MAI4CAREU

Master programmes in Artificial Intelligence 4 Careers in Europe

University of Cyprus

HUMAN-CENTERED INTELLIGENT USER INTERFACES - MAI648

Marios Belk

2022

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CONTENT 2

Human-Computer Interaction Principles

CONTENTS

- Introduction to HCI
- History of HCI
- Studying HCI
- Popular Models in HCI
- Mental Models
- Metaphors
- Visual Affordance
- Conceptual and Ideal Models
- User Interaction
- Usability

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CONTENT 2

Learning Outcomes

- Understand the main principles of human-computer interaction
- Learn how to design usable interactive systems
- Name the core components of a human-centered intelligent user interface

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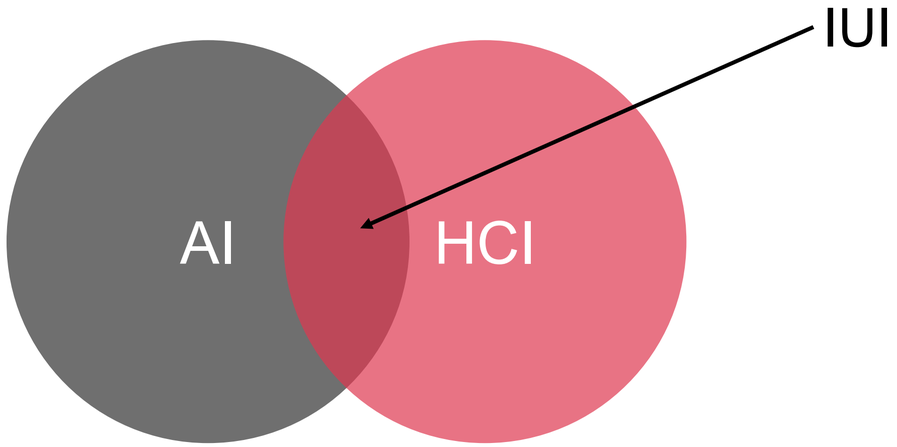
Intelligent User Interfaces

- IUI falls within the intersection of **Artificial Intelligence** and **Human-Computer Interaction** aiming to design and develop more efficient and effective user interfaces through the use of intelligent computation methods



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CONTENT 2

Mini Discussion – What is Artificial Intelligence?

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Mini Discussion

- What is Artificial Intelligence?
- *Artificial intelligence (AI) is intelligence demonstrated by machines. AI research has been defined as the field of study of intelligent agents, which refers to any system that perceives its environment and takes actions that maximize its chance of achieving its goals - Wikipedia*

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Machine Learning

- Branch of Artificial Intelligence
- Method of data analysis that automates analytical model building
- Systems can learn from data, identify patterns and make decisions

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Why is Machine Learning Important in IUI?

Classification

- Derive meaning from complicated or imprecise data, extract patterns
- Map a data item to a predefined class
  - By considering the visual behavior of users, classify them as Wholists or Analysts
- Understand existing data as well as predict how new instances will behave

Clustering

- Group users with similar characteristics (e.g., common browsing activity)
- Recommend items from other users to new users that belong to the same cluster

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Discussion: Examples of Supervised and Unsupervised Approaches

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Human-Computer Interaction

- The scientific area of Human-Computer Interaction (HCI) **studies our interaction with computers**
- It gives an emphasis on the requirements' analysis, design, development evaluation interactive computer systems, *i.e.*, systems that interact extensively with their users [ACM SIGCHI 1992]

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ACM SIGCHI - Special Interest Group on Computer-Human Interaction

- The ACM Special Interest Group on Computer-Human Interaction is the world's largest association of professionals who work in the research and practice of computer-human interaction
- An interdisciplinary group of computer scientists, software engineers, psychologists, interaction designers, graphic designers, sociologists, multi-media designers, and anthropologists
- Aiming to have a shared understanding that designing useful and usable technology is an interdisciplinary process, and when done properly it has the power to transform persons' lives

