

# Human Cognition

**SWE 632**

**Fall 2021**



# Logistics

- Tech talks now 15 minutes (rather than 20)
- Anyone still looking for a project group or tech talk group?
- HW0: due today --> short extension to 9/1 4:30pm for those who just joined
- HW1: due in 2 weeks
- Tech Talk Schedule

# HW1

## Description

In this assignment, you will create an initial prototype of your application. It must be implemented as a web application and be accessible by visiting a publicly available URL.

You are not expected to submit a complete web app, but rather a prototype that focuses on a few of the most interesting use cases. Other features should be left unimplemented. Rather than implement backend functionality and logic, you are encouraged to focus on functionality that users will directly interact with. You should describe the use cases that you have chosen to implement. In grading your submission, we will test your app to check that these use cases are implemented. We will not, in this assignment, assess the usability of how effectively your UI supports these use cases.

You are free to choose to reuse and incorporate into your project code from public sources (e.g., a starter project for a framework), provided that you explicitly list in your submission all of these sources.



# A Note on Proper Use Cases

- Should be written from the User's perspective
- Should focus on a specific goal that the user is trying to complete
- Should *briefly* explain how the user gets there
- Good Example:
  - In the car rental page the user will be able to enter all of the required information to rent a car including the pickup and drop off location, the amount of time required, and the number of days required.
- Bad Example:
  - The car rental page provides information and actions for renting cars.



# Class Overview

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- Part 1 - Human Cognition: Why is this important for us?
- Part 2 - Human Psychology 101: Abridged for Engineers
- Part 3 - Design Implications of Human Psychology: People Matter
- 7 minute Break
- Part 4 - Group Activity: Norman's Designing for Action Principles

# In Class Discussion

- *Today's question:*
  - What makes someone an expert?



# What Makes Someone an Expert?

- We will revisit this later in the lecture...

# Why is Human Cognition Important?

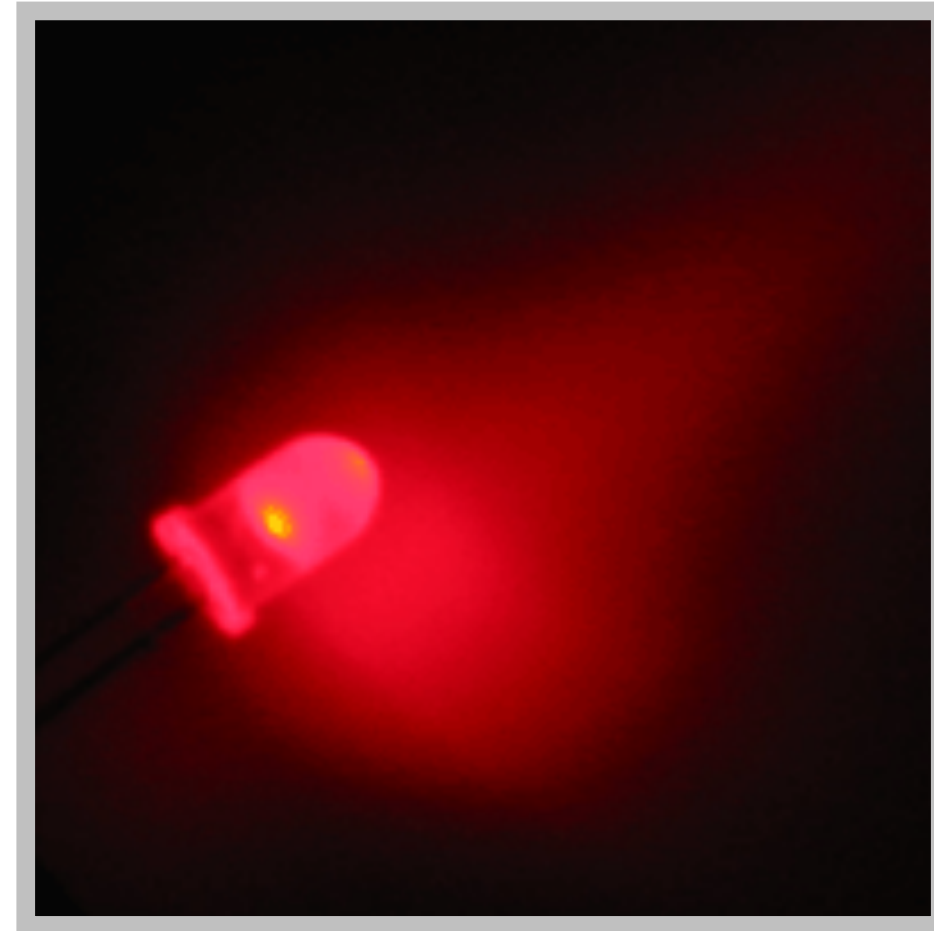
# Importance of Understanding People



# Real World Example: 3 Mile Island



# Real World Example: 3 Mile Island





*Thinking Fast and Slow*



$$17 \times 24 =$$



# Two Types of Human Cognition

## Type 1 System

- Automatic (unconscious)
- Effortless
- “Fast” thinking
- Associative
- Heuristic
- Gullible
- Can’t be turned off

## Type 2 System

- Voluntary (conscious)
- Effortful
- “Slow” thinking
- Planning
- Logical
- Lazy
- Usually only partly on

# Examples of System 1

- Detect that one object is more distant than another.
- Orient to the source of a sudden sound.
- Complete the phrase “bread and...”
- Make a “disgust face” when shown a horrible picture.
- Answer to  $2 + 2 = ?$
- Drive a car on an empty road.
- Understand simple sentences.

# Examples of System 2

- When System 1 does not offer an answer (e.g., 17 x 24)
- When an event is detected that violates the model of the world that System 1 maintains (e.g., cat that barks)
- Continuous monitoring of behavior—(keeps you polite when you are angry)
- Normally has the last word



# *Psychology 101:* Attention

# Attentional Resources are Fixed

## Instructions

**Count how many times the  
players wearing white pass  
the basketball.**



# Attentional Resources are Fixed



# Attentional Resources are Fixed

- System 2 activity takes conscious attention
- Attentional resources are fixed
- Pupils dilate as mental effort increase
- If demands exceed max, tasks prioritized.

# Examples of Attention Limitations

- Can walk and talk
- But not walk and compute  $23 \times 78$
- Constructing complex argument better when still



# Attentional Limitations - Demo

- Remember the following digits:
- 8 3 5 2 1 9 0 5 1

# Attentional Limitations - Demo

- Would you prefer

- (a)



- (b)

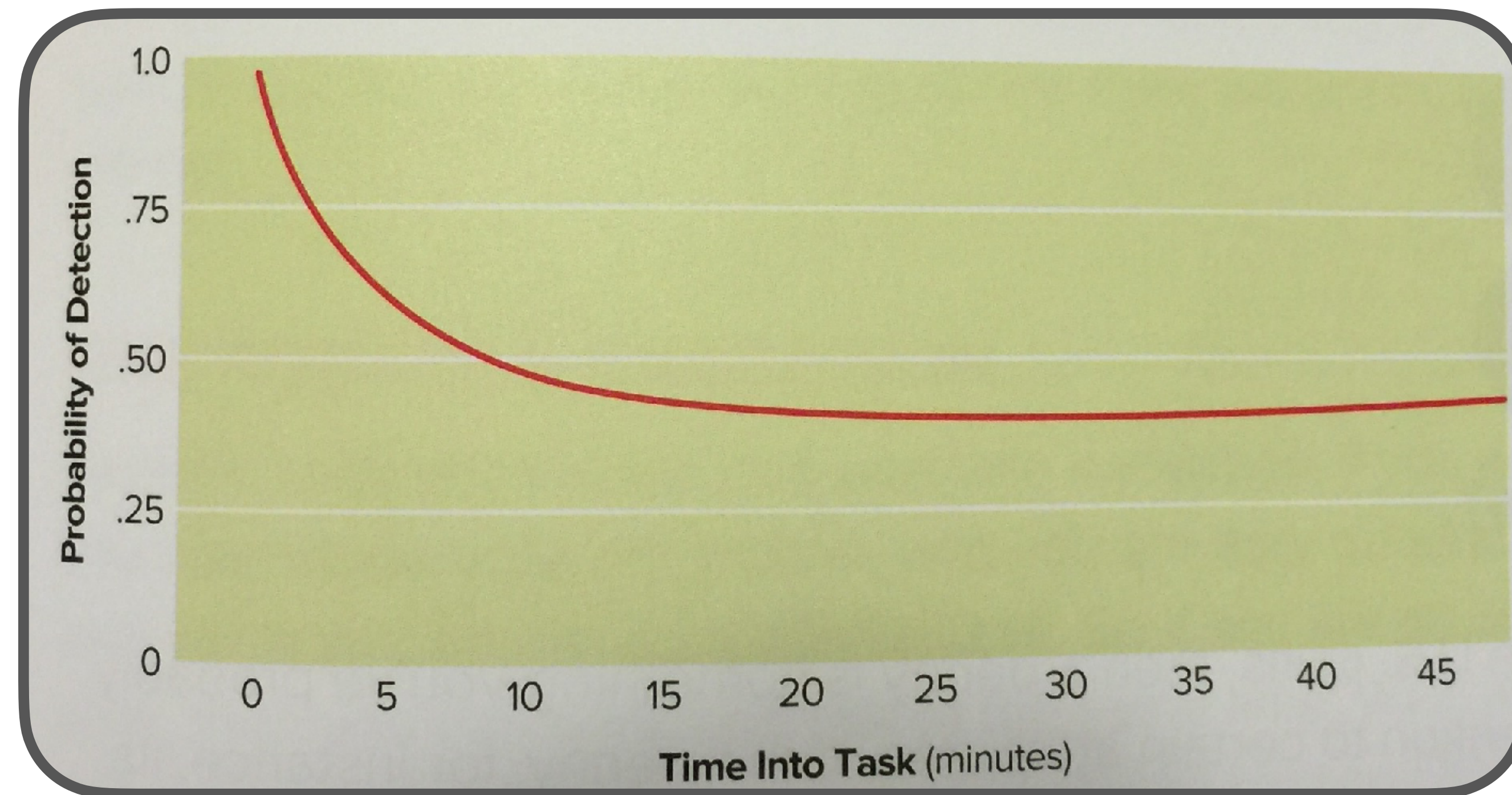


# Attentional Limitations - Demo

- More likely to choose (a) when attentional resources are stressed
- Self control require attention and effort



# Intense focus is unsustainable



# Coexistence of Systems 1 and 2

- System 1 processes normal, everyday, expected activities at low cost.
- System 2 takes over when necessary, at higher cost.
- Law of least effort: pays for System 2 to be lazy.



# Psychology 101: Memory

# Short Term Memory (STM)

- Primary, active memory used for holding current context for System 2
- Unless actively maintained (or encoded to long-term memory), decays after seconds
- Capacity ~ 4 items

# Chunking - Demo

What is the easiest to remember?

- A. A lock combination with 8 numbers in order: 10, 20, 30, 40, 50, 60, 70, 80
- B. A lock combination with 8 numbers in order: 50, 30, 60, 20, 80, 10, 40, 70
- C. A string of 10 letter: R, P, L, B, V, Q, M, S, D, G
- D. A string of 52 letters: I pledge allegiance to the flag of the United State of America.



# Chunking

- Items in memory encoded as **chunks**
- A chunk may be anything that has meaning
- # of chunks in STM fixed, but remembering bigger chunks lets you remember more
- Memory retention relative to the concepts you already have
- —> schemas & mental models (next lecture!)

# Long Term Memory (LTM)

- Items in short term memory may be encoded into storage in long term memory
- LTM capacity not limited
- Information must be retrieved from long term memory (i.e., through System 1)
- Many factors influence what is encoded into LTM and how it is encoded

# Memory is Reconstructive - Example

- How fast was the car going when it hit the other vehicle?

VS.

- How fast was the the car going when it smashed into the other vehicle?
- 2x more remember seeing broken glass





# Memory is Reconstructive - Example

- How fast was the car going when it hit the other vehicle?

VS.

- How fast was the car going?
- 2x more remembered broken glass

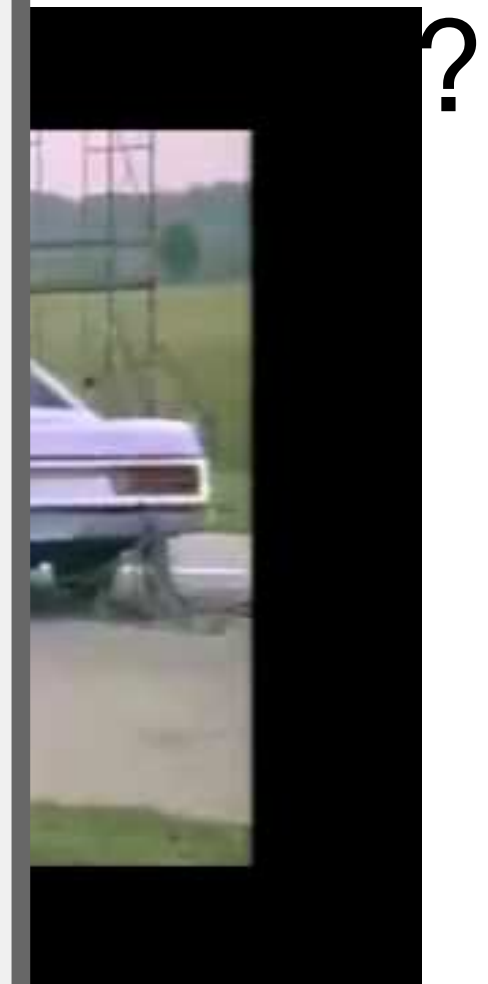
JOURNAL OF VERBAL LEARNING AND VERBAL BEHAVIOR 13, 585–589 (1974)

## Reconstruction of Automobile Destruction : An Example of the Interaction Between Language and Memory'

ELIZABETH F. LOFTUS AND JOHN C. PALMER

*University of Washington*

Two experiments are reported in which subjects viewed films of automobile accidents and then answered questions about events occurring in the films. The question, "About how fast were the cars going when they smashed into each other?" elicited higher estimates of speed than questions which used the verbs *collided*, *bumped*, *contacted*, or *hit* in place of *smashed*. On a retest one week later, those subjects who received the verb *smashed* were more likely to say "yes" to the question, "Did you see any broken glass?", even though broken glass was not present in the film. These results are consistent with the view that the questions asked subsequent to an event can cause a reconstruction in one's memory of that event.



