Information Input and Processing

Introduction

Most powerful, efficient, and flexible information processing and storage device

Information Theory

- Human information processing
- Information processing capacity (human sensory channels)
- Choice reaction time

Limitations

- Most of its concepts are descriptive rather than explanatory
- Offers only the most rudimentary clues about the underlying psychological mechanisms of information processing

Concept of Information

- ***Information:*** Reduction of Uncertainty
- Occurrences of highly certain events don't convey much information since they only confirm what was expected
- Occurrences of highly unlikely events convey more information

Measuring Information

Equally Likely Alternatives:

A ***Bit*** is the amount of information required to decide between two equally likely alternatives

$$H = \log_2 N$$

H = information in bits
N = # alternatives

Examples

- Randomly chosen digit from the set of numbers 0 to 9 would convey:

$$H = \log_2 10 = 3.322 \quad \textit{bits}$$

- Randomly chosen letter from the set of letters A to Z would convey:

$$H = \log_2 26 = 4.27 \quad \textit{bits}$$

Measuring Information – cont.

Not Equally Likely Alternatives:

$$h_i = \log_2 (1/p_i)$$

h_i = information associated with event i in bits

p_i = probability of occurrence of event i

Measuring Information – cont.

Average information conveyed by a series of events having different probabilities

$$H_{av} = \sum_{i=1}^{N} p_i \left(\log_2 \frac{1}{p_i = 1} \right)$$

Example

Two events, first event's probability = 0.1 and the second event's probability = 0.9.

$$H_{av} = 0.1 \times \left(\log_2 \frac{1}{0.1} \right) + 0.9 \times \left(\log_2 \frac{1}{0.9} \right) = 0.469$$

Redundancy

- Reduction in information from maximum
  - owing to unequal probabilities of occurrences

- Maximum possible information
  - Alternatives are equally probable

Redundancy

$$\%\,\text{Redundancy} = \left(1 - \frac{H_{av}}{H_{\max}}\right) \times 100$$

Bandwidth

- Rate of information transmission over a channel (bits / second)
  - For ear (8000 – 10000 bits/sec)
  - For eye (1000 bits/sec)
- >>> information absorbed & interpreted by the brain
- Filtering

Applications of Information Theory

- ***Hick-Hyman Law:***
  - choice reaction time is linear function of stimulus information

Applications of Information Theory – cont.

- Stimuli from original source of information:
  - Direct
  - Indirect (HF aspect)
    - Coded
    - reproduced

- ***Display:***
  - Any indirect method of presenting information

Types of Information Presented by Displays

- Dynamic
  - Traffic lights, speedometers, radar display, and temperature gauge
- Static
  - Printed, written, and other forms of alpha numeric data; traffic signs; charts; graphs; and labels

Types of Information Displayed

- Quantitative
- Qualitative
- Status
- Warning and Signal
- Representational
- Identification
- Alphanumeric and Symbolic
- Time-Phased

Quantitative Information

- Temperature
- Speed

Dynamic

- Nomographs

Static

Qualitative Information

- Approximate value
- Trend
- Rate of Change
- Direction of change
- Changeable variable
- Predicted on quantitative parameter
- Displayed Indication rather than value

Status Information

- Condition or status of a system
  - On-off indications
- Indications of one of a limited number of conditions
  - Stop-caution-go lights
- Indications of independent conditions of some class
  - TV channel

Warning and Signal Information

- Emergency or unsafe conditions
- Presence or absence of some condition
  – Aircraft or light house beacons

Representational Information

- Pictorial or Graphic representation of objects, areas, or other configuration
  - Dynamic images
    - TV or Movies
  - Symbolic
    - Heart beats
      - oscilloscope
      - blips on a cathode-ray tube
  - Static information
    - Photographs, maps, charts, diagrams, blueprints
  - Graphic
    - Bar graphs, line graphs

Identification Information

- Identify some static condition, situation, or object
- Usually coded form
- e.g.
  - Identification of hazards
  - Traffic lanes
  - Color coded pipes

