Human computer interaction

Arguments concerning second partial exam

Virtual reality

Definition of Virtual Reality Virtual reality (VR) enables users to interact with digitally created environments. It's designed to simulate a physical presence in an imaginary or reconstructed space.
The key to VR is its ability to provide users with an engaging and immersive experience.
The level of immersion can be so deep that it makes the user feel as though they are truly present within the virtual space.

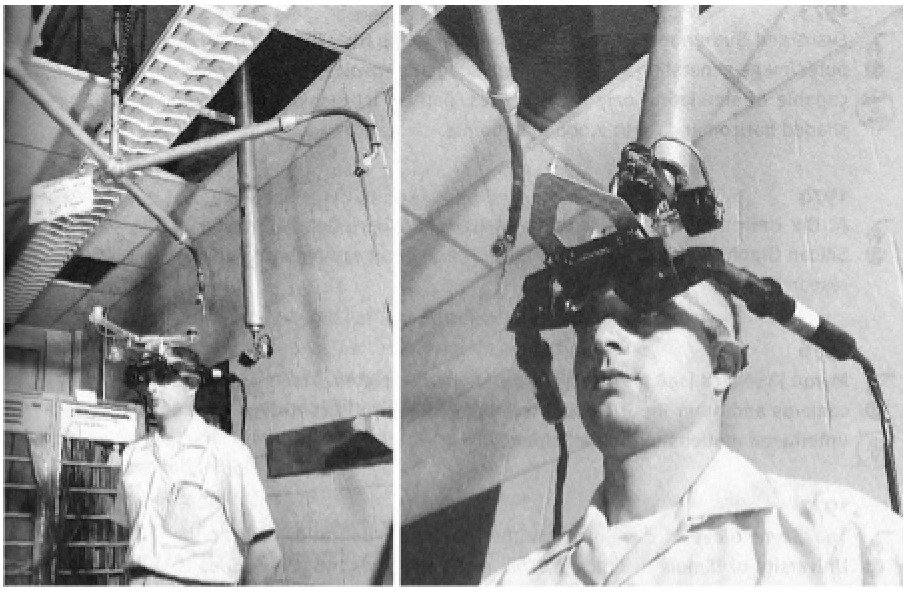
VR evolution

Lenticular stereoscope (1849)
The lenticular stereoscope, made by Sir Charles Wheatstone, was an early pioneer of the VR who contributed to the development of immersive experiences. This optical device was designed to create a three-dimensional (3D) illusion by presenting a slightly different image to each eye, mimicking the way human vision perceives depth.

View-Master (1939)
View-Master stereoscopes gained popularity in the mid-20th century, utilizing circular cardboard discs with pairs of small transparent colour pictures to create 3D scenes when viewed through binoculars.

Sensorama (1949)
Sensorama was one of the pioneering VR systems, offering an immersive mechanical experience aimed at stimulating multiple senses.
It integrated various sensory components such as stereoscopic 3D display, visual display, spatialized stereoscopic audio, vibration, wind, and scent to provide users with a multi-sensory experience.

The sword of damocles (1966)
It is often regarded as one of the **first VR headsets** and a pioneering piece of technology in the field of virtual environments. Users could interact with the system to **manipulate elements** like perspective and narrative progression using knobs, joysticks for direction and perspective, or buttons to trigger specific events or scene changes.



VR: Technological Advancements

The 1990s saw important advancements in computer graphics and computing capabilities, which allowed for more realistic and complex VR environments.
Public Fascination with VR: The concept of VR captured the public's imagination, featuring prominently in movies, books, and media, contributing to a growing interest in the technology.
Challenges: Despite the excitement, the technology faced limitations, such as high costs, bulky hardware, and needing more high-quality content, which hindered widespread adoption.

Nintendo Virtual Boy (1995)
A portable **3D gaming console** that was one of the first attempts to bring VR technology to the home market, though it was not fully immersive and faced several challenges.
Initial response to the console was underwhelming, with reviewers noting several design problems. The system failed to gain popularity with the VIRTUAL BOY general public.

VR in the 2000s

Advancements and Setbacks Advances in technology led to smaller, more efficient sensors and displays, making VR headsets lighter and more comfortable to wear, although still not widely adopted by the general public.
Setbacks and Challenges: The cost of VR technology remained prohibitively high for most consumers, limiting its accessibility and adoption. There was a lack of compelling VR content and applications that could drive widespread consumer interest and justify the investment in VR systems.

PlayStation 2's EyeToy (2003)
The gaming industry continued to experiment with VR, with systems like the PlayStation 2's EyeToy offering rudimentary VR experiences through motion capture, indicating the potential for future gaming applications.

VR Renaissance: 2010's

Improved Immersion and Accessibility: Advances in display technology, motion tracking, and wireless connectivity significantly enhanced the VR experience, making it more immersive and accessible to a broader audience.
Cost: The introduction of smartphone-powered VR headsets like Samsung Gear VR and Google Cardboard democratized access to VR, allowing millions to experience virtual environments at a low cost.
Virtual Reality for Education and Training: VR's potential for immersive learning experiences was recognized in various sectors, including medicine, education, and professional training, providing users with valuable, hands-on experiences in a controlled, virtual setting.
Oculus (later acquired by Facebook), HTC, and Sony entered the market with consumer-friendly VR headsets that were **more affordable and easier to use**. These headsets offered immersive experiences without requiring users to invest in expensive hardware setups or possess specialized technical knowledge.

VR Now

VR has continued to evolve. Companies like Meta Valve, have led the charge, introducing next-generation VR headsets that offer higher resolutions, wireless connectivity, and integrated hand tracking allowing for longer and more complex VR experiences.
The proliferation of affordable standalone VR devices has also democratized access to virtual worlds, enabling a broader audience to explore the potential of VR technology without the need for a high-end PC or console.

Spatial Computing Concept: Integration of the digital world with the surrounding physical environment. (e.g. Apple vision pro)

VR devices

In virtual reality systems, users can engage with the VR environment using a spectrum of devices tailored to the system's requirements.
Basic inputs: Keyboards or joystick can be used for simple navigation and control.

VR Equipment: Controllers

Buttons controllers: Handheld devices that allow users to interact with the virtual environment using buttons.
Hands-free controllers: One example is the **haptic gloves**. This input-output device is an advanced kind of controller. It can provide tactile feedback, such as vibrations, resistance, and pressure, mimicking the feeling of touching objects in the virtual world.
Hand tracking: These tools bridge the gap between physical actions and digital responses, creating a convincing sense of presence within the virtual world.
VR Headset: A head-mounted display providing stereoscopic 3D views with separate images for each eye, along with stereo sound to create an engaging audiovisual experience. It typically features sensors like **accelerometers** and **gyroscopes** for motion tracking and 3D audio system.
Haptic suits: It's a wearable device that provides **physical feedback** to the user's body. It is designed to simulate real world sensations, like touch or impact, by applying forces, vibrations, or movements.

eXtended reality

Extended Reality (XR) is an umbrella term encapsulating Augmented Reality (AR), Virtual Reality (VR), Mixed Reality (MR), and everything in between. XR is revolutionizing everyday consumer experiences and transforming diverse industry segments from industrial manufacturing and healthcare to education and retail.

VIRTUAL REALITY

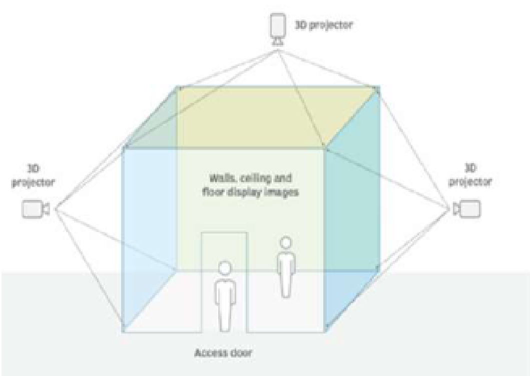
VR refers to a simulated environment that is generated by computer technology, providing users with a fully immersive and interactive experience.
In VR, users are typically equipped with specialized headsets or goggles that track their head movements and display 3D visuals and audio in real-time, creating the perception of being present in a virtual world.
This immersive environment can be entirely computer-generated or a combination of computer-generated elements and real-world imagery. Users can interact with the virtual environment through controllers or gestures, allowing them to manipulate objects, navigate through spaces, and engage with virtual characters or scenarios.
VR technology aims to replicate sensory experiences, including sight, sound, and sometimes touch, to transport users to simulated environments.

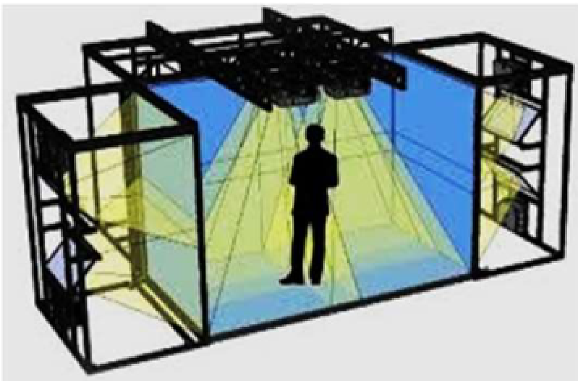
Cave

• A VR cave, also known as a **CAVE** (Cave Automatic Virtual Environment), is a multi-sided immersive virtual reality (VR) system that typically consists of three to six walls arranged in a cube or rectangular shape, with stereoscopic projections onto each wall. Users stand or walk within the enclosure wearing stereoscopic glasses or headsets, which track their movements and adjust the perspective of the projected visuals accordingly, creating a seamless and immersive experience.
• The term "cave" originates from the early days of VR research, where systems were often built in small, enclosed spaces resembling caves. However, modern VR caves can vary in size and configuration, from small-scale setups suitable for individual users or small groups to larger installations designed for collaborative or research purposes.
• Car Simulators often use a “cave” environment to fit the car and the driver in the simulated driving experience.

