Lecture 16. Interaction paradigms applied to the design of displays and controls

CENG 412-Human Factors in Engineering

July 13 2009

Announcements

- Guidelines for oral presentation posted
- Guidelines for project reports posted
- Deadline for submission of all materials for oral presentation: Sunday July 19
- Deadline for submission of final project report: Monday July 27 by the start of the class

Outline

- Principles of display design
- Principles of control design and usage

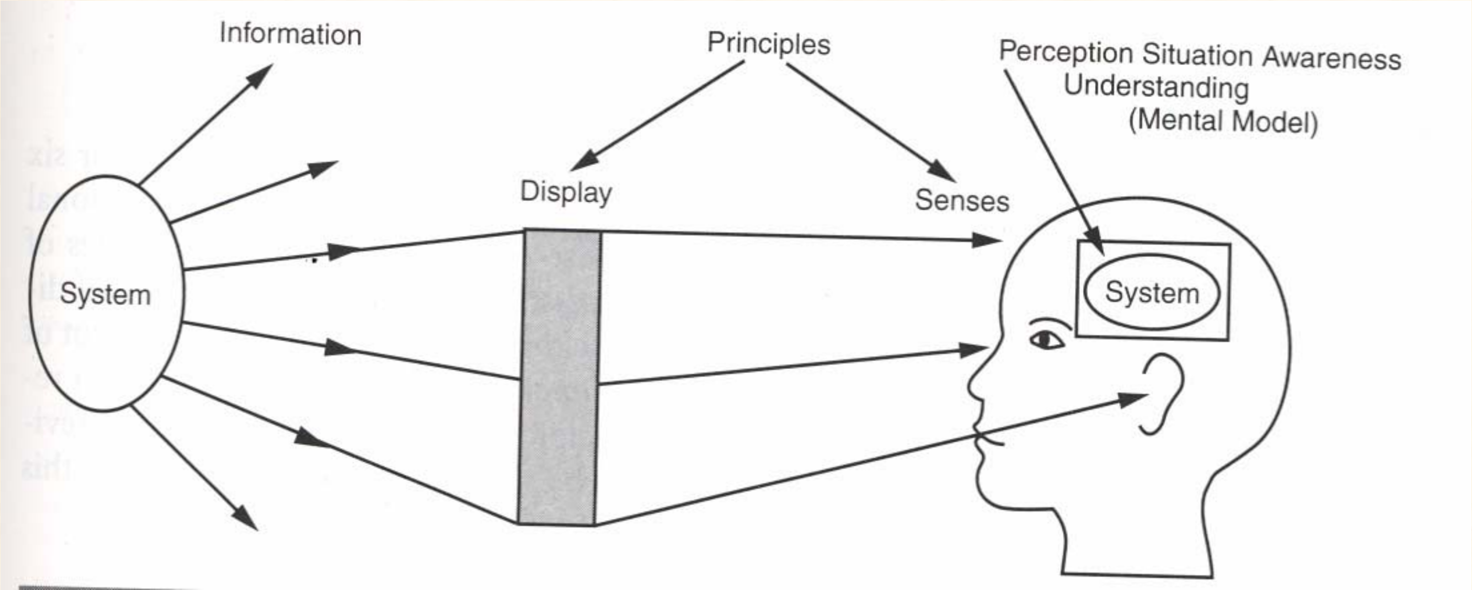
Reading: Wickens

pp. 186-193 (13 principles of display design)

pp. 218-225 (principles of response selection and discrete control activation)

What is a display?

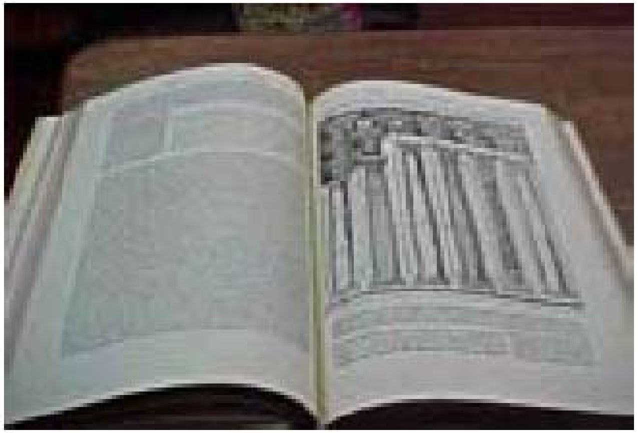
- A human-made artifact designed to:
  - Facilitate perception of information
  - Facilitate integration of information for the completion of a certain task
  - Facilitate further processing of information
  - Give appropriate feedback to user's actions
- Acts as a medium between the information generated by the system and the user's mental model of the process.

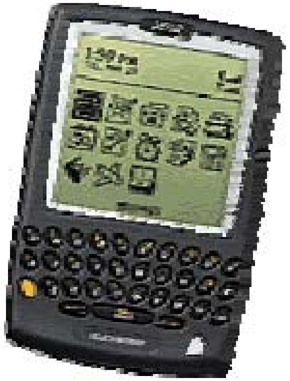


Types of Displays

- A display does not have to be associated with a computer (example: speedometer on car, knob on gas stove – position shows current setting).
- A display can be static: e.g. road signs
- Displays may be visual, auditory, haptic (touch), etc. Examples:
  - Visual: Flashing light on ambulance,
  - Auditory: siren on ambulance,
  - Haptic: cell phone in "vibrate" mode

Static versus dynamic displays





A classification of displays

Along three dimensions:

- ***Physical properties*** (physical implementation of the display)
  - Color or monochrome; visual or auditory modality etc.
- ***Task*** that the display is intended to support
  - information visualization
  - search, query
  - process control, decision-making
  - learning
- ***Characteristics of the human user*** that dictate the best mapping between display and task
- Guidelines for display design can be structured along these 3 dimensions as well.

Example: ignoring physical constraints

Example: ignoring physical constraints

News coverage

Published: May 02, 2006

- NEW YORK (AdAge.com) “Starting today air travelers passing through Chicago's O'Hare Airport terminal 3 will be able to impersonate Tom Cruise's character from "Minority Report" and use their hands to manipulate content -- weather, news [] -- on a giant 10-by-7-foot screen. Accenture's new billboards operate like gigantic interactive computer screens.”

Example: ignoring physical constraints

- What users say:

  "It sure is a great demo. But it's a bad product."