# Memory is reconstructive

- Not stored files on a disk
- Encoded in brain, may be different every time retrieved
- Remember pieces, reconstruct other details based on expectations on what must have occurred
- Hard to distinguish similar memories



# *Psychology 101:* Learning

# Rehearsal

- Information may be repetitively experienced or actively repeated (“subvocalization”)
- 232 535 487 235
- More times information is rehearsed, better memory

# Depth of Processing

- More time spent interacting with information, more likely it is to be remembered

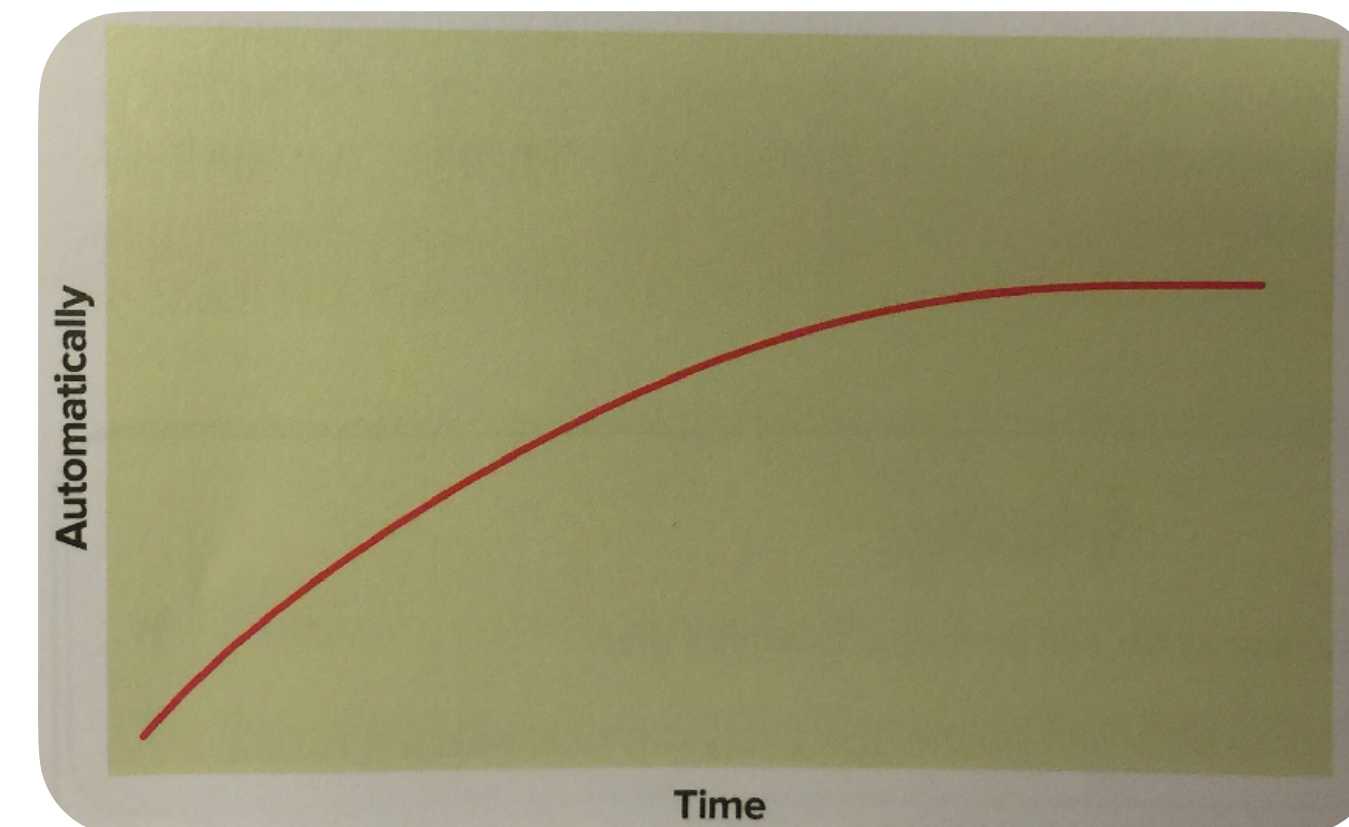
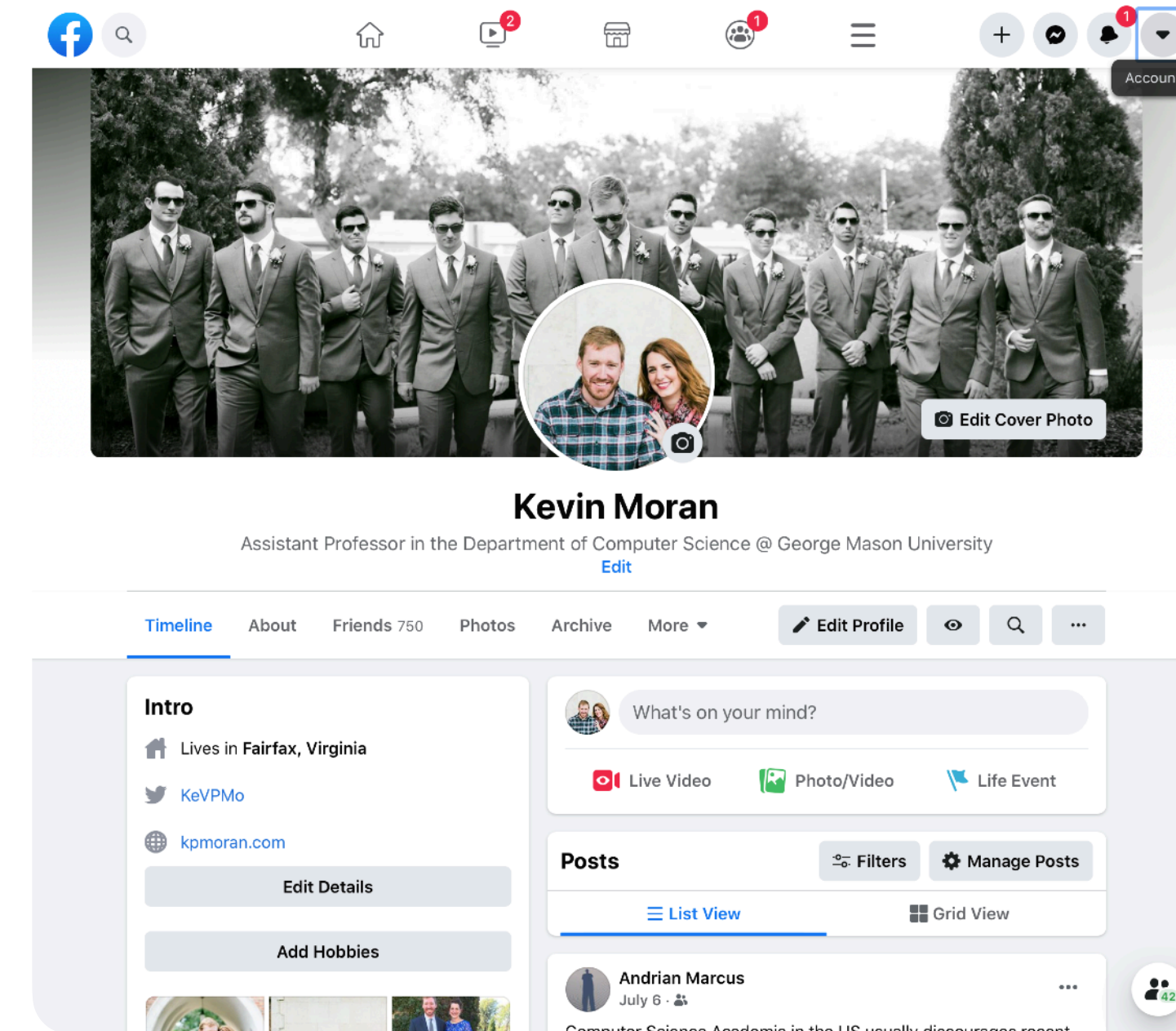


# Automaticity

- This effect happens for sequences of actions (“**scripts**”) as well.
  - Example: tying shoelaces
- More repetitions, faster, requires less conscious attention.
- Responsibility shifts from System 2 —> System 1

# Habit formation takes time

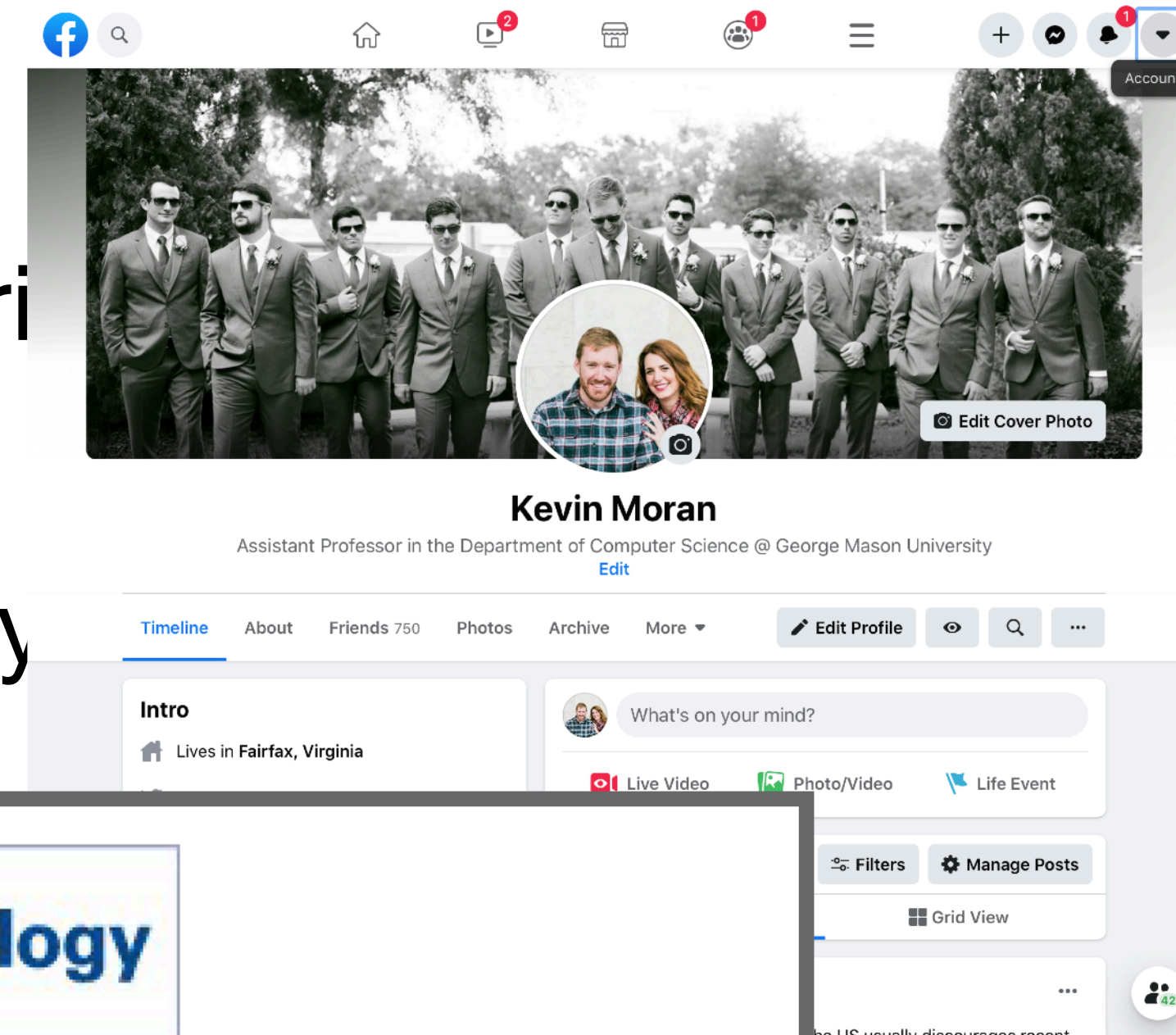
- How long does it take to form an eating, drinking, or checking FB before bed habit?
- Mean: 66 days, Min: 18 days, Max: 254 days
- More complex behaviors take longer to become habit





# Habit formation takes time

- How long does it take to form an eating, drinking, or exercise habit?
- Mean: 66 days, Min: 18 days, Max: 254 days
- More complex habits take longer



fore bed

## European Journal of Social Psychology

Research Article

### How are habits formed: Modelling habit formation in the real world<sup>†</sup>

Phillippa Lally✉, Cornelia H. M. van Jaarsveld, Henry W. W. Potts, Jane Wardle

First published: 16 July 2009 | <https://doi.org/10.1002/ejsp.674> | Citations: 500

<sup>†</sup> This research was conducted by Phillippa Lally when she held a Medical Research Council PhD studentship and has been written up during an Economic and Social Research Council postdoctoral fellowship.

