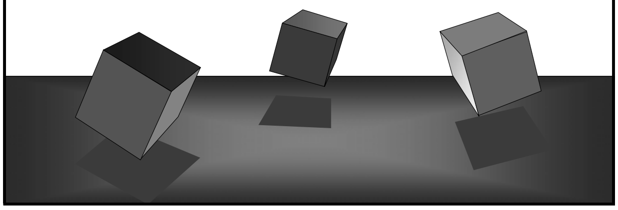
Cognitive Psychology

PSYC230

Lecture #15



Last time

Decision making

Normative (Rational) Models

Expected Value Theory
Subjective Utility Theory

Descriptive Decision Models

Framing & Sunk Cost Effects

Recognition-Primed Decision Making (RPD)

The SRK Model

Heuristics & Biases

Reasoning & Logic

Inductive & Deductive Reasoning

Neuropsychology of Decision Making

The story of Phineas Gage
Gage was foreman of railway construction gang
an explosion blew his metre-long tamping iron
through the side of his head

The tamping iron went in point first under his left cheek and completely out through the top of his head, landing about 25 to 30 meters behind him

Phineas was knocked over but may not have lost consciousness even though most of the front part of the left side of his brain was destroyed

Neuropsychology of Decision Making

The story of Phineas Gage

Several months after the accident Phineas returned to work, but because his personality had changed so much, the contractors who had employed him would not give him his place again.

He had been their most capable and efficient foreman, one with a “well-balanced mind” He was now “fitful, irreverent, and grossly profane, showing little deference for his fellows” His friends said he was “No longer Gage.”

He was also “impatient, obstinate, capricious and vacillating...unable to settle on any of the plans he devised for future action.”

Neuropsychology of Decision Making

Somatic Marker Hypothesis
(Bechara, Damasio, Tranel & Anderson, 1994)

During decision-making, emotional and visceral representations associated with an option (from prior experience) are re-activated to implicitly influence decision-making

The Iowa Gambling Task

4 decks of cards,
participants may choose
cards from any deck
Some cards pay $$
others cost $$

Neuropsychology of Decision Making

Somatic Marker Hypothesis
(Bechara, Damasio, Tranel & Anderson, 1994)

The Iowa Gambling Task

Two of the decks have large rewards but overall will lose money,
two decks have smaller rewards but will have positive payoff overall

Neuropsychology of Decision Making

Somatic Marker Hypothesis & the Iowa Gambling Task

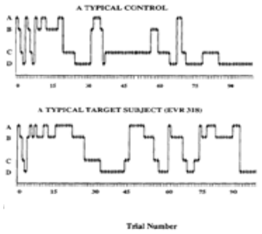
Healthy control participants will eventually select correct decks

Healthy controls develop anticipatory GSRs prior to making card choices

Patients with damage to the VMpfc will not

VMpfc patients do not develop anticipatory GSRs prior to making card choices

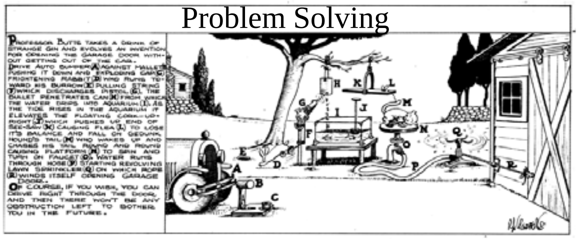
no expectation of the future consequences of their decisions



Bechara *et al.* (1994)

Substance abusers also show impairment on the gambling task & reduced anticipatory GSRs

Problem Solving



Problem solving can be thought of as a chain of decisions

We make each decision based on experience (& heuristics)

Problem Solving

History – Problem solving was an early area of interest

E.L. Thorndike's
Puzzle box experiments
(1898 - 1911)

Found gradual, trial & error problem solving, no effect of imitation,
led to *Law of Effect*

Wolfgang Kohler's
Observations of ape behaviour
(1913 to 1920)

Found sudden, insightful, discontinuous problem solving
wrote *Gestalt Psychology* (1929)

Gestalt psychologist from the University of Berlin, marooned at a primate research facility on Tenerife (Canary Islands) at the start of WWI. He had nine chimpanzees of various ages in a large outdoor pen to watch & study.

