Cognition

PSYC 2040

W10: Complex problem solving

today’s agenda

- analogies
- experts vs. novices
- search as problem solving
- creativity and problem solving

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activity

- 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 harmless at a low intensity, but at sufficiently high intensity is able to destroy the tumor. At such high intensity, however, the ray will also destroy the healthy tissue it passes through on the way to the tumor. What can be done to destroy the tumor while preserving the healthy tissue?

activity

- 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 landmines. These roadblocks were designed in such a way that it was possible for small groups of the fortress-owner's men to pass over them safely, but a large group of men would set them off. The general devised the following plan: He divided his troops into several smaller groups and ordered each of them to 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.

Gick & Holyoak (1980)

- Duncker (1945): base (fortress) and target (radiation) problem
- 10% were able to solve the problem right away, but 30% could solve it when they read the story of the general before. After being given an additional hint – to use the story as help – 75% of them solved the problem.
- solution involves recognizing and mapping
- schema induction can be helpful

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experts vs. novices

- experts focus on deeper shared principles whereas novices focus on superficial structural similarities
  - Chi, Feltovich, and Glaser (1981): physics (conservation of momentum vs. ramps/pulleys)
  - Stains and Talanquer (2008): chemistry (acid-base reaction vs. water as a product of a reaction)
- experts are better able to spontaneously retrieve prior examples that share key domain principles

activity

- A balloon floating is like___ because___”

activity

- “Catching a cold is like ____ because___”

analogy generation task

- give people a target phenomenon and ask them to produce a similar phenomenon and to explain their rationale
- what people produce as analogous tells us something about how their knowledge is encoded.
- open-ended vs. prompted task

For the open-ended task, the instructions were "Analogies are based on similarities between two things. Because things may be similar in many ways, there are many ways to draw an analogy and no single correct way. We are studying students' analogies. As part of this study, we would like to compare students' analogies with those drawn by experts. Please complete the analogies on the back side of this page."

For the prompted task, participants were similarly told about the comparison between students and expert analogies, but had different instructions concerning the kind of analogies to focus on: "Science is mostly about understanding what causes things to happen. Often, this understanding is built through analogical reasoning. In this survey, you will be asked to build analogies based on causal similarities." The instructions further included these illustrative examples:

> *An example of a causal analogy is*:
> Getting in an auto accident is similar to tripping on a step because they both can be caused by not paying attention.
> *An example of a non-causal analogy is*:
> Getting in an auto accident is similar to tripping on a step because they both can result in getting hurt.
> The first example is causal because it relates an underlying and common reason for two distinct events. This second example is non-causal because the similarity is a common outcome of two distinct events.

