Humans in Interaction: Input, Output, and Memory

People-Oriented Computing
23.9.2019

Learning Goals

After this lecture you should:

- Have familiarity with key interaction paradigm shifts, including associated systems and people
- Have an understanding of basic interaction frameworks
- Be familiar with basics of human sensory channels as input and output channels for interaction
- Have an understanding of foundational concepts of human memory

Agenda

- Interaction Paradigms (continued from last week)
- Interactive Systems and Humans
- Human Input and Output
- Human Memory

INTERACTION PARADIGMS (PART II)

Interaction as Communication

Interaction Paradigms (Part I)

- Time Sharing
- Video Display Units
- Programming Toolkits
- Personal Computing
- Windows and WIMP
- Interface Metaphors
- Direct Manipulation

Interaction Paradigms (Part II)

- Hypertext
- World Wide Web
- Computer-Supported Cooperative Work
- Agent-based Interfaces
- Multimodality
- Ubiquitous Computing
- Sensor-based and Context-aware Interaction
- Augmented and Virtual Reality

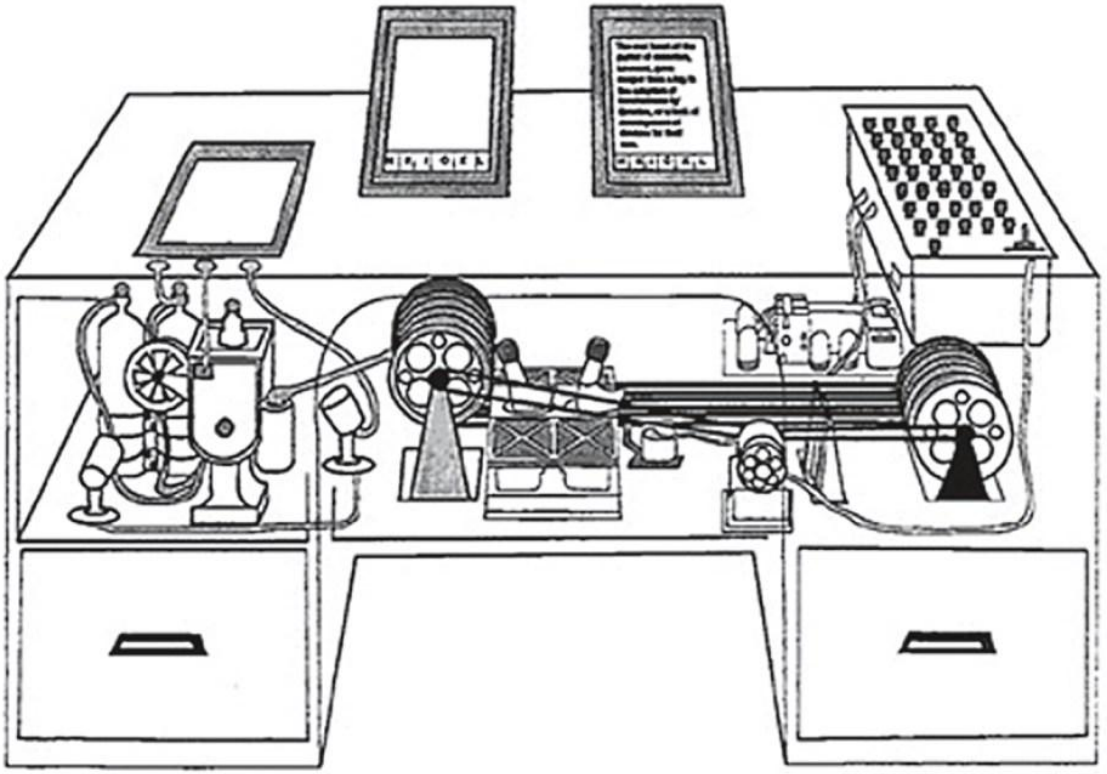
Hypertext (1940s-1960s)

- In 1945, Vannevar Bush published "As We May Think" in *The Atlantic Monthly*
- A response to the proliferation of scientific knowledge produced during WWII and the challenges of keeping track of the growing body of scientific literature
- Bush believed that keeping abreast of the increasing flow of information was crucial for progress

Hypertext

- “As We May Think” proposed an innovative future for information storage and retrieval to improve human capacity of knowledge access
- The proposed “memex” apparatus was a desk with the ability to produce and store massive amounts of photographic copies of documents
- Memex could keep track of links between parts of different documents, created an interconnected mesh of data, similar to information storage in the human brain
- Revolutionary idea to store not only information but associations between information

Hypertext



source: boingboing.net

Hypertext

- Ted Nelson (1960s) inspired by Bush's work to create a machine language equivalent of memex
- Nelson created Xanadu, a revolutionary information publishing and retrieval system based on interconnected, non-linear text and other media
- Supported new way of information browsing and non-linear consumption of information
- Coined the term "hypertext" to distinguish the non-linear structure of media storage and presentation
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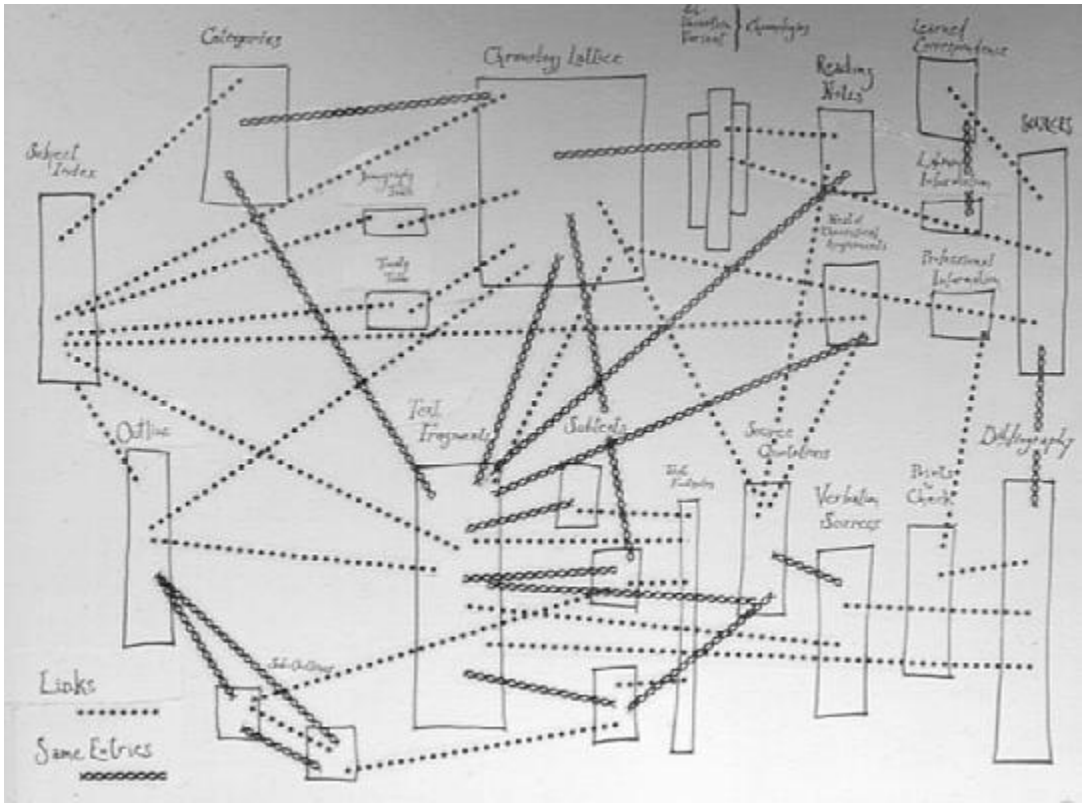
Hypertext

