### Human Information Processing

**Similar Terms**
- Cognitive Psychology
- Cognitive Engineering
- Engineering Psychology

**Intellectual Antecedents**
- Neobehaviorism
- Verbal Learning
- Human Engineering
- Communication Engineering
- Computer Science
- Linguistics

### Human Mind/Brain Analogies

Historically, the human mind has been compared to the highest levels of contemporary technology.

- Water works
- Clock works
- Industrial organization
- Telephone switching circuits
- Digital computers

### Information Processing Paradigm

**Information – The Reduction of Uncertainty**

**Notes:**
- The occurrences of highly probable events do **NOT** convey much information; on the other hand, occurrences of highly unlikely events, **DO** convey large amounts of information.
- The importance of the message is not directly considered, only the likelihood of its occurrence is considered.

### Information Theory

Based on the principles of communication engineering **not** on cognitive psychology.

- Concepts are descriptive rather than explanatory.
- Offers only rudimentary clues about the underlying psychological mechanisms of information processing.
- Most useful for determining information processing capacity of different sensory channels and/or choice reaction times.
- Provides basis for measuring, coding, displaying.

### Information Units of Measurement

**Bit – The amount of information required to differentiate (decide) between two equally likely events.**

**Equally Likely Probabilities**
\[ H = \log_2(N) \]

**Unequal Likely Probabilities**
\[ H = \log_2 \left( \frac{1}{p_i} \right) \]

### Equally Likely Examples

- **Paul Revere – Old North Church**
  - “One if by land, two if by sea”
  - Alternatives – Land and Sea
  \[ H = \log_2(2) = 1 \text{ bit} \]

- **Randomly chosen digit (0 – 9)**
  \[ H = \log_2(10) = 3.3 \text{ bits} \]

- **Randomly chosen letters (A – Z)**
  \[ H = \log_2(26) = 4.7 \]
### Equally Likely Examples

<table>
<thead>
<tr>
<th>Land = Light</th>
<th>Sea = No Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note: If three choices (not coming, land, sea) then</td>
<td></td>
</tr>
<tr>
<td>( H = \log_2(3) = 1.6 \text{ bits} )</td>
<td></td>
</tr>
<tr>
<td>Not Coming = No Light</td>
<td>Land = 1 Light</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Digit</th>
<th>Bits</th>
<th>Letter</th>
<th>Letter</th>
<th>Letter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0000</td>
<td>A</td>
<td>00001</td>
<td>K</td>
</tr>
<tr>
<td>1</td>
<td>0001</td>
<td>B</td>
<td>00010</td>
<td>L</td>
</tr>
<tr>
<td>2</td>
<td>0010</td>
<td>C</td>
<td>00111</td>
<td>M</td>
</tr>
<tr>
<td>3</td>
<td>0111</td>
<td>D</td>
<td>01001</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>0100</td>
<td>E</td>
<td>01010</td>
<td>O</td>
</tr>
<tr>
<td>5</td>
<td>0101</td>
<td>F</td>
<td>01110</td>
<td>P</td>
</tr>
<tr>
<td>6</td>
<td>0110</td>
<td>G</td>
<td>01111</td>
<td>Q</td>
</tr>
<tr>
<td>7</td>
<td>0111</td>
<td>H</td>
<td>10000</td>
<td>R</td>
</tr>
<tr>
<td>8</td>
<td>1000</td>
<td>I</td>
<td>10001</td>
<td>S</td>
</tr>
<tr>
<td>9</td>
<td>1001</td>
<td>J</td>
<td>10101</td>
<td>T</td>
</tr>
</tbody>
</table>

### Information Measurements - continued

Average Information Conveyed by a series of events having different probabilities of occurrence.

\[
H_{\text{Average}} = \sum p_i \times \log_2 \left(\frac{1}{p_i}\right)
\]

Redundancy is the reduction in information due to unequal probabilities of occurrence.

\[
\text{Redundancy (\%)} = \left(1 - \frac{H_{\text{Average}}}{H_{\text{Maximum}}}\right) \times 100 \%
\]

Bandwidth – The rate of information transmitted over a single channel, measured in bits per seconds (bps).

Sensitivity – Keenness or resolution of sensory system

### Examples

**Redundancy**

- English Language - Not all letters occur with same frequency / probabilities and some often occur together as pairs th and qu. Redundancy \(\cong 68\%\)

**Bandwidth**

- Human Hearing = 8000 bits per second
- Human Vision = 1000 bits per second

Both of which are much faster than can be processed and interrupted by our brains, hence serve as a filter.

