King Saud University

College of Engineering

IE – 341: “Human Factors Engineering”

Spring – 2024 (2nd Sem. 1445H)

Chapter 3. Information Input and Processing

Part – 3: Choice Reaction Time Experiments

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Chapter Overview

Information Processing and Compatibility

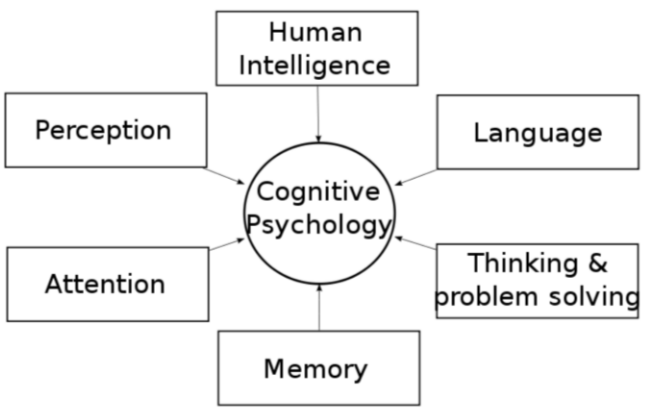
1. Information Display – Coding (Ch. 3)
2. Fitts' Law (Ch. 3, Ch. 9)
3. Hick Hyman Law (Ch. 3)
4. Signal Detection Theory (Ch. 3)
5. Memory - Attention (Ch. 3)
6. Compatibility - Part 1 - Spatial Compatibility (Ch. 10)
7. Compatibility - Part 2 - Movement - Modality Compatibility (Ch. 10, Ch.3)

Contents

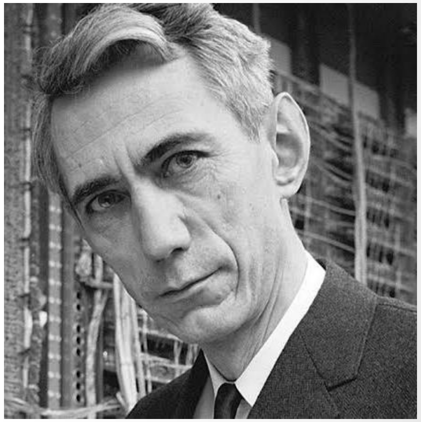
Information Theory

Information Theory

- Information Processing is AKA:
  - Cognitive Psychology
  - Cognitive Engineering
  - Engineering Psychology



- Objectives of Information Theory:
  - Finding an operational definition of information (1948)
  - Finding a method for measuring information
  - Note, most concepts of Info. Theory are descriptive (i.e. **qualitative** vs. **quantitative**)



Claude Shannon

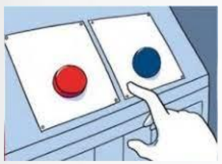
- Information (Definition):
  - "Reduction of Uncertainty"
  - Emphasis is on "highly unlikely" events
  - Example (information in car):
    - "Fasten seat belt": likely event ⇒ not imp. in Info. Th.
    - "Temperature warning": unlikely event ⇒ imp.

Unit of Measure of Information

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

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

  - H : amount of information **[Bits]**



  - N: number of equally likely alternatives
  - 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"

  - e.g.: 4 equally likely alternatives ⇒ $H = \log_2 4 = 2$
  - e.g.: equally likely digits (0-9) ⇒ $H = \log_2 10 = 3.32$

  - e.g.: equally likely letters (a-z) ⇒ $H = \log_2 26 = 4.70$

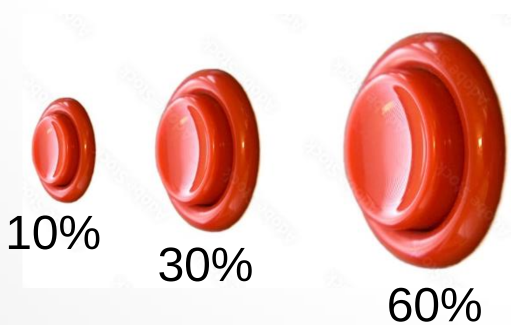
Note, for each of above, unit [bit] must be stated.