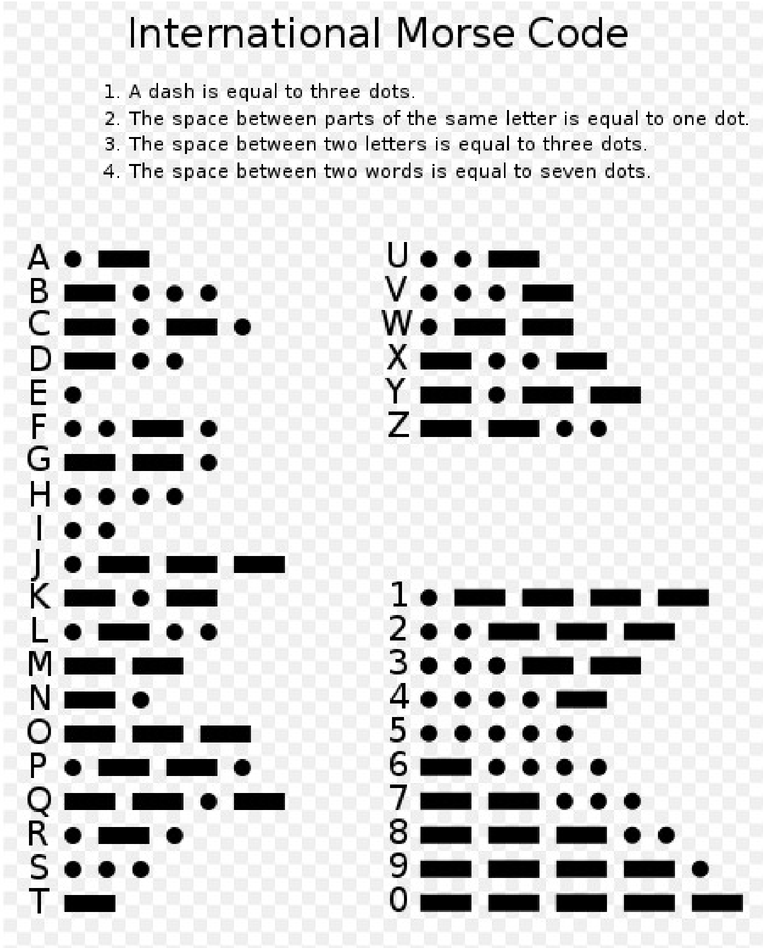
Alphanumeric and Symbolic Information

- Verbal, numeric, and related coded information
  - Usually static
    - Signs
    - Labels
    - Placards
    - Instructions
    - Music notes
    - Printed and typed material (braille & computer printouts)
  - Dynamic
    - News bulletins by moving lights on a building

Time-Phased Information

- Pulsed or time-phases signals
- Signals controlled in terms of signal duration and of intersignal intervals, and of their combinations
  - Morse code
  - Blinker light

Morse Code


International Morse Code
1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to seven dots.
A • —
B — • • •
C — • — •
D — • •
E •
F • • — •
G — — •
H • • • •
I • •
J • — — —
K — • —
L • — • •
M — —
N — •
O — — —
P • — — •
Q — — • —
R • — •
S • • •
T —
U • • —
V • • • —
W • — —
X — • • —
Y — • — —
Z — — • •
1 • — — — —
2 • • — — —
3 • • • — —
4 • • • • —
5 • • • • •
6 — • • • •
7 — — • • •
8 — — — • •
9 — — — — •
0 — — — — —

Displays

- some present more than one type of information
- Displayed information is used for more than one purpose
- Selection depends on nature of information to be displayed

Selection of Display Modality

Use auditory presentation if:	Use visual presentation if:
The message is simple	The message is complex
The message is short	The message is long
The message will not be referred to later	The message will be referred to later
The message deals with events in time	The message deals with location in space
The message calls for immediate action	The message does not call for immediate action
The visual system of the person is overburdened	The auditory system of the person is overburdened
The receiving location is too bright dark adaptation integrity is necessary	The receiving location is too noisy
The person's job requires moving about continually	The person's job allows remaining in one place

Coding of Information (of Stimuli)

- Original stimulus information is converted to a new form and displayed symbolically
  - Radar screens (aircraft – blips)
  - Maps (population size – letter size of city name)
  - Electronic resistors (colored strips – resistance)

Utility of Stimulus Dimension

- **Visual**
  - Size, Brightness, Color, Shape
- **Auditory**
  - Frequency, Intensity. on-off pattern
- **Ability of people to**
  - Identify a stimulus along dimension
    - ***bright – dim or large – small***
  - Distinguish stimuli along dimension
    - ***Which of two stimuli is brighter or larger***

Absolute Judgment – Single Dimension

Range of Identification (7 ± 2)

Stimulus Dimension	Av. # discriminations	# bits
Pure tone	5	2.3
Loudness	4 – 5	2 – 2.3
Size of viewed objects	5 – 7	2.3 – 2.8
Brightness	3 – 5	1.7 – 2.3

Absolute Judgment – Multiple Dimensions

- Orthogonal: independent values on dimensions
  - Each dimension carries unique information
  - All combinations of the two dimensions are equally likely
    - **Circles – Squares &**
    - **Red – Green**

Absolute Judgment – Multiple Dimensions

- Redundant: the value on one dimension helps predict the value on the other dimension
  - Shape and Color
    - Complete Redundancy
      - All Circles **Green**
      - All Squares **Red**
    - Partial Redundancy
      - 80% Circles **Green**
      - 80% Squares **Red**

Combining Dimensions

- Increase number of identifiable stimuli
- Orthogonal > Redundant

Characteristics of Good Coding System

- Detectability of Codes
- Discriminability of Codes
- Meaningfulness of Codes
- Standardization of Codes
- Use of Multidimensional Codes

Compatibility

- Relationship of stimuli and response to human expectations

- Process of information transformation (Recoding)

Compatibility ↑ ***Recoding*** ↓

  – Faster learning
  – Faster response times
  – Fewer errors
  – Reduced mental workload

Conceptual Compatibility

- Meaningful codes and symbols to users
  - Aircraft symbol on map – airport
  - Meaningful abbreviations

Movement Compatibility

- Relationship between movement of displays & controls and the system being displayed or controlled
  - Clockwise rotation – increase controlled parameter
  - Upward movement on a scale – increase displayed parameter

