LE/EECS 4441 - Human-Computer Interaction
Recitation Set (Sample Version)

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December 12, 2022

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1 Administrative

1.1 Disclaimer

The following document contains detailed lecture notes in tandem with important reading notes.

Additionally, this works well with an additional PDF which contains control questions with full solutions.

If there are any errors, please reach out to S. Thank you!!

1.2 Grading Scheme

The course has been offered with the following schedule and weighting.

Activity	Description	Weight	Due Date
Participation	Top Hat Quizzes	5%	Periodic
Student Questionnaire	Quiz	1%	September 14, 2022
Mini Research Assignment	Take-Home Lab	5%	October 1, 2022
Ethics Quiz	eClass Quiz	4%	October 7, 2022
Midterm Exam	In-Class (on eClass)	15%	October 17, 2022
Project Proposal	Group Activity	15%	November 4, 2022
Project Report	Group Activity	35%	December 6, 2022
Project Presentation	Group Activity	5%	November 28 - 30, 2022
End of Term Exam	In-Person	20%	December (TBA), 2022

2 Course Introduction

2.1 Persuasive Technology

We may think of Persuasive Technology as a system that aims to **change behaviours of a user** through **social influence**.

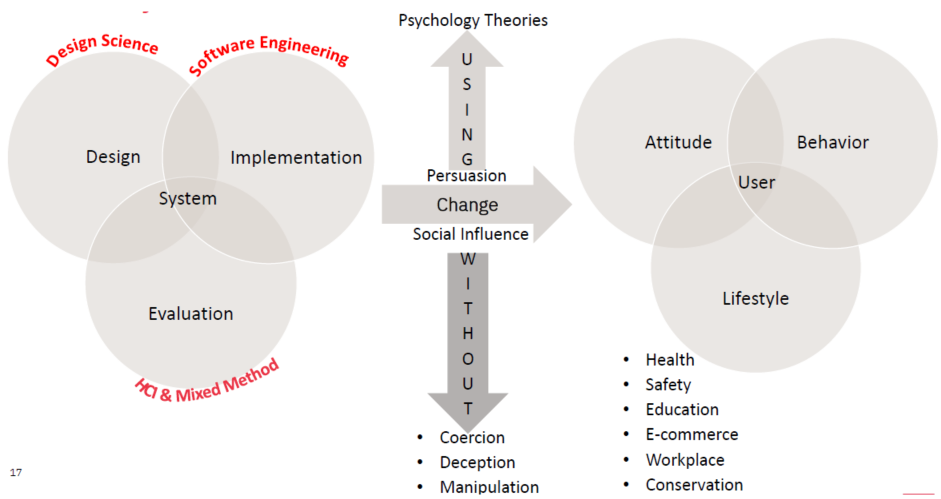


Figure 1: Persuasive Technology Structure

2.2 Ethics Research Guiding Principles

There are three principles for Ethics Research Guiding Principles. They are:

- Respects for Persons
  - Allows persons to be able to make decisions for themselves
  - Gives the person autonomy
- Concern for Welfare
  - Ensures persons are not exposed to unnecessary or unmanaged risk
- Justice
  - Treat all persons **fairly** and **equitably**

3 Chapter 1: Historical Perspective

3.1 What is HCI?

Introduction

- Human-Interaction (HCI) is the study of how humans interface/interact with computers.
- It has applications in Commerce and Manufacturing, Education, Medical Application, Video Games, etc.,
- The central old disciplines from which HCI derived include Human Factors and Ergonomics. However, many other disciplines are instrumental to HCI such as Psychology, Sociology, Anthropology, and Cognitive Science.

  * Human factors deal with our capabilities and limitations which seek to reduce errors and accidents.

  * In this view, HCI is human factors, but narrowly focused on human-interaction with computing technology of some sort.

3.2 HCI versus UX

Human-Computer Interaction

- Objective Measurement
- Academic-Focused
- Focuses on the the Human Factors, and on the Performance / Design of systems that are efficient, safe, comfortable, and even enjoyable for the humans that use them.
- Focuses on the research to understand the user.

  * How people use the technology

  * The impact on the user

User Experience

- Subjective Measurement
- Industry-Focused
- Focuses on the product, and satisfaction.
- Applies HCI research to build user-friendly products.
- Improves the commercial value of the product

4 HCI versus UX User Studies

Recall that a user study is an experiment with human participants. The difference between metrics can be summarized below.

Dependent Variable	Possible Metrics	Domain	Study
Efficiency	Task completion times Error rates	HCI	User Research
Ease of learning	Time to learn Error rates while learning	HCI	User Research
Memorability	Time to complete task Error rates	HCI	User Research
Effectiveness	Task completion rates	HCI	User Research
Ease of Use	Time to learn Error rates while learning Self-report	HCI/UX	User Research/ User Experience
Usefulness	Self-report	UX	User Experience
Satisfaction	Self-report	UX	User Experience

Figure 2: HCI and UX User Study Variables

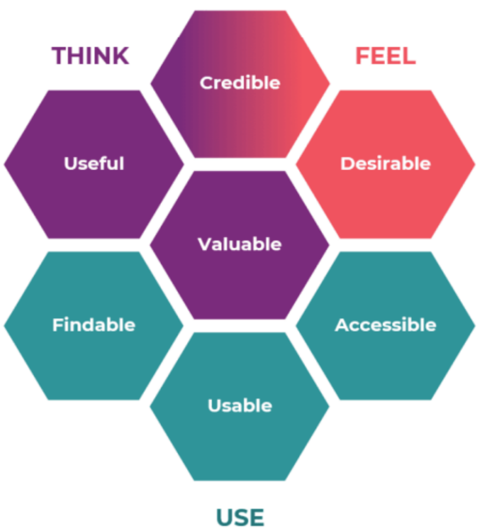


Figure 3: Peter Morville's User Experience Honeycomb

5 Significant Event Time-Line

5.1 Vannevar Bush - "As We May Think" (1945)

- A Scholarly Article, which discussed the problem of information overload
- Brings up the necessity to develop an efficient mechanism that can handle storage, management, dissemination, and access of scholarly materials
- **Proposed Solution: Memex (Collective Memory Machine)**
  - An extension of the human memory, which can be used to navigate the knowledge maze.
  - Supported associative indexing, which is where points of interest can be connected and joined so that selecting one item immediately and automatically selects another.
  - Predicted the PC, Internet, WWW, Hyptertext, and Online Encyclopedias
  - Served as the foundation for new media. This is in the mouse, word processor, and hypertext.

5.2 Ivan Sutherland - Sketchpad (1962)

- The first program to utilize GUI
- Was a graphics system that supported the manipulation of geometric shapes and lines on a display using a light pen.
- Brought Error Tolerance (Easy Feedback and Mistake Fixing)
- Computer graphics could be used for artistic and technical purposes. It aimed to help Engineers speed up their drawing tasks.
- Influenced:
  - Modern Computer-Aided Design (CAD)
  - GUI
  - OOP (Drawings - Copy/Paste)
- The light pen was a pointing device for making input. It was the first direction-manipulation interface

- * Direct Manipulation: Provides a psychological context for a suite of related features that naturally come together in this new genre of human-computer interfaces.

  These features included:

  - Visibility of Objects
  - Incremental Action
  - Rapid Feedback
  - Reversibility
  - Exploration
  - Syntactic Correctness of all Actions
  - Replacing Language with Action

5.3 Douglas Engelbert - Computer Mouse (1963)

- Symbolizes the emergence of HCI. It changed the face of HCI
- Instead of typing commands, a user could manipulate a mouse to control an on-screen tracking symbol, or cursor.

  * Worked on multiple-window display and hypermedia
- Replaced the light pen, because it was too awkward for a user to hold the pen in the air, in front of the display for long periods of times.
- The first prototype included two potentiometers positioned at right angles to each other.

  * Large metal wheels were attached to the shafts of the potentiometers and protruded slightly from the base of the housing.

  * The amount of rotation of each wheel altered the voltage at the wiper terminal of the potentiometer.
- Underwent future refinements:

  * Potentiometer wheels being replaced with a rolling ball assembly

  * Note: The mouse was not commercialized until 1981, where it was sold alongside the Xerox Star software
- The work of Douglas was inspired by Vannevar Bush.

  Engelbert worked on the Joystick, Light Pen, and Track Ball

5.4 HCI's First User Study (English, Engelbert)

- Topic: Display Selection Techniques for Text Manipulation

  * Marked an important milestone in empirical research in HCI

- A controlled experiment comparing several input devices capable of both selection and x-y position control of an on-screen cursor.

- The order of administering the device conditions was different for each participant, a practice known today as counterbalancing.

1. Mouse

2. Light Pen

   * Selection involved pressing a switch on the barrel of the pen

3. Joystick

   * An embedded switch was included for selection and was activated by pressing down on the stick.

4. Knee-Controlled Lever

   * Connected to two potentiometers

   * The device did not include an integrated method for selection. Instead, a key on the system's keyboard was used

5. Grafacon

   * A commercial device used for tracing curves

   * Consisted of an extensible arm connected to a linear potentiometer with the housing for the linear potentiometer pivoted on an angular potentiometer.

   * User gripped the knob and moved it around to control the on-screen cursor. Pressing the knob caused a selection.

The comparative evaluation measured

- User's Access Time: The time to move the hand from the keyboard to the device.
- Motion Time: The time from the onset of cursor movement to the final selection

- The trial began with the participant pressing and releasing the space-bar on the system's keyboard, whereupon a cursor appeared on the display.

- The participant moved his or her hand to the input device and then manipulated the device to move the cursor to the target. With the cursor over the target, a selection was made using the method associated with the device.

- Mean Task Completion Time

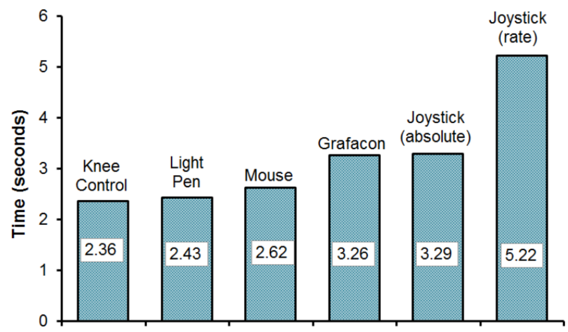


Figure 4: User Study: Mean Task Completion Time

* Note: The access time for the knee-controlled lever is, of course, zero. Thus, it is not the best device in terms of time, although it may appear that way.

- Mean Error Rate

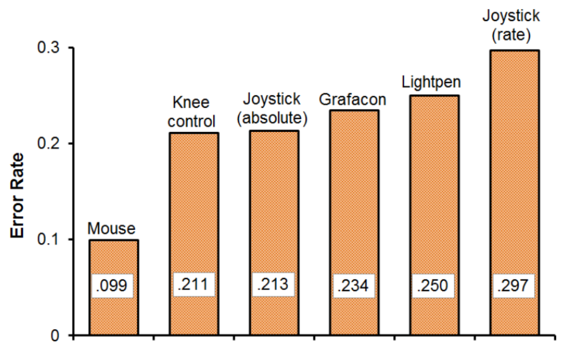


Figure 5: User Study: Mean Error Rate

$$* \; Mean\ Error\ Rate = \frac{Ratio\ of\ Missed\ Target\ Selections}{All\ Selections}$$

The mouse was the clear winner

5.5 Xerox Star (8010) Launches (1981)

- Started development in 1977, and launched in 1981

  * Star refers to the software component

  * 8010 refers to the hardware component

- Marks a watershed moment in the history of computing.

