King Saud University

College of Engineering

IE – 341: “Human Factors”

Spring – 2016 (2^{nd} Sem. 1436-7H)

Chapter 3. Information Input and Processing

Part – 3: Choice Reaction Time Experiments

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Information Theory

- Information Processing is AKA:
  - Cognitive Psychology
  - Cognitive Engineering
  - Engineering Psychology
- Objectives of Information Theory:
  - Finding an operational definition of information
  - Finding a method for measuring information
  - Note, most concepts of Info. Theory are descriptive (i.e. **qualitative** vs. **quantitative**)
- Information (Def^n):
  - "Reduction of Uncertainty"
  - Emphasis is on "highly unlikely" events
  - Example (information in car):
    - "Fasten seat belt": likely event ⇒ not imp. in Info. Th.
    - "Temperature warning": unlikely event ⇒ imp.

Unit of Measure of Information

- Case 1: **≥ 1 equally likely alternative events**:

$$H = \log_2 N = \frac{\log N}{\log 2}$$

  - o H : amount of information **[Bits]**
  - o N: number of equally likely alternatives
  - o e.g.: 2 equally likely alternatives ⇒ $H = \log_2 2 = 1$

    ⇒ **Bit** (Def^{n}): "amount of info. to decide between **two** equally likely (i.e. 50%-50%) alternatives"

  - o e.g.: 4 equally likely alternatives⇒ $H = \log_2 4 = 2$
  - o e.g.: equally likely digits (0-9)⇒ $H = \log_2 10 = 3.32$
  - o e.g.: equally likely letters (a-z)⇒ $H = \log_2 26 = 4.70$

- Note, for each of above, unit [bit] must be stated.

Cont. Unit of Measure of Information

- Case 2: **≥ 1 non-equally likely alternatives**:

$$h_i = \log_2 \frac{1}{p_i}$$

  - h_i**:** amount of information [Bits] for single event, i
  - p_i: probability of occurrence of single event, i
  - Note, this is not usually significant

    (i.e. for individual event basis)

Cont. Unit of Measure of Information

- Case 3: **Average info. of non-equally likely series of events**:

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

  - o H_{av}: average information [Bits] from all events
  - o p_i: probability of occurrence of single event, i
  - o N : num. of non-equally likely alternatives/events
  - o e.g.: 2 alternatives ($N = 2$)
    - Enemy attacks by land, $p_1 = 0.9$
    - Enemy attacks by sea, $p_2 = 0.1$
    - ⇒

$$H_{av} = \sum_{i=1}^{2} p_i \left(\log_2 \frac{1}{p_i}\right) = p_1 \left(\log_2 \frac{1}{p_1}\right) + p_2 \left(\log_2 \frac{1}{p_2}\right)$$

$$= 0.9 \left(\log_2 \frac{1}{0.9}\right) + 0.1 \left(\log_2 \frac{1}{0.1}\right) = 0.47$$

Cont. Unit of Measure of Information

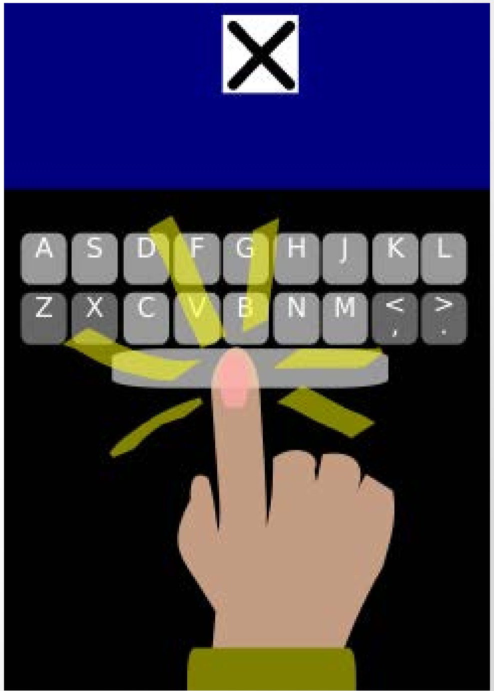
- Case 4: **Redundancy**:
  - o If 2 occurrences: equally likely ⇒
    - $p_1 = p_2 = 0.5$ (i.e. 50 % each)
    - ⇒ $H = H_{max} = 1$
  - o In e.g. in last slide, departure from max. info.
    - = 1 – 0.47 = 0.53 = 53%
  - o $$\% Redundancy = \left(1 - \frac{H_{av}}{H_{max}}\right) * 100$$
  - o Note, as departure from equal prob. ↑ ⇒ %Red. ↑
  - o e.g.: not all English letters equally likely: “th”,“qu”
    - ⇒ %Red. of English language = 68 %
    - PS. How about Arabic language?

