

## Lec 3

# Cognitive Artifacts & Epistemic Practice



Cogs 102A \* Distributed Cognition

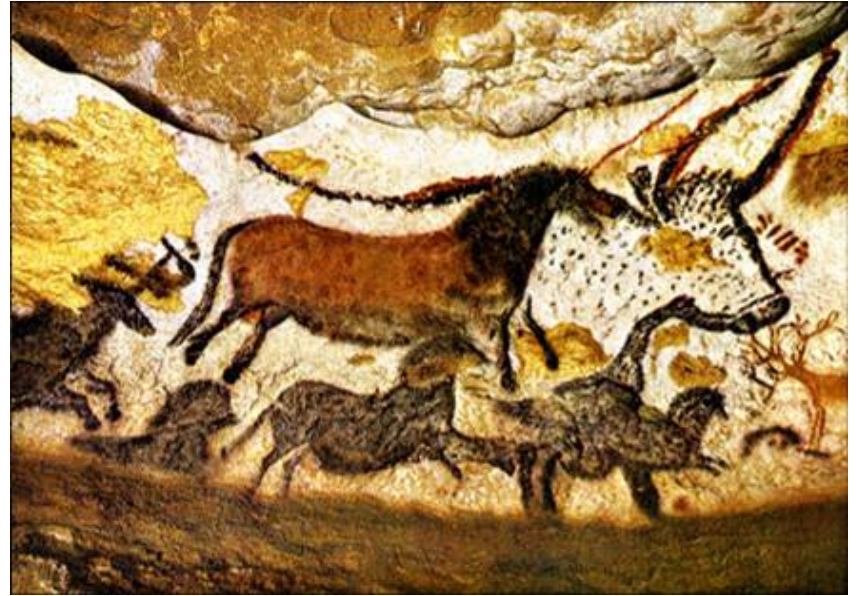
# Cognitive Artifacts

Humans use and make tools



~1,500,000 Years Ago  
Acheulian tools, *Homo erectus*

~150,000 Years Ago  
Lescaux cave paintings



~5,500 Years Ago  
First writing

# Cognitive Artifacts

= Any object and/or practice that makes a task cognitively easier



A human cognitive specialization:

We create, learn, and use  
Cognitive Artifacts  
to alter what we can achieve

# Cognitive Artifacts Make Tasks Easier

- Kirsh (1995) suggested two types of practices make tasks easier:
- **“Pragmatic Acts”**
  - Change the world in a way that makes a task **physically** easier
    - i.e. Reduce energetic costs
    - e.g. Use a wheel, a lever, a mitt...  
depending on the task



- **“Epistemic Acts”**
  - Change the world in a way that makes a task **cognitively** easier
    - Actions that re-present the problem in such a way as to help make its solution more obvious
    - These acts manipulate information such that the required perceptual or computational processes are easier



# Epistemic Acts

Some informational problems concern **Perception**

What are the "problems" of perception? (See last lecture!)

What tasks do we undertake with perception?

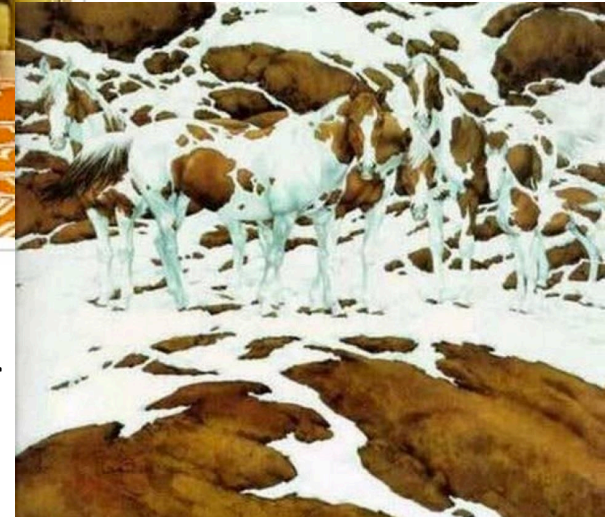


Notice, Examine



Search

Identify, Classify



Making a perceptual task easier  
is an epistemic act

# Epistemic Acts

Choice: A primary cognitive problem

Selecting from alternatives



Easier if reduce degrees of freedom

e.g. 2 things to choose between vs. 12

e.g. If have to share, choose easiest to divide (i.e. task-dependent)

# Epistemics

- “Epistemic” = “Of or relating to knowledge”
  - This term will arise in a variety of contexts in this class . . .
  - e.g. “*Epistemic Status*”
    - Expert differs from vs. Novice
  - e.g. “*Epistemic Stance*”
    - I act like I know, or don’t know
  - e.g. “*Epistemic Engine*”
    - Difference between interlocutors’ epistemic status that drives conversation
      - e.g. Ask/Answer

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      - Difference between interlocutors’ epistemic status that drivee conversation
      - e.g. Ask/Answer
    - e.g. “*Epistemic Advantage*”
      - When an environmental change simplifies a cognitive problem
    - e.g. “*Epistemic Action*”
      - Action that can provide an epistemic advantage
- Future classes**
- Today’s focus:**