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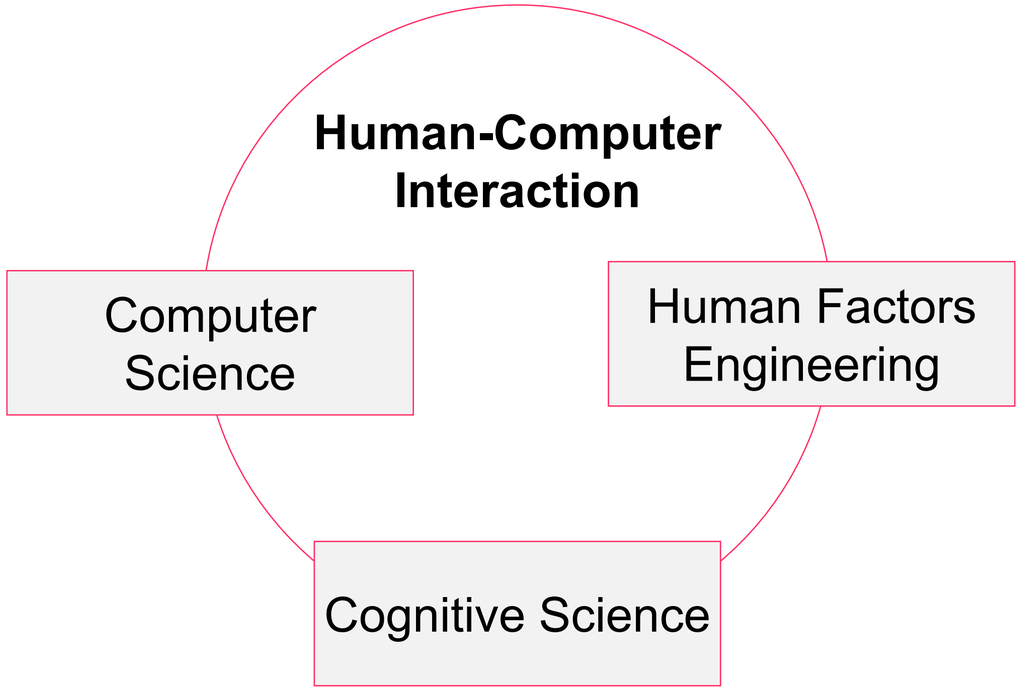
Multi-disciplinary Field of HCI



https://www.interaction-design.org/literature/topics/human-computer-interaction

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HCI – A Historical Perspective

- **1980s:** Researches and practitioners understood the need to study how users interact with computer with the arrival of personal computing
  - machines like the Apple Macintosh, IBM PC 5150 and Commodore 64 were used in homes and offices
- Computers were available to general consumers, for gaming, accounting, calculations etc.

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HCI – A Historical Perspective

- Researchers and practitioners investigated in the field of HCI
- In the beginning, researchers focused on improving the usability of desktop computers (*i.e.*, practitioners concentrated on how easy computers are to learn and use).
- With the rise of technologies, Internet, smartphones, XR technologies, and the increase of users and data, HCI embraced aspects beyond the desktop computer towards mobile and heterogenous devices
- HCI includes more fields today

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- *"…it no longer makes sense to regard HCI as a specialty of computer science; HCI has grown to be broader, larger and much more diverse than computer science itself. HCI expanded from its initial focus on individual and generic user behavior to include social and organizational computing, accessibility for the elderly, the cognitively and physically impaired, and for all people, and for the widest possible spectrum of human experiences and activities. It expanded from desktop office applications to include games, learning and education, commerce, health and medical applications, emergency planning and response, and systems to support collaboration and community. It expanded from early graphical user interfaces to include myriad interaction techniques and devices, multi-modal interactions, tool support for model-based user interface specification, and a host of emerging ubiquitous, handheld and context-aware interactions."*
- *— John M. Carroll, author and a founder of the field of human-computer interaction*

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Societal Impact of HCI

- Large social impacts - *e.g.* systems in critical functions

- What examples can you think of?

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Why do we need theory in Human-Computer Interaction?

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Why do we need theory in Human-Computer Interaction?

- Interacting with computers is a cognitive process
- To explain and predict the behaviour of people when communicating with computers, it is necessary to take into account the cognitive processes that are triggered
- Understand the limitations in terms of users' perceptual capabilities

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Why do we need theory in Human-Computer Interaction?

- There is a need for evidence-based knowledge of what users are expected to be able to do and what they are not expected to be able to do
- In order to identify the causes of the problems that users encounter when using computer systems
- We need to develop tools and methods for the design of interactive systems with a focus on human-centered design

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HCI

- Understand the human
- Understand the computer

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The Human Aspect in HCI

- **Cognitive Psychology**
- Study and understand the functions of humans when they react to stimuli triggered by cognitive processes
- Study and understand the process by which they take actions to achieve their goals

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Popular HCI Models

- Human Processor Model – HPM
- Norman's Model of Interaction

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Human Processor Model - HPM

- A cognitive modeling method used to calculate how long it takes to perform a certain task
- Explains human behavior by modeling humans as *“information processors”*