Key features of a VR cave

• Stereo Projection: High-resolution projectors display stereoscopic images onto each wall of the enclosure, creating a 3D visual experience for users.
• Motion Tracking: Tracking systems, such as infrared cameras or motion sensors, monitor the position and orientation of users within the VR space, allowing for real-time adjustments to the projected visuals based on users' movements.
• Interaction Devices: Users may interact with the virtual environment using handheld controllers, motion-tracking devices, or other input mechanisms, allowing them to manipulate objects, navigate through the virtual space, or engage in interactive simulations.
• Surround Sound: Surround sound systems or spatial audio technologies provide synchronized audio cues and effects that enhance the sense of immersion and presence within the virtual environment.
• Collaborative Capabilities: Some VR caves support multiple users simultaneously, enabling collaborative experiences where participants can interact with each other and with shared virtual objects or environments.





AUGMENTED REALITY

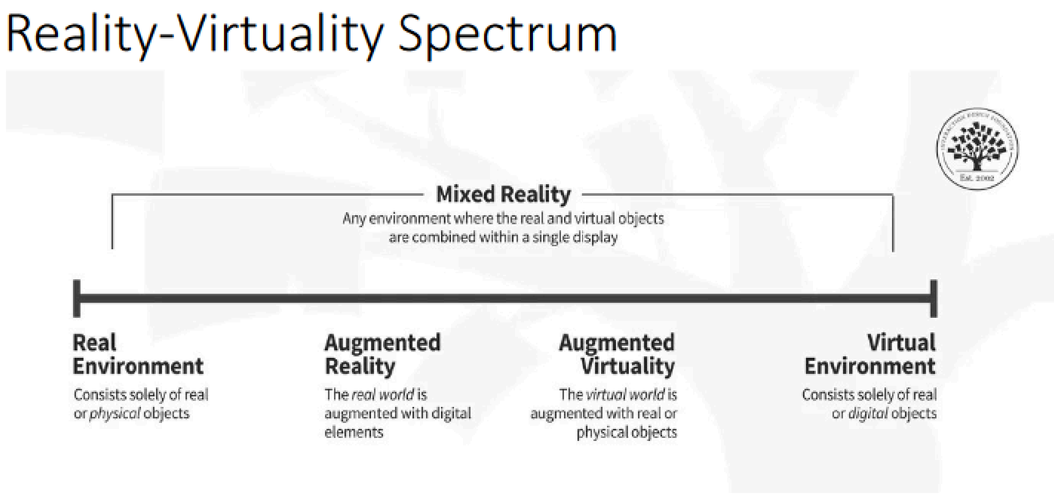
(AR) refers to a technology that overlays digitally created content onto the real world, typically through the use of devices such as smartphones, tablets, or specialized AR glasses.

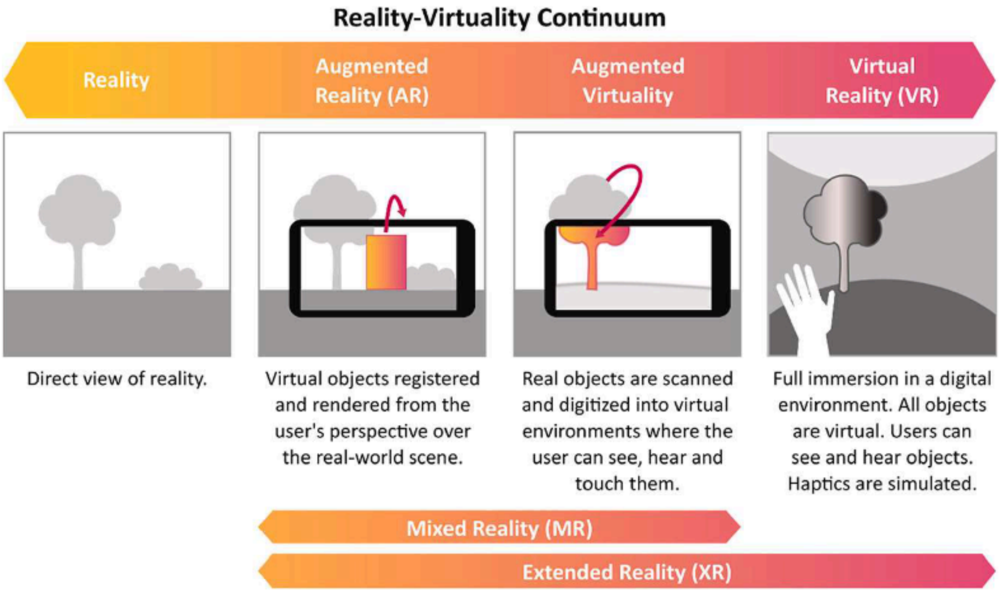
It blends virtual elements, such as images, videos, or 3D models, with the user's physical environment in real-time, creating an interactive and immersive experience.
AR systems commonly utilize computer vision, depth sensing, and GPS technologies to accurately align virtual objects with the user's perspective and location, enhancing their perception of reality.

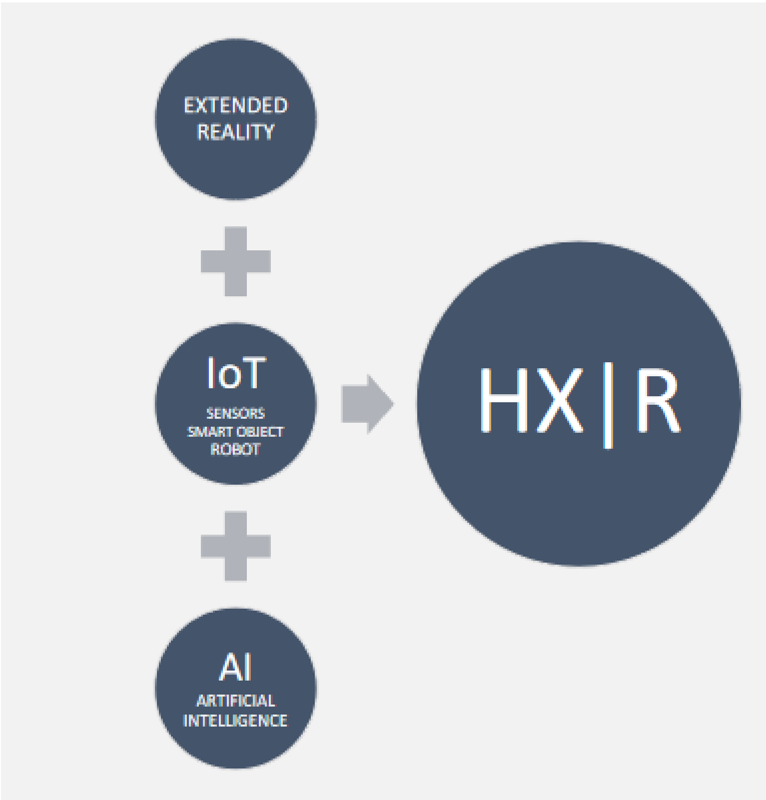
eXtended Reality

• Paul Milgram introduced the groundbreaking concept of the **Reality-Virtuality Continuum** in 1994, illuminating the dynamic shift between the tangible physical world and the entirely digital or computer-simulated realm.
• Over time, as technology advanced, a comprehensive term emerged to encapsulate this evolving landscape: eXtended Reality (XR), often abbreviated as **XR**. XR serves as the inclusive umbrella term encompassing Virtual Reality (VR), Augmented Reality (AR), Mixed Reality (MR), and potential forthcoming immersive realities.
• By embracing XR, we acknowledge and embrace the entirety of the spectrum spanning real-world environments to digitally mediated experiences.

Augmented reality: Digital layer over physical elements.
Mixed reality: Digital elements can interact with physical elements.
Virtual reality: Fully immersive digital environment.







"HX | R" refers to "Human Experience | Reality". This notation might be used to represent a conceptual framework or model that considers both human experience and the objective reality (or the environment) in the design and evaluation of interactive systems.

EVALUATING XR from an HCI Perspective

- Input Interface Usability
- Hardware Comfort
- Navigation, Agency and Control

- Cybersickness
- Aesthetics and Visual Design
- Immersion
- Presence
- Engagement – Emotional Engagement
- Accessibility and Inclusivity
- Sensory Feedback
- Interactivity/Interaction Design
- Other UX parameter
- User Performance
- Spatial Awareness
- Social Interaction (if any)
- User General Satisfaction

PRESENCE

Presence in virtual reality (VR) refers to the sensation of being physically present in a computer-generated environment, despite the awareness of being in a physical space. It is the **subjective feeling of "being there"** within the virtual world, often accompanied by a sense of immersion and engagement that can evoke emotional responses similar to those experienced in the real world.