Spatial Compatibility

- Physical arrangements in space of controls and their associated displays

Modality Compatibility

- Certain stimulus-response modality combinations are more compatible with some tasks than with others
- The way our brains are wired

Modality Compatibility

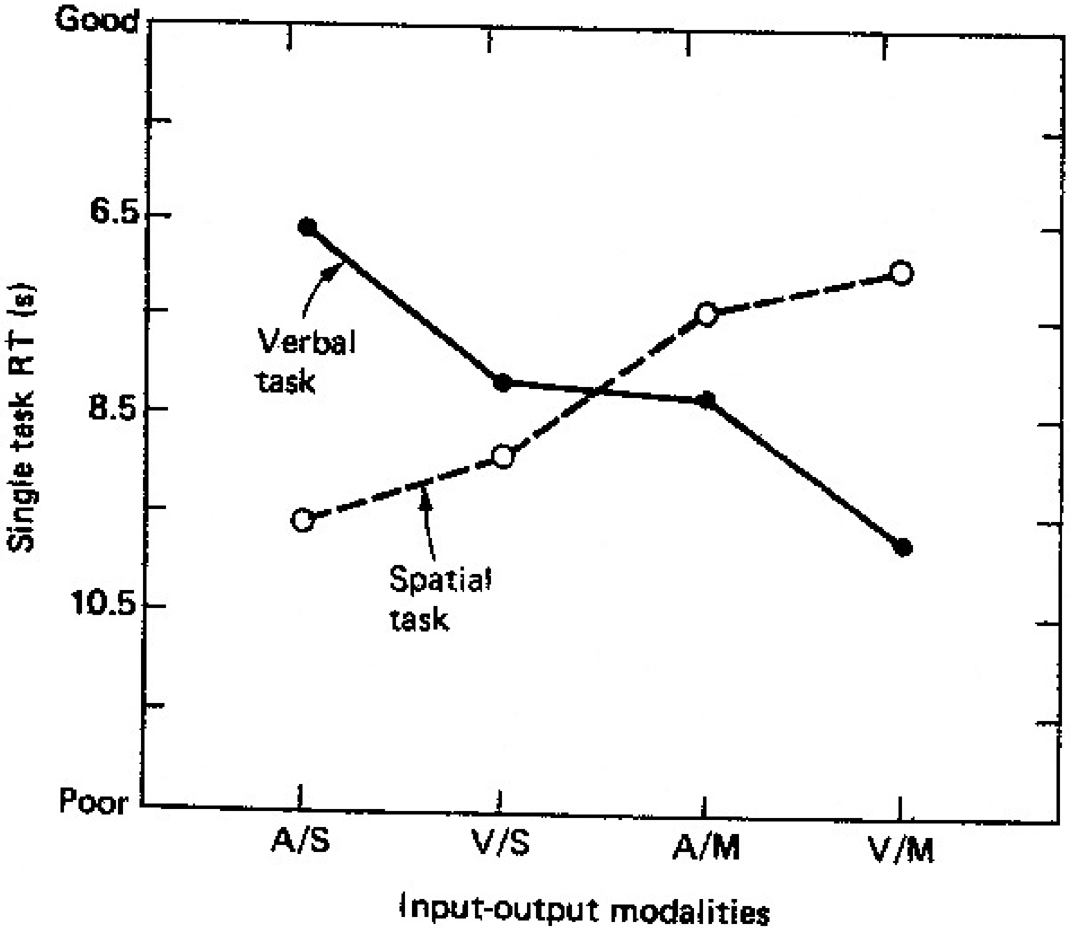


FIGURE 3-1
An example of modality compatibility. Input modality: A = auditory (speech) and V = visual (displayed on screen). Output modality: S = spoken response and M = manual response. For verbal tasks, the best input-output combination is A/S. For spatial tasks, the best combination is V/M. (*Source: Wickens, Sandry, and Vidulich, 1983, Fig. 6. Reprinted with permission of the Human Factors Society, Inc. All rights reserved.*)

Origin of Compatibility Relationships

- Intrinsic in the situation
  - Turn steering wheel right to turn right
- Culturally acquired
  - Push light switch up to turn lights on

Identification of Compatibility Relationships

- Certain relationships are manifest
  - Spatial compatibility
- Relationships are not obvious

A Model of Information Processing

- Abstract representation of a system or process
- Not judged to be correct or incorrect
- Evaluate its utility

A Good Model

- Account for behavior of actual system or process
- Generate testable hypotheses

A model

- Mathematical
  - Information Theory
  - Signal Detection Theory
- Physical
- Structural
  - Human Information Processing Model (organize)
- Verbal

A Model of Information Processing

- Hypothetical black boxes
- Processing stages assumed to be involved in the system