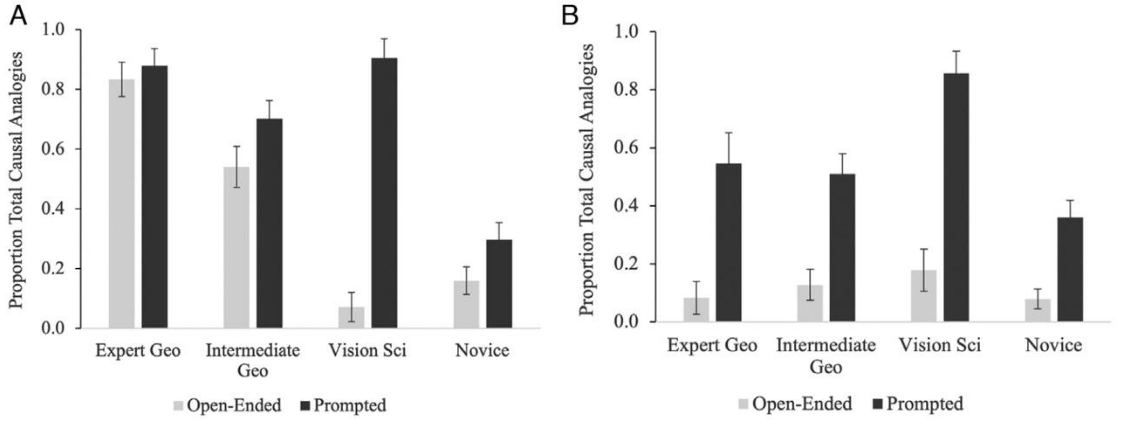
paper

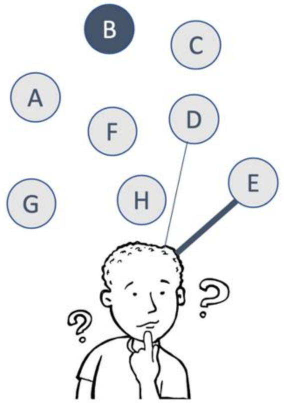
curse of expertise

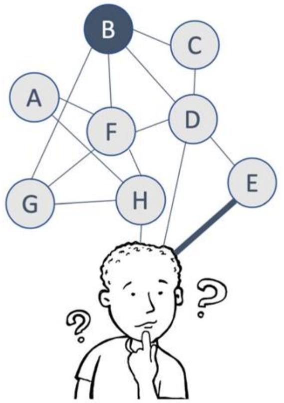
- scientists have more scientific explanatory knowledge than novice nonscientists
- scientists only spontaneously apply their explanatory knowledge specific to their domain of expertise (“curse of expertise”)
- “practicing connections”

balloon

cold







Practicing Connections: A Framework to Guide Instructional Design for Developing Understanding in Complex Domains

Laura Fries[1] · Ji Y. Son[2] · Karen B. Givvin[1] · James W. Stigler[1]

paper

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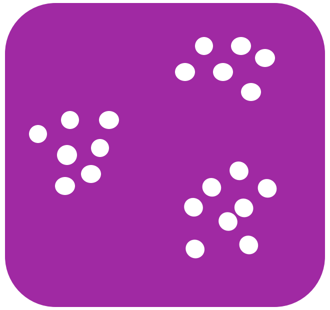
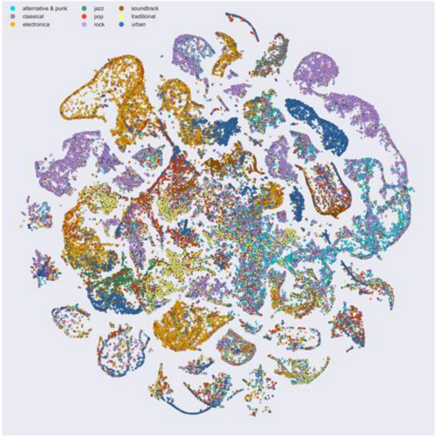
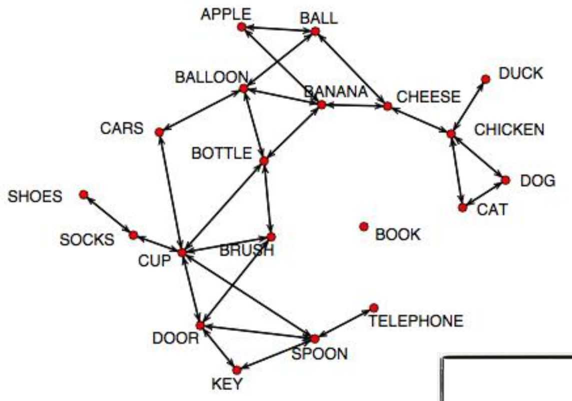
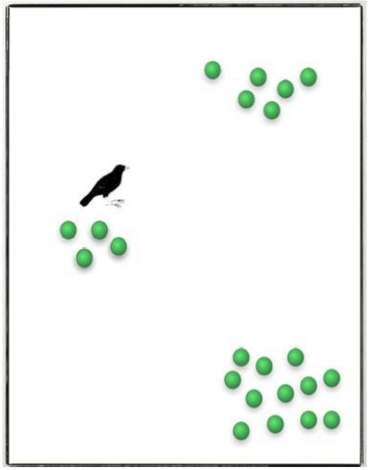
search as problem solving

- search is required whenever resources are distributed in space or time (“patchy” landscape)
- external search
    - looking for a parking spot
    - what Netflix show to watch
    - finding a partner
- internal search
    - grocery list
    - brainstorming
    - communication