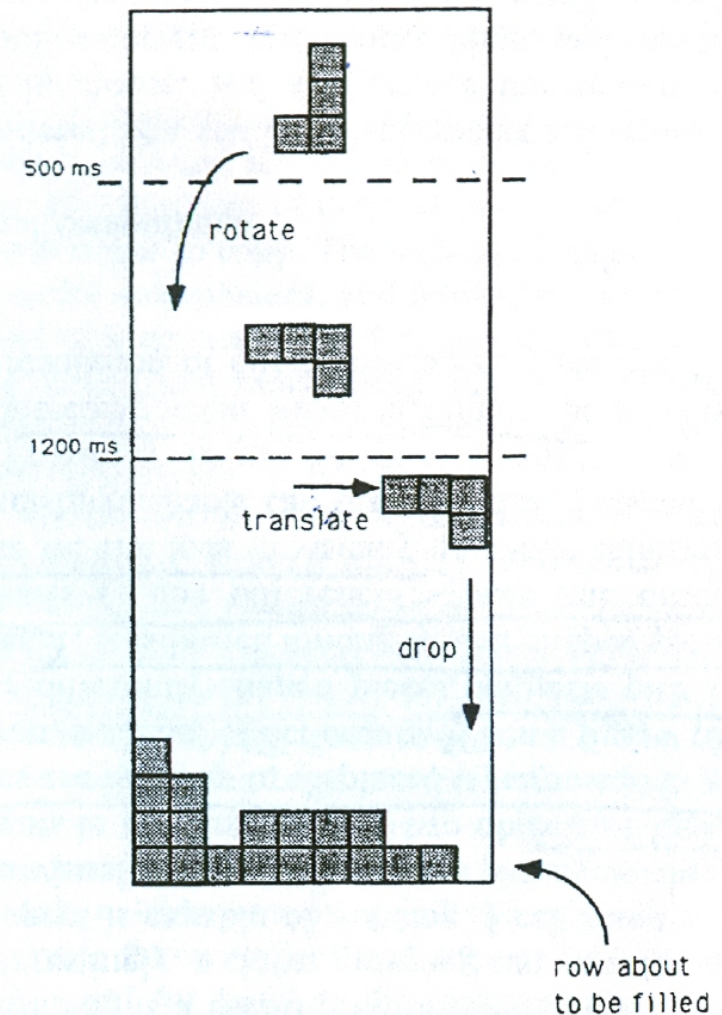


# Epistemic Acts

e.g. *TETRIS* (Kirsh & Maglio, 1995)

- Arcade game, manipulate block-objects (“Zoids”) to fit them together, cover maximum area
- As Zoids appear, use Rotate, Translate, Drop-Into-Place, to position them optimally w/others
- Experts especially will rotate Zoid just to see if it will fit better
  - An Epistemic Act
  - i.e. It offers the Epistemic advantage of an easier judgement of fit

*D. Kirsh / Artificial Intelligence 73 (1995) 31–68*



# Pragmatic & Epistemic Action

- Many actions provide **both**  
Pragmatic & Epistemic advantages

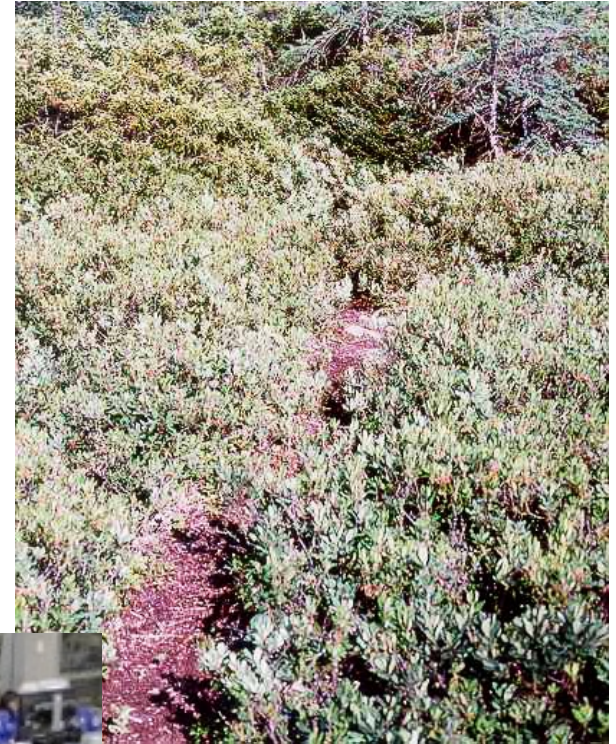
e.g. Paths

## Pragmatic:

- Affords walking by eliminating obstacles

## Epistemic

- Simplifies perception -  
makes *where* to walk **salient**



This will be an issue  
In Lab 3...

# Costs & Benefits of Doing Cognition

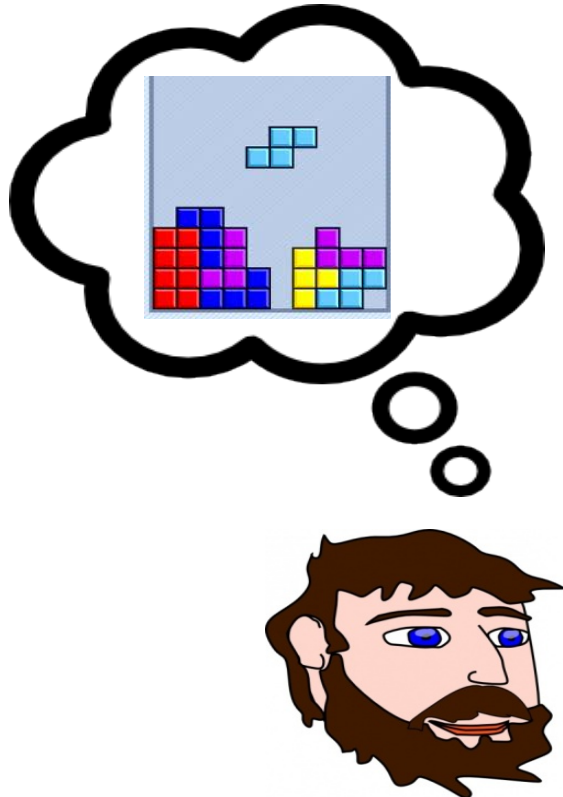
- What makes a problem “cognitively easier”?
  - Especially when working “under pressure”...
  - e.g. Time constraints, Cognitive load, Unexpected opportunity, etc.
- Easier if the problem can be re-arranged to improve...
  - Time - Quicker is better
  - Effort - Less is better
  - Errors - Fewer is better
- So, any practices that can accomplish these “cognitive savings”  
are Epistemic Acts