  "Here's what happens. You walk up to it, you move your hands, touch the screen, things move around, data is exposed, etc. It's cool. For 10 seconds. And then you realize that because the screen is so damn big, and because your arms are so much shorter relative to the screen size, that you are way too close to actually read anything you just selected. It's like trying to watch a 50" TV from 1 foot away. It doesn't work."

http://37signals.com/svn/archives2/a_great_demo_a_bad_product.php?42#comments

13 Principles of Display Design

- Perceptual principles
- Mental model principles
- Principles based on attention
- Memory principles

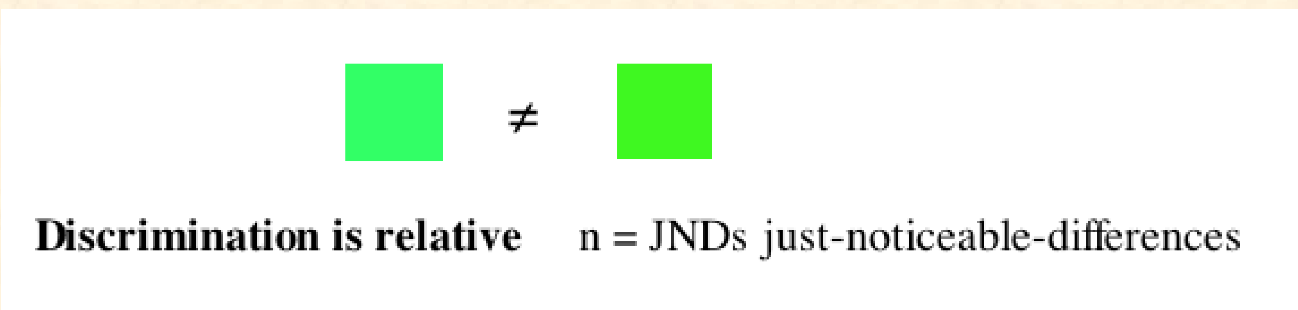
Perceptual principles

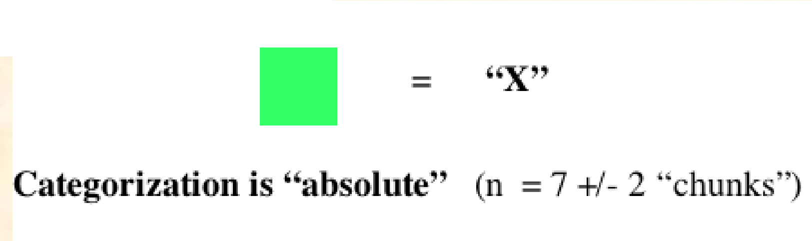
1. Make displays legible (or audible)

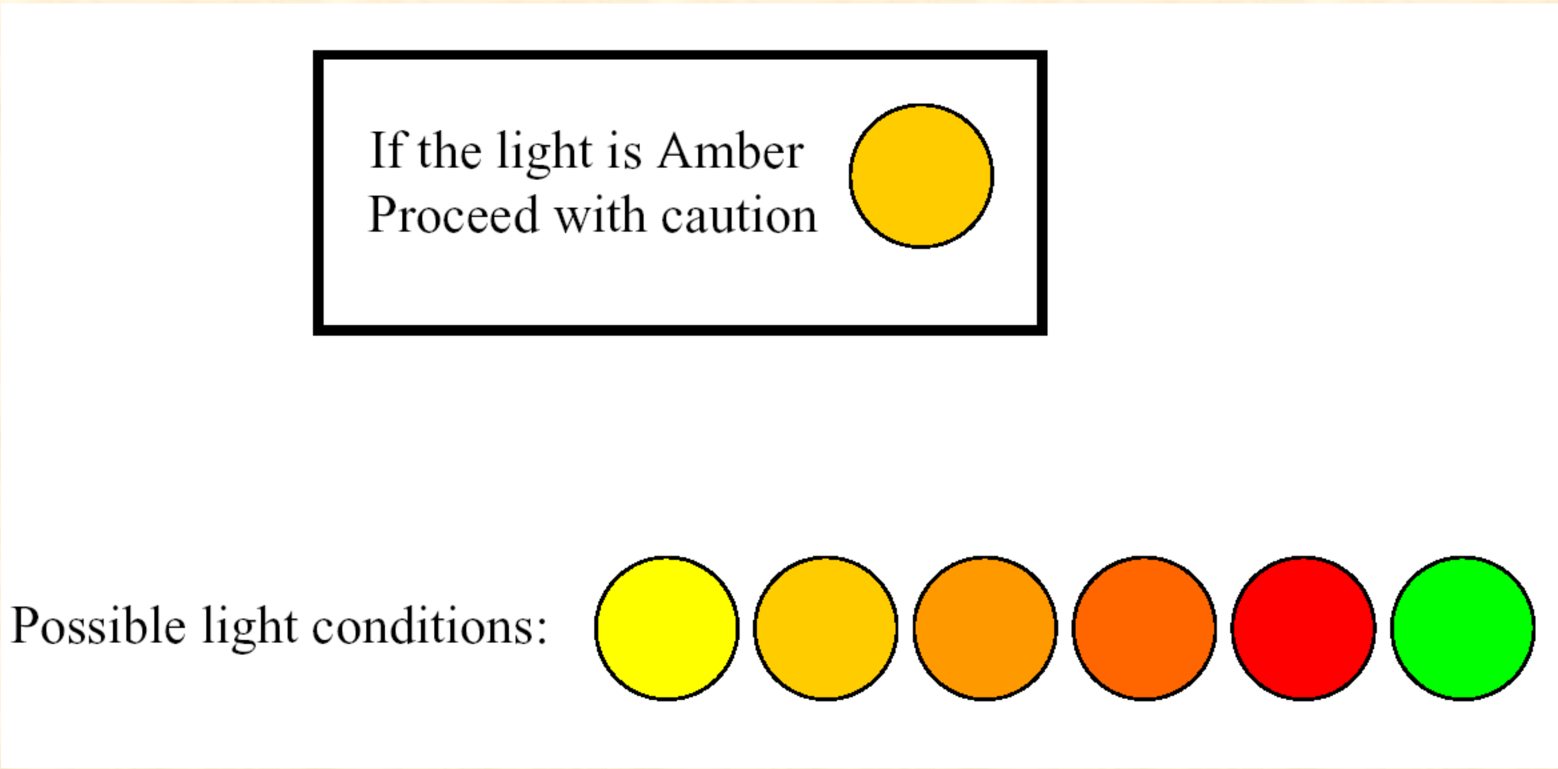
Perceptual principles

2**. Avoid absolute judgment**

- When two (visual) stimuli are next to each other we can make very fine discriminations
- Our ability to distinguish between stimuli when only one of them is present is much more limited
- This process is called absolute judgment
  - When only one stimulus is present, distinguishing it from others=comparing it with mental reps of the other possible memory
  - Overload of the working memory





