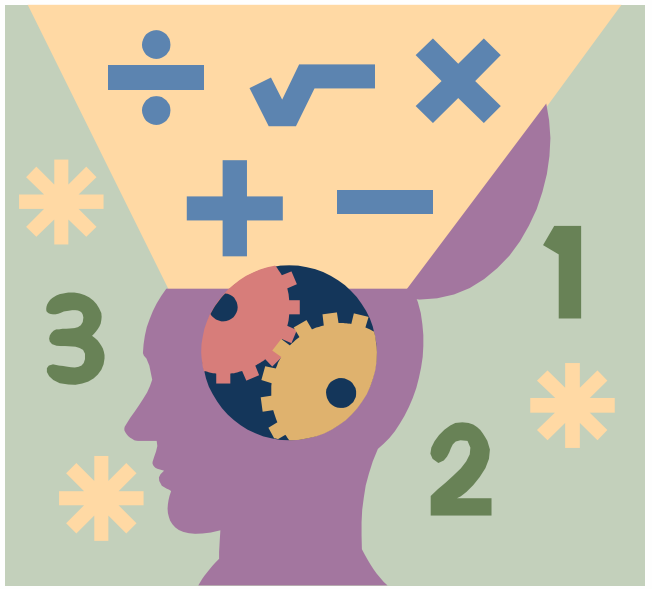
Overview of Human Cognition

and its Impact on User Interface Design



Stepping Back, Big Picture Recap

- Output
  - Output hardware (CRTs, LCDs, etc)
  - Pixel level operations (frame buffer, bitblt, color models)
  - Stroke level operations (line props, polylines, path model)
  - Component level operations (widgets, interactor tree)
  - Window level operations (damage / redraw)
- Input
  - Input hardware (mouse, keyboard, etc)
  - Event devices and sampled devices modeled as events
  - Higher-level events modeled as well (enter / exit)
  - Event Queue and Dispatch strategies

A Whirlwind Overview of Cognition

- Mental Models
- Affordances
- Color
- Performance characteristics of people
- Errors

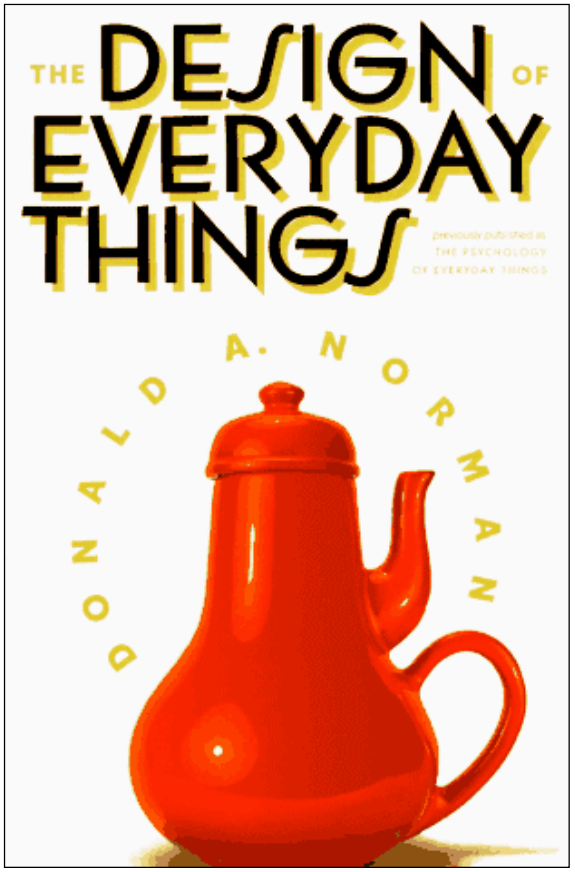
- How these affect design and implementation of GUIs
- Afterwards, advanced interaction techniques

Design of Everyday Things

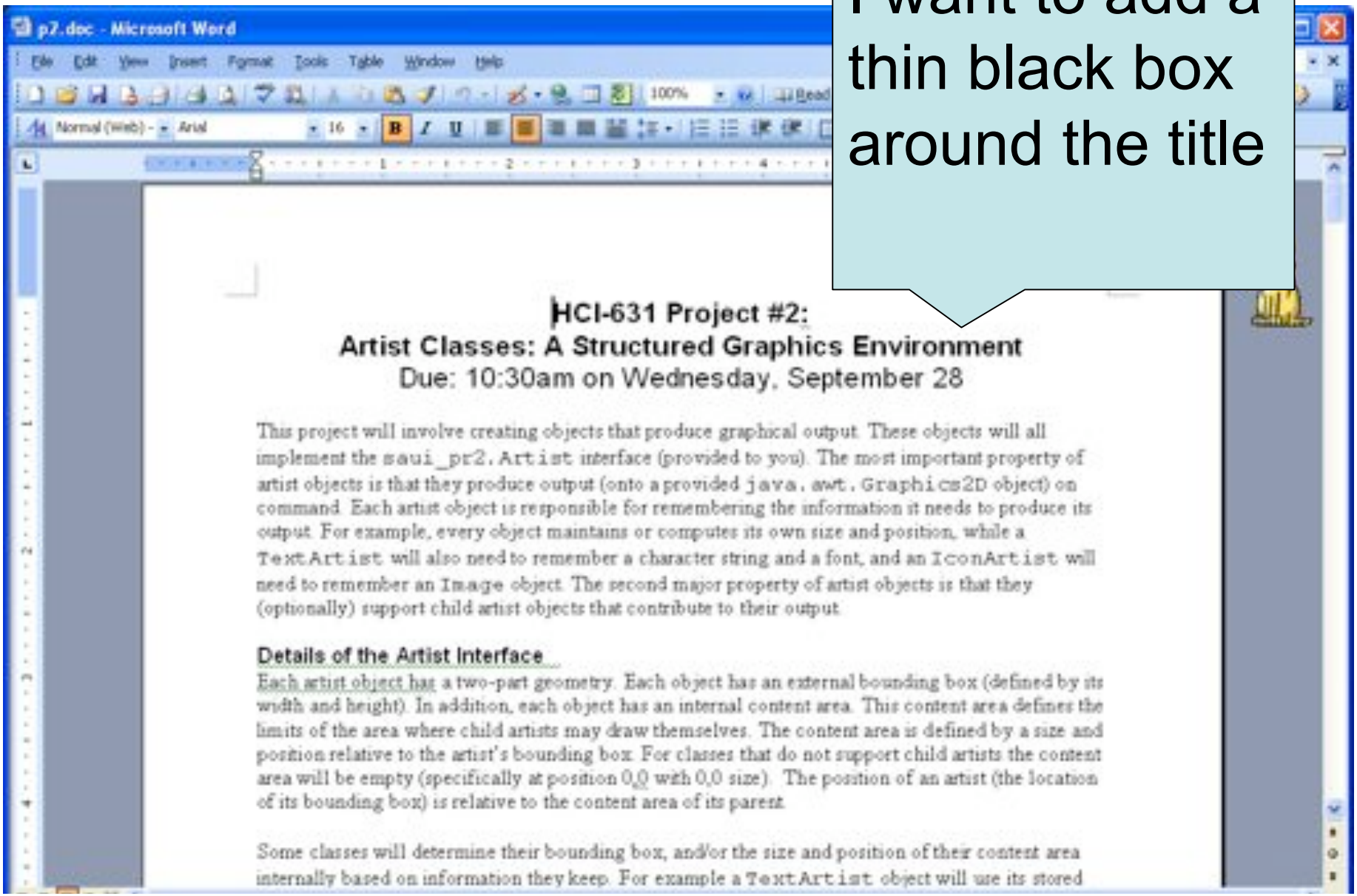
- By Don Norman (UCSD, Apple, HP, NN Group)
- Design of everyday objects illustrates problems faced by designers of systems

- Explains conceptual models
  - doors, washing machines, digital watches, telephones, ...
- Resulting design guides

–> **Highly recommend this book**



The “Interface Cycle”



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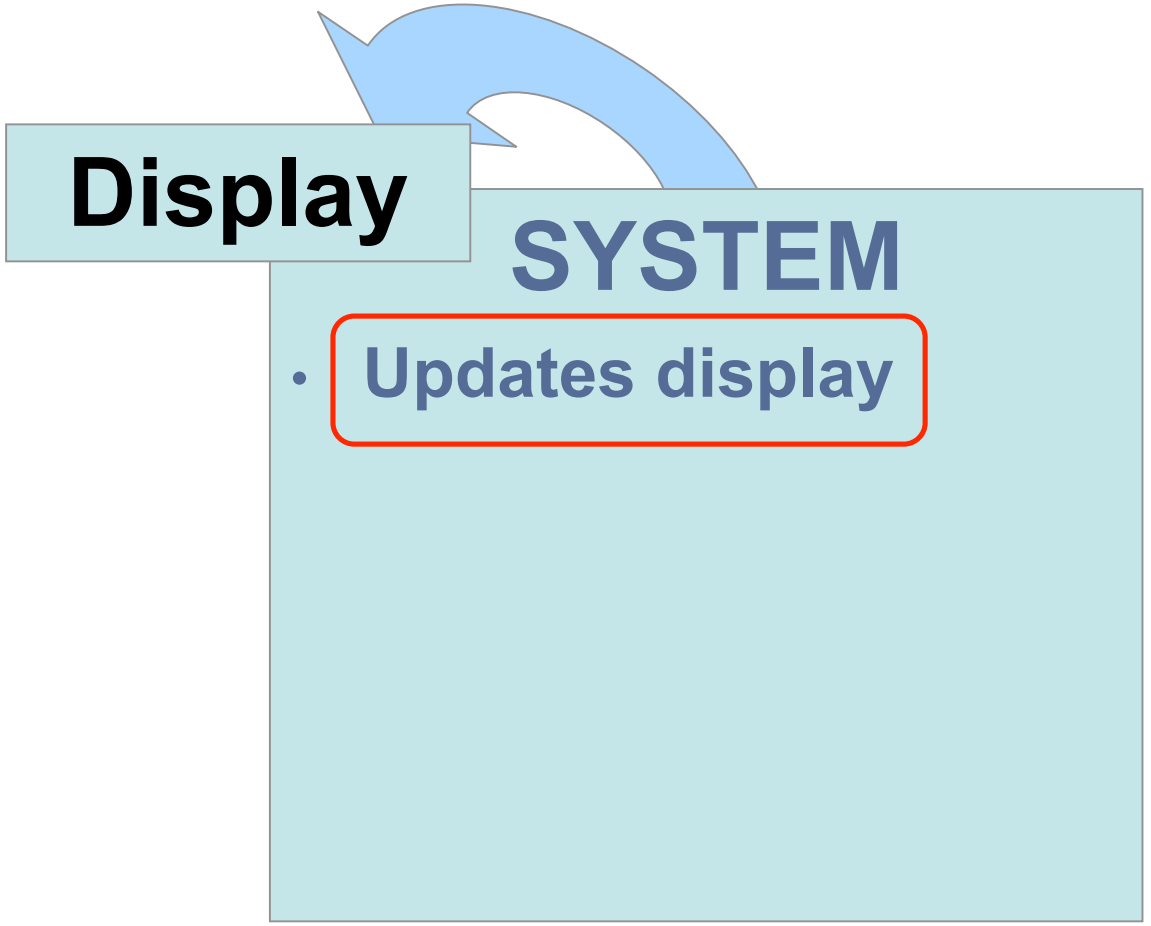