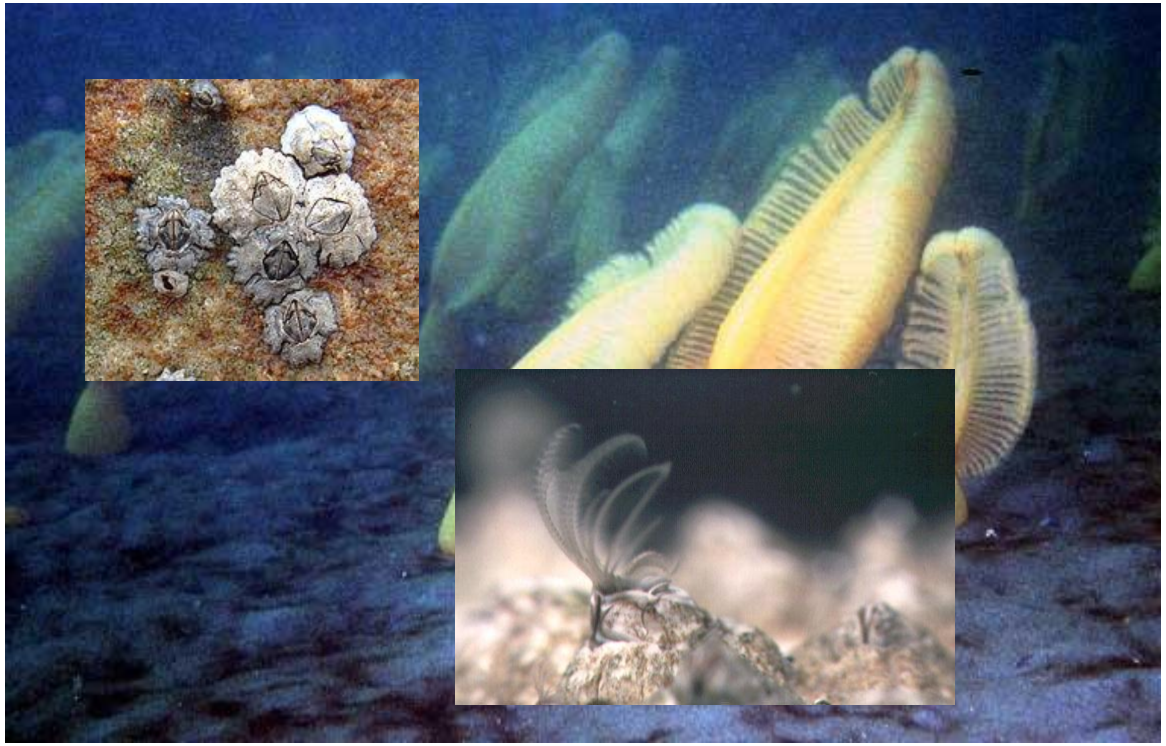






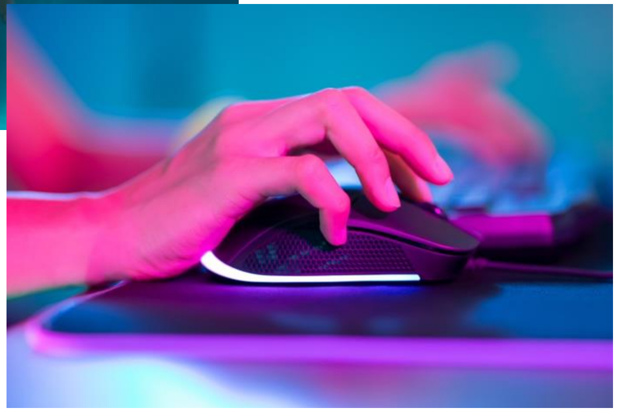
life without search?

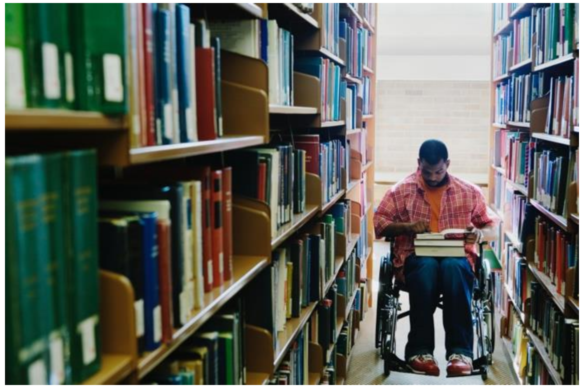
- sea pens (relatives of coral) and barnacles
- no exploration, only exploit (or reject) what floats by



how to search?

- you could find something, but something better off could be found later….
- when not to search: exploit the current item, and when to keep looking – explore further?





explore-exploit tradeoffs

- searching for resources can be thought of as a trade off between exploration (of new areas) and exploitation (of current areas)
- foraging can be described as "optimal" if individuals begin to explore when a current area is sufficiently depleted
- domain-general mechanism

Table 1. Examples of trade-offs between exploitation and exploration across cognitive domains

Animal foraging	Exploiting a known berry bush versus exploring for new bushes
Visual search	Analyzing one spot on a chest radiograph versus looking for the next spot to check
Information search	Searching within a document versus searching for new documents; deciding when to accept an item on a menu versus continuing to look for new items
Search in memory	Trying to remember more African animals versus switching to Australian animals
Search in problem solving	Focusing on solutions that have worked in the past versus seeking new solutions
Social (group) learning	Learning or copying existing knowledge versus using innovation to seek new knowledge

optimal leaving

- leave a patch when you would do worse by staying in it than by finding another patch (Marginal Value Theorem – Charnov, 1976)
- i.e., leave when instantaneous rate of return falls to the mean rate of return in environment
- but this optimal point can be difficult to compute – animals use simple heuristics instead...

