

Mark Van Selst
San Jose State University

COGNITION

Chapter 9: Problem Solving

Fundamentals of Cognitive Psychology *(Kellogg)*

Fall 2013

Defining a problem

There is a problem when a goal is not immediately able to be achieved (e.g., Reitman, 1965; Newell & Simon, 1972).

Problem-solving is the identification and selection of solutions to the problem.

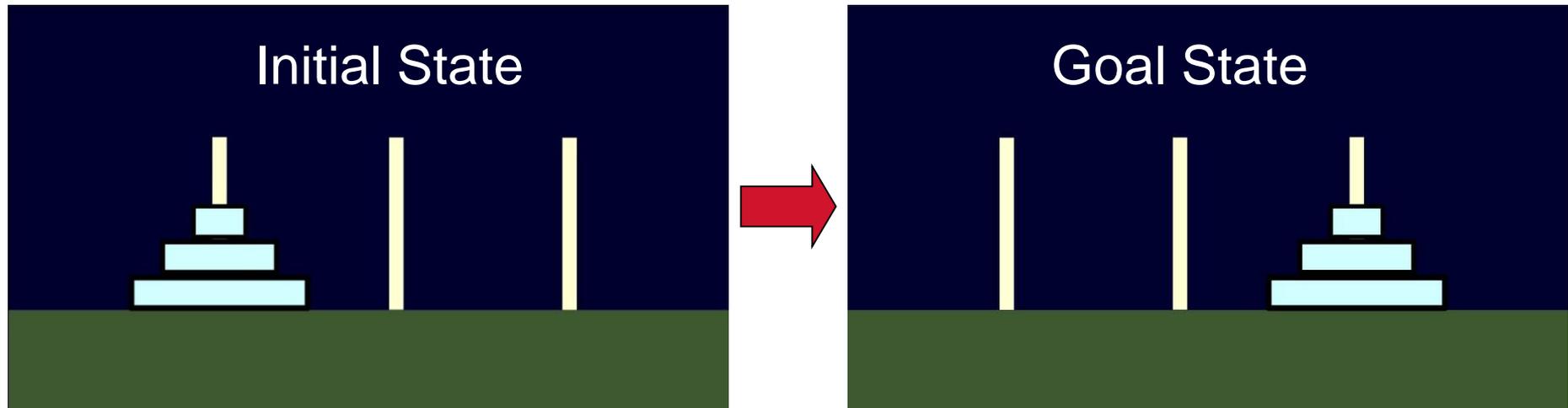
Directed and Undirected Thinking

- **Directed: Goal-oriented and rational**
 - Requires a clear well-defined goal
- **Undirected: Meanders (day dreams, dreaming, drifting thoughts, etc.)**
 - Plays a role in creativity and poorly-defined problems

Well-Defined and Ill-Defined Problems

Tower Of Hanoi (well-defined problem)

Move from start state to end state by moving one disk at a time, and never placing a smaller disk on a larger disk.



Well-Defined Problem

Goal State (clear)

Initial State (clear)

Subgoals (problem can be broken down)

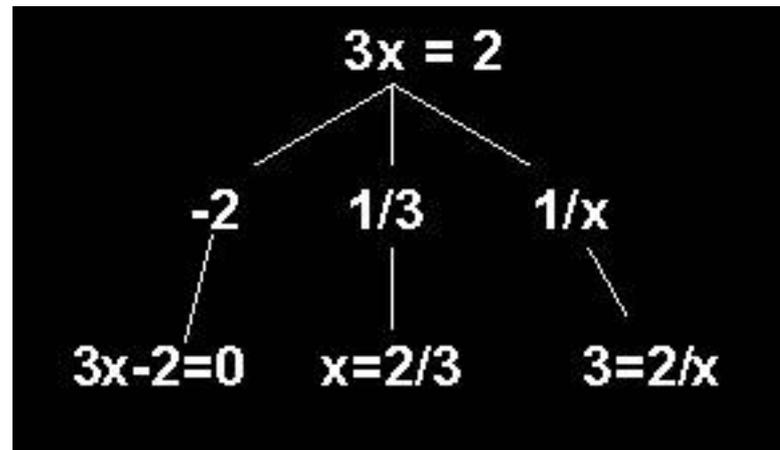
Problem Space (all possible legal moves [operators])

Problem Space (Newell & Simon)

all possible legal moves

Each legal move from the initial state to some intermediate state is specifically defined by an OPERATOR.

