Human Sensors

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https://www.theiilab.com/

Lecture notes in this series are based on

- Ahmed Sabbir Arif. 2021. Statistical Grounding. *Intelligent Computing for Interactive System Design: Statistics, Digital Signal Processing, and Machine Learning in Practice*, ACM
- Ann Blandford, Dominic Furniss, Stephann Makri. 2016. Qualitative HCI Research: Going Behind the Scenes. Morgan & Claypool
- Jonathan Lazar, Jinjuan Feng, Harry Hochheiser. 2017. Research Methods in Human-Computer Interaction. Morgan Kaufmann
- I. Scott MacKenzie. 2013. Human-Computer Interaction: An Empirical Research Perspective, Morgan Kaufmann
- Interaction Design Foundation. 2022. Design Thinking
- Lecture notes of Amy Bruckman, Mark Dunlop, Niels Henze, I. Scott MacKenzie, Laura Moody, Albrecht Schmidt, Kami Vaniea

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1

Descriptive Models of Human

Time Scale of Human Action

Human Factors Model

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Models of the Human

- Descriptive models are tools for thinking a descriptive model for the human
- There are many
  - Model Human Processor
- We begin with two useful models for the human

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Time Scale of Human Action

Scale (sec)	Time Units	System	World (theory)
10^7	Months		SOCIAL BAND
10^6	Weeks		
10^5	Days		
10^4	Hours	Task	RATIONAL BAND
10^3	10 min	Task	
10^2	Minutes	Task	
10^1	10 sec	Unit task	COGNITIVE BAND
10^0	1 sec	Operations	
10^{-1}	100 ms	Deliberate act	
10^{-2}	10 ms	Neural circuit	BIOLOGICAL BAND
10^{-3}	1 ms	Neuron	
10^{-4}	100 μs	Organelle	

Allen Newell. 1990. Unified Theories of Cognition. Cambridge, Harvard University Press, MA.

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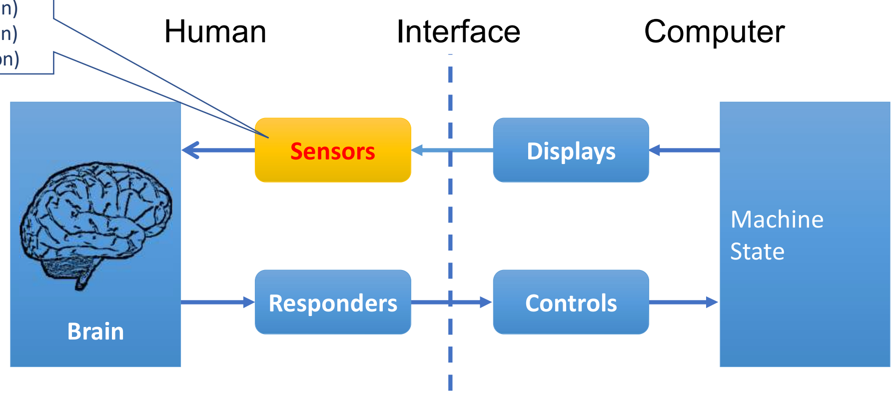
Human Factors Model

1. Vision (sight)
2. Hearing (audition)
3. Touch (taction)
4. Smell (olfaction)
5. Taste (gustation)



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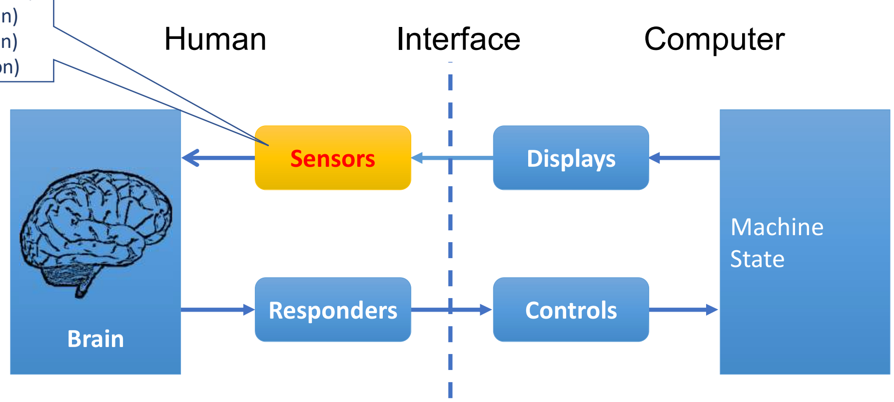

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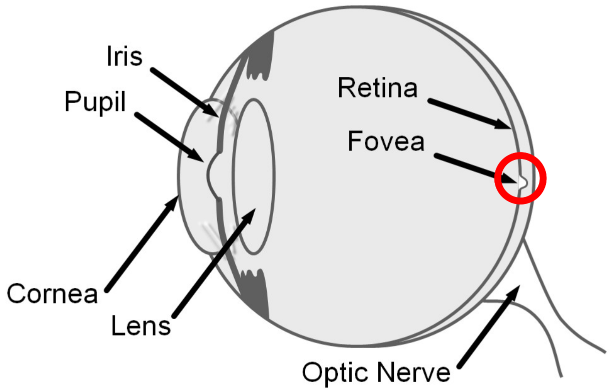
Vision: The Eye