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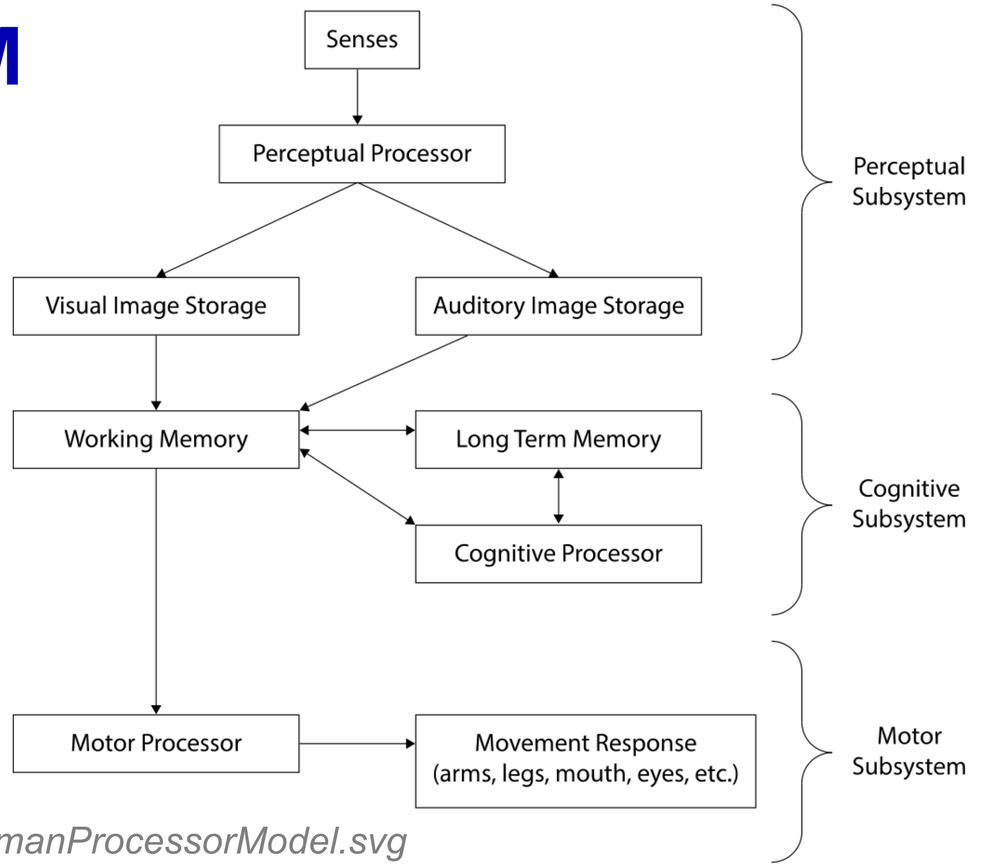
Human Processor Model - HPM



https://en.wikipedia.org/wiki/Human_processor_model#/media/File:HumanProcessorModel.svg
Public Domain, https://commons.wikimedia.org/w/index.php?curid=75184457

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The Role of Human Memory in HPM

- Human memory plays a crucial role in the model
- Three types of memory
  - *Sensory memory:* acoustic and visual memory, which preserves its information for milliseconds
  - *Short-term memory or working memory:* In this memory the information is preserved for a few seconds
    - Relevant experiments have shown that the number of items that can be retained in short-lived memory is 7 +/- 2
  - *Long-term memory:* Information is preserved for a long time like knowledge, experiences etc

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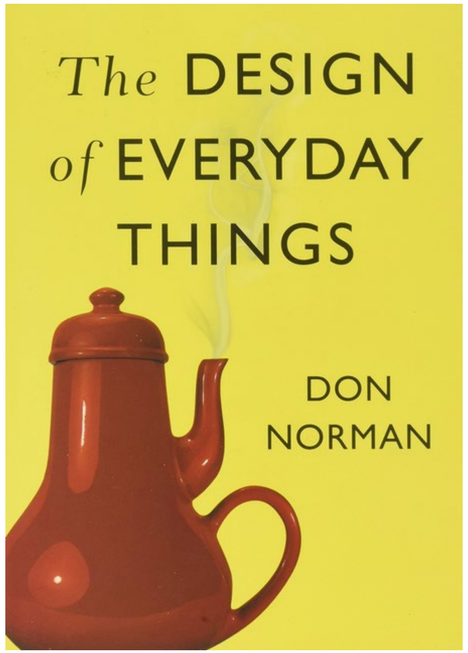
Norman's Model of Interaction

- Aims to model how people act when they are interacting with objects in the world to achieve goals
- Known as "The Seven Stages of Action", or "Norman's Action Cycle"
- Reported in Donald Norman's book "The Design of Everyday Things"



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Norman's Model of Interaction

1. Setting the next goal 2. Forming an intention to act 3. Identifying and selecting a sequence of actions 4. Execute sequence of actions – *physical action*	**Execution part**
5. Perception of the new situation 6. Interpretation of the situation 7. Evaluation of the outcome. Is the evaluation successful?	**Evaluation part**

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Example of everyday interactions with the world?

