

HUMAN INFORMATION PROCESSING

Cornell University

DEA 3250/6510

Information Aquisition

- Information is the key to survival.
- Information about our external world is acquired by exteroceptors (5 senses - vision, audition, olfaction, tactile, gustation).
- Information about our internal state is acquired by interoceptors (e.g. kinesthesia, proprioception).
- The brain must sift this constant information stream for relevant cues (signals) rather than irrelevant cues (noise).

Quantifying Information: Information Theory

- Information is the reduction of uncertainty.
- Highly probable events convey little information and merely confirm what we anticipate.
- Highly improbable events convey greater information because they are not anticipated.

Information and Behavior

- Information load has functional effects on human performance.
- Information load dramatically affects the speed of a response.
- Information load dramatically affects the accuracy of a response.

Information: Reaction Time

- The speed of reaction to information depends on the time to:
 - Activate the sensory receptor
 - Transmit nerve impulses from the sense organ to the brain
 - Process nerve impulses in the brain
 - Transmit nerve impulses to muscles
 - Energize and activate muscles
 - Execute movement

Simple Reaction Time

- Simple reaction time (SRT):

Stimulus —————> Response

- SRTs typically range between 150-200 milliseconds (0.15 - 0.2 seconds).
- Auditory SRTs approx. 50 msec. faster than visual SRTs (at 55 mph this equates to ~ 4 feet difference in braking distance).

Choice Reaction Times

- When the operator has choices among alternative stimuli and/or responses (choice reaction time - CRT) then the information load affects reaction times.



CRTs: Hick's Law (1952)

- In making choices a person gains information at a constant rate:

$$\text{Mean CRT} = K \log_2 (n+1)$$

where n = number of choices

+1 = has event occurred or not

K = constant

CRTs: Hick's Law

Information Theory

- Information is quantified in bits (binary digits), and represented by H
- $H = \log_2 N$ (number of alternatives)
- With 2 alternatives $H = 1$ ($\log_2 2=1$)
- With 4 alternatives $H = 2$ ($\log_2 4=2$)
- With 8 alternatives $H = 3$ ($\log_2 8=3$)

Information and CRT

Information Theory

- When alternative choices are not equiprobable, then the information associated with an even (H_i) is:
$$H_i = \log_2 (1/p_i) \quad \text{where } p_i = \text{probability of } i$$
- For a series of events of differing probabilities:
$$H_{av} = \sum_{i=1} p_i(\log_2 1/p_i)$$

Example

- Assume 2 events of unequal probabilities, $p_1=0.9$ and $p_2=0.1$

$$\begin{aligned} H_{av} &= [(0.1(\log_2 1/0.1)) + (0.9(\log_2 1/0.9))] \\ &= 0.332 + 0.137 \\ &= 0.469 \text{ bit} \end{aligned} \rightarrow$$

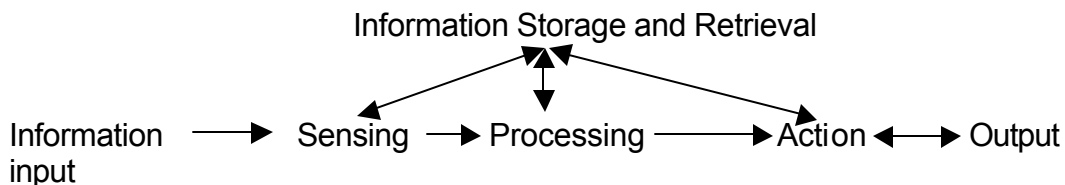
Redundancy

- In information theory, redundancy is the reduction in information from the maximum information because of unequal probabilities of occurrence:
$$\% \text{ redundancy} = (1 - (H_{av}/H_{max}) \times 100$$
- From previous example:
$$\begin{aligned} \% \text{ redundancy} &= (1 - (0.47/1.0) \times 100 \\ &= 0.53 \times 100 = 53\% \end{aligned}$$
- Because certain letter combinations are highly probable (th, qu, st) and others highly improbable (cw, tx, xq) the English language is ~68% redundant.

Bandwidth

- Bandwidth is the rate of information transmission over a channel.
- Bandwidth of the eye is ~ 1,000 bits/sec
- Bandwidth of the ear is ~ 10,000 bits/sec
- Bandwidth of the brain is much lower than that of the sensory systems!
- Most sensory information is filtered out of the system at a peripheral level to better match the capacity of the brain, which functions as a limited single channel capacity system.

Functional Information Processing



Sensory Input

- Sensory receptors transduce external energy in a limited spectrum into nerve impulses.
- Sensory information is actively organized by perceptual processes to create an internal representation of our external world.
- Perceptual organization occurs in a 'top-down' manner to impose order on sensory information.

Perceptual Processes

- Detection - determination of whether a stimulus is present or absent. Not a foolproof process.
 - False alarm - report that stimulus is present when absent.
 - Miss - report that stimulus is absent when present.
- Recognition - noticeable familiarity without the ability to label the stimulus.
- Identification - full identification of the stimulus (recognition + labeling).

Perceptual Organization

- Gestalt principles:

- Proximity
- Similarity
- Closure
- Continuity
- Figure-ground

- Constancies:

- Size
- Shape
- Color
- Brightness

Constancies

- Color - colors appear the same under a wide range of lighting conditions (e.g. snow looks white and coal looks black in sunlight or moonlight).
- Brightness - object brightness looks the same under a range of lighting levels (e.g. the paper of a book looks white under low through bright light).

Perceptual Processes

- Perception - is an active process whereby the brain strives to make sense of sensory information and fit this to a known pattern.
- Perception creates our reality.
- Perception can easily be fooled to create illusions.

Visual Illusions

- Illusions can arise because of cue conflicts.

Visual Illusions

- Illusions can arise because of cue competition.

Visual Illusions

- Illusions can arise because of cue ambiguity.

Visual Illusions

- Illusions can arise because of cue orientation.

Visual Illusions

- Illusions can arise because of time and redundancy.

Visual Illusions

- Illusions can arise because of context.

Visual Illusions

- Illusions can arise because of mixed cues.

Depth Perception

- Linear environmental cues help with depth perception.

Depth Perception

- Environmental texture cues help with depth perception.

Display Design

- There are principles of perception that apply too each of the senses.
- Ignoring the principles of perception can create dysfunctional information displays.
- Knowledge of the principles of perception helps us to design more effective information displays.