- We obtain about 80% of our information via vision (the eye)



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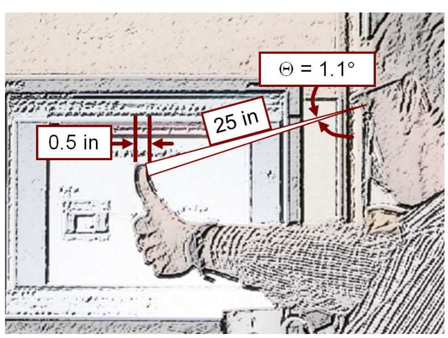
Fovea Image

- Sharp central vision
- 1% of retina, 50% of visual cortex
- Fovea image is ≈1° of visual angle:



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Visual Stimulus

- Physical properties of light
  - Frequency
  - Intensity (luminance)
- Create subjective properties of vision
  - Color
  - Brightness

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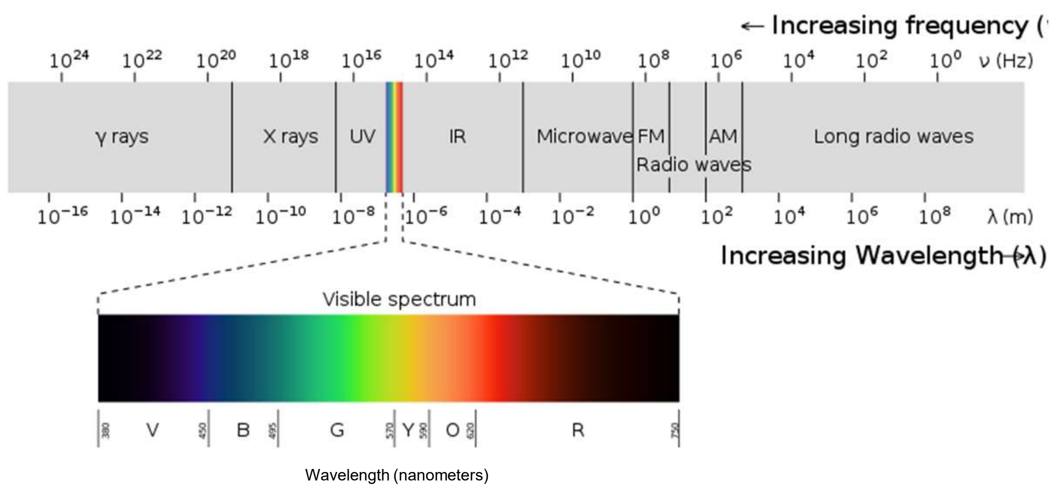
Color Spectrum



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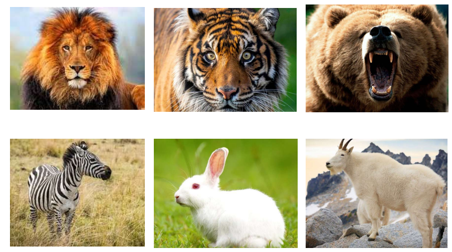
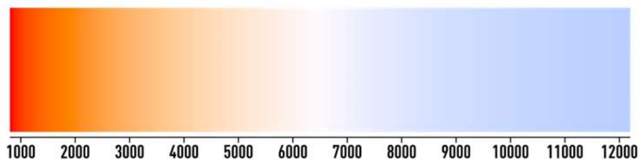
Warm and Cool Colors



- Warm colors are associated with daylight or sunset
  - Hues from red through yellow, browns, and tans
- Cool colors are associated with a gray or overcast day
  - Hues from blue-green through blue violet, most grays
- Historical disagreement about the colors that anchor the polarity
  - Modern theories put the peak contrast between red-orange and greenish-blue



- There are perceptual and psychological effects to this contrast
  - Warm colors advance or appear more active; arouse or stimulate
  - Cool colors tend to recede; calm and relax

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Warm and Cool Colors

- Warm colors such as red and orange seem to activate the survival mode, which
  - *Increases* speed and force
  - *Decreases* patience and creativity

Clara Vetter. 2019. The effects of colors on behavior. Neurofied. https://neurofied.com/effects-of-color-on-behavior

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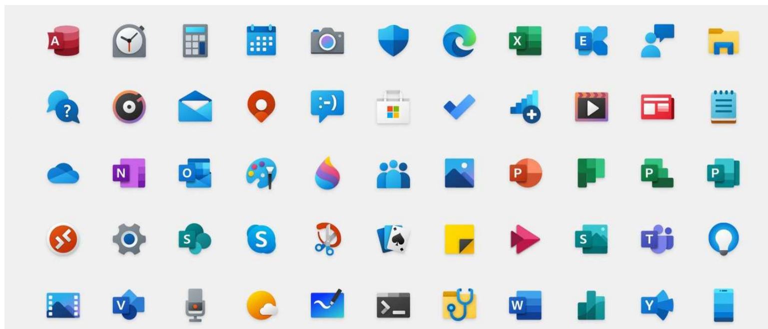
Warm and Cool Colors



