Response Selection & Control of Movement
Objectives

16.400/453

• 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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Image by MIT OpenCourseWare.
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

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
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

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

Image by MIT OpenCourseWare.
Speed accuracy tradeoff for aimed movements

Fitts Law

Movement time = a + b \cdot \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 = \(a + b \cdot \log_2(A/W + 1)\)

- **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)
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