- The Star was the first commercially released computer system with a GUI.

  * Supported Windows, icons, menus, and a pointing device (WIMP)

  * Supported direct manipulation and What-you-see-is-what-you-get (WYSIWYG)

- Display was bit-mapped

- Used the first commercialization of the mouse, licensed out by Engelbert.

- Intended to be an office automation system. It used the desktop metaphor.

- Failed, it was not a personal computer. Unlike the Apple II which succeeded, it did not have a spreadsheet application, and could not run any spreadsheet or other application available in the market. The architecture was closed, and as a result, could only run applications developed by Xerox

- While the direct manipulation user interface of the Star may have been intuitive, the system just didn't reach the right audience.

5.6 ACM SIGCHI Formed - 1982

- 1982 → First CHI Conference in Maryland → Announcing the first ACM SIGCHI Conference in 1983

- Emphasis: The needs and behavioural characteristics of the users, with talk about the user interface and the human factors of computing

- SIGCHI: ACM Special Interest Group on Computer-Human Interaction

- Computer-Interaction is an interdisciplinary group composed of computer scientists, software engineers, psychologists, interaction designers, graphic designers, sociologists, and anthropologists

- Mission: Allows members to:

  * Invent and develop novel technologies and tools

  * Explore how technology impacts peoples lives. How they interact with it, and how it changes society.

  * Inform public policy

  * Design new interaction techniques and interfaces

- People are brought together by a shared understanding that designing useful and usable technology is an interdisciplinary process. When done properly, it has the power to transform persons' lives

- The CHI conference brings together both researchers and practitioners

5.7 Card, Moran, Newell - The Psychology of Human-Computer Interaction (1983)

- The book published in 1983 and co-authored by Stuart Card, Tom Moran, and Allen Newel

- Emerged form work done at Xerox PARC

- Applied Information-Processing Psychology Project (AIP):

  * The AIP mission was to create an applied psychology of human-computer interaction by conducting requisite basic research within a context of application

  * Applied psychology is built upon basic research in psychology The first 100 pages provide an overview of core knowledge in basic psychology regarding:

  - Human Sensory (Perceptual Subsystem): To visually perceive a stimulus
  - Cognitive Systems: To decide on the appropriate reaction
  - Motor Systems: To react and move the hand/cursor to the target

- Book connected low-level human processes with the seemingly innocuous interactions humans have with computers (e.g., typing or using a mouse)

- The framework for this was the model human processor (MHP).

5.8 The Model Human Processor (MHP)

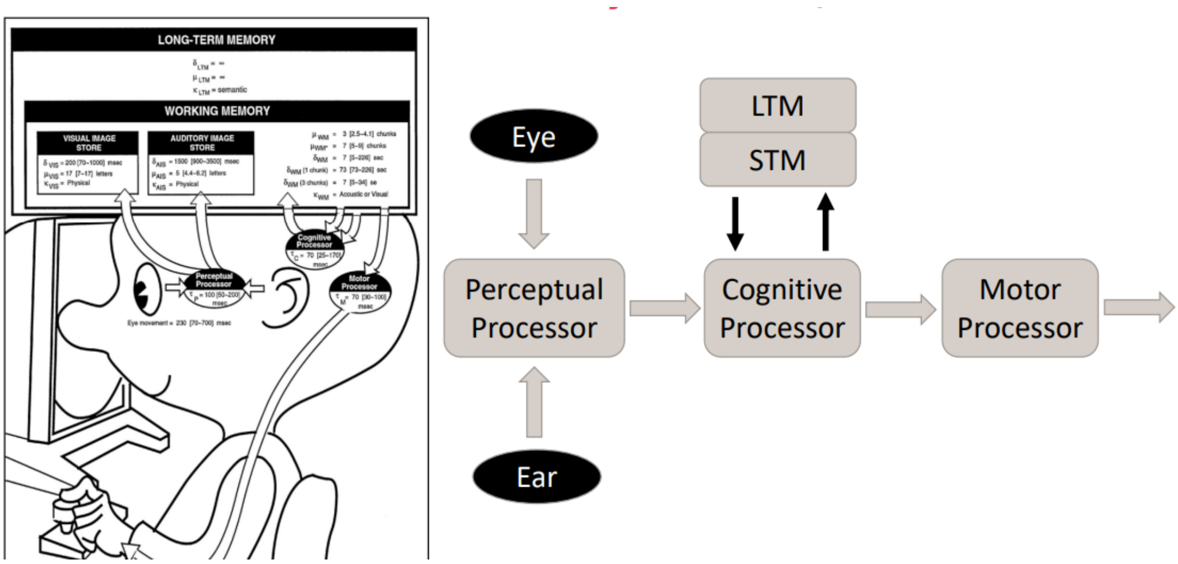


Figure 6: User Study: Mean Error Rate

Some interesting synergy between Psychology and Computer Science:

- Human behaviour can be understood, even modeled, as an information processing activity.

  * (Shannon): The transmission of information is done through electronic channels.

  * These are picked up as a way to characterize human perceptual, cognitive, and motor behaviour.

- Current Dilemma: Experimentation cannot be done until it is too late. The system is built and the degrees of freedom are bound.

- Mission: Generate tools for thought. A causal reference to models - models of interaction

  * Type 1: Quantitative and Predictive

  * Type 2: Qualitative and Descriptive

- A model's purpose is to tease out strengths and weaknesses in a hypothetical design and to elicit opportunities to improve the design.

We can use models to describe or predict user interaction by performing back of the envelope calculations:

- We use rough calculations that are based on data and concepts gleaned from basic research in experimental psychology
- Approximate Solution" Using the model human processor to illustrate each step, from stimulus to cognitive processing to motor response.
- There is nominal prediction accompanied by a fastman prediction and a slowman prediction
- Four Low-Level Processing Cycles:
  1) A Perceptual Processor Cycle (t_p)
  2) Two Cognitive Processor Cycles ($2t_c$)
  3) Motor Processor Cycle (t_M)
- For each, the nominal value is bracketed by an expected minimum and maximum. These are obtained from basic research in experimental psychology.
- $Reaction\ Time = t_p + 2t_c + t_m$

Parameter	Mean	Range
Perceptual Processor Cycle Time	100 ms	50-200 ms
Cognitive Processor Cycle Time	70 ms	25-170 ms
Motor Processor Cycle Time	70 ms	30-100 ms

5.9 Keystroke Level Model (KLM)

- If a complex task can be deconstructed into primitive actions, there is a good chance the time to do the task can be predicted by dividing the task into a series of motor actions interlaced with perceptual and cognitive processing cycles
- Prediction is important, because it is relevant to the bigger picture of designing systems. If some primitive actions can be eliminated or shortened, ample processing time can be saved. This is to say that we have an increase in the efficiency of user systems

5.10 Apple Macintosh Launches - (1984)

- Heralded the new age of:
  * GUI (Paradigm Shift from CLI)

* Direct-Manipulation

* Point-Selection Interface (Mouse)

- Sleek, cool, simple, intuitive, and easy to use

  * Its success came from truly being a personal computer of the time.

5.11 25th Anniversary of "CHI", the SIGCHI Annual Conference - (2007)

6 Birth of HCI

- 1983 marks a good year to peg as the birth of HCI
    * First ACM SIGCHI Conference
    * Card, Moran, Newell - The Psychology of HCI Book
    * The Arrival of the Macintosh
- GUIs entered the mainstream, and consequently, a much broader community of users and researchers were exposed to this new genre of interaction. Designing good user interfaces was good business, but it wasn't easy by any means.
- GUI Evolution:

	Xerox Alto	Xerox Star	Apple II	Apple Macintosh
Proposition	1972	1977	19976	1979
Designed by	Xerox PARC	Xerox's SDD	Apple	Apple
Technology	Research workstation	Commercial workstation (for distributed computing)	PC hooked up with a TV & optional mouse	PC with 1-button mouse, GUI, monitor
Goal	Allowing professionals to share information	Automation of office tasks	Low-cost, user-friendly (great graphics)	Low-cost, high utility, easy to use
Influenced by	Douglas Engelbart's oN-Line System (NLS)	Sketchpad & Xerox Alto	Woz's Atari's arcade video game: Breakout	Xerox Star
Release Year	1973	1981	1977	1984
Target users	Prestigious colleges & government offices	Large corporations & trading partners	Home consumers	Home consumers
Why it failed or was successful	Lack of commercial business model	Too much innovation, costly, closed system, did not meet needs of managers & executives (eg spreadsheet), organizational disconnect	Highly successful: displayed color, supported spreadsheet (VisiCalc)	1st 100 days, sold 72K; sales slowed down: did not hit the 1M mark until March 1987

Figure 7: GUI Evolution

- Microsoft Windows was a late comer in GUI (1985). It took them until 1990 (Windows 3.0) to get it right and in 1992 (Windows 3.1) they were a serious contender to Mac OS.

7 Growth of HCI Research

- Research interest in human-computer interaction, at least initially, was in the quality, effectiveness, and efficiency of the user interface. How quickly and accurately can people do common tasks using a GUI versus a text-based command-line interface?
- A classic example of a research topic in HCI is the design of menus:

  * Menus require recognition

  * Typing requires recall
- It is know that recognition is preferred over recall in user interfaces, at least for novices

8 Chapter 2: The Human Factor

8.1 Introduction

- The deepest challenges in human-computer interaction lie in the human factor.
- Human scientists confront something computer scientists rarely think about: variability...
- The variability humans bring to the table means our work is never precise. It is always approximate.
- The more we understand humans, the better our chances are of designing interactive systems - interactions - that work as intended.
- A grounded and rigorous approach to empirical research requires small and narrowly focused questions.

8.2 Descriptive Models

- Descriptive models seek to delineate and categorize a problem space. This is to say we want to analyze and understand the problem space by:

  1) Breaking the problem space down into parts

  2) Studying how the parts differ and/or relate

  3) Studying the parts strengths and weaknesses

- Descriptive models provide tools for thinking, informing, and improving interaction design.
- They are not tools for predicting!
- Some examples in HCI of descriptive models include:

  1) The Model Human Processor (MHP)

  2) Newell's Time Scale of Human Action

  3) Frame Model of Visual Attention

  * Do note that items 2 and 3 relate to HCI in that they both seek to explain time and visual attention, which is of course a scarce resources.

8.3 Newell's Time Scale of Human Action

- A descriptive model of the human which delineates the problem space by positioning different types of human actions in timeframes within which the actions occur.