Presence in VR is characterized by several key components:

- <u>Immersion</u>: The degree to which the VR environment surrounds and captivates the user's senses, creating a convincing illusion of reality. Immersive elements such as high-quality graphics, realistic sound effects, and responsive interactions contribute to the feeling of presence.
- <u>Sensory Input</u>: The integration of sensory stimuli, including visual, auditory, and sometimes tactile feedback, that align with the user's actions and perceptions within the virtual environment. Consistent and synchronized sensory input enhances the sense of presence by reinforcing the illusion of being in a different space.
- <u>Agency and Control</u>: The sense of agency and control over one's actions and interactions within the VR environment. Users feel empowered to navigate, manipulate objects, and influence the virtual world, which enhances their sense of presence and involvement in the experience.
- <u>Social Interaction</u>: The ability to interact with virtual characters or other users within the VR environment, fostering a sense of social presence and connectedness. Social interactions, such as communication, collaboration, or shared activities, can enhance the feeling of presence by simulating interpersonal relationships and social dynamics.
- <u>Spatial Awareness</u>: The perception of spatial relationships and dimensions within the virtual environment, including depth perception, scale, and spatial orientation. Accurate spatial rendering and consistent spatial cues contribute to the user's sense of presence by creating a convincing sense of space and location.
- <u>Emotional Engagement</u>: The emotional responses evoked by the VR experience, including feelings of excitement, curiosity, empathy, or immersion. Emotional engagement enhances the sense of presence by creating a personal and meaningful connection to the virtual world, leading to a deeper and more memorable experience.

Presence in VR is often considered a key determinant of the technology's effectiveness and impact on users' perceptions, behaviors, and experiences. By creating immersive and compelling virtual environments that foster a strong sense of presence, VR developers can maximize the potential for engagement, learning, and enjoyment among users.

Evaluation studies: from controlled to natural settings

Evaluation

Integral part of the design process that involves **collecting and analyzing** data about users' (or potential users') experiences when interacting with a design artifact. The aim is to improve the design
The focus is twofold:
- usability
- user experience

Some designers still believe that if they can use an artifact and find it attractive, others will do as well.
The problem with this assumption is that designers may then design **only for themselves**.
Evaluation enables to check whether the design is appropriate and acceptable for the **target population**.

Iterative design and evaluation is a continuous process. Understanding what aspects to evaluate, where and when are crucial.
Why should we evaluate? Assessing that the product meets target users' requirements and expectations.
A product that is usable, may not lead to a satisfactory UX. Nowadays users expect much more than just a usable system—they also look for a pleasing and engaging experience from more products.
From a business perspective: Well-designed products **sell** → evaluation should be considered an investment.

What should we evaluate? Anything! It depends on the very goals of the project and the development stage (Presence, immersion, agency and control, spatial awareness, social and emotional engagement).
What to evaluate ranges:
- from low-tech prototypes to complete systems
- from a particular screen function to the whole workflow
- from aesthetic design to safety features.
In the end, the main criteria are whether the design does **what the users need and want it to do**; that is, will they use it?

Where should we evaluate? It really depends on the product to be evaluated and on the purpose of the evaluation (In the lab, Living lab, In the wild).

In the lab

Some characteristics, such as **web accessibility**, are generally evaluated in a lab because it provides the control necessary to investigate systematically whether all of the requirements are met. This is also true for design choices, such as choosing the size and layout of keys for a small handheld device for playing games.

Living lab

A compromise between the artificial, controlled context of a lab and the natural, uncontrolled nature of in-the-wild studies. They provide the setting of a particular type of environment, such as the home, a workplace, or a gym, while also giving the ability to control, measure, and record activities through embedding technology in them.

The **DOMHO** project aimed to enhance the lives of individuals with **disabilities** and **older adults** by integrating home automation technologies based on the Internet of Things (IoT) into their daily routines.
Through **focus group** sessions, an advanced smart apartment was developed to cater specifically to the needs of these individuals and their caregivers. **Evaluation studies** conducted by HTlab highlighted the positive impact of IoT technologies on independence, autonomy, and user experience, including voice-controlled devices.
Additionally, a methodological approach was identified to assess an individual's ability to use voice commands effectively, contributing to the project's overall success in improving the quality of life for its target users.

The concept of a lab is changing to include other spaces where people's use of technology can be studied in realistic environments:
• Bringing the technology at their own places
• Involving citizens into scientific research projects (Citizen science)
<u>Citizen science</u>: volunteers work along with scientists to collect data regarding a specific research issues.
For instance: Foldit is an online puzzle video game developed by the University of Washington's Center for Game Science in collaboration with the UW Department of Biochemistry. It engages players in solving complex protein folding puzzles, which are crucial for understanding the structure and function of proteins in biology.

In the wild

Some UX aspects can be evaluated more effectively in **natural settings**. E.g., in natural settings, the UX researchers can easily see how the children naturally engage with the toy and when they get bored.
Remote studies of online behavior, such as social networking, can be conducted to evaluate natural interactions of participants in their context (own homes or workplace).
In the wild (<u>field studies</u>): The goal of field studies is to evaluate products with users in their **natural settings**.
• Help identify opportunities for new tech
• Establish the requirements for a new design
• Facilitate the introduction of tech or inform deployment of existing tech in new contexts

METHODS
• Observations
• Interviews
• Interaction logging

The data collection should be as **unobtrusive** as possible → We can record events and conversations or ask participants' notes as diaries
However…
- diary studies require people to document their activities or feelings at certain times, and this can make them reflect on and possibly change their behavior
- It is very hard to anticipate what is going to happen and to be present when something interesting does happen.
Field studies can also be virtual (VR) to investigate online communities. The aim is typically to study interaction behaviors. The researcher becomes a participant of the community him/herself.

In the lab: Assessing the usability of an interface > more control on the variables
Living lab: Assessing the accessibility of a device > compromise between full control and full naturalness
In the wild: Assess the effectiveness of an AR-navigation system > more spontaneous interaction

When should we evaluate? It depends on the type of product and on the development process that is followed.
The evaluation is run **during the design**. Applies to early prototypes or for fine tuning mature
designs.
The evaluation is on the **finished product**. It can focus on the needed improvements of an existing product.
When the project follows short cycles of design the evaluation effort can be almost continuous.

Types of evaluation

We classify **evaluations** into three broad categories, depending on the setting, user involvement, and level of control.

Controlled settings directly involving users

• Main methods: usability testing & experiments
• Users' activities are controlled to test hypotheses and measure or observe certain behaviors
• Examples: usability labs and research labs

Natural settings involving users

• Main methods: field studies

• Little/no control of users' activities to determine how the product would be used in the real world
• Examples: online communities and products that are used in public places

Any settings not directly involving users

• Main methods: inspections, heuristics, walk-throughs, models, and analytics
• Researchers critique, predict, and model aspects of the interface to identify usability issues
• Examples: online communities and products that are used in public places

Pros and cons

Controlled settings directly involving users:
- ✅ Good at revealing usability problems
- ❌ Poor at capturing context of use

Natural settings involving users:
- ✅ Good to show how people use tech in natural context
- ❌ Time-consuming and more difficult to conduct

Any settings not directly involving users:
- ✅ Relatively quick to perform
- ❌ Can miss unpredictable usability problems and subtle aspects of the user experience

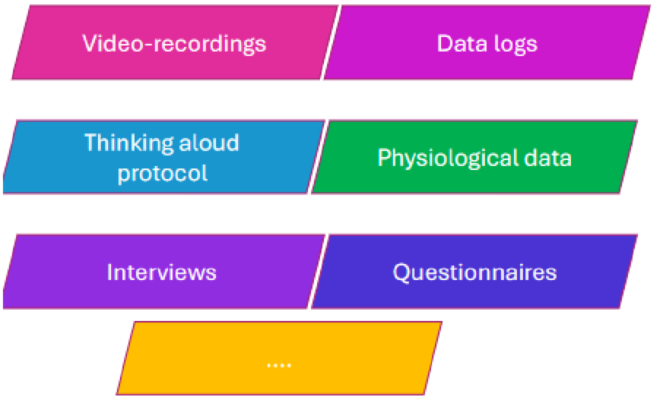
Selecting and combining methods

Using a combination of methods can provide a richer understanding.

CONTROLLED SETTING
Allow to **test hypotheses** about specific features of the interface and the results can be **generalized** to the wider population.

UNCONTROLLED SETTING
Allow access to **unexpected data** that provide different insights into people's perceptions and their experiences.

Usability evaluations typically involved a mixed-method approach.



Representative list of **quantitative** measures:
• number of users completing a task successfully
• time to complete a task
• time to complete a task after time away from the product
• number and type of error per task
• number of navigation to online help / help requests
• number of users making a particular error

Equipment

Increasingly portable equipment > lab-in-a-box

Conducting experiments

Specific hypothesis can be tested to predict users' behavior.
The task is to find the latest news on a web interface. An example of a hypothesis:
We hypothesize that interface A is easier to navigate compared to interface B. Therefore, users will be faster in finding the latest news on interface A compared to B.