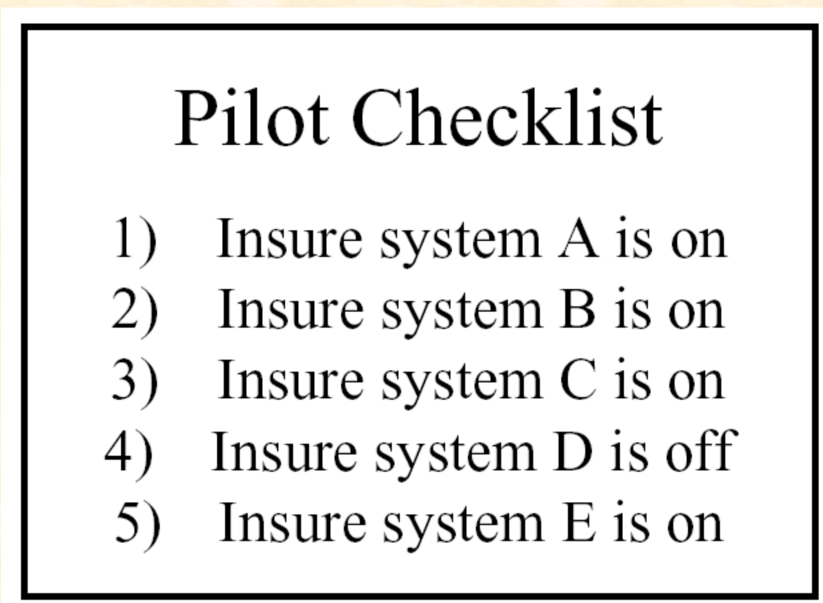

If the light is Amber
Proceed with caution
Possible light conditions:

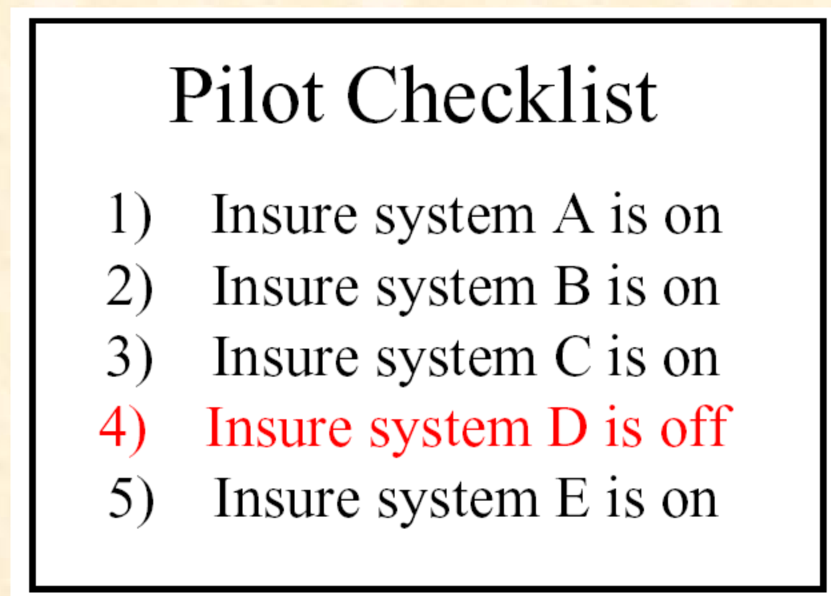
Perceptual principles

3. Top-down processing

People perceive and interpret signals in accordance with what they expect to perceive on the basis of past experience.

context: see example b) p. 187

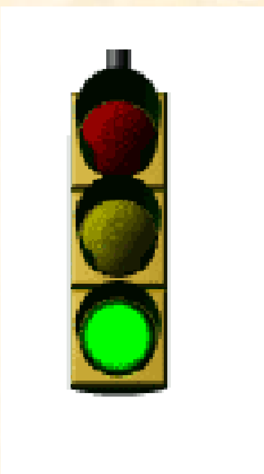


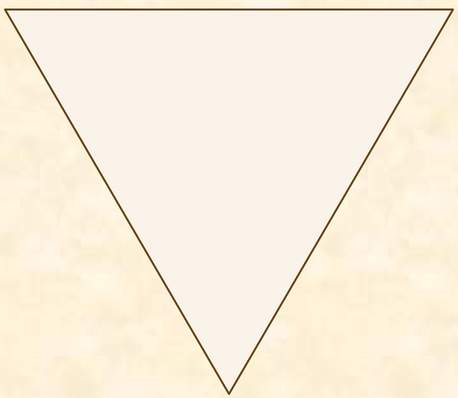


Perceptual principles

4. Redundancy gain

- Redundancy is not repetition! Use alternate forms when possible (shape/location, audio/visual)

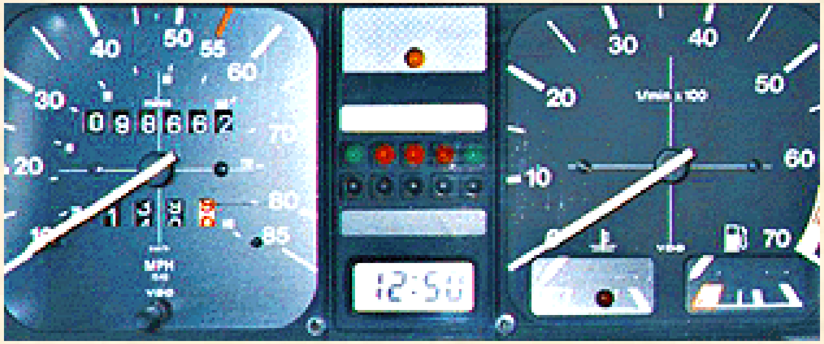




- Can you find an example of display using redundancy gain?