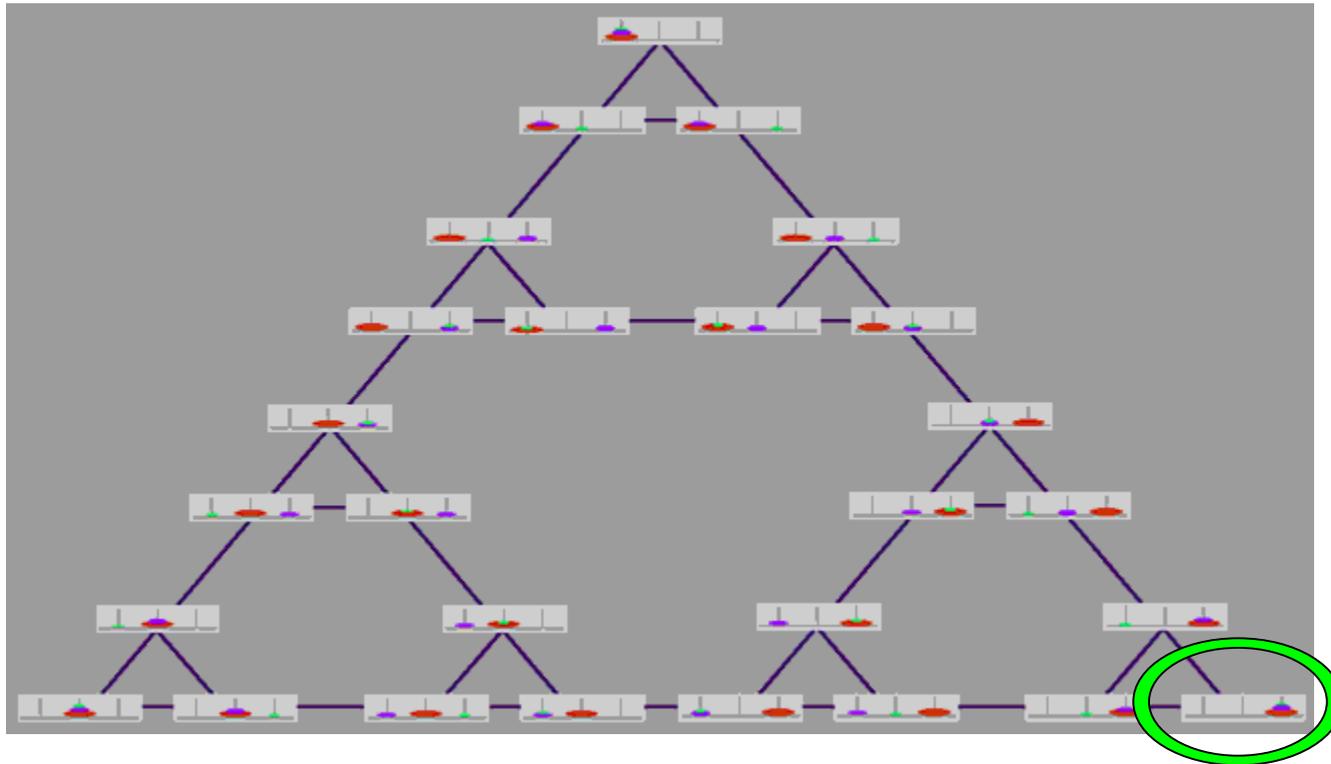
Solve for x :



Tower Of Hanoi (the problem space)

Well-Defined Problem

- Goal State, Initial State, Subgoals, Problem Space



• Goal State

all possible legal moves (operator actions)