A Model of Information Processing

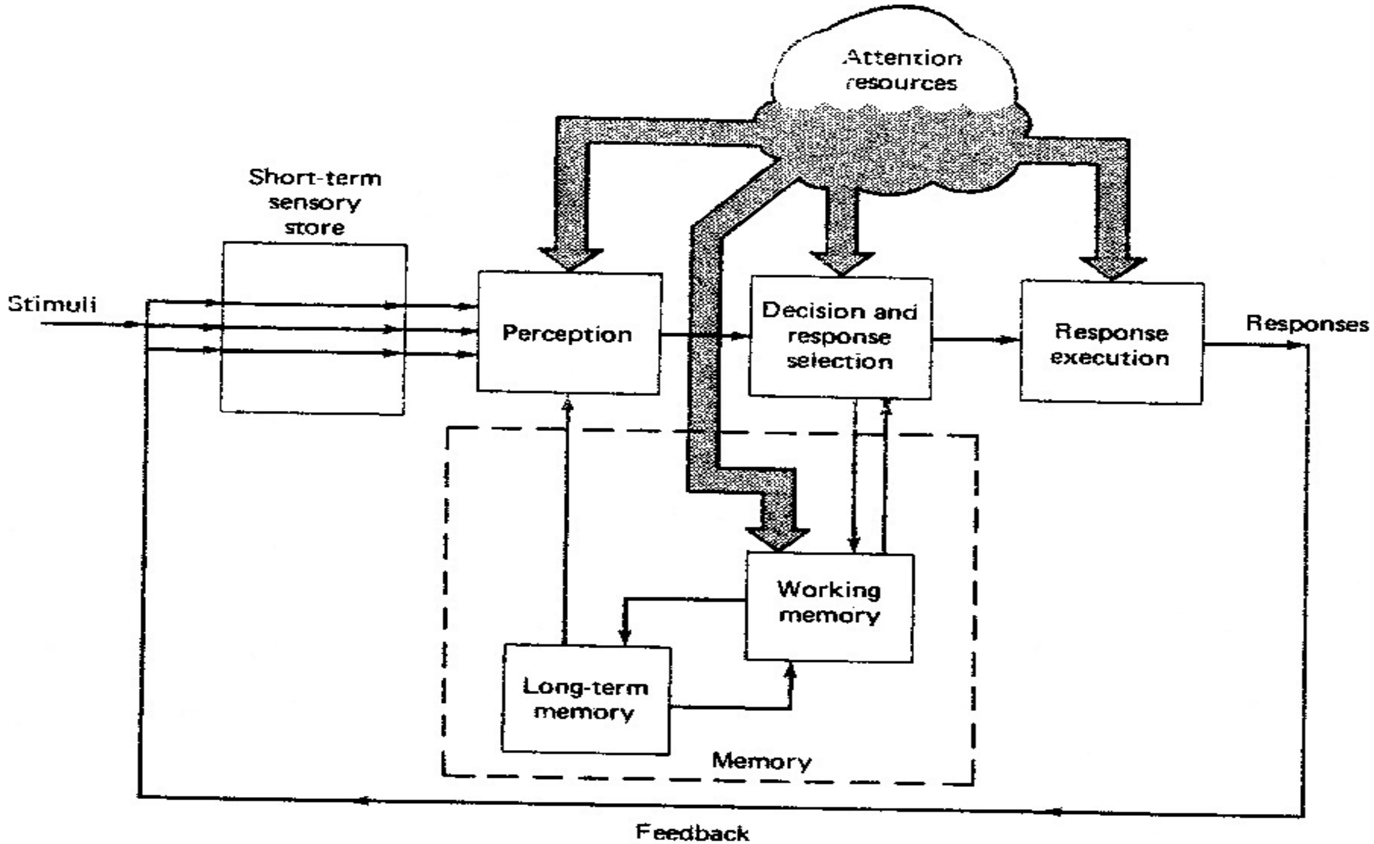


FIGURE 3-2
A model of human information processing showing the major processes, or stages, and the interrelationships. (*Source: Wickens, 1984, Fig. 1.1. Reprinted by permission of the publisher.*)

Perception

- Various levels
  - Stimulus
  - Task
- Basic Form (Simple Detection)
  - Signal or target is present
- Identification & Recognition
- Involve prior experience and learned associations

Signal Detection Theory (SDT)

- Two discrete states (signal & no signal)
- Not easy to discriminate
  - Cavity on a tooth x-ray
  - Blip on a radar screen
  - Warning buzzer in a noisy factory

Concept of Noise

- Interfere with signal detection
- External to person
  - Noises in a factory
  - Electronic static and false radar returns
- Internal within person
  - Miscellaneous neural activity