Testing hypothesis

Investigating the relationships between **variables**
<u>dependent</u> → what the researcher measures (e.g., time taken to find latest news)
<u>independent</u> → what the researcher manipulates (e.g., different web interfaces)
Null hypothesis: no differences expected
Alternative hypothesis: differences expected
The researcher will set up **hypothesis** to test the effect of the independent variable(s) on the dependent variables.
ALTERNATIVE HYPOTHESIS (H1) → one-tailed
The user will be faster at finding the latest news using the web interface in version A compared to B.
ALTERNATIVE HYPOTHESIS (H1) → two-tailed
There will be a difference in the time to find the latest news between version A and version B.
NULL HYPOTHESIS (H0)
There will be no difference in the time to find the latest news between version A and version B.

The researcher will need to set up the conditions and to find ways to keep other variables (*Text size, Resolution, Screen brightness*) **constant** → EXPERIMENTAL DESIGN

Experimental design

Between-subjects: a single group of users is randomly assigned to each experimental condition.
✅ no learning effect
✅ no ordering effect

❌ larger sample

Within-subjects: all participants perform all conditions
✅ smaller sample size
❌ potential ordering effects
❌ potential learning effects

Participants’ rights and informed consent

Participants need to be fully informed about
• the **goal** of the evaluation,
• **what** they will be asked to do,
• what **data** will be collected and how,
• how data will be **treated** and **protected**,
• and their **rights**
→ INFORMED CONSENT

Ethical approval

Special review board (Institutional Review Board) typically are involved to approve the study and also release a standard template for the informed consent.
Special care needs to be taken when the study involves **vulnerable participants** (e.g., children, older adults).

VIDEO ANALYSIS

WHAT IS IT?

Interdisciplinary method for observing interactions between people and interaction with objects in a specific environment.
Allows to investigate the actions of the subject at several levels:
- verbal production
- nonverbal production
- use of artifacts and technologies

It’s a measurement method.
Some authors consider it as a microscope, because it allows us to observe in detail the events.

WHY?

- Videos are a (relatively) economic and informative source of data. They allow us to record user behavior in a natural context. We can observe the effects on the direction of the eyes, posture, facial expression and gestures.
- The videos can be examined in detail and repeated by one or more independent judges. They can also be shared with the participants.
- They are a useful tool for spreading and disseminating research results.

- Some players in our research may not be able to provide information through other methods of investigation.
- Some of the ways to automatically record events, often do not return all event details. Log data does not record actions addressed to non-selectable areas.
- Allow you to investigate how a certain process takes place over time.
- Videos are suitable for many different survey contexts: for example in the workplace (Heath, Luff, Hindmarsh,2010), in educational (Goldman, 2009) and domestic field.

Making video analysis basically means making order in the actions and/or events we observe in the videos.
Two main approaches:
Top-down structured video analysis: Events of interest are determined a priori
Bottom up video analysis: Events of interest are determined during the analysis

TOP DOWN STRUCTURED VIDEO ANALYSIS

CODING SCHEME: List of events of interest within the video

BOTTOM UP VIDEO ANALYSIS

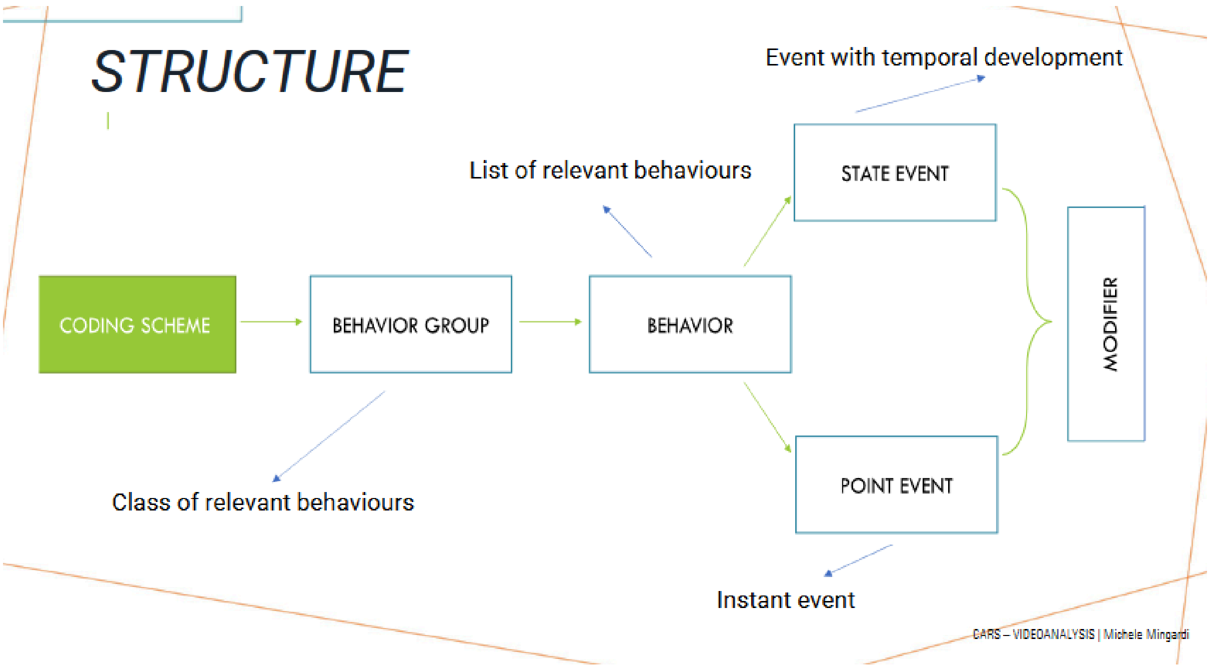
Breakdown Analysis: Qualitative and systematic analysis method that can be integrated with other measures (for instance performance). Interruptions or slowdowns in the course of projected action, which reveal opportunities for action identified by the subject but no longer adequate.
It’s useful to look at breakdown because:
- Are spontaneous
- Reveal the real understanding of the user respect to the device
- May be observed
- Are followed by attempts to resolve the breakdown

1. Identification of the breakdown
2. Delimitation of each episode (what are the indices defining the beginning and the end of the breakdown?)
3. Analysis: for each episode we must identify
   a) The general course of action and the objects involved
   b) Operations performed on the device after the breakdown and the objects involved before and after the episode
   c) Events in the environment

P05 stops marinating ('Chef cycles') → P05 verifies the product and realizes that the sealing of the envelope has not been done correctly → Decides to perform a new cycle → Conclusion. Start the new cycle successfully

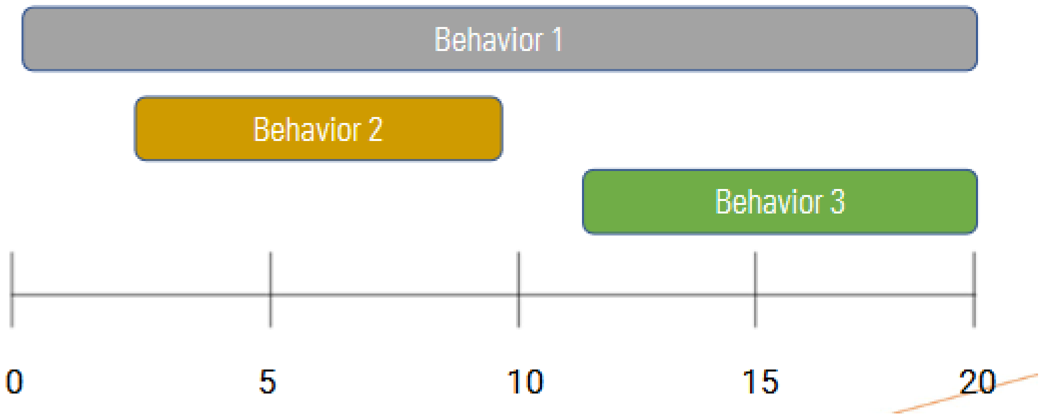
CREATING THE CODING SCHEME

If video analysis is a **measurement method**, the coding scheme is the **measuring instrument** → Consists of a list of codes that describe the behaviors of interest.

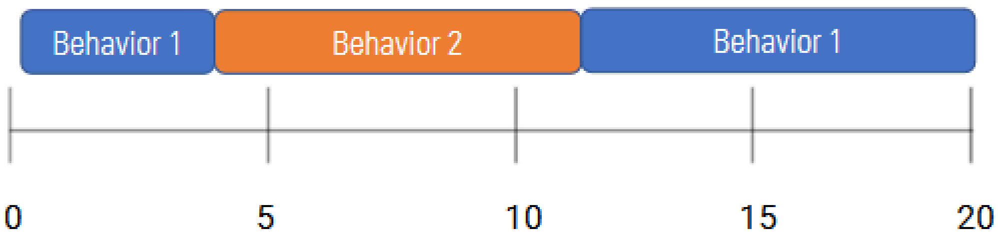


STATE EVENT

It's crucial to identify behavioral indices that represent the beginning and end of the behavior. When does behavior start? When does behavior stop?
Can be mutually exclusive. When one behavior is active, the other one cannot be active



In some cases one of the behaviors must **always** be active



MODIFIER

Attributes that we can assign to one or more behaviors. They are organized into groups (Modifier group)

Do not confuse a behavior with a modifier!
A classic example is the outcome of a task: success vs. failure

SUBJECTS

When more participants are present in our observation, we can code who is doing the action.