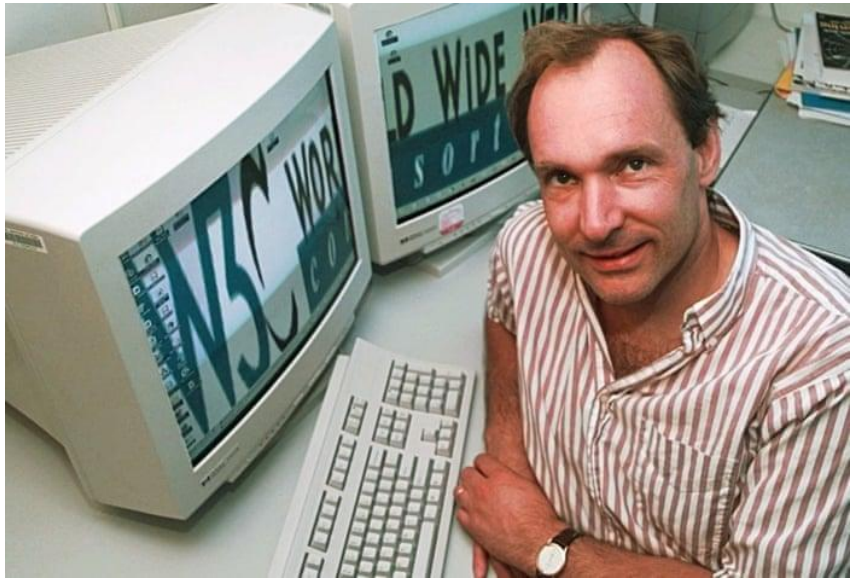


source: xanadu.com.au

The World Wide Web (1990s)

- The internet refers to a collection of computers linked by data connections
- Although the internet had been in existence since the 1960s there were no interfaces to make it easily usable and accessible

The World Wide Web

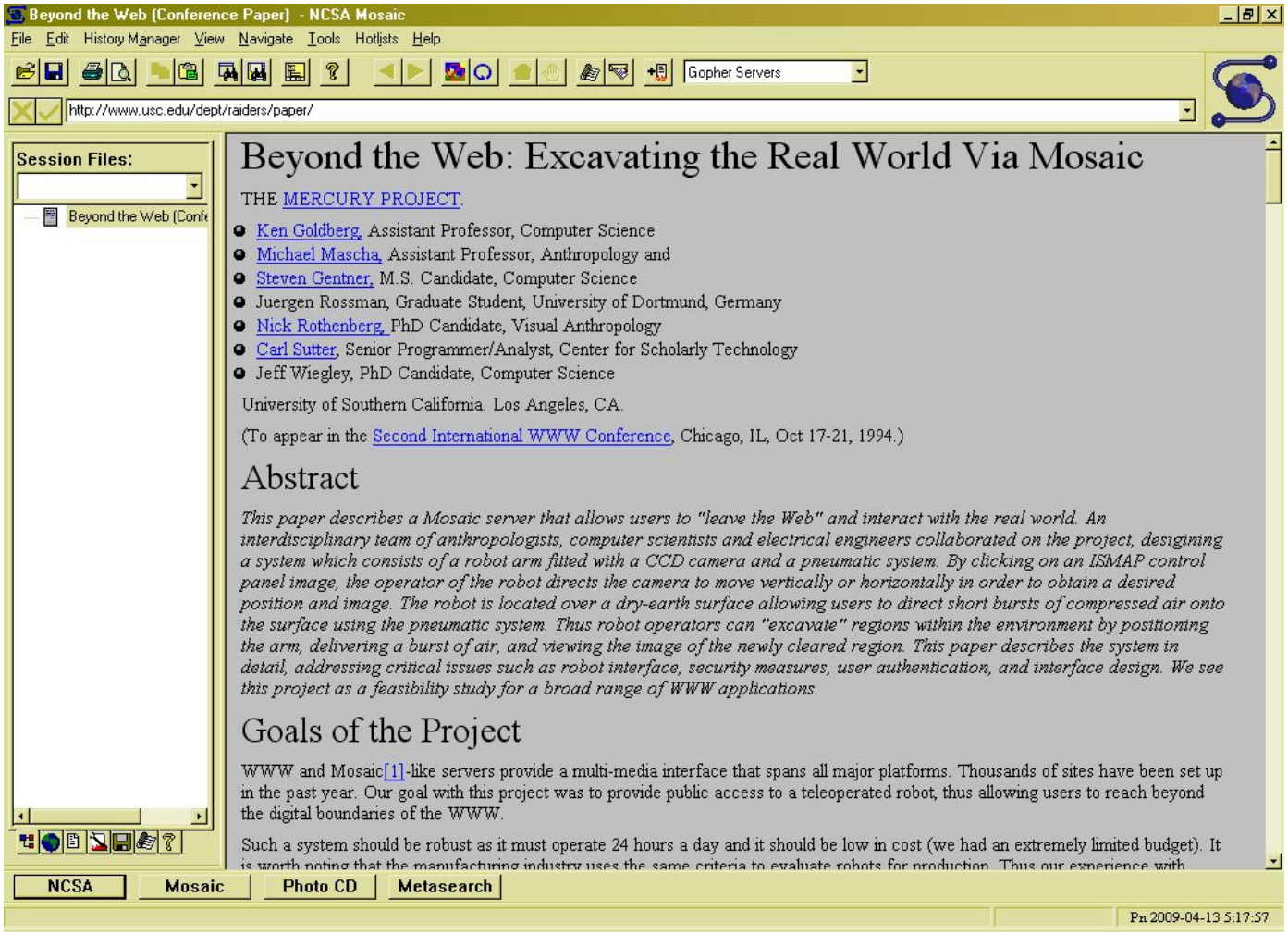


- The hypertext concept is the basis of underlying structure of the modern World Wide Web
- Tim Berners-Lee (CERN, MIT) conceived of the idea of merging hypertext with the internet to create the World Wide Web
- First website went online in 1991 **http://info.cern.ch**