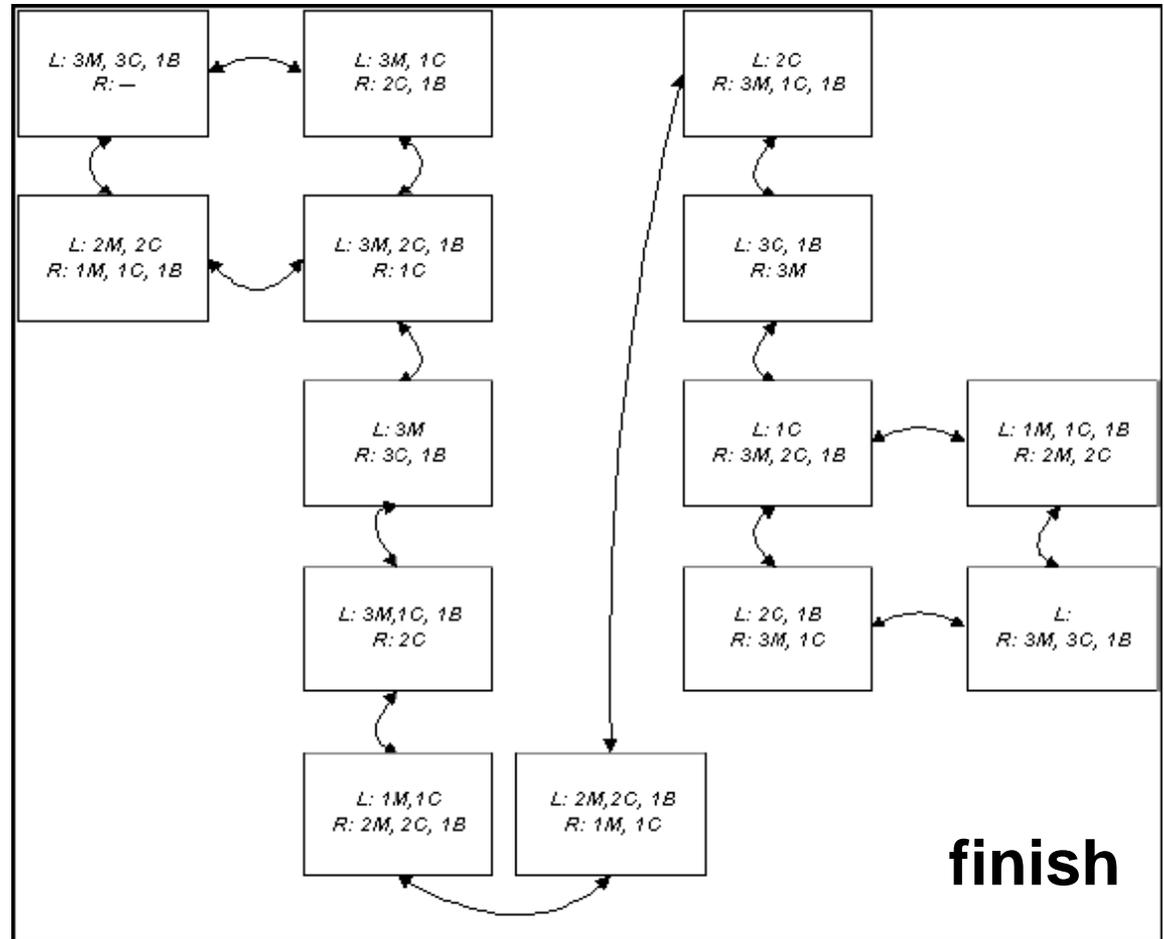
Missionaries and Cannibals

- Your task is to take 3 missionaries and 3 cannibals across the river.

- The boat holds 2.

- The cannibals must never outnumber the missionaries (or they will eat them).

start



- How do you advance in your chosen career?
 - What is the goal state?
 - What is your current state (initial state)
 - What are the intermediate goals (subgoal decomposition)
 - What are all possible operations [OPERATORS] that could be employed (i.e., what is the problem space?)

Well-defined problems

- Your car doesn't start in the morning and you want to try and find out what's wrong with it
- You want to beat an opponent at chess
- You want to find a street in an unfamiliar city

Ill-defined problems

- You want to be happy
- You want to be successful
- Draw a picture
- Write an essay

Productive and Reproductive Problem Solving

The GESTALT approach to problem solving differentiates between:

Productive Thinking

- insight and creativity

Reproductive Thinking

- following a sequence known to produce a workable answer

Gestalt approach to problem-solving

Adapted their problem-solving approach from perception. Perception inherently involves **restructuring**.

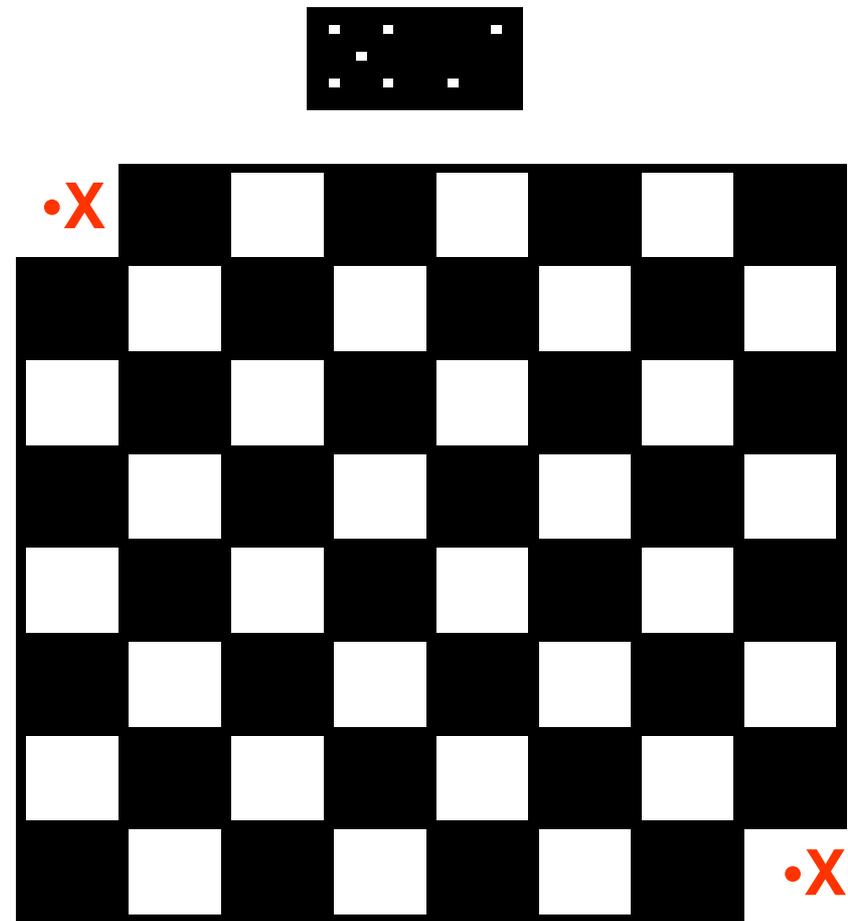
- Two views of Necker cube seen by restructuring image to see as “right” or “left”

Person often has to **restructure** a problem in order to gain **insight** into its solution



Chessboard / Domino Problem (Mutilated Chessboard Problem)

We have a chessboard with the two opposing corners removed, so that there are only 62 squares remaining. Now we take 31 dominoes shaped such that each domino covers exactly two squares. The question is: is it possible to arrange the 31 dominoes so that they cover all 62 squares on the chessboard?