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Example of everyday interactions with the world?

- 1) My goal is going to a cafe across the street
- 2) I form the intention of crossing the street to reach the cafe
- 3) I select the action to press the button of the crosswalk signal for crossing the street
- 4a) I actually do press the button of the crosswalk signal (physical action)
- 4b) I do cross the street (physical action)
- 5) I perceive that I'm now across the street
- 6) I interpret this perception and..
- 7) …evaluate the outcome – was this action successful in moving closer to my goal? (Y/N)

Source: https://www.guerillagirl.de/2017/03/18/seven-stages-of-action-don-norman/

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Norman's Model of Interaction

- Norman's model of interaction can provide insights on when a system can fail or create difficulties
- It can help create designs to support users in achieving their goals
  - *e.g.*, make options visible for helping in the execution part
  - provide feedback for helping in the evaluation part
- "Gulf of execution" or "gulf of evaluation", according to Donald Norman

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Norman’s Model of Interaction

- Repeated cycle
- Allows the integration of more detailed, empirical and analytical work into a common framework
- Focuses only on the user's view of the interaction
- Does not attempt to deal with system communication via interface

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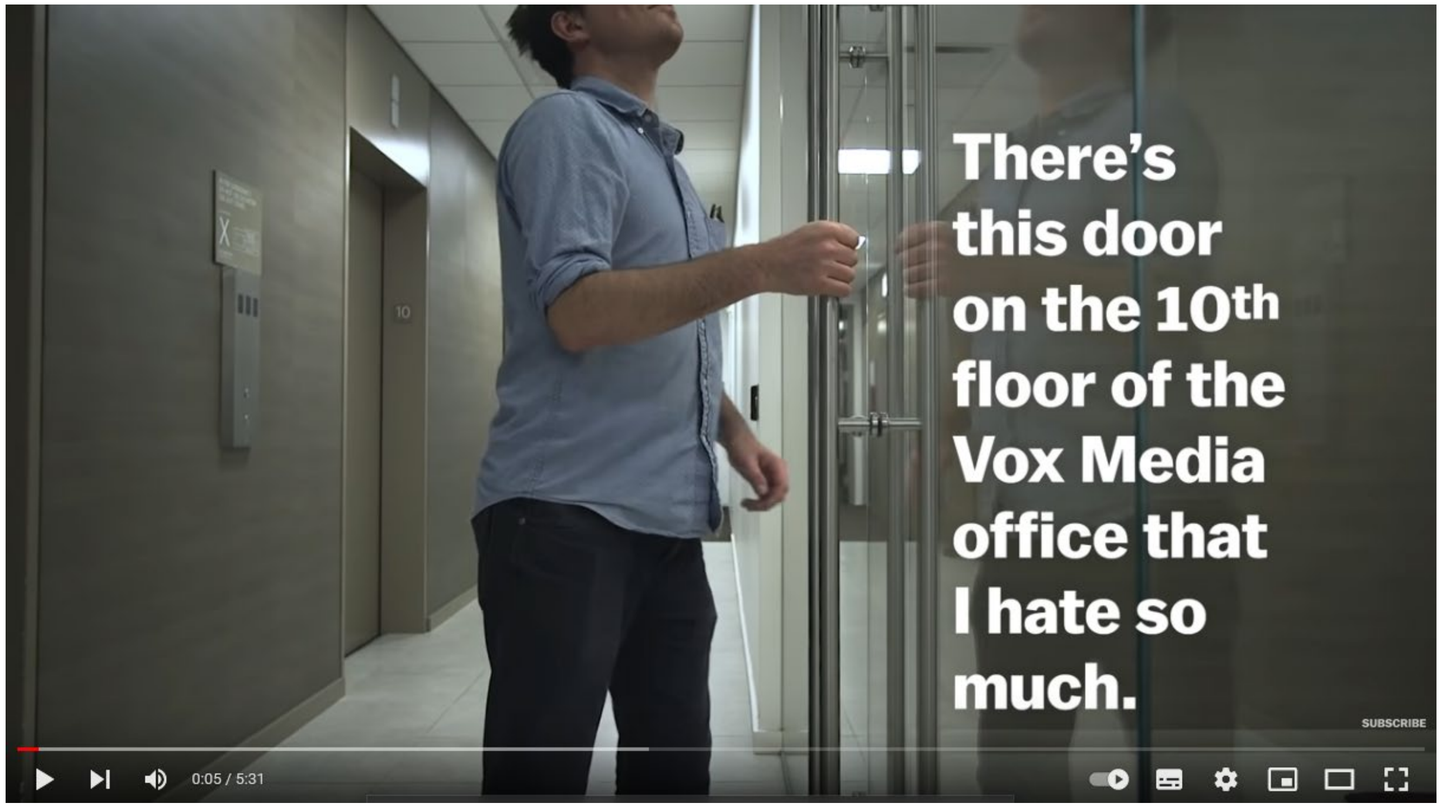
Bad Doors



https://www.youtube.com/watch?v=yY96hTb8WgI

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CONTENT 2

HCI

- Understand the human
- Understand the computer

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Why study interaction devices?