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**:

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

  - H_{av}: average information [Bits] from all events
  - p_i: probability of occurrence of single event, i
  - *N* : num. of non-equally likely alternatives/events
  - 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**:
  - If 2 occurrences: equally likely ⇒
    - $p_1 = p_2 = 0.5$ (i.e. 50% each)
    - ⇒ $H = H_{max} = 1$
  - In e.g. in last slide, departure from max. info.
    - = 1 – 0.47 = 0.53 = 53%

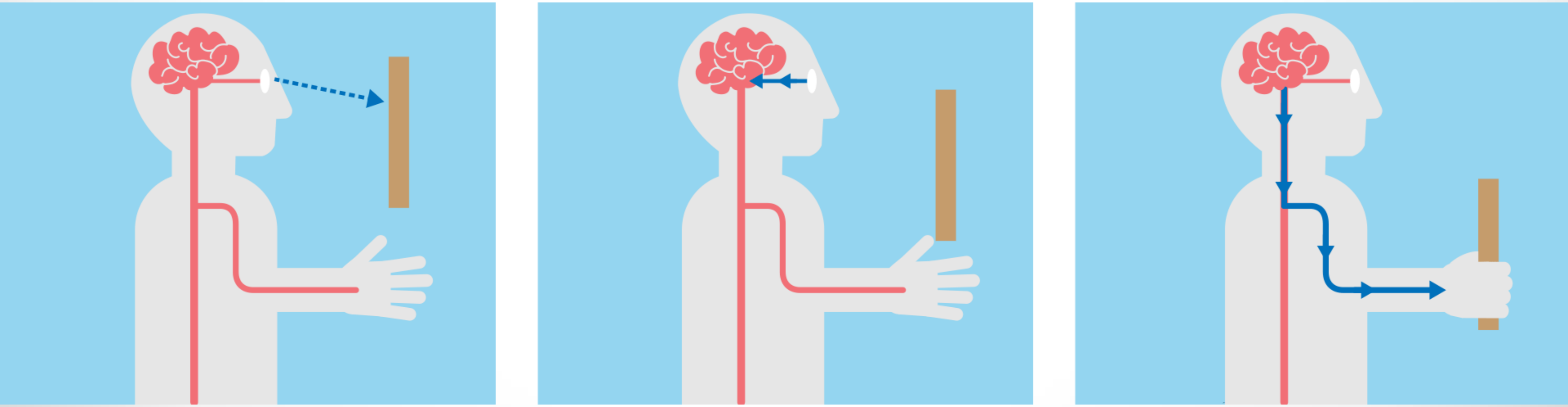
  - $$\% \, Redundancy = \left(1 - \frac{H_{av}}{H_{max}}\right) * 100$$
  - Note, as departure from equal prob. ↑ ⇒ %Red. ↑
  - e.g.: not all English letters equally likely: "th","qu"
    - ⇒ %Red. of English language = 68 %
    - ps. how about Arabic language?

kh-aa خ	H-aa ح	j-eem ج	th-aa ث	t-aa ت	b-aa ب	a-lif ا
S-aad ص	sh-een ش	s-een س	z-aa ز	r-aa ر	dh-aal ذ	d-aal د
q-aaf ق	f-aa ف	gh-ain غ	3-ain ع	Dh-aa ظ	T-aa ط	D-aad ض
y-aa ي	w-aaw و	h-a ه	n-oon ن	m-eem م	l-aam ل	k-aaf ك