Monkeys showed “insight” during problem-solving.

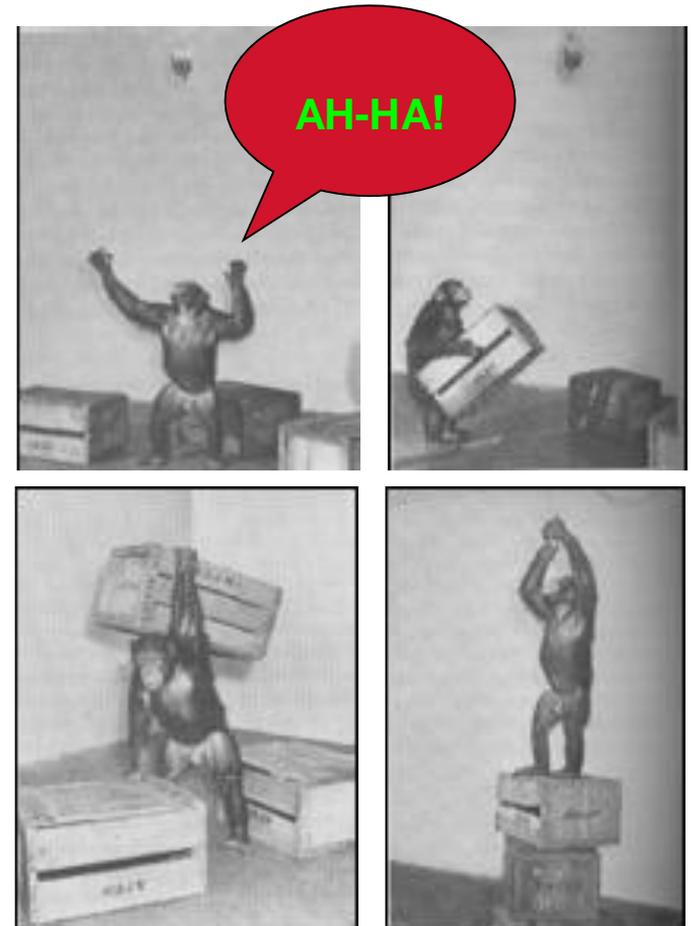
- Demonstrated productive “new way of structuring elements showing insight and creativity”
- Deep useful understanding of the nature of the problem
- versus trial-and-error (a.k.a., reproductive // tried and true // rule-based) problem solving (e.g., of the cat-in-the-box of Thorndike, 1898).

Solved problems by using tools.

Sultan stacks boxes to reach bananas.

Cognition

Van Selst (Kellogg Chapter 9)





Gestalt approach to problem-solving

THE CANDLE PROBLEM (Dunker, 1945)

- Fix lit candle to wall, with candle, box of nails & box of matches.

THE TWO-STRING PROBLEM (Maier, 1931).

Subjects in room with 2 strings hanging from ceiling and set of other objects (nut, bowl, pliers, sandwich, ...).

- Task is to attach the strings. However, cannot reach them at same time.

WATER-JUG PROBLEM

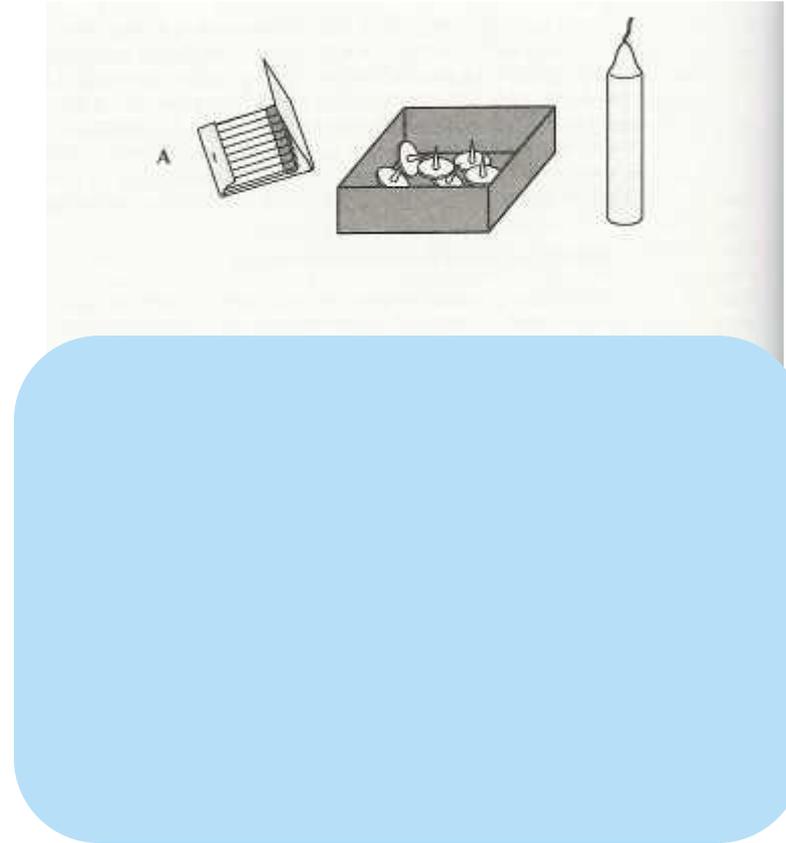
- The subject is given a set of jugs of various stated capacities, and is asked to measure out a desired quantity of water