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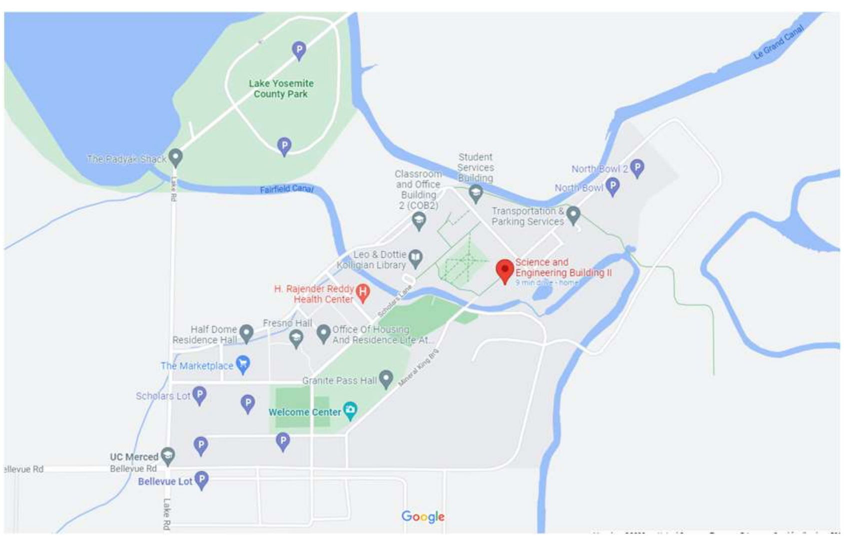
"Pop" Visual Elements



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Interpreting the Signal

- Color blindness or color deficiency

Female	0.5%
Male	8.0%

- We perceive
  - About 150 hues
  - About 7 million colors
- How many can you name?
  - **About 12**

Color Blindness: https://www.colourblindawareness.org/colour-blindness

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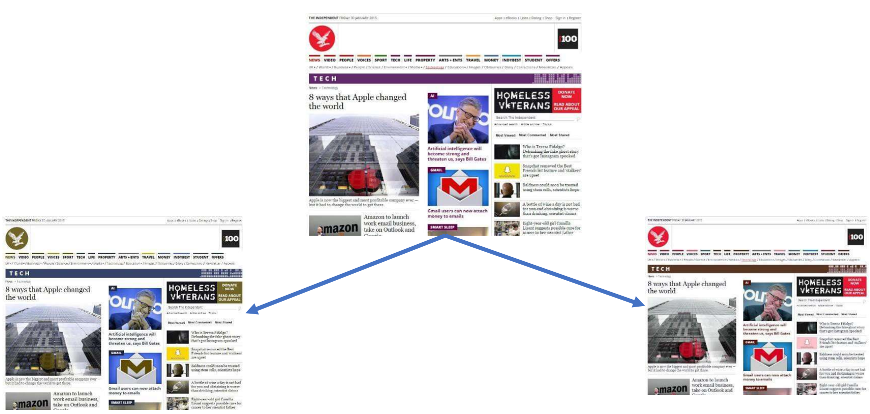
Color Blindness Simulation



Deuteranopia/Protanope
(Red/Green)

Tritanope
(Blue/Yellow)
rarer

http://www.color-blindness.com/coblis-color-blindness-simulator

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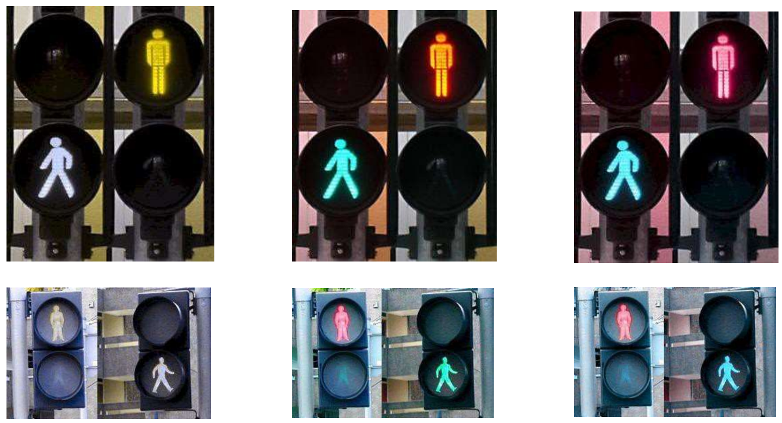
Color Blindness Simulation



Red/Green

Blue/Yellow
rarer

European Traffic Light *Aufgenommen am 20. August 2005 *Source: selbst fotografiert Photographer: Robert Ionescu User:Caterham {{cc-by-2.0}} UK Traffic light from https://www.southampton.gov.uk

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Don't Use Color Alone

- Color can be good discriminator and easy to remember, identify
- But don't rely on it as sole difference

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Fixations and Saccades

- Fixation
  - Eyes are stationary (dwell)
  - Take in visual detail from the environment
  - Long or short, but typically at least 200 ms
- Saccade
  - Rapid repositioning of the eye to fixate on a new location
  - Quick: ≈120 ms