Perceptual principles

- **5. Discriminability**



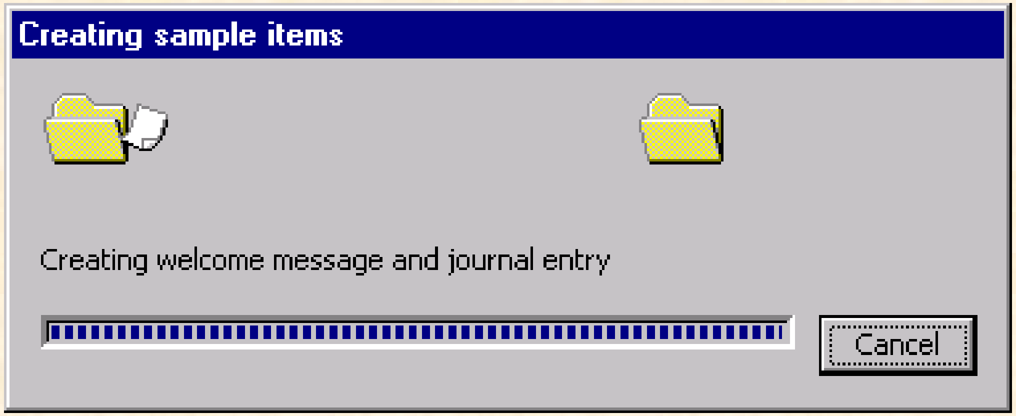
Mental model principles

- **6. Principle of pictorial realism**
  - Display should present spatial analog for real world : a display should look like the variable that it represents
  - If system variable analog, display should be analog
  - Direction and shape of display should be compatible with system variables (e.g., thermometer) and with the user's mental model
  - Multiple elements must be configured in a manner that looks like how they are configured in the environment that is represented

Mental Model Principles

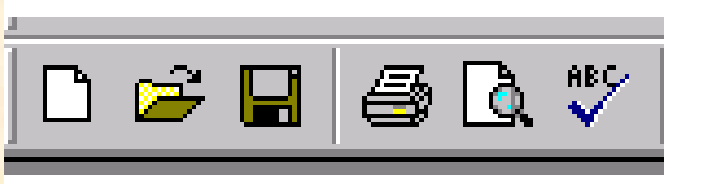
- **7. Principle of the moving part:**

The moving elements of any display of dynamic information should move in a spatial pattern and direction that is compatible with the user's mental model of how the represented element moves.



Attention-based principles

- **8. Minimizing information access cost**
  - – Cost is measured in time and effort of the user to move selective attention from one display location to another to access information.
  - – Design solution: Keep frequently accessed sources in such a location that the cost of traveling between them is small.
  - – Example from UI design: toolbars
    - Fast access to common actions, often customizable

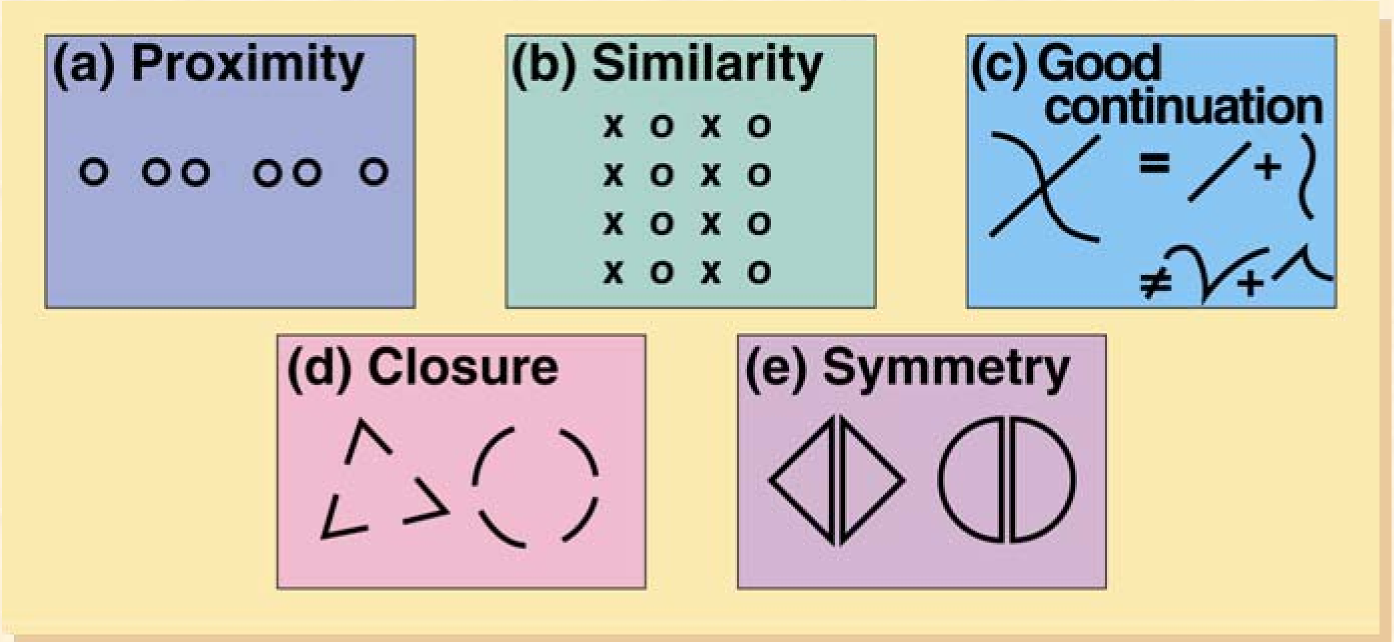


Attention-based principles (2)

- **9. Proximity compatibility principle**

  Sometimes two or more sources of information must be mentally integrated to complete the task. Parts of the information should be close together, but not too close.

  instead use perceptual grouping rules



Attention-based principles

10. Principle of multiple resources:

- Dividing information display between modalities (audition and vision).
- Minimizes interference from several visual stimuli
- Enables multi-tasking

Memory principles

11. Replace memory with visual information: provide a good balance between knowledge in the world vs knowledge in the head

too much knowledge in the world: visual cluter, complicated navigation scheme, difficult information retrieval

too much knowledge in the head: memory overload

Memory principles

- **12. Principle of predictive aiding**

Help with making prediction in the future.