NINE-DOT PROBLEM (Scheerer, 1931)

- Connect all nine dots by drawing four continuous lines?

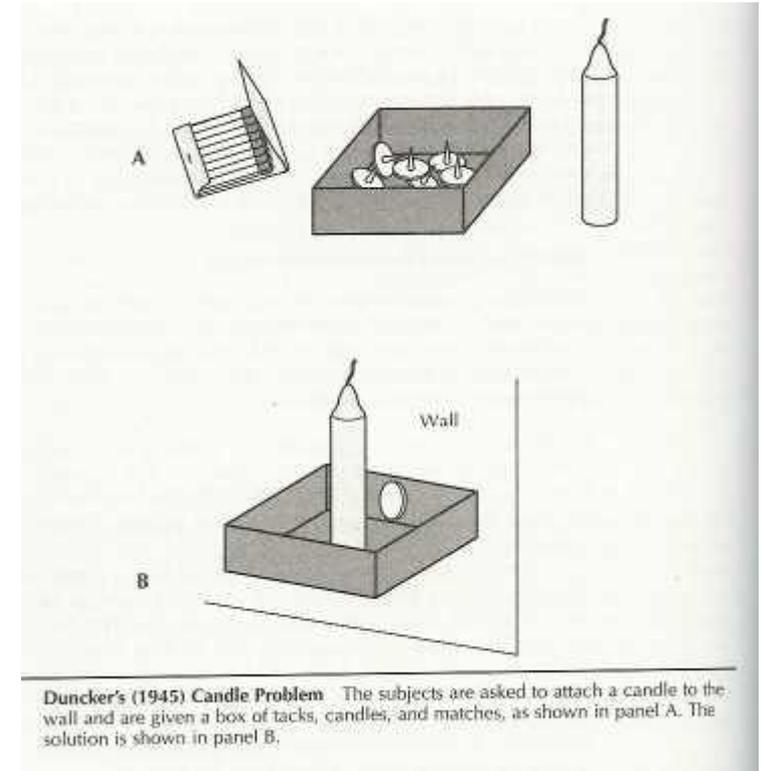
Duncker's (1945) Candle Problem (Functional Fixedness)

- Participants were provided a candle, a box of nails, and several other objects, and asked to attach the candle to the wall so that it did not drip onto the table below.
- Participants tried to nail the candle directly to the wall or to glue it to the wall by melting it. Very few thought of using the inside of the nail box as a candle-holder and nailing this to the wall.
- The participants were “fixated” on the box’s normal function of holding nails and could not reconceptualize it in a manner that allowed them to solve the problem.