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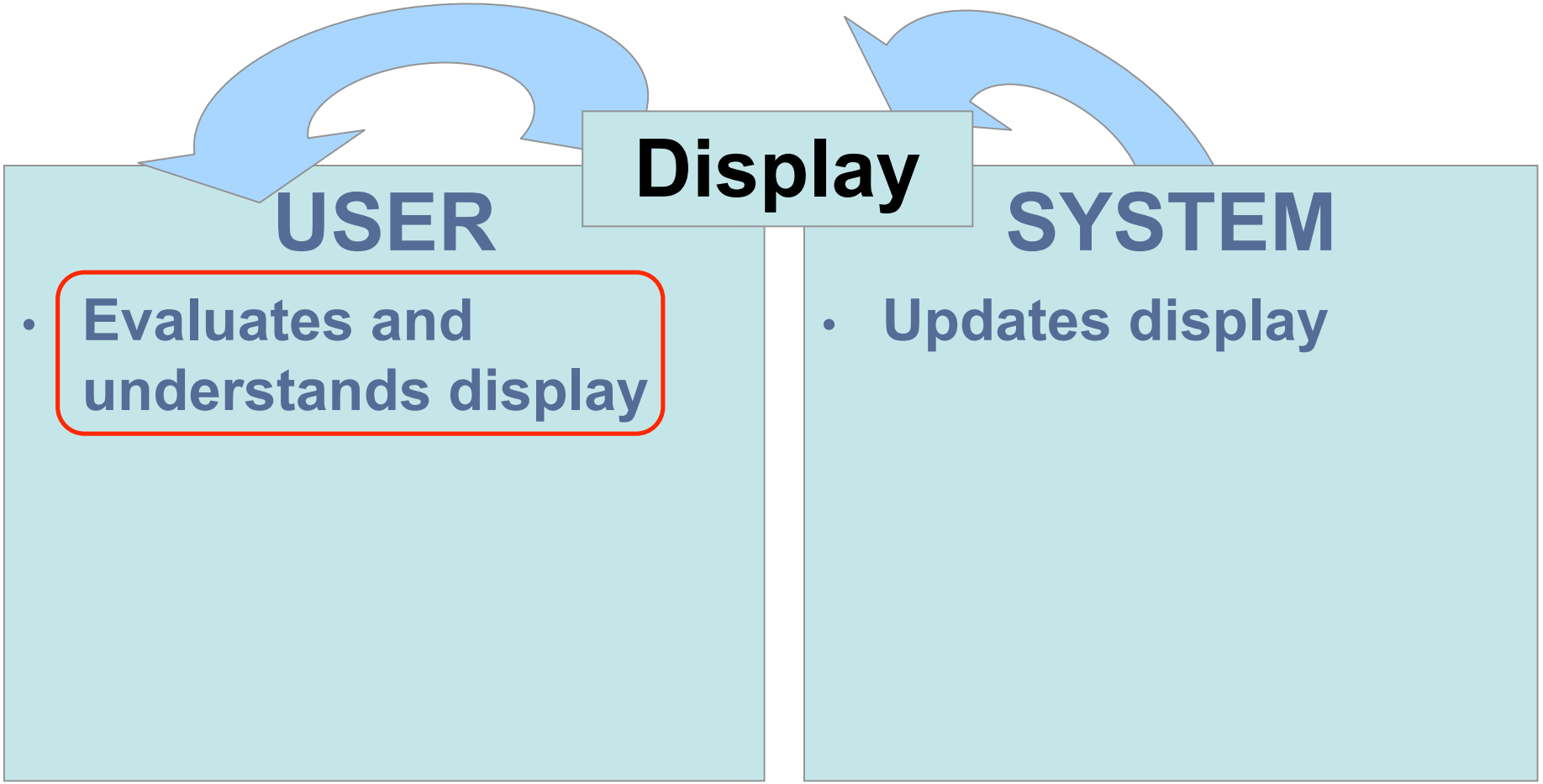

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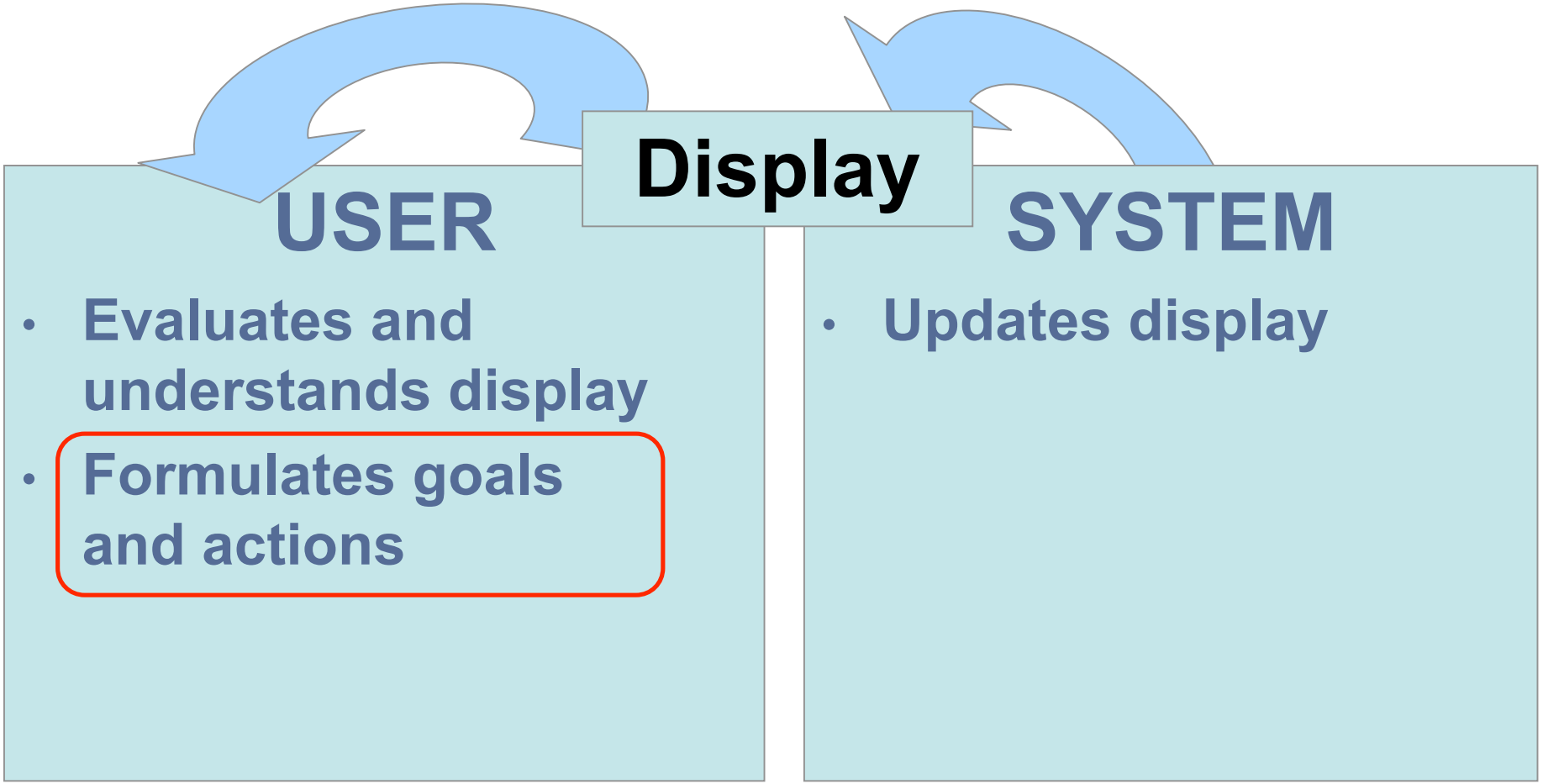

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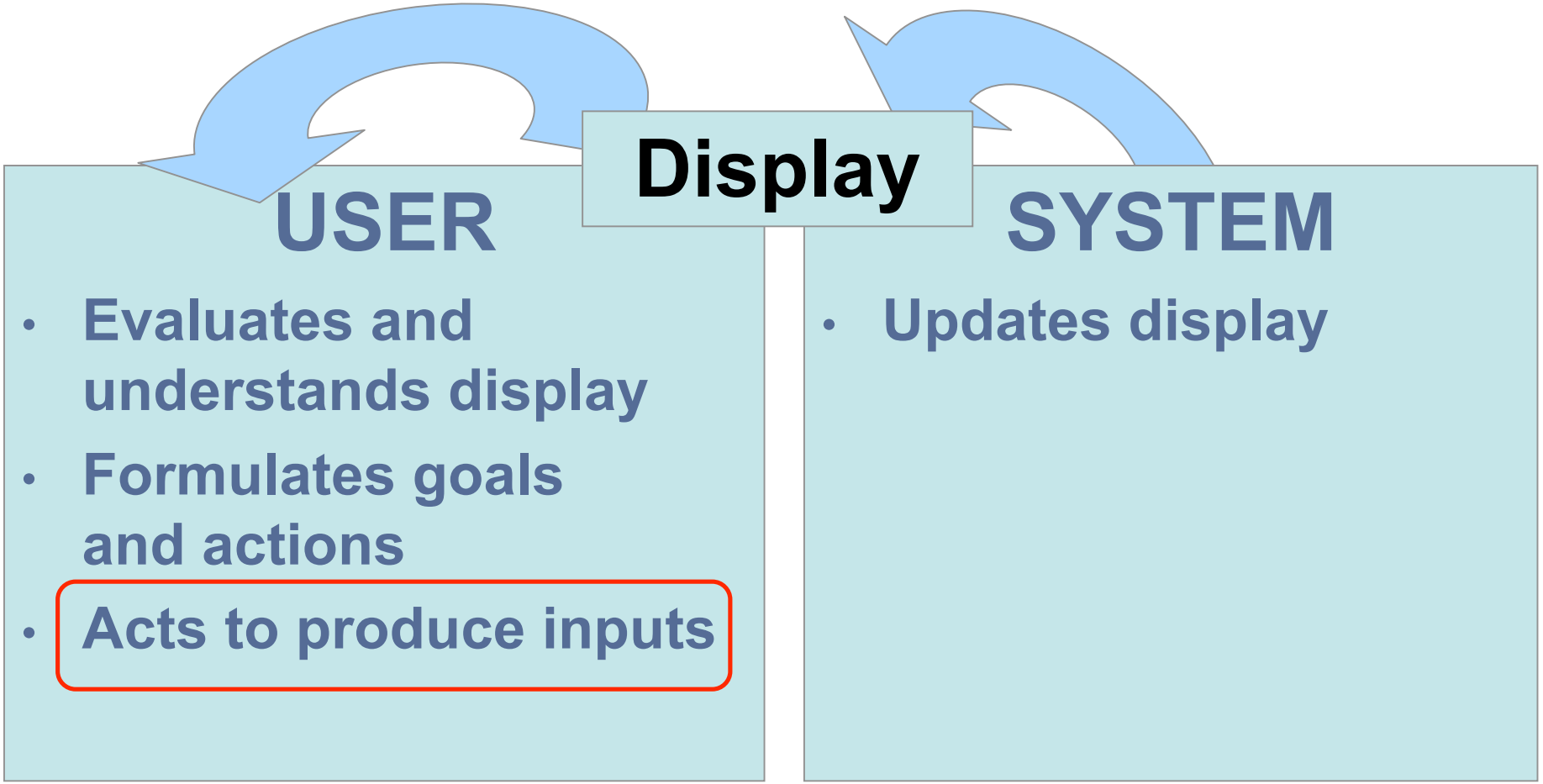