- The following bands include:

  - Biological Band

    a) i.e., Neural Impulses

    b) Nature: Highly quantitative, experimental, empirical

    c) Time Frame: Ranges within a few microseconds to about 10 ms.

  - Cognitive Band

    a) i.e., Selection Techniques, Menu Design, Text Entry, Audio Feedback, Gestural Input, Turn Taking (In Games)

    b) Nature: Primarily quantitative, experimental, empirical

    c) Time Frame: A few hundred milliseconds to a few dozen seconds.

    * These are deliberate acts, operations, and unit tasks

    Note: The Model Human Processor lies here!

  - Rational Band (Goal-Oriented)

    a) i.e., Web Navigation, User Search Strategies, user-Centered Design, Collaborative Computing, Ubiquitous Computing, Social Navigation, Situated Awareness

    b) Nature: Quantitative and Qualitative

    c) Time Frame: In the span of minutes, tens of minutes, or hours

    * Means-to-and-End Theories

  - Social Band

    a) i.e., Workplace Habits, Groupware Usage Patterns, Social Networking, Online Dating, User Style and Preferences

    b) Nature: Highly qualitative, non-experimental. Interviews, observation, case studies, scenarios

    c) Time Frame: In the span of days, weeks, or months

    d) TAM: Technology Acceptance Model

    * Key factors that determine the adoption of a new technology

    Organizational Theory

  - Historical Band

    a) Operating at years to thousands of years

– Evolutionary Band

a) Spanning at tens of thousands to millions of years

- Do note that each band is divided up into three levels. Moreover, the biological band is the lowest, while the social is the highest
- Research at the bottom of the scale is highly quantitative in nature. As we approach the near top (Social Band), research methods tend to be qualitative and non-experimental. However, no band is purely one type. They use both quantitative and empirical experiments, just in different ways.
- This model reflects the multidisciplinary nature of the field. HCI research is both high and also low level. Take a look at the scale!
- The most important common dependent variable in research in HCI is time - the time for a user to do a task.

8.4 Frame Model of Visual Attention

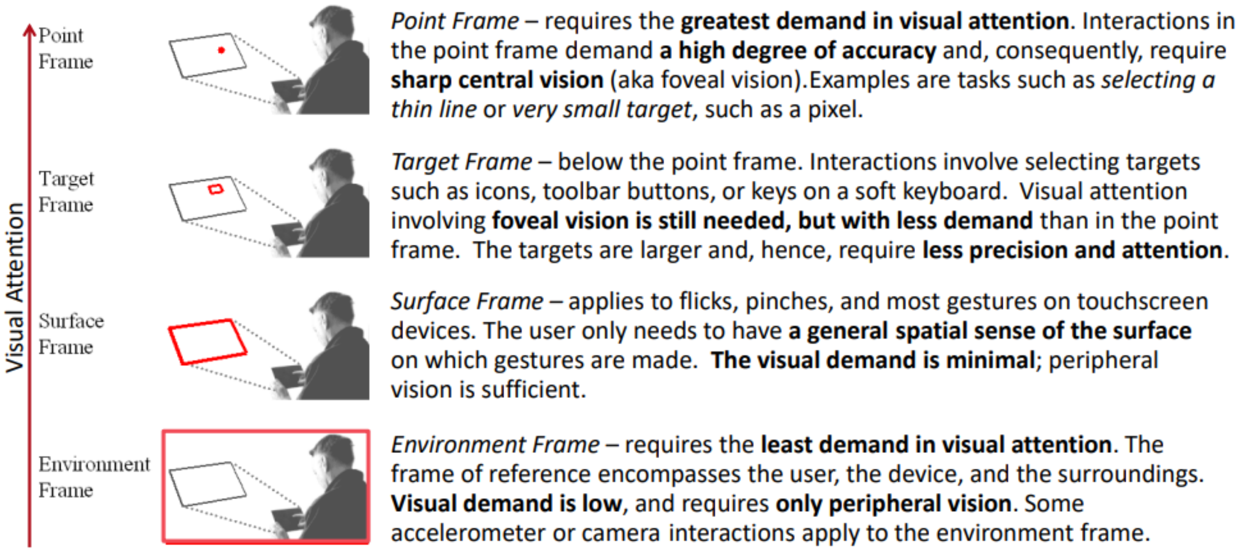


Figure 8: Frame Model of Visual Attention

- This is a descriptive model split into four main parts.
- The fovea is the part of the eye, which allows for sharp vision.

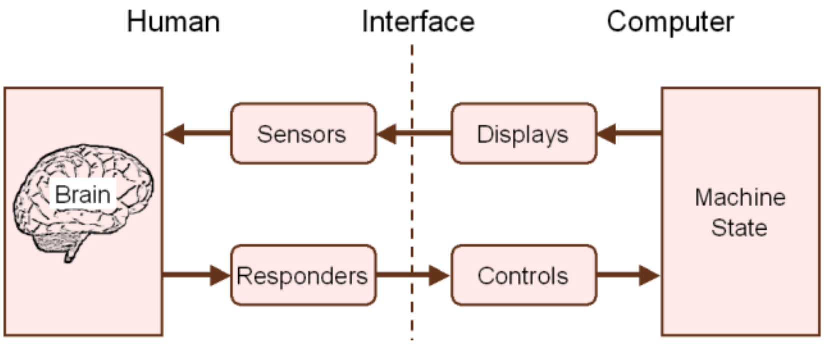


Figure 9: Descriptive Model: Human-Machine Model - Human Factors View

8.5 The Human-Machine Model

- Recall:There are many ways to characterize the human in interactive systems (i.e., Model-Human Processor)
- Human factors (capabilities, limitations) researchers often use a model showing a human operator confronting a machine like so.
- The Dashed Vertical Line - An interface where the interaction takes place. This is the location where researchers observe and measure the behavioural events that form the interaction.
- This model simplifies the human to three components:
  a) Sensors
  b) Responders
  c) Brain

8.6 Sensors: The Five Senses

- One feature the senses share is the reception and conversion into electrical nerve signals of physical phenomena. The signals are transmitted to the brain for processing.
- Sensory stimuli and sense organs are purely physiological
- Perception, discussed later, includes both the sensing of stimuli and the use of the brain to develop identification, awareness, and understanding of what is being sensed

8.6.1 Sight (Vision)

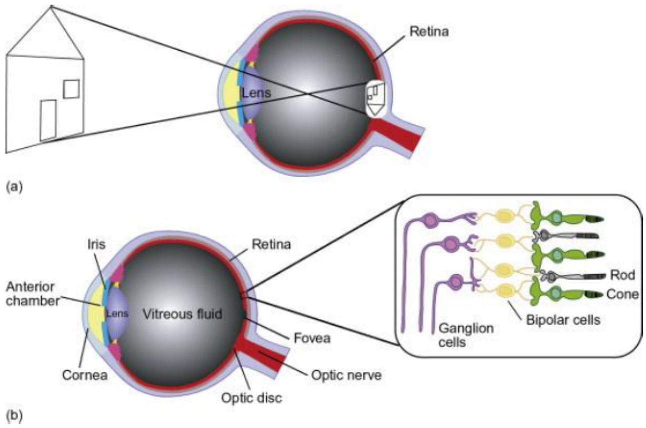


Figure 10: Eye Schema

- The visual sensory channel is hugely important, as most people obtain about **80%** of their information through the sense of light

  * The visual system compensates for movement and changes in luminance

  We use context to resolve any sort of visual ambiguity, which may occur due to overcompensation

- Act of seeing begins with the reception of light through the eyes lens

- The **retina** is a transducer, converting visible light into neurological signals sent to the brain via the **optic nerve**

  * Humans can only see visible light within 380 - 700 nm

  * Images are focused upside-down on the retina!

  * Rods are used for low-light vision

  * Cones are used for color-vision

- The **fovea** is responsible for sharp central vision, such as reading or watching television

- Interpreting the Signal:
  - Visual Angle(V): The angle a viewed object subtends at the eye
  - Visibility Acuity: Ability to perceive detail (limited)

- Perceptual Constancy: Perception of a familiar object as having a constant shape, size, and brightness despite the stimulus changes that occur.
- Overlapping: An illusion which helps perception of size and depth.
- Layering: An illusion in perception of depth by virtue of having a background, middle ground, and foreground.
- Brightness: A subjective property of the eye that includes perception by the brain. We react to levels of light and are affected by the luminance of an object.

  * Measured by the just noticeable difference (JND)

  * Visual acuity increases with luminance, as does flicker. Do note that blue acuity is the lowest
- Colour: Made up of hue, intensity, and saturation, we use cones which are sensitive to colour wavelengths.

The stages of reading include:

1. Perception (of the visual pattern)

   * Identification, Awareness, Understanding

   * Fixations (of the eye)

   * Saccades (Rapid Eye Movement between Fixations)

2. Decoding (Word Shape)

   * Using internal representation

3. Interpretation

   * Using (context) knowledge of syntax, semantics, pragmatics.

4. Negative Contrast (Improves reading from computer screen)

Some examples of visual ambiguity include:

- Necker Cube: Shift in orientation
- Rubin Vase: A vase, or two faces?
- Ponzo Illusion: Perspective illusion. Both are the same size
- Muller-Lyer Arrows: Same length of the middle line
- Escher's Staircase (Penrose Illusion): Stairs always going up, yet returning to the same spot.
- Penrose Triange: Incomplete Figure with a missing back piece,.

8.6.2 Hearing (Audition)

- The detection of sound by humans
- Sound Waves → Cyclic fluctuations of pressure in a medium such as air.

  * Occur when physical objects are moved or vibrate
- Hearing occurs when sound waves reach a humans ear and stimulate the ear drum to create nerve impulses that are sent to the brain
- Hearing in tandem with perception provides us with information about the environment. That is, distances, directions, objects, quality, familiarity, etc.,

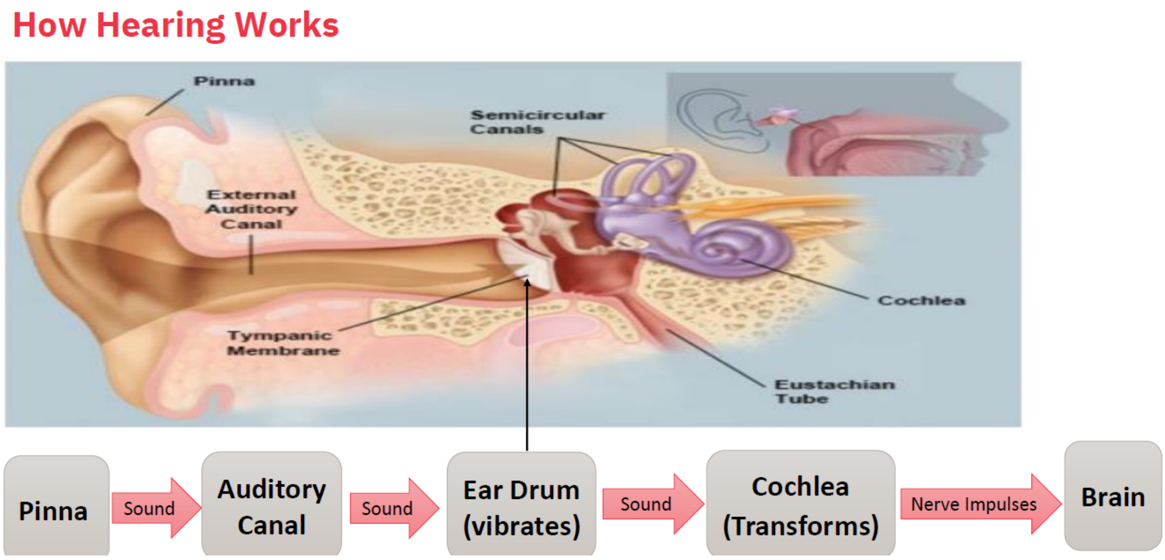


Figure 11: Hearing Schema

The characteristics of sound include:

- Pitch

  * The subjective analogue to the physical property of frequency, which is the reciprocal of the time between peaks in a sound waves pressure pattern.