### Sensing Information

**Direct** – Original Source

- Indirect - Displayed (Coded or Reproduced)
- Coded - Alphanumeric text and symbols
  - Reproduced - enlarged, amplified, filtered, enhanced, distorted

**Information Display**

- Applies to any indirect method of presenting information.
- Static - labels, placards, textbooks, traffic signs
- Dynamic - radar screens, speedometers, thermometers

### Information Classification – continued

**Quantitative Information** – Numeric Value

**Qualitative Information** – Trend, Rate/Direction of Change

**Status Information** – Status or Condition

**Warning Information** – Indicates Unsafe Condition

**Representative Information** – Maps, Symbols

**Identification Information** – Bar Codes, Sport Jerseys

**Alphanumeric** – Text and Numbers, Symbols

**Time Phased Information** – Duration or Spacing

### Information Perception Modalities

- **Visual**
- **Aural**
- **Tactile**
- **Olfactory**
- **Vestibular & Proprioceptors**
Visual Presentation of Information

- Complex messages
- Lengthy messages
- Later reference
- Describes or details spatial location
- Does NOT require immediate attention
- Overburdened auditory system
- Noisy receiving environment
- Stationary work area

Auditory Presentation of Information

- Simple / short messages
- No later reference required
- Deals with temporal events
- Requires immediate attention
- Overburdened visual system
- Extreme lighting conditions (dark adaptation integrity)
- Continually moving work area

Information Coding

Coding – Occurs when the original stimulus is converted to a new form and displayed symbolically.

Note: Symbols include alphanumeric text.

Absolute vs. Relative Judgments
- Absolute – Comparison example held only in memory
- Relative – Two simultaneous stimuli

Dimensions – Single and Multiple

Coding Dimensions

Multi-Dimensional
- Sounds – Pitch and Loudness
- Visual Symbols – Size, Shape, Color

Orthogonal – Independent of other dimension
- Example:
  - Shape – circle and square
  - Color – red and green
  - red circle, red square, green circle, green square

Redundant – One dimension predicts the other
- Example:
  - All squares are red, all circles are green
  - Knowing the color predicts the shape and vice versa.

Characteristics of Effective Coding Systems

- Detectability – Threshold
- Discriminability – Difference Threshold
- Meaningfulness – Inherent or Learned
- Standardization – Consistency
- Multidimensional – Increases Discriminability

Compatibility (Transformation / Recoding)

- Conceptual Compatibility – The degree to which codes and symbols correspond to the people’s mental models.

- Movement Compatibility – Relationship between the movement of controls / displays and the system’s response to such movements.

- Spatial Compatibility – The physical arrangement in space of controls and their associated relationship to displays.

- Modality Compatibility – Certain stimulus / response modality combinations are more “natural” for certain tasks than are other modality combinations.
**Human Perception**

- Various Levels – Depends on stimulus and task at hand.
- Single Level – Detection
- Multiple Levels – Identification and Recognition
- Involves prior experiences and learned associations.

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**Memory**

- Sensory Storage (STSS)
  - Temporary Storage Mechanism
  - Iconic Storage - Visual
  - Echoic Storage - Auditory
- Working Memory – “Short Term”
  - Capacity of Working Memory (7 ± 2)
  - Retention in working memory = constant rehearsal
  - Searching Working Memory < 40 ms
- Long-Term Memory

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**Signal Detection Theory (SDT)**

- Concept of Noise
  - Random variations of “non-signal” activity added to actual information relevant “signal”.
  - Noise is a condition imposed on the information signal.
  - Noise is a system phenomena that may originate in the transmitter, receiver, or medium.
  - Random variation of noise levels is assumed to be normally distributed. (Gaussian – White Noise).

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**Signal Detection Theory - continued**

- Signal Processing Outcomes
  - Hit – Correct reception of true signal
  - Rejection – Correct rejection of false signal
  - Miss – Non-reception of true signal
  - False Alarm – Incorrect reception of false signal

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**Response Criterion**

- Likelihood of Observing Signal
  - Depends on “Response Criterion Level”
  - Say “Signal” or “No Signal”
- Beta = Signal-to-Noise Ratio at a given criterion level
  - Response Bias
- Sensitivity d’ = Keenness or resolution of sensory system
- Response Criterion Level and Sensitivity are independent

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**Influences on Response Criterion**

- Setting of Response Criterion Level depends on costs and benefits associated with possible outcomes.
  - Increase Response Criterion (shift towards right)
    - Beta Increases
    - Say “Signal” less often
    - Number of Hits Decreases / Number of False Alarms Decreases
    - Number of Misses Increases
    - “Conservative”
  - Decrease Response Criterion (shift towards left)
    - Beta Decreases
    - Say “Signal” more often
    - Number of Hits Increases / Number of False Alarms Increases
    - Number of Misses Decreases
    - “Risky”
Concept of Response Criterion

- Signal $+$ noise distribution
- Probability of Occurrence
- Say "signal" if high
- Say "no signal" if low
- Noise only distribution
- Correct rejection
- Hit
- Miss
- False alarm

Sensitivity $= d'$

Beta $= b / a$