16.400/453J

Human Factors Engineering

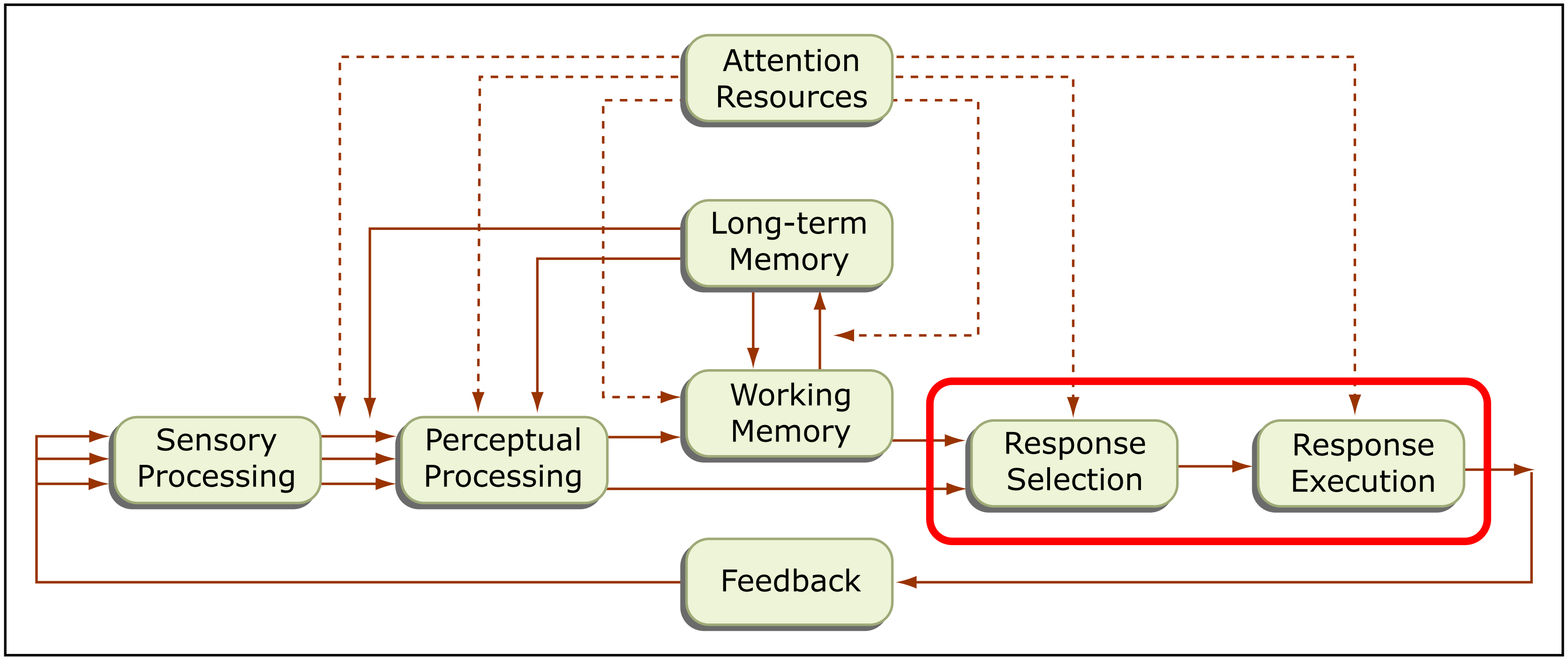
Response Selection & Control of Movement

Massachusetts Institute of Technology

Objectives

- Reaction times for increasing decision complexity
  - Simple, recognition, choice experiments
  - Hick-Hyman Law
- Speed accuracy tradeoff
  - Fitts' law
- Stimulus-Response (S-R) compatibility
- Feedback

Human Information Processing



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The selection of skill based responses

- Reaction Time Studies
- Pioneer reaction time study was conducted by Donders (1868)
  - Simple reaction time is shorter than a Recognition (Go/No Go) reaction time
  - Choice reaction time is longest of all

Donders, F. C. 1868. On the speed of mental processes. Translated by W. G. Koster, 1969. *Acta Psychologica* 30: 412-431.