Concept of Noise

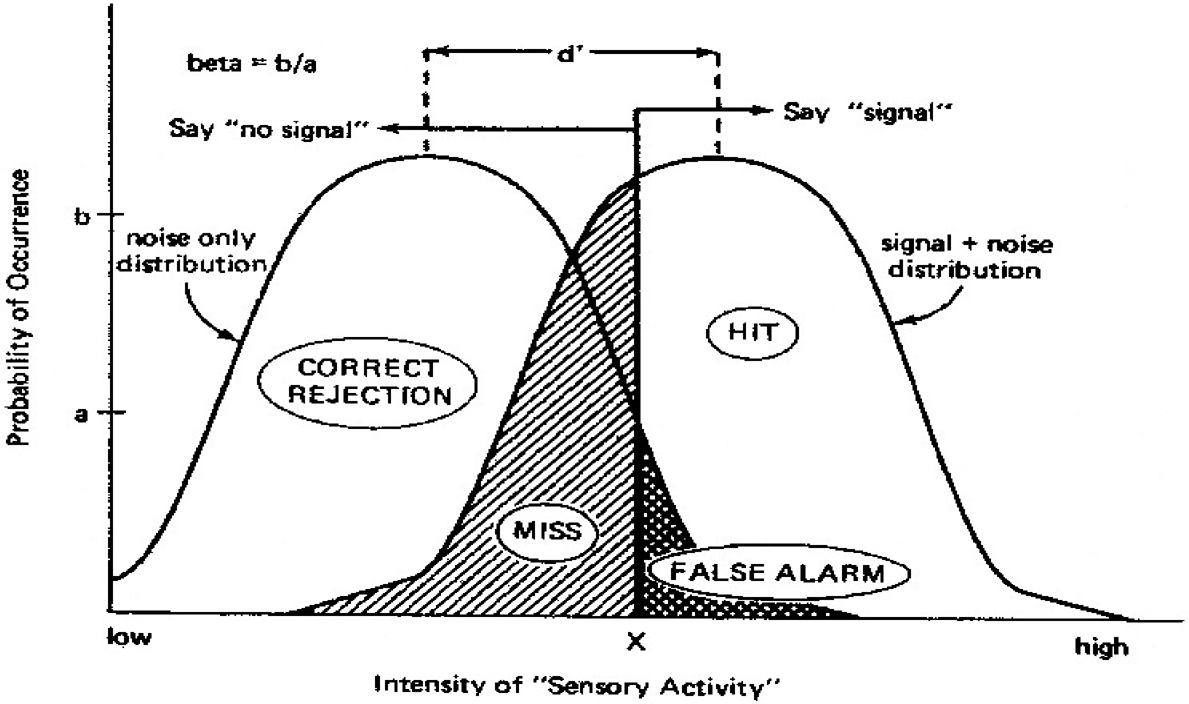
- Varies over time
  - intensity distribution (normal)
- signal intensity is added to noise intensity
- Should decide at any time whether sensory input is:
  - Noise *or*
  - Noise **+** Signal

Possible Outcomes

- ***Hit:*** saying there is a signal when there is a signal
- ***False Alarm:*** saying there is a signal when there is no signal
- ***Miss:*** saying there is no signal when there is a signal
- ***Correct Rejection:*** saying there is no signal when there is no signal

Concept of Response Criterion

FIGURE 3-3
Illustration of the key concepts of signal detection theory. Shown are two hypothetical distributions of internal sensory activity, one generated by noise alone and the other generated by signal plus noise. The probabilities of four possible outcomes are depicted as the respective areas under the curves based on the setting of a criterion at X. Here *d'* is a measure of sensitivity, and beta is a measure of response bias. The letters *a* and *b* correspond to the height of the signal-plus-noise and noise-only distributions at the criterion.



Signal to Noise Ratio

$$beta = \frac{\text{height (signal} + \text{noise) distribution curve}}{\text{height (noise) distribution curve}}$$

at the Response Cretrion

Beta **>** 1 ➔ ***Conservative*** Person

Beta **<** 1 ➔ ***Risky*** Person

Influencing the Response Criterion

- Likelihood of observing a signal
- Costs & Benefits associated with the 4 possible outcomes

Concept of sensitivity

- Resolution of sensory system
- Ability to remember physical characteristics of a signal

Of a person

- Measured by degree of separation between the two distributions (units of st.dev.)
- Independent of response criterion

Concept of sensitivity

- Greater separation →
  - Greater sensitivity
- Greater amount of noise →
  - Smaller separation
- Weaker and less distinct signal →
  - Smaller separation
- Memory aids increase sensitivity

Application of SDT

- Sonar target detection
- Industrial inspection tasks
- Medical diagnosis
- Eyewitness testimony
- Air traffic control

Application of SDT

Caution

- SDT developed from Lab controlled experiments
- Application situations may not match these conditions

Human Memory

- Sensory Storage
- Working Memory
- Long term memory

Human Memory

- Vast
- Imperfect
- Incredible amount of information in long term storage
- Trouble retrieve it when needed

Sensory Storage

- Temporary storage mechanism
- Prolongs stimulus representation for a short time after stimulus has ceased
- Original sensory representation
  - Tactual sensory storage
  - Olfactory sensory storage
  - Iconic storage **(< 1 sec)**
  - Echoic storage **(few seconds)**

Working Memory

- Direct attention to process
- Encode information
- Transfer information
  - Sensory memory ➔
  - working memory
- Three types of codes

Coding Info in Working Memory

- Visual
- Phonetic

> - **Visual and Auditory Representations of Stimuli**
> - **Can be generated by stimuli of the opposite type or internally from long-term memory**

- Semantic

> - **Abstract Representations of the meanings of a stimulus**

Coding Info in Working Memory

- All 3 codes can exist for a particular stimulus
- Letters read from a page ➔ Phonetic code
  - Letters “E” & “D”
  - Letters “E” & “F”
- Code letters on VDT ➔ phonetically dissimilar

Capacity of Working Memory

- To keep info ➔ Rehearsal
- Info decay over time
- Rapidly with more items in working memory
- Max # items **7 ± 2**