The World Wide Web

- In 1989,Berners-Lee started the World Wide Web project as a way to facilitate distribution of scientific data over the internet
- The World Wide Web (WWW), built atop the internet provides access to information on the internet through standard protocols, notations, and addressing systems
- The WWW abstracts underlying complexities of transmission protocols and data access from users
- First WWW browser (1991) was text based
- By 1993 several graphical web browsers (e.g. Mosaic) were available

The World Wide Web



source: wikipedia.org

The World Wide Web

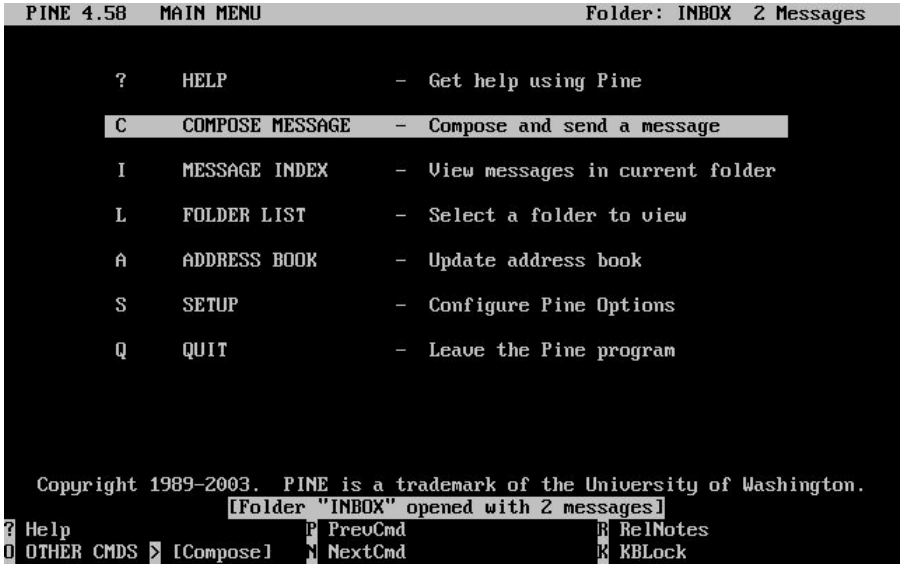
- The WWW was a revolutionary paradigm
- Lowered the barrier for access to the internet
- Lowered the barriers to creating and publishing information, thus leading to the rapid growth and increased value of internet content including leisure and commerce
- Increased access to internet in turn led to increase in computer purchases and use

Computer-Supported Cooperative Work

- Advent of computer networks beginning in the 1960s enabled computers to communicate with each other
- Networks facilitated collaboration among individuals using computers resulting in CSCW (Computer-Supported Cooperative Work) systems

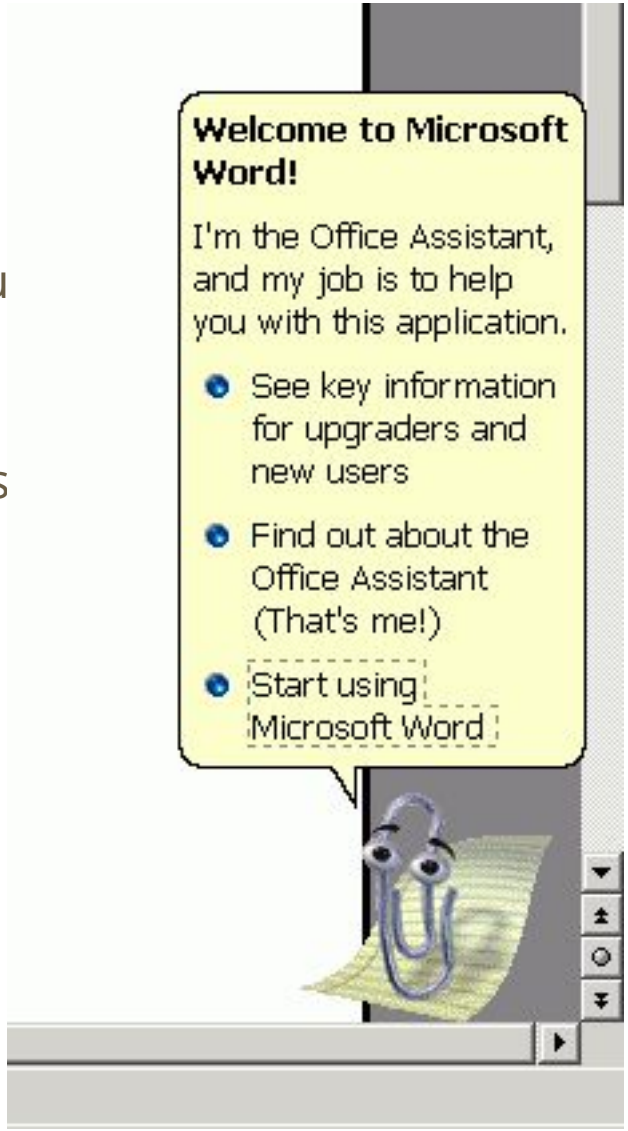
Computer-Supported Cooperative Work

- Transition from systems for individual use to systems for group and organizational use
- CSCW systems allowed for interaction between humans via computers and need to support the needs of multiple users
- Email is an early example of a CSCW system
- Subsequent computer-based communication tools and social media platforms arose from this paradigm



Agent-Based Interfaces

- A departure from direct manipulation
- Creates the illusion of someone working on you behalf to perform tasks
- Can perform repetitive tasks, respond to events and learn from user actions



Agent-Based Interfaces

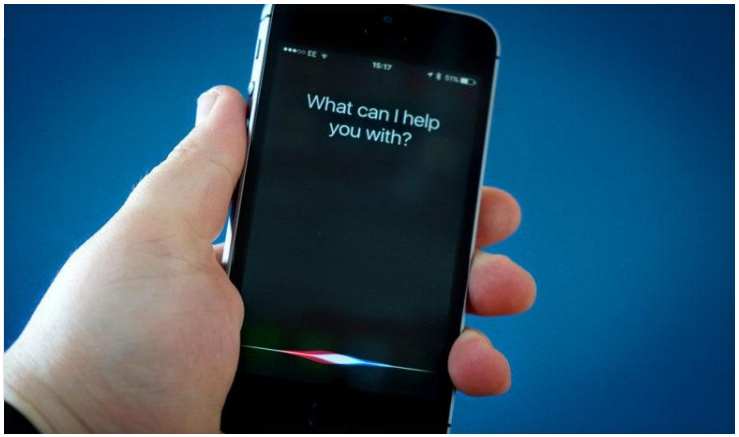
- Agents can be simple actors that follow commands or intelligent and proactive
- Early example was Eager, a cat icon that would observe HyperCard programmers and suggest next actions
- Interaction language has always been a challenge for designing agents
- Recent innovations, e.g. Apple's Siri have made great strides in agent interaction

