

# Cognitive Neuroscience for AI Developers

## Psychology – Historical Approaches



# What is psychology?

- Psychology is the **scientific** study of mind and behavior.
  - Internal mental events: perception, reasoning, language, visual imagery
  - External events: behavior, speech
  - Scientific Method (only modern Psychology, not like Philosophy)
- Many competing theories
  - Voluntarism
  - Structuralism **Cataloging “stuff” in our head**
  - Functionalism
  - Gestalt theory
  - Psychoanalytic psychology
  - Behaviorism



Source: wikipedia.org

Wilhelm Wundt (German physiologist and psychologist, seated) with colleagues in his psychological laboratory, the first of its kind.

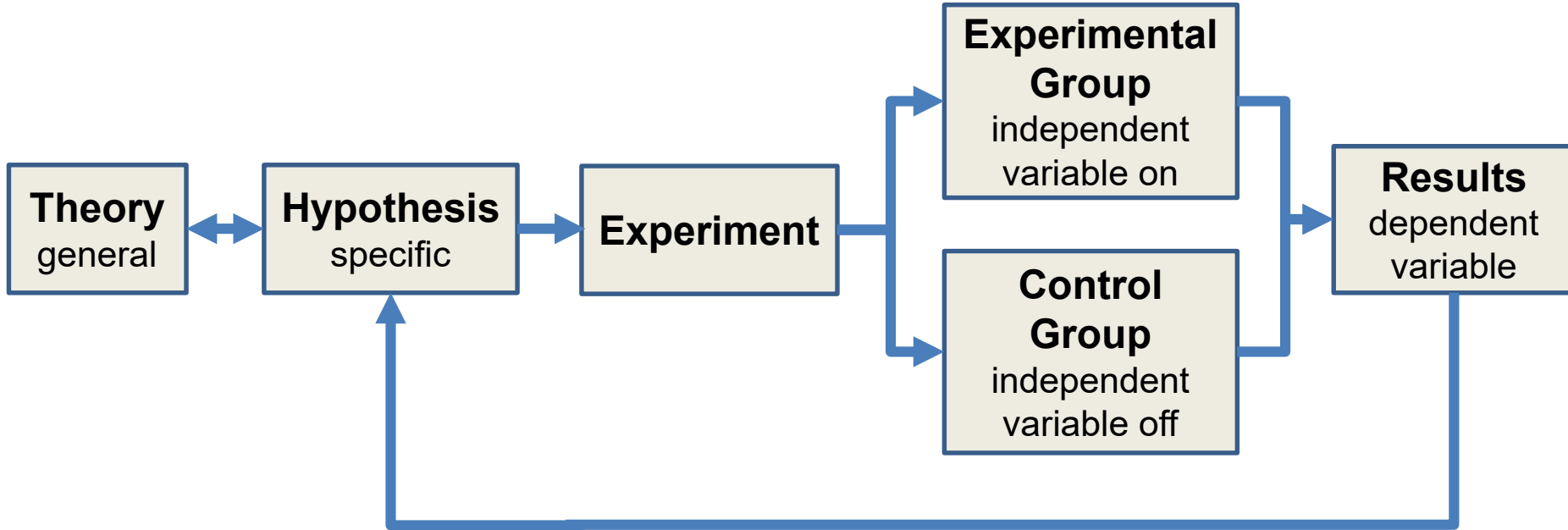
# The psychological approach to Cognitive Science

- Psychology as a science since late 19th century
- Relatively young discipline compared to philosophy
- Relatively old discipline compared to AI and robotics
- First discipline to study mental phenomena with scientific methods
- Broad field with many subdisciplines and competing theories

# Psychology and the scientific method

- Early psychologist relied on **introspection** and **phenomenology**
- Main methods (now):  
questionnaires, surveys, case study analysis, recording of behavior
- Scientific method (Hypothetic-Deductive-Approach)
  - Experiments to test hypotheses
  - Hypotheses testing to construct or adjust theories
  - Theories to generate new hypotheses
- Experiments
  - **Independent variable:** manipulated by experimenter
  - **Dependent variable:** what is measured or observed
  - **Minimum of two conditions:** experimental group vs control group