  * The human ear can pick up between 20 Hz to 20 kHz

  * Below 16 Hz, sound is felt as vibrations

- Loudness

  * The subjective analogue to the physical property of intensity

  * Amplitude / Intensity is measured in decibels (dB)

  * The human hearing range is from 0db to 120-130 db

- Timbre (Tone)

  * Richness / brightness, Quality

  * Results from the harmonic structure of sounds

- Attack

  * The time taken for the amplitude to reach its maximum level. This is to say, the build-up over time of harmonics

- Envelope

  * The way a note and its harmonics build up and transition in time – from silent to audible, back to silent

Some types of auditory illusion (perception) include:

- Shepard Tone: Creates the illusion of an ever-increasing pitch by using superposition of multiple sine waves, separated by octaves, layered on top of each other.

8.6.3 Touch (Tactition)

- One component of the somatosensory system, which includes sensory receptors in the skin, muscles, bones, joints, and organs that provide information on a variety of physical or environmental phenomena.
    a) Thermoreceptors (Temperature)
    b) Nociceptors (Pain)
    c) Mechanoreceptors (Pressure)

- Tactile feedback refers to information provided through the somatosensory system from a body part. Do note that some areas are more sensitive than others.

- Kinesthesis: Awareness of body position and movement. It affects comfort and performance.

8.6.4 Taste (Gustation)

- A direct chemical reception of sweet, salty, bitter, and sour sensations through taste buds in the tongue and oral cavity

8.6.5 Smell (Olfaction)

- The ability to perceive odours.
    * Occurs through the sensor cells in the nasal cavity

- Has strong links to emotion and memory

- Has applications in:
    a) Smell-o-Vision (Tubes / Theatres)
    b) Odourama (Scratch and Sniff Cards)
    c) Smell Tags

Flavour is the perceptual process in the brain that occurs through a partnering of the smell and taste senses.

8.6.6 Other Senses

- The word, "sense" appears in many contexts apart from the five senses

  Examples: Sense of Urgency, Direction, Balance, Timing, Music, Morals, etc.,

8.7 Responders (Outputs)

- There is an intersection among the responders and sensors:
  - a) Tactile
  - b) Eyes

8.7.1 Mapping of Cerebral Cortex to Responders (and Sensors)

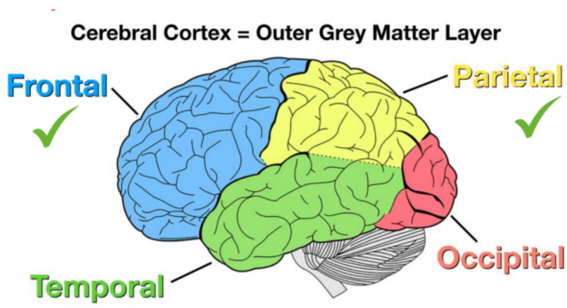


Figure 12: Brain Schema

- Frontal Lobe
  - Motor Movement
    - a) Skeletal Muscle Movement
    - b) Ocular Movement
    - c) Speech Control
    - d) Facial Movement
  - Physical Actions → Planning, Control, and Execution of Voluntary Movements
  - Mapping → Primary Motor Cortex
- Parietal Lobe
  - Somatosensory Support
    - a) Awareness of Somatic Sensation (Touch-Related, Pain)
    - b) Processing Somatic Sensation
    - c) Proprioception: The coordination of limb movements and positions through the perception of stimuli within muscles and tendons
  - Mapping:
    - * Primary Sensory Cortex (Awareness of Som.S)
    - * Somatosensory Association Cortex (Processing Som.S, P)

- Occipotal Lobe (Visual)
- Temporal Lobe (Gustatory, Olfactor, Auditory)

8.7.2 Handedness: Edinburgh Handedness Inventory

- Handedness exists along a continuum
- Relevant in touch and pressure-sensing displays
- Hand Dominance can be measured by using the Edinburgh Handedness Inventory

	Left	Right
1. Writing	☐☐	☐☐
2. Drawing	☐☐	☐☐
3. Throwing	☐☐	☐☐
4. Scissors	☐☐	☐☐
5. Toothbrush	☐☐	☐☐
6. Knife (without fork)	☐☐	☐☐
7. Spoon	☐☐	☐☐
8. Broom (upper hand)	☐☐	☐☐
9. Striking a match	☐☐	☐☐
10. Opening box (lid)	☐☐	☐☐
Total (count checks)		

Difference	Cumulative Total	**RESULT**

Instructions
Mark boxes as follows:
x preference
xx strong preference
blank no preference

Scoring
Add up the number of checks in the "Left" and "Right" columns and enter in the "Total" row for each column. Add the left total and the right total and enter in the "Cumulative Total" cell. Subtract the left total from the right total and enter in the "Difference" cell. Divide the "Difference" cell by the "Cumulative Total" cell (round to 2 digits if necessary) and multiply by 100. Enter the result in the "RESULT" cell.

Interpretation of RESULT **LQ = [(R – L)/(R+L) x 100]**
-100 to -40 left-handed
-40 to +40 ambidextrous
+40 to 100 right-handed

Figure 13: Edinburgh Handedness

- We use this information of handedness to prevent occlusion. That is, the covering of certain elements by handedness.

  * We can strategically place UI elements on the display to reduce occlusion

8.7.3 Voice

- Vocalized sound by exhaling air through the larynx
- Speech with automatic recognition by computers works best with limited vocabulary, speaker dependence, and discrete words.
- Non-Speech Vocalized Sounds
  - Acoustic parameters of the (physical) sound signal, measured over time.
  - Data stream is interpreted as an input channel, which is particularly useful to specify analogue parameters.
  - CHANTI (Vocally Enhanced Ambiguous Non-Standard Text-Input)

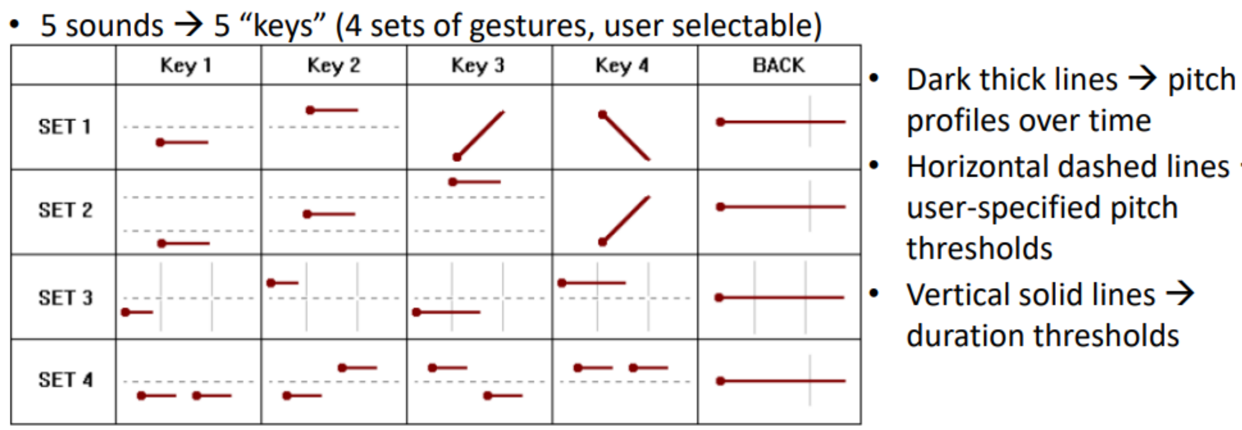


Figure 14: CHANTI System

8.7.4 Eyes

- The eyes can be used as responders, by taking advantage of eye tracking.
- Eye Tracking Model: Modified Version of HMM

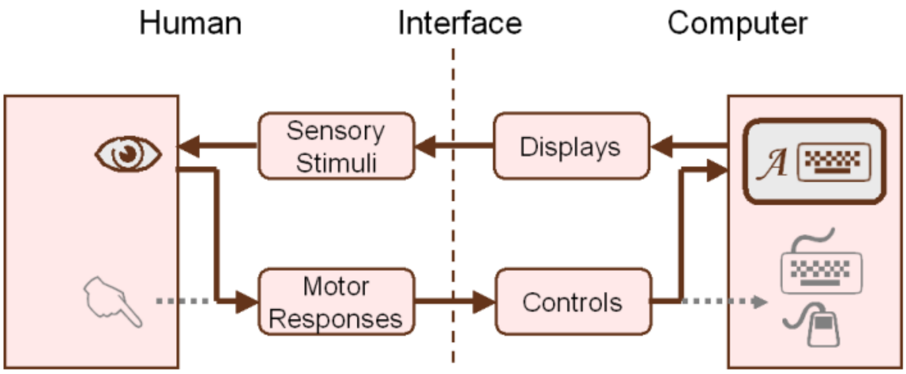


Figure 15: Responder Eye

- The eye provides motor responses that control the computer through soft controls - virtual or graphic controls that appear on the system's display.

  $Saccades \rightarrow Movement$

  $Fixations \rightarrow Selections(Interval)$

  $Scanpath \rightarrow Map(Saccades, Fixations)$

8.7.5 Face Tracking

- Playing a game (StarJelly) using face tracking
- Results show that Device Tilt is better than Face Tracking by a magnitude equal to about 7.

8.7.6 Others

- Facial Expression
- Body Movement
- Tongue
- Breadth

9 Chapter 3: The Brain

9.1 Introduction

- Memory is the human ability to store, retain, and recall information
- There are similarities between the human and computer memory
  - Declarative / Explicit Area (Data Space) stores information about events in time and objects in the external world. That is, they store experiences.
  - Procedural / Implicit Area (Code Space) stores information about how to use objects or how to do things.
- There are three types of memory, which we will cover in greater depth later:
  1. Sensory Memory
     a) For sensing, and perception (perceiving stimuli)
  2. Working (Short-Term) Memory
     a) For actively manipulating information
     b) Readily available for access
     c) Store for less than a minute
  3. Long-Term Memory

     A declarative/explicit area which can be used for passively holding information so that it can be accessed and utilized in the future.