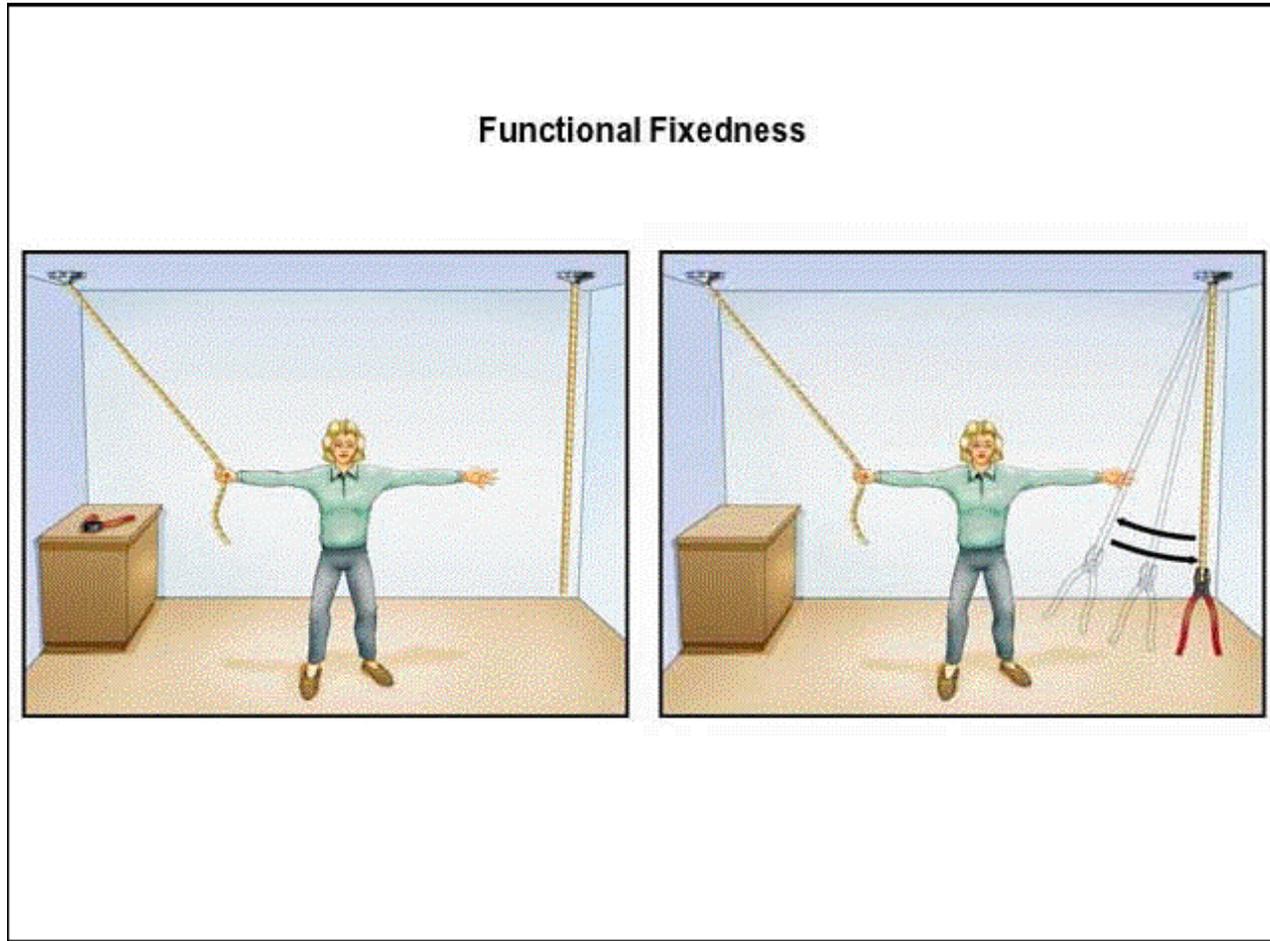


Duncker's (1945) Candle Problem (Functional Fixedness)

- Participants were provided a candle, a box of nails, and several other objects, and asked to attach the candle to the wall so that it did not drip onto the table below.
- Participants tried to nail the candle directly to the wall or to glue it to the wall by melting it. Very few thought of using the inside of the nail box as a candle-holder and nailing this to the wall.
- The participants were “fixated” on the box’s normal function of holding nails and could not reconceptualize it in a manner that allowed them to solve the problem.



The Two-String Problem



Functional Fixedness

Birch and Rabinowitz (1951) adapted the two-cord problem from *Maier (1930, 1931)*, where subjects would be given 2 cords hanging from the ceiling, and 2 heavy objects in the room.

They are told they must connect the cords, but they are just far enough apart that one cannot reach the other easily.

The solution was to tie one of the heavy objects to a cord and be a weight, and swing the cord as a pendulum, catch the rope as it swings while holding on to the other rope, and then tie them together.

The participants are split into 3 groups:

- Group **R**, which completes a pretask of completing an electrical circuit by using a relay
- Group **S**, which completes the circuit with a switch
- and Group **C** which is the control group given no pretest experience.

Group R participants were more likely to use the switch as the weight, and Group S were more likely to use the relay. Both groups did so because they were previous experience led them to use the objects a certain way, and functional fixedness did not allow them to see the objects as being used for another purpose.

the water-jug experiment (Luchin 1942, 1959)

The subject is given a set of jugs of various stated capacities, and is asked to measure out a desired quantity of water.

Problem	Capacity Jug A	Capacity Jug B	Capacity Jug C	Desired quantity
1	21	127	3	100
2	14	163	25	99
3	18	43	10	5
4	9	42	6	21
5	20	59	4	31
6	23	49	3	20
7	15	39	3	18
8	28	76	3	25
9	18	48	4	22
10	14	36	8	6

the water-jug experiment (Luchin 1942, 1959)

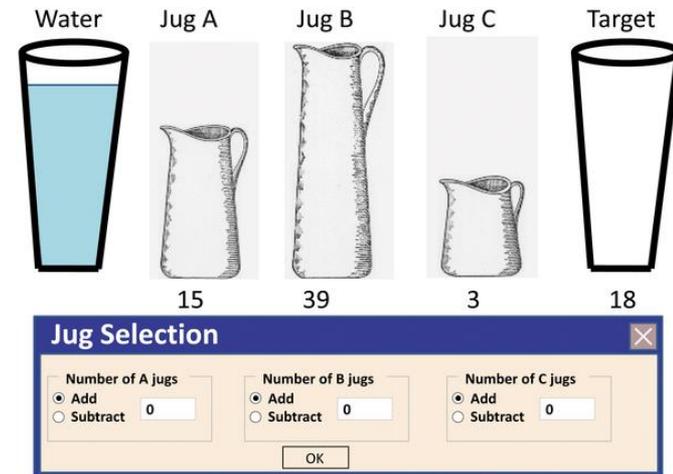
All problems except 8 can be solved by $B - 2C - A$.
 For problems 1 through 5 this solution is simplest.
 For problem 7 and 9 the simpler solution is $A + C$.
 Problem 8 cannot be solved by $B - 2C - A$, but can be solved by $A - C$.
 Problems 6 and 10 can be solved more simply as $A - C$.