Multi-Modality

- Interaction advances allowed people to engage in multiple tasks simultaneously
- Multi-modality enables the use of multiple “channels” of human communication means to interact
  - Visual channel
  - Audio channel
  - Haptic (touch) channel

Multi-Modality

- Conventional computer systems with keyboard, pointing device, visual display and audio output are inherently multimodal
- However, genuinely multimodal systems rely more heavily on simultaneous or flexible use of multiple communication channels
  - E.g. combining gestures and voice commands



source: gizmodo

Ubiquitous Computing (1990s-2000s)

- Researchers at Xerox PARC (1980s) attempted to move computing “off the desktop” and into everyday life
- Mark Weiser (1991) wrote “The Computer for the 21st Century” which introduced the vision of Ubiquitous Computing
- Making computing seamless with everyday activities
- Computing at different scales from handheld to wall-size displays

Ubiquitous Computing

- Ubiquitous Computing also refers to a shift in computer to human ratios
  - 1950s: many humans to one computer
  - 1970s – 1980s: one computer to one human
  - 1990s – present: many computers to one human

Ubiquitous Computing

source: adaptivepath.org

Sensor-based and Context-aware Interaction

- Context-aware computing extends the notion of ubiquitous computing
- More invisibility and seamlessness of computing with everyday life
- Information gathered from people's activities through sensing and context
- Sensed information used by systems to provide functionality and support for human activities

Sensor-based and Context-aware Interaction

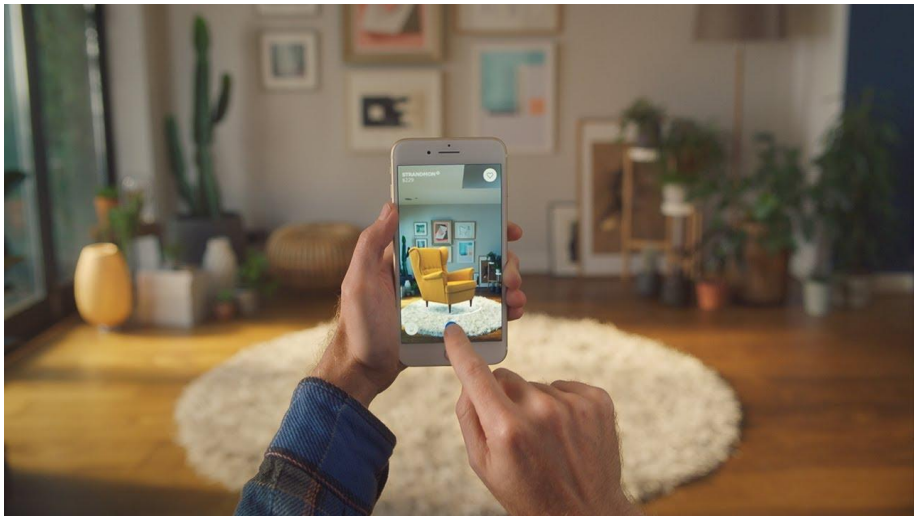
- Presently systems pose challenges relating to privacy of information collection and use
- Systems that act based on collected data using artificial intelligence may also make poor decisions or act in ways that are undesirable

Augmented/Virtual Reality

- Augmented reality
  - Combines physical world and digital content
  - Requires knowledge of environment
  - QR codes, IR sensors
- Virtual reality
  - Replaces physical world with digital world
  - “Full immersion”, 3D interaction
  - Gesture recognition, eye gaze, full body sensing

Augmented/Virtual Reality

- Ivan Sutherland's "Sword of Damocles" (1965)
- Since ~2010 new technology breakthroughs
  - Google Glass, Microsoft Hololens, HTC Vive, Magic Leap, etc.
- Many applications: entertainment, medicine, training



source: ikea.com

HUMANS AND INTERACTIVE SYSTEMS

Interactive system

Traditionally interactive system's purpose is to aid a user in accomplishing a *goal* within an application *domain*

- Domain – area of expertise and knowledge in a real world activity, consists of concepts
  - E.g., graphic design domain has geometric shapes, drawing utensils, drawing surface, etc. as concepts
- Task – operation to manipulate concepts within a domain
- Goal – a desired output from a task or sequence of tasks