- We need to know what information goes in and out from the computer
  - In terms of input/output devices, sensors

- We need to know what computers can it do
  - In terms of memory, processing, networks

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Computers today are everywhere

- **At home**
  - PC, smart TV
  - microwave, washing machine
  - central heating
  - security system
- **In your pocket**
  - smartphone
  - electronic car key
  - USB memory

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Input Devices

- Text input
  - Computer keyboards
  - Special keyboards, like keyboard for school-age children
- Pointing devices
  - Mice
  - Joystick
  - Touch screens
- Text, handwriting, voice recognition

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Output Devices

- Image and Video Imaging Units
- Printers
- Sound

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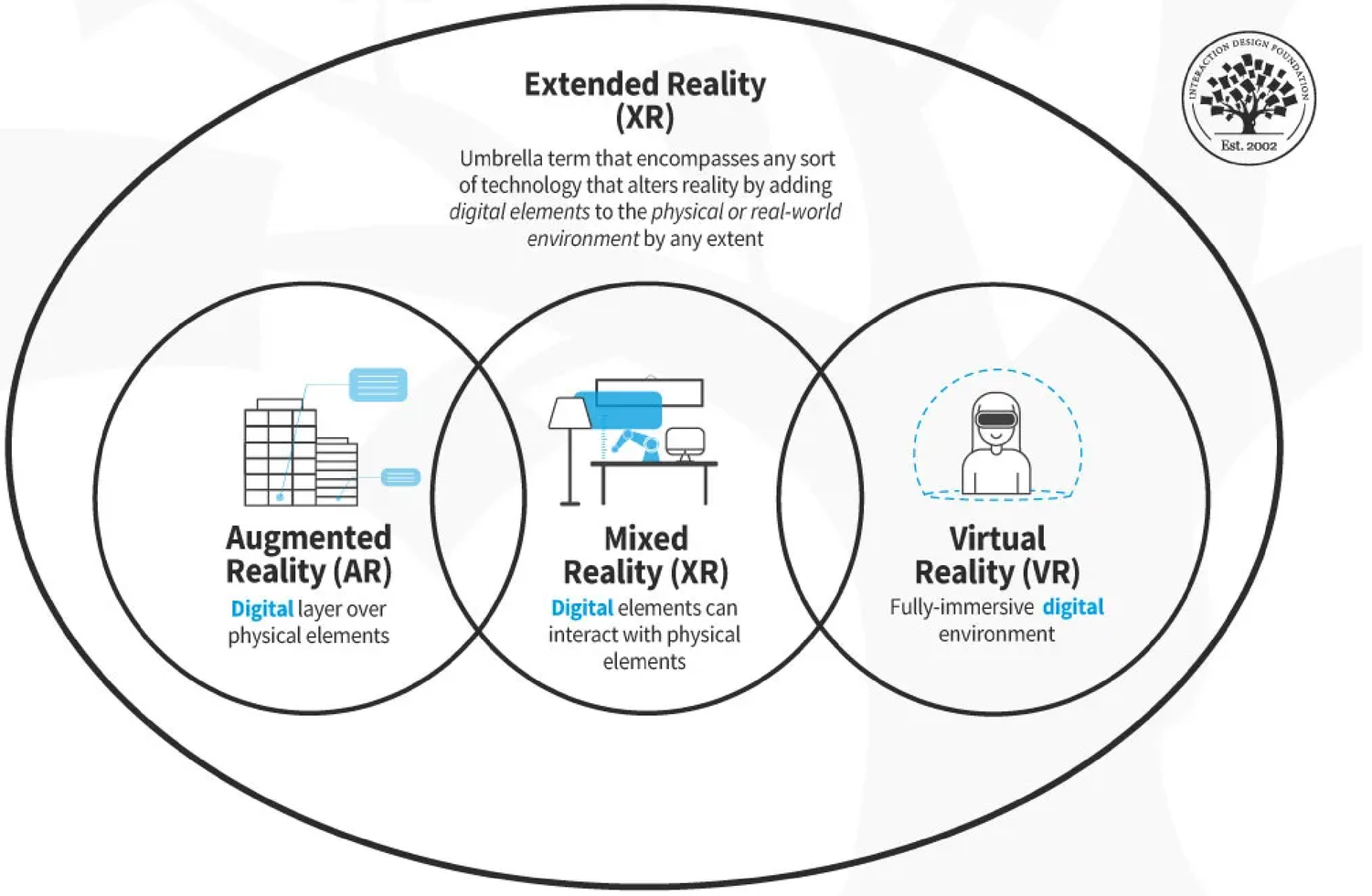
Extended Reality



https://www.interaction-design.org/literature/topics/extended-reality-xr

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https://www.microsoft.com/en-us/hololens