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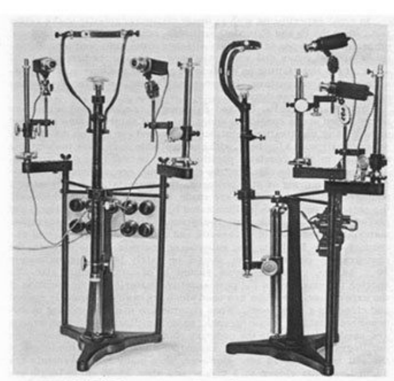
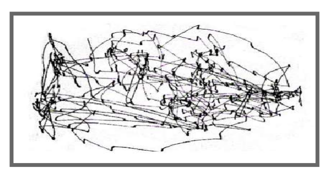
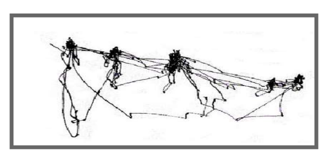
Yarbus' Eye Tracking Research (1965)



The Unwanted Visitor
by Ilya Repin (1844-1930)



"Remember the position of people and objects in the room"



"Estimate the ages of the people"

Benjamin W Tatler, Nicholas J Wade, Hoi Kwan, John M Findlay, Boris M Velichkovsky. 2010. Yarbus, Eye Movements, and Vision. i-Perception, 1, 7-27.

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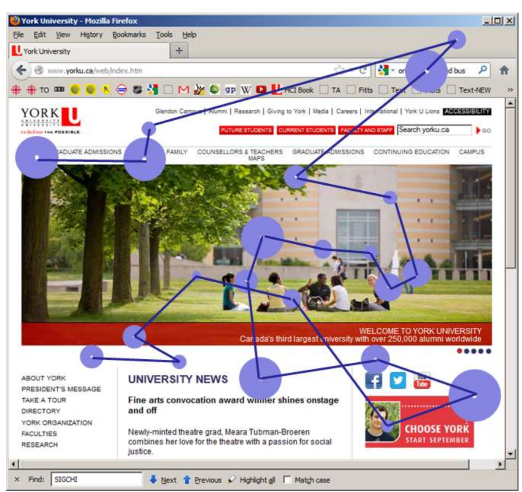
Scan Paths

- Visual depiction of saccades and fixations
- Saccades → straight lines
- Fixations → circles
  - Diameter of circle ∝ duration of fixation
- Applications
  - User behavior research (e.g., reading patterns)
  - Marketing research (e.g., ad placement)

Scan Paths: Example



Dyslexia

- One in every 10 to 20 people in has some degree of dyslexia
  - A person with dyslexia may:
    - read and write very slowly
    - confuse the order of letters in words
    - put letters the wrong way round – such as writing "b" instead of "d"
    - have poor or inconsistent spelling
    - understand information when told verbally, but have difficulty with information that's written down
    - find it hard to carry out a sequence of directions
    - struggle with planning and organization
- However, people with dyslexia often have good skills in other areas, such as creative thinking and problem solving

NHS choices
https://www.nhs.uk/conditions/dyslexia

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Designing for Dyslexia

- Support readability tools
  - Avoid text in images/excessive CSS control freakery
- Support flexible navigation with a variety of paths

usabilla
http://blog.usabilla.com/how-to-design-for-dyslexia

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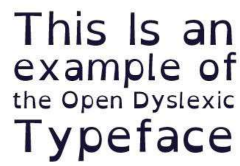
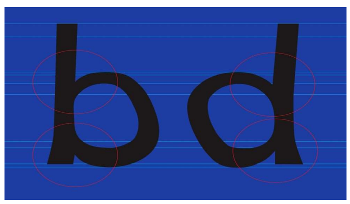
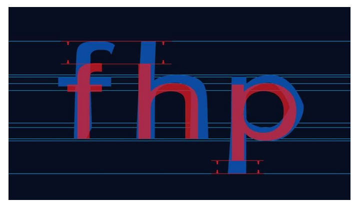
Designing for Dyslexia: Typeface

- Reduce in-word character separation
- Increasing between word separation
- Avoid italics and underlining
- Use a sans-serif or typefaces developed for dyslexic users





Tweak similar looking letters like “b” and “d” so they could not be easily confused



Make the upright sticks on letters longer to reduce confusion

Richard Gray. 2017. The Typeface that Helps Dyslexics Read. BBC.

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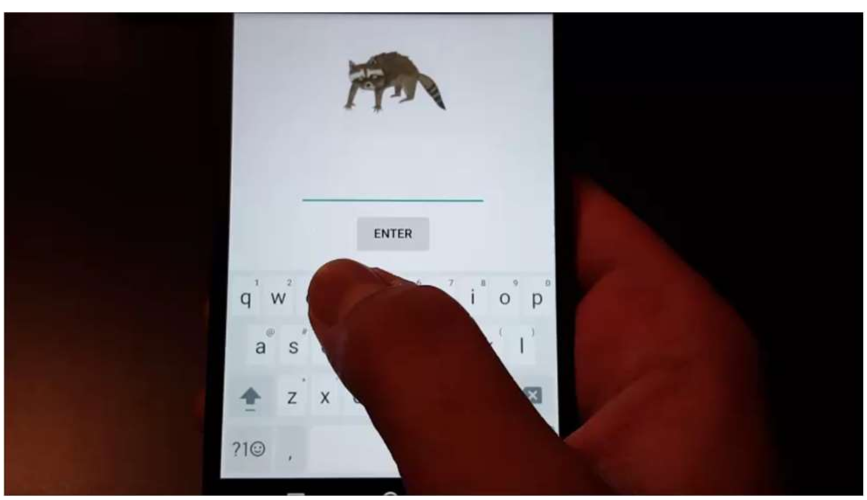
Color-Coded Feedback: Example 1