# *Psychology 101:* **Affect**

# Affect

- Current emotional state
- *Valence*: positive or negative
- *Arousal*: strength of activation of sympathetic nervous system



# Affect Affects Focus and Creativity

- Negative affect / high arousal

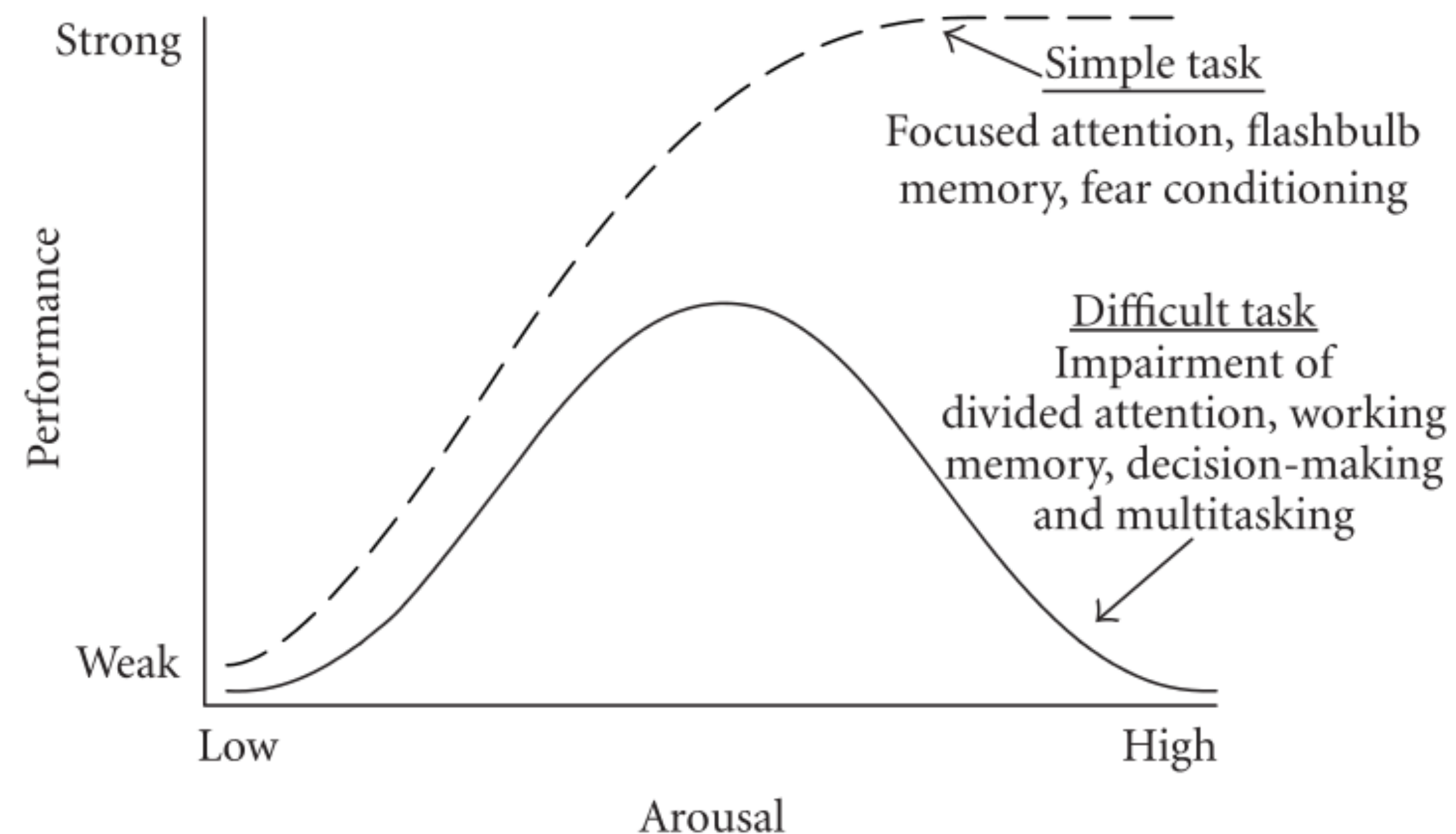
- Escape from danger
- Fire & door doesn't open —> push harder
- Neurotransmitted bias brain to focus on problem & ignore distractions
- Tunnel vision on most salient aspects

- Positive affect / lower arousal

- Better brainstorming and generating alternatives
  - More likely to work around minor difficulties —> better usability
- See bigger picture, less focused

# Performance / Arousal Curve

- Yerkes / Dodson law
- Arousal increases performance for System 1 tasks, but only increases performance on System 2 tasks up to a threshold



# Design Implications from Psychology



# General Design Implications

- Take advantage of System 1 where possible
- Don't confuse System 1 (e.g., consistent mapping in next lecture)
- Users can be stubborn (sunk cost investment in current strategy)
- People can get upset when have goals they cannot accomplish, as attentional resources exhausted solving problem and less self control
- Let users doing something else while waiting

# *Design Implications:* What Makes an Expert?

# What Makes an Expert?

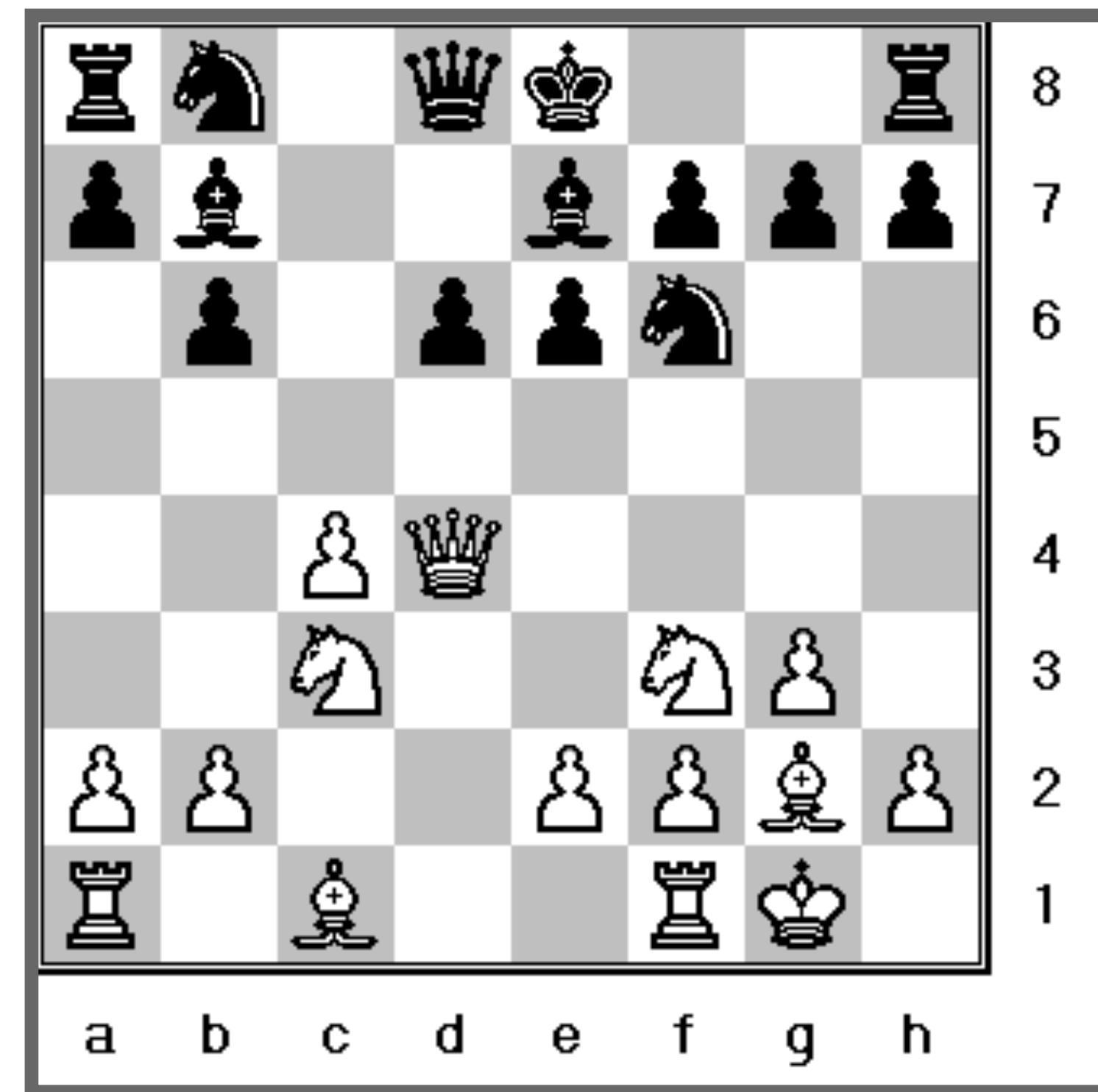


# What Makes an Expert?

- Experts are more intelligent?
  - IQ doesn't distinguish best chess players or most successful artists or scientists (Doll & Mayr 1987) (Taylor 1975)
- Experts think faster or have larger memory?
  - World class chess experts don't differ from experts (de Groot 1978)

# What Makes a Grand Master a Chess Expert?

- Memory for *random* chess boards: *same* for experts and novices
- Memory for position from *actual* game: much better for *experts* than novices
- [deGroot 1946; Chase & Simon 1973]



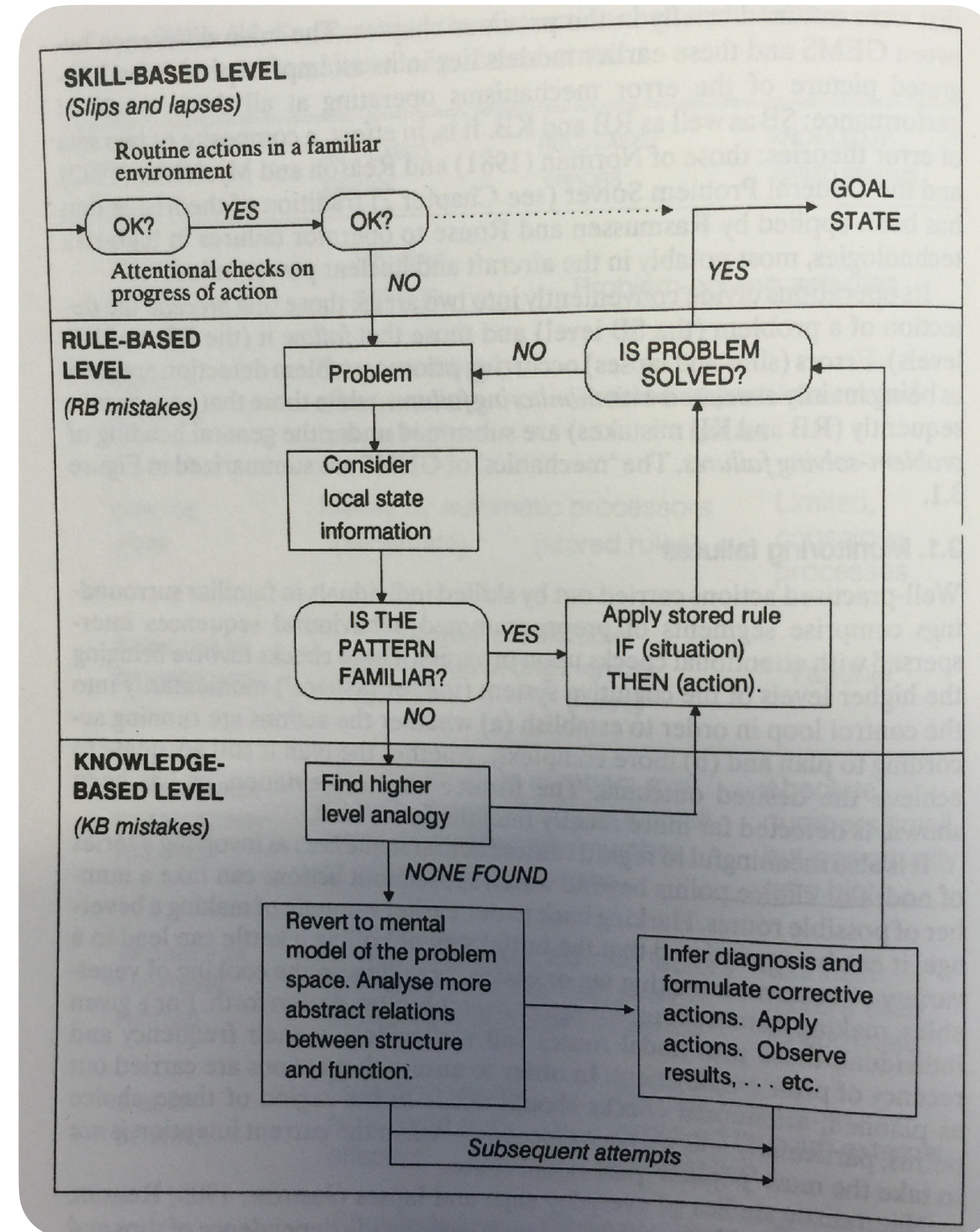


# Schemas (a.k.a chunking)

- Experts *think differently*.
- Have schemas that help them to
  - Recognize and react to common situations through System 1
  - Encode the world in more abstract terms
  - Solve problems more effectively