Chimps appeared to solve problems by suddenly seeing how elements could be rearranged.
Not gradual trial-and-error but sudden *insight*

Problem Solving

Information processing approach
(Representational Change Theory)

Focus on mental representation of the problem space, and spreading activation in semantic memory

The Problem Space

includes:
initial state
goal state
strategies to reach the goal
(including rules)

How do we solve problems?

Non-experts must first work to identify and define the problem space and then apply appropriate strategies

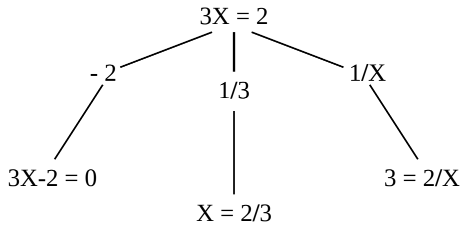
Sometimes called
"*searching the problem space*"

3 phases

1. Represent the problem
2. Generate possible solutions
3. Evaluate the solutions

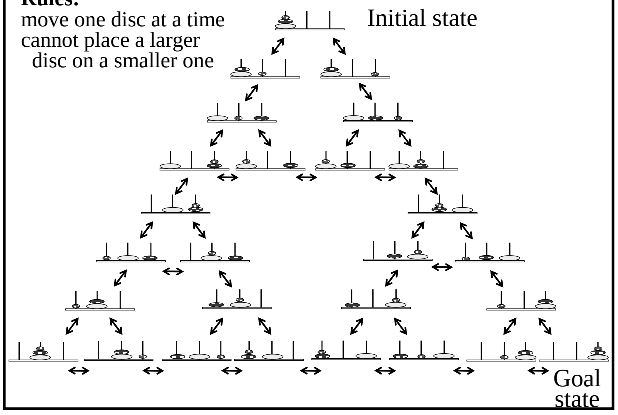
The Problem Space

Represented as a tree diagram of the problem with possible states and possible actions



Problem space for three disc TOH problem

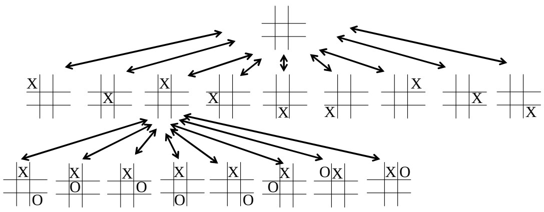
Rules:
move one disc at a time
cannot place a larger disc on a smaller one



The Problem Space

We need to develop a mental representation of the problem space and then search through it to find a path to the solution

Mentally representing a problem space can be *HARD*



The Problem Space

We need to develop a mental representation of the problem space and then search through it to find a path to the solution

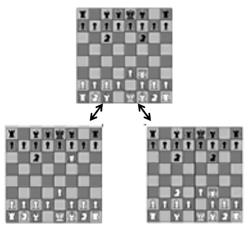
Sometimes constraints in the problem space can be used to reduce the potential number of alternative solutions and make certain problems easier to solve

Sometimes not…

Chess:
30-35 legal options at each move
30-35 possible replies

Representing the problem space for 1 move ahead requires representation of 1000 possibilities

2 moves ahead = 1000 X 1000 possibilities
3 moves ahead = 1000 X 1000 X 1000 possibilities…



representing a game of 40 moves would require a problem space of 10^{120} possible combinations…

10^{120} possible chess moves is not <u>too</u> hard for a computer…

Chess-playing computers are capable of considering 200 million moves per sec

Until 1988, a chess-playing computer had never beaten a human grand master

In 1988 a computer named *Deep Thought*
(developed by Carnegie-Mellon University)
defeated chess grand master Bent Larson of Denmark

World Chess Champion Gary Kasparov smashed *Deep Thought* in 41 moves in 1989

In May 1997 a computer named *Deep Blue* defeated still-reigning World Champion Gary Kasparov
(a rematch from Kasparov's 1996 win)