# Psychology and the scientific method



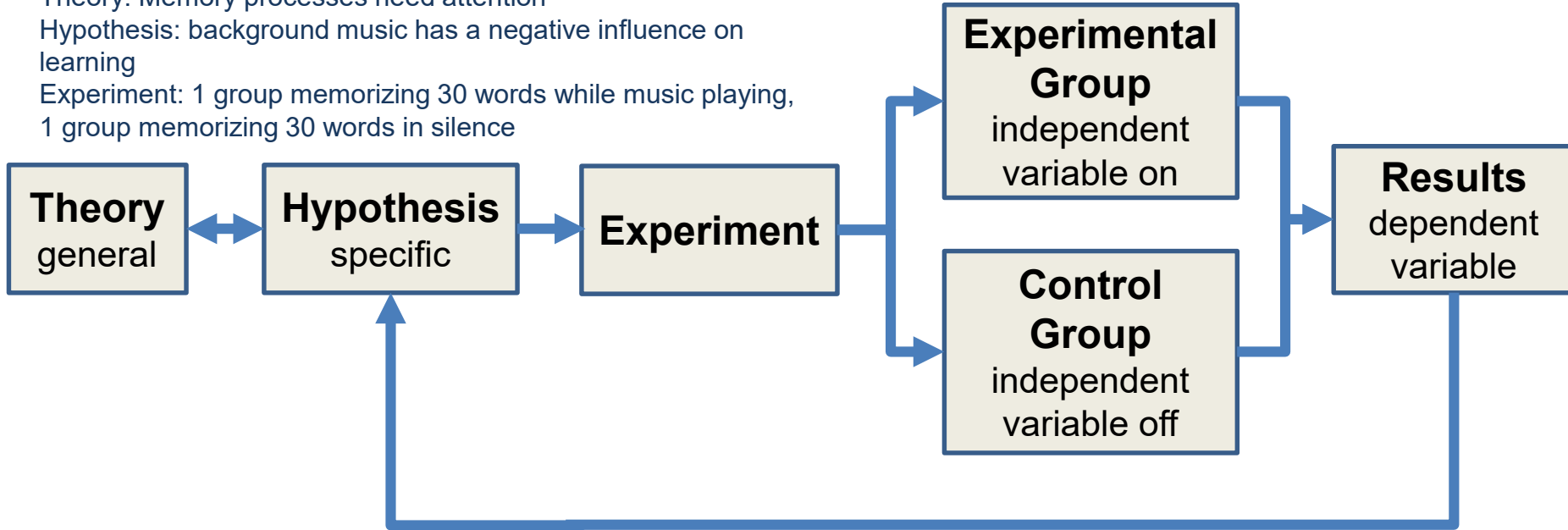
# Psychology and the scientific method

Example:

Theory: Memory processes need attention

Hypothesis: background music has a negative influence on learning

Experiment: 1 group memorizing 30 words while music playing,  
1 group memorizing 30 words in silence