Minimizes load on prospective memory

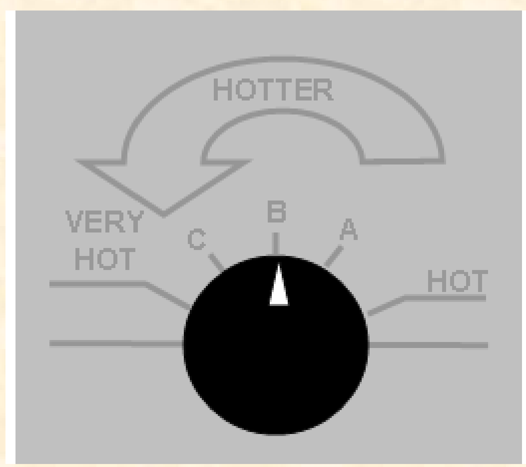
A predictive display replaces a resource-demanding cognitive task with a simpler perceptual one.

Memory principles

13. Principle of consistency

- Design displays that are consistent with other displays users concurrently use or have used in the past
  - Example: Consistent color coding or icons across displays

- The diagram below represents the control panel of a gas water heater, which is located, like many other heaters, in a very poorly illuminated space. The panel is used to adjust the heater's set point to the water temperature desired by the user. It is made of light gray metal with raised letters, arrow, and lines. These markings are the same color as the panel. The continuous rotary knob is black with a white pointer. The "HOT" setting is "about" 50° C. "A", "B", "C" and "VERY HOT" are not described in the operating instructions. A municipal law requires that water heaters be set to lower than 65° C to avoid burns.
- Discuss this diplay from a human factors engineering perspective. What specific principles are violated by this design ? Explain how they are violated.



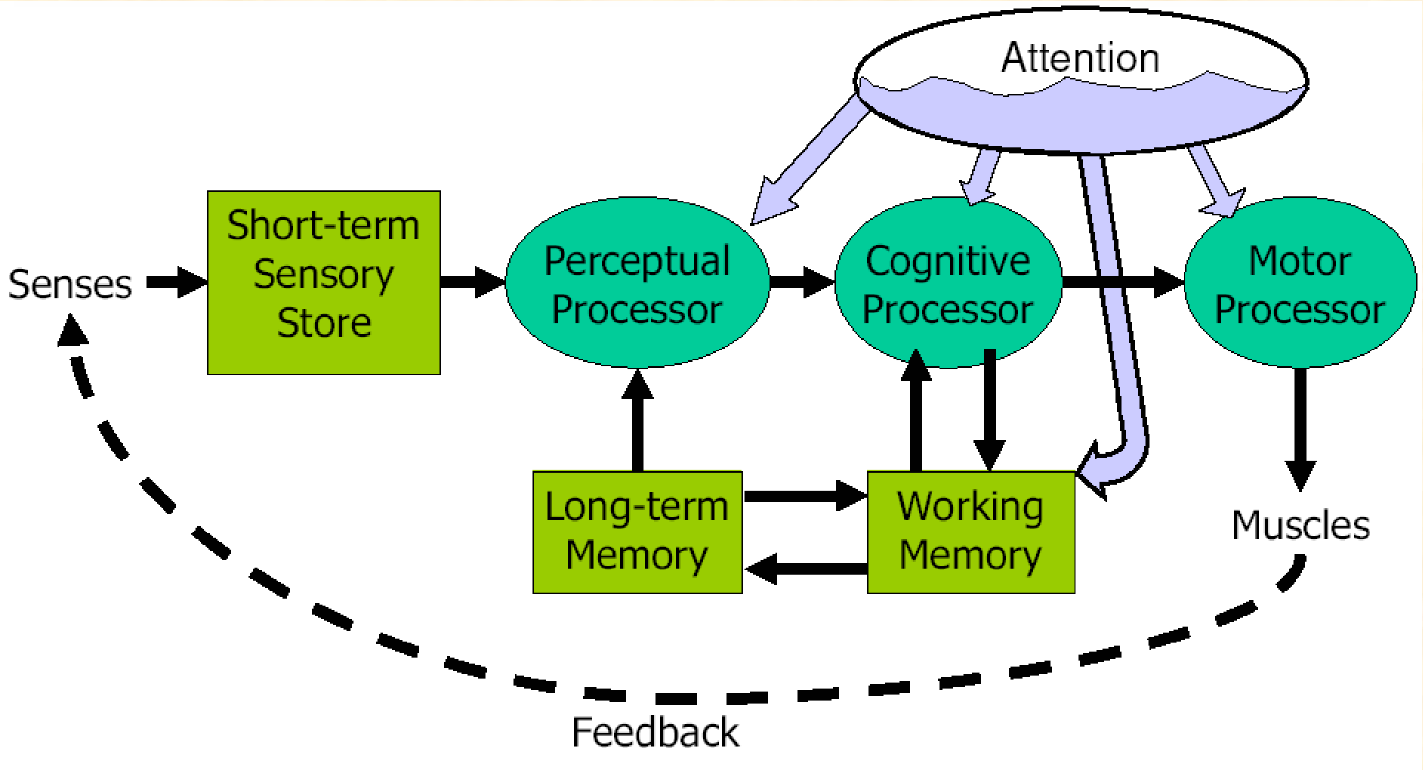
Controls

- Display is the perception.
  - Seeing
  - Hearing
  - Other
- Control is the action after a decision is made.

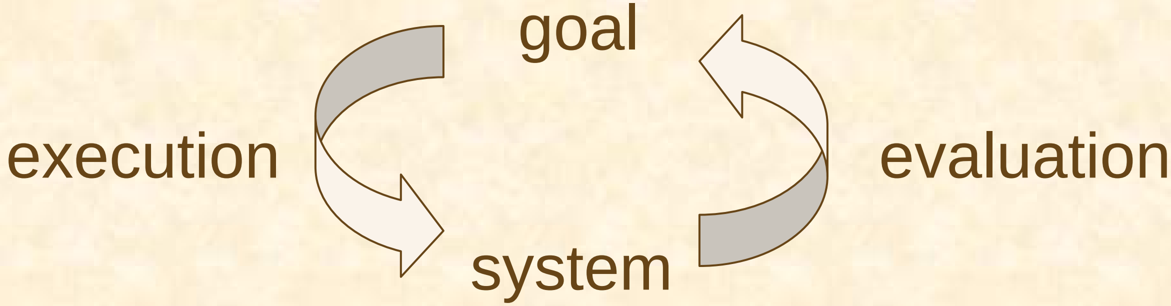
Control

- Involves the selection and execution of responses.
- Includes the feedback loop.
- To discuss control design, we will use both the Human Processor Model and Norman's interaction model