barnacle vs. bumblebee search

- barnacle search: explore multiple options without reward, until a final option is chosen and exploited for reward – *optimal stopping*
- bumblebee search: ongoing switch between exploring for options and exploiting them and exploring again, getting reward all along – *optimal foraging*
- when do humans face these problems in life?

external search: mate choice

- mate choice involves:
  - assessing relevant cues of mate quality
  - processing cues into judgment of mate quality
- searching a sequence of prospects and stopping on the basis of judged quality
- a barnacle-like search – keep looking until someone good enough is found

speed dating session (Todd et al., 2007)

- both men and women stated that they prefer mates who possess attributes similar to their own (likes-attract)
- mate choices, however, do not align with these preferences
- men appeared to base their decisions mostly on the physical attractiveness of the women and were less choosy
- women considered their own attractiveness and chose desirable candidates among a smaller pool
- adaptive? “ecologically rational”?

when to stop studying?

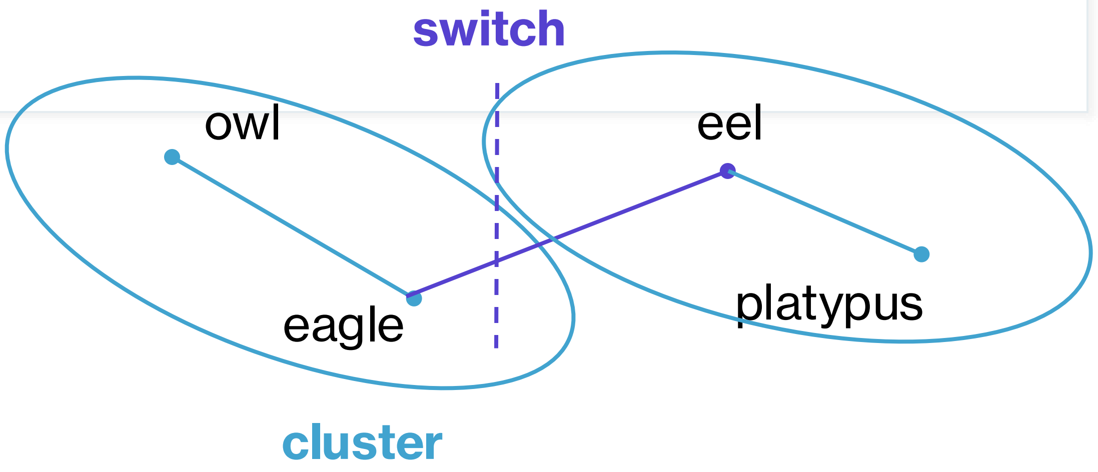
- absolute rule: study an item until its degree of learning meets an internal criterion
- rate rule: study as long as you feel you are learning, but stop if learning is too slow
- people stop studying when their rate of learning is low (Metcalfe and Kornell, 2005): content is already learned or too difficult to learn

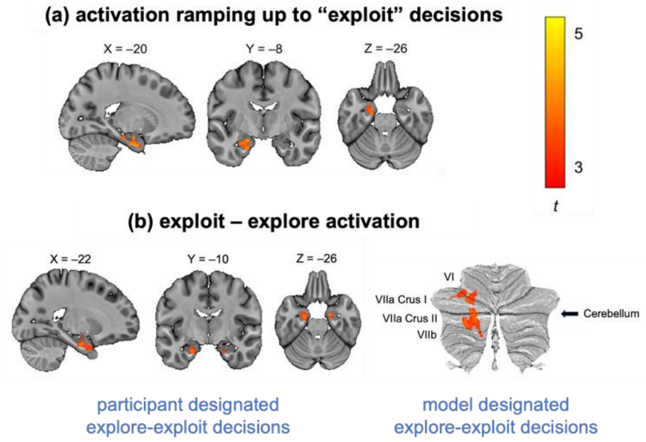
study time and animal foraging

- win-switch strategy
  - people decline study of items they have just studied, or that they know they already know
    - bees and bats not visiting old locations
    - foraging in rats
  - participants initially avoid but return to certain already studied items later
    - temporal calibration by bees
- Goldilocks principle
  - people pluck off the easiest as-yet unlearned items first for learning, before they turn to more difficult items
    - seabirds (oystercatchers) pick smaller bivalves

optimal internal search

- behavioral and neural evidence that humans optimally switch between clusters when searching through memory (Hills et al., 2012)
- age-invariant patterns (Zemla et al., 2023)
- people use a combination of semantic and phonological information to navigate semantic memory (Kumar et al., 2022)