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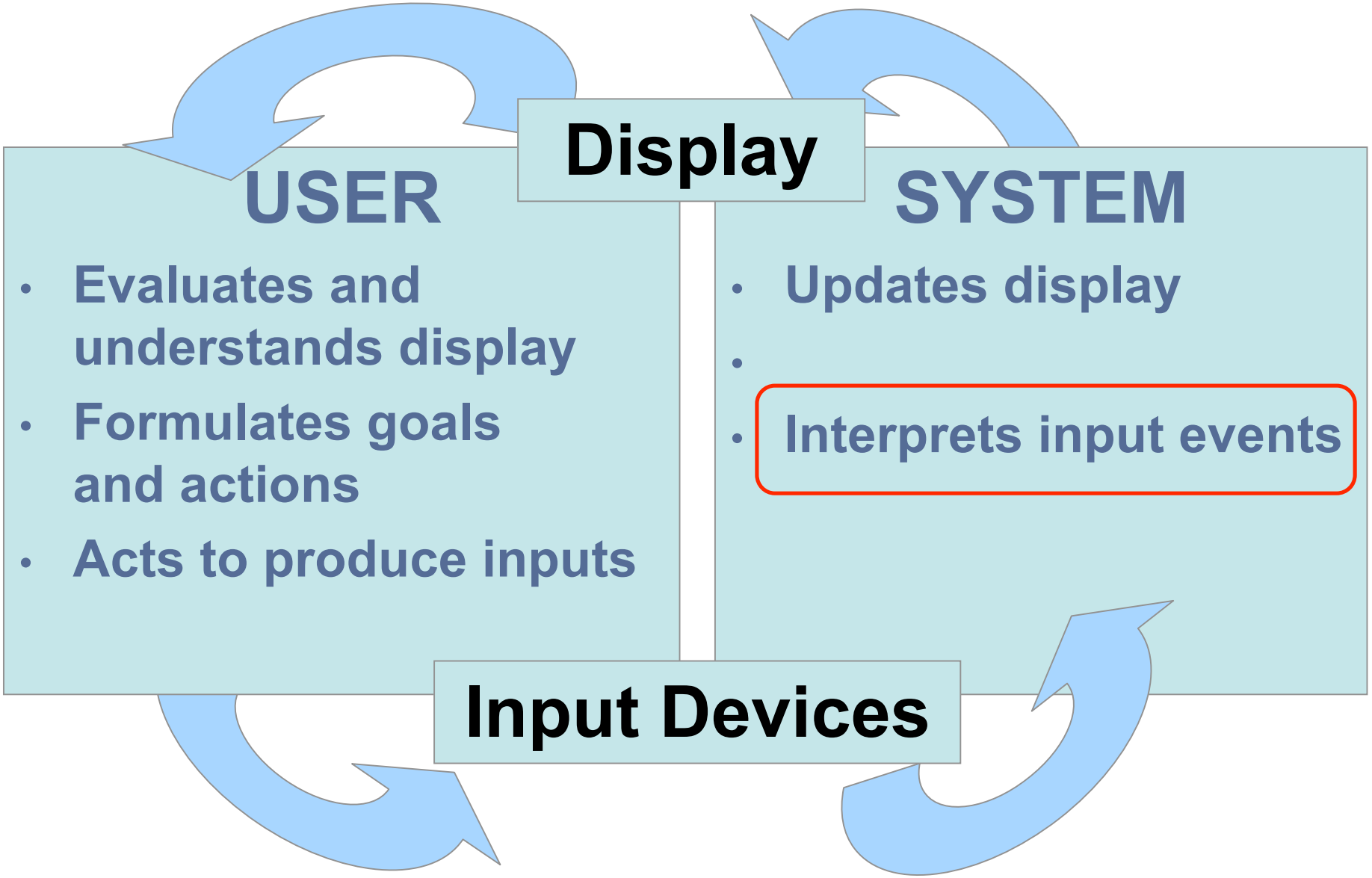

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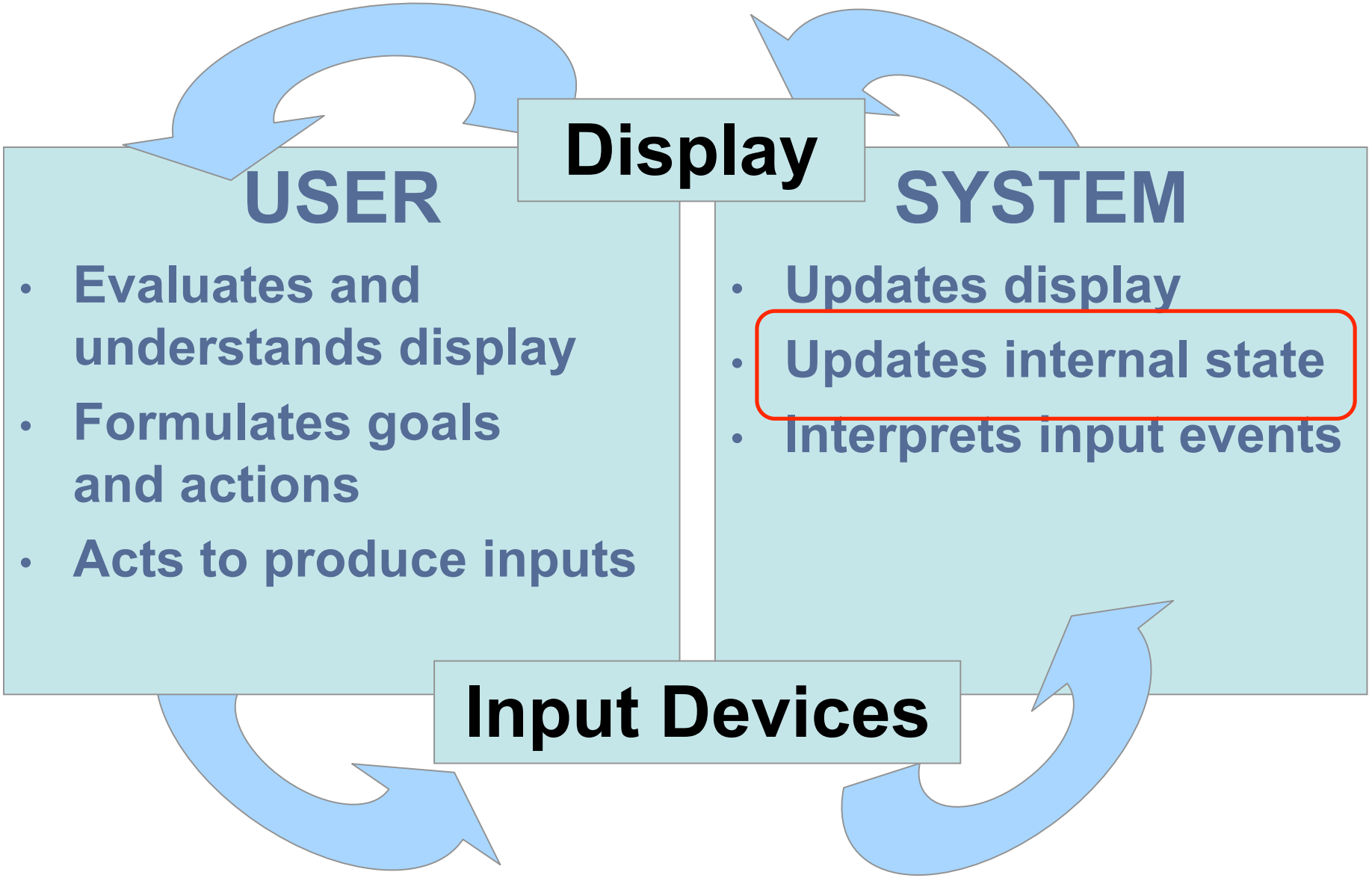
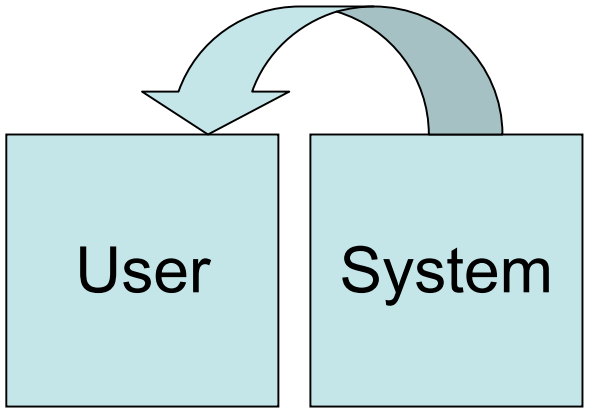


Norman's "Gulfs"

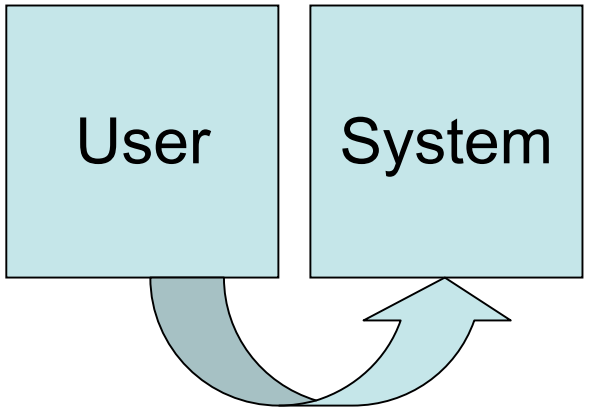
- Norman describes two user activities bridging users and systems
- The Gulf of Evaluation
  - User perceives and interprets state of system
  - What is the state of the system?