     Lifespan: Days, Weeks, Months, Years

9.2 Characterization of Memory in Terms of Stages: The 3-Box Model

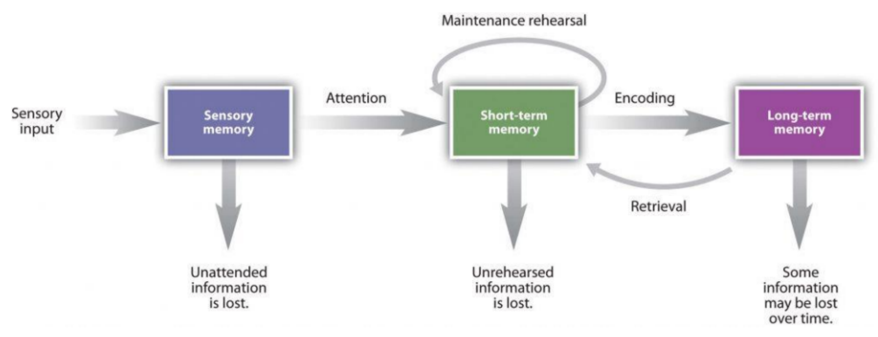


Figure 16: Brain Schema

- Short-Term Memory is synonymous with RAM
- Long-Term Memory is synonymous with a hard-disk

9.3 Sensory Memory

- Acts like a buffer in memory:
    a) For storing stimuli received through the senses
    b) Continually overwritten (Information lost permanently)
- Types / Categories:
    1. Iconic
       Visual Stimuli
    2. Echoic
       Aural (Audio) Stimuli
    3. Haptic
       Tactile Stimulia (wrt Touching)

9.4 Short-Term Memory (STM)

- Serves as a Scratch-Pad (Cache-Like) for temporary storage and recall
- Rapid Access: Readily Available ($\approx 70ms$)
- Rapid Decay: ($\approx 200ms$)
- Limited Capacity: (Miller's 7 ± 2 items (uni-dimensional stimulus) at a time)
    a) Chunking helps to improve short-term memory

9.4.1 Improving Short-Term Memory

1. Chunking (Mental Gymnastics)
    - A simple but powerful process within the brain: our ability to associate multiple items as one.
    - So-called chunking is a process whereby humans group a series of low-level items into a single high-level item
    - The process of chunking is most informal and unstructured. Humans intuitively build up chunked structures recursively and hierarchically, leading to complex organizations of memory in the brain.
    - Example: $416736210040631 \rightarrow 415 - 736 - 2100 - 40631$

2. <u>Maintenance Rehearsal (Rote Rehearsal)</u>

    - Most effective at committing information to short-term memory. It's also somewhat useful in terms of long-term memory
    - Repeating of information in order to memorize it.
    - Continually re-activates items in short-term memory
    - Example: Sub-Vocal Articulation (Say it in your head!)

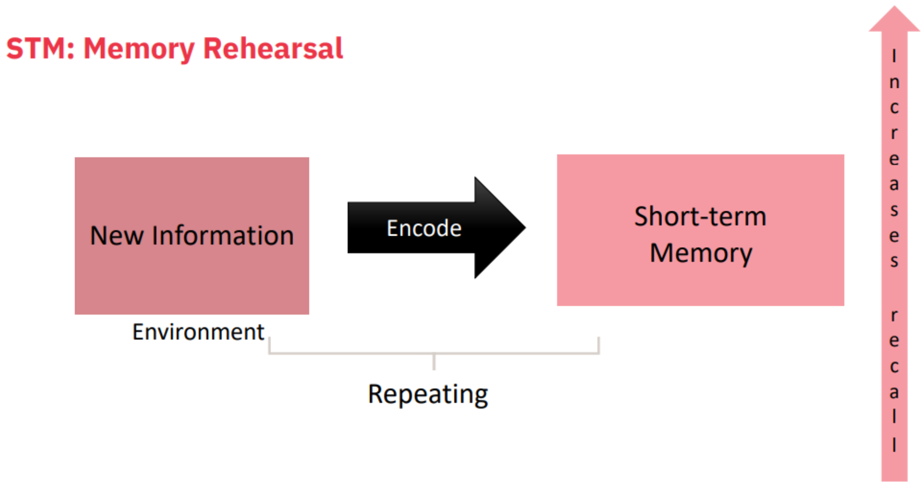


Figure 17: Maintenance Rehearsal

3. <u>Make Items Different</u>

    - Similar items are much harder to remember
    - When you keep more than one item in memory, make them different from each other.

      * i.e., It's easier to remember two people's names who are very different from each other, compared to two people's names who are very similar

4. Pay Attention

    - Diverting attention (a scarce resource) ends rehearsal and starts decay.
    - User has limited attentional resources
    - Diversion to similar types of information is worse the dissimilar. With dissimilar, it has a minor effect

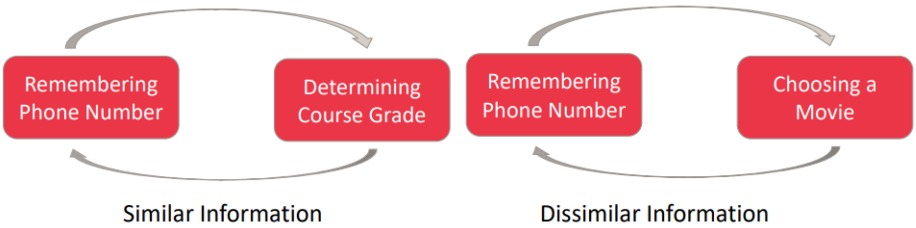


Figure 18: Maintenance Rehearsal

9.5 Long-Term Memory (LTM)

- Experience, whether from a few days ago or from decades past are collected together in long-term memory
- General Characteristics:
    - Our repository for all knowledge
    - Slow Access: 1-10 seconds
    - Slow Decay, If Any
    - Huge Capacity
    - Learning, Education, and Training should lead to long-term memories
- Strength of long-term memory is related to frequency and recency of use.

9.5.1 Improvement of Long-Term Memory (Elaborative Rehearsal)

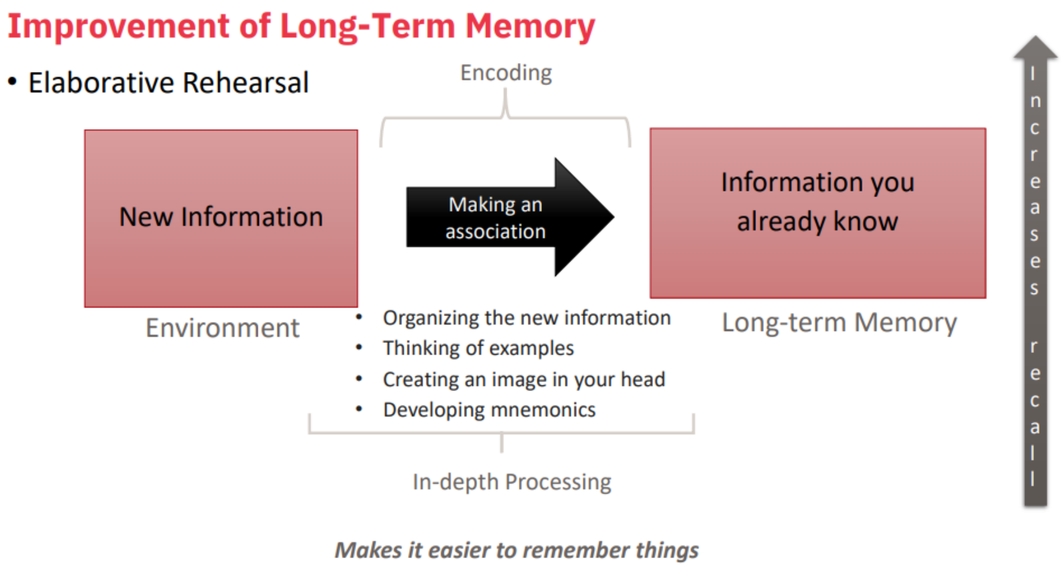


Figure 19: Elaborative Rehearsal

- Example: Associating a Definition with Word Structure

  S

  H

  A

  Designer

  Observes Participants

  Without

  Interfering or Intruding

  N

  G

9.5.2 Types of Long-Term Memory

1. Explicit: Conscious, Declarative

   - Semantic (Meaning) Memory:

     a) WHAT is it?

     b) Database of facts, meanings, procedures, and general knowledge about things. Do note that not everything stored here is necessarily correct.

     c) Built through repetition and familiarity. Thus, you use it, or you lose it.

     d) Although recallable, not always

   - Episodic Memory:

     a) WHAT happened? (Events, Experiences)

     b) Memory of specific events

     - Information can change with each telling

2. Implicit: Unconscious, Difficult to Articulate

   - Procedural Memory:

     a) Highly-learned tasks, skills

     b) Something can be done almost automatically

   - Emotional Conditioning:

     a) Triggers (emotions)

     b) Responses to a scary situation

9.5.3 Long-Term Memory Concepts

1. Item Strength Decays Exponentially

2. New Items Replace Old Items

3. Recall Degrades Faster than Recognition

   a) Recall is the ability to retrieve information from memory

   b) Recognition is the ability to recognize information as being familiar

4. Degradation Increases for Things with Fewer Connection

9.6 Cognition (Thinking)

- The human process of conscious intellectual activity, such as thinking, reasoning, and deciding.

- Used to solve problems in our physical environment with relation to the use of models

9.6.1 Tools for Reasoning

- Deduction
  - Deductive Reasoning → Derivation of logical conclusions from premises.
  - Moving from general to specifics
- Induction
  - Inductive Reasoning → Generalize from cases-seen to cases unseen
  - Moves from specifics to generalities
- Abduction
  - Abductive Reasoning → Reasoning from event (effect) to cause
  - That is, moving from outcome to cause (If-Else)

9.6.2 Tools for Problem-Solving

1. Models
2. Issues

9.7 Language

9.7.1 Introduction

- Language is the mental faculty that allows humans to communicate
- Language as speech is available without effort. Children learn to speak and understand speech without conscious effort as they grow and develop.
- Learning to write demands effort, considerable effort, spanning years of study and practice.
- Humankind is defined by language, but civilization is defined by writing

9.7.2 Redundancy and Entropy

Redundancy

- Redundancy → What we inherently know

- Native speakers of a language innately possess an immense understanding of the statistics of language. We automatically insert words that are omitted or obscured. We anticipate words, letters, or entire phrases.

Entropy

- Entropy → What we don't know (Uncertainty). This refers to information.
- If redundancy in the language is what we inherently know, entropy is what we don't know - the uncertainty and forthcoming letters, words, phrases, ideas, concepts, and so on.

Although text-entry is hugely important in HCI, our interest here is language itself in a written form.