Ahmed Sabbir Arif, Cristina Sylla, Ali Mazalek. 2016. Learning New Words and Spelling with Autocorrections. In Proceedings of the 2016 ACM International Conference on Interactive Surfaces and Spaces (ISS 2016). ACM, NY, 409-414.

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Color-Coded Feedback: Example 2

Sean DeLong, Ahmed Sabbir Arif, Ali Mazalek. 2019. Design and Evaluation of Graphical Feedback on Tangible Interactions in a Low-Resolution Edge Display. In ACM International Symposium on Pervasive Displays (PerDis 2019). ACM, NY, Article 8.

Human Factors Model

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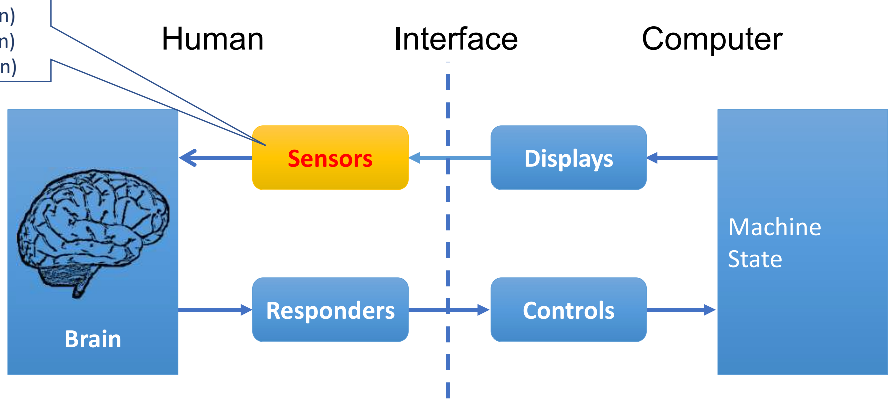

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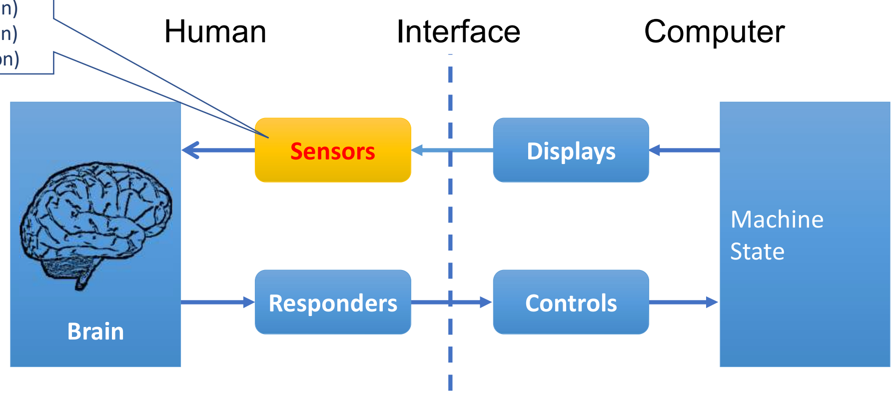

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Hearing (Audition)

- Sound is cyclic fluctuations of pressure in a medium, such as air
- Created when physical objects are moved or vibrated

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Auditory Stimulus

- Physical properties of sound
  - Frequency
  - Intensity
- Create subjective properties of hearing
  - Pitch
  - Loudness

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Properties of Sounds

- Dynamics/Amplitude (loudness)
- Frequency (pitch)
- Timbre/tone color (richness/brightness)
- Duration (tempo/rhythm)

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Dynamics/Amplitude (Loudness)

- Higher amplitudes correspond with louder sounds

- Perception:
  - Loudness
  - Humans perceive sounds at very low and very high frequencies to be softer than sounds in the middle frequencies, even when they have the same amplitude

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Frequency (Pitch)

- Enables us to judge sounds as being *higher* or *lower*
- High-pitched sound causes molecules to rapidly oscillate
- Pitch can only be determined when a sound has a frequency that is clear and consistent enough to differentiate it from noise

- Perception:
  - Pitch is primarily based on a listener's perception
  - Not an objective physical property of sound

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Timbre/Tone Color (Richness/Brightness)

- Sounds with various timbres produce different wave shapes
  - Affect our interpretation of the sound
- Results from harmonic structure of sound
- The same frequency from different instruments are distinguished, in part, due to timbre
  - The sound by a trumpet has a different tone color than the sound from an oboe

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Duration (Tempo/Rhythm)