Types of reaction time experiments

Simple reaction time experiments

- only one stimulus and one response
- 'X at a known location,' 'spot the dot,' and 'reaction to sound'

Recognition reaction time experiments

- there are some stimuli that should be responded to (the 'memory set'), and others that should get no response (the 'distractor set').
- Go/No Go: 'Symbol recognition' and 'tone recognition'

Choice reaction time experiments

- User must give a response that corresponds to the stimulus, (e.g., pressing a key corresponding to letter if the letter appears on screen)

http://biae.clemson.edu/bpc/bp/Lab/110/reaction.htm#Kinds

Simple and choice reaction time

- In a simple reaction time (RT) situation
  - There is no uncertainty what the signal is
  - There is no uncertainty how to respond
    - Sprinter in the starting blocks

- In a choice reaction time task

  (combines recognition and choice)
  - There can be more than one signal
  - More than one type of response
  - Each response corresponds to a signal

Factors affecting simple RT

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Factors affecting simple RT

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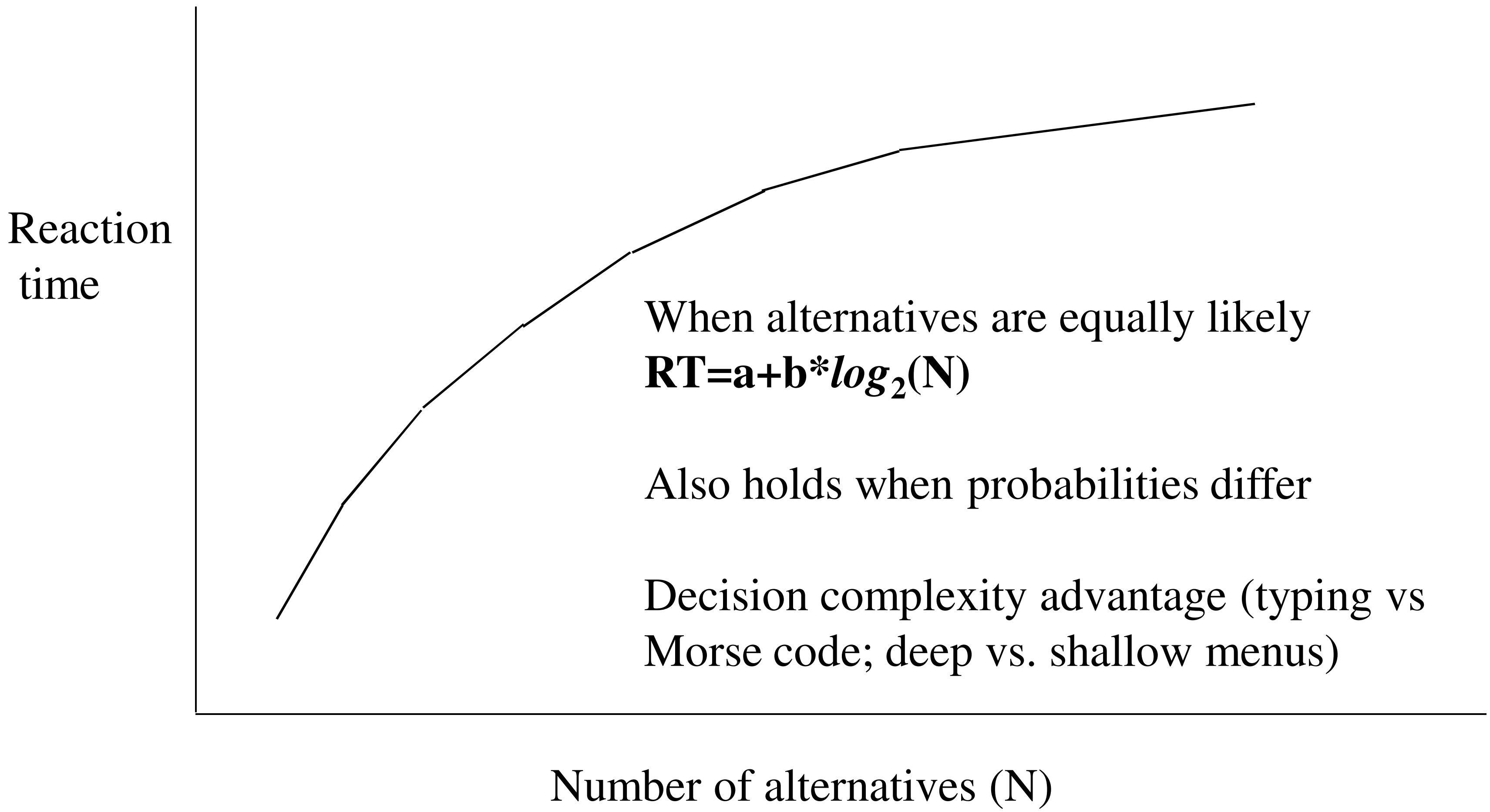
Factors affecting choice RT