# Cognitive "Savings"

- Speed

e.g. Mental rotation of TETRIS zoid takes 700-1500 msec

- In game, rotation only takes 150 msec (See Kirsh & Maglio 1994)



# Cognitive "Savings"

- Accuracy
  - e.g. Look up spelling in a dictionary



- e.g. Use catchy mnemonics to promote accurate recall



In musical notation...

Spaces correspond to notes "FACE" 😊

Lines correspond to notes "EGBDF" - ?

"Every Good Boy Deserves Fun!"

# Cognitive "Savings"

- Precision
  - e.g. Measuring tape has recurrent pattern in size & spacing of lines and numbers that enables precise measurements



Note this Cultural Convention now shapes what is expected in “measuring”

# Cognitive "Savings"

- Simplicity
  - e.g. Re-ordering blocks (ABC...) easier if laid out on surface, not stacked
    - Don't have to deal with balance, support, etc  
so, simplifies problem to only ordering



# **Cognitive Artifacts**

Anything that provides an epistemic advantage

Consider the following cognitive problem...



How much is 72,853.41  
divided by 57?

(Please solve “in your head”)



How much is 72,853.41  
divided by 57?

(Please solve “in your head”)

How much is 72,853.41  
divided by 57?

(Ok to use pen & paper)

How much is 72,853.41  
divided by 57?

(Ok to use *any* means)

How much is 72,853.41  
divided by 57?

ANSWER: 1,278.13

# Cognitive Work

- Adopting DCog perspective, it becomes apparent that cognitive work often consists of **Transforming Information**
- Arithmetic
  - e.g. Present as  $3457 \div 23$ , unable to use learned (cultural) practice afforded by  $23 \overline{)3457.0}$ , so **transform** how problem is presented to solve it
- "How a cockpit remembers its speed" (Hutchins, 1995)
  - e.g. **Transform** # on speed card to spatial location of speed bug to use spatial proximity of needle
- Conversation
  - Collaborative sequence of **transformations** of semiotic resources (More later!)

# Cognitive Artifacts

Re-Present the problem to provide an epistemic advantage

$$\begin{array}{r} 017 \\ 25 \overline{) 425} \\ \underline{00} \\ 42 \\ \underline{25} \\ 175 \\ \underline{175} \\ 000 \end{array}$$



- e.g. If dismantle previous configuration, can “notice” new possibilities (as in Candle problem, below)
- Generally operate by simplifying (reduce degrees of freedom in) perception, choice, computation, communication