- Duration is the amount of time that a pitch or tone lasts
  - Can be described as long or short
- Duration of a tone influences the timbre and rhythm of a sound
  - A classical piano piece will tend to have notes with a longer duration than the notes played by a keyboardist
    - Assists in distinguishing notes of the same pitch coming from different instruments
- The duration of a sound or tone begins once the sound registers and ends after it cannot be detected

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Recap: Don't Use Color Alone

- Color can be good discriminator and easy to remember, identify
- But don't rely on it as sole difference

- Provide auditory feedback, when appropriate

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Association & Training

	Audio Clip #1	**Truck backing up**
	Audio Clip #2	**Windows notification**
	Audio Clip #3	**Subway arriving**

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Every Windows Startup & Shutdown Sound

https://www.youtube.com/watch?v=0UUAQiT2-Xc

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Recap: Time Scale of Human Action

Scale (sec)	Time Units	System	World (theory)
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Allen Newell. 1990. Unified Theories of Cognition. Cambridge, Harvard University Press, MA.

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Low-vision and Blind People

- Auditory feedback is dominant
- Reduce duration
- Increase learnability, intuitiveness

- Combine with additional interactions
  - Touch, gestures, etc.

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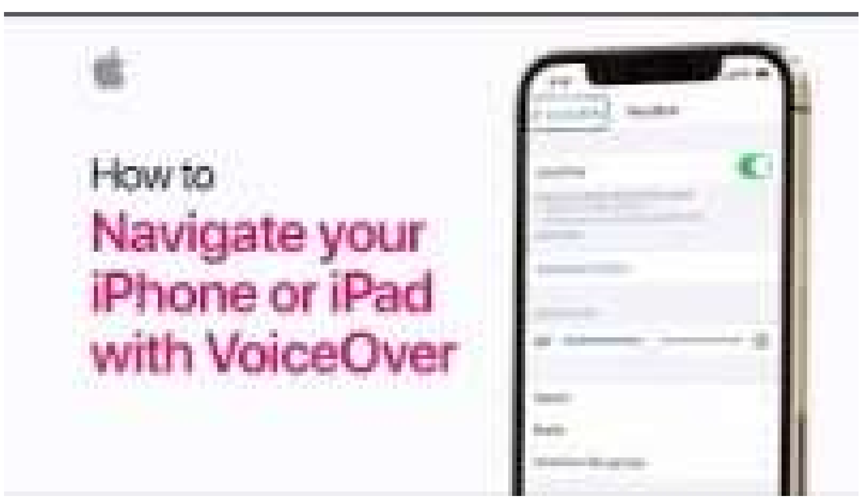
Apple's VoiceOver Feature



https://www.youtube.com/watch?v=qDm7GiKra28

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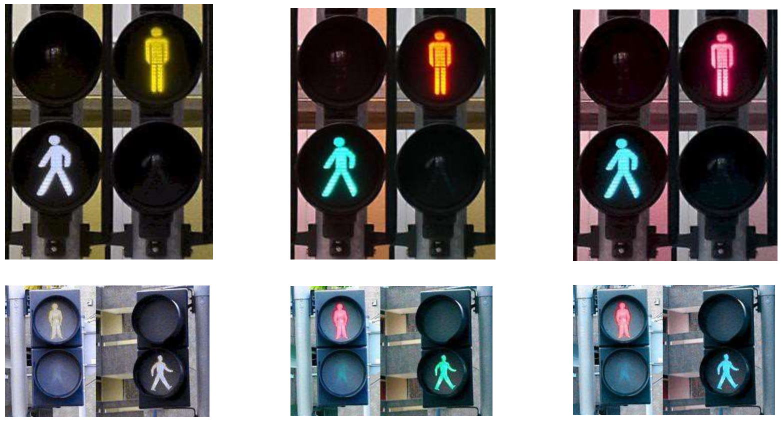
Recap: Color Blindness Simulation



Red/Green

Blue/Yellow
rarer

European Traffic Light © Bob Ionescu

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Example: Senorita

Gulnar Rakhmetulla, Ahmed Sabbir Arif. 2020. Senorita: A Chorded Keyboard for Sighted, Low Vision, and Blind Mobile Users. In Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI 2020). ACM, NY, 1–13.

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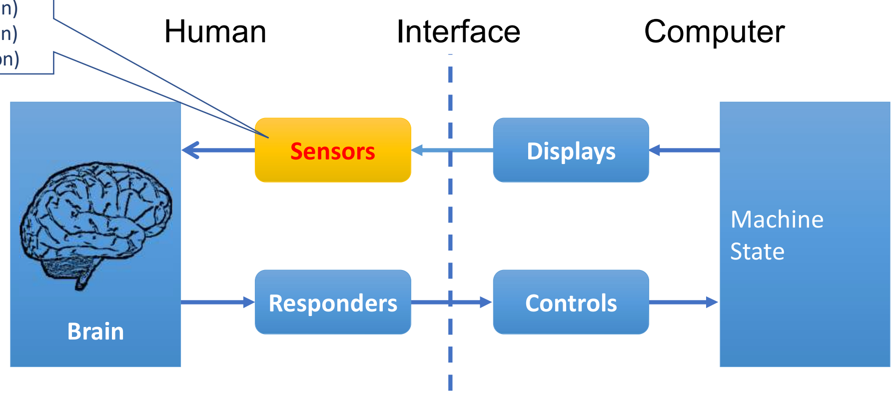