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Mental Models

- Mental representations of reality
- Used so that we can predict the usage of computing devices
- Can help to develop ways to solve problems and test alternatives
- Main categories
  - Structural Models
  - Functional Models

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Structural Models

- Models that describe the structure and operating principle of a system or device
- Can be useful in case the system does not work well
- Engineers and designers must have good knowledge of the respective structural models of these systems

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Functional Models

- Models that do not describe the exact structure of systems but the functions
- In many cases they are created by transferring a user's experience from another device or knowledge area
- With the widespread spread of technology (and the plethora of systems that surround us), users are limited to knowing only the functional models of systems

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Incorrect Mental Models

- Many people have incorrect mental models
- Why?
- Generalization for different settings
- General valve theory, where “more is more” principle is generalised to different settings (*e.g.*, gas pedal, gas cooker, radio volume)

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Incorrect Mental Models

- For example, in a lift or pedestrian crossing
- Often we press the button twice
- Why?
  - Because we think it will make the green lights turn on faster, the elevator will move down faster

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Metaphors

- The system's interface is designed to represent physical entities with which the user is familiar
- In this way the user can predict the use of the system
- In essence, the user builds the correct ideal model for the system
- Enables large-scale use of computing systems

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Metaphors - Challenges

- Finding suitable metaphors is not always easy
- The metaphor in a two-dimensional space can break cultural and ethical rules (*is it possible to place the recycling bin on the desk?*)
- It forces users to understand the system only through the metaphor and ignore important functions that are not clearly represented by the metaphor
- Limit design creativity in terms of developing new conceptual models for users
- Inadequate or poor metaphors are perpetuated by their widespread use

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Visual Affordance

- Characteristics of an object indicating its correct use based on its appearance
- Examples
  - Chair: sitting
  - Table: place objects on the table
  - Computer: ?
- For simple objects, their use should be self-evident
- Complex objects and systems may need instructions for use

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Conceptual Models

- All the relevant mental models involved in the design phases of developing and operating a computing system
- The different ways in which the system is perceived by its designers and end-users
- Two categories
  - Designer Models
  - User Models

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Designer Models

- Designer models or system models are the mental models that designers develop of the system and the future user's interaction with it
  - structural and functional models

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User Models

- User models are the mental models that the user ultimately develops when learning and using the system
  - functional models

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Ideal Models

- According to the principles of human-centered design, the mental models of the designer and the user should be coupled as much as possible
- Since the user forms an image of the system mainly through the user interface, it is evident how important it is to design ideal models for the implementation of successful interactive systems

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How do we guide the user to create the right ideal model?

- Use the correct interface metaphor if possible - *metaphors*
- Provide visual objects whose use is inferred from their form - *visual affordance*
- Use the correct visual mapping of tools - controls to functions - *visual mapping*
- Use constraints on possible user actions to protect against errors - *constraints*
- Provide effective information about the state of the system after each meaningful user action - *causality of interaction*

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Visual Mapping

- Relationship between controls and their actions
- Cause – effect
  - Like turning the steering wheel to the left leads to turning the car to the left
- Other examples
  - Oven knobs

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Constraints

- Visual limitations: Limitations on possible actions as inferred from the appearance of objects
- Examples in real life: cables

- *Can you think of constraints in interactive system design?*

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Causality

- Anything that takes place immediately after a user's action is perceived by the user as the result of the action
- Interpretation of system feedback: The user tries to interpret the result of the action.
  - This information must always be given to the user
- Incorrect system causality leads to confusion for users
- Invisible effects lead to repeated execution of actions