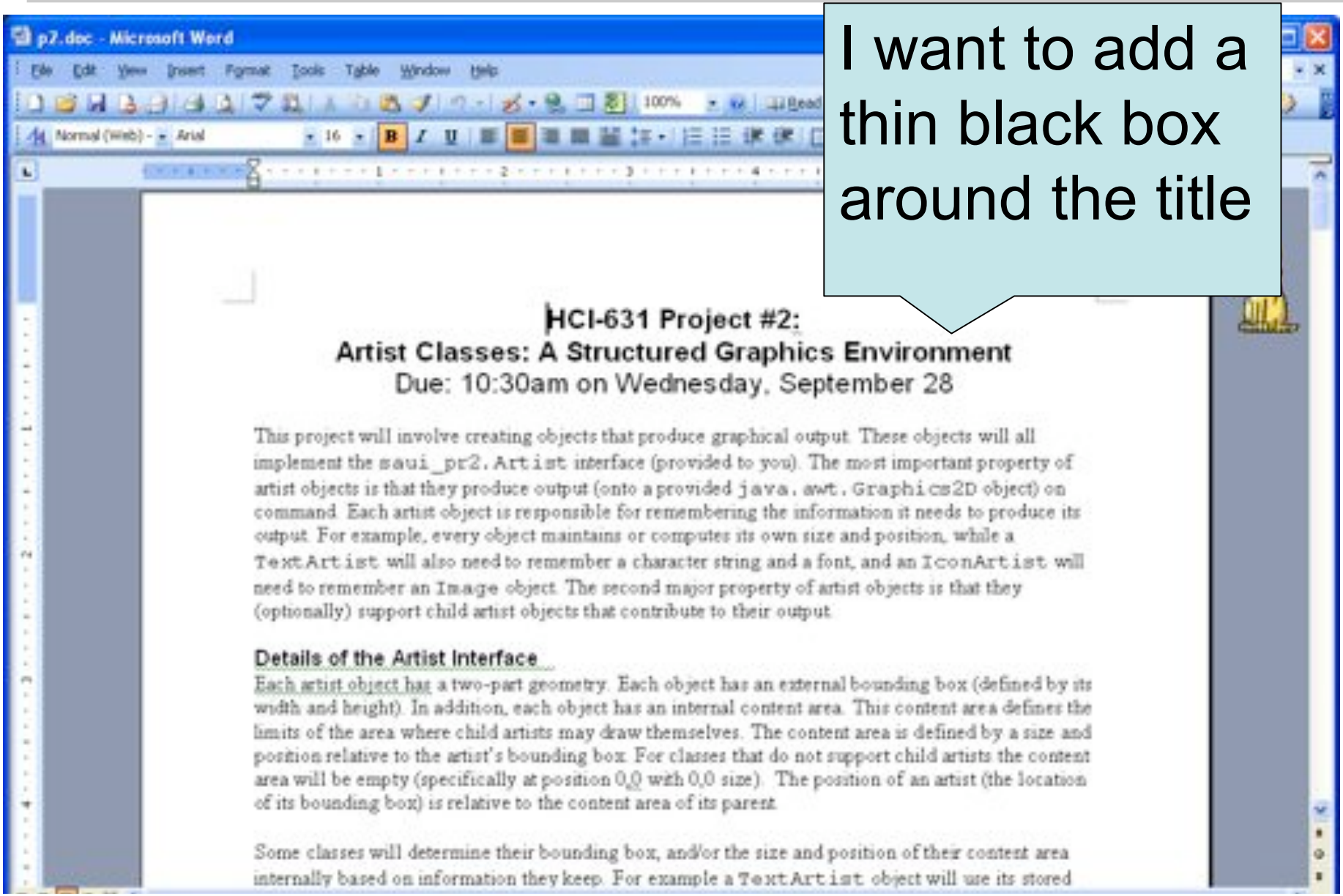
Norman's "Gulfs"

- Norman describes two user activities bridging users and systems
- The Gulf of Evaluation
  - User perceives and interprets state of system
- The Gulf of execution
  - User formulates inputs to achieve goals

- Making these "gulfs" small makes the interface much easier to use

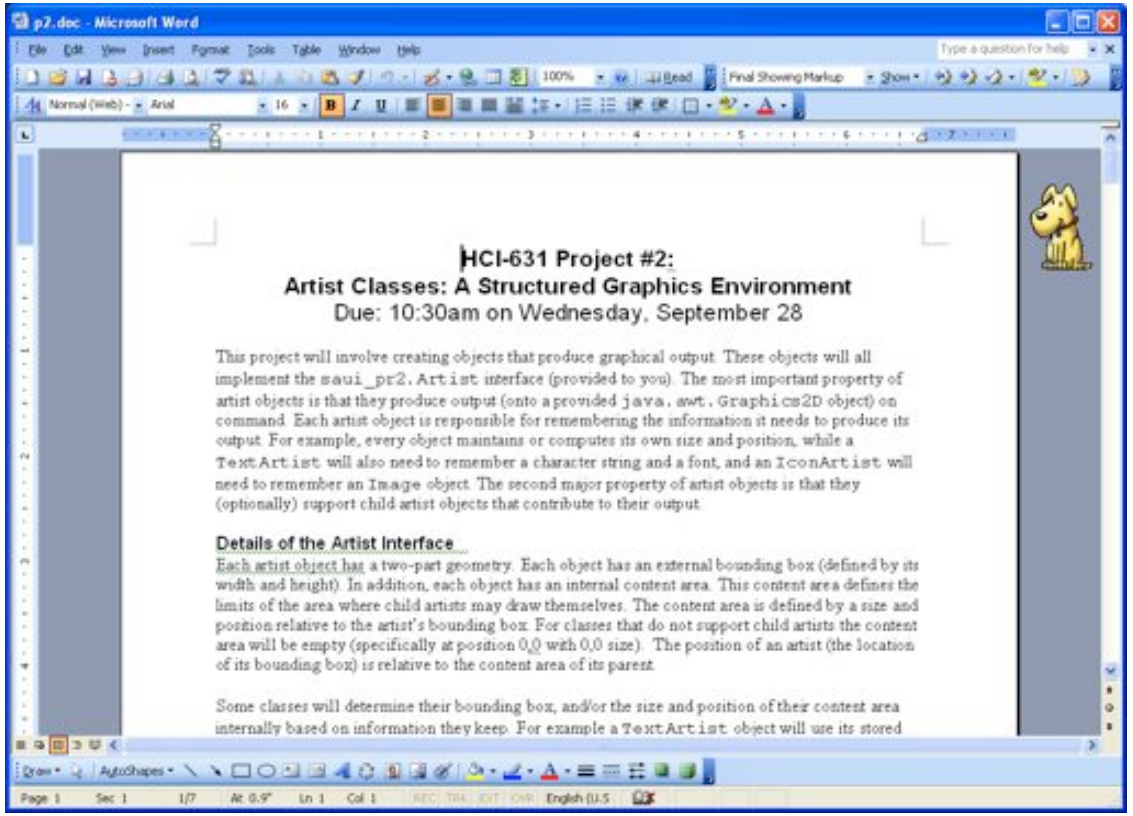


Example Gulfs of Evaluation?



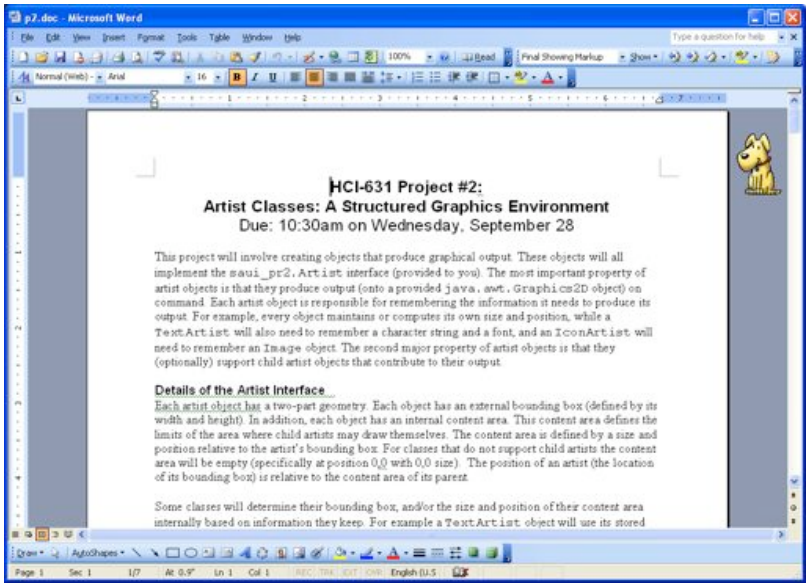
Example Gulfs of Evaluation?

- User understands and evaluates display
  - In this case pretty easy to see no black box around text yet
  - Compare editing web page in text editor



Example Gulfs of Evaluation?

- User understands and evaluates display
  - In this case pretty easy to see no black box around text yet
  - Compare editing web page in text editor
- Formulates goals and actions
  - Add a black box
- Acts to produce inputs
  - This is the hard part here
  - Too many buttons?
  - Too many menus?
  - What's the dog on the side for?

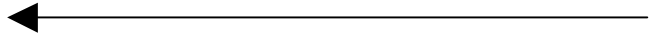


Example Gulfs of Execution?

Gulfs of Evaluation and Execution

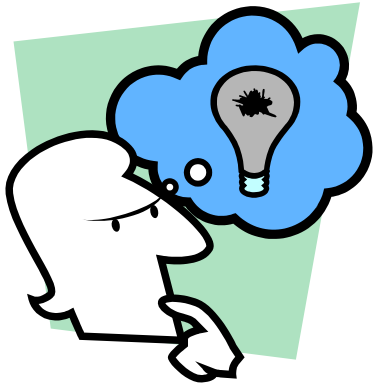
- Some causes of Gulf of Evaluation
  - Poor use of colors
  - Bad layout, poor grouping
  - Important information looks same as unimportant
  - Forcing people to remember lots of things
  - Lack of feedback in response to inputs
- Some causes of Gulf of Execution
  - Don’t know what is possible
  - Widgets might not have meaning (solvable with experience)
  - Interaction patterns might not have meaning (see above)
    - Example patterns: Dialogs, Shopping Carts

How to Address These Gulfs?