The Model Human Processor



execution/evaluation loop



- user establishes the goal
- formulates intention
- specifies actions at interface
- executes action
- perceives system state
- interprets system state
- evaluates system state with respect to goal

Example: Chapter 9 story

- The rental car was new, and as he pulled onto the freeway entrance ramp at dusk, he started to reach for what he thought was the headlight control. Suddenly, however, his vision was obscured by a gush of water fluid across the windshield.. As he reached to try to correct his mistake, his other hand twisted the very sensitive steering wheel and the car started to veer of the ramp. Quickly, he brought the wheel back but overcorrected, and then for a few terrifying moments the car seesawed back and forth along the ramp until he brought it to a stop, his heart pounding. He cursed himself for failing to learn the location of controls before starting his trip. Reaching once more for the headlight switch, he now activated the flashing hazard light-fortunately, this time, a very appropriate error.

- **Describe the driver's unsuccessful interaction with the car controls using Norman's interaction model.**

Principles of Response Selection

Decision complexity

- The speed with which an action can be selected is strongly influenced by the number of possible alternative actions that could be selected.
- Hick-Hyman Law of reaction time shows a logarithmic increase in reaction time (RT) as the number of possible stimulus-response alternatives (N) increases. Humans process information at a constant rate. $RT = a + b\text{Log}_2 N$

$$H = \sum_{i}^{n} p_i \log_2(1/p_i + 1)$$

Hick-Hyman Law

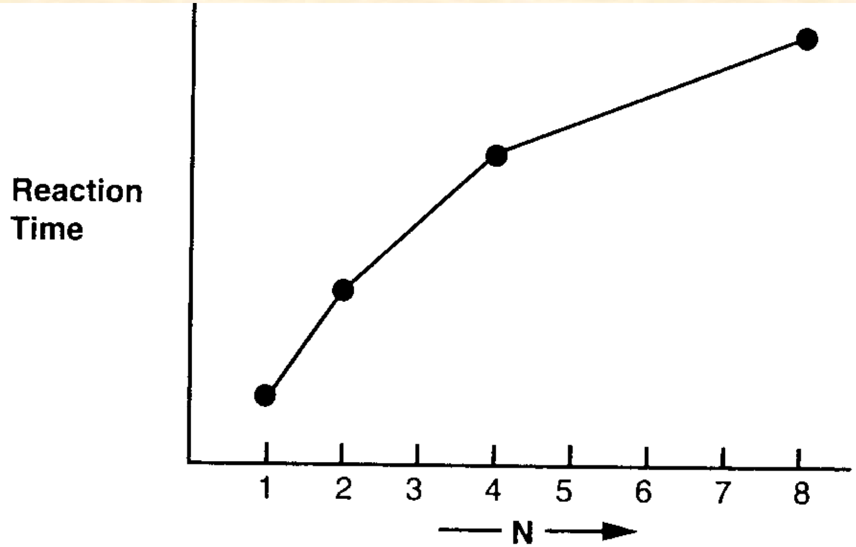


FIGURE 9.1

The Hick-Hyman Law of reaction time. The figure shows the logarithmic increase in RT as the number of possible stimulus-response alternatives (N) increases. This can sometimes be expressed by the formula: $RT = a + b\text{Log}_2 N$.

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- The most efficient way to deliver a given amount of information is by a smaller number of complex decisions rather than a large number of simple decisions.

Response expectancy

- We perceive rapidly and accurately that information that we expect.
- We don't expect a car to suddenly stop in front of us on the freeway. It takes time to perceive and to respond.
- We use the ***************** to help us expect a red.

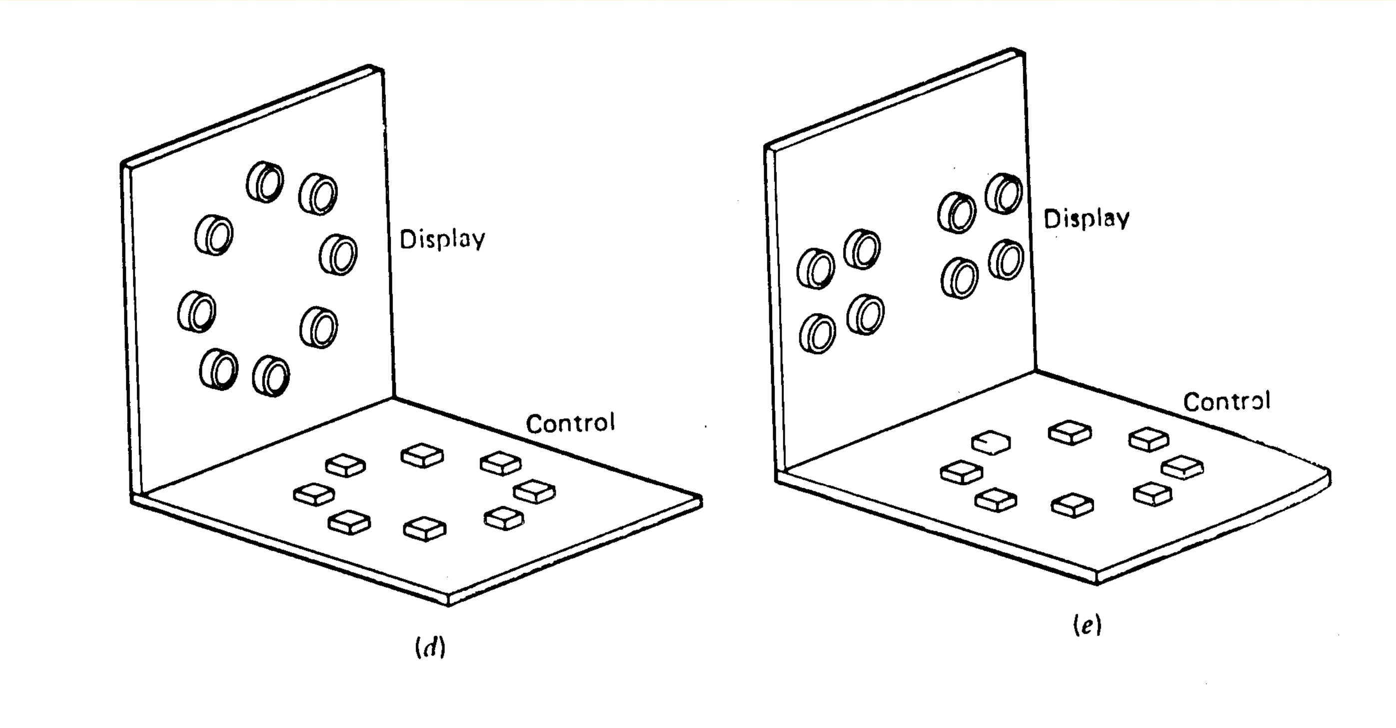
Response expectancy

- We perceive rapidly and accurately that information that we expect.
- We don't expect a car to suddenly stop in front of us on the freeway. It takes time to perceive and to respond.
- We use the yellow caution light to help us expect a red.