SET UP THE CODING SCHEME

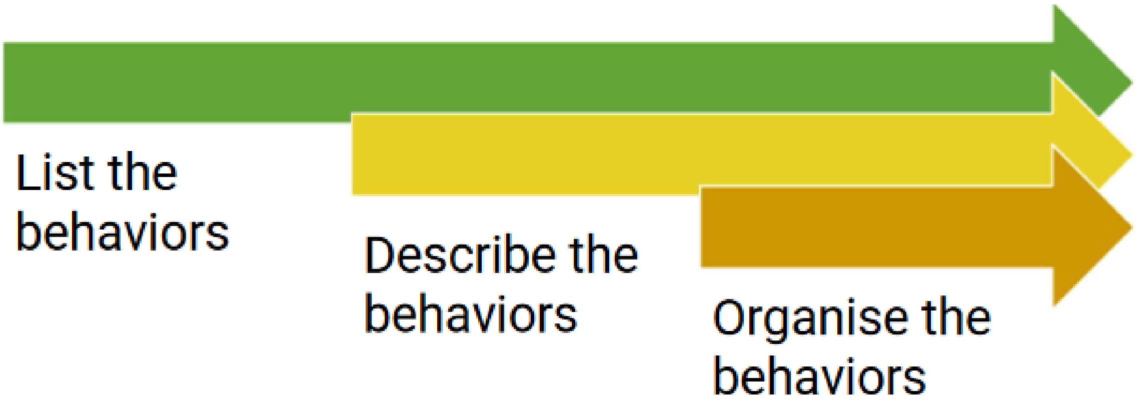
1.RESEARCH QUESTION
What question do I want to answer?
Which version of the app is less distracting?
Which version of the app is easier to use?
2.BEHAVIORS
What are the behaviors/events that allow me to answer the research question?
Pressing a button, Reading instructions, Opening oven door
3.CHARACTERISTICS OF BEHAVIOUR
What characteristics do the identified behaviors have?
Are they point events?
Are they mutually exclusive?
Are they independent or can they be grouped?
4.BEHAVIOURAL INDICES
What behavioral indicators allow me to determine the beginning and end of each behavior?
They must be objective and unique
5.Do we need modifiers to complete the encoding?

EXAMPLES OF TYPICAL MEASURES

With video analysis we can measure the frequency and the duration of specific behaviors
How many buttons did he press?
How long before you find a button?
How much time do you spend on a certain page?
While interacting with a device, we can measure different behavioral indices that can be informative.
<u>Completion of the task</u>
One key aspect to assess is the successful completion of the task by participants. If multiple participants fail to complete a task, it may indicate its complexity or the difficulty in understanding or executing required actions. Additionally, it's valuable to evaluate the extent to which participants have progressed in task completion, such as identifying if they have completed a portion of the actions or sub-tasks correctly, such as 30% or 50% of the task.
<u>Completion time</u>
Normally, shorter completion times indicate efficiency and easy understanding of interface/device operation.
In comparison between user groups, it may indicate that the interface is more suitable for a certain group.
<u>Errors</u>
The mistakes made by the participants can be very informative compared to what is wrong with the system. In general, we can distinguish:

- Errors that prevent task completion
- Errors that slow task completion

Depending on the specific situation we can identify different types of errors.
Basically…



AT WHAT STAGE OF RESEARCH SHOULD THE CODING SCHEME BE PREPARED?
NOW! Once we define the protocol of observation (setting, equipment, participants, data collected..) we prepare a draft in which we list all that we expect to observe to be able to answer our question.
Once the data collection is finished we refine the previously constructed draft by adding the description of behaviors and behavioral indices. At this stage we can also add behaviors or modifiers.

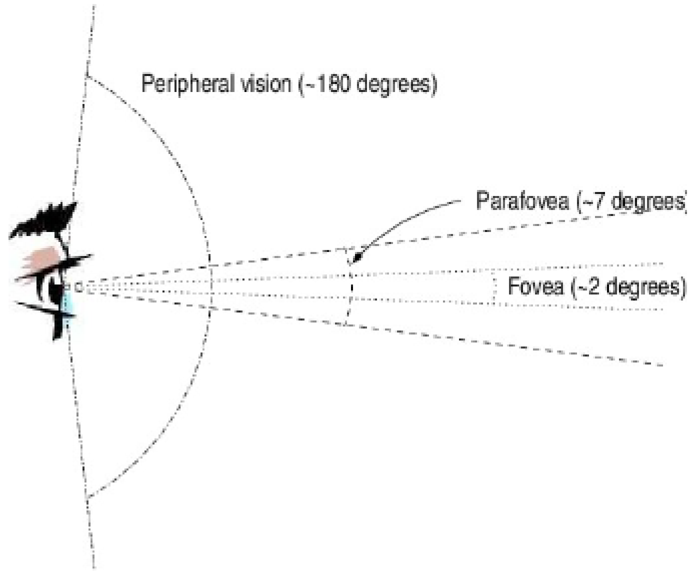
Eye Tracking

BASIC ANATOMY KNOWLEDGES OF THE VISUAL SYSTEM

1.Visual system

THE IMPORTANCE OF VISION
Around 75% of information about the outside world is acquired through this sense.
RETINA
"The back of the eyeball". It has the necessary elements to translate the light signal into an electrical signal and send it to the visual cortex (phototransduction) for interpretation.
PHOTORECEPTORS
Cones: mostly located in the central area of the retina. <u>High color sensitivity</u> and high visual acuity.
Rods: located in the periphery of the retina. <u>High light sensitivity</u>.
FOVEA
• Less than 2º of visual field
• Rod-free
• Maximum visual acuity
• Color vision
• Communicates with 50% of the visual cortex

REGIONS OF THE FIELD OF VIEW



2.Eye movements

FIXATION

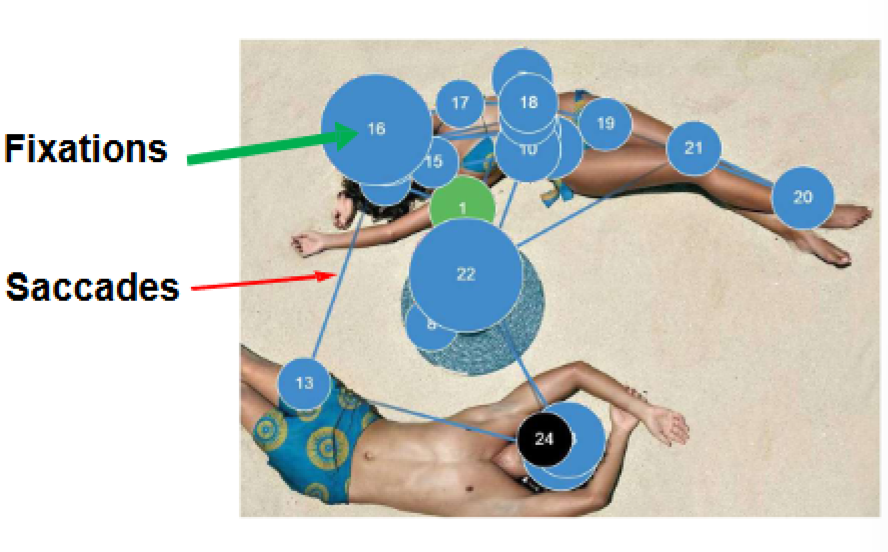
• Fixations are the most common eye movement and can be used to make inferences about cognitive processes and attention.

• During a fixation, eyes stop scanning the scene and hold the foveal area of our field of vision in one place. This allows the visual system to take in detailed information on what is being looked at.

SACCADES

Saccades are rapid eye movements that quickly shift the focus of gaze (sguardo) between different points in the visual field. They are essential for tasks like reading or scanning the environment.

Positioning the relevant information inside the fovea for the subsequent perceptual and cognitive processing (saccades).



SMOOTH PURSUIT
Smooth pursuit eye movements allow the eyes to smoothly follow moving objects in the visual field → Keeping **stable** the image of moving objects on the **retina**
MICROSACCADES, TREMORS, DRIFTS
Useful in preventing the perceptual decay of stationary objects
• Microsaccades are a kind of fixational eye movement, characterized as small, involuntary, jerk-like movements, similar to tiny versions of voluntary saccades.
• Tremors are a kind of fixation eye movement, consisting in constant, involuntary tremor that occur even when the eye appears still.
• Drifts are slow, irregular, smooth-motion eye movements that occur during attempted fixation.

3.Theoretical hints

Eye-Mind Assumption
The eye-mind assumption states that a link exists between the eyes and the mind, such that whatever the eye fixates on, the mind processes.
In other words: close relationship between what is being observed and what is being processed → Assessing attentive process.
Cognitive process ← → Eye movements
We can consider eye movements as a direct index of the distribution of attentive resources.
Covert attention - Overt attention
However, what we are directly observing is not always the focus of our attention. While overt visual attention is the act of physically directing the eyes to a stimulus, covert visual attention is related to a mental shift of attention without physical movement.
Covert attention precedes eye movements and during fixation, it can be deployed to multiple locations simultaneously.