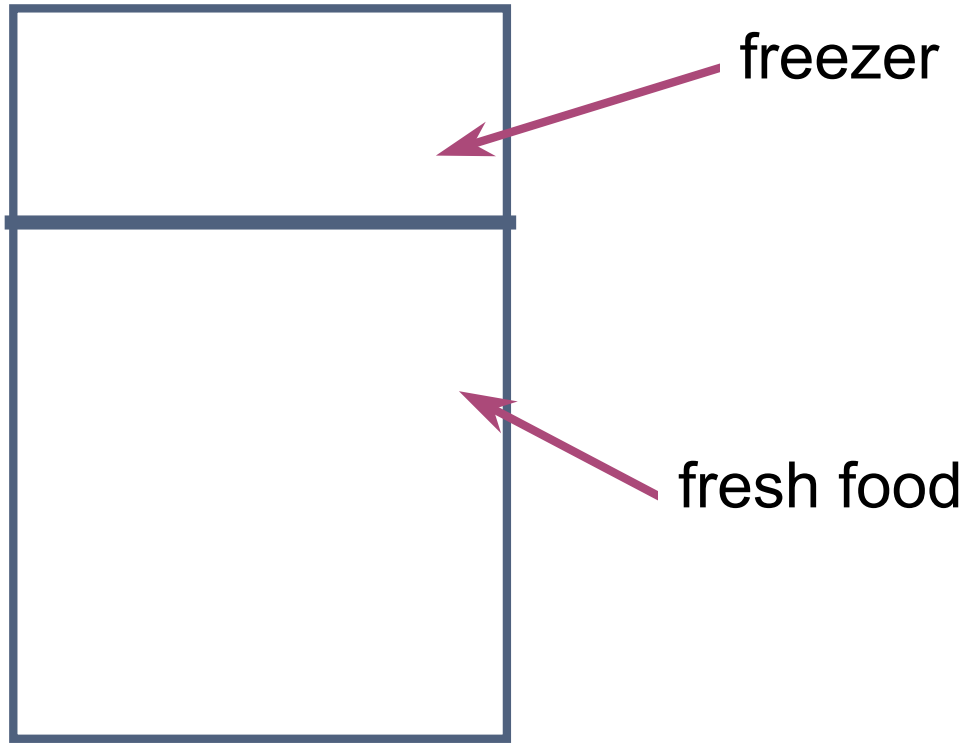
- Simple answer: Good Design
- More complex answer:
  - Mental Models 
  - Affordances
  - Feedback
  - Mappings
  - Metaphor
  - Color
  - Visual Grouping / Separation
  - Layout
- Note: rapid coverage of cognitive science topics

Mental Models

- Mental representation of how object works & how interface controls affect it
- People may have preconceived models that are hard to change
  - (4 + 5) vs. (4 5 +)
  - dragging to trash?
    - delete file but eject disk
- Interface must communicate model
  - visually
  - online help and documentation can help, but shouldn't be necessary



Mental Models Example: Refrigerator



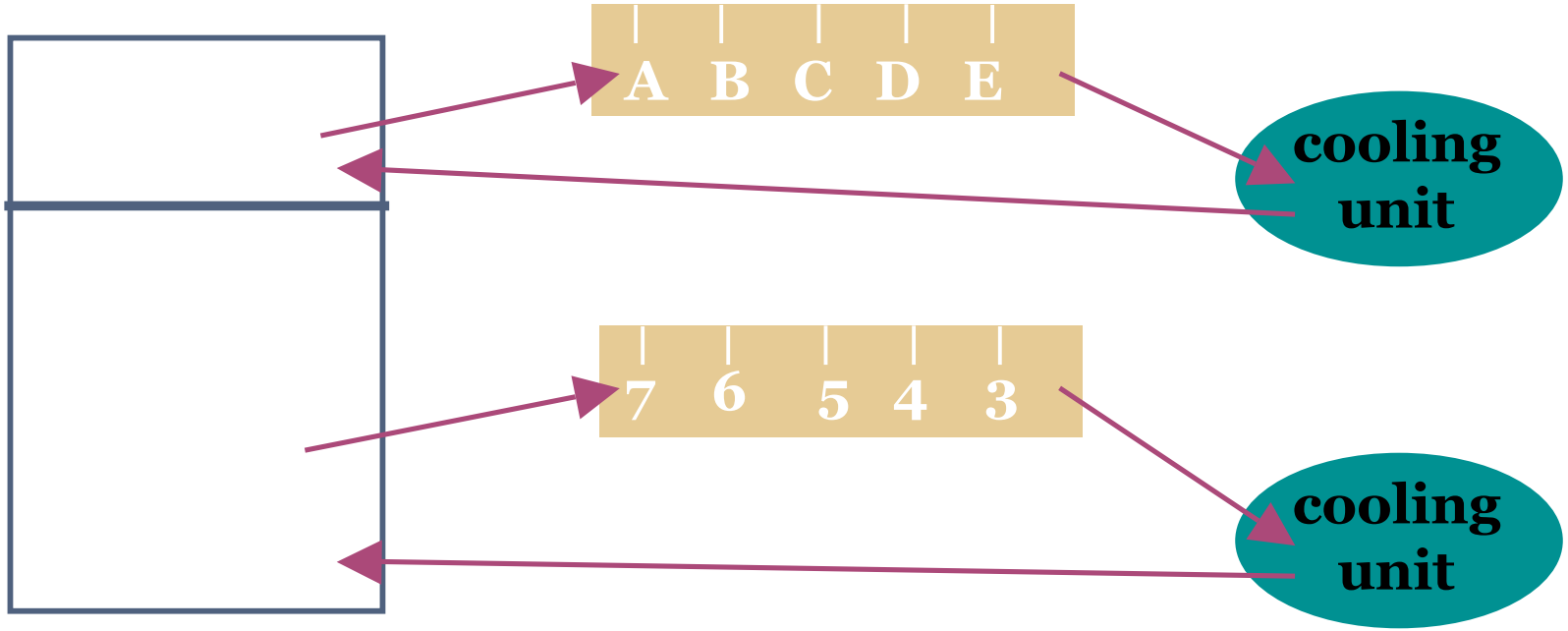
Problem: freezer too cold, but fresh food just right

Refrigerator Controls

Normal Settings	**C** and **5**
Colder Fresh Food	**C** and **6-7**
Coldest Fresh Food	**B** and **8-9**
Colder Freezer	**D** and **7-8**
Warmer Fresh Food	**C** and **4-1**
OFF *(both)*	**0**

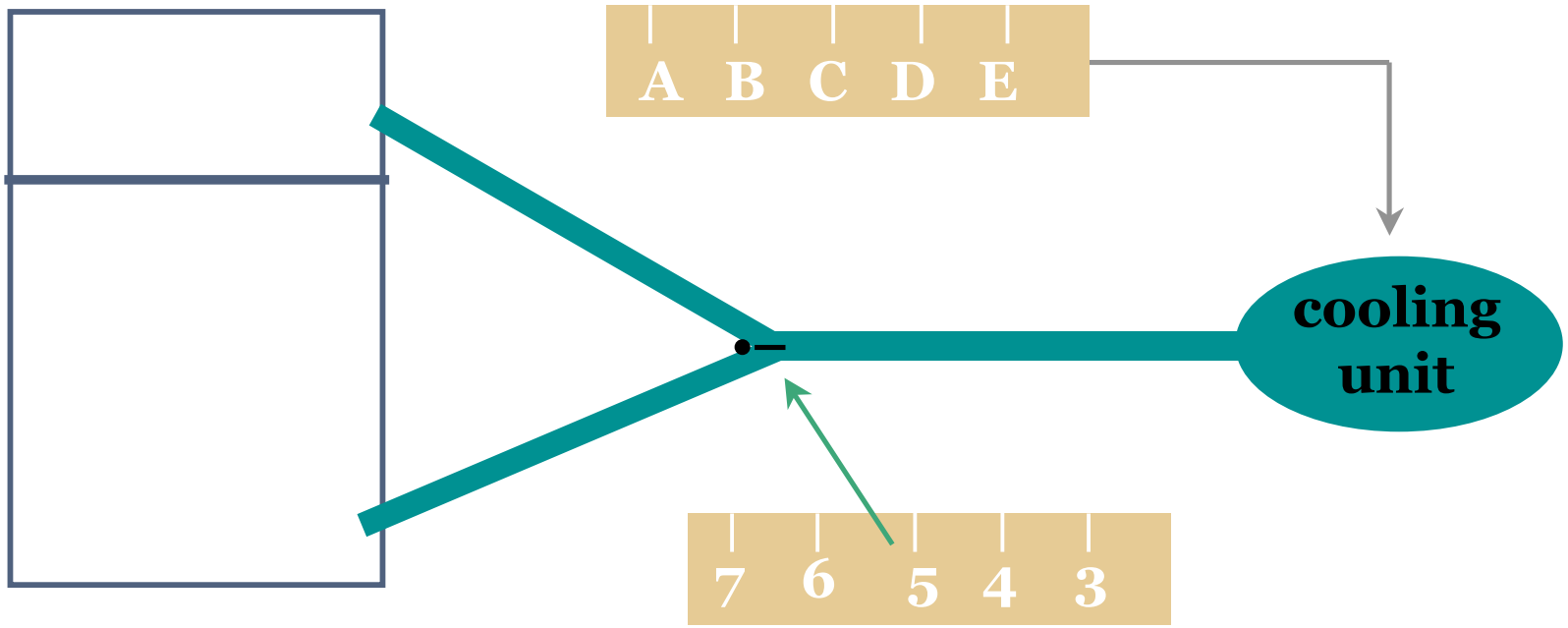
What is a typical conceptual model?