Reaction Time Experiments

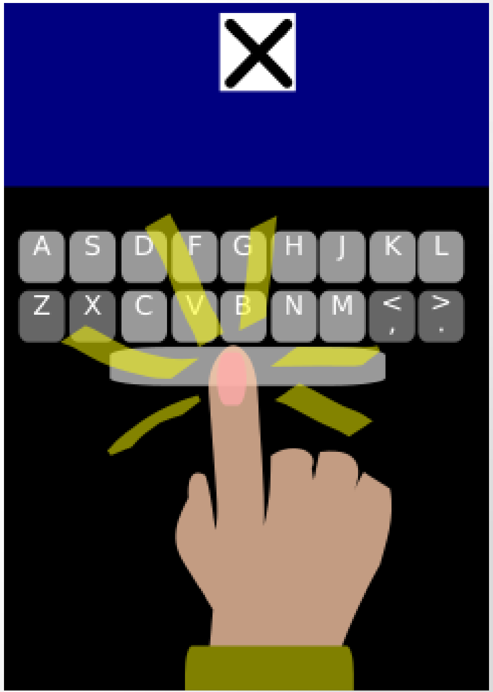
Reaction Time Experiments

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



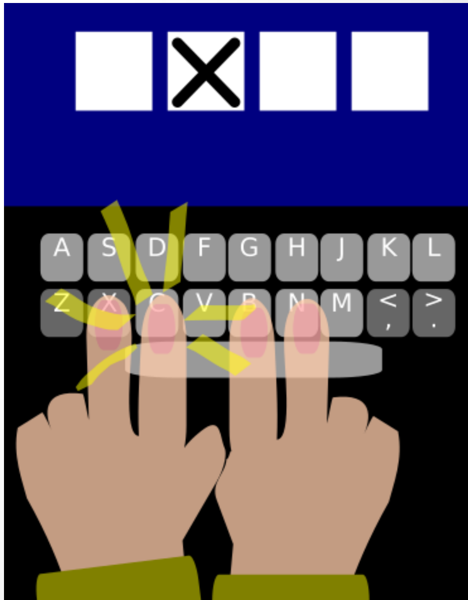
Cont. Reaction Time Experiments

1. Simple Reaction Time Tasks (SRT)
   - Used to test how fast human responds in presence of 1 stimulus
   - e.g. starting to run when hearing starting gun in a race, or moving car when traffic light is green, etc.
   - try experiment (aka *Deary-Liewald task*):
     as fast as you see icon on screen, press ‘space bar’:
   - Note, how this tests has two aspects:
     - Correct response rate
     - How fast you respond (ms)
   - 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?