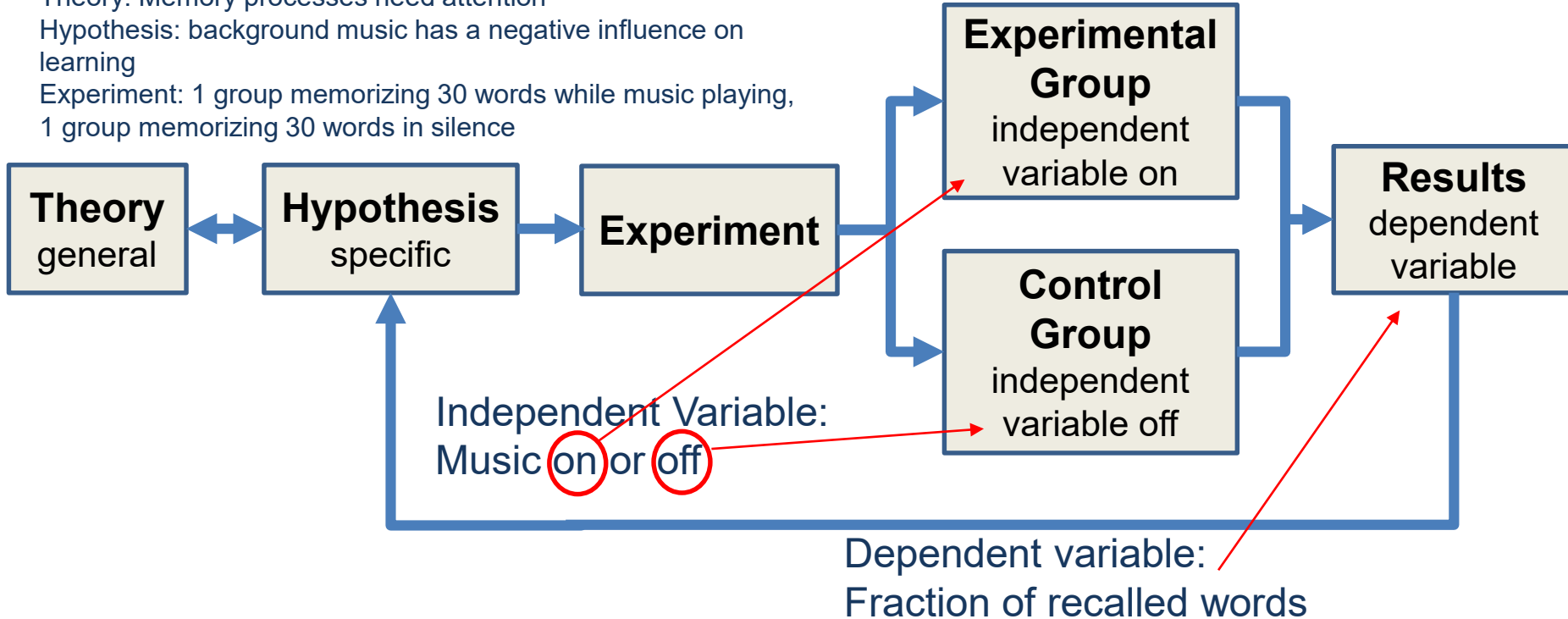
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**Attention:** There are other potential factors that have on unwanted effect

- e.g. day time: strategy **randomize** the assignment of participants
- e.g. age of participants, strategy: **counterbalance** the age of participants
- **systematic errors** are not taken into account by statistical testing  
(personal experience: systematic errors underestimated)

# Intelligence tests

- Psychology was not only interested in understanding the mind but started early to **measure** it
- Intelligence test were developed over a century ago
  - **Alfred Binet** developed methods to measure intelligence to improve France's education system
  - 1920 Binet's test were adapted by **Lewis Terman** at Stanford university to measure intelligence of students -> Stanford-Binet Intelligence Quotient (IQ) has been influential ever since
- Cultural bias in the test
  - e.g. task to name different coins -> advantage for rich people
- IQ tests were reworked several times (to reduce cultural bias)

# Intelligence tests

Still critiques of IQ-Test:

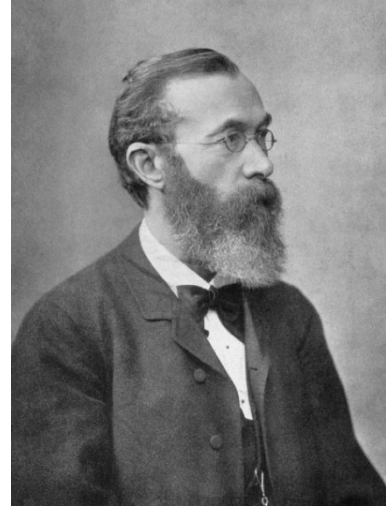
IQ test assumes that:

- a) **general intelligence is innate** -> not true  
-> In twin studies it was shown that IQ can improve when children are moved to intellectual supportive environment
- b) **intelligence can be measured with one number** -> there are different aspect of intelligence  
-> Howard Gardner (2011) -> **different types of intelligence** (at least eight):  
linguistic intelligence, musical intelligence, logical-mathematical intelligence, bodily-kinesthetic intelligence (athletes), interpersonal intelligence (sales persons), intra personal intelligence (self-knowledge)...