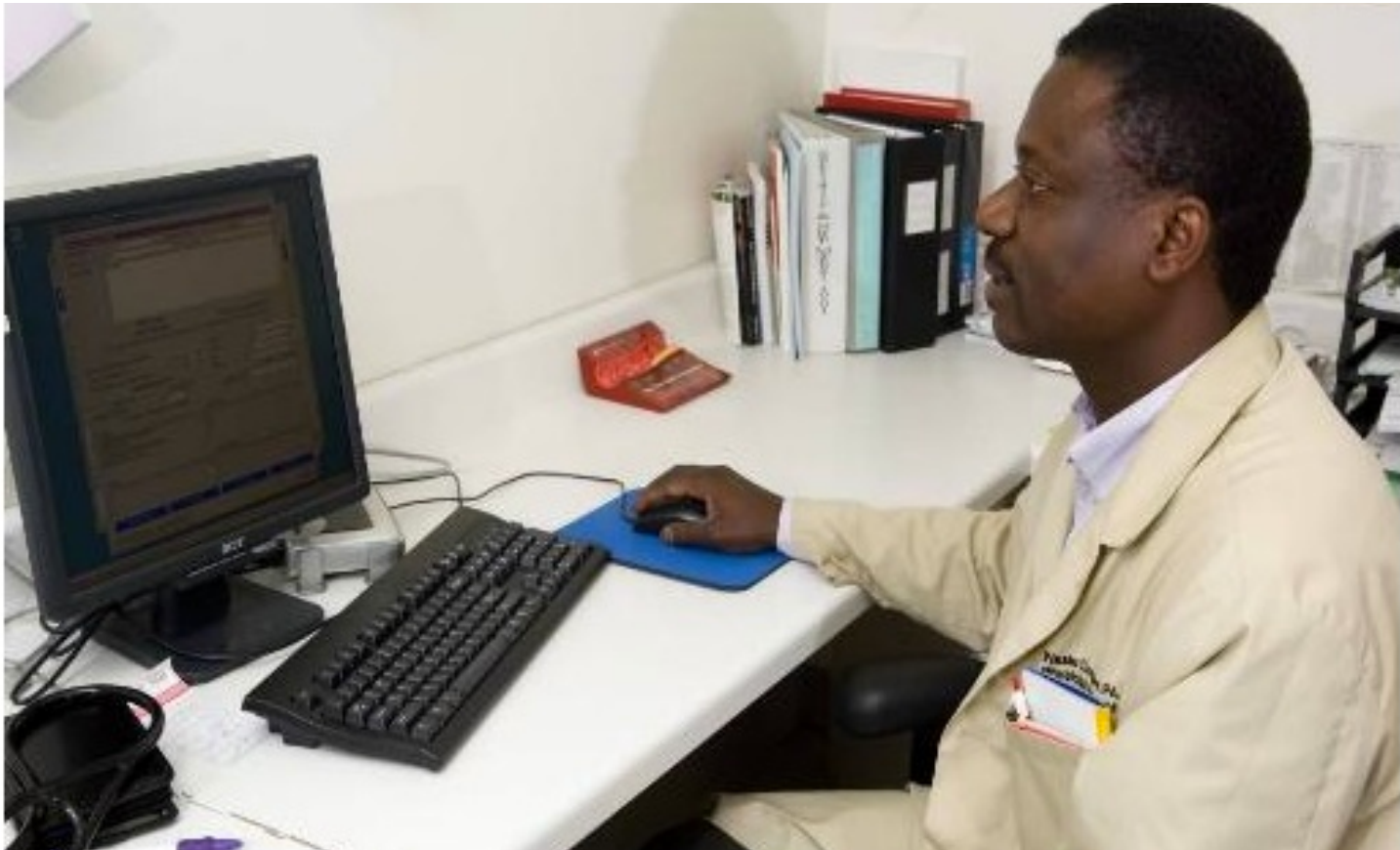


# Cognitive Artifacts

- Many are cultural "crystallizations of partial solutions to common problems" (Hutchins 2005)
- Includes the Objects themselves
  - Such as calculators
  - Structure constrains pertinent practices, via physical & cultural affordances
- And the Practices
  - e.g. Tap number, then function, then next number; Slide beads
  - Plus learn, adapt to Google version, etc



Don't need to know why it works to use it!



Many of our cognitive artifacts constrain our behavior  
in ways we may not understand,  
that are nonetheless effective in helping us solve problems

# Cognitive Artifacts

- Cognitive artifacts include *ephemeral* Words & Gestures
  - Provide and alter information
- **“Semiotic resources”**
  - Objects, situations, and practices that enable “Meaning Making”
    - Its raining, we’re cold & drenched, I roll my eyes and say  
“Don’t you just love the rain?”
    - Its raining, we’re watching from our cozy window, I smile and say  
“Don’t you just love the rain?”
  - Any such resources, long-lasting material or ephemeral, that are used to make meaning are “Semiotic Resources”
- Much more on this to come!

# Cognitive Artifacts

- But many are “**Material Anchors**” (Hutchins 2005) - durable, constraining
  - From simple tools, to images, to complex technology
  - Their physical presence & features offer advantageous affordances
- Stable & Shareable
  - Writing, sketch, highlighting, etc. outlast verbalizing or imagining
  - Multiple agents can modify, (e.g. record changes) for future agents’ use
  - “Independent” (Kirsh 2009) of (possibly absent) creator’s point of view
- Can be manipulated
  - Juxtaposition – Much easier to determine if puzzle pieces fit, if you can actually handle them



# Cognitive Artifacts

- But note – regardless of a tool's design, its epistemic value is always **Task-Dependent**
- e.g. Measuring tape typically affords accurate, consistent measurement

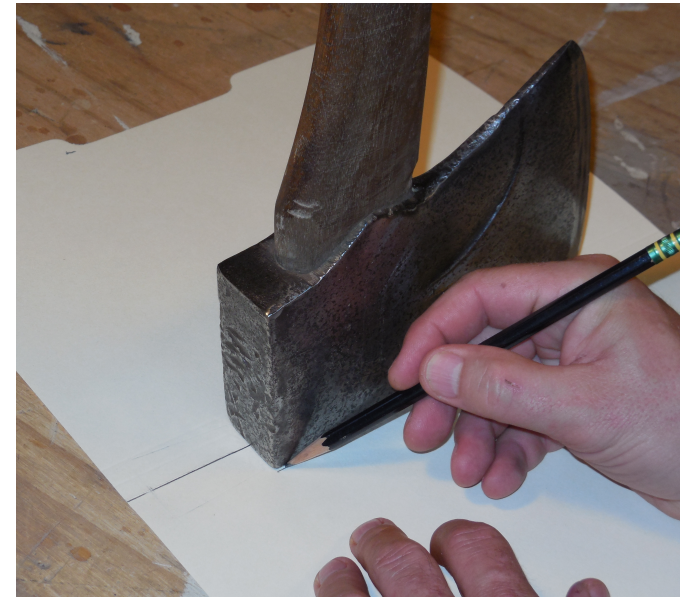


- But also affords being used a ribbon to wrap a gift of diet candy
- This juxtaposition promotes a very different "meaning"!



# Cognitive Artifacts

- So, ANYTHING can be a Cognitive Artifact!
  - Based on HOW you use it
  - e.g. Any objects, integrated w/other semiotic resources, (assigned names, pointed to, moved in space, etc.) can be used to provide epistemic advantages



NOTE: It requires cultural practices to make the object's "meaning" intelligible.

## Role of Culture

- Since Cognitive Artifacts are defined by how they are used in context, their design and use is necessarily **Cultural**



- That is, Culture is not an after-the-fact modification of cognition, but is as constitutive as brains or bodies!