# Different Behavior Types

- Skill / Rule / Knowledge



# Don't Make the User Think

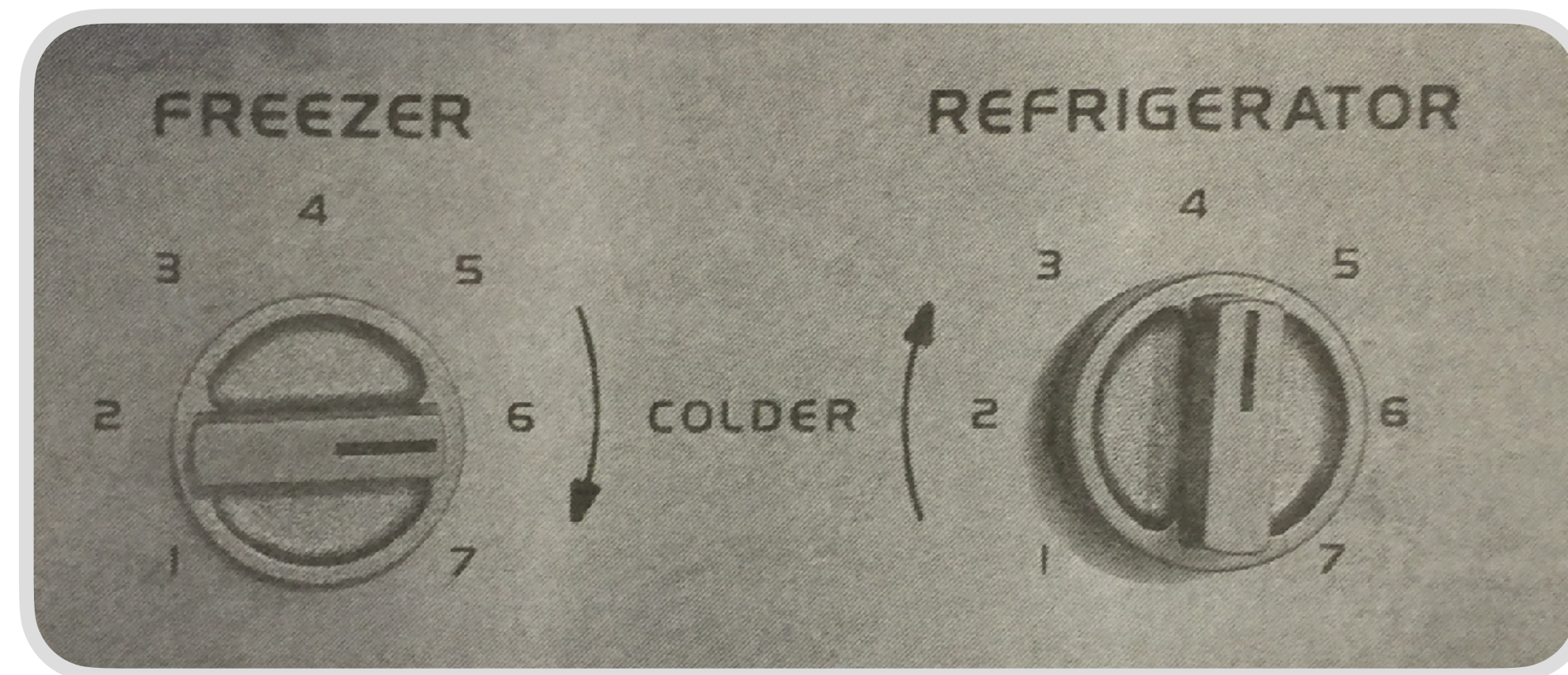
- Let users use (automatic) skills of System 1 rather than (conscious) knowledge-based problem solving of System 2
- Key principle (it's the title of one of the course textbooks....)
  - We'll come back to this idea often in the future
- What this means: let users think about everything except for interface interactions
  - If user goal is to write a document, want user thinking about what they're writing, not how to use word processor



# Mental Models

# Mental Models (a.k.a Conceptual Models)

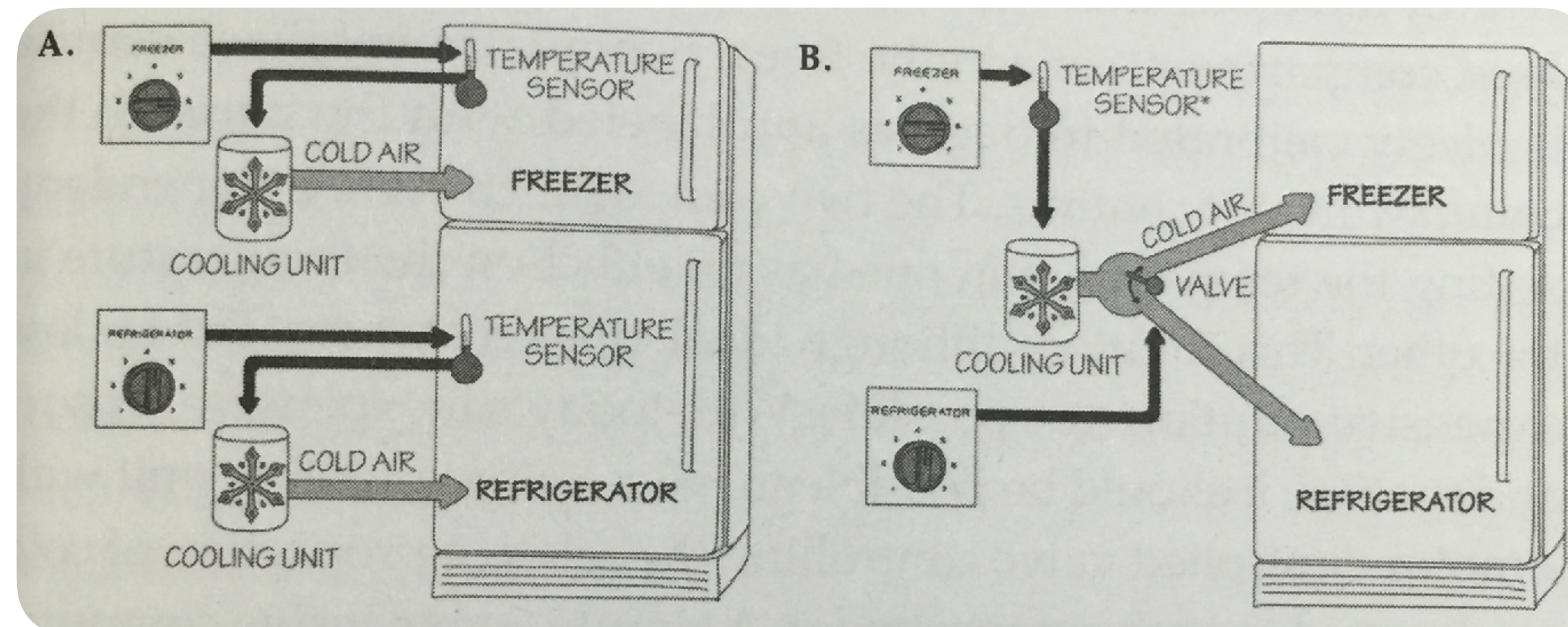
- Internal representation in the head of how something works in the real world
- E.g., changing appropriate knob adjusts temperature in freezer or refrigerator





# Mental Models

- Only single temperature sensor.
- Controls not independent, need to adjust both.
- (also delayed feedback)



# Distributed cognition

| TABLE 3.1. Tradeoffs Between Knowledge in the World and in the Head                                                                                                                                   |                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Knowledge in the World                                                                                                                                                                                | Knowledge in the Head                                                                                                                                                                            |
| Information is readily and easily available whenever perceivable.                                                                                                                                     | Material in working memory is readily available. Otherwise considerable search and effort may be required.                                                                                       |
| Interpretation substitutes for learning. How easy it is to interpret knowledge in the world depends upon the skill of the designer.                                                                   | Requires learning, which can be considerable. Learning is made easier if there is meaning or structure to the material or if there is a good conceptual model.                                   |
| Slowed by the need to find and interpret the knowledge.                                                                                                                                               | Can be efficient, especially if so well-learned that it is automated.                                                                                                                            |
| Ease of use at first encounter is high.                                                                                                                                                               | Ease of use at first encounter is low.                                                                                                                                                           |
| Can be ugly and inelegant, especially if there is a need to maintain a lot of knowledge. This can lead to clutter. Here is where the skills of the graphics and industrial designer play major roles. | Nothing needs to be visible, which gives more freedom to the designer. This leads to cleaner, more pleasing appearance—at the cost of ease of use at first encounter, learning, and remembering. |

# External Representations

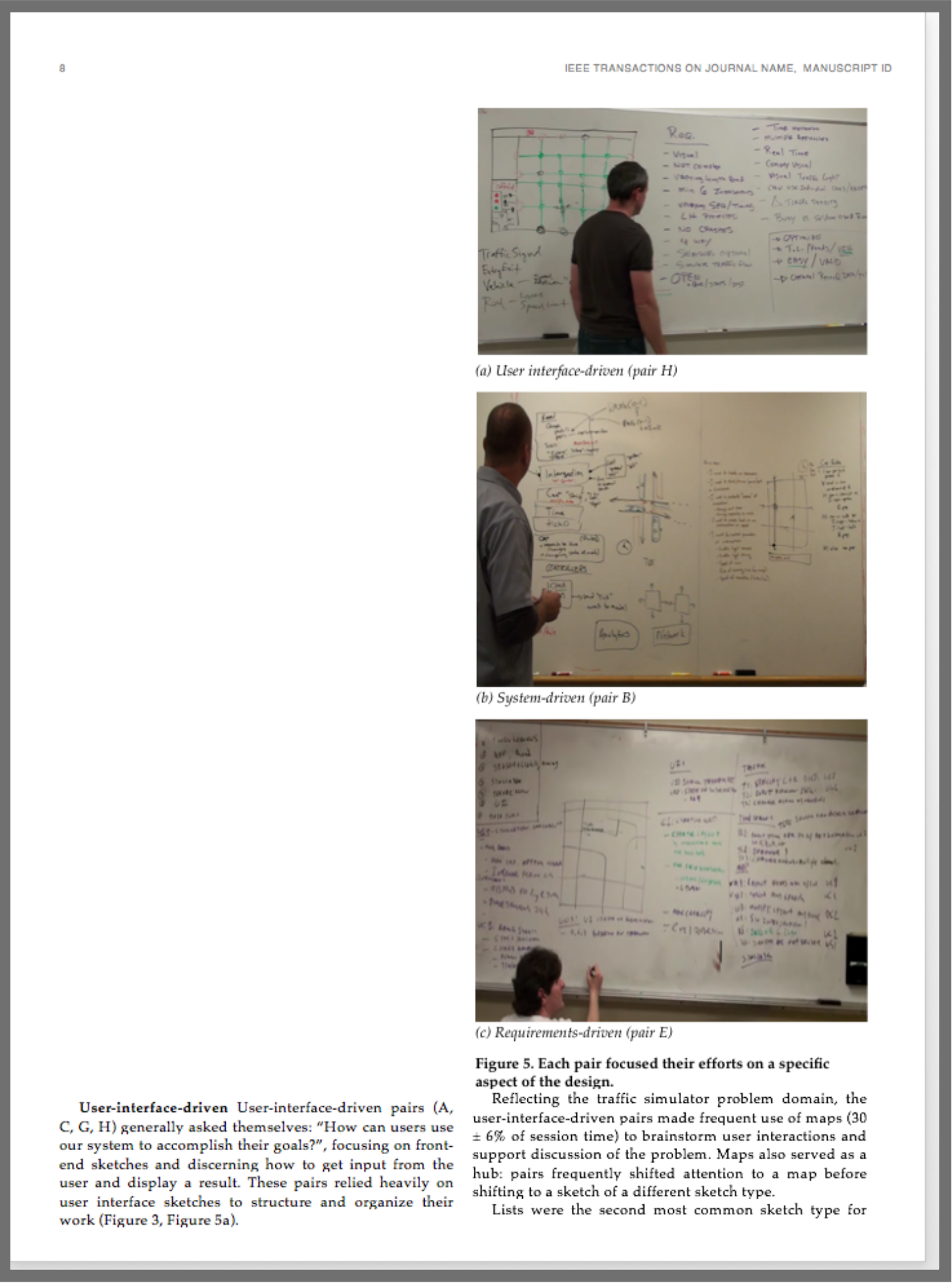
- Reduce STM burden
- Help restructure and reframe problem w/ new abstractions, changing operators
- Encode information and relationships through use of space
- Serve as reminders for future goals