4.EYE TRACKING METRICS

FIXATION
Fixation frequency: reflects the attention to one or more stimuli or an element of the stimulus, as well as reflecting the complexity (so the effort required) and emotional value of them. It is usually < 3Hz
Fixation duration: voluntary state in which the gaze remains stationary at a point from 100 to 500 ms.
The time for first fixation (TFF): the amount of time that it takes a respondent to look at a specific stimulus
SACCADES
•Duration: The time taken to complete the saccade. Most saccades are complete within a few tens of milliseconds.
•Peak velocity: The highest velocity reached during the saccade.
•Latency: The time taken from the appearance of a target to the beginning of a saccade in response to that target.
SCAN PATH
A scan path is a **graphical depiction** that combines the eye's fixations and saccades over a visual medium.
Types of Scan Paths:

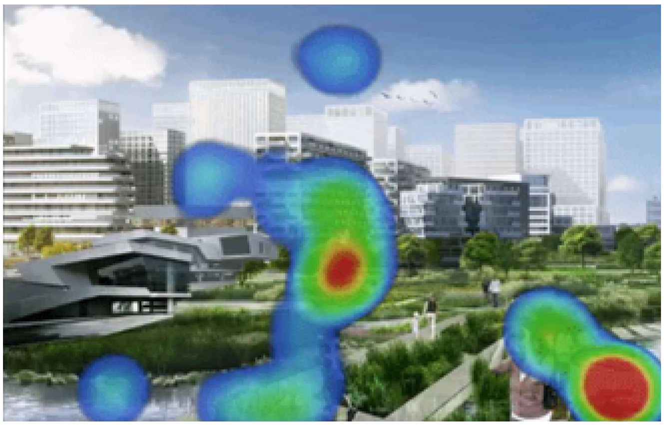
Static Scan Path: Represented through an image, illustrating the sequence of visual fixations and saccadic movements at a glance.
Dynamic Scan Path: Visualized through a video, showing the real-time movement of fixations and saccades across the visual field.
Scan paths are used to analyze and understand the visual behavior and focus areas during viewing tasks, providing insights into perceptual and cognitive processes.

AREA OF INTEREST

Area Of Interest (AOI) is an analytical tool designed to calculate quantitative measures of eye movements.
You delineate a **boundary** around a specific area of an image that you desire, then analyze the metrics of interest within this defined space (usually Fixation and Saccades parameters).
For example, you can compute the frequency and the duration of Fixation within that area.

HEAT MAP

Heat maps are visual representations that indicate the **intensity of gaze concentration** over specific areas in a visual medium.
Color Indicators in Heat Maps:
The color spectrum ranges from red to green.
•**Red**: Indicates areas of highest gaze interest.
•**Green**: Represents areas with less gaze concentration.
Heat maps can also be static or dynamic.
Heat maps are used to identify which parts of a visual stimulus attract the most attention.



Other metrics aside eye movements

BLINK

Blinks are the closing and opening of the eyelids. They are used in a wide array of fields where human function and behavior are studied.
The average human has a blink rate of 12 times per minute and an average blink lasts for 0.3 seconds. It can be informative of one's level of workload (Marquart et al., 2015).

- Blink Frequency is **inversely related** to the level of mental load (Holland and Tarlow, 1972) and performance (McIntire et al., 2014).
- Blink duration decreasing is related to increased mental load level (Ahlstrom and Friedman-Berg, 2006).

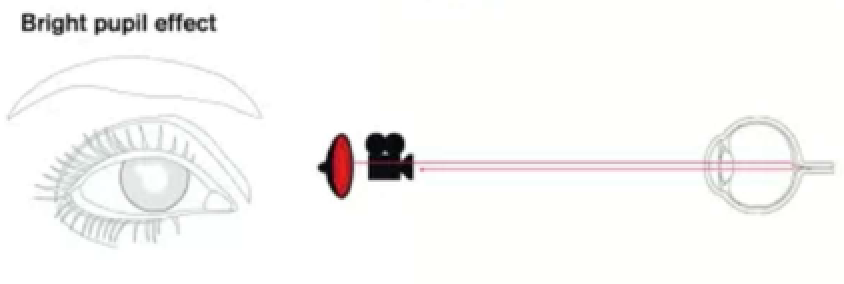
PUPILLOMETRY

Pupillometry is the measurement of pupil size variation → Involuntary reflex leading to dilation or narrowing of the pupil in the ranges between 1.5 and 8 mm.

Three stimuli that lead to increased pupil dilation:
• Light
• Emotional stimuli
• Increasing cognitive load
Pupil diameter increases with increasing mental load (Kahneman, 1973; Marinescu et al., 2018).
COMMON METRICS SUMMARY
1. **Time to First Fixation in Target AOIs**: Shorter times are preferable, indicating quicker engagement.
2. **Fixation duration Target Area of Interest (AOI)**: An increase in fixation duration suggests greater engagement, interest, and cognitive processing.
3. **Frequency of Fixations and Saccades**: A higher count is negatively correlated with the efficiency of visual search.
4. **Transitions Between AOIs**: More transitions indicate less efficient visual searching.
5. **Pupil Diameter**: Larger diameters indicate increased cognitive load and emotional arousal.

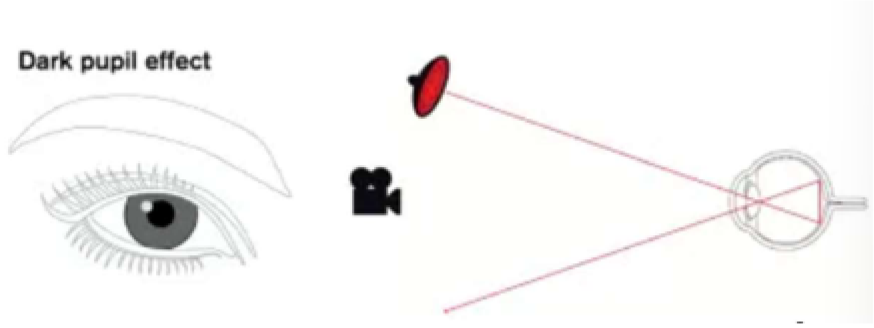
5.EYE TRACKER RECORDING METHOD

VIDEO-OCULOGRAPHY
What is VOG?
•VOG, is the most used eye-recording method (excluding the clinician field)
•Core Component: A small video camera that captures images and sends them to a PC for processing.
High precision vs. Moderate tolerance to movements
Basic principle: the estimation of the position of the eye based on pupil tracking using corneal reflex.
1.Near-infrared light is transmitted by the eye tracker.
2.The light is reflected in your eyes.
3.The eye tracker's cameras detect those reflections.
4.The eye tracker uses mathematics and filtering to determine where you are gazing.
Bright Pupil Effect
• Produced by the infrared illumination of the eye that facilitates the procedure of locating the eye on the monitor.
• Coaxial illumination at the bottom of the retina
<u>Used in</u>: Low light condition



Dark Pupil effect
The light enters the eye, reflects off of the retina, and then exits the eye off-axis and away from the camera. This causes the pupil to appear darker than the rest of the eye in the image.

• Non-coaxial source of illumination
Used in : High light condition



Eye-Tracker devices categories (For VOG recording method)

Chin guard
Eyelink 1000 – Up to 1000Hz; Monocular (one eye)/Binocular (both eyes).
Head mounted Eye Tracker
Eyelink II– Up to 500 Hz; Monocular/Binocular.
Glasses
SMI Eye Tracking Glasses 2 wireless 60/120 Hz Binocular
Remote E.T.
SMI RED500; 500 Hz Binocular.
VR
Vive Pro Eye 120 hz
AR
Hololens 2 - 30Hz

EYE TRACKING: APPLICATIONS

A First general distinction.
Evaluation Method
Eye Tracking as a tool for the objective quantification of visual processes and user attention. Eye behavior is controlled to draw inferences about cognitive processes or visual exploration patterns of the user. (Our focus)
Interaction Method
Eye Tracking as a visual control input system for software (e.g. videogames or accessible technologies).

Applications

Industrial application
Changes in pupil diameter and Blink are used to monitor cognitive load in real time, helping to identify when workers are experiencing mental overload. This can guide adjustments in task allocation and workflow to maintain optimal performance and safety.
Scan paths provide insights into workers' visual attention and strategies. For example, analyzing these paths can help in optimizing the layout of workstations.

Marketing
<u>Scan paths</u> reveal the saccades sequence and duration of visual fixations, showing how consumers view and process advertisements, products, and digital content.
<u>Heat maps</u> use color coding to visually represent where consumers are focusing the most within a visual field, highlighting areas that attract or miss attention.
Sport
<u>Scan paths</u> track the sequence and focus of eye movements, providing a visual map of how experienced athletes versus novices view their environment during sports activities.
In experts the focus on the targets is anticipated compared to non-experts (Ranieri et al. 2018).
USABILITY TEST
Eye tracking provides direct observations of how users interact with a product or interface, highlighting what attracts attention and what gets overlooked.
<u>Identify Usability Issues</u>: By observing the natural viewing patterns and struggles of users, designers can identify problematic aspects of the interface that may not be evident through traditional testing methods.
USABILITY
Time taken to make the first fixation (TFF) or number of fixations performed before placing the gaze in an Area of Interest (AOI).
Low TFF: high efficiency in identifying a target stimulus

Duration of the first fixation: Provides information on the recognition and identification of a target stimulus

Total number of fixations and saccades
High: ineffective search due to application layout

Target fixations/Total fixations
Low: application layout issues

PRELIMINARY STEPS TO THE EXPERIMENT

Take into consideration:
- Stimuli resolution
- Input command used by the participant (e.g., mouse and keyboard). Simple and nonintrusive input command for task execution

Preparation of the laboratory
• Thanks to the Eye Tracker portability, each place can be an eye tracking lab
• However, it is important to keep in mind some features
EASILY ACCESSIBLE
• Consider the characteristics of the participants (e.g., mobility impairment)
• Deciding how to arrange the equipment in the environment
ISOLATION AND CONTROL OF THE ENVIRONMENT
Isolation from light and noise
Eliminate external sources of infrared
• Reduce external light sources (neon lights are preferred because they emit less infrared than ordinary light sources)

DON’T MAKE THE ROOM TOO DARK
A room too dark makes pupillometry measurements unreliable
SEPARATE THE SUPPORTING SURFACES
Mouse or Keyboards on the same working plane of the instrument lead to artifacts
LIMIT ELECTROMAGNETIC DISTURBANCES
Disturbances are more visible in systems that use magnetic properties; however, it is good practice to reduce sources of interference as much as possible
PERFORM EYE TRACKING CALIBRATION ON EACH SUBJECTS

HUMAN-ROBOT INTERACTION

HRI is related to human-computer interaction (HCI), robotics, artificial intelligence, the philosophy of technology, and design.
HRI focuses on developing robots that can interact with people in various everyday environments. This opens up design challenges, related to robotic appearance, behavior, and sensing capabilities, to inspire and guide interaction.