source: zvv.ch

An Interaction Framework

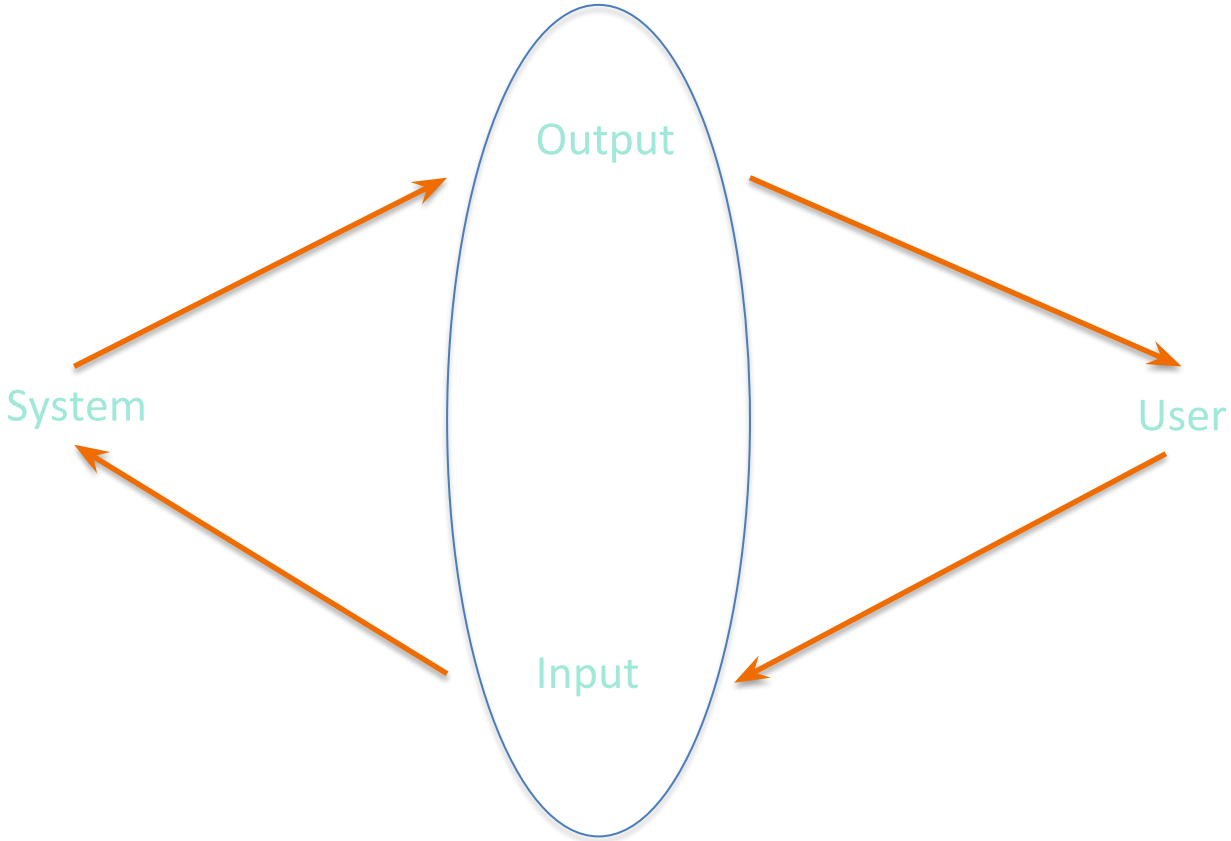
Four major components

- The system
- The user
- The input
- The output

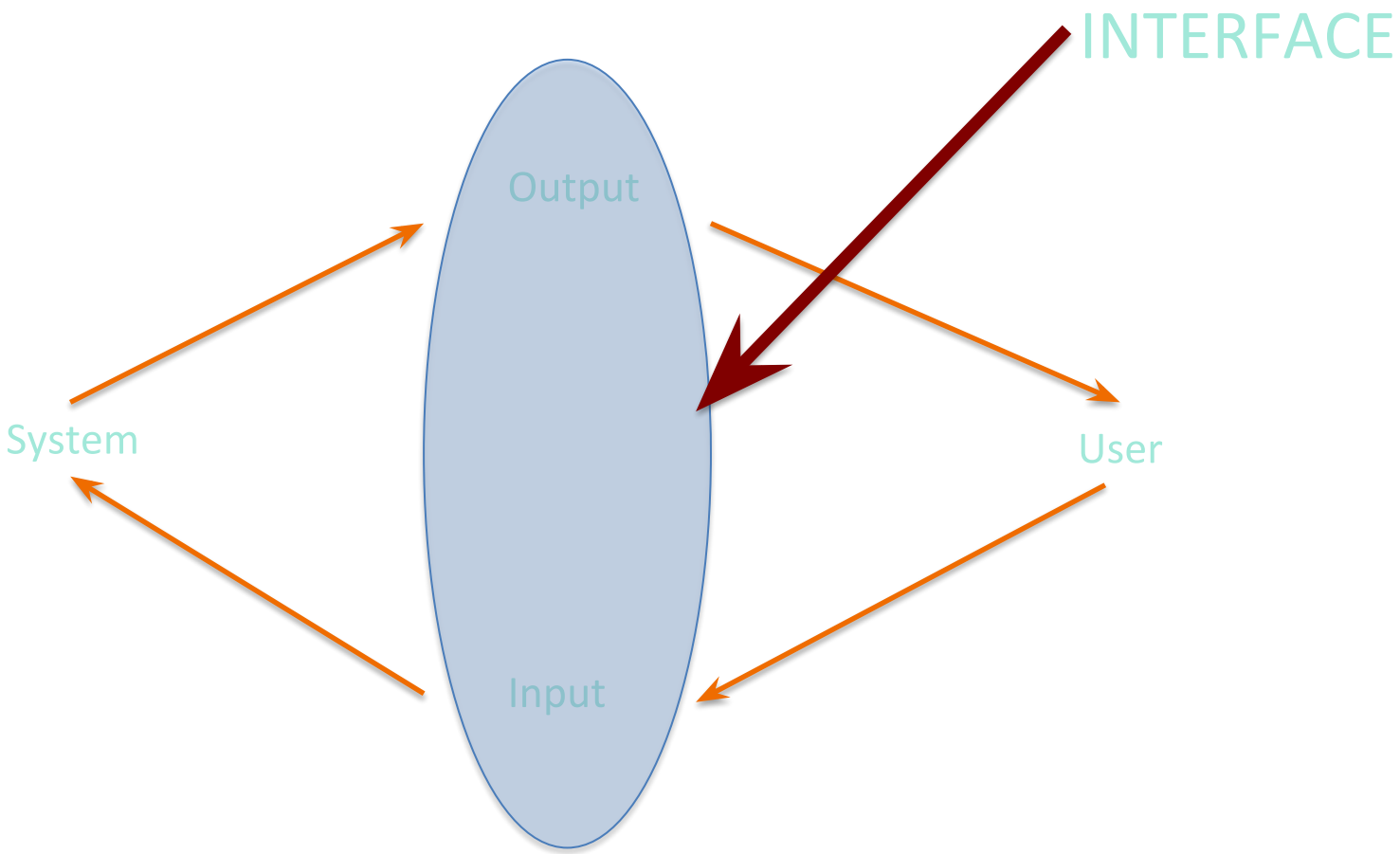
An Interaction Framework

- System has its own language
- User has his/her own language
- User can only manipulate the system through *input*
- The state of the system can only be communicated to the user through *output*