# Voluntarism

- **Mind consists of mental elements** assembled into higher cognitive components **through the power of will** (= voluntary effort of the mind)
- **Goal:** Periodic table of mental elements (influenced by chemistry)
- **Method:** Introspection („inward looking“)
  - Look inward to identify mental elements
  - Presented students colored objects and asked for their experiences
  - Wundt wanted to systemize introspection: students were put in state of attention and experiments were repeated several times



Source: wikipedia.org

**Willhelm Wundt**  
**1832-1920**

# Voluntarism

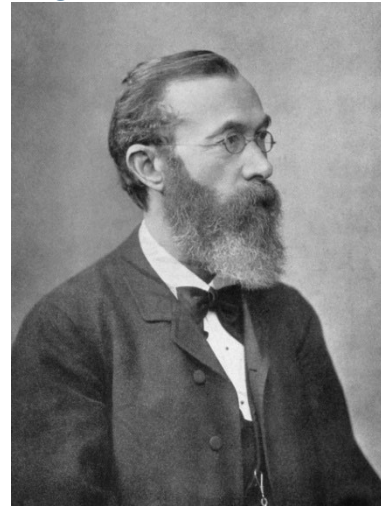
- **Wundt wanted to study consciousness**
- **Two types of conscious experience**
  - **Immediate experience:** direct awareness of something  
(we see a red rose)
  - **Mediate experience:** mental reflection  
(mental reflections about an object, e.g. tell someone about rose)
- **„Tridimensional theory of feeling“** -> all feelings characterized by three dimensions (experiments with metronome)  
Pleasure – Displeasure, Tension – Relaxation , Excitement – Depression



Source: wikipedia.org  
Willhelm Wundt 1832-1920

# Summary and Critique of Voluntarism

- Beneficial as Voluntarism was the first (scientific) attempt to studying the mind
- However: Introspection is a problematic method
  - mental experiences change over time
  - act of introspecting changes experiences
- Wundt was never able to find a list of mental elements comparable to the periodic table of elements

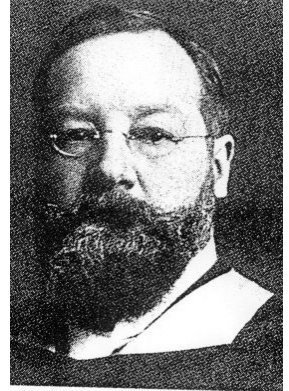


Source: wikipedia.org

**Wilhelm Wundt**  
1832-1920

# Structuralism – What the mind is

- Shares some ideas with voluntarism, Subject matter: Conscious experience
- **Mind as passive agent**, with mental elements combining according to mechanistic laws
- **Titchener wanted to avoid the Stimulus Error**: confusing true experience with description of that object based on language and previous experiences -> **only well trained observers can accurately introspect**
- **Three goals:**
  - Describe consciousness in terms of most basic components
  - Discover the laws by which these components associate
  - Understand relation between elements and psychological conditions



Source: wikipedia.org

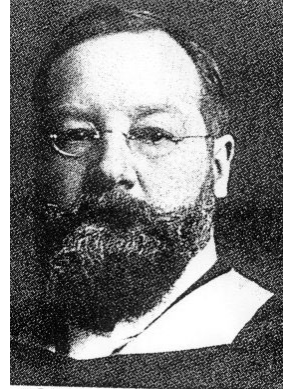
Edward Bradford  
Titchener  
1867-1927  
American  
psychologist



# Structuralism – What the mind is

- **Combination of elements not affected through active will,**  
The mind as a passive mechanism or substrate within which elements are combined according to a set of laws (mind is a reagent, sometimes participants were called reagents)

**Reagent is a substance added  
to a mixture to produce a  
chemical reaction**



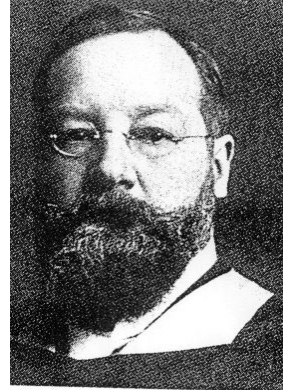
Source: wikipedia.org

Edward Bradford  
Titchener  
1867-1927

- **Total of 44,000 sensation elements described** (Titchener, 1896)
- **Sensations can be characterized by four attributes:** quality, intensity, duration, clearness (sensation one pays attention to), later also extensity (extent to which sensation fills space -> pressure from pencil vs. chair bottom)

# Summary and Critique of Structuralism

- Same points of criticism as for Voluntarism
- **Difference to Voluntarism:** Refinement of experimental procedures
- **Training of study participants biases responses even more**

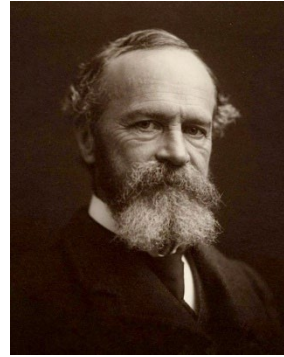


Source: wikipedia.org

Edward Bradford  
Titchener  
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# Functionalism – What the mind does