# Designing for Human Actions

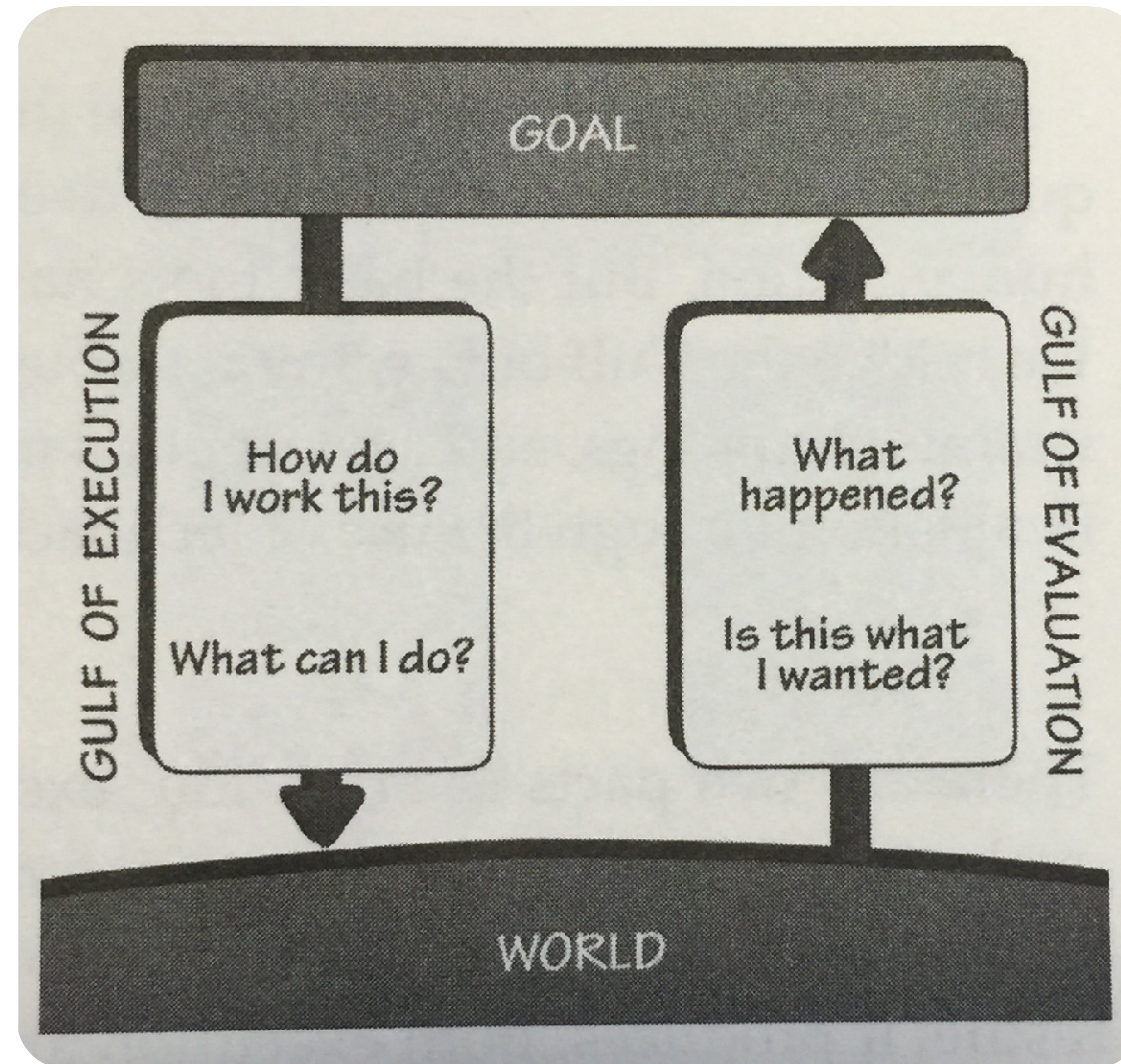
# Humans are Goal-Oriented

- Goal: Make text flow into empty space





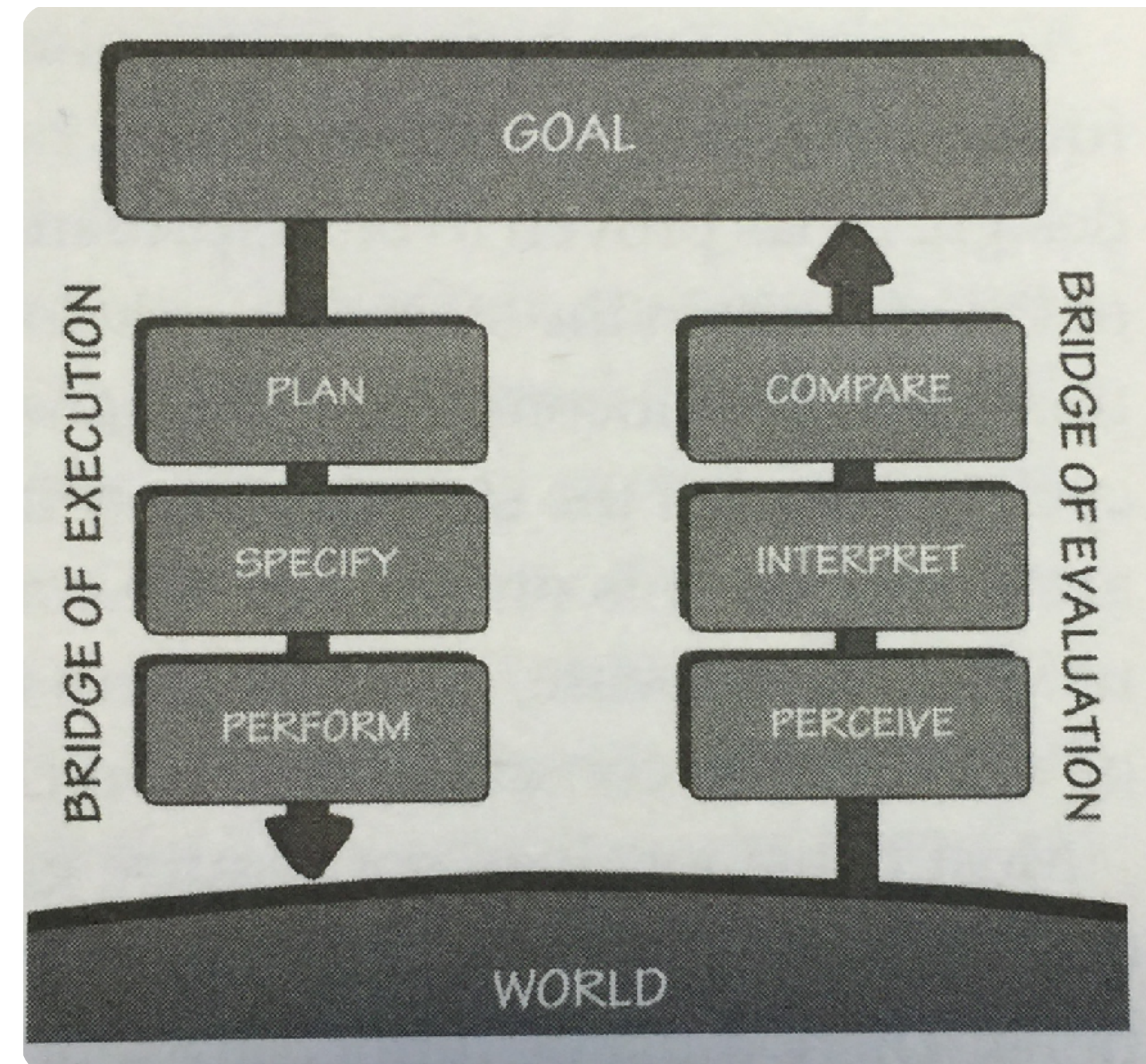
# Gulfs of Execution and Evaluation





# Norman's 7 Stages of Action

1. Goal (form the goal)
2. Plan (the action)
3. Specify (action sequence)
4. Perform (action sequence)
5. Perceive (the state of the world)
6. Interpret (the perception)
7. Compare (outcome w/ goal)



# Designing for Action

- Key challenge is designing interactions that help users to accomplish their goals

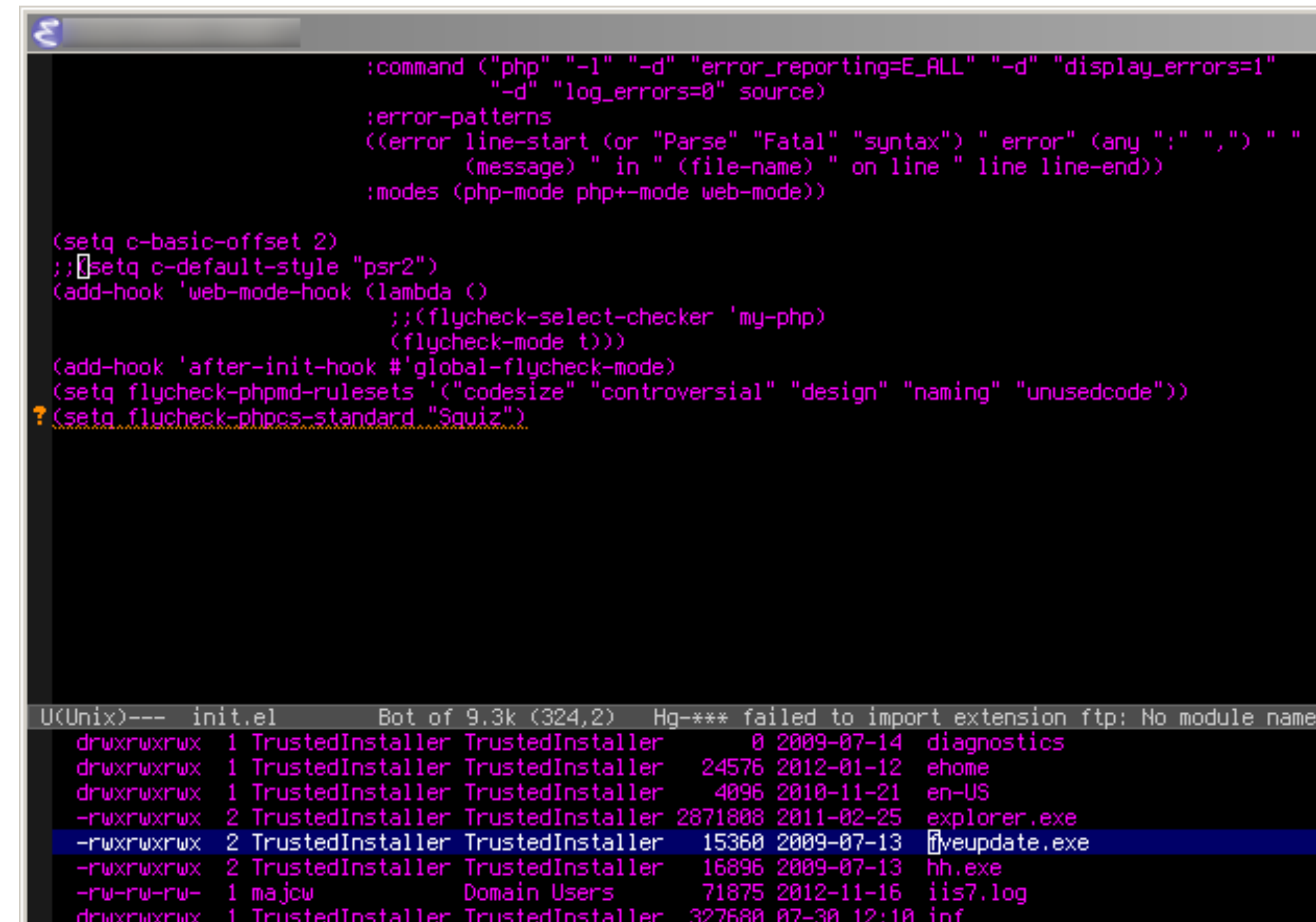
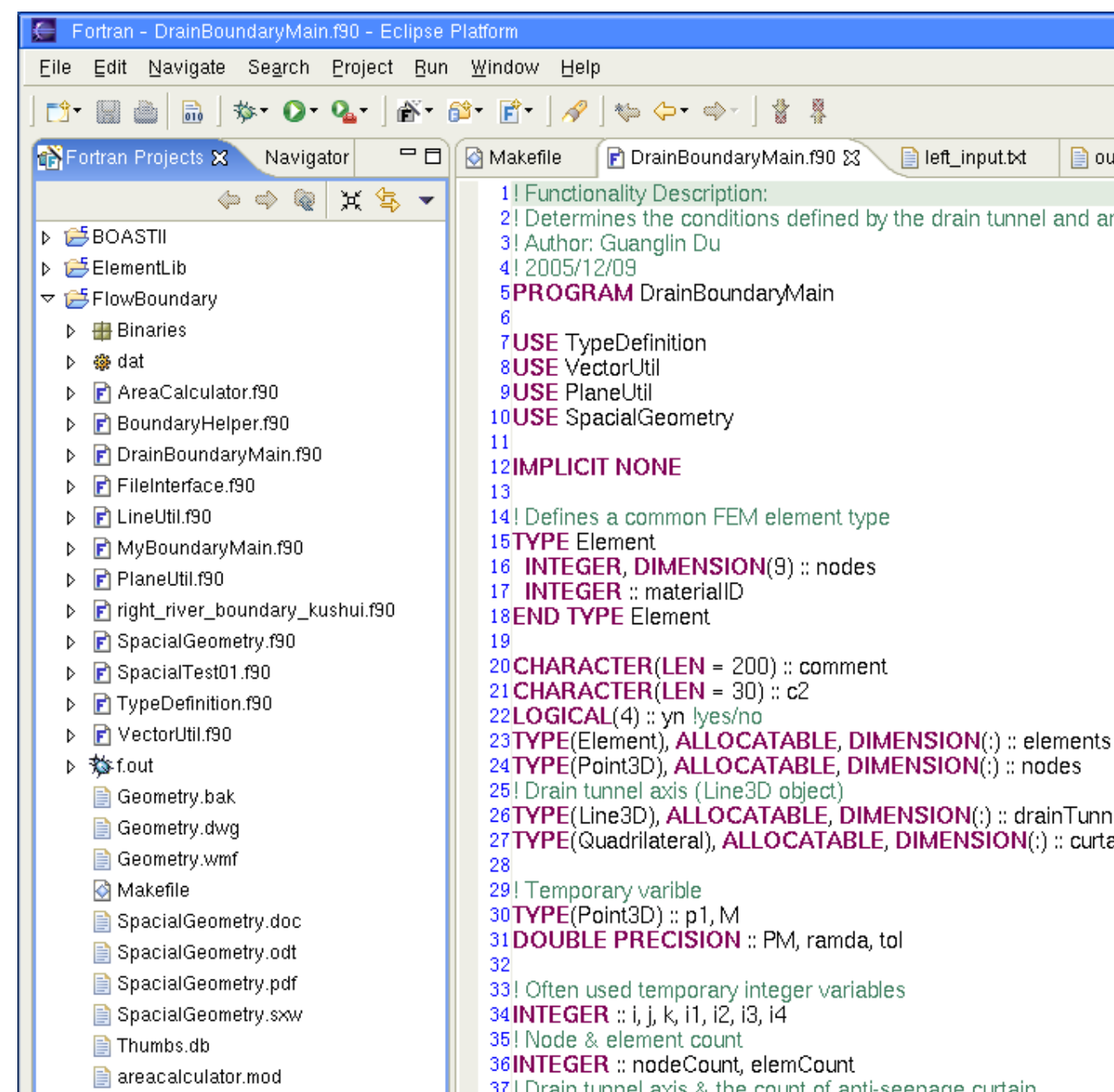
# 7 Principles of Designing for Action