A Common Conceptual Model



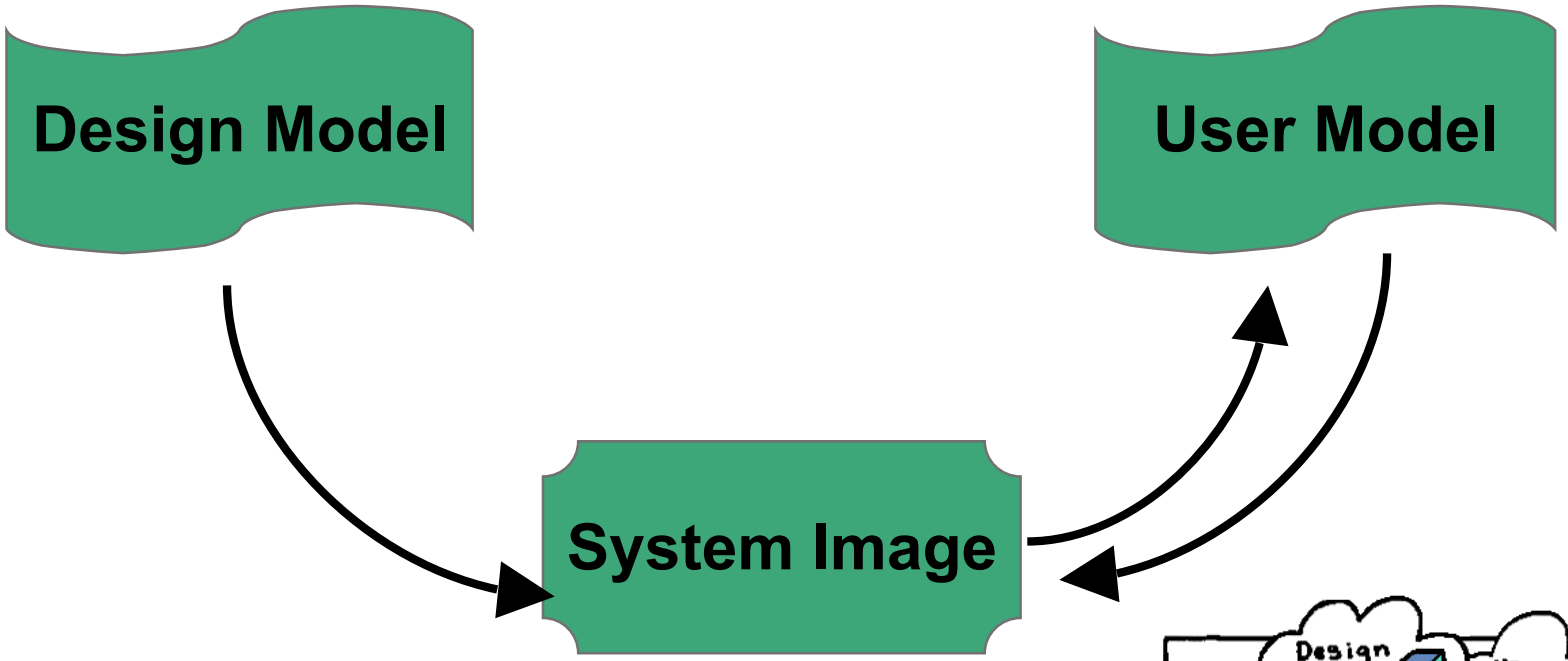
independent controls

Actual Conceptual Model

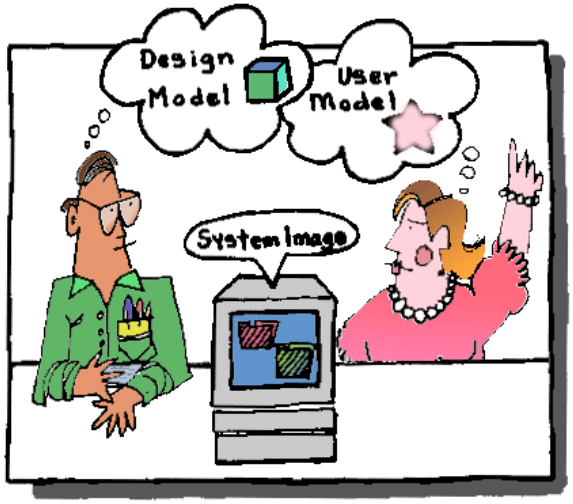


- Now can you fix the problem?
- Possible solutions
  - make controls map to user's model
  - make controls map to actual system

Design Model & User Model



- Users get model from experience & usage
  - through system image

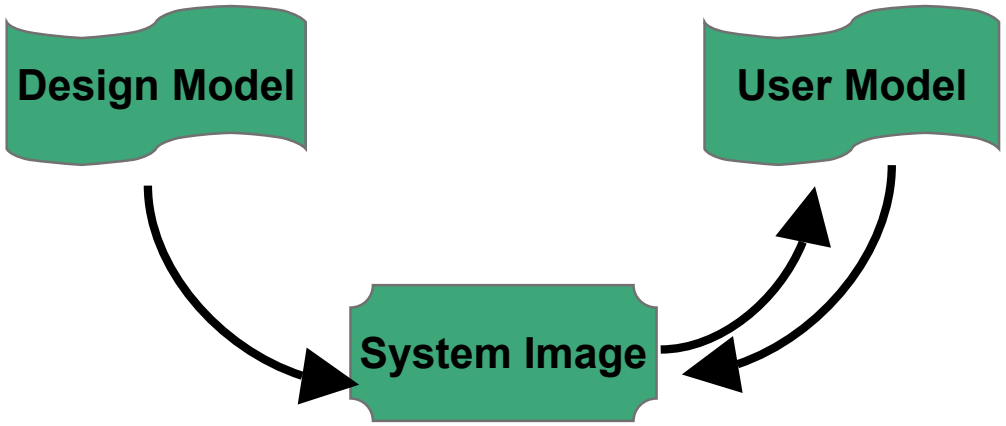


Mental models

- People inevitably build models of how a system works
  - can't help but do it
  - may be highly detailed and functional
  - may be quite naïve
- Generally not complete, not necessarily "logical"
  - Ex. children and computers
  - Ex. you and your car
  - Ex. your mental map of Funchal

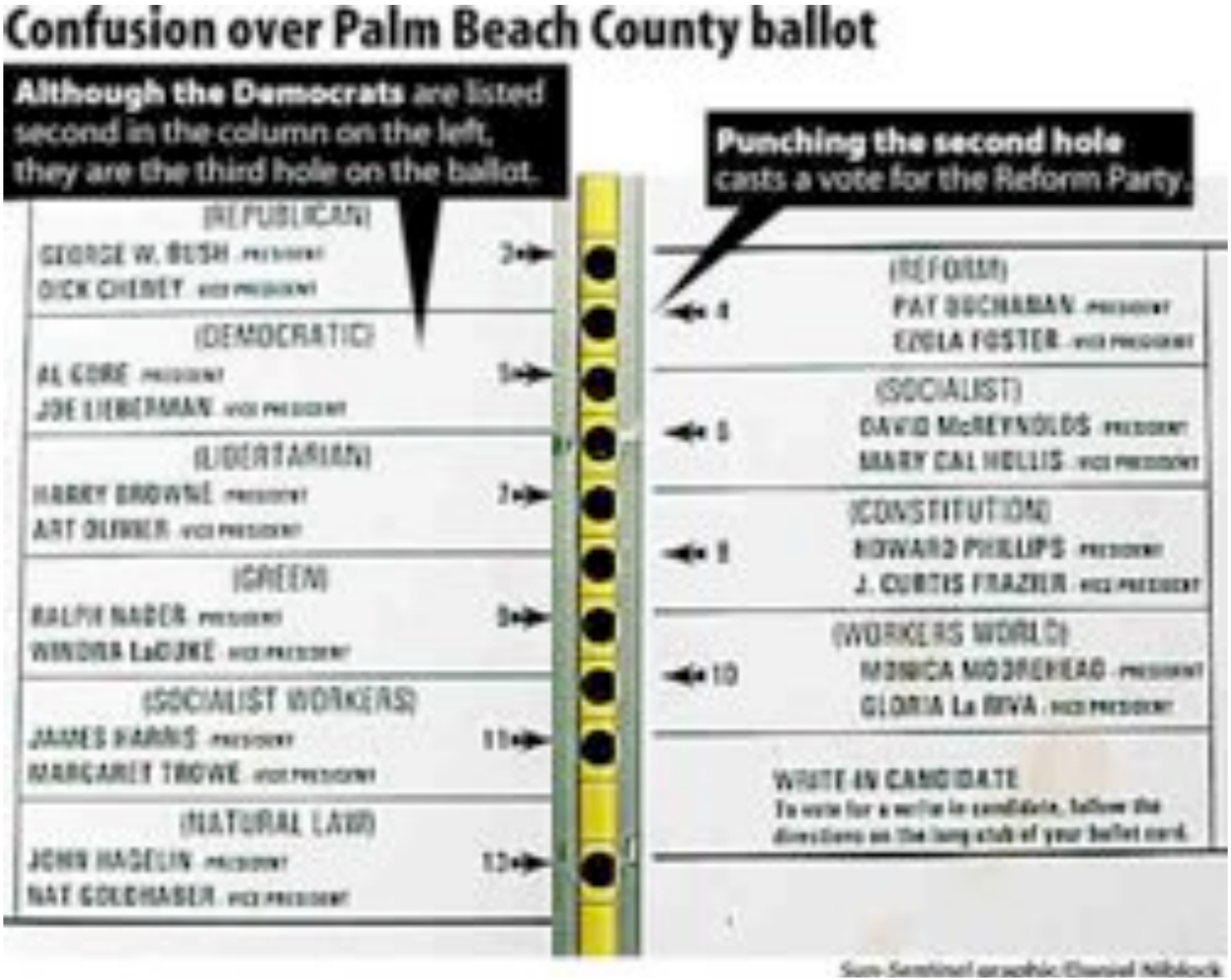
Conceptual Model Mismatch

- What if design model and user model don't match?



- Mismatch can lead to…
  - Slow performance
  - Errors and inability to recover
  - Frustration
  - ...

Notorious Example



Key points about mental models

- The system designer has too good a mental model
  - Nearly perfect mental model
  - Really good prediction of what system does
  - Real users won't ever have that good a model
- Design Implication #1
  - HCI Mantra: "You are not the user"
  - System implementer knows too much and can't forget
- Design Implication #2
  - Try to design for a clear mental model and foster that model

Outline

- Mental Models
- Affordances
- Feedback
- Mappings
- Metaphor
- Color
- Visual Grouping / Separation
- Layout

Affordances

- Well-designed objects have *affordances*
  - clues to their operation that are readily apparent
  - often visual, but not always (e.g., speech)
  - Allows and promotes certain actions
    - Door knobs afford turning
    - Handle of hammer affords grasping in a particular way

Affordances as Perceptual Clues

Siemens Pocket PC Phone
Pen input, no keypad

Handspring Treo
Pen input/keypad input

Affordances as Perceptual Clues

- Poorly-designed objects
  - no clues or misleading clues

French artist Jacques Carelman

Crazy design for a screw punch!

“Virtual affordances”

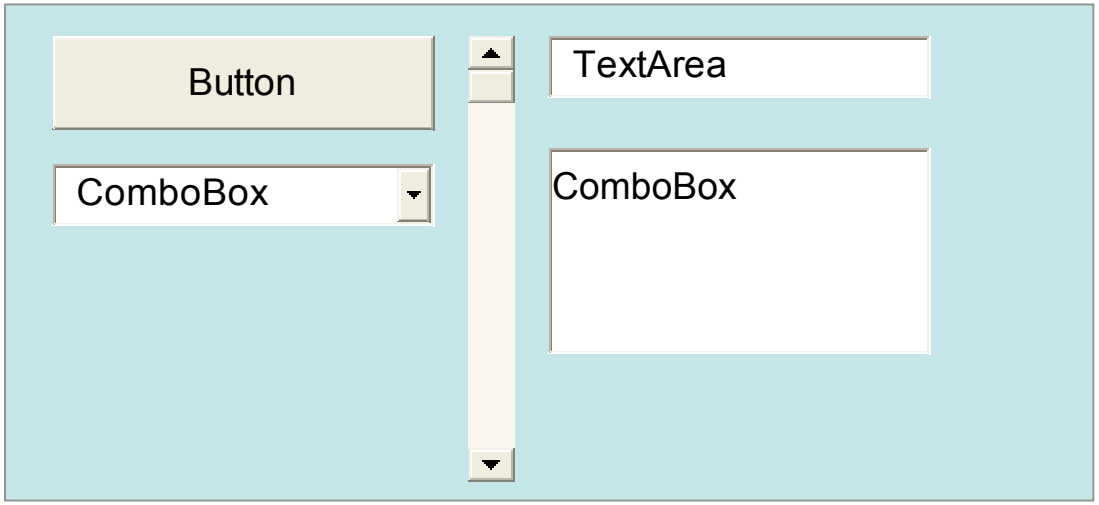
- Visual appearance can suggest function
  - Example: Knurling
  - Small ridges typically found on knobs
  - Increases friction → Affords grip

- Leveraging real-world knowledge
  - Don’t have to know about knurling for this to afford “grip” with the mouse

“Virtual affordances”

Design Implications

- Design Implication
  - Make sure objects that users can manipulate have affordances that suggest how they work
- Standard GUI widgets have “standard” affordances



- New GUI widgets (or web apps) will need well-designed visual affordances

Administrivia

- P3 Progress?