- **Focuses on what the mind can do** (not on mental elements)
- **Mental processes and functions** instead of mental elements
- **The mind as a stream of consciousness** (not mind as elements): mind is a process undergoing continuous change
- **Substantive thought** occurs when mind slows down (focus attention, in contrast to transitive thought)
- **Transitive thoughts**: less focused from of thinking



Source: wikipedia.org

William James  
1842-1910  
American  
psychologist

# Functionalism – What the mind does

- **Three major themes of functionalism** (proposed by Rowland Angell, 1907):
  - **Mental operations** (how mental process operates, what is accomplished under which conditions they occur)
  - **Fundamental utilities of consciousness**  
(role of consciousness for survival of the organism)
  - **Psychophysical relations** (relation of the psychological mind and the physical body)
- Strongly influenced by **Darwin**'s theory of natural selection (how did the mind develop under evolutionary pressure)
- Precursor of **Evolutionary Psychology** (*"the study of behavior, thought, and feeling as viewed through the lens of evolutionary biology"*) <https://www.britannica.com/science/evolutionary-psychology>

# Summary and Critique of Functionalism

- **Wide variety of methods:** e.g. questionnaires, objective behavioral descriptions, but also introspection
- **No clear definition of the word function**
  - 1) function refers to an process itself (perception and memory)
  - 2) function refers to the usefulness of the process  
(e.g. how does memory contribute to survive)
- **Too practical:** Often too focused on usefulness of function
  - Structuralism vs. Functionalism (Fight which is better basic or applied science)

# Gestalt psychology

„The whole is greater than the sum of its parts.“



Source: wikipedia.org

**Max Wertheimer**  
1880-1943



Source: www.uni-giessen.de

**Kurt Koffka**  
1886-1941



Source: psychestudy.com

**Wolfgang Kohler**  
1887-1967

# Gestalt psychology

„The whole is greater than the sum of its parts.“ (Gestalt = Integrated whole)

- **As functionalism counterreaction to structuralism** -> Conscious wholes cannot be reduced into parts (physics analogy: mental parts combined into wholes is the same as particles ordered in a field of force)
- **Main method:** Phenomenology (subjective experience, observers describe subjective experience, in contrast to introspection phenomenology focuses on **immediate subjective perception**)
- Greatest contribution of Gestalt psychology in **perception and learning** (looser in methodology e.g. observed animals finding solutions)

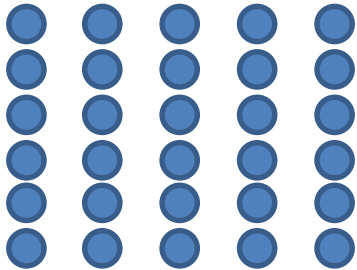
# Gestalt psychology

*„I stand at the window and see a house, trees, sky. Theoretically, I might say there were 327 brightnesses and nuances of color. Do I have 327? No. I have sky, house, and trees.“ (Max Wertheimer)*

## Gestalt principles of perceptual organization (Max Wertheimer)

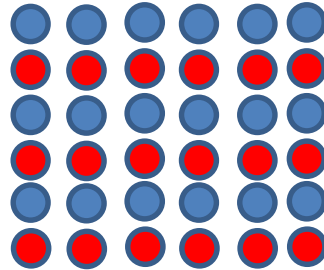
(ways in which visual parts group to form objects)

Just a few principles!



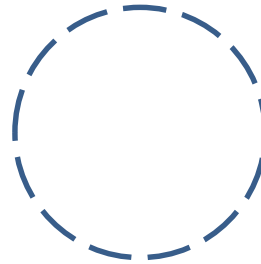
Parts that are closer  
tend to be connected

**Proximity**



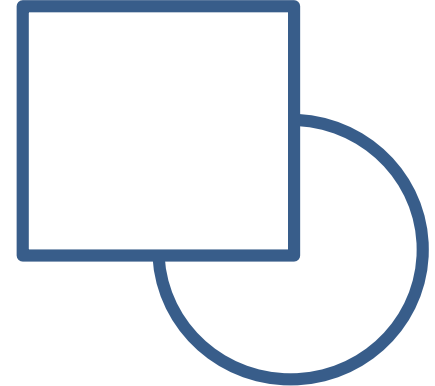
Parts that are similar  
tend to be connected