Lundin et al. (2023)

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creativity

- convergent thinking: unite many different concepts into a single idea
  - Remote Associates Test (RAT)
- divergent thinking: generate as many different ideas as possible
  - Alternative Uses Test
  - Divergent Associations Test (DAT)

RAT task

- Each RAT question presents three cue words that are linked by a fourth word, which is the correct answer.

DAT task

- https://www.datcreativity.com/task

Your score is 84.3, higher than 82.82% of the people who have completed this task

	friend	cloud	praline	ghost	tarp	monk	goat
friend							
cloud	90						
praline	105	95					
ghost	63	73	99				
tarp	95	82	98	90			
monk	72	90	95	66	91		
goat	75	83	74	75	82	78	

The average score is 78, and most people score between 74 and 82. The lowest score was 24 and the highest was 96 in our published sample. Although the scores can theoretically range from 0 to 200, in practice they range from 6 to around 110 after millions of responses online. See how other people are performing on Twitter.

The Divergent Association Task is a quick measure of verbal creativity and *divergent thinking*, the ability to generate diverse solutions to open-ended problems. The task involves thinking of 10 words that are as different from each other as possible. For example, the words *cat* and *dog* are similar, but the words *cat* and *book* are not. People who are more creative tend to generate words that have greater distances between them. These distances are inferred by examining how often the words are used together in similar contexts. Still, this task measures only a sliver of the complex process of creativity. See the frequently asked questions for more details.

We have validated this task on around 9,000 participants from 98 countries across the world. People who score higher on the task tend to be able to:

- think of novel and more varied uses for common objects (Alternative Uses Task)
- find associations between related words (e.g., *giraffe* and *scarf*; Bridge-the-Associative-Gap Task)
- solve more insight and analytical problems

Other research has found that people who score higher on the task:

- notice more patterns in images (Bellemare Pepin et al., 2022)
- generate more novel metaphors (Pont-Niclòs et al., 2024)
- score higher on other divergent and convergent thinking tasks (Ding et al., 2024)
- have more creative everyday behaviour (Ishiguro et al., 2025)
- benefit less from AI assistance when writing creative stories (Girotra et al., 2023) or generating ideas (Memmert, Mies, & Bittner, 2024)

memory and creativity

- search (verbal fluency) is positively correlated with convergent and divergent measures of creativity
- working memory supports convergent thinking

Memory and creativity: A meta-analytic examination of the relationship between memory systems and creative cognition

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Abstract
Increasing evidence suggests that specific memory systems (e.g., semantic vs. episodic) may support specific creative thought processes. However, there are a number of inconsistencies in the literature regarding the strength, direction, and influence of different memory (semantic, episodic, working, and short-term) and creativity (divergent and convergent thinking) types, as well as the influence of external factors (age, stimuli modality) on this purported relationship. In this meta-analysis, we examined 525 correlations from 79 published studies and unpublished datasets, representing data from 12,846 individual participants. We found a small but significant ($r = .19$) correlation between memory and creative cognition. Among semantic, episodic, working, and short-term memory, all correlations were significant, but semantic memory – particularly verbal fluency, the ability to strategically retrieve information from long-term memory – was found to drive this relationship. Further, working memory capacity was found to be more strongly related to convergent than divergent creative thinking. We also found that within visual creativity, the relationship with visual memory was greater than that of verbal memory, but within verbal creativity, the relationship with verbal memory was greater than that of visual memory. Finally, the memory-creativity correlation was larger for children compared to young adults despite no impact of age on the overall effect size. These results yield three key conclusions: (1) semantic memory supports both verbal and nonverbal creative thinking, (2) working memory supports convergent creative thinking, and (3) the cognitive control of memory is central to performance on creative thinking tasks.

paper

next class

- decision making

Here are the to-do's for the week:

- Week 10 Exit Ticket (due Thursday)
- Week 10 Quiz (due Sunday)
- Post any lingering questions here
- Extra credit opportunities:
  - Submit Exra Credit Questions (1 point for 8 submissions)
  - Submit Optional Meme Submission (1 point for winners!)

Before Tuesday

- Complete W11 Activity 1

Before Thursday

- Complete W11 Activity 2

After Thursday

- See the Apply section