# Cognitive Biases

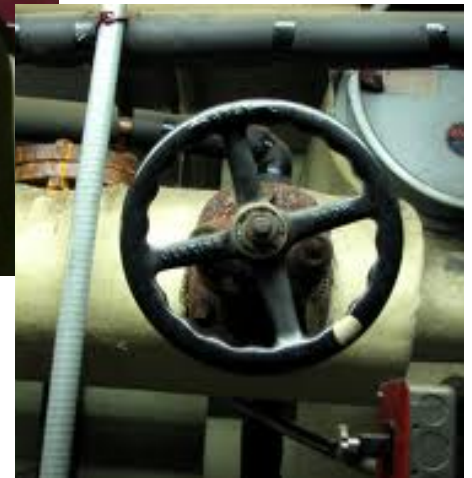
- Cognitive science has identified several biases (good & bad) in the way that humans solve problems
- Some are perceptual, others concern memory & reasoning
- These inform practice and tools
  - Since we are prone to see things, engage with things in certain ways
  - Biases arise that suit our typical problem-solving needs
  - Thus they shape our cognitive artifacts
    - See Hutchins 2005; Shepard 1994



# Cognitive Biases

## Use of Space

- To simplify perception, choice, computation, communication, etc.
- See last lecture!



# Cognitive Biases

Large objects/events are salient, occupy more visual field

- e.g. Loom object to get infant's attention
- e.g. Large advertisement or store display is “eye catching”

Also, we are better at judging *length* than area, so putting items in a line is better for estimating # than in jumbled pile



# Cognitive Biases

## Visual vs. Visualized

- Recognition easier than Recall

*Easier!*

TEST  
FILL IN THE BLANKS

Who coined the terms...

"Epistemic action"? \_\_\_\_\_

"Ecological perception"? \_\_\_\_\_

TEST

SELECT THE CORRECT NAME:

Kirsh    Gibson

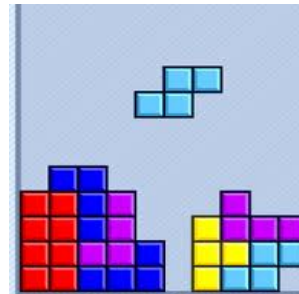
Who coined the terms...

"Epistemic action"? \_\_\_\_\_

"Ecological perception"? \_\_\_\_\_

- Perception more robust than Mental Imagery

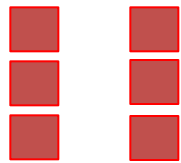
Thus, Tetris players  
rotate Zoids...



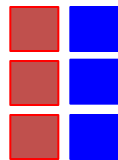
# Cognitive Biases

## Gestalts

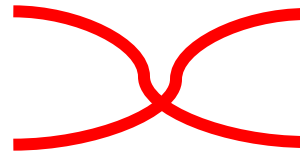
- How we organize perceptual relations, our default groupings



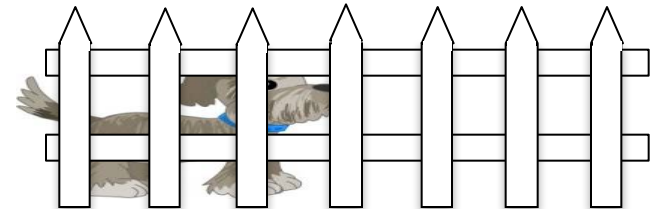
Proximity



Similarity



Good Continuation



Common Fate

- Such "automatic" processes require less cognitive effort than "deliberate" (planned, explicit, conscious, etc.) processes do

# Cognitive Biases

## Iconic vs. Arbitrary

- El hombre, mujer, y nino comenzaron su viaje bajo la luna llena.
- The man, woman, and child began their journey under a full moon.

The **Iconic** representation – given its perceptual similarity to its referent – is much more readily accessible



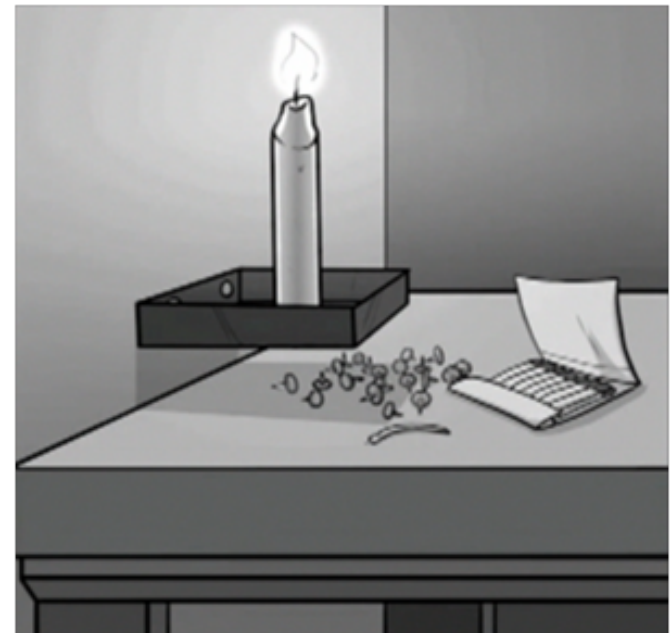
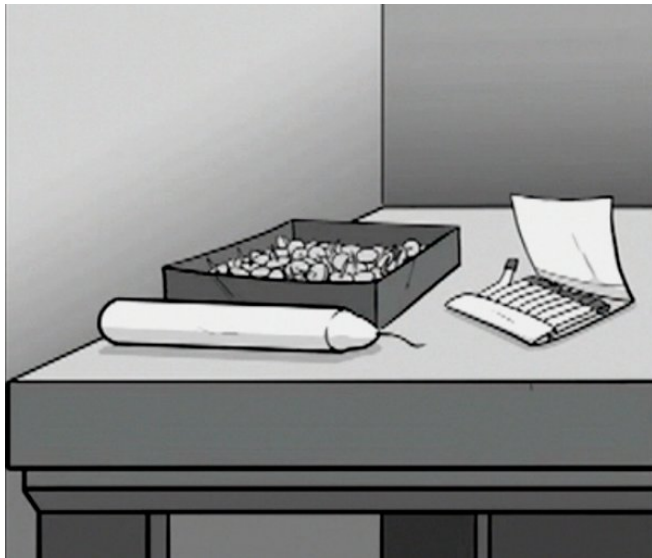
# Cognitive Biases