Choice Reaction Time Experiments

- Important information theory applications:
  - Simple reaction time tasks (SRT)
  - Choice response time tasks (CRT) or Hick's Law
  - Hick-Hyman Law

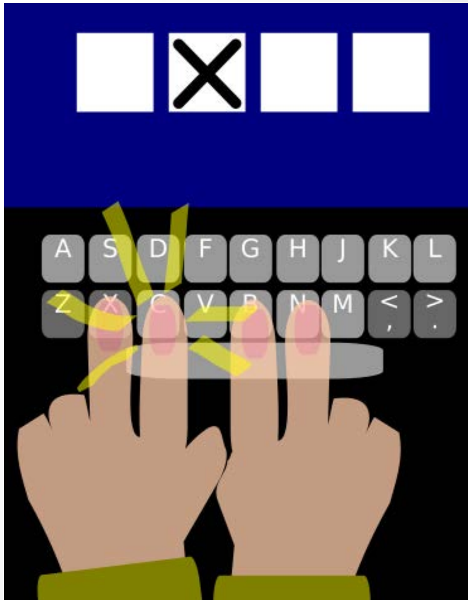
Cont. Choice Reaction Time Experiments

- Simple Reaction Time Tasks (SRT)
  - o Used to test how fast human responds in presence of 1 stimulus
  - o e.g. starting to run when hearing starting gun in a race, or moving car when traffic light is green , etc.
  - o try experiment (aka *Deary-Liewald task*): as fast as you see icon on screen, press [‘space bar’]:
  - o Note, how this tests two aspects:
    - Correct response rate
    - How fast you respond (ms)
  - o How much did you score?
    - Experiment shows: humans can score for 1 choice: $< 200\ ms$
    - How much do you expect when there is more than one choice?



Cont. Choice Reaction Time Experiments

- Choice Response Time task (CRT)
  - o Used to test how fast human responds in presence of *more* than 1 stimulus, i.e. multiple stimuli
  - o e.g. choosing a digit on keyboard from ‘0’ to ‘9’
  - o Each stimulus requires a different response
  - o In general, more stimuli/responses ⇒ slower RT
  - o try 2nd experiment:
    there are now 4 blocks (choices), with ‘X’ appearing in either of 4 possible positions (i.e. 4 stimuli)
  - o As fast as you see ‘X’ come on, press letter on keyboard that corresponds to it
  - o Note how RT/error rate are now greater