**Similarity**



Parts that form a (nearly)  
Complete object go together

**Closure**



Parts that are simple  
will group together

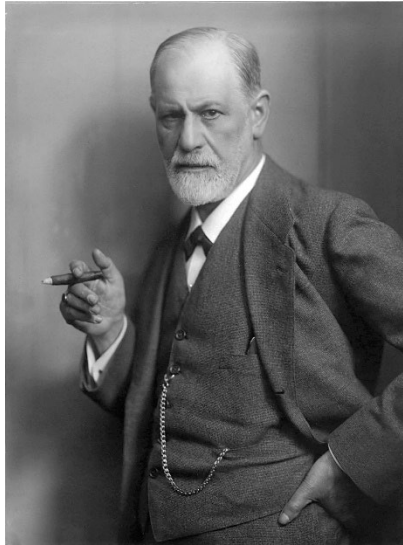
**Pragnanz**



# Summary and Critique of Gestalt Psychology

- Phenomenology approach lacks scientific rigor
- Data was not gained in experimental settings so there was no statistical analysis
- Principles of perceptual organization are just descriptive but do not provide explanations

# Psychoanalytic psychology



Source: wikipedia.org

Sigmund Freud  
1856-1939

The mind is made up of „miniature minds“ that compete with each other for control of behavior.



Source: britishpsychotherapyfoundation.org.uk

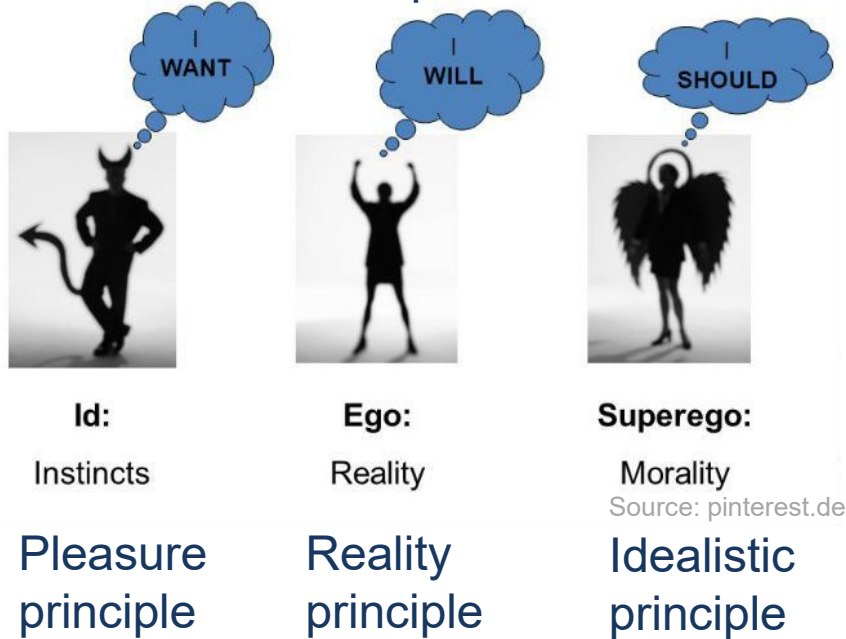
## Three-tiered system of consciousness

- **Conscious mind** (contains thoughts and feelings which we are aware of, home address)
- **Pre-conscious mind** (thoughts we can bring to consciousness with efforts, recall what one did last Friday)
- **Unconscious mind** (thoughts and experiences that can never be brought to consciousness, childhood memories)

# Psychoanalytic psychology

Three other mental structures with different operation modes

- **Id** contains unconscious impulses and desires (e.g. hunger) -> wants to attain gratification for desires immediately
- **Super ego** is responsible for ethical sense -> motivates the individual to act morally
- **Ego** balances the demands of super ego and id -> operates in a pragmatic way



# Psychoanalytic psychology



Source: simple.wikipedia.org

- Link the three mental structures (id, super ego, ego) to three-tiered system of consciousness: metaphor of iceberg
- **Id** is completely unconscious and powerful
- **Super-ego** tries to suppress the needs of the id
- **Ego** tries to balance needs of super ego and id
- **If ego fails to satisfy one -> anxiety**
- Ego constructs defense mechanism to shield itself against anxiety
  - **Repression:** banishing of anxiety arousing thoughts from consciousness
  - **Sublimation:** transform of unacceptable impulses in socially valued motivations