## Functional Fixedness

A common obstacle to successful problem solving

- e.g **Candle & Tack Box Problem** (Duncker, 1945)

INSTRUCTIONS: Provided with a candle, matches, a box of thumbtacks, attach lit candle to a corkboard wall such that it does not drip



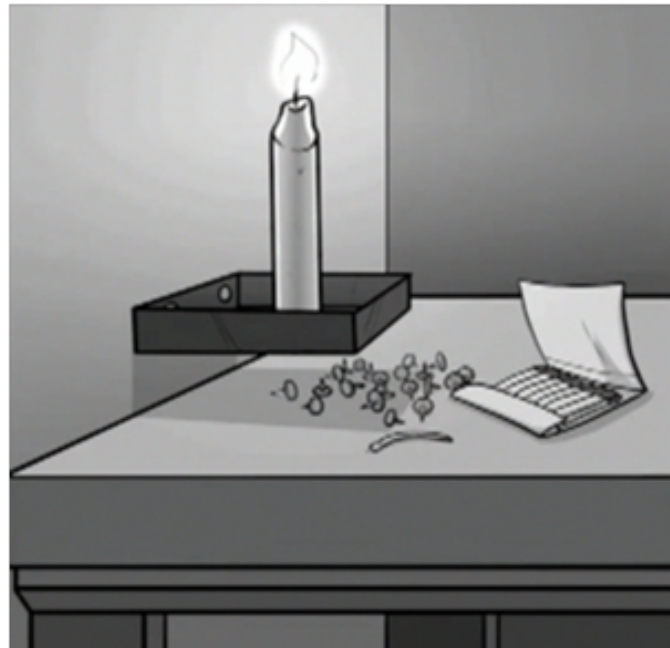
SOLUTION: Empty box of tacks, tack it to the wall and stand lit candle in it

# Cognitive Biases

## Multi-Modal Integration

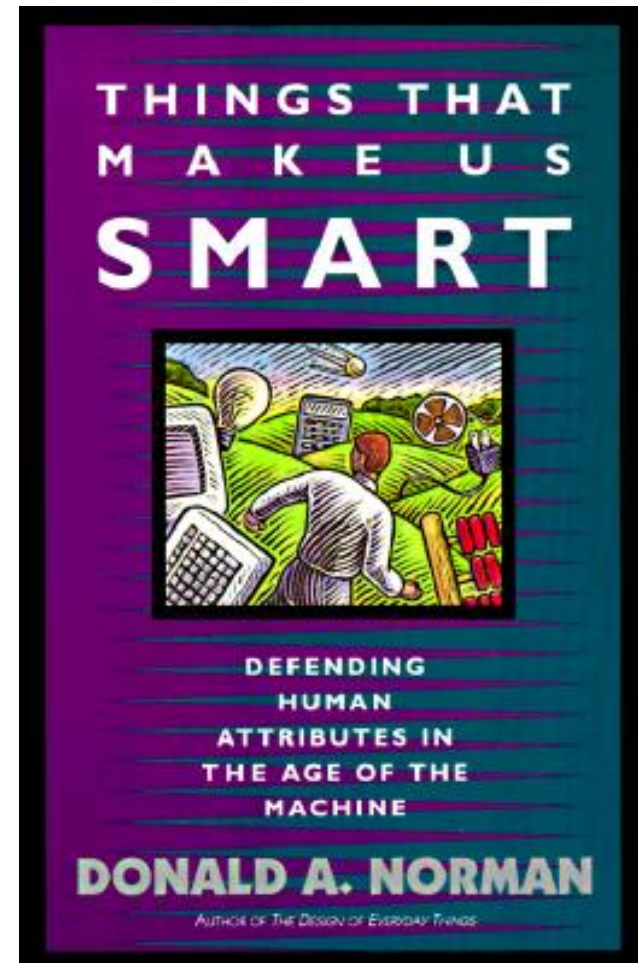
Integrated input from multiple modalities can often be used more efficiently

- e.g. Recognition more rapid and reliable when hand AND eye involved
- e.g. The minority who solved the Candle problem were most likely to have handled the box immediately before the “Aha!” moment (Spivey 2009)



# Design

- **Design** of everyday things provides affordances for our engaging w/them & using as them as cognitive resources
- e.g. Doorknobs: right size, at right height, for grasping