Capacity of Working Memory

- ***Chunk*** info into familiar units
  - C.A.T.D.O.G.R.A.T ➔ CAT.DOG.RAT
  - 966 1 46 76 301 <<< 96614676301

- ***Meaningful Chunks***
  - IB MJF KTV ➔ IBM JFK TV

Practical Implications

- Avoid presenting more than five to nine chunks of info (*to remember*)
- Present info in meaningful and distinct chunks
- Provide training on how to recall information by chunking

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Searching Working Memory

- Search time *increase linearly* with # items memorized
- 38 ms
  - Item in memory or not
- Items are searched one at a time

Long-Term Memory

- Info transfer ➔
  Working memory ➔
  Long-Term memory ➔
  semantically coding it
  - Supply meaning
  - Relate to already stored info

- More organized info ➔
  easier to transfer ➔
  easier to retrieve

- Retrieval weaken info utilization

Mnemonics – Ease Retrieval

- First letters of the items ➔
  - **make a word or sentence**
- Form images (bizarre) ➔
- **Connecting items on the list**

Decision Making

- Heart of Info Processing
  - Complex
  - Evaluate alternatives
  - Select course of action
- Seeking relevant info
- Estimating probabilities of outcomes
- Attaching values to anticipated outcomes

Decision Making

- Decision making time **>** choice reaction time
- Limited by human capacity to process and evaluate info
- Methods for presenting and preprocessing info
  - Improve quality of decision

Computer Aided Decision Making

- Aggregate probabilities as new info is present
- Keep track of several hypotheses, alternatives, or outcomes of sequential tests at one time
- Select best source of info to test specific hypotheses

Human Biases in Decision Making

1. Undue weight to early evidence
   – Subsequent info less important
2. Conservative
   – Don’t extract enough info from sources
3. Subjective odds are not given enough weight
4. More info ➔ more confidence in decision
   – Not necessarily accurate

Human Biases in Decision Making

5. Seek more info than can be adequately absorbed

6. Treating all info as equally reliable

7. Limited ability to handle max number of hypotheses at a time (3 to 4)

8. Focus on few critical attributes
   – Consider the highest 2 to 4 in rank

Human Biases in Decision Making

9. Seek info confirms chosen course of action
   - Avoid info disconfirm the choice
10. Potential loss has greater influence than potential gain
11. Mildly positive outcomes are more likely than mildly negative or highly positive outcomes
12. highly negative outcomes are less likely than mildly negative

Attention

- Kids never pay attentions
- We do,
  - *but* to wrong thing;
  - *hence,*
  - miss important things
- It’s something we can direct

Selective Attention

- Monitoring several channels of info to perform a single task
- # channels ⬆ performance ⬇
  - Load stress (*more important*)
  - Speed stress

Selective Attention

- Sampling multiple channels
  - Frequently occurring signals
  - Memory limitations
    - Forget to sample a source
    - Sample more than necessary
  - High stress
    - Fewer sources are sampled
    - Perceived important & salient

Guidelines for Selective-Attention Tasks

- Use as few channels as possible
  - Increase signal rate
- Provide info as to relative importance of the various channels
- Reduce overall level of stress
- Provide preview info of future likelihood of the signal

Guidelines for Selective-Attention Tasks

- Training to scan channels
- Reduce scanning requirements
  - Put multiple visual channels close together
- Multiple auditory channels should not mask one another
- Stimuli requiring individual responses should be separated
  - Rate enough to be responded to individually
  - Permit person to control rate of stimulus input where possible

Focused Attention

- Attend to one source of info and exclude other sources

- Influenced by proximity of the sources in physical space

Guidelines for Focused-Attention Tasks

- Distinction of competing channels from the one to attend to
- Separate competing channels in the physical space
- Reduce # competing channels
- Channel of interest
  - Larger
  - Brighter
  - Louder
  - More centrally located

Divided Attention (time-sharing)

- Attention paid to *2 or more* separate tasks performed simultaneously
- Declined performance
- Exceed info processing capacity

Single-Resource Theories

- One undifferentiated source of resources
- Shared by all mental processes
- Difficulty ⬆ Demand Resources ⬆
- Fewer resources left for other tasks

Multiple-Resource Theories

- Several independent resource pools

- Resources Allocation Dimensions:
  - Stages
  - Input Modality
  - Processing Codes
  - Responses

Guidelines for Divided Attention Tasks

- Minimize # potential sources of info
- Provide info regarding relative priorities of tasks (dividing attention strategy)
- Minimize difficulty level of tasks
- Dissimilar tasks (stages, modalities, and coding)
- Training (especially manual tasks)

Sustained Attention – Vigilance

- Maintain attention and remain alert to stimuli over prolonged periods of time
- System monitor, observing dials and computer screens for occasional critical stimulus demanding action