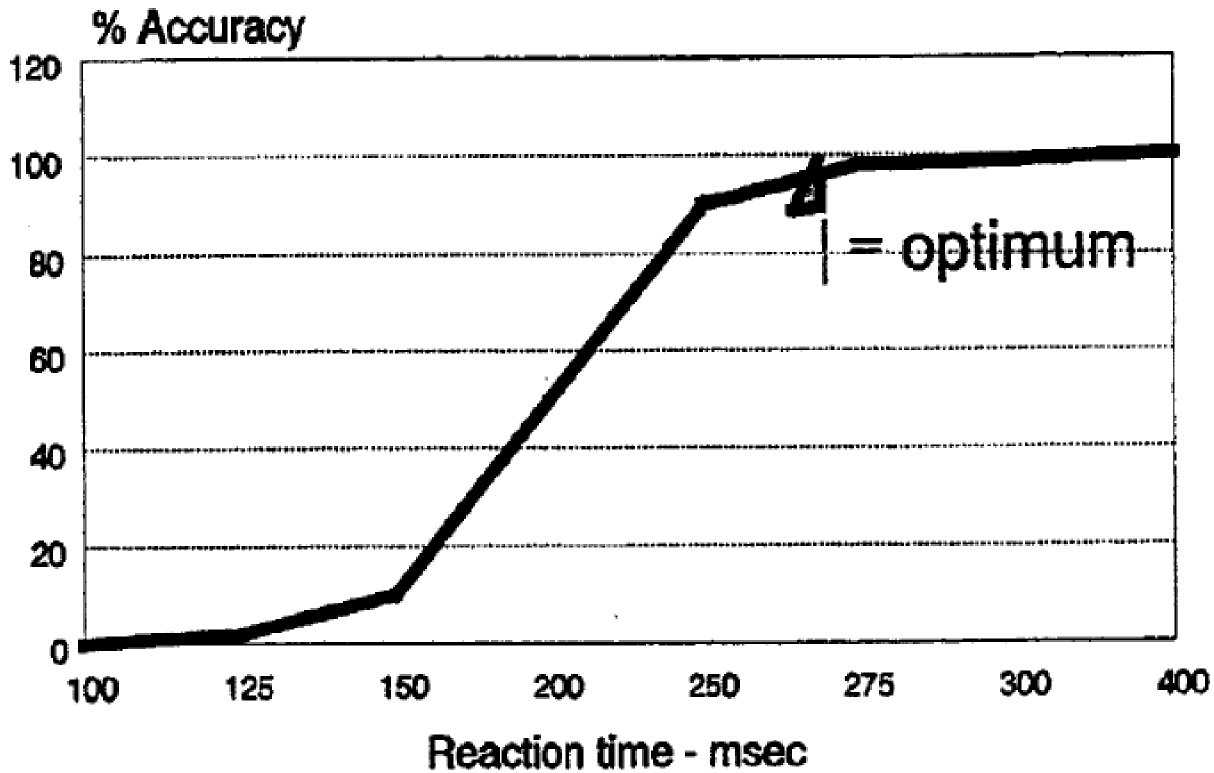


Cont. Choice Reaction Time Experiments

- Cont. Choice Response Time task (CRT)
  - o *Simplest* CRT experiment: 2 stimuli/responses $\Rightarrow$
    - Minimum RT = $250\ ms$
    - Typical average: $350\ - 450\ ms$
  - o Note, results greatly affected by type of stimulus & response mode (e.g. verbal/ written/ physical, etc.)
  - o Also, response speed proven to be affected greatly by:
    - Age
    - Intelligence
    - Conditions (e.g. rested vs. tired, hungry or not, etc.)
    - Speed-accuracy tradeoff (i.e. your aim to make less mistakes or higher speed)

Cont. Choice Reaction Time Experiments

Speed-accuracy tradeoff



Cont. Choice Reaction Time Experiments

- Cont. Choice Response Time task (CRT)
  - So what is significance of measuring CRT?
  - RT is indication of time required to
    - Process/interpret information (i.e. stimuli)
    - Retrieve information from memory
    - Initiate muscle responses
    - i.e. gives good indication of time required to “think” (basic thought process)
  - This is important part of “cognitive psychology” field

Hick's and Hick-Hyman Laws

- Hick's Law
  - Named after British psychologist *William E. Hick*
  - Conducted experiments on CRT in 1950's
  - He found (1952):
    - Cognitive information capacity: is assessed as rate of gain of information
    - As # of equally likely stimuli alternatives ↑ ⇒ RT to stimuli ↑ logarithmically
    - i.e. RT vs. # stimuli in Bits: **linear function** (amazing find!)
    - Given *n equally likely* choices, $\overline{RT}$ (T) required to choose among the choices is:

$$\boldsymbol{T = b \cdot \log_2(n+1)}$$

where,

b: *empirical* constant (determine from data for person)