Subjects who worked through all problems in order:

83% used $B - 2C - A$ on problems 6 and 7.
 64% failed to solve problem 8.
 79% used $B - 2C - A$ on problems 9 and 10.

Subjects who saw only last 5 problems.

Fewer than 1% used $B - 2C - A$.
 Only 5% failed to solve problem 8.
 Problem can be overcome by warning subjects.



After problem 5, Lurchins told some subjects "Don't be blind", which caused more than 50% to find the simpler solution on the remaining problems.

Gestalt approach to problem-solving

THE CANDLE PROBLEM (Dunker, 1945)

→ **Functional Fixedness: limited by thinking about the normal functional uses of an object**

THE TWO-STRING PROBLEM (Maier, 1931).

→ **Functional Fixedness: limited by thinking about the normal functional uses of an object**

WATER-JUG PROBLEM

→ **Fixation** occurs when solver is fixated on wrong approach to problem. It often is result of past experience.

→ **Fixation** refers to the blocking of solution paths to a problem that is caused by past experiences related to the problem

→ **NEGATIVE SET (set effects)** - bias or tendency to solve a problem a particular way

NINE-DOT PROBLEM (Scheerer, 1931)

→ fixation, negative set

Restructuring Using Analogies (Duncker, 1945)

- One special kind of restructuring, is analogical problem solving.
- To find a solution to one problem - the so called target problem, an analogous solution to another problem - the source problem, is presented.

As a doctor you have to treat a patient with a malignant, inoperable tumor, buried deep inside the body. There exists a special kind of ray, which is perfectly harmless at a low intensity, but at the sufficient high intensity is able to destroy the tumor - as well as the healthy tissue on his way to it. What can be done to avoid the latter?

When this question was asked to participants in an experiment, most of them couldn't come up with the appropriate answer to the problem. Then they were told a story that went something like this:

Reasoning by Analogy

This is the “source” problem

In this case it is an ISOMORPH of the “target” problem

A General wanted to capture his enemy's fortress. He gathered a large army to launch a full-scale direct attack, but then learned, that all the roads leading directly towards the fortress were blocked by mines. These roadblocks were designed in such a way, that it was possible for small groups of the fortress-owner's men to pass them safely, but every large group of men would initially set them off. The General divided his troops into several smaller groups and made each of them march down a different road, timed in such a way, that the entire army would reunite exactly when reaching the fortress and could hit with full strength.

Note that superficial similarities can cause people to attempt to use similar solutions but may not detect isomorphs when presented with models from other domains.

Means-End analysis heuristic

- Identify difference between current & goal state.
- Create sub-goal & select operator that achieves it.
- If operator cannot be applied then use means-end-analysis recursively (i.e. repetitively) to remove blocking conditions.

Novice vs. Expert Problem Solving

- **Backwards Chaining** (working backwards)... working back from the end state until reaching the origin state. This is common for novice problem-solvers in the domain (also used by experts).
- **Forwards Chaining** (working forwards). Experts are much more likely to start from the origin point and move forward whenever the problem strikes them as readily solvable.



10 suggestions for improving problem solving

1. Increase domain knowledge
2. Automate some components
3. Follow a systematic plan
4. Draw inferences
5. Develop subgoals
6. Work backwards (if the goal state is well-defined)
7. Search for contradictions
8. Search for relations among problems (analogies?)
9. Find a difference problem representation
 - Think of the chess board / dominoes vs. slices of bread
10. Practice!

Creativity

The process of producing something that is both original and worthwhile.

CREATIVITY

Torrence (1974, 1984, 1988) test of creative thinking: It is how much you produce. It includes the diversity, numerosity, and appropriateness of responses to open-ended questions (such as think of all the possible ways to use a paperclip). There is a particular emphasis on how much a person had used unusual or richly textured details in completing a figure or task.

Wiesberg (1988, 1995, 1999): what distinguishes remarkably creative individuals from less creative individuals is their expertise and commitment to their creative endeavor.

- Highly creative individuals work long and hard, studying the work of their predecessors and their contemporaries, to become thoroughly expert in their fields. From this it could be argued that creativity itself is just the application of expertise (i.e., nothing special).

Baron (1988): personality-based perspective. An openness to new ways of seeing, intuition, alertness to opportunity, a liking for complexity as a challenge to find simplicity, independence of judgment that questions assumptions, willingness to take risks, unconventionality of thought that allows odd connections to be made, keen attention and a drive to find pattern and meaning. These attributed, when coupled with the motivation and the courage to create produce a creative individual.