9.7.3 Redundancy in English

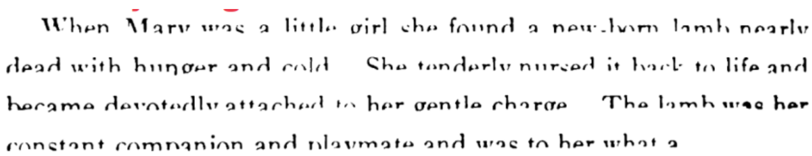


Figure 20: Example: Redundancy

- There is more information in the top-half of text compared to the bototm. We know this because it's easier to read with it, compared to without.
- The bottom half is redundant. We can do without it.
- We can use this information to compress information and increase efficiency and speed

9.7.4 Shannon's Letter Guessing Experiment

Mode 1: One Guess Per Letter

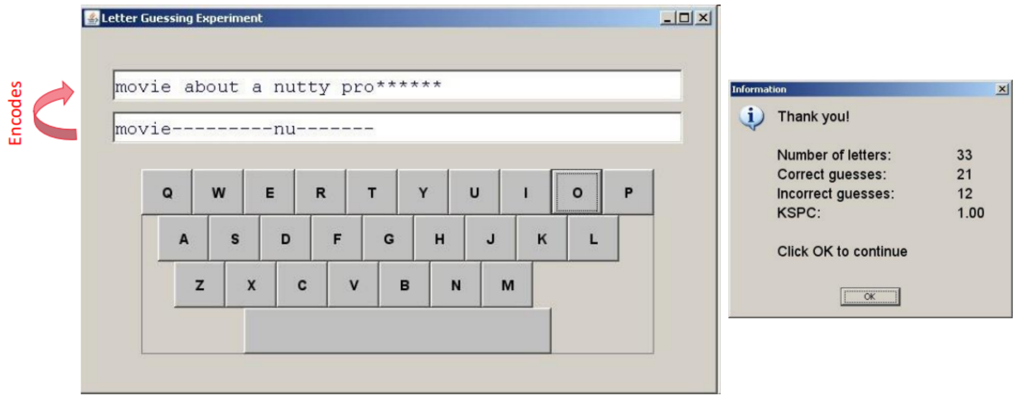


Figure 21: Mode 1: One Guess

- As guessing words proceeds, the phrase is revealed to the participant, letter by letter.
- The results (reduced text) are recorded in the line below each phrase in the figure.

  a) *Dash* → *CorrectGuess* → Redundancy (What is Known)

  b) *Letter* → *IncorrectGuess* → Entropy (What is Not Known)

  (New Information is Being Presented)
- Errors are more common at the beginning of words, less common as words progress.
- Both lines in each phrase-pair contain the same information in that it is possible, with a good statistical model, to recover the first line from the second.

  Because of redundancy in printed English, a communications system need only transmit the reduced text. The original can be recovered using the statistical model.
- Considering letter frequency alone, the entropy is about 4.25 bits per letter.
- Considering previous letters, the entropy is reduced because there is less uncertainty about forthcoming letters.

- Considering long range statistical effects (up to 100 letters), Shannon estimated the entropy of printed English at about one bit per letter with a corresponding redundancy of about 75 percent
- $Keystroke\ per\ Character = \frac{Correct+Incorrect}{Number\ of\ Letters}$
- For one-guess mode, KSPC is always 1!

Mode 2: Guess Until Correct

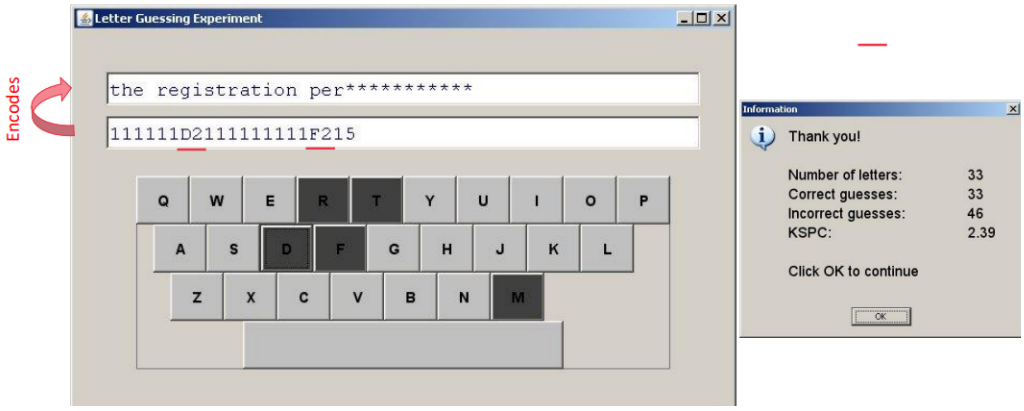


Figure 22: Mode 1: One Guess

- The top line is hidden initially, consisting of a string of asterisks. This is just the the former case.
- Participants guess letters until they get it correct:

  a) Keys are darkened for incorrect guesses

- The top line is revealed letter-by-letter as guessing continues
- *Bottom Line* → Number of guesses revealed (HEX) until correct
- For this mode, $KSPC \geq 1$. If it equals 1, this means the person got a 100% accuracy

10 Chapter 4: Human Performance

10.1 Shannon's Entropy

We calculate Shannon's Entropy by using the following formula:
$H(X) = -\sum_{i=1}^{n} p_i \times log_2(p_i)$

1. Find the Entropy for a Sequence of Numbers 1, 2, 3, 4

   Note: $-log_x = logx^{-1} = log\frac{1}{x}$
   First, we calculate the entropy for each number

   We know that $P_i(EachNumber) = 0.25$

   $H(X_i) = 0.25 \times log_2(\frac{1}{4})^{-1}$

   $H(X_i) = 0.25 \times log_2(4)$

   $H(X_i) = 0.25 \times 2$

   $H(X_i) = 0.5$

   Then, we calculate the entropy for the set

   $H(X) = 4 \times 0.5 = 2$

   Thus, 2 bits are required to represent each number in the set.

   Thus, for the set of 4 numbers, the total number of bits is
   $2^{H(X)} = 2^2 = 4$

Number	Encoding
1	00
2	01
3	10
4	11

10.2 Human Performance

- Human Movement is ubiquitous in computing

  a) Our arms, wrists, and fingers interact with the computers input devices.

- Human Performance:

  a) Matching human movement capabilities and limitations with interaction techniques

  b) HCI aims to optimize performance by understanding human capabilities and limitations

- The focus of movement research lies in:

  a) Modelling of Human Performance

  b) Prediction and Measuring of Time Taken to Complete a Given Task

  c) Ways by Which Performance Can Be Measured

- Performance can be measured by Fitts Law. That is, the amount of time required for a person to move a pointer to a target area.

- Performance can also be measured by Hicks Law. That is, a psychological principle which states that the more options are available to a person, the longer it will take for him or her to make a decision about which option is best.

10.2.1 Human Performance and Variability

- Humans bring diversity and variability, and these characteristics bring imprecision and uncertainty

- Humans vary from

  a) Age

  b) Fitness

  c) Geographic Location

  d) Personality

- Human Performance varies from:

  a) Person to Person

  b) Trial to Trial

  c) Task to Task

  c) With Amount of Practice

- At its core, human performance is:
  - Using their sensors, brain, and responders to do things. When the three elements work together to achieve a goal, human performance arises
  - A better performance is typically associated with faster or more accurate behaviour, and this leads to a fundamental property of human performance.

10.2.2 Speed-Accuracy Trade-Off

- Go faster and errors increase; slow down and accuracy improves.
- Clearly, research on a new interface or interaction technique that seeks to determine the speed in doing a task must consider accuracy as well.
- Other quantifiable properties of human interaction with computing systems

10.2.3 Measuring Human Performance

- External Apparatus Needed
- Observe and Log Events and Time of Events
- Difficult to observe cognitive operations separate from sensory input and response output.

10.2.4 Simple Reaction Time

- One of the most primitive manifestations of human performance, defined as the delay between the occurrence of a single fixed stimulus and the initiation of a response assigned to it.
- Involves Sensory Stimulus → Cognitive Operation → Motor Response

  Note: The Cognitive Operation is so trivial that the task is relatively easy to study
- The movement time is dependent on age, fitness, etc., The younger and more fit you are, the faster your motor system is.

- Reaction time is dependent on stimulus type. That is, simple reaction times differ according to the stimulus source with approximate values of:

    a) 150ms (Auditory)

    b) 200ms (Visual)

    c) 300ms (Smell)

    d) 700ms (Pain)

10.2.5 Extensions of Simple Reaction Tasks

- Each adds a layer of complexity to the cognitive operations
- As we go further down the list, more time is required for each task

1. Physical Matching

    - The user responds as quickly as possible by pressing one of two keys if the second stimulus matches the first stimulus or not. (Same Presentation)
    - More complicated than simple reaction, since the user must compare the stimulus to a code stored in working memory.

2. Name Matching

    - The same as physical matching, except the words or stimulus may vary in appearance: uppercase or lowercase, font-family changes, font-size changes.
    - A match is deemed to occur if the words are the same, regardless of the look of the fonts
    - Should take longer than physical matching, because the user must now wait until the visual code has been recognized and an abstract code representing the name of the letter is available.

3. Class Matching (Taxonomy)

    - Font-Variance will be used
    - A match is deemed to occur if both symbols are of the same class; that is, both are letters or both are digits
    - Class matching takes longer still, because the user has to make multiple references to long-term memory

4. Visual Search

    - A variation on reaction time. Here, the user scans a collection of items, searching for a desired item. Time increases with the number of items to scan

10.3 Movement: Fitts Law

- Derived from Shannon's Theorem (17), which talks about the information capacity of a channel

    a) Analogous to transmission of information.

    b) The movement of human motor systems is viewed as transferring bits of information

- That is, motor movements are assigned indices of difficulty (units of bits)

- A model of human psychomotor behaviour:

  - The amount of time required for a person to move a pointer to a target area.
  - A function of:

    a) Distance from the Target Object (Amplitude) (D)

    b) Objects Size (Width / Diameter) (S)

  - Objects that are further away and smaller take a longer time to locate and point to it.
  - Follows the Speed-Accuracy Trade-Off: Greater speed of pointing infers a decrease of accuracy in the form of overshooting and undershooting.

- Applications:

    a) Kinematics

    b) Human Factors

    (Designing Systems to Match Human Capabilities / Limitations)

  Note: Not doing this will produce errors (i.e., Aviation Domain) within interfaces

10.3.1 Empirical Formulas

Fitt's Law	Shannon's Theorem
$ID = \log_2\left(\frac{D}{S}+1\right)$ $MT = \left(a + (b \times ID)\right)$ $IP = \frac{ID}{MT}$ **Definitions** 1. IP: Index of Performance 2. D: Distance to the Target (cm) 3. S: Size of the Target (cm) 4. a, b: Empirically Determined Constants 5. ID: Index of Difficulty (bits) 6. MT: Movement Time (seconds)	$C = Blog_2\left(\frac{S}{N}+1\right)$ **Definitions** 1. C: Capacity of Channel (bits/sec) 2. S: Signal Power (Watt) (Good) 3. N: Noise Power (Watt) (Bad!) 4. B: Bandwidth of Channel (Hz) (Width of the Channel)

Figure 23: Fitts law

10.3.2 Application of Empirical Formulas

- Using Fitts Law, calculate the Index of Difficulty for Element F and N. Based on your results, which element would be easier to, "click"? Do note that we will assume the given distance is measured from the home position of a smart phone button to the target, based on their midpoints.