HRI is a multidisciplinary and problem-based field by nature and by necessity.
HRI brings together engineers, psychologists, designers, anthropologists, sociologists, and philosophers, along with scholars from other application and research domains.
- develop the robotics hardware and software
- design the aesthetics of the embodiment and behavior of the robot
- identify the required domain knowledge for particular applications
- analyze the behavior of humans when interacting with robots in different contexts

HRI - DESIGN ASPECTS

How does a pile of wires, motors, sensors, and microcontrollers turn into a robot that people will want to interact with?
Although it sounds like magic, the trick of turning metal and plastic into an interaction partner is in the iterative and interdisciplinary process of robot design.
Various approaches can be adopted to conduct the design process:
→ Inside-out (or Frankenstein) approach
→ Outside-in (or user-centered) approach

Inside-out (or Frankenstein) approach
The design process starts “from the inside” and builds up “to the outside”:
→ solving technical issues first
→ designing the robot's appearance and behavior later
In other words, we take whatever technology is available and put it together to get certain robotic functions. The robot’s appearance and the specific interaction capabilities then have to be built on top of this technical infrastructure.
<u>Limitations</u>: a lack of consideration of the social context of use within the design process can lead to surprising effects in robot interaction.

Outside-in (or user-centered) approach
→ determine the characteristics of the users and context of use (who will use the robot, where, and how)
→ based on this, decide on specific robot design features, such as appearance, interaction modalities, and level of autonomy
→ finally, identify the technology needed to develop the pre-designed robot
In other words, the design process starts from the interaction that we expect the robot to be engaged in, which will determine its outside shape and behaviors.
Once the design has been settled upon, we work all the technology into it.
the multidisciplinary effort
<u>Designers</u> might work on developing specific concepts for the design.
<u>Social scientists</u> may perform exploratory studies to learn about the potential users and context of use.
<u>Engineers</u> and computer scientists need to communicate with the designers to identify how specific design ideas can be realistically instantiated in working technology.

ROBOT MORPHOLOGY AND FORM

A common starting point for designing HRI is to think of what the robot is going to be doing. In HRI, **form** and **function** are inherently interconnected and thus cannot be considered separately.
<u>Organism-based robots</u>
- Androids and humanoids (most closely resemble humans in appearance, but they have a lot to live up to in terms of capabilities)
- Zoomorphic robots (shaped like animals with which we are familiar (e.g., cats or dogs) or like animals that are familiar but that we do not typically interact with (e.g., dinosaurs or seals))
- Minimalist robots (HRI designers, eager to make robot appearances commensurate with their limited capabilities, also design minimalist robots, which explore the minimal requirements necessary for inspiring social HRI)

<u>Robjects</u>
interactive robotic artifacts whose design is based on objects rather than living creatures.
Sociable Trash Box robots are an example of robjects. They are robotic objects with interaction capabilities: they can walk alone in public spaces for the purpose of tracing humans and trash and to collect the trash.

ROBOT AFFORDANCE

Affordance: perceivable relationships between an organism and its environment that enable certain actions (e.g., a chair is something to sit on, but so is a stair).
When designing a product, it is fundamental to:
- make its affordances explicit
- incorporate user expectations and cultural perceptions.

Since robots are novel interaction partners, affordances are particularly important for signaling appropriate ways of engaging with them.
This will allow to develop common ground between robots and humans so that people can understand robot capabilities and limitations appropriately and adapt their interactions accordingly.

Appearance: a robot's appearance is an important affordance because people tend to assume that the robot's capabilities will be commensurate with its appearance.
- if a robot looks like a human, it is expected to act like a human;
- if it has eyes, it should see;
- if it has arms, it should be able to pick up things or shake hands.

Interaction modality: the robot's interaction features elicit specific actions and interactions in humans
- If a robot speaks, e.g. "Hello," people will expect it to understand natural language and carry on a conversation.
- If it expresses emotions through facial expressions, people might expect it be able to read emotions.
- if it has a touch screen on its body, people might expect to interact with the robot through the touch screen.

ROBOT DESIGN PATTERNS

In the design process of a robot, besides the characteristics of individual robots (appearance, sensing abilities, or actuation), designers need to consider **design patterns** as well.
"a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice".
Peter Kahn et al. (2008), inspired by Christopher Alexander's idea of design patterns in architecture.
- can have several different instantiations
- can be combined, so that less complex patterns can be integrated into more complex patterns
- serve to describe interactions with the social and physical world

Didactic communication pattern (the robot assumes the role of a teacher)
- clear explanations of concepts using simple language, visual aids, or demonstrations
- feedback on the user's progress or performance
- elements of encouragement and motivation

Motion pattern (the robot initiates movements and aligns it with the human counterpart of the interaction)
- performing functional movements, directly related to the task
- navigate obstacles, reach destinations, or follow paths

Initial introduction pattern (how the robot is presented to users when they first encounter it)
1) Greeting: The robot says "Hello" or welcomes the user.
2) Demonstration: The robot showcases its main functions.
3) Instructions: The robot explains how users can interact with it.

An example of **robot design pattern combination**, where less complex patterns are integrated into a more complex pattern, describing a specific type of interaction with the social and physical world
Didactic communication pattern + Motion pattern = Robotic tour guide

How to develop robot design patterns?
HRI design patterns can be developed based on:
- observation of human interactions
- prior empirical knowledge about humans and robots
- designers' experiences with HRI, through an iterative design process

Although Kahn et al.'s design patterns are not meant to be exhaustive, they emphasize the idea that the design should focus on the relationship between humans and robots.

HRI - DESIGN PRINCIPLES

Matching the form and function of the design
If your robot is humanoid, people will expect it to do humanlike things - talk, think, and act like a human.
If this is not necessary for its purpose, such as cleaning or performing industrial operations, it might be better to stick to less anthropomorphic designs.
Consider norms and cultural stereotypes
People can also be prompted to associate specific social norms and cultural stereotypes with robots through design.
For example, people expect that a robot made in China would know more about tourist destinations in that country (Powers et al., 2005; Lee et al., 2005).
Underpromise and overdeliver
When people's expectations are raised by a robot's appearance or by introducing the robot as intelligent or companion-like, and those expectations are not met by its functionality, people get disappointed.
This can negatively affect their interaction.
It is better to decrease people's expectations about robots (Paepcke and Takayama, 2010), which might have been increased by how robots are portrayed in society.
Interaction expands function
Users often project their expectations onto the robot's design. Therefore, designing robots with some *ambiguity* can be advantageous, especially for those with limited capabilities. This approach enables users to interpret the design in diverse ways.
<u>The case of Paro</u>
This baby seal robot invokes associations with pets, but it also does not get compared to animals they know (cats, dogs), which would lead to disappointment.
Therefore, Paro passes as a pet-like character even though its capabilities are significantly below those of a typical domestic animal or that of an actual seal baby.
Do not mix metaphors
Design should be approached holistically. The robot's capabilities, behaviors, affordances for interaction, and so forth should all be coordinated.
If you design a humanlike robot, people may find it disturbing if it has skin covering only some parts of its body.
Similarly, if the robot is an animal, it may be strange for it to talk like an adult human or try to teach you mathematics.
This is related to the <u>Uncanny Valley effect</u>: inappropriately matched abilities, behaviors, and appearance often lead to people having a negative impression of the robot.

HRI - ANTHROPOMORPHIZATION

Anthropomorphization is the attribution of human traits, emotions, or intentions to nonhuman entities.
A special example of anthropomorphization is called pareidolia, the effect of seeing humanlike features in random patterns or mundane objects.
In the photo of the Cydonia area took on Mars on July 25 in 1976, many people saw a face, which sparked many speculations about the existence of life on Mars. The NASA took a higher resolution photo in the exact same location in 2001, which revealed that the structure photographed in 1976 is certainly not a human face.

People's innate predisposition to anthropomorphize things has become a common design affordance for HRI.
People readily anthropomorphize all kinds of robots, with appearances ranging from minimalist to indistinguishable from the human form.