1. Discoverability
2. Feedback
3. Conceptual Model
4. Affordances
5. Signifiers
6. Mappings
7. Constraints



# 1. Discoverability

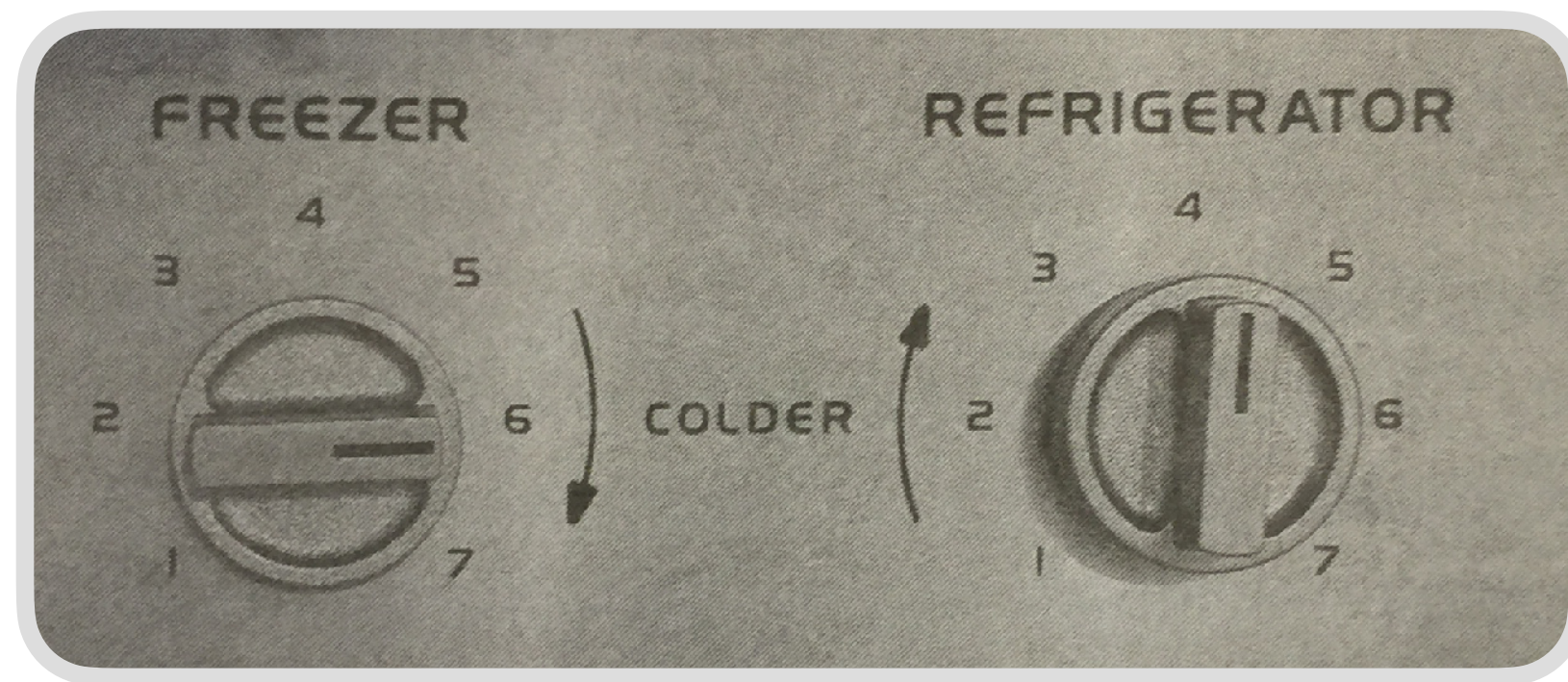
- IT should be possible to determine possible actions and current state of device
- Which has more discoverable commands: Eclipse or emacs?





## 2. Feedback

- There should be full and continuous info about the results of actions and the current state



# 3. Conceptual Model

- Design should project all of the information needed to create an *accurate* conceptual model.



# 4. Affordances

- The proper affordances exist to make the desired actions possible.
- Affordance: Relationship between an object and a user that determines how it can be used.

| Browser       | Tabbed browsing | Pop-up blocking <sup>[note 1]</sup> | Incremental search | Ad filtering           | Page zooming <sup>[note 2]</sup> | Full text search of history | Content-modal dialogs <sup>[note 3]</sup> |
|---------------|-----------------|-------------------------------------|--------------------|------------------------|----------------------------------|-----------------------------|-------------------------------------------|
| Amaya         | Yes             | N/A                                 | No                 | No                     | Yes                              | No                          | ?                                         |
| AOL Explorer  | Yes             | Yes                                 | No                 | No                     | Yes                              | No                          | ?                                         |
| Arora         | Yes             | Yes                                 | Yes                | Yes                    | Yes                              | No                          | No                                        |
| Avant         | Yes             | Yes                                 | No                 | Yes                    | Yes                              | No                          | ?                                         |
| Camino        | Yes             | Yes                                 | Yes                | Yes                    | Yes                              | No                          | ?                                         |
| Chromium      | Yes             | ?                                   | Yes                | ?                      | Yes                              | ?                           | ?                                         |
| Dillo         | Yes             | N/A                                 | No                 | No                     | No                               | No                          | No                                        |
| Dooble        | Yes             | Yes                                 | Yes                | Yes                    | Yes                              | Yes                         | ?                                         |
| ELinks        | Yes             | N/A                                 | Yes                | N/A                    | N/A                              | No                          | No <sup>[note 4]</sup>                    |
| Flock         | Yes             | Yes                                 | Yes                | Yes                    | No                               | No                          | ?                                         |
| Galeon        | Yes             | Yes                                 | Yes                | Yes                    | Yes                              | No                          | No                                        |
| Google Chrome | Yes             | Partial <sup>[note 5]</sup>         | Yes                | No <sup>[note 6]</sup> | Yes                              | Yes                         | No <sup>[note 7]</sup>                    |
| ICat          | Yes             | Yes                                 | No                 | Yes                    | Yes                              | No                          | ?                                         |

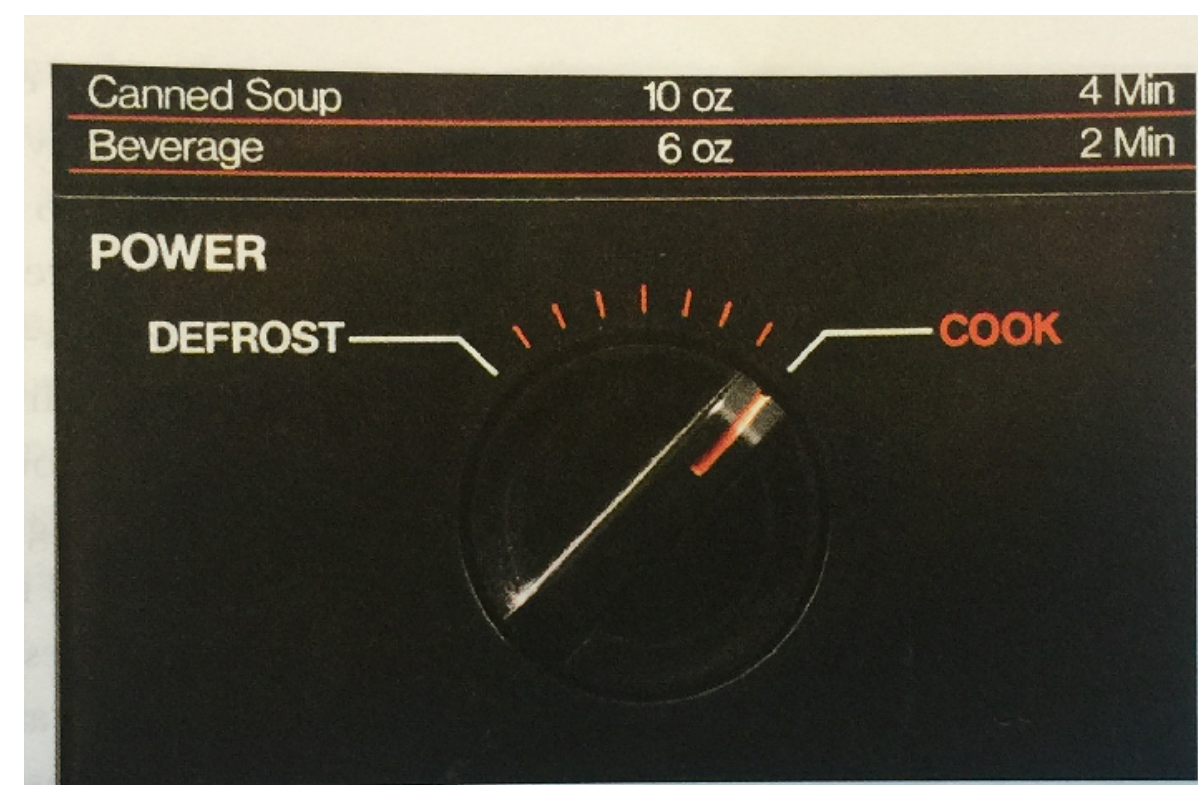
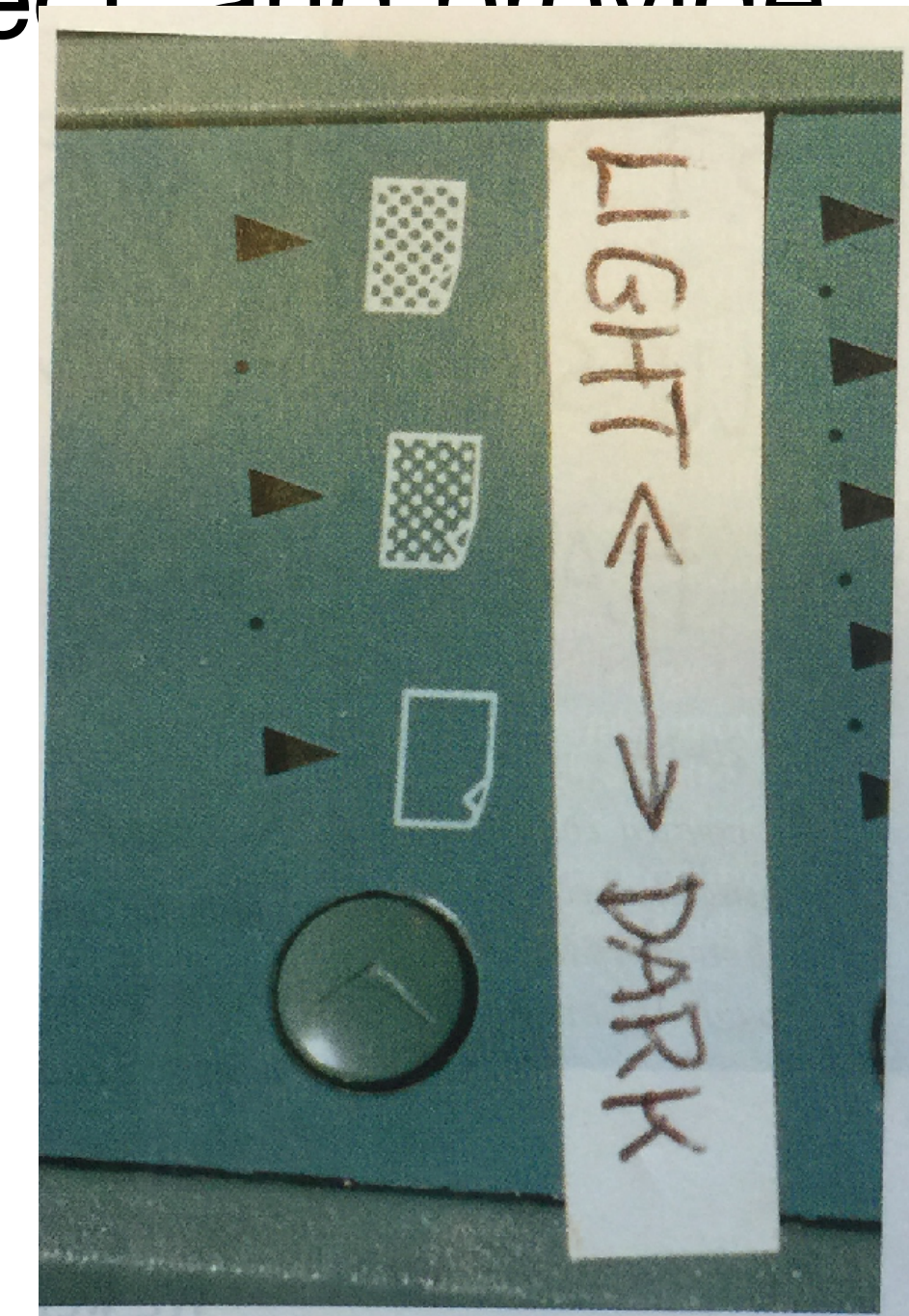