Element F

$1.5cm \times 1.5cm$

7cm from 'Home' Position

Element N

$0.5cm \times 0.5cm$

3cm from 'Home' Position

$ID(F) = log_2(\frac{7cm}{1.5cm} + 1) \approx 2.50$

$ID(N) = log_2(\frac{3cm}{0.5cm} + 1) \approx 2.81$

Therefore, Item F will be easier to thus reach.

10.4 Skilled Behaviour

- In many cases, human performance improves considerably and continuously with practice. This is according to the Power Law of Practice
- Skilled Behaviour is a property of human behaviour whereby human performance necessarily improves through practice. That is, ones ability to do these tasks is likely to bear significantly on the amount of practice done.
- Categories:

  a) Sensory-Motor Skills

  b) Mental Skills
- One way to study skilled behaviour is to record and chart the progression of skill over a period of time:

  a) Level of Skill → Dependent Variable → Speed, Accuracy

  b) Time → Convenient Procedural Unit → Trial Iteration, Block / Session Number, Temporal Unit
- Measuring and modelling the progression of skill is common in HCI research, particularly where users confront a new interface or interaction technique
- A, "new" interaction technique may require practice to outperform a, "current" technique (i.e., OPTI vs QWERTY)

10.5 Factors That Affect Performance

1. Secondary Tasks
   - We may act in the presence of a secondary task, such as listening to the radio, conversing with a friend, or driving a car.
   - Clearly, context plays an important role, as do the limits and capabilities of the sensors, the brain, and the responders.
2. Attention
3. Motivation
4. Fatigue

11 Chapter 5: Interaction Elements

11.1 Introduction

- We begin with the basic properties of human input to computers (knobs / controls) and the responses produced (the dials /displays)
- By convention, the terms input and output are with respect to the machine;
  - Input, or input devices, are inputs to the machine that are controlled or manipulated by human outputs.
  - Outputs are limbs, sounds, eye motions, blinks, breath, electric body signals, and so on.

12 Soft Controls

- Traditionally, these were hard, physical controls for systems.
- Once built, they were fixed for life. This meant that their behaviours were constrained to a small set of relationships with the displays they accompanied.
- The advent of computers with software, displays, and point-and-click interactions changed this:
  - Through soft interfaces, the way humans interact with technology changed.
  - The malleability of a display, through software, brings unlimited possibilities to a relatively small physical space. The result is soft controls.
- Soft controls refer to dynamic, on-screen controls created by software.

12.1 Stimulus-Response Compatibility

- The Stimulus-Response Compatibility is the degree to which the physical arrangement of the stimuli matches the location of the expected response.
- *Good Mapping* $\rightarrow$ *Congruence*

  i.e., Mouse and Monitor Control

- Natural Responses:

  - Faster to learn, understand, and remember

- Unnatural Response

  - Harder to discover, execute, and remember

12.2 Types of Natural Mapping

- Spatial Similarity (Mapping)
  - Occurs when the physical layout matches the on-screen layout
    i.e., Monitor Configuration
  - Also known as Stimulus-Response Compatibility
- Conceptually or Metaphorical Similarity
  - Making systems functions more transparent through familiar metaphors
  - Culturally Dependent
    i.e., Light Switch
- Behavioural Similarity
  - Making the response of a UI resemble a users actions
    i.e., Smartwatch: "Raise to Wake" Gesture

12.3 Control-Display Relationships (Mappings)

- Control-Display Relationships are not something users think much about. This is how human interaction should be - where a relationship between what a user does and what is experienced is natural, seamless, intuitive, and efficient.
- The relationships attribute how a controller property maps to a display property.

  Types of Relationships:

  a) Spatial (Displacement)
  - Movement of a device affects <u>movement</u> of a response.
  - There can be a delay (latency) in movement response

  b) Dynamic (Velocity)
  - Movement of a device affects <u>speed</u> of a response

  c) Physical (Acceleration)
  - Whether <u>movement</u> or <u>force</u> affects a response

12.4 Natural Control versus Learned (Cultural) Control

- Whenever there is a spatial transformation, the ensuing relationship - no matter how easy we accept it or adapt to it - is learned, not natural.

12.5 Population Stereotype / Cultural Standard

- If the relationship is expected and considered correct by a majority of people within a population, such as a cultural, ethnic, or geographic group, then the relationship holds; it is accepted and considered natural by that relationship. However, it is still a learned relationship.

12.6 Spatial Relationships / Mappings

12.6.1 Congruent Mapping

- Congruent mapping occurs when there is an exact spacial correspondence between the controller input and the display output

12.6.2 Transformed Spatial Mapping

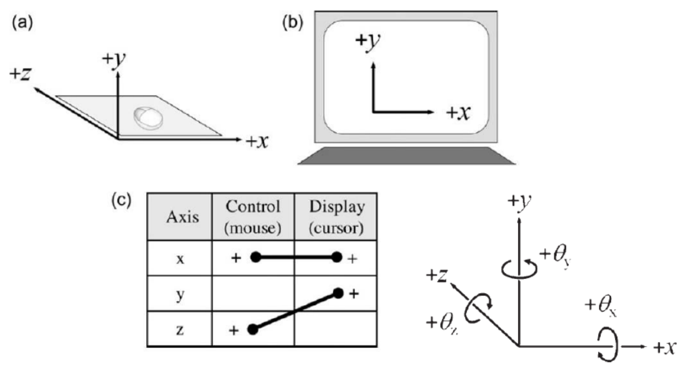


FIGURE 3.5

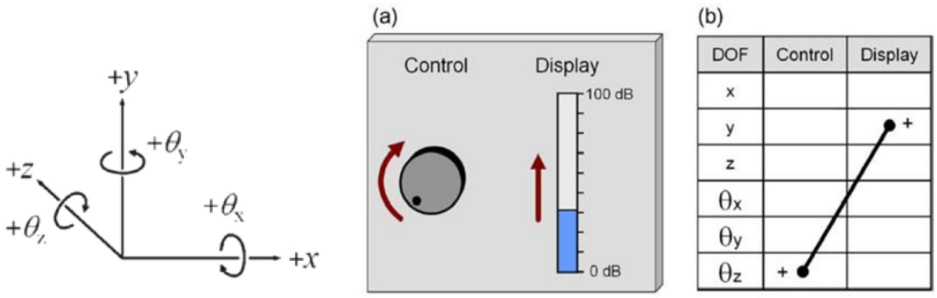
Axis labels. (a) Control space. (b) Display space. (c) Control-display mapping for a mouse and cursor.

Figure 24: 3D Transformed Spatial Mapping

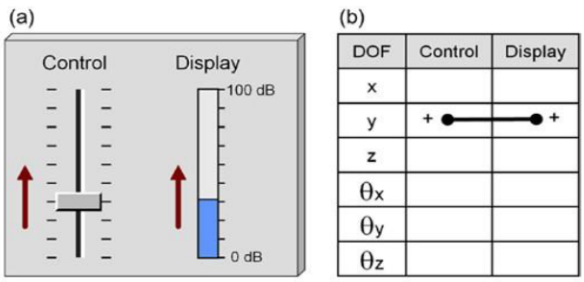
- Movement in 3D space can occur along the three linear axes, and also the three rotational axes.
- Mouse x-axis motion maps to cursor x-axis motion.
- Mouse z-axis motion maps to cursor y-axis motion.

  - Note: This y-axis cursor motion is an example of transformed spatial mapping.

12.6.3 Transformed, Learned Relationship

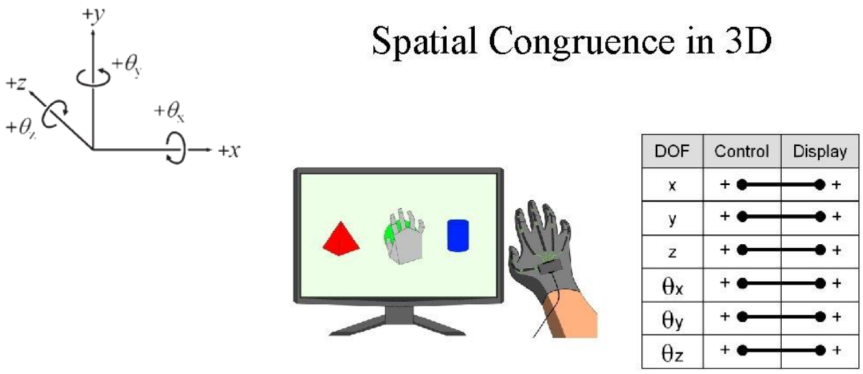


12.6.4 Naturally, Spatially Congruent Relationship

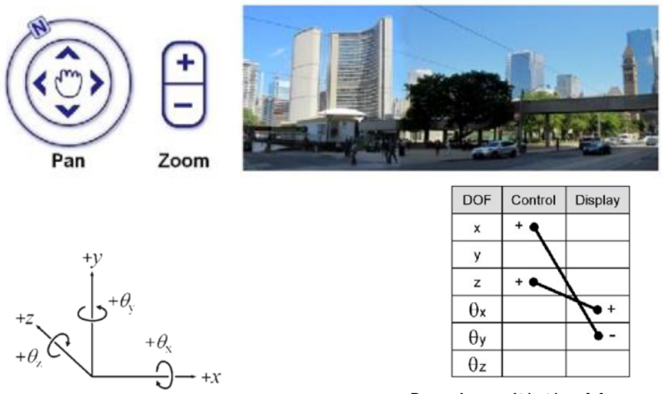


- The best possible scenario is spatial congruence, which for a linear display, implies using a slider or linear control.

12.6.5 Full Congruence in 3D



12.6.6 Spatial Transformation: Google Street View



Panning with the Mouse

- Panning
  - Rotating the camera view left-right and up-down
  - L/R (x-axis) Movement → Effects Rotation(y-axis)
  - F/B (z-axis) Movement → Effects Rotation (x-axis)
- Zooming
  - Changing the magnification of a view
- Positioning
  - A change in the camera position, constrained in the discourse of Google Maps

12.7 Dynamic Relationships

1. Control-Display (CD) Gain

    - Represents the amount of movement in a display object, such as a cursor, for a given amount of movement in a control
    - $CD\ Gain = \frac{Display\ Movement}{Control\ Movement}$
    - Moving the Control Panel Slider to, "slow" reduces the CD gain, meaning that more controller movement is required for each unit of cursor movement.
    - Lowering the CD gain for slow controller movements is useful to enhance the precision of target selection at the end of a point-select operation.
    - Increasing the CD gain allows for faster movement and a greater range of movement in a limited area (e.g., less need to reposition the mouse)

2. Non-Linear (Power Gain)

    - Often, the relationship between controller-motion and cursor-motion is non-linear, and uses a power function.
    - In this case, the amount of cursor motion depends on the velocity of mouse motion as well as a controller motion
    - This is enabled by selecting "Enhance Pointer Precision" in the Mouse Control Panel

12.7.1 Optimizing CD Gain: A Tricky Problem

- The problem of optimizing is trickier than it seems.
- Varying CD gain evokes a trade-off between:
    - Gross Positioning Time: Time getting to the vicinity of a target
    - Fine Positioning Time: The Final Target Acquisition
- In a simplistic sense, the optimal setting is that which minimizes the combined gross and fine positioning time.
    - Other factors, such as the display size, or scale also bring into question the optimization of CD gain.
    - The majority of studies found that significant performance benefits are not achieved by adjusting CD.