Sustained Attention – Vigilance

- Vigilance decrement
  - Speed &
  - Accuracy of signal detection

- Less in real life than in lab studies

Sustained Attention – Vigilance

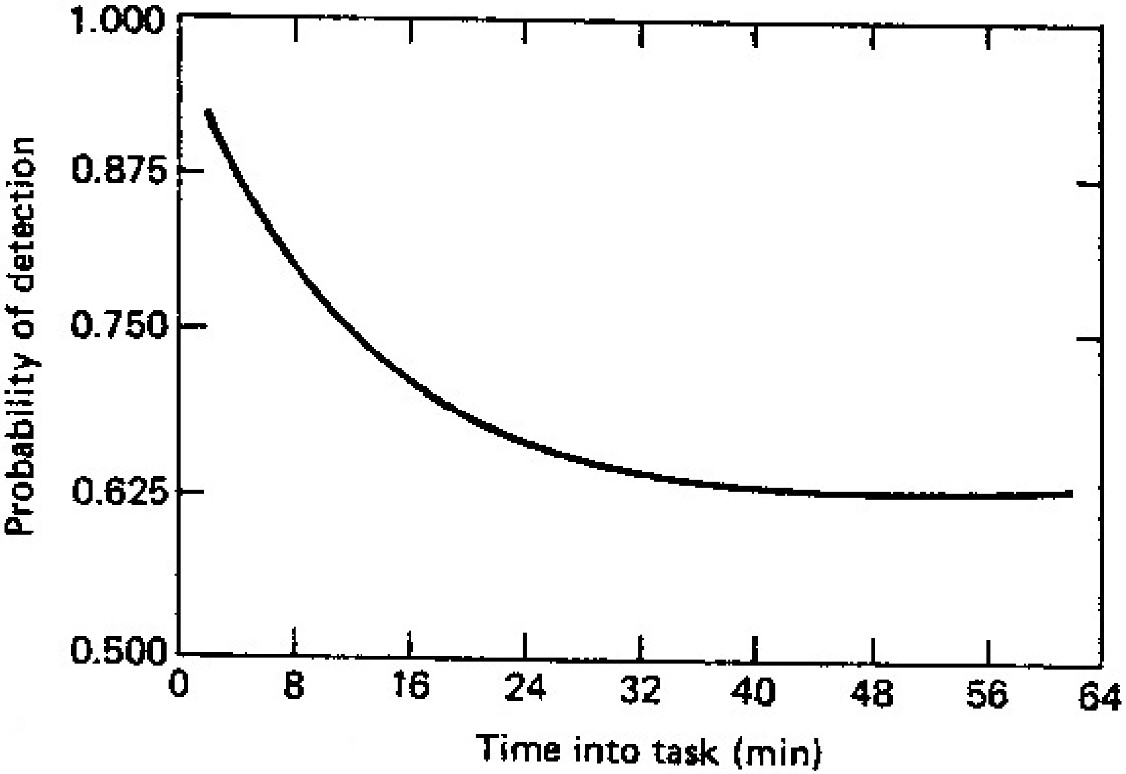

FIGURE 3-4
A typical vigilance decrement showing the probability of detecting a signal as a function of time into task. The equation for the function is: Predicted probability $= A \cdot e^{-T1 \cdot t} + A / (1 + e^{-T2 \cdot t})$. Where $A = 0.6419$; $T1 = 0.05319$; $T2 = 0.04633$; t = time into task in minutes. (*Source: Giambra and Quilter, 1987, Fig. 1. Reprinted with permission of the Human Factors Society, Inc. All rights reserved*)

Guidelines for Sustained Attention Tasks

- Appropriate work-rest schedule and task variation
- Conspicuity of signal ⬆
- Uncertainty about time and place of signal occurrence ⬇
- Examine operators and inform them of their performance

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Guidelines for Sustained Attention Tasks

- Adequate training
- Motivate by emphasizing task importance
- Maintain optimal levels of environmental factors (noise, temp, illumination, etc.)

Age and Information Processing

- Slowing of performance
- Disruption of working memory by shift of attention
- Difficulty searching long-term memory
- Difficulty dealing with incompatibility
- Decrements in perceptual encoding of ambiguous stimuli

Guidelines for Designing Information Processing Tasks for the Elderly

- Strengthen displayed signals
- Reduce irrelevant details (noise)
- Maintain high level of compatibility
- Reduce time-sharing demands
- Allow time between response and signal of next response
- Allow time for practice and learning

Mental Workload

- Measurable quantity of information processing demands by a task
  - Allocate functions and tasks between humans and machines
  - Compare alternative equipment
  - Monitoring operators
  - Select operators

Criteria of Mental Workload Measurement System

- Sensitivity
- Selectivity
- Interference
- Reliability
- Acceptability

Mental Workload Measurement

- Primary Task Measures
- Secondary Task Measures
- Physiological Measures
  - HR , brain potential, pupillary response, respiration rate & body fluid chemistry
- Subjective Measures