# 5. Signifiers

- Signifiers should communicate the object and provide feedback



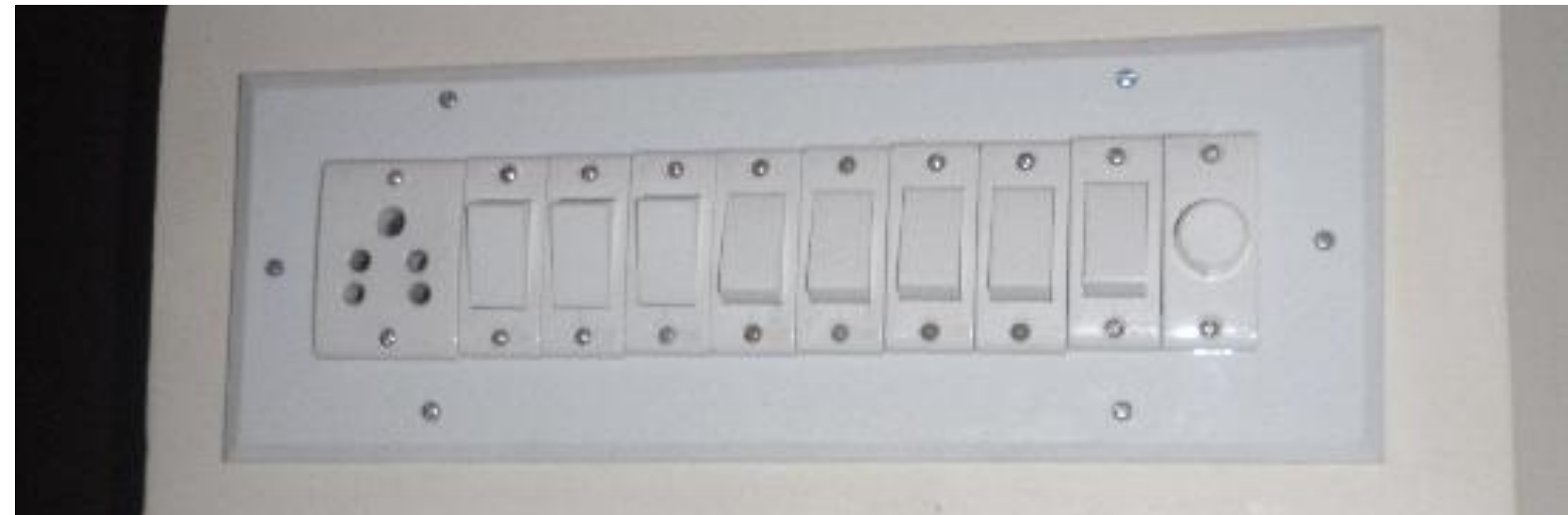
object and provide





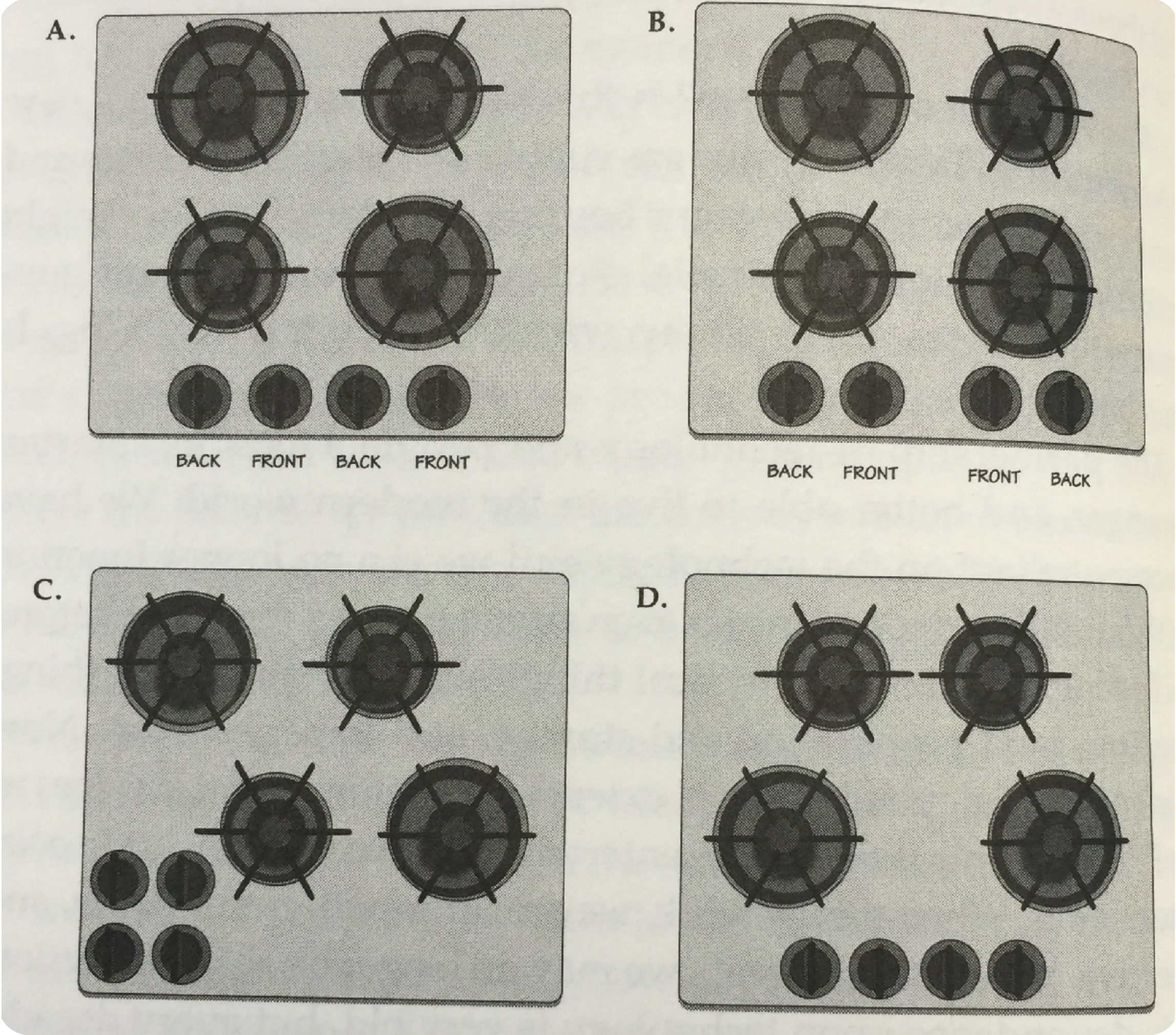
# 6. Mapping

- The relationship between controls and their actions should follow intuitive spatial layouts and temporal contiguity.





# Example - Stove Burners



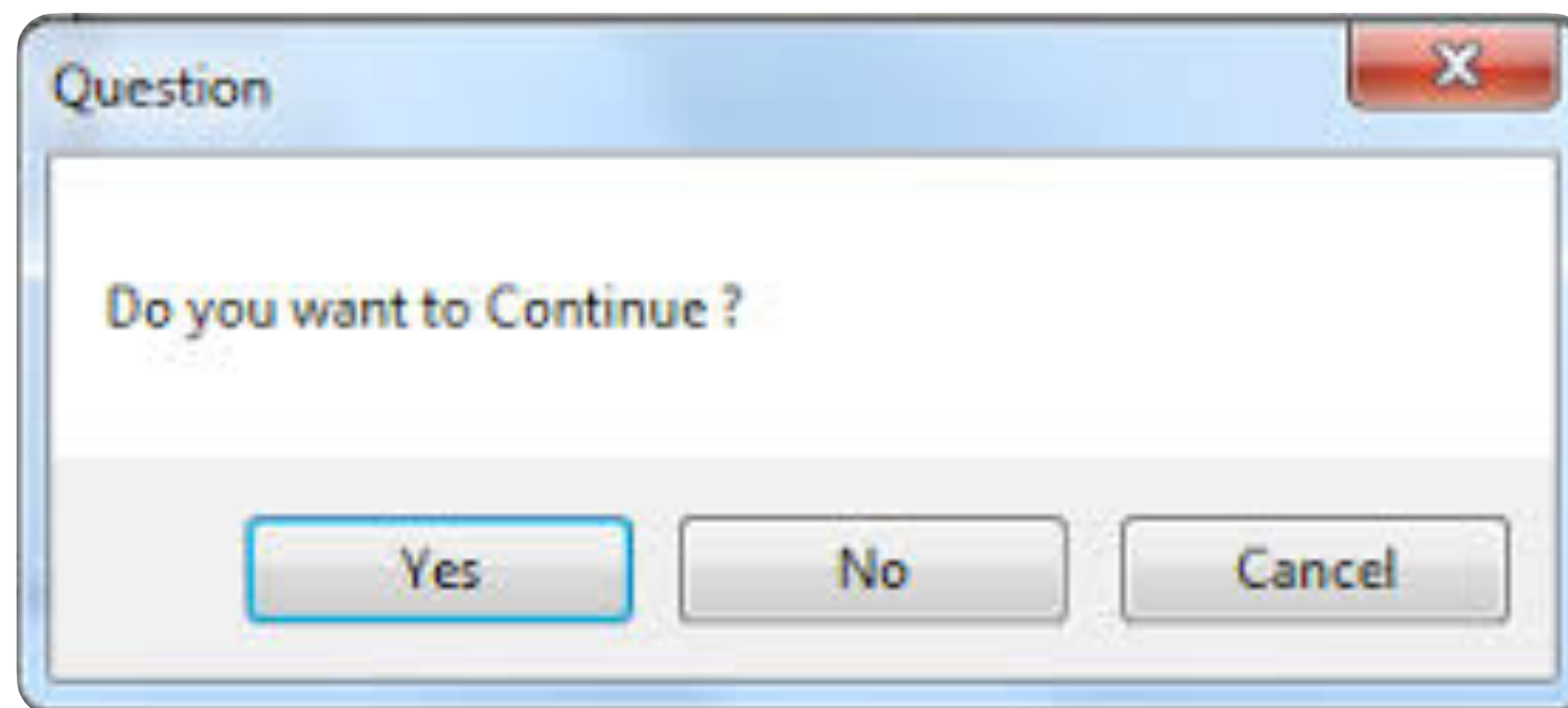


# Natural Mapping

- Best mapping: controls mounted next to item to be controlled
- Second best mapping - controls as close as possible to item to be controlled
- Third best mapping - controls arranged in same spatial configuration

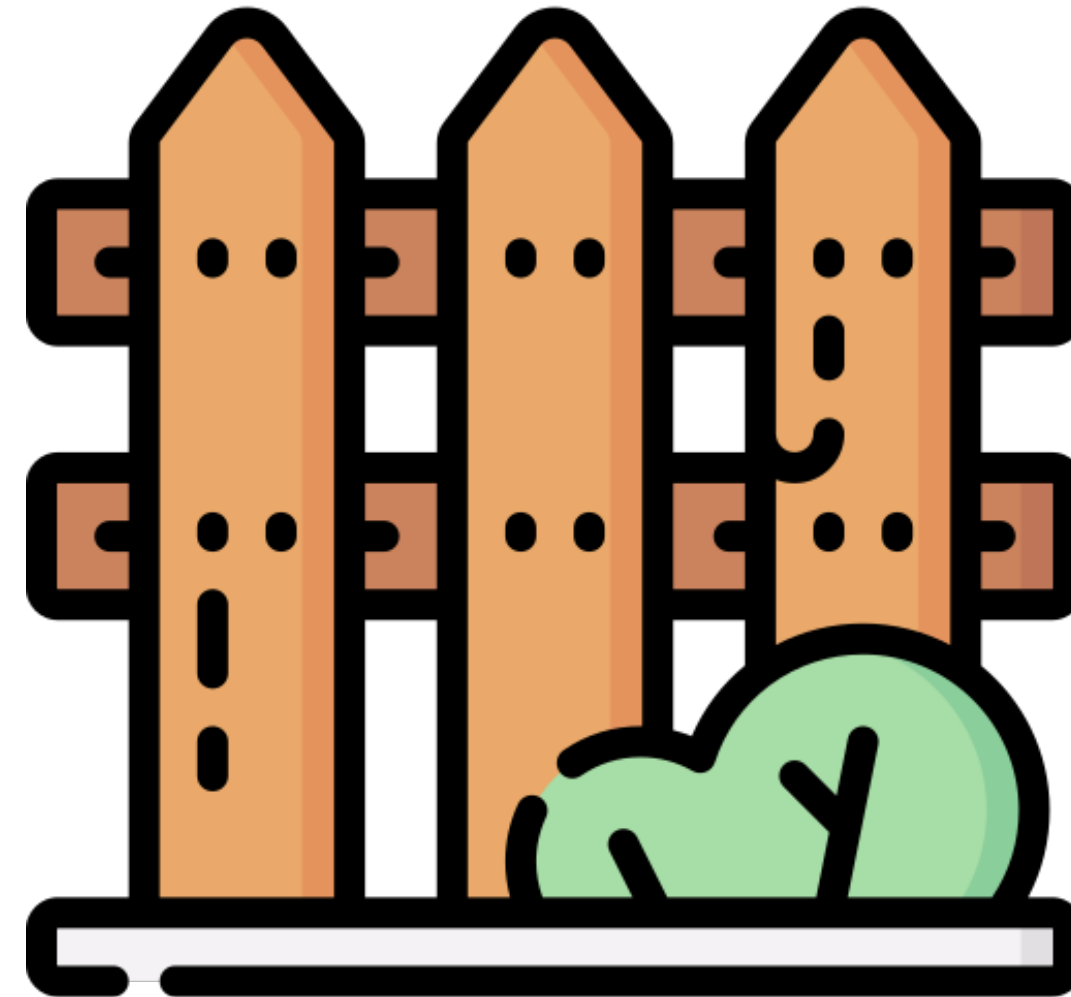
# Consistent Mapping

- Control consistently leads to same action
- Facilitates System 1 - taking action always leads to the same effect