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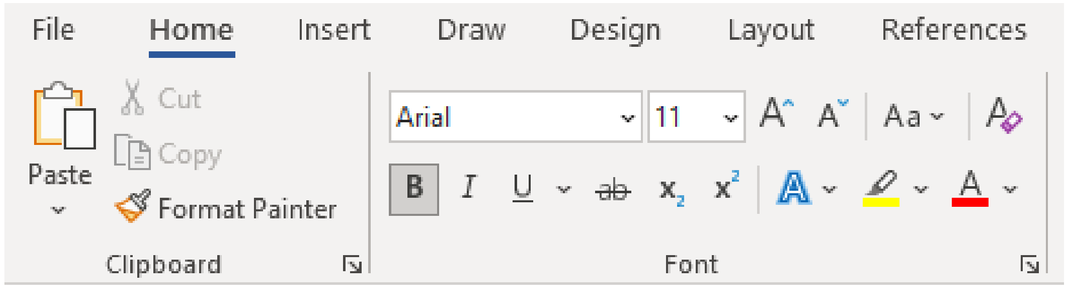
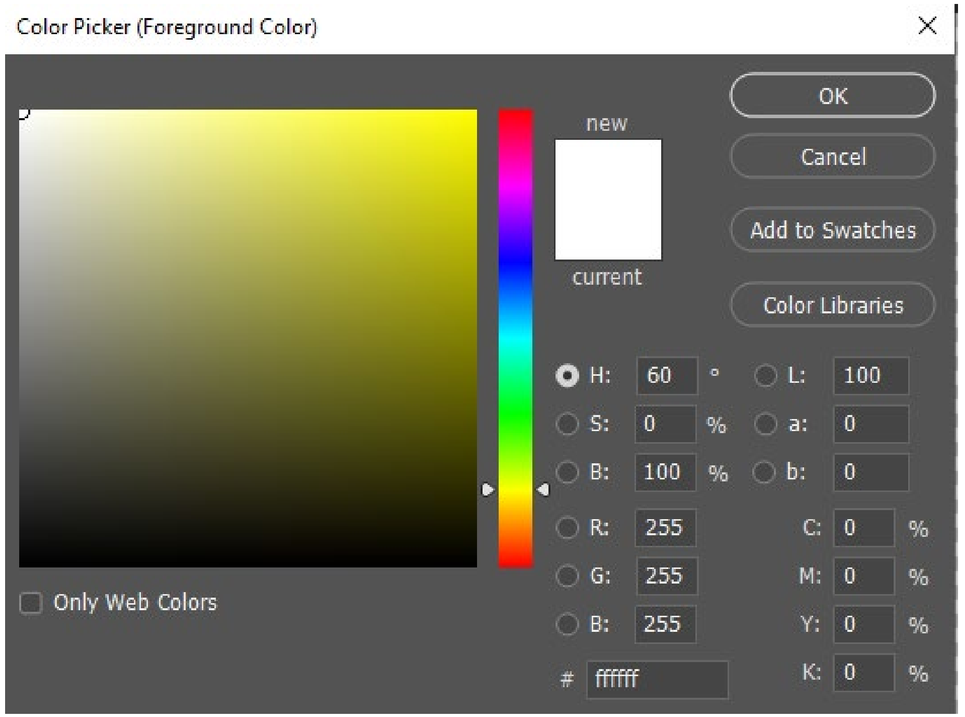
Causality in WYSIWYGs

- What You See Is What You Get



Microsoft Word



Adobe Photoshop

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User Interaction Principles

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User Interaction

- What is the purpose of an interactive system?
- To assist the end-users to achieve their objectives within a certain application domain
- The application domain defines a knowledge area for some real-world activity

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User Interaction Styles

- Command line interfaces
- Options menu
- Natural language
- Q&A with dialogue
- Forms and worksheets
- Windowed environments

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Command Line Interface

- Direct wording of instructions
- Nowadays it has a complementary role
- Provide direct access to all system functions

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Command Line Interfaces

- Flexible
- Useful for repetitive tasks
- Difficult to learn and use, and to detect errors
- Suitable for experienced users

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Options Menu

- The set of options available to the user is presented in the form of a menu
- Based on recognition rather than recall
- The menu options must have a logical meaning and must be logically grouped

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Options Menu

- Options are typically hierarchically grouped
- Option may use text-based or graphical elements
- Require a small number of keystrokes

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Options Menu

- Consume screen space
- Not suitable for data entry
- The number of options in each menu should be between 4 and 12
- The grouping of options shall be based on thematic criteria
- It should be possible to navigate through the menu hierarchy, with provision for undo, abort and backtrack.

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Natural Language

- Attractive means of communication
- Understanding natural language is of great research interest
- NLP: Natural language processing is a subfield of linguistics, computer science, and artificial intelligence concerned with the interactions between computers and human language, in particular how to program computers to process and analyze large amounts of natural language data [Wikipedia]

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Question Answer – Query Dialog

- The user replies:
  - To Y/N questions
  - With numbered options
  - Natural language queries retrieve information from a database
- Query Dialogs are suitable for new users
- They are very much used in information systems

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Form Fills and Spreadsheets

- They are mainly used for data entry
- Transferring the process of filling in a paper form
- Does not require recall
- Take up a large screen space
- Requires a cursor control mechanism on the screen

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WIMP – Windows, Icons Menus and Pointers

- **WIMP** stands for "windows, icons, menus, pointer", denoting a style of interaction using these elements of the user interface [Wikipedia]
- Example: Microsoft Windows

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Usability Principles

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Usability

- When designing interactive systems, we define usability objectives
- Usability: noun, the trait of being easy to use
- A key parameter of the quality of an interactive system
- Definitions of usability are defined in international standards concerning software quality (ISO/IEC 9126) and human-computer interaction (ISO/DIS 9241-11).