**Freuds model of the mind as machine with interacting parts -> he used many terms from mechanics and electronics**

# Summary and critique of Psychoanalytic psychology

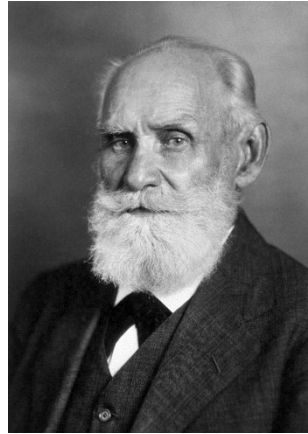
- Approach stimulated further research in the area of unconscious processes and inspired generations in clinical practice
- **Critique:** Freud overestimated parental and early childhood influence
- **Scientific shortcomings:** theory not based on objective observations but on notes about Freud's patients
- Freud's ideas have no predictive power

# Behaviorism – The mind as a black box



Source: wikipedia.org

**Edward L. Thorndike**  
1874-1949



Source: wikipedia.org

**Ivan Pavlov**  
1849-1936

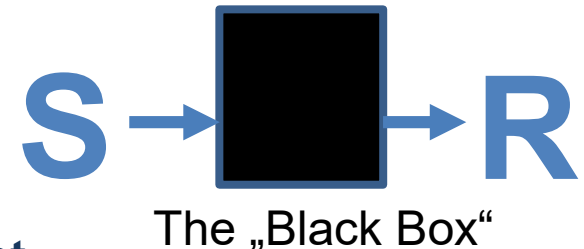


Source: wikipedia.org

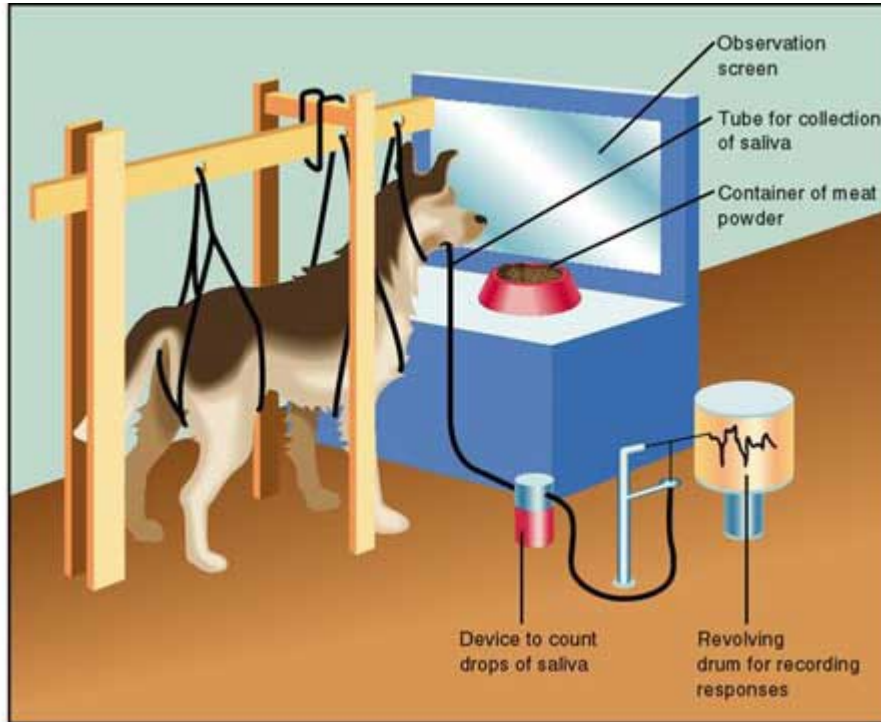
**Burrhus F. Skinner**  
1904-1990

# Behaviorism – The mind as a black box

- Mind is too complex to be studied scientifically
- Behaviorists thought that the scientific method cannot be applied to the mind (no good technique) -> behavioral experiments
- Behaviorism influenced by animal research
- Humans were lumped in the same category as animals -> more general/natural science
- Behaviorists rejected introspection
- Most important stimuli are **reward and punishment**