# 7. Constraints

- Provide physical, logical, semantic, cultural constraints to guide actions and ease interpretation





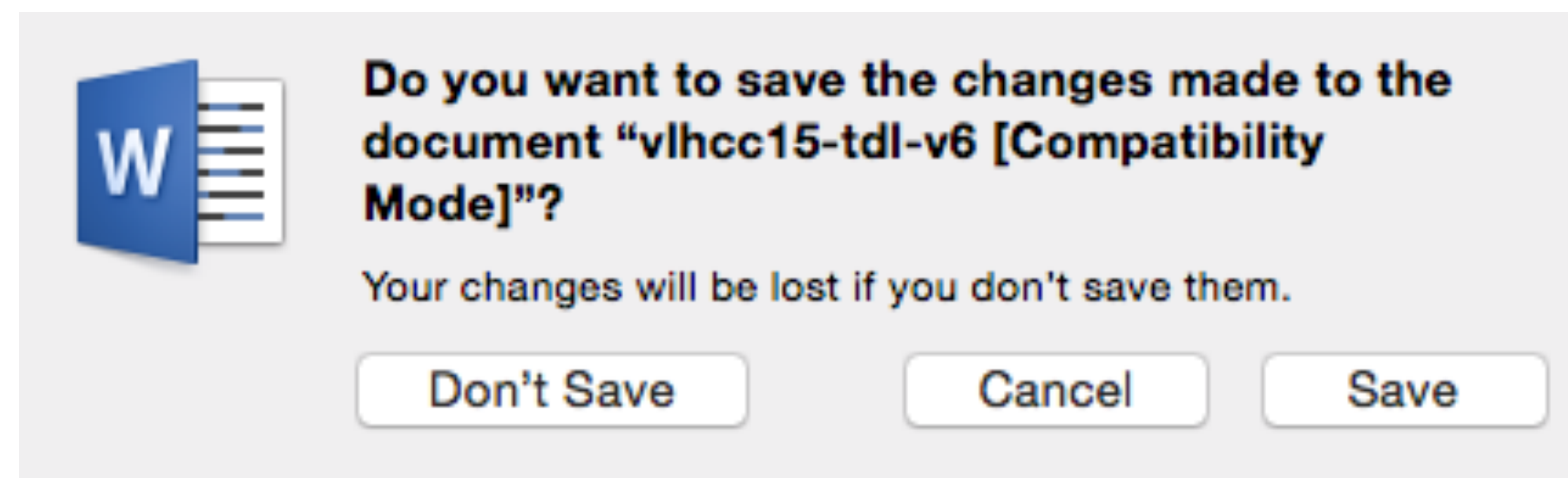
# Physical constraints

- Constrain possible operators (e.g., round peg, square whole)
- Rely on properties of artifact, no training required



# Lock-Ins

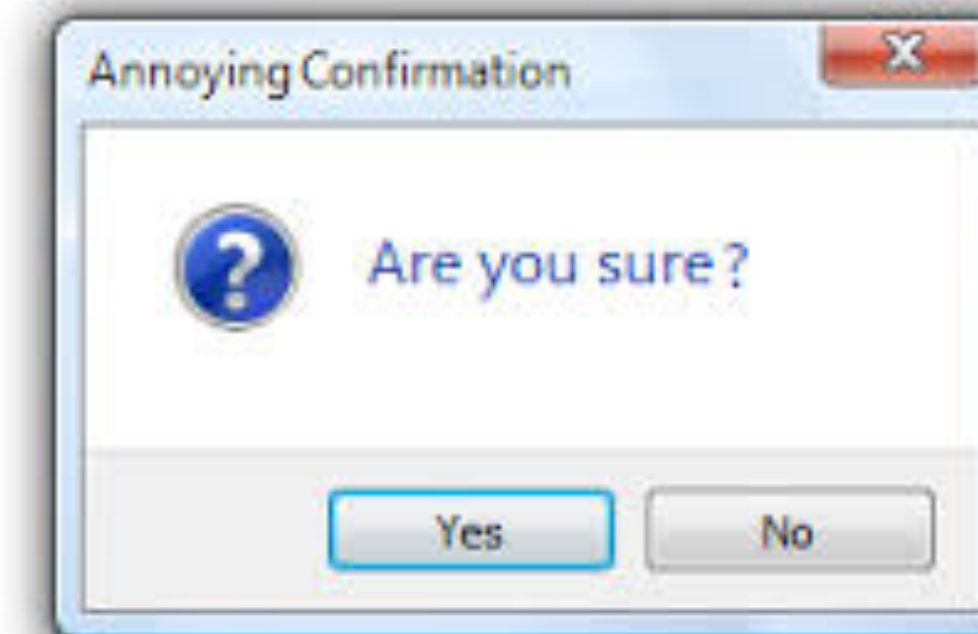
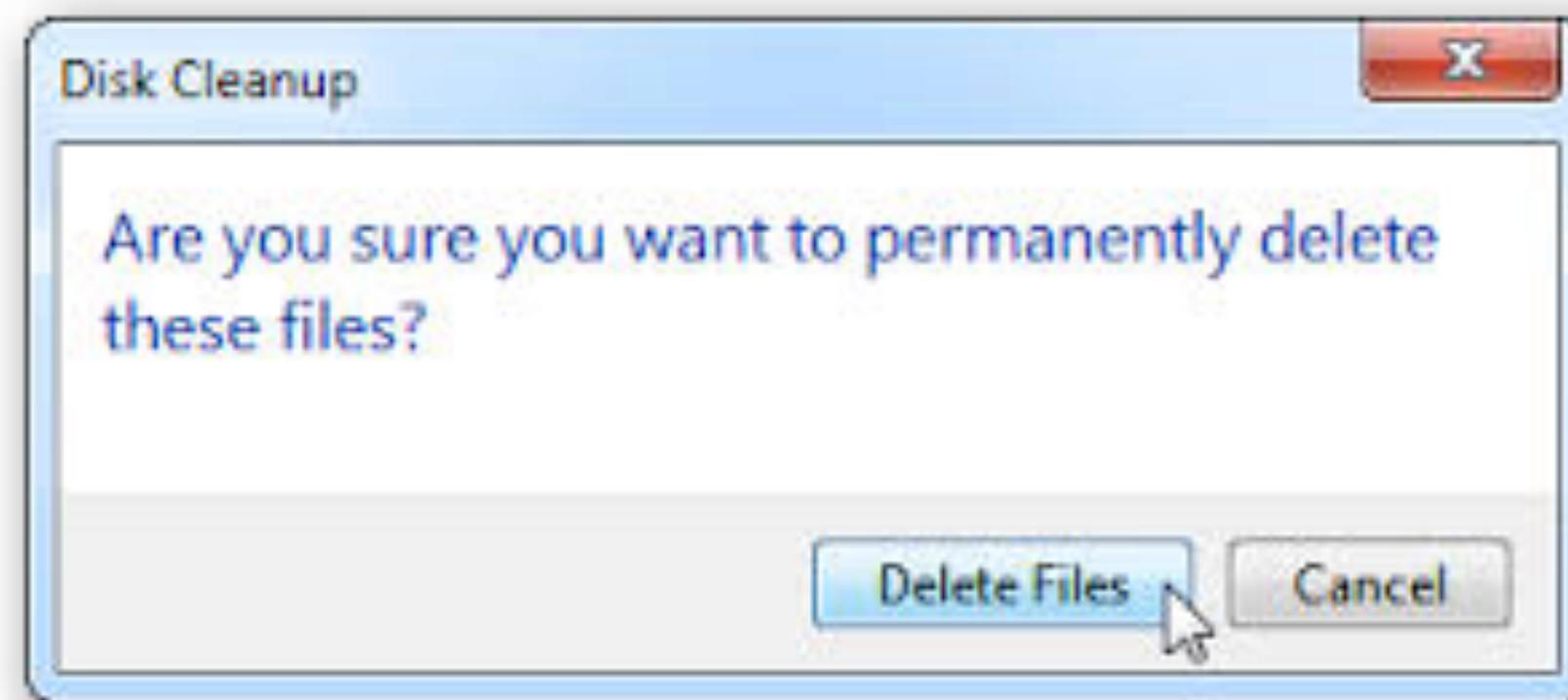
- Keeps an operation active, preventing someone from prematurely stopping





# Lock-Outs

- Prevents an event from occurring



# Inter-Locks

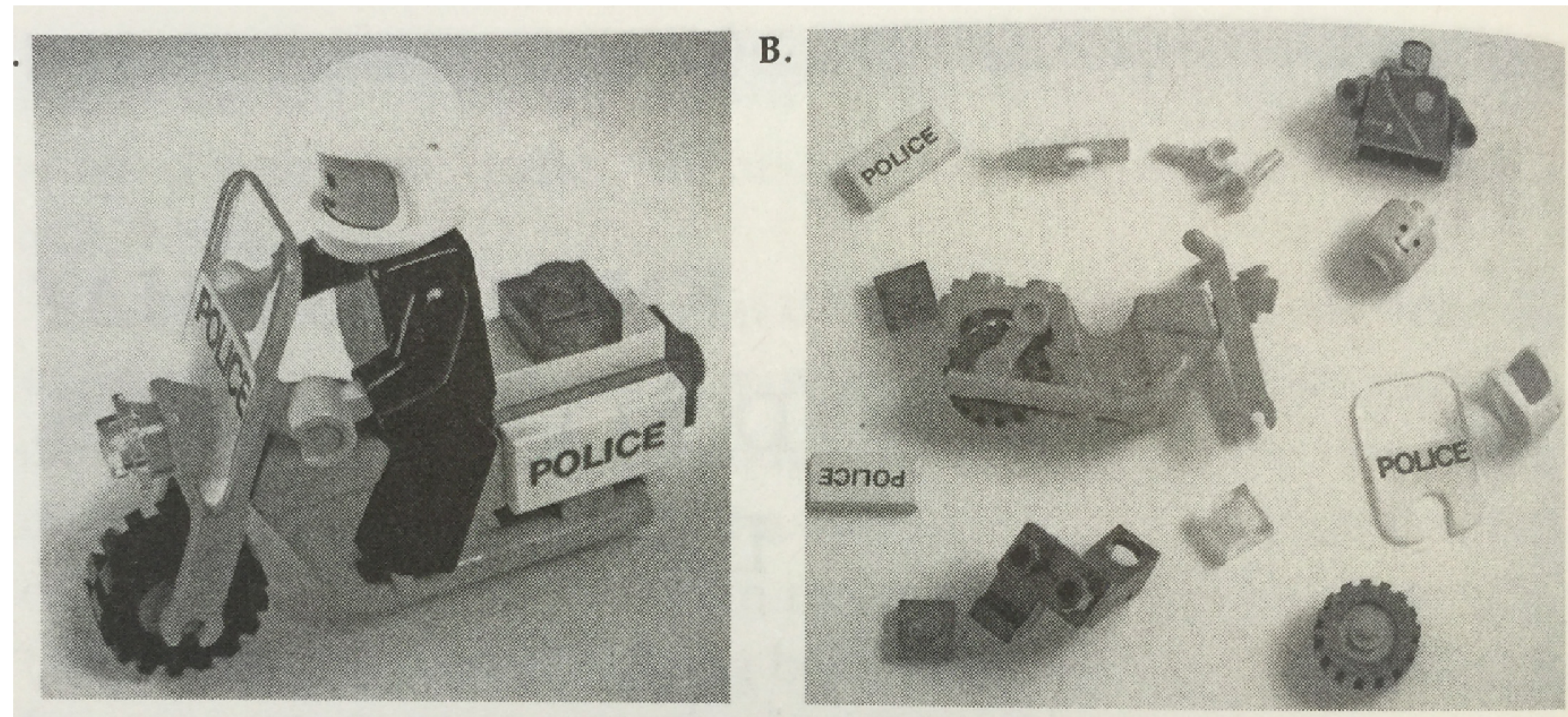
- Force actions to take place in the proper sequence





# Cultural, Semantic, & Logical Constraints

- Norms, conventions that describe possible actions





# Example: Faucets

- *Control 2 Variables:* temperature, rate of flow
- *Physical Mental Model:* water enters through 2 pipes
- *Potential Solutions:*
  - Separate controls for hot and cold
  - Control only temp / control only flow
  - On / off
  - One control

# Example: Faucets

- Mapping problems:
  - Which controls hot and which cold?
  - How do you change temperature w/ out flow rate?
  - How do you change flow w/out temperature?
  - Which direction increases water flow?



# Example: faucets

- Standard conventions: left hot, right cold; counter-clockwise turns it on
- But
  - Not in England
  - Not always on shower controls
  - Not always for blade controls

**10 Minute Break**

# Group Activity



# Group activity

- In groups of 3 or 4
- Pick a **complex** application or website
- List violations of Norman's principles for designing for action
  - List name of principle (e.g., discoverability)
  - Identify a user goal and relevant features of the application
  - Explain how the design violates the principle
- Submit through blackboard (preferred) or on paper

# Norman's designing for action principles

1. Discoverability - make it possible to determine possible actions and state
2. Feedback - full and continuous feedback about result of action
3. Conceptual Model - design communicates info for conceptual model
4. Affordances - desired affordances exist
5. Signifiers - effective use of signifiers to communicate
6. Mapping - relationship between controls and goals uses good mapping
7. Constraints - physical, logical, semantic, cultural constraints



# Acknowledgements

- Incorporates revisions from Dr. Kevin Moran's SWE 632 course