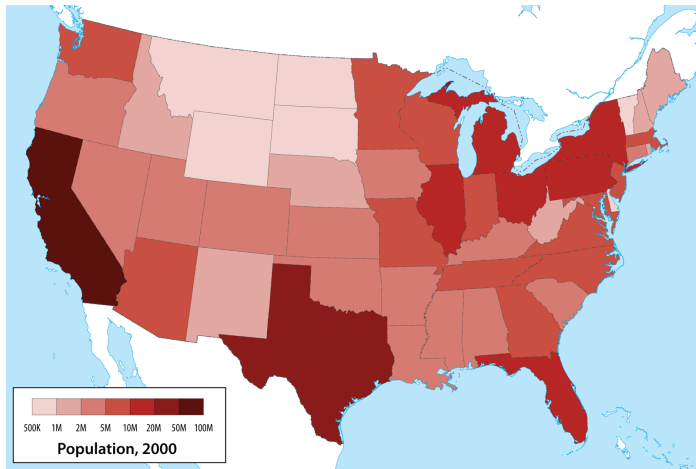


The best designs exploit our biases, and are sensitive to task demands

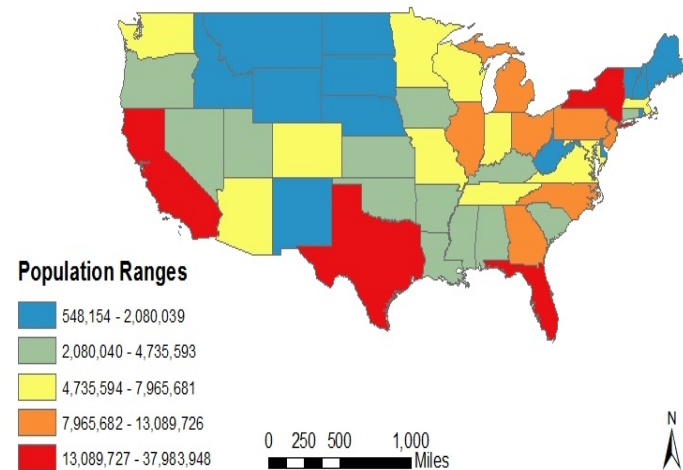


# Design: Exploit Biases

- **Iconicity**
  - See Norman 1994 reading
  - e.g. Map of US population is easier to interpret if...
    - Greater saturation (vs. arbitrary colors) = greater population



Easy to interpret at a glance!

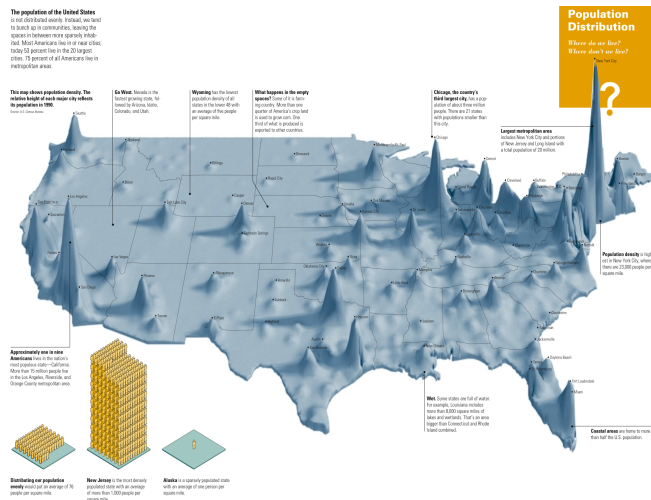


Requires consulting legend

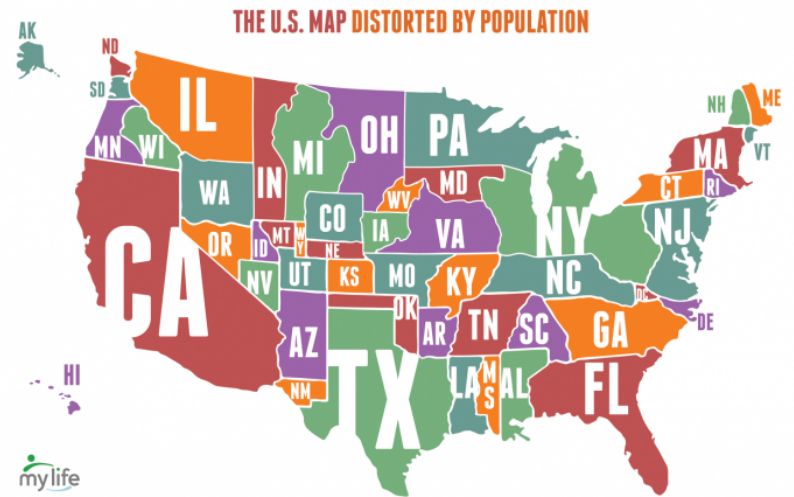
# Design: Exploit Biases

- **Iconicity**

- See Norman 1994 reading
- e.g. Map of US population is easier to interpret if...
  - Greater saturation (vs. arbitrary colors) = greater population
  - Taller/bigger image (vs. numbers) = greater population



Easy to interpret at a glance!



Requires a trade-off, since violates memory

# Design: Task-Dependent

## List vs. Matrix (see Norman 1994 Reading)

- |            |   |                                       |
|------------|---|---------------------------------------|
| Inderal    | • | 1 tablet 3 times a day                |
| Lanoxin    | • | 1 tablet every A.M.                   |
| Carafate   | • | 1 tablet before meals and at bedtime  |
| Zantac     | • | 1 tablet every 12 hours (twice a day) |
| Quinaglute | • | 1 tablet 4 times a day                |
| Coumadin   | • | 1 tablet a day                        |

List – difficult to  
consult for  
what to do next?

# Design: Task-Dependent

## List vs. Matrix (see Norman 1994 Reading)

- Inderal • 1 tablet 3 times a day
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- Quinaglute • 1 tablet 4 times a day
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List – difficult to consult for what to do next?

Matrix re-presents information in functional categories

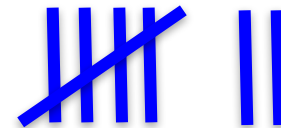
Drug \ Time	Breakfast	Lunch	Dinner	Bedtime
Lanoxin	X			
Inderal	X	X	X	
Quinaglute	X	X	X	X
Carafate	X	X	X	X
Zantac		X		X
Coumadin				X

Easier to search for what to do next!

