1.1 – Interaction Between Humans and Computer Systems

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1.1.1 – Introduction to HCI

1. Importance of Designing for Users

- **User-Centric Design:** Systems should align with users' day-to-day activities.
- **Design Challenges:** Designing systems that are reliable, consistent, and user-friendly is complex.
- **Regulatory Requirements:** National health and safety requirements mandate that systems be safe, functional, and adjustable to user needs.

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2. History and Evolution of HCI

- **Early Research:**
  - **Early 20th Century:** Focus on physical labor and human performance in factories.
  - **WWII:** Research in human-machine interaction due to advancements in weaponry.
  - **1949:** Establishment of the Ergonomics Research Society.
- **Ergonomics vs. Human Factors:**
  - **Ergonomics:** Focus on physical device attributes and user performance.
  - **Human Factors:** Includes cognitive aspects; used interchangeably with Ergonomics in different regions.
- **Shift to HCI:**
  - **Information Science and Technology:** Impacted HCI with advancements in information storage and access.
  - **Terminology Evolution:** "Human-Machine Interaction" to "Human-Computer Interaction" reflecting a specific focus on computers.

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3. UX Design

- **Definition:**
  - **User Experience (UX) Design:** Encompasses all aspects of user interaction with a product, including usability, aesthetics, and performance.
- **Importance:**

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- **User Retention:** Good UX is crucial for maintaining user engagement and satisfaction.
- **Business Impact:** Positive UX can lead to increased revenue and customer loyalty.

- **Key Aspects of UX Design:**
    - **Utility:** Meeting practical needs.
    - **Desirability:** Visual appeal.
    - **Practicality:** Intuitive interface.
    - **Availability:** Accessibility for all users.
    - **Sturdiness:** Support and problem resolution.
    - **Authenticity:** Reliability and trust.

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4. UX Design Components

- **User-Centered Design:** Prioritizing user needs and preferences.
- **Usability:** Ensuring effectiveness and ease of use.
- **Information Architecture:** Structuring data for user navigation.
- **Visual Design:** Aesthetic and brand consistency.
- **Prototyping:** Testing design concepts.
- **User Research:** Understanding user preferences and issues.
- **Accessibility:** Inclusive design for diverse abilities.
- **Wireframing:** Creating low-fidelity models of user interfaces.
- **Interaction Design:** Facilitating meaningful user interactions.

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5. Usability Principles

- **Learnability:** Ease of learning the product.
- **Efficiency:** Minimizing effort and time.
- **Memorability:** Ability to recall usage after a break.
- **Error Prevention and Recovery:** Minimizing and correcting errors.
- **Satisfaction:** Overall positive user experience.

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6. Interaction Models

- **Command-Line Interface (CLI):** Text-based commands.

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- **Graphical User Interface (GUI):** Visual elements like buttons and icons.
- **Natural Language Interface:** Conversational interaction.
- **Touch-Based Communication:** Using gestures on touchscreens.
- **Augmented Reality (AR):** Interaction with digital elements in the physical world.

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7. Evolution of HCI

- **Early Computing (1940s-1950s):** Limited to punch cards and command-line interfaces.
- **Mainframe and Terminal Computing (1960s-1970s):** Introduction of text-based terminals.
- **Personal Computing (1980s):** Rise of personal computers and GUIs.
- **Mouse and Pointing Devices (1980s):** Adoption of pointing devices.
- **World Wide Web (1990s):** Introduction of web browsers and hyperlinks.
- **Ubiquitous Computing (1990s-2000s):** Embedding computing in everyday objects.
- **Mobile Computing (2000s-Present):** Rise of smartphones and touchscreens.
- **Social Media and Collaboration (2000s-Present):** Transformation in communication and collaboration.
- **Gesture-Based Interfaces (2010s-Present):** Interaction through natural movements.
- **Voice and Conversational Interfaces (2010s-Present):** Voice recognition and virtual assistants.
- **Explainable AI and Ethical Considerations (Present-Future):** Focus on transparency, trust, and inclusivity in AI systems.