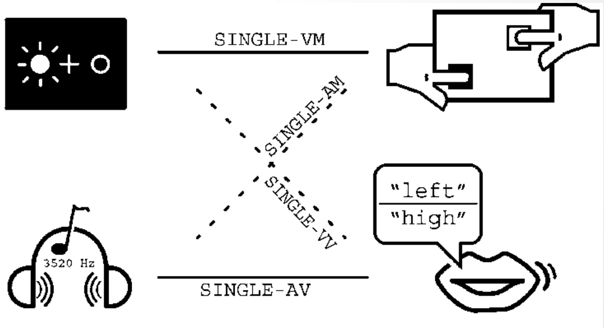
Cont. Reaction Time Experiments

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



Cont. Reaction Time Experiments

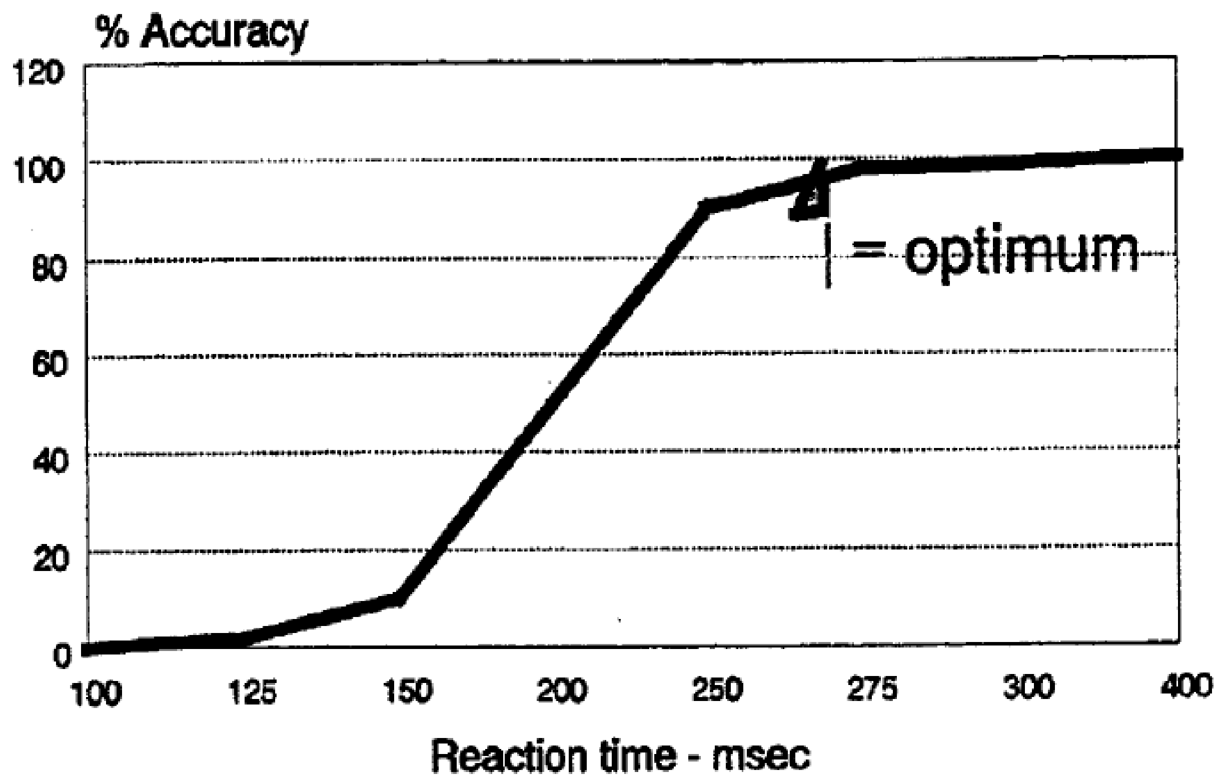
2. Cont. Choice Response Time task (CRT)
   - *Simplest* CRT experiment: 2 stimuli/responses $\Rightarrow$
     - Minimum RT = $250\ ms$
     - Typical average: $350\ - 450\ ms$
   - Note, results greatly affected by type of stimulus & response mode (e.g. verbal/ written/ physical, etc.)*
   - Also, 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)

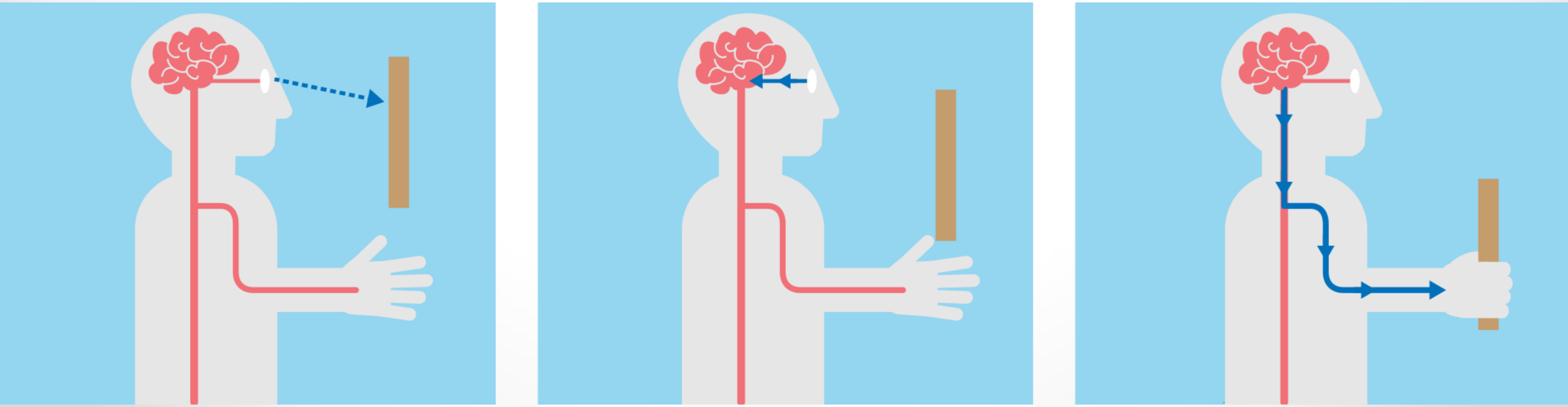
Cont. Reaction Time Experiments

Speed-accuracy tradeoff



Cont. Reaction Time Experiments

2. 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

3. 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 (next slide)
     - 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,

