrons *scatter* (absorb and then emit) photons

5. Derived propositions: *all* of physics except subatomic and gravitational

1.34 Example from biology: Darwin's theory of evolution (informal)

1. Definitions: organism, species, inheritance, reproduction, etc.

2. Axiom 1: Individual organisms of the same species exhibit more or less inherited, random, variation on many traits.

4. Axiom 2: All organisms produce more offspring than can survive (reproduce).

5. Axiom 3: Natural selection: the traits of the organisms who produce the most offspring (usually the most adapted to the environment, those who survive the longest) will dominate in future generations.

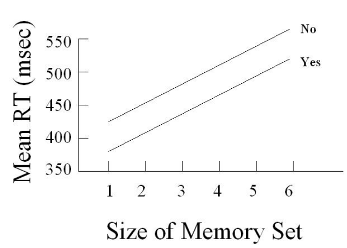
6. Derived propositions: evolution of species, fossil record, modern cases of speciation resulting from adaptation to specific environments (e.g., moths in England)

1.35 Example from psychology: No examples that have proved as successful as the ones above. Psychology has few grand theories; mostly has models of specific experimental paradigms or specific mechanisms of cognitive, emotional, behavioral, etc. processes.

1.36 Model of short-term memory scanning (based on Sternberg's experimental work and his and other's theories)

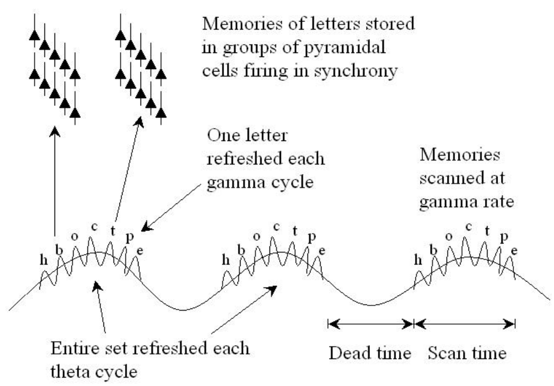
1. The paradigm: present subjects with several items to remember then, after a short delay (2-3 sec) present them with a test item. Subjects are to say "yes" the test item is among the remembered items or "no" it is not. Operationalization of short-term memory functioning in general.

2. Typical results:



3. Sternberg's model: serial exhaustive search of memory set, that is test item is compared (fixed time per comparison) to the memory set items one at a time; when all comparisons are concluded result is available. This implies $RT = mI + T_r$, where RT is response time, I is the number of memory set items, m is the time taken to compare the test item to a memory set item, and T_r is the residual response time (all other sources, e.g., motor response, decision, etc.). Typically, m is about 35 msec.

4. This theory explains Sternberg's results and many others quite well. However, it doesn't explain other results, e.g., serial position effects (for short memory set - test item durations, when test item is among last few memory set items to be listed RT is faster), at all. New theory needed. Also, it doesn't say how this serial exhaustive scanning mechanism is implemented in the brain. A theory of Lisman and Idiart does both and also explains why typical short-term memory capacity is around 7 items (gamma/theta = 40/6 = 6.67).



6. Other models exist to explain the same data. All have been simulated and/or calculated (Townsend and Ashby). Where are we?

Feynman space-time diagram relevant to QED