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1.1.2 - Input and Output Channels in Human-Computer Interaction (HCI)

Human-Computer Interaction (HCI) involves the transfer of information between users and computers, where the concepts of input and output channels play a crucial role. Understanding these channels—sight, hearing, touch, visual, and angle—helps in designing effective and intuitive interfaces.

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1. Sight

Role in HCI: Sight is the primary channel through which users receive information from a computer. It includes the visual display of data, graphics, and user interfaces.

Physical Basis:

- **Human Eye Structure:** Light enters through the cornea, is focused by the lens, and projected onto the retina. The retina contains photoreceptors (rods and cones) that convert light into electrical signals.
  - **Rods:** Sensitive to low light but cannot detect fine detail.
  - **Cones:** Responsible for color vision and fine detail, concentrated in the fovea.

Visual Perception:

- **Size and Depth Perception:** Size constancy helps perceive objects as having a consistent size despite varying distances. Depth cues like overlap, relative size, and familiarity contribute to understanding object positioning.
- **Brightness:** Perceived brightness is influenced by luminance (the amount of light) and contrast between an object and its background.
- **Color Perception:** Determined by the wavelength of light. The human eye can perceive around 150 hues, but color blindness affects 1% of women and 8% of men, often limiting red-green differentiation.

Processing Challenges:

- **Optical Illusions:** Our visual system can be tricked by illusions (e.g., the Ponzo illusion) due to how it interprets depth and size.
- **Reading:** Involves detecting visual patterns, decoding language, and processing text. Factors like font size, line spacing, and contrast affect readability.

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2. Hearing

Role in HCI: Hearing is crucial for auditory feedback, alerts, and multimedia content. It helps users perceive sounds related to system status or notifications.

Physical Basis:

- **Ear Structure:** Sound waves enter through the outer ear (pinna and auditory canal), cause vibrations in the middle ear (ossicles), and are transmitted to the inner ear (cochlea).
  - **Cochlea:** Contains hair cells that convert sound vibrations into electrical impulses for the brain.

Sound Processing:

- **Frequency and Pitch:** High frequencies correspond to high pitches and vice versa.
- **Amplitude:** Determines loudness.
- **Timbre:** Differentiates sound sources (e.g., a violin vs. a piano playing the same note).
- **Localization:** Sound direction and distance are inferred from timing differences and intensity changes between ears.

Applications in HCI:

- **Alerts and Notifications:** Can signal system states or user actions.

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- **Multimedia:** Enhances user experience through music, voice commentary, and sound effects.

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3. Touch

Role in HCI: Touch provides tactile feedback and helps users interact with devices through physical contact. It is essential for applications like virtual reality and accessibility tools.

Physical Basis:

- **Mechanoreceptors:** Detect pressure and texture changes. They include rapidly adapting receptors (respond to quick changes) and slowly adapting receptors (respond to sustained pressure).
- **Kinesthesia:** Awareness of body and limb positions through joint receptors.

Applications in HCI:

- **Haptic Feedback:** Used in touchscreens and other devices to provide physical feedback (e.g., vibrations or texture sensations).
- **Accessibility:** Touch-based interfaces, like Braille displays, assist users with visual impairments.

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4. Visual and Angle

Visual Angle:

- **Definition:** The visual angle refers to the size of an object's image on the retina, determined by the object's size and distance from the observer.
- **Measurement:** Expressed in degrees or minutes of arc, affecting how we perceive object size and detail.

Applications in HCI:

- **Design Considerations:** Interface elements need to be sized appropriately based on their visual angle to ensure they are legible and accessible.
- **Depth and Perspective:** Understanding visual angles helps in designing three-dimensional interfaces and virtual environments.

Summary

In HCI, understanding how sight, hearing, touch, and visual angles function is crucial for creating effective and user-friendly interfaces. Sight primarily serves as the main source of information display, hearing provides auditory feedback and alerts, touch enables physical interaction and feedback, and visual angles influence how information is perceived in terms of size and depth. Integrating these channels thoughtfully ensures that computer systems are accessible, efficient, and engaging for users.