- Factors affecting simple RT also affect choice
- In a choice response time situation
  - user is transmitting information from stimulus to response
- Hick (1952) and Hyman (1953) performed experiments
  - By varying number of stimulus-response alternatives
- Hick-Hyman Law (H-H Law)
  - Choice RT increases linearly with stimulus information

Hick (1952) On the rate of gain of information. *Quarterly JEP*, 4:11-26, 1952

Hyman, R. (1953). Stimulus information as a determinant of reaction time. *JEP, 45,* 423-432.

Hick-Hyman law



When alternatives are equally likely
RT=a+b**log_2***(N)**

Also holds when probabilities differ

Decision complexity advantage (typing vs Morse code; deep vs. shallow menus)

Problems with Hick-Hyman

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Speed accuracy tradeoff

- Possible to be fast and error prone **OR** slow and precise
- People tend to make more errors when they respond more rapidly and vice versa

- Due to **strategies** that reflect different payoffs between errors and response speed
- Due to **control devices** that induce faster but less precise control

Control device effect

- QWERTY and Dvorak keyboards
  - Qwerty designed to avoid jamming in typewriters (1868)
  - Dvorak (1932)
- QWERTY persists even though Dvorak is claimed to offer a 5-10% advantage

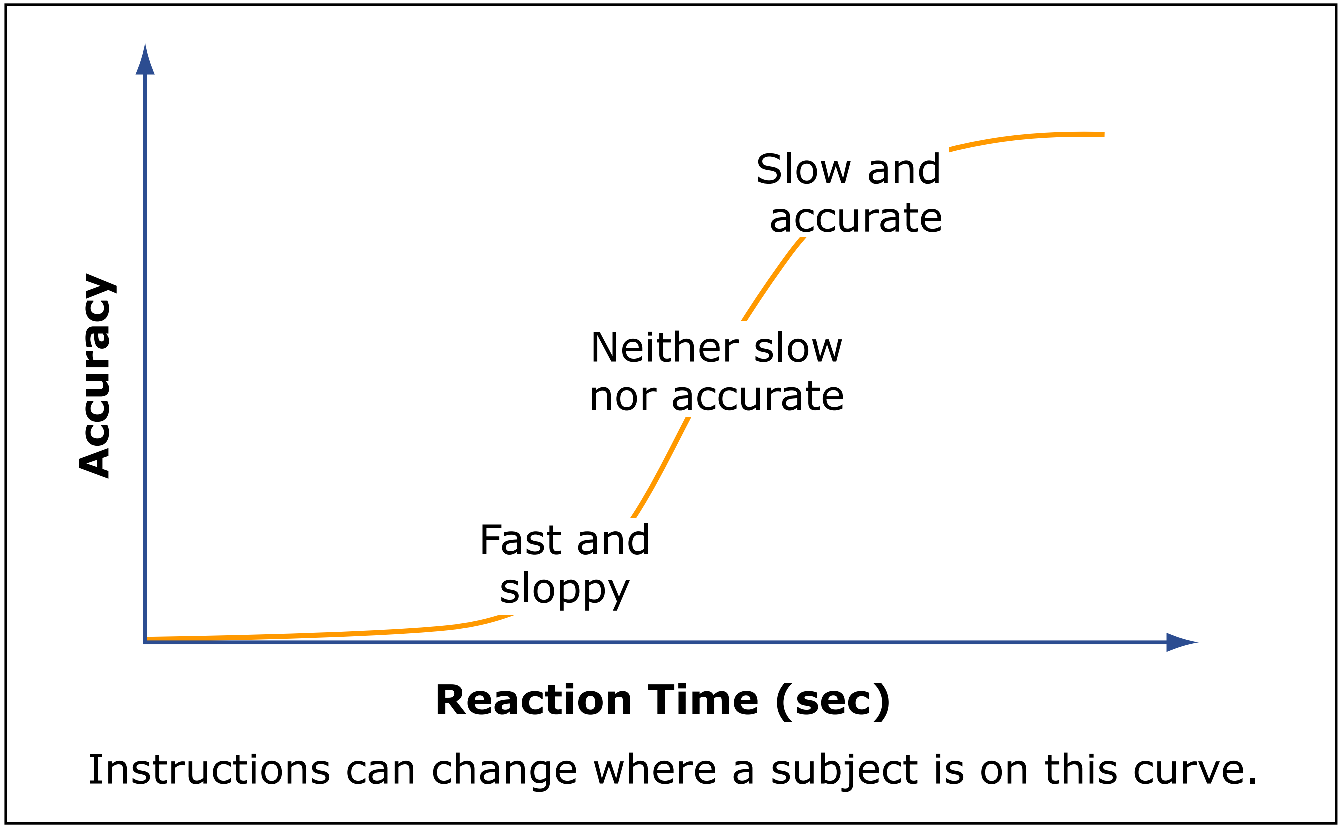
Dvorak Keyboard Layout

This image is in the public domain.

Further reading: http://wwwpub.utdallas.edu/~liebowit/keys1.html

Speed accuracy tradeoff

- Instructions, auditory vs. visual stimuli, stress
- Regulations in the nuclear industry require workers to wait a certain amount of time before responding



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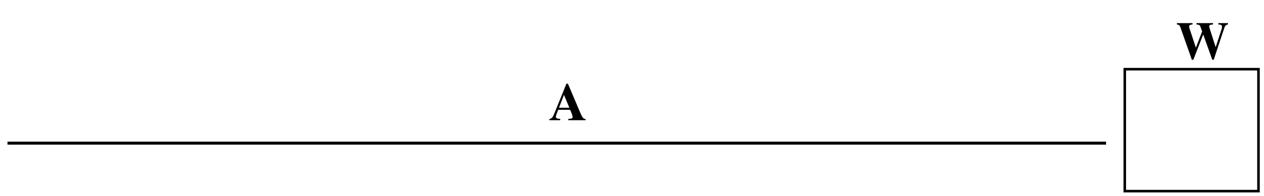
Speed accuracy tradeoff for aimed movements

Fitts Law

Movement time=a+b * log_2(2A/W)

= time required to rapidly move from a starting position to a final target area

- A=movement amplitude
- W=target width
- Very general law
- **a** and **b** depend on device and user characteristics