Creativity

- Convergent vs divergent thinking (what can a brick be used for)
- Cultural Blocks (how to get a Ping-Pong ball out of a vertical tube cemented to the floor)

CREATIVE INDIVIDUALS

- Extremely high in motivation
- Nonconforming but dedicated to maintaining standards of excellence and self-discipline
- Deep belief in the value of their creative work (and will criticize & improve)
- Careful choice of problem
- Thought process characterized by insight and divergent thinking
- Risk taking
- Extensive knowledge of relevant domain (experts have: more knowledge, better knowledge, and more inter-connected knowledge structures)
- Profound commitment to the creative endeavor

TYPES OF CREATIVE CONTRIBUTIONS

- **replication:** to show that a given field is where it should be
- **redefinition:** refine where the field is
- **forward incrimination:** move the field in a direction it is already moving
- **advance forward incrimination:** moves beyond where others in the field are ready for the field to go
- **redirection**
- **reconstruction-redirection:** attempt to move the field back so that it can move forward from that point
- **reinitiation:** a new and not yet reached starting point
- **integration:** synthesis of formerly distinct or divergent ideas

NOTE: I WILL NOT ASK YOU TO KNOW THESE “TYPES”

Stages of the Creative Process

PREPARATION

- development of expertise; training and background

INCUBATION

ILLUMINATION

- Non-detailed grasp of the deep structure of the solution

VERIFICATION

- Ensuring that the solution works

Key Terms (partial list)

- Directed / undirected thinking
- Well / ill –defined problems
- Initial state
- Goal state
- Subgoal
- Operator
- Problem space
- (Re)Productive thinking
- Isomorphic problems
- Algorithm
- Heuristic
- Metacognition
- Creativity
- Incubation
- Verification
- Functional fixedness
- Negative set
- fixation

Assignment #8

METACOGNITION

GOAL: To have you demonstrate your grasp of metacognition.

REQUIREMENT: find (and cite) any three definitions of metacognition as used in the domain of psychological research (versus the Tony Robins late night commercial). Find, and summarize, at least one EMPIRICAL journal article investigating metacognition. At least two of the sources should be “reputable” sources (e.g., articles, university faculty web page, etc.)

Due Date: start of class.

- Be sure to include a photocopy or printout of the title page of the journal article (not the PsycInfo abstract) with your assignment.
- It is highly suggested that you start work on this assignment well before it is due.

Assignment #9 (LANGUAGE):

GOAL: To have you demonstrate your grasp of the importance of cognitive psychology in the study of language (e.g., as touched on in the discussion on page 369).

REQUIREMENT: Discuss how language can affect learning. The discussion should focus on the habitual patterns induced by the language of the person and how those thoughts might change as the learners' vocabulary expands (e.g., "learns the jargon of the discipline"). An extreme version of what I am hoping you will write would be a student submission on "how the Sapir-Whorf hypothesis applies to new concept learning." Essentially what I want you to write on is how new language acquisition impacts the learning of new "skills" such as mathematics or research methods. This essay will NOT be based on your opinions. It is to be based solely on RESEARCH FINDINGS as reported in peer-reviewed PSYCHOLOGY journal articles. As such, be sure to include a summary of what one or more articles suggests regarding this issue. You MUST use the SJSU electronic database "psycinfo" or "psycARTICLES" to aid your search and you must include one or more complete (preferably APA-style) citations to content-appropriate academic journal articles from peer-reviewed journals. It is ok to check your potential articles with me in the days before the assignment is due for either clarification about meaning or to ensure that they are sufficiently scientifically rigorous.

Due Date: start of class.

- Be sure to include a photocopy or printout of the title page of the journal article (not the PsycInfo abstract) with your assignment.
- It is highly suggested that you start work on this assignment well before it is due.

Assignment #10

(Biases in Reasoning and Decision Making):

GOAL: To have you demonstrate your grasp three different cognitive biases in decision-making. One of these must be the "*Anchoring and Adjustment*" heuristic; another must relate to the work of Kahneman. The remaining one is any cognitive biases in decision-making not already included in your write-up that was discussed in class or which is mentioned in the text (group think, framing, etc.).

REQUIREMENT: Write a report discussing the heuristics that have influenced three separate decisions that you have personally made. Provide a brief description of each of three scenarios in which you had to make a decision (or were involved in the decision making) and the cognitive biases that may have been involved (possibly in retrospect). Each of the three sections of this assignment will include a clear definition of the heuristic(s), the description of the situation, and statements that indicate why each heuristic applies to the situation as you have described it. It is possible (but not required) that multiple heuristics may have influenced each decision; you may note this, but you must describe three separate decision-making episodes. One of the episodes must use the "anchoring and adjustment" heuristic, another as discussed by Kahneman. The other heuristic is up to you.

Due Date: start of class.



Copyright 2013 / Van Selst

www.calstate.edu

www.sjsu.edu/psych