Pupillary Response for Mental Workload

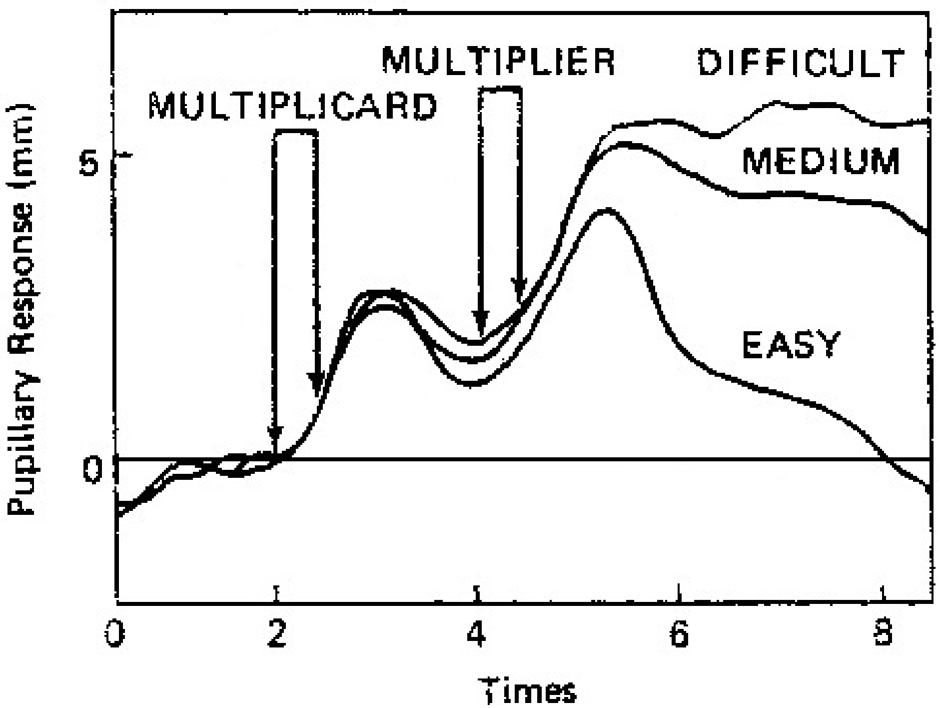

FIGURE 3-5
Pupillary responses during mental multiplication tasks that differ in cognitive difficulty. Both the amplitude and the duration of the dilation increase as a function of task difficulty. (*Source: Ahern as presented by Beatty, 1982, Fig. 5. Copyright 1982 by the American Psychological Association. Reprinted by permission of the author.*)

Brain Potential

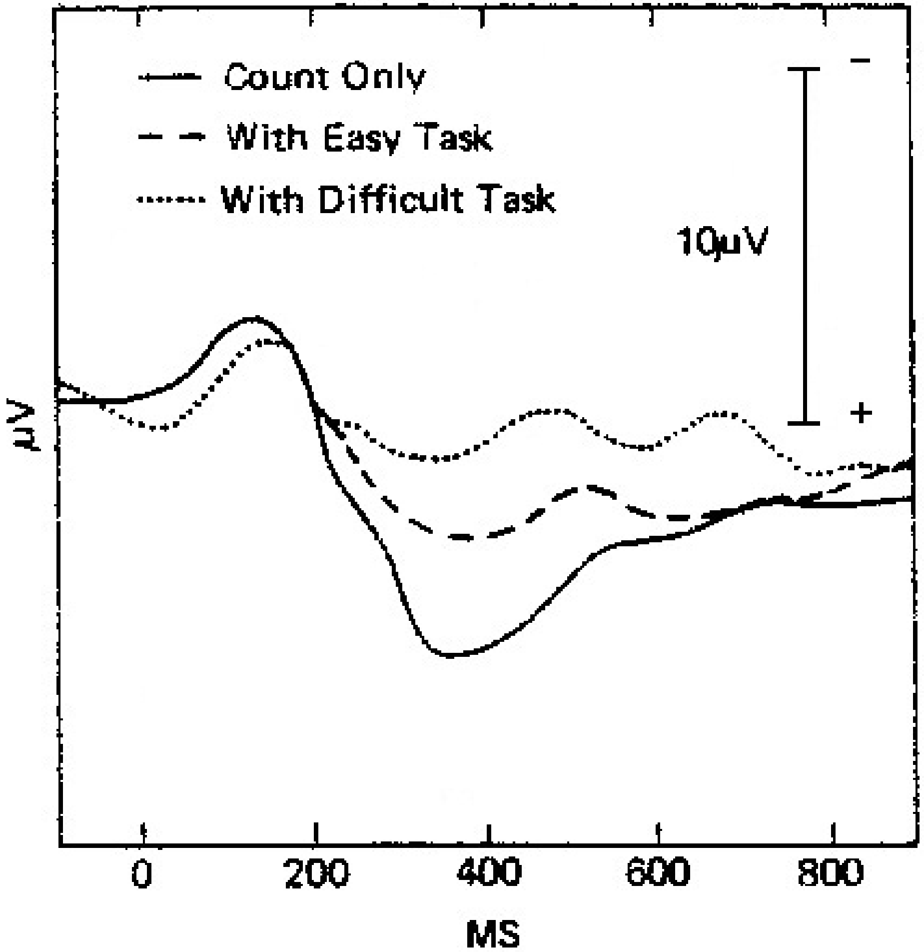

FIGURE 3-6
Effect of perceptual and cognitive task difficulty on the P300 event-related brain potential. As task difficulty increases, the magnitude of the P300 potential is decreased. (*Source: Adapted from Kramer, Wickens, and Donchin, 1983, Fig. 3. Copyright by the Human Factors Society, Inc., and reproduced by permission.*)