An Interaction Framework



An Interaction Framework



The Interface

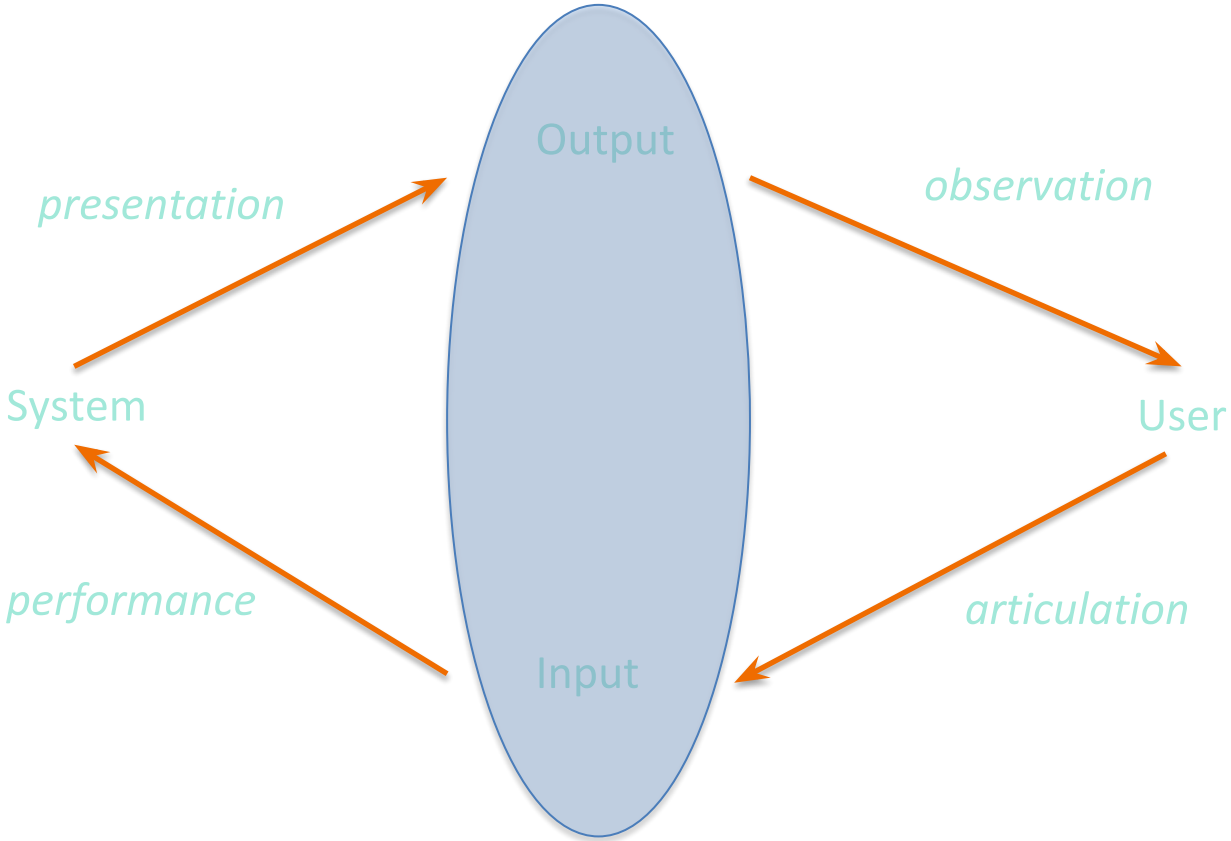
An interactive system's interface can be thought of as the combination of the input provided by the user and the output provided by the system

The interface serves as the "translator" between the system and the user

The Interface

- The user needs to be able to articulate their goals and tasks in the input language specified by the interface
- The input needs to be translated into stimuli for the system upon which the system can perform
- The new state of the system must be presented as output as specified by the interface
- The output must be observed and interpreted by the user

An Interaction Framework



source: zvv.ch

ZVV Example

- Domain: ticket purchasing for public transit
- Tasks: selecting destination, choosing fares, making payment, etc.
- Goals: e.g., purchase a half-fare ticket from current destination to Zürich HB for immediate use using a debit card
- Input: Onscreen button presses, insertion of payment card, physical button presses, removal of paper ticket
- Output: Interactive screens in a logical sequence, confirmation messages, instructions, queries and prompts, buttons for making selections, progress bar with status message, illumination of ticket repository, etc.

An Interaction Framework

- This formulation is system-centric, focuses what comes into and out of the system
- A more people-centric view would consider a human receiving input from a system and providing output to it

INPUT-OUTPUT CHANNELS

Human-centric Models of Interaction

- The Model Human Processor (Card, Moran, Newell)
  - Considers the human as an input-output machine that processes physical stimuli and produces a physical response
- The 7-Stage Model of Interaction (Don Norman)
  - Conceives of interaction in two human-centric phases of execution and evaluation in the world

Human Input and Output

- Input to humans occurs primarily through the five senses
  - Vision, hearing, touch, smell, taste
- Human output occurs through motor control of effectors, i.e., physical action
  - E.g., limbs, head, eyes, vocal system, fingers

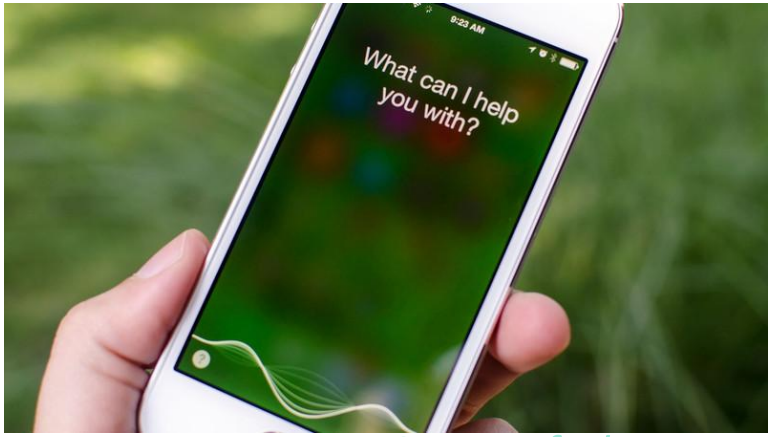
Human Input and Output

- In interactive systems, human input is primarily through vision, hearing, and touch (haptics), other input is still rare
- Output is traditionally finger and hand movement (keyboards and pointing devices, touch screens)
- Increasingly other output is used, e.g. head movement, voice commands, facial gestures, eye movements, hand and body gestures
  - In conjunction with advances in sensor and recognition technologies