After the match, Kasparov claims *Deep Blue* was unfairly "anticipating" his moves

Adriann de Groot
Psychologist & chess master
"Thought and Choice in Chess"
(Dutch thesis - 1946; English book - 1965)

Human chess players consider only a few developments of the game at each move (not all possible moves or the entire problem space)

Excellent players (at the grandmaster level) do not consider any more moves than good tournament players

They do consider better moves (as rated by other players), and they assess moves more quickly

Better players reconstruct (from memory) briefly presented board positions more accurately than less good players

Chase & Simon (1973)

For valid board positions experts recalled 91% of positions vs. 41% for other players
For random board positions: no difference
Concluded difference was not just result of better memory

Expert Chess Players represented the positions in larger chunks
Experts use shorter glances - identify chunks faster

Grand masters may have 10,000-100,000 patterns stored in LTM

Experts quickly recognise the problem as being of "type x" and can apply past solutions (sometimes automatically)

IBM's Deep Blue

How did the chess-playing computers finally beat the human grand masters?

These computers had been built to use *chess knowledge* rather than brute force algorithms

They "mentally" re-represented the problem space and employed human-like heuristics

A more efficient approach.
Modern versions require only a standard desk-top PC

Knowledge-rich vs Knowledge-lean
and Expertise

Knowledge-lean problems are problems which do not require a lot of specialist knowledge to solve. All the knowledge required to solve the problem is given in the specification of the problem.
Example: the Tower of Hanoi

Knowledge-rich problems are problems that require a lot of specialist knowledge (called *expertise*) not included in the specification of the problem.
Example: the game of chess

Knowledge-rich vs Knowledge-lean
and Expertise

The greatest difference between experts and novices is in representing the problem

Experts are able recognise the deep structure of problems and ignore the superficial structure

Schoenfeld and Herman (1982): mathematics professors and mathematics novices were presented with mathematical problems and were asked to group them by similarity.
Novices tended to group the problems by superficial details (surface structure)
Professors tended to group the problems by similarity of solution methods (deep structure)

Knowledge-rich vs Knowledge-lean
and Expertise

Experts also apply heuristics
learned from previous experience

Chess masters regularly study previous games

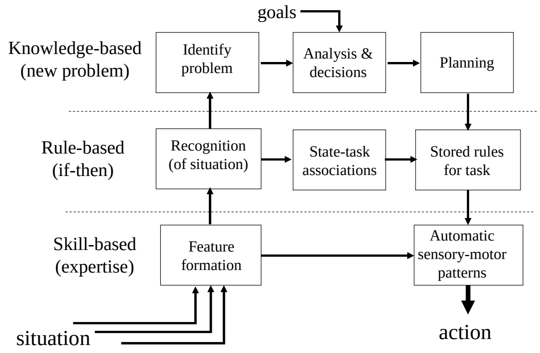
Experts knowledge is not only more extensive,
it is better organised :
Extensively cross-referenced, with a rich network
of connections between concepts

Experts understand better the *relationships*
in their domain

The 10-year rule for the acquisition
of expertise in a complex skill
(Ericsson et al, 1993)

The SRK Model

Rasmussen



Solving a problem is a function of your
previous experience

*Have you encountered a problem
like this before?*

Yes, frequently Use skill-based expertise

Yes, sort of… Use rules (heuristics) learned
from similar experiences

No, never Identify problem space & goals,
plan & hypothesise, build a mental
model, trial & error algorithms

Without prior experience you may need to use an
algorithm (like a computer or Thorndike's cats)

Algorithm: a problem-solving method which
will, step-by-step, try every possibility.

Algorithms <u>will</u> ultimately be successful
(if all the possible steps are known).
Disadvantage: slow.

Example: crossword puzzle clue
"*sharp tongue*"

_ c_ _ bi _

An algorithm solution, insert every possible letter in
each space & check dictionary definitions

approximately 460,000 possibilities

Problem-Solving Heuristics

Working backward: start at the goal state
and work towards initial state

Difference reduction (*hill climbing*) method:
working forward

Means-ends analysis (goal reduction):
creation of sub-goals (that are solvable)

Analogy heuristic: mapping the solutions from
one problem onto another

Working backward heuristic

Examine the goal state to determine the penultimate
step to achieve it, then the step before that, etc...