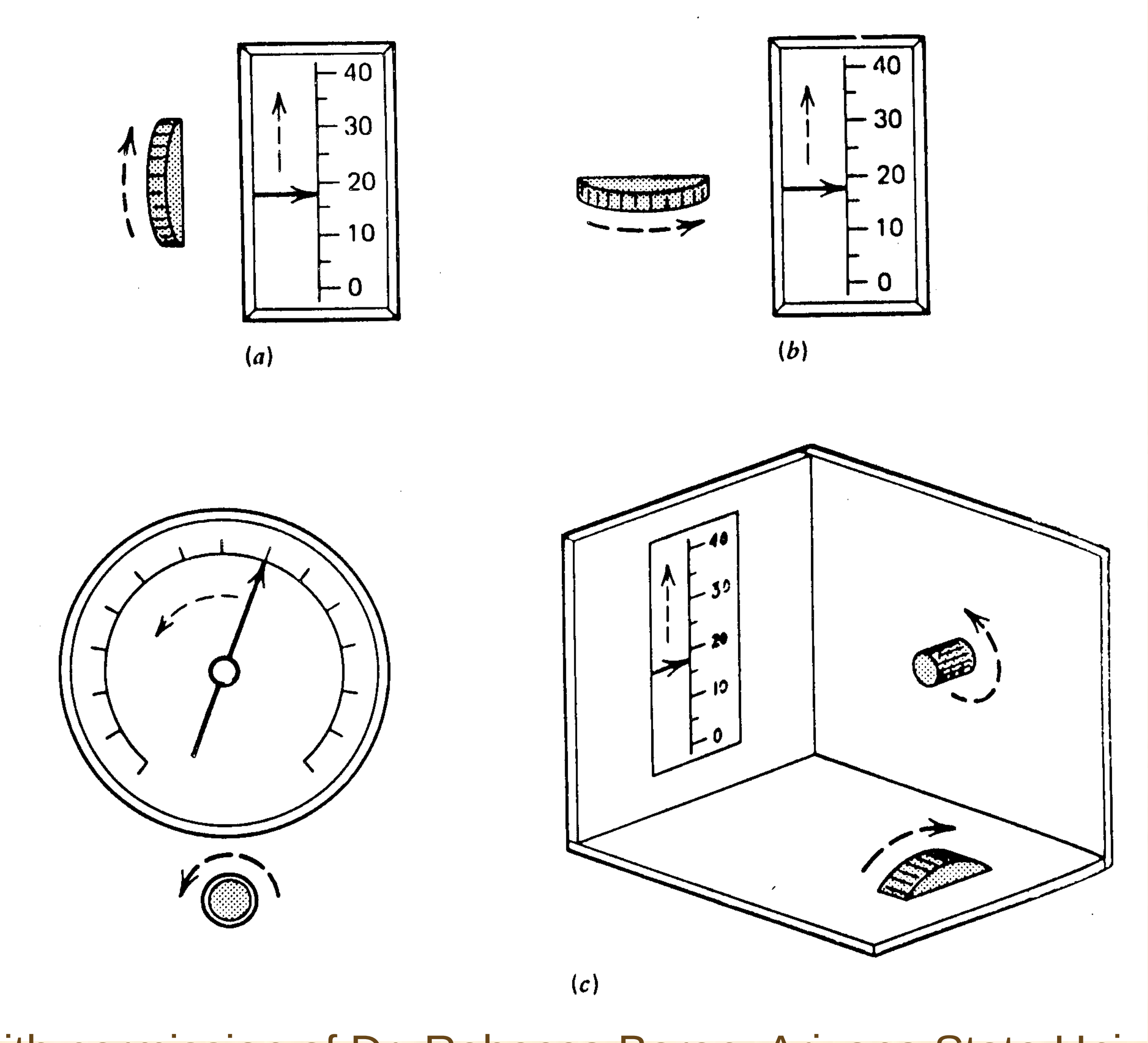
Compatibility

- Good stimulus-response compatibility (display-control compatibility) aids in response selection.
- Two sub principles:
  - Location compatibility (mapping)
  - Movement compatibility (moving a lever right should move the display to the right).

Location Compatibility



Movement Compatibility



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Speed-accuracy tradeoff

- Sometimes positively correlated, sometimes negatively correlated.
- The first three principles result in a positive correlation. Whatever makes the response selection faster makes it less prone to error.
- In a few cases, control devices differ in the speed-accuracy tradeoff because one induces faster, but less precise behavior or more careful but slower behavior

Feedback

- Instantaneous or nearly instantaneous feedback is helpful.
- If there is a lag of even 100 msec, an unskilled operator will have difficulty.

Feedback example-Discrete Control Activation

A toggle switch provides visual feedback, an auditory click, and a tactile snap with the sudden loss of resistance.