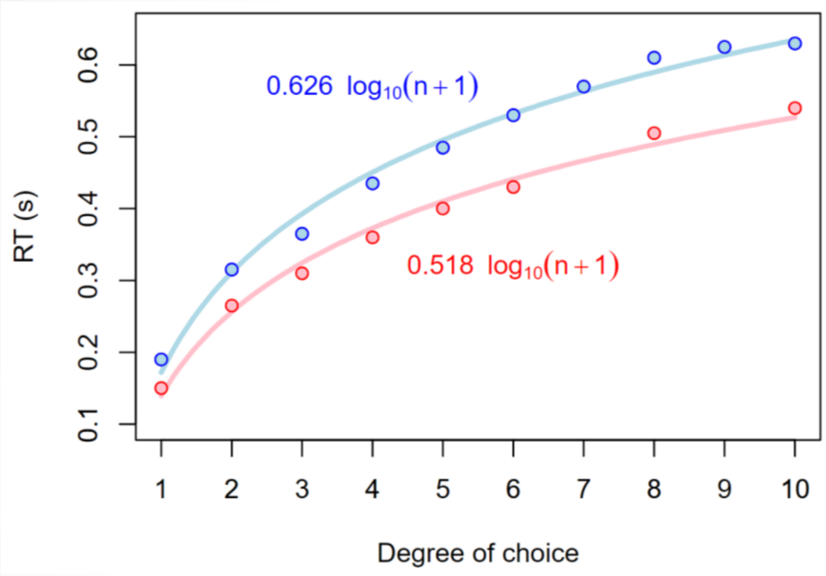
b: *empirical* constant (determine from data for person)

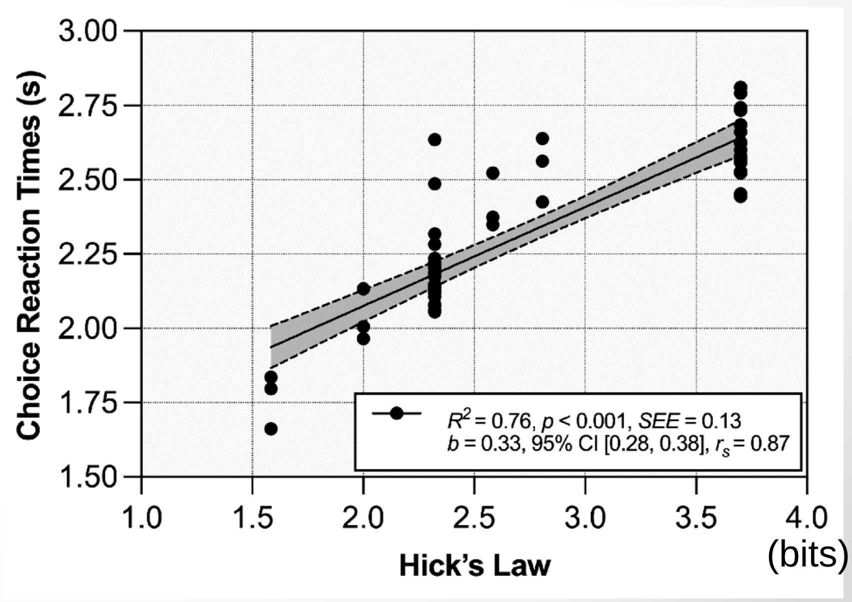
Note how $\log_2$ indicates how "binary" search is performed