# DESIGN: Task-Dependent

- Best mathematical symbol depends on which computational task . . .

- Tally marks - To rapidly count & compare # objects;



- Simple cumulative (visual) mark-to-object correspondence
- vs. Arabic numerals, where need to write new numeral for each increase, via recount or addition

1 2 3 4 5 6 7

- Roman Numerals - Easier to add than Arabic

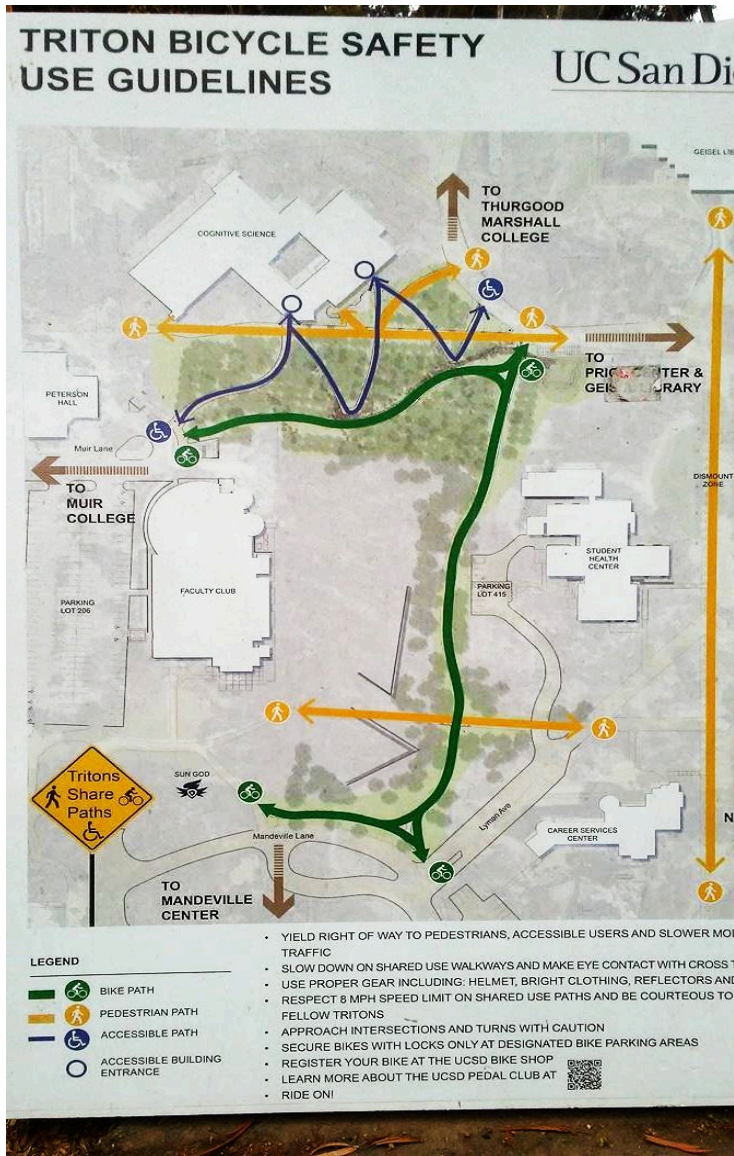
- e.g. CVI (106) + CXVII (117) = CCXVIII (223)
- No need for ZERO !

- Arabic numerals - Easier for most other calculations

- Such as arithmetic algorithms for multiplication & division

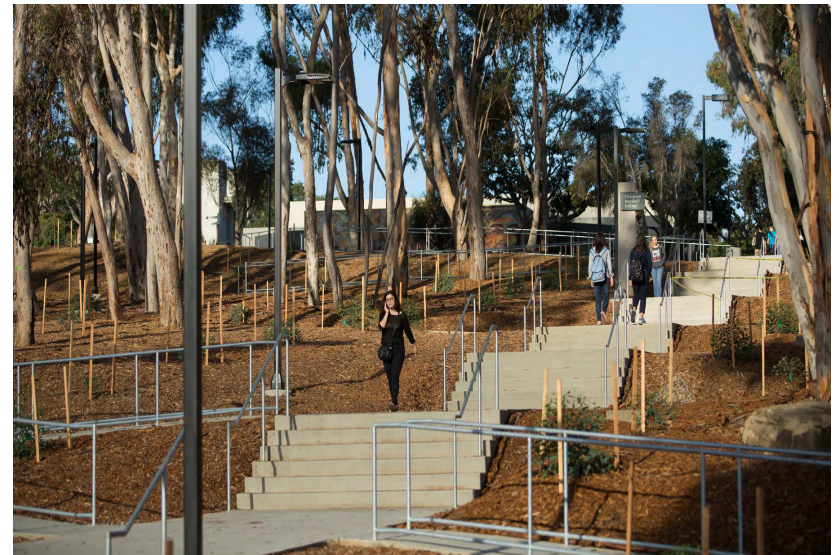
$$\begin{array}{r} 291 \\ 45 \overline{)13095} \\ \underline{90} \\ 409 \\ \underline{405} \\ 45 \\ \underline{45} \end{array}$$

# Design: Task-Dependent



- **(Re-) Orient Map**

- Traditionally North is Up
  - As it is on this UCSD path map
- But, *better* if map is oriented from perceiver's current point of view



e.g. Map of the above path is positioned facing west (toward CSB)– Hard to interpret!!

In this week's lab, you will DESIGN SPACE  
to provide Epistemic and Pragmatic advantages  
for one of two different tasks . . .