- 3 minutes break

Outline

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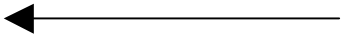
- Affordances
- Feedback 
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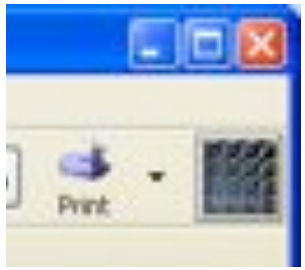
Feedback

- Response by the system to the actions of the user
  - Cause and effect
  - Essential for forming mental models
- Making “system state” visible
  - The system did “the right thing”
    - Immediate – Button goes down
    - Intermediate – Thin black box appears on screen
    - Delayed – Amazon “Thank you for shopping” + email
  - Sometimes just to let you know the system is still alive



Feedforward

- Feedforward
  - What will happen if you execute the action
  - Ex. web page mouseover, word processing i-bar
  - Useful for helping people predict what will happen

Performance properties of people

- Feedback depends on properties of people

- How much can people remember?
- How fast are thing perceived?

How much can a person remember?

- Short term (working) memory
  - small capacity (7 ± 2 “chunks”)
    - 6174591765 vs. (617) 459-1765
    - EDCMBIMGC vs. DEC IBM GMC
  - rapid access & decay
  - for us just: “very limited”

- Long-term memory
  - huge (if not “unlimited”)
  - slower access time
  - but requires effort and may not always work on cue

Simple Experiment

- Need a volunteer
- Start saying the **color** you see in list of words
  - when slide comes up
  - as fast as you can
- Say “done” when finished
- Everyone else time it…

Alice ⇨ **You say “Black”**

Bob ⇨ **You say “Blue”**

Back

Schedule

Change

Home

Red

Black

Yellow

Blue

Design Implications

- Be careful of interference
  - two strong cues in working memory
  - link to different chunks in long term memory
- Design for recognition over recall
  - Recall
    - info reproduced from memory
    - e.g., command name & semantics
  - Recognition
    - presentation of info provides knowledge that info has been seen before
    - e.g., command in menu reminds you of semantics
    - Retrieval cues, e.g., icons, labels, menu names, etc.

How fast are things perceived?

- < ~20ms (1/50 sec) discrete flashes merge into continuous perception
  - CRTs and LCDs refresh 60 times per second
  - Below 50 times per second can start seeing flicker

- Differences in peripheral vision
  - Peripheral vision highly motion sensitive
  - Good for seeing saber tooth tigers
  - Bad for banners ads

How fast are things perceived?

- Fact #1: < ~20ms (1/50 sec)
- Fact #2: Displays update at 50-75hz

- So? Don’t ever have to be faster for user response!
  - People can’t distinguish
  - Get ~1140 million instructions (@3Ghz)
    - You can do a lot with that
    - (First GUIs had ~20K)
    - Not enough? Apply Moore’s law…

How fast are things perceived?

- But don't have to be this strict, ~100ms seems like "instant response"
  - Hard to tell response times below this apart
  - Upper range of eye saccades

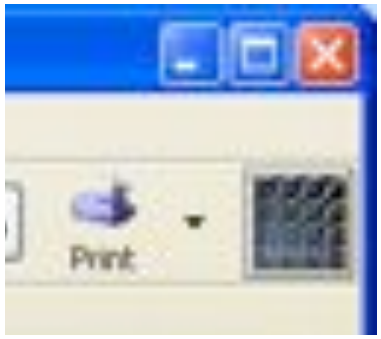
- Except for animation, most GUI responses don't need to be faster than this
  - ~100ms typical human "cycle time" in Model Human Processor
  - ~2.2k million machine instructions
- Experiments suggest a little slower still ok
  - Window dragging ~1/5 second to be acceptable

How fast are things perceived?

- < 1-2 seconds typically “good response time”
  - Similar times in conversational turn taking protocols
  - Longer delays ~5 sec have to say something to keep conversation alive

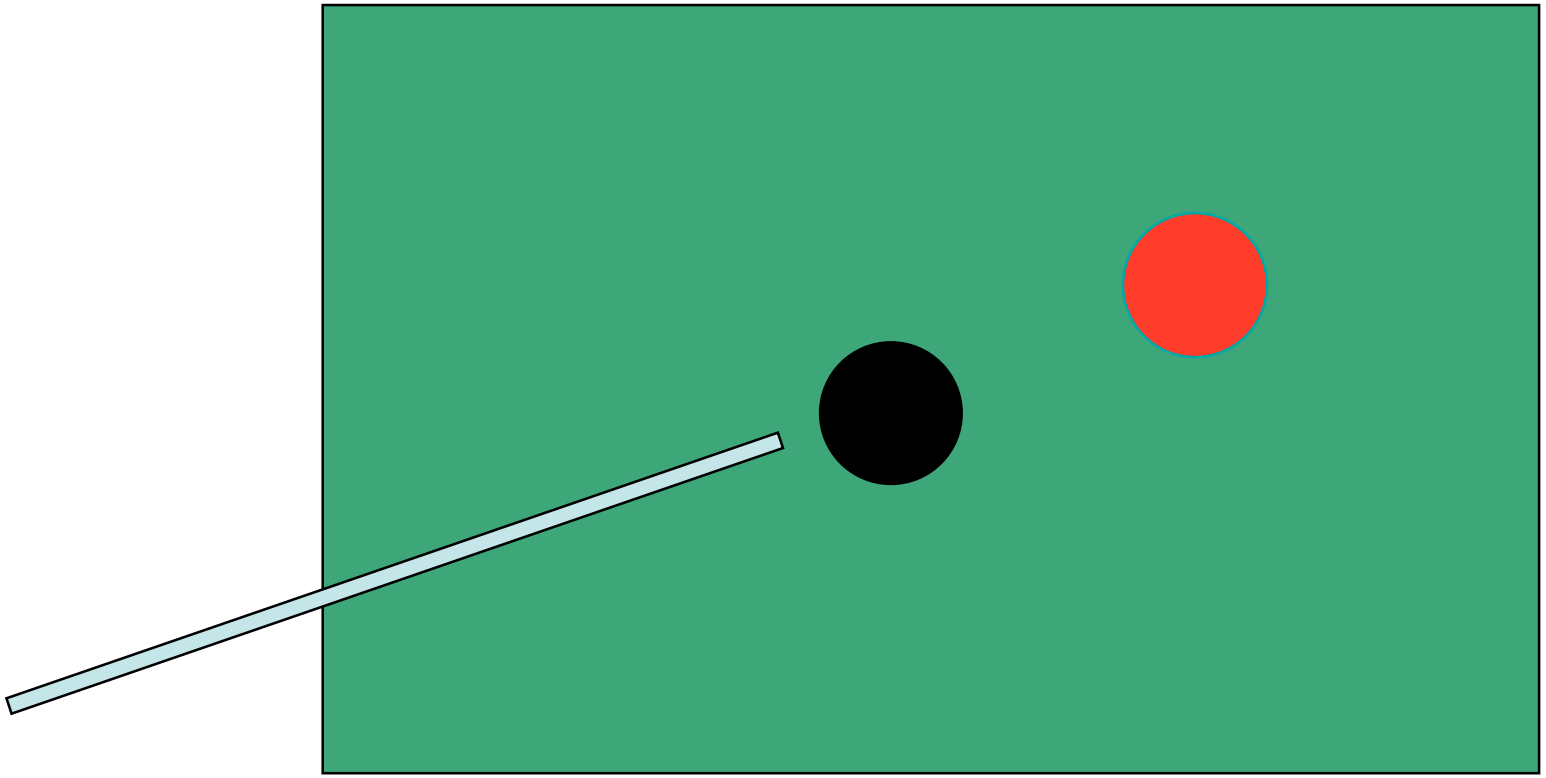
How fast are things perceived?

- > 10-15 sec is typically “bad response time”
  - STM decay effects
  - Need to use progress meters here for feedback



- Web has sort of trained us for slow response times
  - Though lots of times I forgot what I wanted to do by the time a page loaded

Perceptual Causality



- How soon must red ball move after cue ball collides with it?

A little about response times

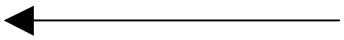
- Good vs. bad response time depends on expectations
  - If you can't meet the goals, manipulate user expectations!
  - Web did this well
  - "This will take 5 minutes to install"
  - Minimum hardware requirements
- Consistency of response is very important
  - Can be more important than time
  - Predictability

A little about response times

- Caveat #1
  - “Premature optimization is the root of all evil (or at least most of it) in programming.” – Donald Knuth
  - Programmer intuitions often wrong
  - Use a profiler, see where time is spent
  - Typically follows Pareto distribution (80/20)
- Caveat #2 – Perceived response times important too!
  - Waiting for elevator
  - Amazon book purchase