      A challenge in optimizing CD gain involves defining optimal performance. The goal of optimizing speed and accuracy is problematic because of the speed-accuracy trade-off

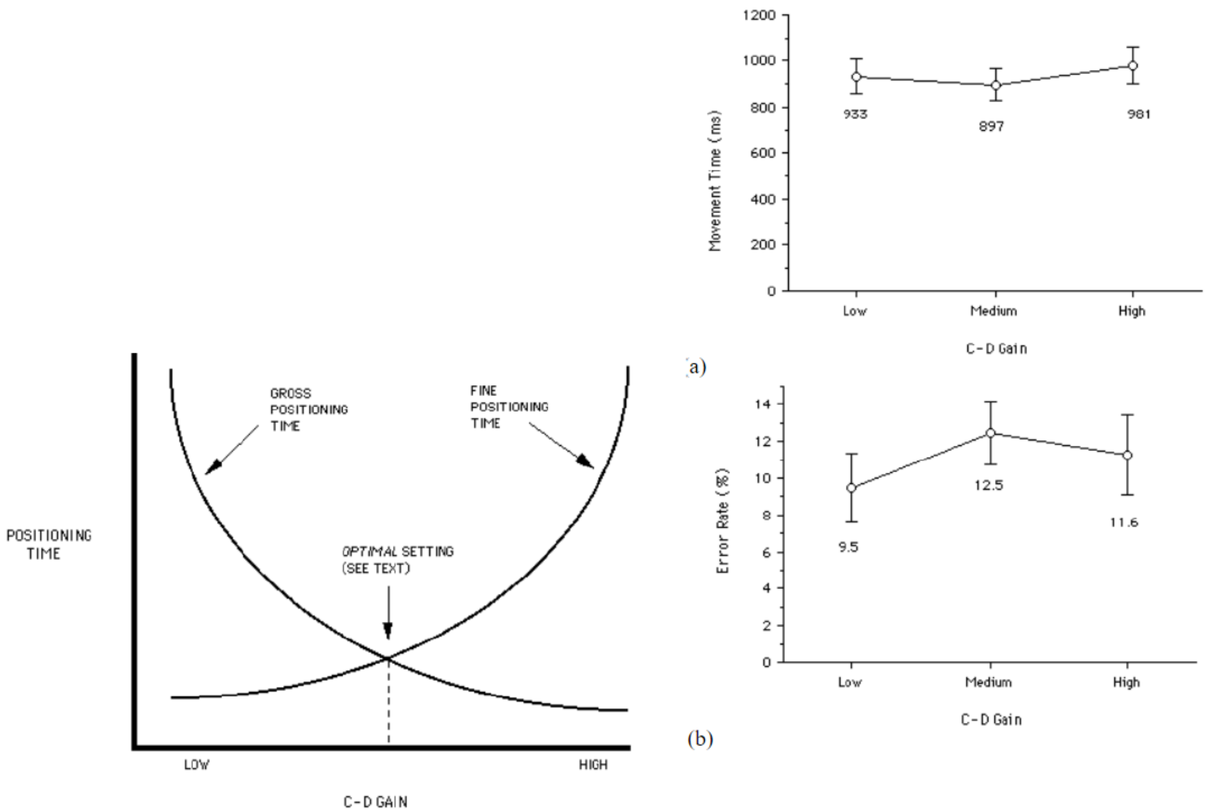


Figure 25: CD Gain Optimization Study

12.8 Physical Relationships: Property Sensed, and Input Devices

- The input controller senses the interaction and converts a property sensed into data that is transmitted to the host computer for processing
- Pointing Devices (Property Sensed):

1. Position
    - Touchpad: Position is sensed, and the relative movement is reported.
    - Drawing tablet: Position is sensed as an absolute coordinate at the point of contact along the x-axis and z-axis. Do note that we have the option of using absolute or relative modes of reporting.

2. Displacement
   - Recall: Displacement is the amount of movement along the x-axis and z-axis
   - Each sample is reported relative to the last sample. For example, a mouse.
3. Force

12.9 Property Sensing: Order of Control

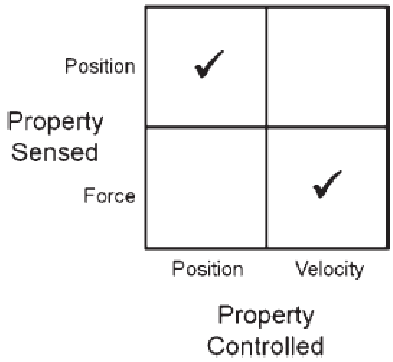
- Position-Control (Zero-Order Control)
  - The most common order of control
  - The sensed property of the input device controls the position of the object or view on a display
  - E.g., Mouse (Controls the Cursor Position)
- Velocity-Control (First Order)
  - The sensed property controls the velocity of the object or view

12.10 Order of Control: Two Types of Joysticks

1. Isotonic (Displacement)
   - User manipulates the stick handle, which, in turn, swivels about a pivot-point
   - The output signal represents the position of the stick as the amount of displacement from the neutral or home position about the x- and z-axis.
2. Isometric (Force)
   - The stick does not move
   - The property sensed is the force applied to the stick
   - The output signal represents the amount of force along the x-axis and z-axis.

Note: For natural, and preferred mappings, Position control is best for a position-seeking device, and velocity-control is best for a force-sensing device.

We can get a visual summary!



12.11 Latency and Human-Computer Interaction

- Human interaction with computers is a two-way structure:
  - As participants in a closed-loop system, we issue commands through input controllers and receive responses on output displays.
  - Subsequent input depends on the latest output
- Human performance and an interaction experience are adversely affected when feedback is delayed.
- The delay between an input action and the corresponding response on a display is called latency or lag.
- Latency is negligible in many interactive computer tasks, such as typing or cursor positioning:
  - 150 ms in VOIP Calls
  - 100 ms in Online Games
- Note: In VR, latency over 20 ms causes motion sickness. We need a minimum of 60 Hz Frame Rate (60 FPS), which has a minimum delay of 17 ms.
- Latency is substantial in remote manipulations and applications. For example, controlling a Space Vehicle has latency due to mechanical linkages, communication channels, etc.,
- Frustration with latency is reduced if the interface includes feedback informing the user that the network is processing the request (i.e., Internet and the Status Feedback Feature)

12.11.1 Causes of Latency

- Input Devices
  - Input devices are usually sampled at fixed rates in the range of 10 to 60 samples per second
- Output Devices
  - 10 Hz Display Rate is the minimum speed requirement to achieve real-time animation
- Software Overhead and System-Related Factors
  - Communication Modes
  - Network Configuration
  - Number Crunching
  - Graphics Rendering
- Low latency is significantly more important than high-quality graphics or stereoscope
- Latency is difficult to measure within a target system, hence it is done externally

12.12 Natural versus Learned Control-Display Relationships

- Natural
  - Makes use of Physical Analogies
  - The System's Controls correspond to the Desired Responses and User Expectations
  - Universal (Independent of a Culture)
- Learned
  - When there is a spatial transformation mapping
  - May be expected and considered correctly by a given Population Stereotype or Cultural Standard

12.13 Mental Models and Metaphors

12.13.1 Mental Model (Conceptual Model)

- Perception of how a system works
- A physical understanding of a UI or interaction technique, based on a real-world experience.
- Corresponds from the User POV

12.13.2 Metaphor

- Mimic of system interaction using real-world analogies
- Facilitates mental model of interactions that are easily learned
- Reduces the Gulf of Execution
- Corresponds from the User POV

12.13.3 Implementation Model

- Interactions are imposed on the user (Should be avoided)
- Based on what is easiest for system implementation, rather than user interaction
- Unlike a Mental Model

12.14 Gulf of Execution

- The disparity between users expectations and what the system allows them to do
- The degree to which the action possibilities of a given system match the user's intended action or mental model
- High Degree = Well-Designed Controls

12.15 Metaphor Examples

1. Scroll Pane (Slider Up, View Up)

   - "Up-Up" $\rightarrow$ A conceptual model that helps our understanding

2. Desktop GUI (Most Common Metaphor)

3. Other Commonly Exploited Real-World Experiences:

    - Shopping Cart

    - Calendar

    - Painting

4. Icon Design

    - Icon design strives to foster mental models
    - Icons trigger a mental image in the users mind. Each button is associated with a function and its icon is carefully chosen to elicit the association in the users mind.

12.16 Modes

- Modes are everywhere, and unavoidable
- Modes have two particular main issues insofar as:
    - Changing modes is unintuitive
    - Lack of Feedback
- There are two kinds of modes:
    - Space Multiplexing: A dedicated physical control for each parameter that is controlled. Each control has a separate physical location with a one-to-one mapping.
    - Time Multiplexing: Has fewer controls than parameters. The same hardware is used for multiple controls and it requires the least space in hardware in trade for a combination of actions to perform your goals.

12.16.1 Solution to Poor Feedback

- Making a modde apparent to the user is a long-standing principle in user interface design. The issue is the quality of the feedback to the user. We can solve this by:
    - Offer Informative Feedback → Shneiderman
    - Make Things Visible → Norman

12.17 Degrees of Freedom

- There are six parameters or degrees of freedom (DOF)
  - Each parameter may be manipulated independently of the others.
  - Most input devices track motion on the x-y plane (2 DOF)
  - Some input devices track in 3D space, along x, y, and z axes (3 DOF)
  - To fully place an object in 3D space, six parameters are required
- In terms of rotations, aircrafts have made synonymous names to the axes:
  - $Pitch(p) \rightarrow x$
  - $Roll(r) \rightarrow y$
  - $Yaw(y) \rightarrow z$
- A case study is the Rockin' Device. A mouse with a rounded bottom which supports rotations on the x and z axes.

12.18 Transition to Touch Interfaces

- Direct touch is the full embodiment of WYSIWYG interaction
- Pressing keys on small keyboards or gesturing with a stylus gave way to finger actions. These finger actions include Swiping, Flicking, Pinching, Tapping, Tilting, etc.,
- Do note that Direct pixel-level selection is difficult. Users typically do not know, and cannot control the precise location of the contact point, because of the Fat Finger Problem:
  - The finger occludes the location of contact
  - Finger contact forms an area, not a point
  - The size and shape of the contact area varies from user to user, and also by usage patterns, such as the force applied or the reach of the arm.

13 For access to the remaining notes, please contact me over LinkedIn or GitHub!