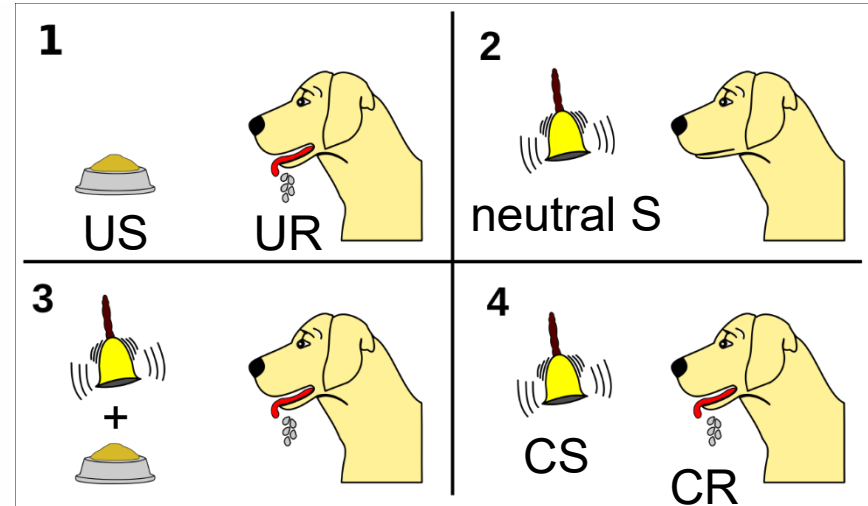


# Behaviorism – Classical conditioning



Source: simplypsychology.org

Just built-in reactions of animals



Source: wikipedia.org

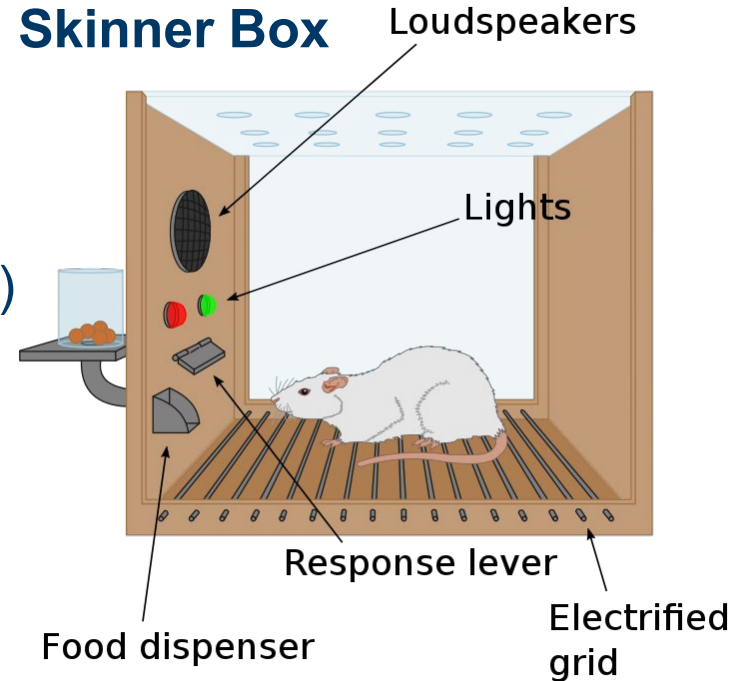
US: Unconditioned Stimulus  
UR: Unconditioned Response  
CS: Conditioned Stimulus  
CR: Conditioned Response



# Behaviorism – Operant conditioning

## Learning through

- **Reinforcement**  
(anything that increases the frequency of the response, e.g. by food)
- **Punishment** (decreases the frequency of responses, e.g. by electric shock)



Source: wikipedia.org

# Behaviorism – Summary and Criticism

- **Strength:** completely objective science of behavior, rigorous scientific methods
- Behaviorism was the dominant paradigm until the 1960s -> **rise of cognitive psychology**
- Edward Chance Tolman (1886-1959) found out that reward and **punishment is not necessary for learning** -> he challenged classical doctrine of behaviorism -> rats can navigate through maze after exploration (no reward or punishment) -> **latent learning**

# Summary of the psychological approach

- **Historical:** many different theoretical positions and schools of thought
- First discipline to systematically apply experiments to study mind
- Initially **lack of precision** and reliance on **non-scientific methods**
- Initially **no overarching theory or framework**

## Today

- Cognitive approach and information-processing perspective
  - > Cognitive Psychology and Cognitive Neuroscience