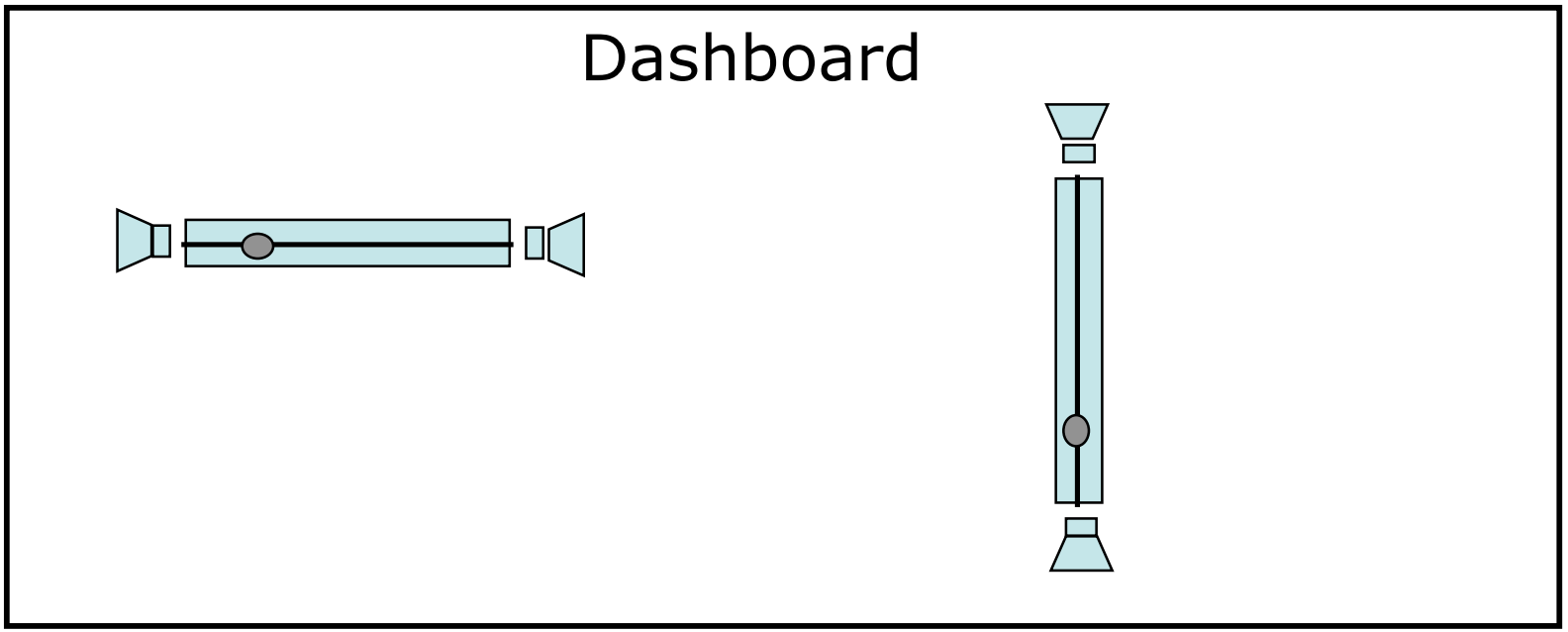
1 minute break

Outline

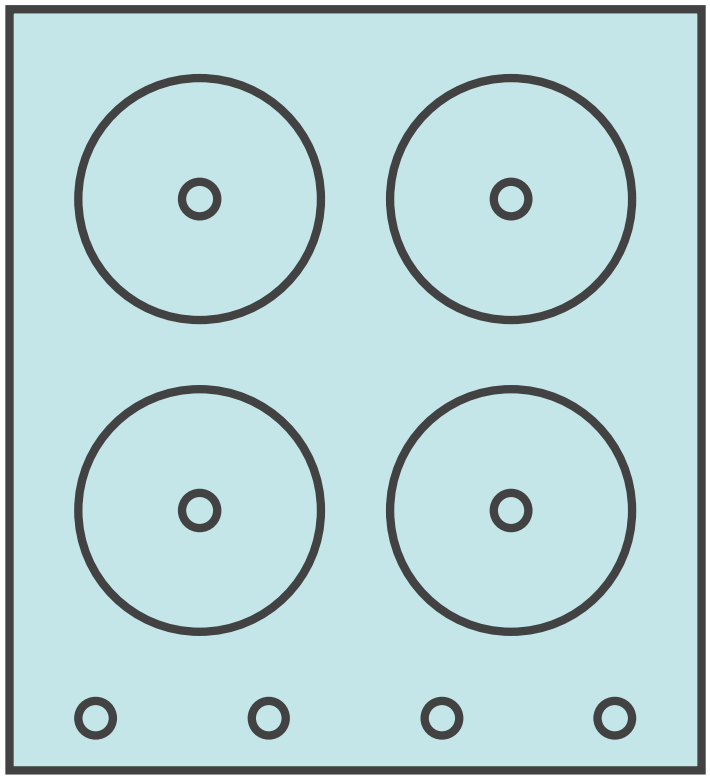
- Mental Models
- Affordances
- Feedback
- Mappings 
- Metaphor
- Color
- Visual Grouping / Separation
- Layout

Map Interface Controls

- Controls should mirror real-world
- Which is better for dashboard speaker front / back control?



Map Interface Controls



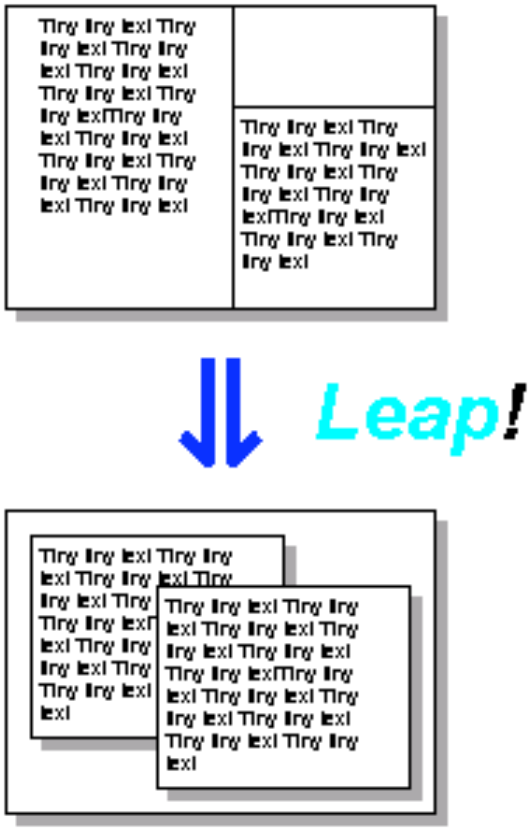
Metaphor

- Definition ?
  - "The transference of the relation between one set of objects to another set for the purpose of brief explanation."

Metaphor

- Lakoff & Johnson, *Metaphors We Live By*
  - "...the way we think, what we experience, and what we do every day is very much a matter of metaphor."
- In our language & thinking - "argument is war"
  - he attacked every weak point
  - criticisms right on target
  - if you use that strategy
- Relationships and navigation
  - going in the wrong direction
  - took a u-turn
  - our marriage is at a crossroads

Desktop Metaphor



- We can use metaphors to leverage existing conceptual models
- Suggests a conceptual model
  - Not really an attempt to simulate a real desktop
  - Leverages existing knowledge about files, folders, trash
  - A way to explain why some windows seemed blocked

Example Metaphors

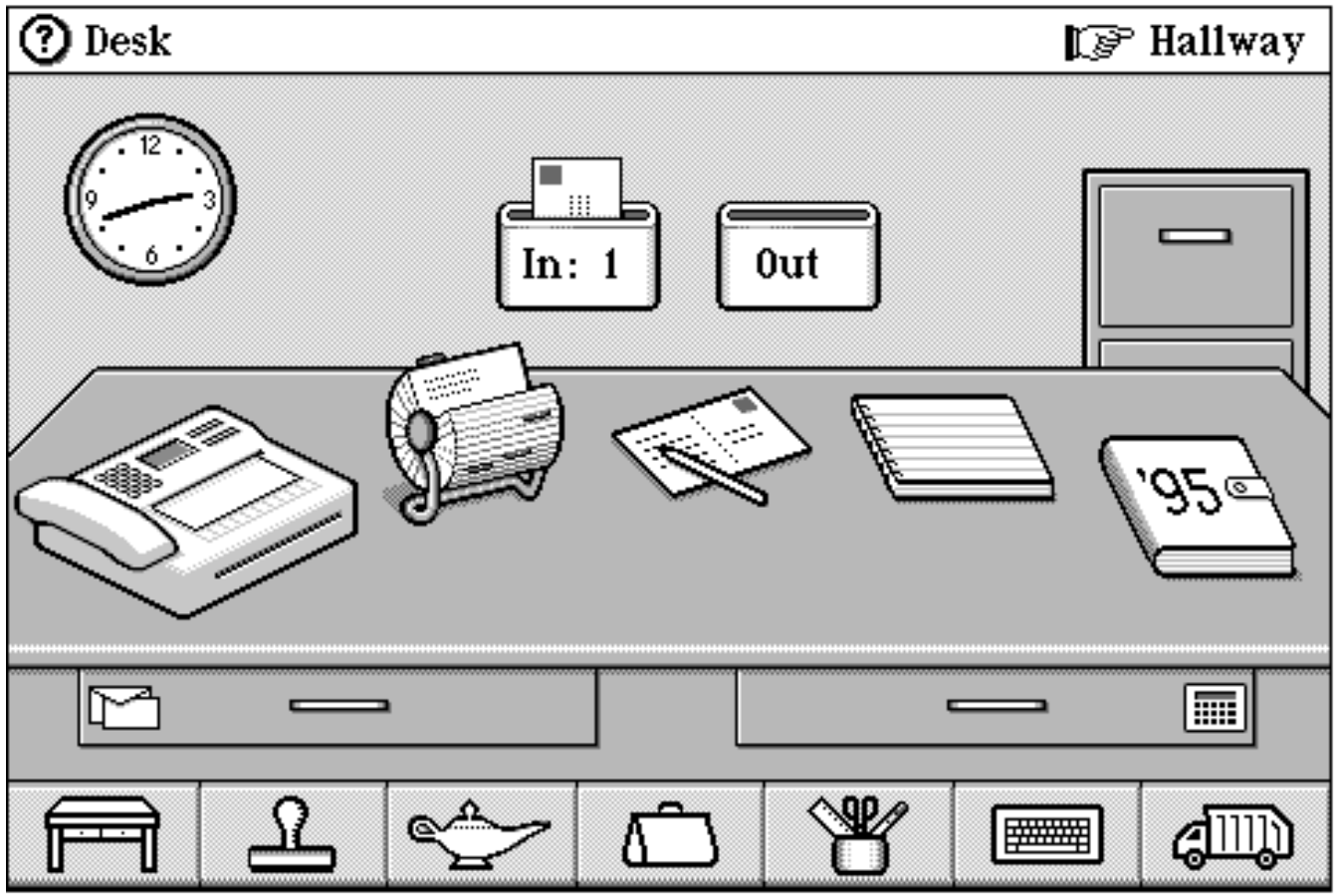
- Data & function
  - rolodex, to-do list, calendar, applications documents, find, assist
- Collections
  - drawers, files, books, newspapers, photo albums
- Actions
  - Cut, copy, paste
  - When was the last time you actually did this for real?

Metaphors Aren't Always Effective

- Mac desktop inconsistent
  - Dragging disk to trash
    - should delete it, *not* eject it

Metaphors Aren't Always Effective

- Magic Cap
  - Somewhat unwieldy, not good use of screen real estate



Metaphors Aren't Always Effective

- Microsoft Bob
  - Set expectations too high

Summary

- Gulf of Evaluation and Execution
- Mental Models
- Affordances
- Feedback
- Mappings
- Metaphor

- Next time:
  - Color
  - Visual Grouping / Separation
  - Layout