Emerging Human Output Used by Interactive Systems

Source: techinsider.io

Source: gamesradar.com



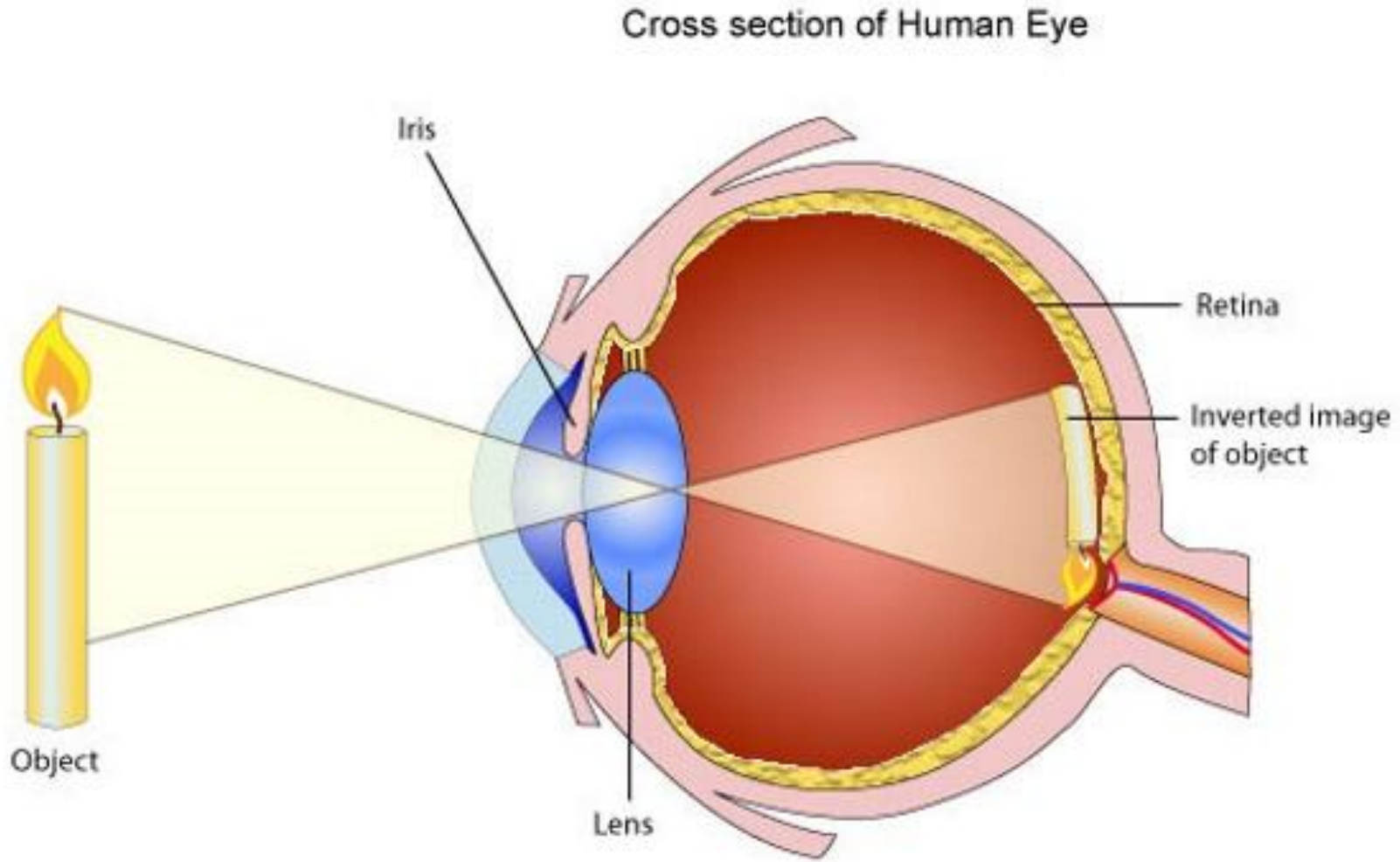
Source: forbes.com

Vision as Input

- Two stages of vision
  - Physical reception of stimulus (i.e., light) from the outside world
  - Processing and interpretation of the stimulus

Vision: Receiving Stimulus

- Light reflected by objects in the world form an image which is received by the eye
- The image is focused (by the cornea and lens) upside-down on the back of the eye (retina)
- Photoreceptors transform the stimulus into electrical signals which are transmitted to the brain



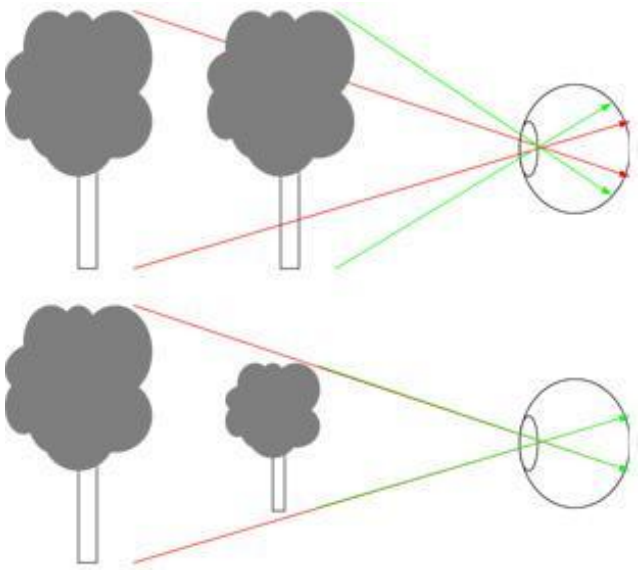
Source: mentalfloss.com

Vision: Receiving Stimulus

- The retina has two types of photoreceptors
- Rods (120 million per eye)
  - Concentrated in the periphery of the retina
  - Highly sensitive to light and permit vision in low light situations
  - Subject to light saturation
  - Unable to resolve fine detail
- Cones (6 million per eye)
  - More light tolerant/less light sensitive
  - Three types each sensitive to a different wavelength
  - Allows for color vision
  - Concentrated on fovea (center of retina) where images are focused

Perceiving Size and Depth

- Size of image on retina is specified as a visual angle
  - Objects of the same size at different distances have different visual angles



Source: stanford.edu

Perceiving Size and Depth

- Two objects of different sizes at same distance – larger object will have a larger visual angle
- Two objects of same size at different distances – closer object will have larger visual angle
- Visual angle indicates how much of the field of view is taken up by the object

Perceiving Size and Depth

- An object (e.g., automobile) does not appear to become smaller as it moves further away even though its visual angle becomes smaller
- Depth perception makes uses of cues
  - Position relative to other objects
  - Size relative to other objects
  - Familiarity

Perceiving Brightness

- Brightness is a subjective response to levels of light
- Brightness is affected by luminance – the measurable amount of light emitted by an object
- Contrast is a function of luminance of an object in relation to the luminance of its background

Perceiving Brightness

- The visual system can compensate for changes in brightness
  - Rods predominate in low-light conditions, provide less detail
  - Visual acuity increases with increased luminance – cones take over and allow for more detailed vision

Perceiving Color

- Color has three components
  - Hue – the wavelength of the light (short for blue, long for red)
  - Intensity – the brightness of the color
  - Saturation – the amount of whiteness in the color
- Humans can perceive ~7 million different colors but generally can only identify about 10

Perceiving Color

- Three types of cones for perceiving color, corresponding to red, green, and blue
- Cones are concentrated in the fovea so color vision is best in the center of the field of vision
- Blue cones are the least frequently occurring (~3-4%) making blue acuity lower

Visual Processing

- Transformation and interpretation of a complete image from light that is projected onto the retina
- Compensates for image movement on the retina and changes in luminescence and color
- Resolves ambiguity based on expectations and experience
- Compensates for incomplete information
- Can overcompensate at times

The quick brown fox jumps over the the lazy dog.

The quick brown fox jumps over the the lazy dog.