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

Hick's and Hick-Hyman Laws

3. Cont. Hick's Law





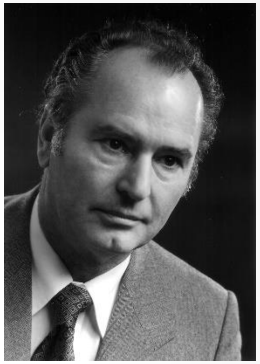
Cont. Choice Reaction Time Experiments

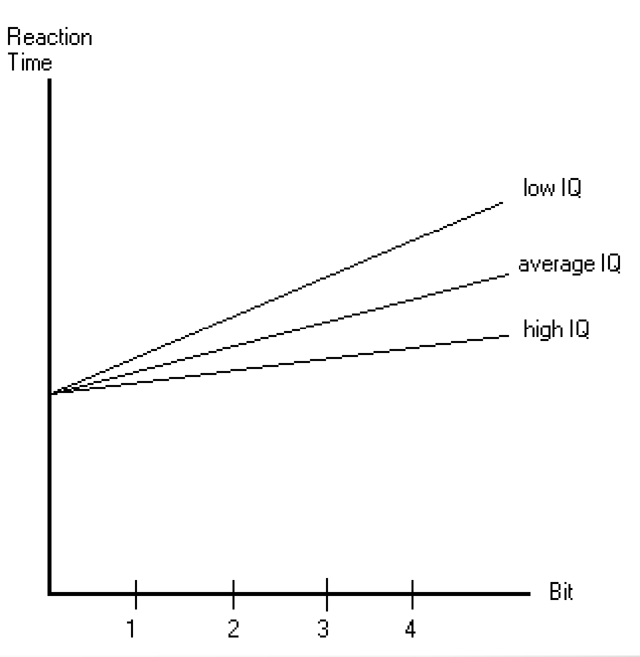
3. Cont. Hick's Law

   - More recent research (*E. Roth*, 1964): RT affected by IQ
   - Time (*T*) required to make a decision,

$$T = \log_2 n / (Processing\ Speed)$$

   - 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

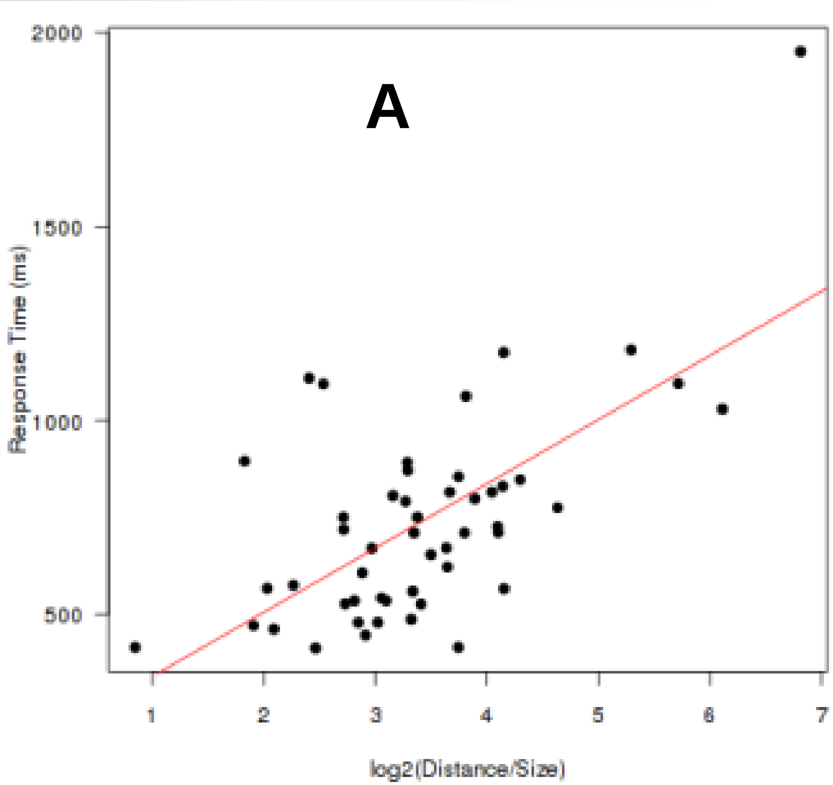
3. Hick-Hyman Law (1953):
   - Hick's law further analyzed by US psychologist: *Ray Hyman*
   - Kept number of stimuli (alternatives) fixed
   - Varied prob. of occurrence of events/choices (e.g. size of targets) ⇒ law is generalized as follows:

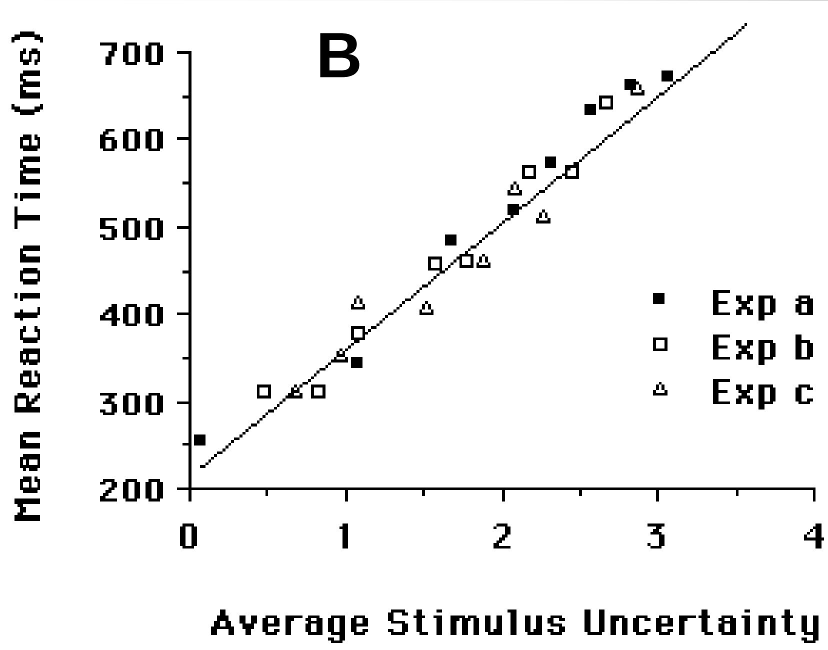
$$T = b \cdot H$$

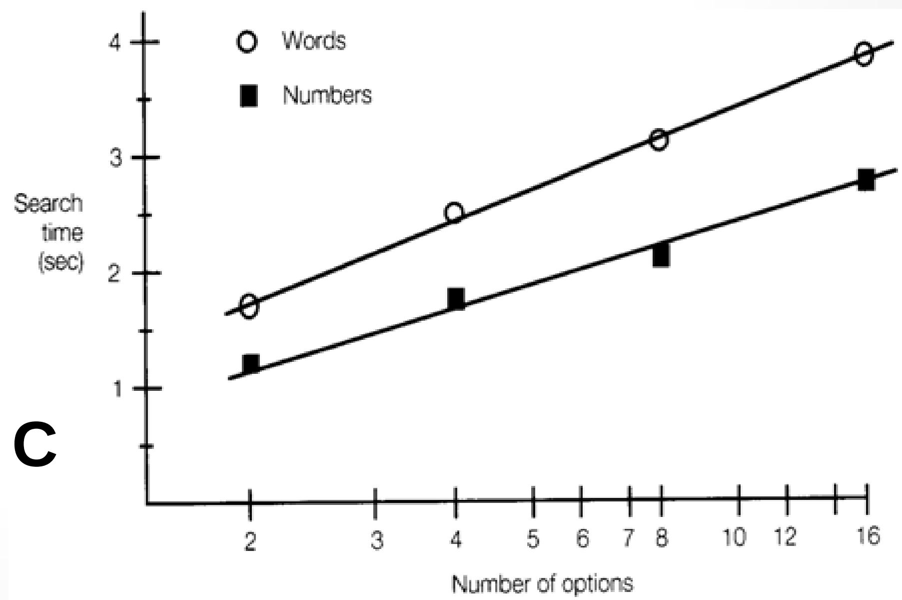
$$H = \sum_{i}^{n} p_i \log_2\left(\frac{1}{p_i} + 1\right)$$

   - 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


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

Videos

- Watch the following videos (applications in HCI):
  - ***Hick's law***: https://youtu.be/ttw5nditisQ?si=BZSRb5LfZyST0anT
  - ***Hick-Hyman Law***: https://youtu.be/558s2nkmdA4?si=E6m1hhhYGr_yWhST

References

- ***Human Factors in Engineering and Design***. Mark S. Sanders, Ernest J. McCormick. 7th Ed. McGraw: New York, 1993. ISBN: 0-07-112826-3.
- ***Simple and choice reaction time tasks***. From: PsyToolkit. Available at: http://www.psytoolkit.org/lessons/simple_choice_rts.html
- For more **simple reaction time tasks**: https://www.humanbenchmark.com/tests/reactiontime
- ***Hick's law***. From Wikipedia, the free encyclopedia. Available at: https://en.wikipedia.org/w/index.php?title=Hick%27s_law&redirect=no