The Nature of Learning and Memory

Arlo Clark-Foos, Ph.D.
• Life Without Memory (Clive Wearing)
  – Video

Clive’s Diary

“10:08 a.m.: Now I am superlatively awake. First time aware for years.”
“10:13 a.m.: Now I am overwhelmingly awake.”
“10:28 a.m.: Actually I am now the first time awake for years.”
Nature’s Influence on Memory

- Genes determine the possible range.
- Reflex actions, simple behaviors
  - Knee-jerk, swallow, suck, grip
Experience (and memory of it) determines our individual differences and allows us to improve upon initial behaviors and reflexes.
Top-Down vs. Bottom-Up Processing

• How well can you read these sentences?

The quick brown fox jumps over the lazy dog.

Pack my box with five dozen liquor jugs.
Memory Shapes Future Behavior

• Context and Expectations

Group 1

Group 2
What do you see?

Bugelski & Alampay (1961)
What do you see?

Jastrow (1899)
What do you see?

Kremen (2010)
What do you see?
HISTORICAL APPROACHES TO SCIENCE AND HUMAN MEMORY
Ancient Greeks

- Introspection, Logic, & Philosophy
- Plato’s Aviary metaphor
Socrates and Plato

• All knowledge is innate,
  *The Republic*

• Intuition and Logic

Aristotle

“other animals (as well as man) have memory, but ... none ... except man, shares in the faculty of recollection”

• Observation and Data ➔ Theories

• Contiguity, Frequency, Similarity

• Memory
  – Replication of sensory perception
  – Passive re-perception
    • Familiarity?

• Reminiscence
  – Replaying an entire experience
  – Temporal contiguity
    • Recollection?
Descartes and Dualism

Mind

Cogito ergo sum
(Descartes, 1637)

Knowledge is mostly innate

Body

Stimulus, Response (reflex arc)
Like a machine/clock
Animal “Spirits” flow

2 October 2017
John Locke’s Empiricism

- Absolute Power of the Monarchy
  - Isaac Newton’s Light and Robert Boyle’s chemicals
    - Associationism (Green, Bitter/Sour vs. Limes)
  - Tabula rasa & Empiricism
    - Knowledge (and memory) come from experience
  - Thomas Jefferson’s Declaration of Independence
    “Life, liberty, and the pursuit of happiness”
• Habit
  – Automatic associations, underlie all three basic forms of memory

1. Representative Memory
   • Most complex, flexible
     * Conscious recollection

2. Mechanical Memory
   • Motor / Procedural actions

3. Sensitive Memory
   • Emotional associations
• 1⁰ Intro Psychology course in America (Harvard, 1869)
  – **Goal of Psychology**: Understand principles that govern formation and maintenance of new skills and memories!

• Empiricism and **Associationism** (Aristotle and Locke)

Memory depends on:
  1. Strengthening of reflex pathways
  2. Associational Links

Two Types of Memories
• Primary memory vs. Secondary memory
Theories of Evolution

Two Darwins: Erasmus (Evolution) and grandson Charles (Natural Selection)

Evolutionary Psychology

Greater capacity for learning and memory
Herman Ebbinghaus
Father of Modern Memory Research
(1850-1909)

• Fechner’s Law and JNDs for Perception (Psychophysics)
  – Mathematical and Statistical Analysis
    • Later, Clark Hull

• Sole Participant & Familiarity (CVCs)

• Memory & Forgetting
  – Retention Curves, Savings
• Experimental Rigor
  – Independent and Dependent Variables
    • Delay Length, List Length, Memory Retention
  – Subject & Experimenter Bias
  – Blind Designs
  – Placebo
Ivan Pavlov
(1849-1936)

• Interaction of nervous system and bodily function (digestion)
  – Like cutting edge technology: Telephones!
  – Nobel Prize in Physiology or Medicine (1904)

• Psychic Secretion and Classical Conditioning
  – US, UR, CS, CR
  – Extinction, Generalization

How powerful is Classical (Pavlovian) Conditioning?
Can a puma fire a canon?

Training by laboratory workers has overcome the puma’s fear of firearms.
Edward L. Thorndike
(1874-1949)

- Student of William James
- Instrumental (Operant) Conditioning
  - Law of Effect
    - The effects of actions affect future actions.
    - Adaptive behaviors should evolve.
  - Reward & Punishment
The Rise of Behaviorism
John B. Watson
Father of Behaviorism
(1878-1958)

• “Purely objective experimental branch of natural science” (1913)

• Rats can run a maze without their senses
  – Everything is S-R

• Little Albert
  – Little Douglas (born 1919 - died 1925)
    (Beck, Levinson, & Irons, 2009)

• Behaviorism and mental events
  “Give me a dozen health infants…” (1924)

The Burning Question
How is Albert today?
B. F. Skinner
(1904-1990)

- Operant Conditioning
- Serendipity and Variable Reinforcement
- *Walden Two* (1948)
- Radical Behaviorist
  - Chomsky & Language
Behaviorism vs. Cognition

- Edward Tolman (1948/51): Neo-Behaviorist

- Cognitive Maps: “Behavior reeks of purpose” (1932)
  - Latent Learning
Behaviorism vs. Cognition: T-maze

(A) Train one or two weeks

(B) Test at the end of each week

Recall place (Cognitivist prediction)

Repeat turn (Behaviorist prediction)
• Striatum vs. Hippocampus (Packard & McGaugh, 1996)
• Habit vs. Explicit Memory

• Implications: Lowering the dosage for infant Tylenol
Mathematical Psychology

• Clark Hull
  – One equation to control them all!

• W. K. Estes
  – Stimulus Sampling Theory
  – Perturbation Model
• Learning by Insight
  – Aha (single trial learning)
    • Aggregate Data
    • Combination Lock Game

• Mood and Memory

• Multicomponent Theory of the Memory Trace
Information

- Claude Shannon @ Bell Labs
  - Information Theory
    - “Chris, a student in your class, is male”
    - Prior knowledge and bits of information.

- George Miller
  - Context and jamming German radios
    - “Help, I’m Drowning” vs Man on Street
  - Total Capacity and Short-term Memory
    - Digit Span and Magic Number 7 ± 2

2 October 2017
• Connectionist Models
  (Rumelhart & McClelland, 1986)
  – Nodes and Connections
  – Distributed Representations
  – Pick’s Disease
1. How do sensations or ideas become linked in the mind?
   – Contiguity, Frequency, Similarity (Aristotle), Pavlov, Thorndike, Hull, Skinner, etc.

2. How are memories built from the components of experience?
   – Associationism (Locke), James, Estes, Rumelhart, etc.

3. To what extent are behaviors and abilities determined by biological inheritance (nature) and to what extent by life experiences (nurture)?
   – Empiricism (Aristotle & Locke & Behaviorism) vs. Nativism (Descartes & Kant)

4. In what ways are human learning and memory similar to learning and memory in other animals, and in what ways do they differ?
   – Evolution (Darwins), Computer Models, Continuum of Cognition (Rumelhart & McClelland), etc.

5. Can the psychological study of the mind be rigorously scientific, uncovering universal principles of learning and memory that can be described by mathematical equations and considered fundamental laws?