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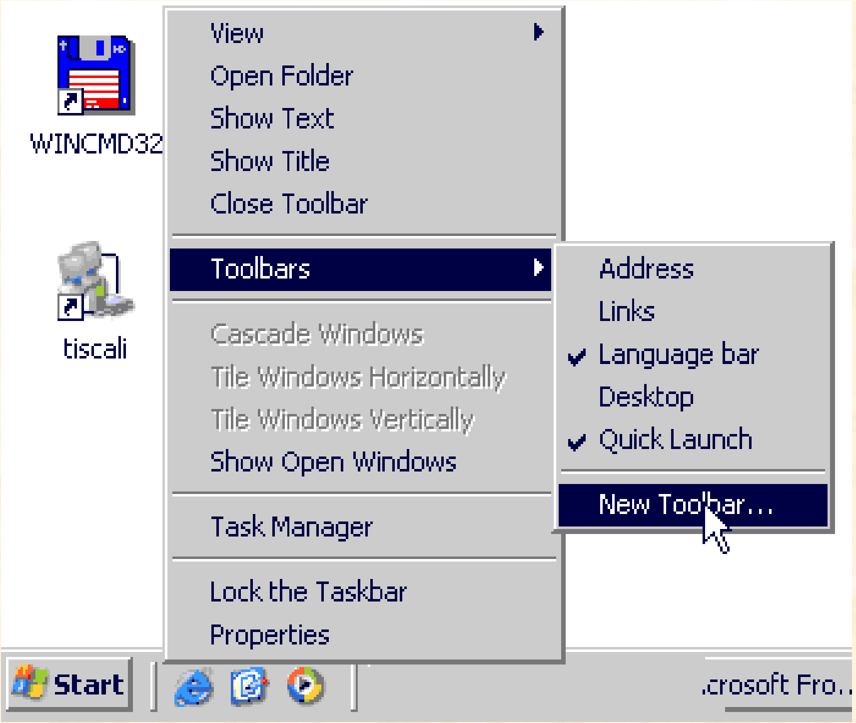
Positioning Control Device

The positioning or pointing task defined as movement of a controlled entity, called a **cursor,** to a destination, called the **target**.



Positioning Control Device

- **Movement time**: controls typically require two different movements:
  - movement of the hand or fingers to the control device
  - movement of the control device in some direction.

Movement Time

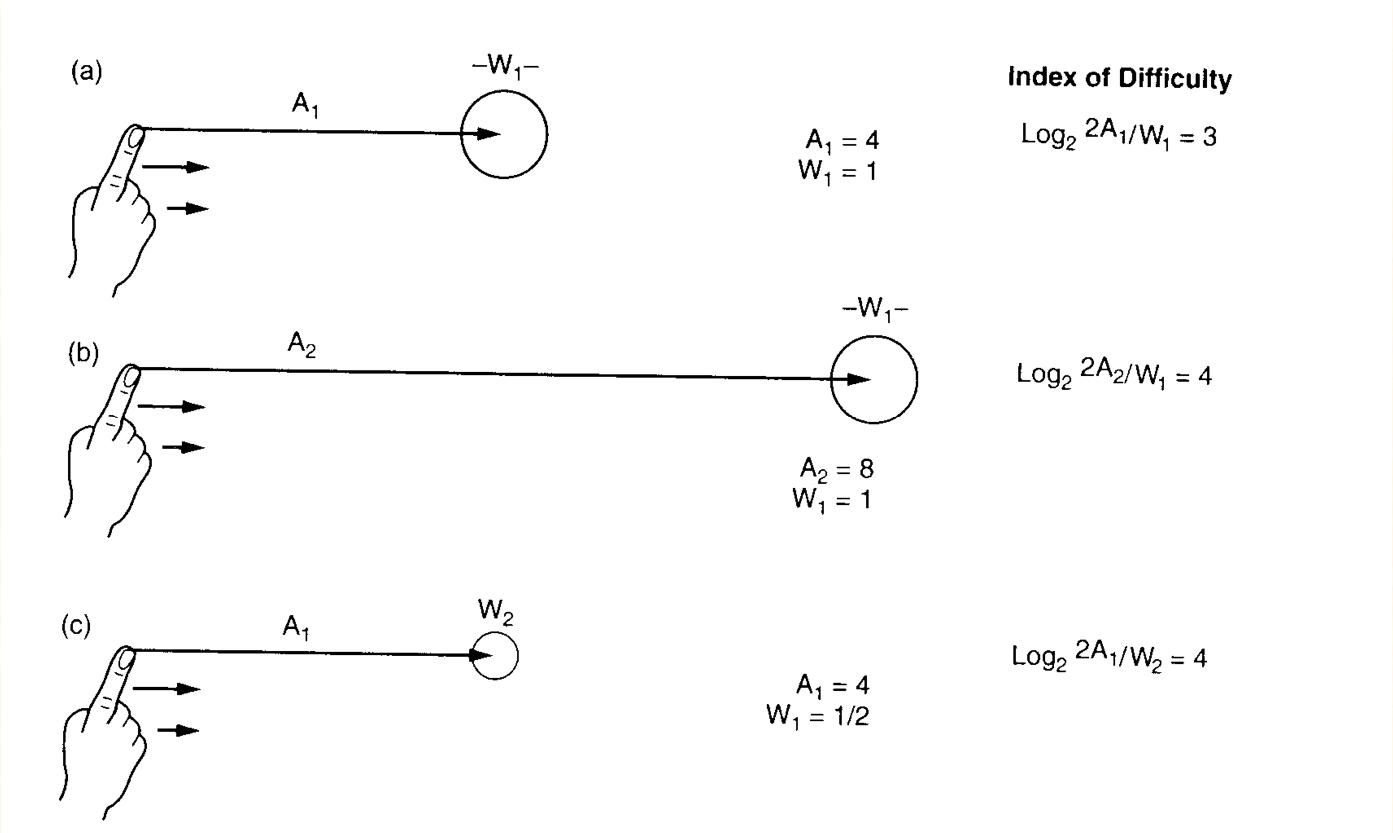
- Predicted by **Fitt's Law**

$$MT = \mathbf{a} + \mathbf{b} \log_2(2A/W)$$

  - MT is movement time
  - A is amplitude of the movement
  - W is width of the movement
  - (2A/W) is the index of difficulty
  - **a** and **b** are constants
- MT is proportional to the index of difficulty

Movement Time – Fitt's Law

$$MT = \mathbf{a} + \mathbf{b}\,\log_2(2A/W)$$



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Movement Time Examples

- If the keys on a keyboard are made smaller, without the space also made proportionally smaller, then movement is more difficult.
- Foot reaching a foot pedal
- Assembly and manipulation under a microscope.

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Summary

- The design of displays and controls is closely related (controls are often times embedded into interactive displays)
- In display design we need to minimize the gulf of evaluation (13 principles of display design)
- In control design we need to minimize the gulf of execution (principles of response selection)
- For the design of positioning control devices we need to study human capabilities (motor processor, Fitts law)