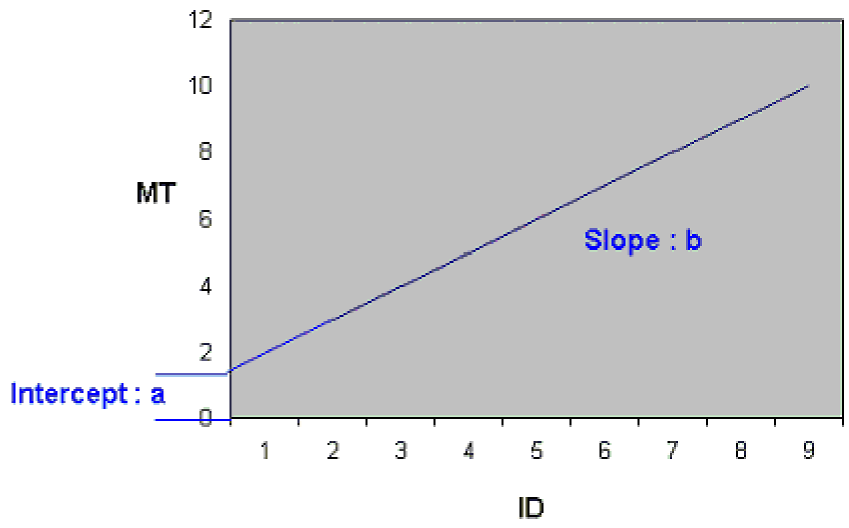


Fitts' law

- *Modified*:
  Movement time=a+b * log_2(A/W + 1)

- *Index of difficulty*
  - log_2(A/W + 1) or log_2(2A/W)

- *Index of performance:*
  - IP = 1/b



S-R compatibility

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Location compatibility

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Principle of congruence

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Movement compatibility

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Movement proximity

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Movement proximity

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Modality compatibility

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Motor system

- Functions
  - movement
  - posture & balance
  - communication
- Guided by sensory systems
  - internal representation of world & self
  - detect changes in environment

3 classes of movement

- Voluntary: reading, writing, playing piano
  - complex actions
  - purposeful, goal-oriented
  - learned: improve with practice
- Reflexes: eye-blink, coughing, knee jerk
  - involuntary, rapid
- Rhythmic motor patterns: chewing, walking, running
  - combines voluntary & reflexive acts
  - initiation & termination voluntary
  - once initiated, repetitive & reflexive

Movement and muscles

- Movement occurs at joints
  - Degrees of freedom (elbow vs. shoulder?)
- Contraction & relaxation of opposing muscles
  - Agonists: prime movers - flexion
  - Antagonists: counterbalance agonists - extension
    - decelerate movement
  - Activity can be measured through EMG (electromyogram)

Images of EMG removed due to copyright restrictions.

Sensorimotor integration

- Movement control more than contraction & relaxation
  - Accurately time control of many muscles
  - Make postural adjustment during movement
  - Adjust for mechanical properties of joints & muscles
    - inertia, changing positions
- Sensory inputs guide movement
  - visual, auditory, tactile
    - location of objects in space
  - Proprioceptive & vestibular
    - position of our body
- Critical for planning & refining movements
- Closed loop vs. open loop control of movement

Error correction

- Feedback:
  - During or after movement
  - Compare actual position with intended position
  - Slower movements
- Feedforward:
  - Sensory events control movements in advance
    - ballistic movements
  - Prediction: internal model of events
  - e.g. catching ball
    - representation of ball trajectory
    - properties of musculoskeletal system
  - Reevaluation after response completed

Feedback

- Feel of button (deflection of key and click of keyboard vs. membrane keyboard)
- Feedback and delays:
  - less than 100 msec to avoid disrupting motor control
  - less than 1.0 sec to avoid disrupting thought
  - less than 10 seconds to keep user's attention focused on the dialog. Feedback regarding magnitude of delay is critical.

General principles of control design

- Decision complexity
  - Simple choices have faster response than complex
- Response expectancy
  - Reaction Time (RT) much smaller for expected events
- Compatibility
  - Location and movement compatibility should match mental model
- Speed-accuracy tradeoff
  - More errors with speeded response
- Feedback
  - Display of system response

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