Helpful when initial state is not well-defined but
goal state is well-defined

Larkin, McDermott, Simon & Simon (1980)
Experts solved physics problem by working
forwards; novices solved it by working
backwards

Working backward heuristic

2 players take turns taking 1-5 coins

The player that takes the last coin wins

What move will guarantee victory for the first player?

Working backward heuristic

Examine the goal state to determine the penultimate step to achieve it, then the step before that, etc...

Helpful when initial state is not well-defined but goal state is well-defined

Helps to re-represent the problem space but slow, lots of possibilities for getting stuck

Does not work well with problems with lots of intervening steps

Hill climbing heuristic

Trying to always move closer to the goal state

At each point, choose the route representing the shortest distance to the goal.

Based on depth-first search & simple measure of distance b/w current state & end state.

Non-demanding, many people will try using it first

Problem: possibilities of local maxima

Hill climbing heuristic

Problem of local maxima

Hill climbing doesn't represent much information about the problem-space as a whole

Initial state: in the valley   Goal state: highest point

Simple "go up" operator may get you stuck in the foothills (a local maxima)

Means-ends analysis

Used in Newell & Simon's general problem solver (GPS)

Involves selecting methods known to be effective in the past

and

Dividing the problem as a whole into several smaller sub-problems, which you then solve one at a time (goal reduction)

(*2nd half of the approach came later and was probably the most important*)

Means-ends analysis

I received an invitation to attend a meeting in Andorra

Problem: how do I get to Andorra?

Available pieces of information:

I am in my office in Hamilton, NZ

Andorra is in the Pyrenees mountains, on the border of France and Spain

no direct route from Hamilton to Andorra

but:

Andorra is fairly close to Barcelona

if I could get to Barcelona, I could get to Andorra from there

Means-ends analysis

Sub-problem: Find a way to get to Barcelona

Available Pieces of Information:

no direct flight from Hamilton to Barcelona, but

there are flights from Auckland to London

there are flights from London to Barcelona

you can drive from Barcelona to Andorra

additional information can be acquired

Problem can be represented as a search through a problem space where nodes = cities & links = routes between them

Problem solving, in travel environment, is a task of finding a feasible routing along the links, from a starting node to a goal node

Analogy heuristic: mapping the solutions from one problem onto another

Re-representing the problem

Works best for *problem isomorphs*
problems with the same structure (solution path) but different content (surface representations)

Problem Isomorphs

Gick & Holyoak (1980)

Had participants read a story about a general attacking a mountain fortress

The roads around the fortress were mined so that any group large enough to capture the fortress would set off the mines

A smaller group wouldn't set off the mines, but would be killed when they arrived at the fortress

General split up his forces and had them converge on the fortress from many directions

Problem Isomorphs

Gick & Holyoak (1980)

Later in the study, participants were given Duncker's (1945) radiation problem

Imagine that a patient enters a hospital with a malignant tumour in his stomach that will eventually kill him if not removed. Although no surgical procedure for removing the tumour exists, a kind of ray could destroy it. At high intensities the ray will destroy the malignant tissue, but will also destroy healthy tissue. At lower intensities, the ray will not harm healthy tissue, but neither does it destroy malignant tissue. Develop a procedure for using the ray that will destroy the tumour byt not damage the healthy tissue surrounding it.

Problem Isomorphs

Gick & Holyoak (1980)

About 10% of participants solved the radiation problem without reading the fortress story

About 30% of participants who read the fortress story solve the radiation problem

Why so few? Is this an representational access problem (encoding specificity) or a heuristic usage issue?

If given a hint that the earlier stories might be relevant, 80- 90% of participants solve the problem

Suggests that the issue was representational access

Strategies for solving problems

1. Break mental sets
2. Find useful analogy
3. Represent information efficiently
4. Find shortcuts
5. Establish subgoals
6. Turn ill-defined problems into well-defined problems

Next time: When heuristics aren't enough
ill-defined problems may require insight and creativity