Reading

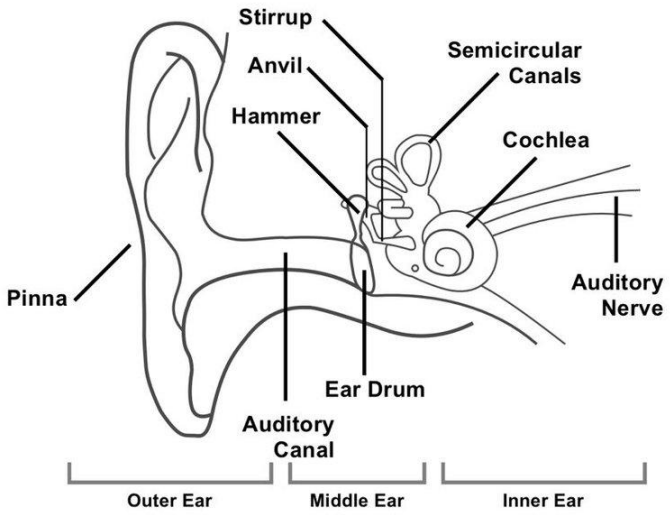
- Especially important aspect of visual perception and processing in interactive systems
- Perception and processing is not strictly serial
- Eye fixates and then jumps in text (saccades)
- Eye makes regressions while reading
- Words are recognized as whole shapes, rather than letter by letter
- Manipulations to word shape (e.g., capitalization) can slow reading speed and reduce accuracy

Hearing

- Generally regarded as the second most important sense to people with typical sensory abilities
- Continuous channel of input

Hearing: Receiving Stimulus

- Human ear has three sections
  - Outer ear – visible part of the ear which protects middle ear from damage and serves to amplify some sounds
  - Middle ear – connected to outer ear by tympanic membrane and contains the ossicles
  - Inner ear – connected to middle ear by cochlea, filled with cochlear liquid



Hearing: Receiving Stimulus

- Sound waves pass through outer ear auditory canal
- Waves vibrate tympanic membrane
- Tympanic membrane vibrates ossicles
- Ossicles vibrate cochlea
- Vibration is transferred to cochlean liquid
- Cochlean liquid vibrations bend inner ear cilia
- Cilia release chemical transmitter which causes impulses in auditory nerve

Hearing: Processing Sound

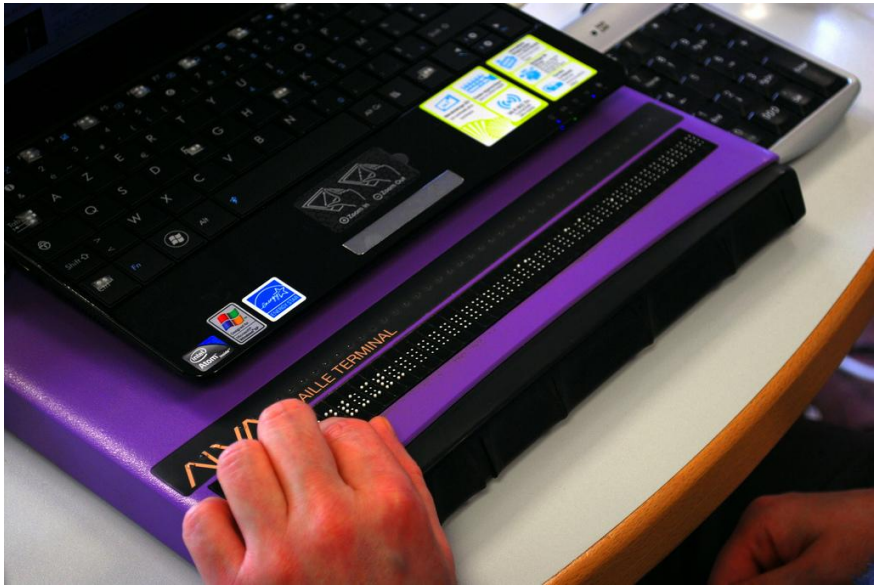
- Sound has key characteristics
  - Pitch – frequency of sound (low vs. high)
  - Loudness – amplitude of sound
  - Timbre – type of sound

Hearing: Processing Sound

- Auditory system performs some filtering of sound
- Filtering out of background noise and focus on important information
- “Cocktail party effect” – illustrates ability to selectively hear sounds that are highly relevant

Touch

- Important input channel in interaction though generally impoverished in digital interfaces compared to visual and auditory
- Human sense of touch is not localized (though as interface output it is mostly localized to hands and fingers)



Touch: Receiving Stimulus

- Three types of sensory receptors for touch
  - Thermoreceptors – respond to heat and cold
  - Nocireceptors – respond to pressure, heat, and pain
  - Mechanoreceptors – respond to pressure
- Mechanoreceptors are most often targeted in interactive systems
  - Rapidly adapting - respond to immediate pressure and stop responding with continued stimulus
  - Slowly adapting – respond continuously to applied pressure
- Concentration of receptors varies throughout the body

Movement: Human Output

- Most human output used by interactive systems is articulated through movement and the motor system (including speech)
- External stimulus (e.g., a question on a screen) is received by sensory receptors and transmitted to brain
- Brain processes the information and generates a response
- Appropriate muscles are told to articulate the response
- Entire process can be divided into reaction time and movement time

Movement: Human Output

- Movement time varies according to individual ability
  - Factors: age, fitness, fatigue, impairment, etc.
- In interactive interfaces, speed and accuracy of movement are key to design and usability
- Fitts's Law is a formulation of the idea that movement time is proportional to distance and target size

HUMAN MEMORY

Human Memory

- Humans are more than processors that take a stimulus and produce a response
- Real interaction involves knowledge, reasoning, cognition, and experience
- Memory plays a critical role

Human Memory

- Human memory stores information needed for activity
  - Factual knowledge
  - Procedural knowledge
  - Experiential knowledge

Human Memory

- Three general types of memory
  - Sensory memory
  - Short-term memory/working memory
  - Long-term memory

Sensory Memory

- Serves as buffer for incoming sensory input
  - Iconic memory – for visual stimuli
  - Echoic memory – for aural stimuli
  - Haptic memory – for touch stimuli
- Decays quickly
- Most information is filtered out and lost
- Some information is transferred to short-term memory by focus or attention

Short-term Memory

- Working memory is a temporary storage for information that is currently being used
- Can be accessed rapidly but also decays rapidly
- Has limited capacity (7 ± 2 units)

Short-term Memory Example

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Short-term Memory Example

Short-term Memory

- Information can be “chunked” – combined into larger units, thus increasing short-term memory capacity
- Patterns and meaningful chunks also aid memory (e.g., 7 words in a language you know, vs a language you don’t)

Short-term Memory Example

- Remember that number?

Short-term Memory Example

41 044 635 44 11

Short-term Memory

- Is subject to recency effects
- May have different channels for different types of information
- May transfer information to long-term memory through repetition or rehearsal

Long-term Memory

- Main repository for memory
- Stores factual, experiential, and procedural knowledge
- Has potentially unlimited capacity
- Slow access time
- Forgetting occurs slowly if at all, slow decay

Long-term Memory

- Two types of long-term memory
  - Episodic – memory of events and experiences in a serial form
  - Semantic – structured record of facts, concepts, and skills, structured as a network

Long-term Memory Acquisition

- Total-time hypothesis – the more time spent learning, the more will be learned
- Distribution of practice effect – learning is more effective if it is distributed over time
- Meaningful information can be learned more easily
  - More easily integrated into the semantic network of memory

Upcoming...

- NO lab THIS WEEK (25.9.2019)
- No reading assignment for next week's lecture
- First lab next week (02.10.2019)
  - Lab will be distributed on 31.09.2019