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Usability Definition from a Software Engineering Perspective

- ISO/IEC 9126 Software engineering — Product quality was an international standard for the evaluation of software quality. It has been replaced by ISO/IEC 25010:2011 [Wikipedia]
- Main attributes
  - Understandability
  - Learnability
  - Operability
  - Attractiveness
  - Usability compliance

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Usability Definition from an HCI Perspective

- ISO 9241-11 definition for Usability:
  - *“the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use”*
  - Usability is focused so that a task is carried out successfully

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CONTENT 2

Usability according to Nielsen

- Usability is a **quality attribute** that assesses how easy user interfaces are to use. The word "usability" also refers to methods for improving ease-of-use during the design process.

Source: Nielsen, J. Usability 101: Introduction to Usability, https://www.nngroup.com/articles/usability-101-introduction-to-usability/

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Usability according to Nielsen

- **Learnability**: How easy is it for users to accomplish basic tasks the first time they encounter the design?
- **Efficiency**: Once users have learned the design, how quickly can they perform tasks?
- **Memorability**: When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- **Errors**: How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- **Satisfaction**: How pleasant is it to use the design?

Source: Nielsen, J. Usability 101: Introduction to Usability, https://www.nngroup.com/articles/usability-101-introduction-to-usability/

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CONTENT 2

Learnability

- How easy is it for users to accomplish basic tasks the first time they encounter the design?
- Predictability
- My knowledge of the system so far helps me to determine the outcome of my future action
- The user forms a mental model of the system
- The user should be able to judge the consequences based on his/her previous interaction with the system

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Questions to evaluate learnability

- How quickly can a novice user start using the system?
- How quickly does a novice user become an advanced user and how quickly does an advanced user become experienced?
- How much training and practice is required?
- Is the user encouraged to explore the system?

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Efficiency

- Once users have learned the design, how quickly can they perform tasks?
- Given a certain task, how long does it take to complete the task
- How many steps does the user need to take to complete the task

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Questions to evaluate efficiency

- How long does it take a user to perform a set of tasks?
- How many steps are required to perform a typical operation?
- How long does it take users to recover from errors?

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Memorability

- When users return to the design after a period of not using it, how easily can they reestablish proficiency?
- Memorability indicates whether and how effectively end-users can recall different functions of the interactive system, after they have interacted and learned the functions

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Measuring memorability

- Evaluating a user on an interactive system and then reevaluating the user again after some time has passed
- Measure whether they can complete the tasks, whether the complete it faster, with less error, less attempts, etc.
- Ask users about user interface aspects and if they remember certain visual designs

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Errors

- How many errors do users make, how severe are these errors, and how easily can they recover from the errors?
- What is an error?
  - A user action that does not complete the desired goal
- Percentage of users who experience errors when performing a function
- Error severity
  - The difficulty with which error recovery is performed determines the severity of errors

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Errors

- Error rate limits
  - E.g., Users must be able to provide their personal information without errors
- Error severity thresholds, catastrophic, significant, insignificant
- Give an example of a catastrophic error
- Error messages should not be confused with other messages
- Ability of users to recover from errors

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User Satisfaction

- How pleasant is it to use the design?
- Significantly indicates how desirable a system is
- Very important factor for entertainment applications, gaming, etc.
- Important for specific markets
  - E.g., Apple Mac preferred selection by designers
  - Blood pressure monitors by doctors

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Questions to evaluate subjective satisfaction

- How much did users enjoy using the system?
- What are the socio-cultural conditions affecting the market uptake of the system?
- How do users rate this system in relation to competing systems?

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Usability Objectives

- Depend on the profile of typical users
- Measured with users who meet the typical user profile
- In real or simulated conditions

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Example of Usability Objective

- Parameter: How fast does a user complete the online checkout process
- Method of measurement: the time required to complete the tasks
- *Worst case:* 1 hour using manuals
- *Best case:* 10 minutes without manuals
- *Current situation:* many users are unable to complete the task

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Sources and further readings

- https://www.interaction-design.org/literature/topics/human-computer-interaction
- HCI course, Department of Computer Science, University of Cyprus

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Thank you.

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