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1.1.3 - Memory: Sensory, Short Memory and Long Term Memory

Sensory Memory

- **Types:**
  - **Iconic Memory:** Brief retention of visual stimuli (e.g., the afterimage of a sparkler).
  - **Echoic Memory:** Brief retention of auditory stimuli (e.g., recalling a question someone asked you).
  - **Haptic Memory:** Retention of tactile information.

- **Function:** Sensory memory acts as a buffer, capturing raw sensory information for a very short period before either discarding it or passing it to short-term memory.

Short-Term Memory (Working Memory)

- **Function:** Serves as a temporary storage system for information that is currently being used or processed.
- **Duration:** Information lasts about 200 milliseconds if not actively rehearsed.
- **Capacity:** Generally able to hold 7 ± 2 items (Miller's Law). Information can be grouped into chunks to improve retention.
- **Chunking:** Organizing information into meaningful groups (e.g., remembering phone numbers by chunks).

Long-Term Memory

- **Function:** Stores information over extended periods, potentially indefinitely.
- **Capacity:** Considered to be vast, possibly infinite.
- **Types:**
  - **Semantic Memory:** Knowledge about the world, facts, and concepts.
  - **Episodic Memory:** Personal experiences and events.
  - **Procedural Memory:** Knowledge of how to perform tasks or skills.
- **Encoding:** Information is transferred from short-term to long-term memory through rehearsal and meaningful association.
- **Retrieval:** Involves either recall (retrieving information without cues) or recognition (identifying previously learned information).

Memory Processes

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- **Storage:** The process of retaining information in long-term memory.
- **Retrieval:** Accessing stored information, which can be facilitated by retrieval cues like categories or vivid imagery.
- **Forgetting:** Theories include:
    - **Decay Theory:** Information fades over time.
    - **Interference Theory:** New information can interfere with the retrieval of old information (retroactive interference) or old information can block the retrieval of new information (proactive interference).

Models of Memory

- **Semantic Networks:** Represent knowledge as interconnected concepts, which helps in understanding relationships between different pieces of information.
- **Frames and Scripts:** Structured representations that organize knowledge about objects and events, respectively.

Memory Enhancement Techniques

- **Distributed Practice:** Spacing out learning sessions (practice effect distribution) helps with retention.
- **Meaningful Learning:** Information is easier to remember when it is meaningful and can be related to existing knowledge.

Memory Challenges

- **Forgetting:** Can be influenced by interference and decay, and is sometimes related to retrieval difficulties rather than actual loss of information.
- **Selective Memory:** Emotional experiences tend to be remembered more vividly than neutral ones.

Memory, with its layers and intricacies, not only helps us navigate daily life but also shapes our identities and experiences. Understanding how it functions and how to optimize it can be incredibly valuable.

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1.1.4 - Reasoning and Problem Soling

Introduction

We've explored how data enters, exits, and is stored in the human body. Now, we turn to how this information is manipulated and processed—an aspect that sets humans apart from other information-processing systems. Unlike animals and artificial intelligence, which handle information in more limited ways, humans can reason and solve problems even with incomplete or ambiguous information. This is a result of our conscious and self-aware cognition, enabling us to tackle new and unfamiliar problems. But how do we achieve this?

Reasoning

Reasoning is the process of using existing knowledge to draw new conclusions or make new deductions. It comes in three primary forms:

1. **Deductive Reasoning**
2. **Inductive Reasoning**
3. **Abductive Reasoning**

Deductive Reasoning

Deductive reasoning involves drawing conclusions that are logically necessary based on the given premises. For example:

- Premise 1: If it is Friday, then she will go to work.
- Premise 2: It is Friday.
- Conclusion: Therefore, she will go to work.

The accuracy of deductive reasoning is dependent on the validity of the premises. If the premises are true and the reasoning is valid, the conclusion must also be true. However, if the premises are false or not fully accurate, the conclusion can also be misleading.

For instance:

- Premise 1: If it is raining, then the ground is dry.
- Premise 2: It is raining.
- Conclusion: Therefore, the ground is dry.