Anthropomorphic designs take advantage not only of appearance and form but also of behavior in relation to the environment and other actors to evoke ascriptions of human-likeness.
For instance, we can use animations to give the robot apparent goals, intentions, and appropriate reactions to events. This is particularly relevant for social robotics.
- Keeping eye-contact
- Smiling
- Nodding
- Gesturing (pointing something while talking about it)

Going beyond appearance, Nicholas Epley and colleagues (Epley et al., 2007) proposed a theoretical framework that became influential both in psychology and in robotics, broadening our understanding of anthropomorphism.
Three core factors determine anthropomorphic inferences about non-human entities:
- effectance motivation
- sociality motivation
- elicited agent knowledge

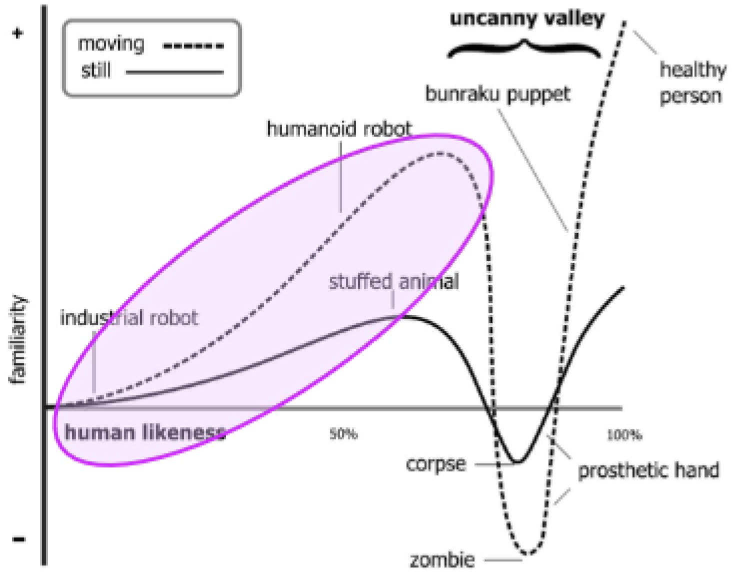
Effectance motivation (Epley et al., 2007)
Desire to explain and understand the behavior of others as social actors.
It can be activated when being unsure about how to deal with an unfamiliar entity. Attributing humanlike characteristics to robots in this case can help to psychologically regain control over the novel situation.
In this case, anthropomorphization can reduce the stress and anxiety associated with interacting with robots.
Sociality motivation (Epley et al., 2007)
Anthropomorphization of robots could also be caused by sociality motivation, particularly by people who lack social connections.
Research supporting this idea → people who have been made to feel lonely in an experimental situation, or who are chronically lonely, anthropomorphize robots to a greater extent than people who are sufficiently socially connected (Eyssel and Reich, 2013).
Elicited agent knowledge (Epley et al., 2007)
Way in which people use their commonsense understanding of social interactions and actors to understand robots.

Research supporting this → People who considered women to be more knowledgeable about dating norms, used more time and words to explain dating norms to a male robot (Powers et al., 2005).
In other words, people attributed different competencies to male and female robots, mirroring their social beliefs.

Resuming, the anthropomorphization dynamics include:
- the attribution of typically human emotions, intentions, traits, or other essentially human characteristics to any type of nonhuman entity (i.e., robot)
- the use of self-related or anthropocentric knowledge structures to make sense of the nonhuman things - or in our case, robots

The Uncanny Valley effect

The essay on the Uncanny Valley effect was written by Masahiro Mori, a robotics professor at the Tokyo Institute of Technology. It appeared in an obscure Japanese journal called Energy in 1970, and in subsequent years, it received almost no attention.
The first English translation of Mori's assay was published only in 2012.
It looks at the relation between the level of "human likeness" (or anthropomorphism) and the emotional response of an observer.
More specifically, on the emotional response, Mori used the term (shinwa-kan), which translation to English remains challenging.
It has been translated as:
- likeability
- familiarity
- affinity
The emotional response of an observer toward a robot becomes increasingly positive as the robot's appearance and behavior become more human-like — **up to a certain point**.



There is a critical threshold where the robot is very close to looking human but not quite there. That point creates a feeling of discomfort or even revulsion in the observer.
The **presence of movement** steepens the slopes (accentua la pendenza).

At 75%-90% of human likeness there are the lifeless entities.
• **Corpses**: when robots have lifeless, cold, and pale appearance, this creates a strong sense of eeriness.
• **Zombies**: when adding movement capabilities to robots appearing cold and pale, this makes them appear creepy and unnatural (like zombies).

Several factors can contribute to the Uncanny Valley effect:
- facial expressions
- eye movements
- skin texture
- overall appearance

If these features are not convincingly human, the observer may experience a strong negative reaction.

DESIGN AND ASSESSMENTS FOR INDUSTRIAL ROBOTICS

Cobots were invented by J. Edward Colgate and Michael Peshkin in 1996 as "a device and method for <u>direct physical interaction</u> between a person and a computer-controlled manipulator."
• Designed to work alongside humans in shared workspaces, allowing cooperative tasks without the need for extensive safety barriers (help humans, not replace them)
• Provided with safety features (e.g., force and power limiting, collision detection, speed and payload limits)
• Ease of programming (teach-and-repeat functionality or offline programming)
• Designed to be adaptable to a variety of tasks and applications

How HCI experts can contribute to the industrial robotics field?

User-Centered Design: Develop intuitive interfaces and controls for easier interaction between workers and robots.
Ergonomics: Enhance the physical and cognitive comfort of workers using robots.
Usability and UX Testing: Conduct tests to ensure robots are user-friendly and meet the needs of the workforce

Beyond Usability and UX …

When human operators work alongside robots, they are not only interacting with a technology, they are collaborating with it.
In this context, there are many <u>human factors</u> that become fundamental for the success of the human-robot collaboration activity and for the human well-being.
<u>Dispositional factors</u>
• General trust in technology
• Learnability (willingness and ability to learn flexibly)
• Problem solving skills
• Negative attitudes toward robots
<u>Cognitive, psychological and affective factors</u>
• Mental and physical workload
• Affective state (including engagement)

• Stress and fatigue
<u>Quality of human-robot collaboration</u>
• Fluency
• Trust
• Mutual support
• Fear of job loss

Monitoring cognitive, psychological and affective factors

Studying attentional demands, memory load, and mental workload during collaborative tasks
• Pupillometry and eye movements
• Heart Rate Variability
• Electrodermal Activity
• Video-analysis of operators' behavior (e.g., identifying erroneous or hazardous behavior)
• Self-reports and interviews
• Which are the conditions or the tasks that elicit higher fatigue in workers?
• Can we capture workers' workload and fatigue fluctuations unobtrusively (e.g., pupil diameter, RMSSD)?

Exploring interactions within Digital Twin platforms

In the industrial sector, Digital twins are digital representations of physical machines that usually allow simulating, testing, monitoring or operating maintenance activities on a digital replica of the industrial robot or machine.
Typically, digital twins platforms are designed for desktop-based (or tablet-based) interactions.
Immersive Virtual Reality (VR) or other eXtended Reality (XR) devices can be exploited for simulating industrial robots.
● high sense of presence
● higher FoV and free space exploration
● physical motion allowed
● immersive 1st person perspective
● multimodal interaction modalities
Using Virtual Reality (VR) as a teleoperation means to guide cobots.
Relations between:
• Embodiment
• Workload
• Presence
• Task performance
Using Mixed Reality (MR) as a teleoperation means to guide cobots.

Learning and training

Cobots are new technologies for most of the workers' population, who therefore need proper training to <u>familiarize</u> and <u>learn</u> how to cooperate and collaborate with them.
• What's the most effective way to train novel operators to work along with cobots?
• Is there a procedure that helps building a positive perception of the technology, building trust and facilitating a seamless introduction of these technologies into industrial settings?

Using Virtual Reality (VR) to guide cobots
• How senior operators (>50yo), who are usually not that familiar with novel technologies, respond to the integration of VR as a mediating technology to guide robots compared to their younger colleagues?
• Which is the most preferred interaction modality in VR for this population? (i.e., using controller buttons or physical actions)

Enhancing the quality of the human-robot collaboration

Even though industrial robots are not designed as social robots, operators establish an <u>actual relation</u> with them.
As they work together, they form an actual <u>team</u>, in which teamwork dynamics arise and influence their collaboration.
• Is the robot perceived as a good support to the human?
• Does the human perceive him/herself as a support to cobots' activity?
• Does the human trust the robots and rely on its capabilities?
• Does the human feel like part of a team characterized by mutual support (human-robot)?
Fluency
According to Hoffman and Breazeal (2009), "fluency in joint action is the quality existent when two agents perform together at a high level of coordination and adaptation, in particular when they practice a task repetitively and are well accustomed to the task and to each other."
This construct thus reflects a high level of coordination and adaptation between the human and the robot, and refers to the human's:
• emotional states experienced during HRC
• perception of the cobot's contribution
• team's harmony
Social and relational dynamics
The introduction of new robotic agents in collaborative work cells undoubtedly impacts the social sphere of the operators. Therefore, studying social dynamics is fundamental for designing robotic systems that support humans and foster their well-being.
When industry aims at including a robot in a team of workers:
• What's the impact on human wellbeing? On its social relations? On the teamwork dynamics?
• How are the roles redistributed between oneself and the robot?
• What's the nature and quality of the interactions established between human operators and the cobot?
• Are there some factors that promote a smooth integration of the technology in the work setting and a positive cooperative environment in many-to-one teams?