Note how $\log_2$ indicates how "binary" search is performed

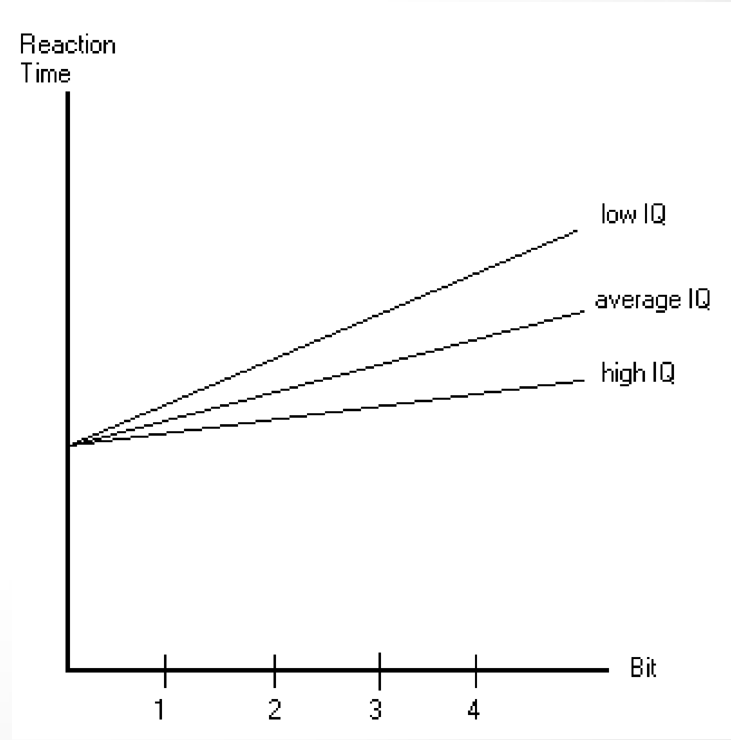
Also, note how "+1" is used to account for 1 choice*

Cont. Choice Reaction Time Experiments

- Cont. Hick's Law
  - More recent research (*E. Roth*, 1964): RT affected by IQ
  - Time (*T*) required to make a decision,

$$T = \text{Processing Speed} \cdot \log_2 n$$

  - Example/summary of Hick's law is shown below
  - Also, note how this indicates that we don't think equally of all alternatives
    (we tend to cancel out ½ alternatives every time we think, as indicated by eq^n)



Cont. Choice Reaction Time Experiments

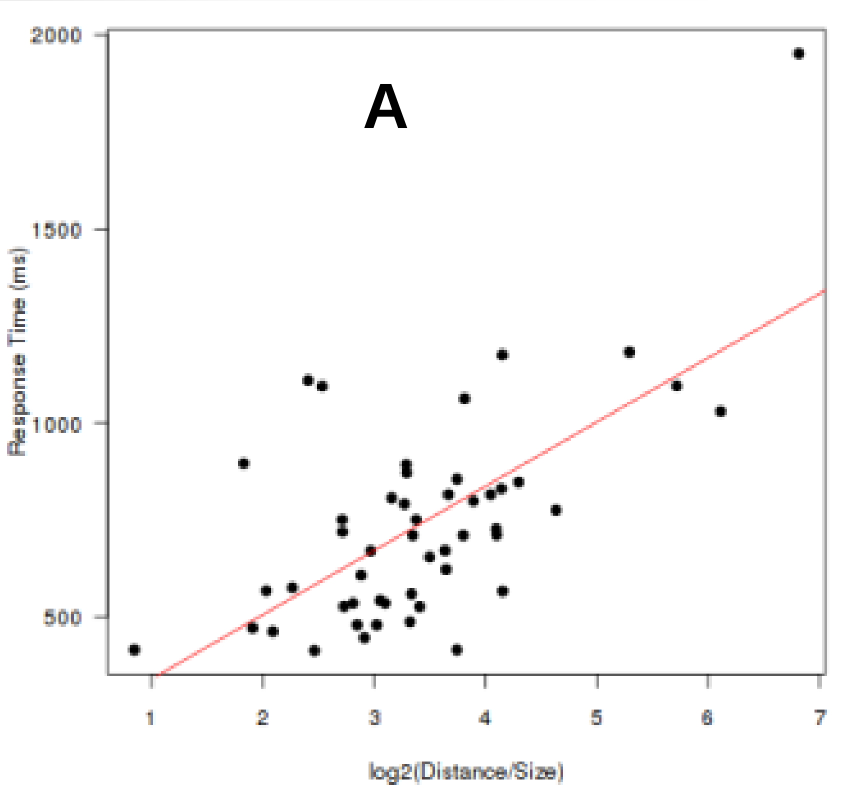
- Hick-Hyman Law (1953):
  - Hick's law further analyzed by US psychologist: *Ray Hyman*
  - Kept number of stimuli (alternatives) fixed
  - Varied prob. of occurrence of events/choices (e.g. size of targets) ⇒ law is generalized as follows:

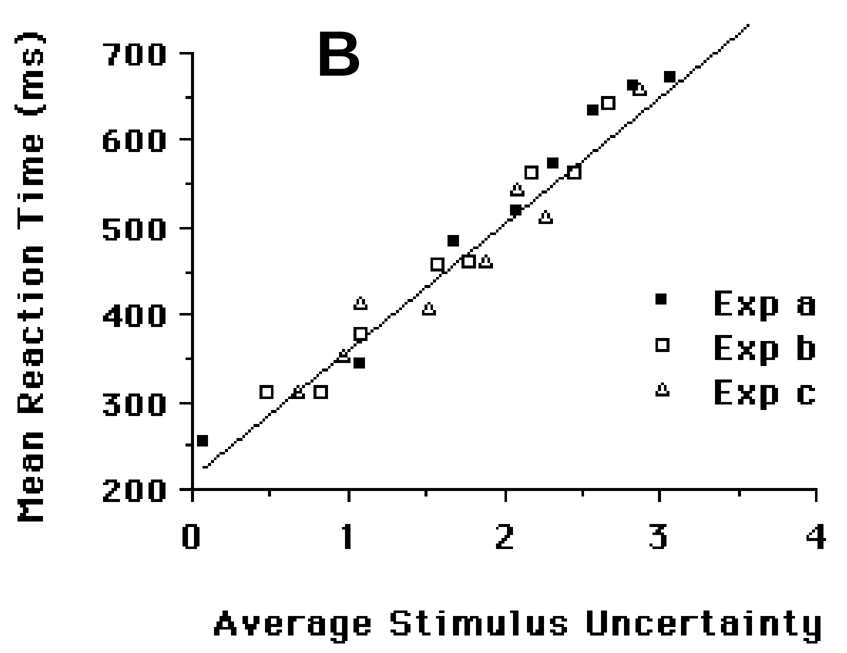
$$\boldsymbol{T = b \cdot H}$$

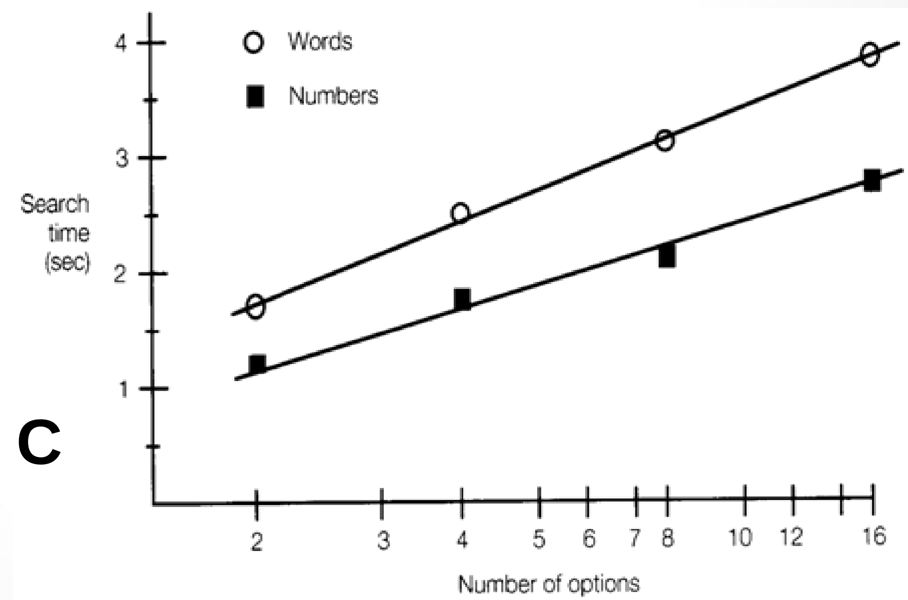
$$\boldsymbol{H = \sum_{i}^{n} p_i \log_2\left(\frac{1}{p_i} + 1\right)}$$

  - He found: **"Hick-Hyman Law"**
    - AGAIN: Reaction time vs. Stimulus (in Bits): linear function!
  - Compare *Hick*, *Hick-Hyman*, *Fitts's Laws* in next slide

SUMMARY


A
Response Time (ms)
2000
1500
1000
500
1
2
3
4
5
6
7
log2(Distance/Size)


B
Mean Reaction Time (ms)
700
600
500
400
300
200
0
1
2
3
4
Average Stimulus Uncertainty
Exp a
Exp b
Exp c


C
Words
Numbers
Search time (sec)
4
3
2
1
2
3
4
5
6
7
8
10
12
16
Number of options