This is a logically valid deduction, but it is factually incorrect because we know that rain makes the ground wet. This highlights the importance of the premises' truth in deductive reasoning.

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Inductive Reasoning

Inductive reasoning involves making generalizations based on specific observations. For example, if every elephant you have ever seen has a trunk, you might conclude that all elephants have trunks. This type of reasoning is inherently probabilistic and not guaranteed to be correct; a single counterexample (e.g., an elephant without a trunk) can disprove the generalization. Inductive reasoning is often used because it allows us to form hypotheses and make predictions based on observed patterns, even though it cannot guarantee absolute certainty.

A classic example of an inductive reasoning experiment is Wason's card selection task, which tests the hypothesis "If a card has a vowel on one side, it has an even number on the other." To test this hypothesis, you need to check:

- The card with the vowel (to ensure it has an even number on the other side).
- The card with an odd number (to ensure it does not have a vowel on the other side).

Abductive Reasoning

Abductive reasoning involves inferring the best explanation for a set of observations. It is often used to generate hypotheses based on incomplete data. For example:

- Observation: Sam consistently drives too quickly after drinking.
- Inference: Sam has likely been drinking if we see her driving too quickly.

Abduction is valuable for generating plausible explanations, but it can be fallible as it relies on the best available explanation rather than absolute proof. This type of reasoning is often used in everyday life and problem-solving contexts, but it can lead to errors if alternative explanations are not considered.

Problem Solving

Problem solving involves applying knowledge to overcome challenges and achieve goals. It can be characterized by:

1. **Gestalt Theory**
2. **Problem Space Theory**
3. **Analogical Reasoning**

Gestalt Theory

Gestalt psychology suggests that problem-solving involves insight and the restructuring of knowledge. Insight is the sudden realization of a solution, and restructuring involves reinterpreting the problem from a new perspective. Gestalt psychologists believed that problem-solving often requires breaking free from conventional thinking patterns, as demonstrated by experiments like

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Maier’s pendulum problem, where participants needed to view the problem differently to find the solution.

However, Gestalt theory has limitations. It does not clearly define how insight occurs or when restructuring happens, leading to its partial replacement by more structured theories.

Problem Space Theory

Newell and Simon’s problem space theory conceptualizes problem-solving as navigating through a "problem space" with various states and transitions. The problem space consists of:

- **Initial State**: The starting point.
- **Goal State**: The desired outcome.
- **Operators**: Actions that transition from one state to another.

Heuristics, such as means-ends analysis, are used to navigate this space efficiently by reducing the difference between the current state and the goal state. For example, if moving a desk involves obstacles, breaking down the problem into subgoals (like making the desk lighter) is a way to solve it.

Analogical Reasoning

Analogical reasoning involves applying knowledge from a familiar domain to a new, but analogous, problem. For example, the solution to a problem involving radiation and a tumor was understood more easily when presented through an analogous story about a general attacking a fortress. Analogies help in transferring knowledge from known scenarios to new challenges.

Skill Acquisition

Skill acquisition is the process of becoming proficient in a specific domain through practice and learning. The ACT* model describes this process as progressing through three stages:

1. **Declarative Knowledge**: Understanding general rules and facts.
2. **Procedural Knowledge**: Developing specific procedures for applying these rules.
3. **Automaticity**: Performing tasks efficiently and with minimal conscious effort.

For instance, a chess player might initially learn the rules and strategies of chess (declarative knowledge), then develop specific strategies and moves (procedural knowledge), and finally, play intuitively and rapidly without deliberate thought (automaticity). This progression involves proceduralization (simplifying and automating rules) and generalization (abstracting common principles).

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Conclusion

Human reasoning and problem-solving involve a complex interplay of different cognitive processes. Deductive, inductive, and abductive reasoning each play unique roles in how we draw conclusions and generate explanations. Problem-solving theories, including Gestalt theory, problem space theory, and analogical reasoning, provide frameworks for understanding how we tackle and resolve issues. Skill acquisition models, like ACT*, highlight how expertise develops over time, transforming general knowledge into highly specialized, efficient problem-solving abilities.

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