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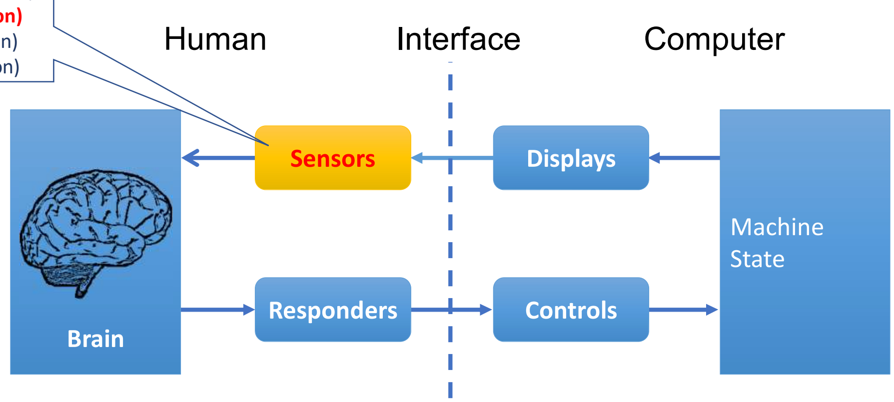

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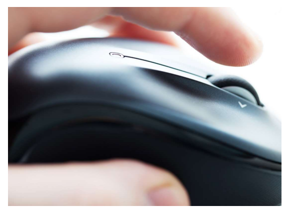
Touch (Tactition)

- Part of somatosensory system, with
  - Receptors in skin, muscles, joints, bones
    - Sense of touch, pain, temperature, shape, texture, resistance, etc.

- Tactile feedback examples:

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Touch in User Interface

- Touchscreens
  - Multi-tap and gestures
  - Screen reader
- Haptic feedback
  - Vibration
  - Shape (obstacles, constraints)
  - Texture
  - Resistance

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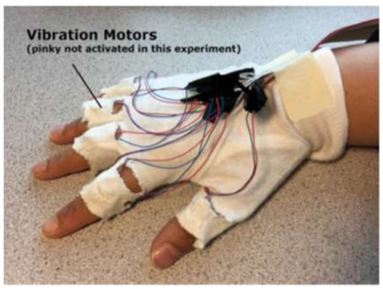
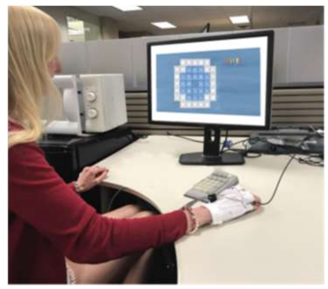
Touch: Haptic Feedback via Vibration

- Improved performance in precise selection
  - Can be provided on reaching target, on selection, or both
- Facilitates learning (passive haptic learning)
- Can be removed when transitioned from novice to expert





Seim et al. (2017)

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Touch: Haptic Feedback via Vibration

- Duration of the vibration control signal should be between 50 and 200 ms (Kaaresoja & Linjama, 2005)
- Perceived pleasantness depends on the characteristics of the tactile feedback parameters that define the wave shape of the stimuli (Koskinen et al., 2008)
- Most pleasant tactile feedback on finger:
  - 46 mA drive current for the piezo actuator
  - 16 ms drive time for the vibration motor

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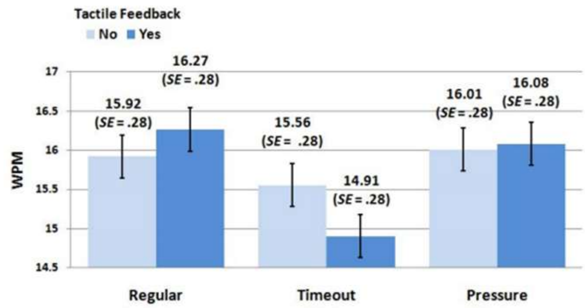
Vibration Example

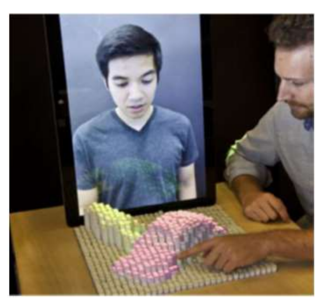


Ahmed Sabbir Arif, Mauricio H. Lopez, Wolfgang Stuerzlinger. 2010. Two New Mobile Touchscreen Text Entry Techniques. Poster at the 36th Graphics Interface Conference (GI 2010). CEUR-WS.org/Vol-588, 22-23.

Touch: Shape-Changing Interface

- Beneath the surface of the screen:
  - Microscopic channels prearranged by the manufacturer
  - Small amount of a clear oily substance
- The substance is pumped through the channels for solid buttons

Tactus Technology (the Verge)



MIT Media Lab's inFORM

Touch: Haptic Feedback via Force

- Apply 3D force vectors at different points for kinesthetic feedback
  - Usually grounded on one part of the **body** (e.g., forearm) or a **surface** to provide feedback on another (e.g., fingers) by exerting localized forces that restrict the natural degrees of freedom of the body
  - Separate motors are required for each component of the exerted force

CyberGrasp

CyberForce

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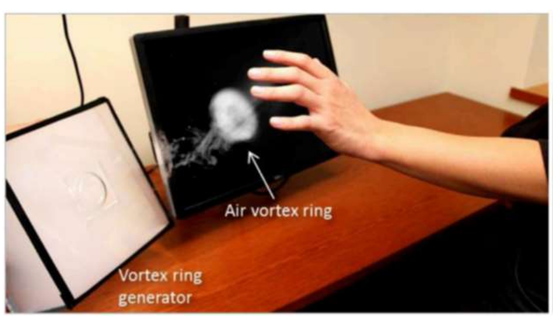
Touch: Haptic Feedback via Air Vortex

- Uses air vortex rings for to provide feedback
- Can be focused to travel several meters and impart perceptible feedback



Microsoft Research AirWave

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Touch: Haptic Feedback via Sound Waves

- Phased array of transducers produce ultrasound waves and focused on a point in space above the device

Ultraleap

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Non-Vibration Haptic Feedback

- Virtual reality
  - Type of haptic feedback
  - Patterns, duration, intensity, etc. must be determined based on the system (different range for different systems)

Meta's Sci-fi Haptic Glove Prototype Lets You Feel VR Objects Using Air Pockets, The Verge

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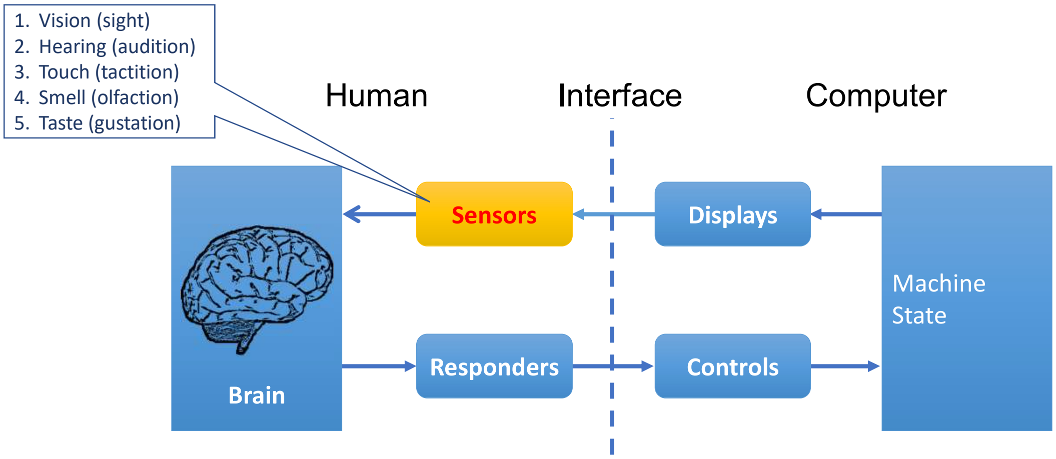
Human Factors Model



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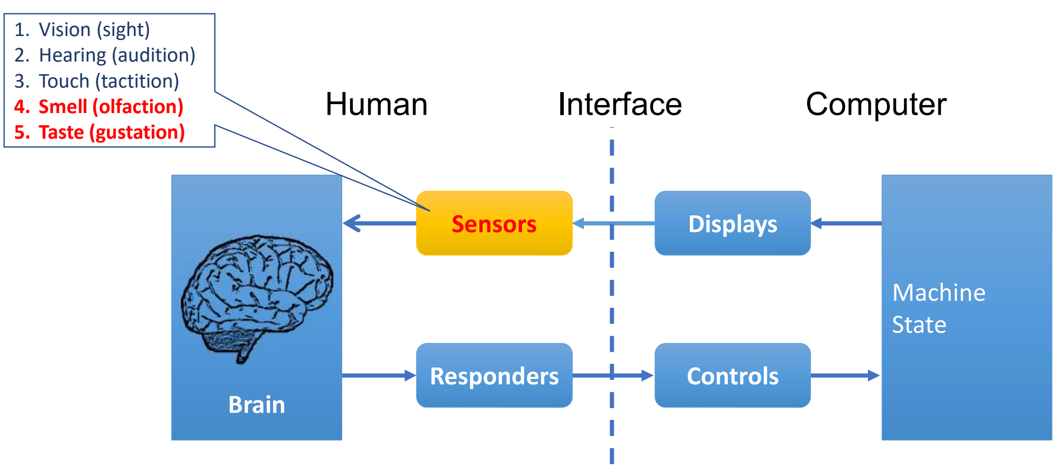
Human Factors Model



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Smell (Olfaction) & Taste (Gustation)

- Smell (olfaction)
  - Ability to perceive odours
  - Occurs through sensory cells in nasal cavity
- Taste (gustation)
  - Chemical reception of sweet, salty, bitter, and sour sensations
- Flavor
  - A perceptual process that combines smell and taste

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Smell in Learning & Simulation

- To increase presence and immersion:
  - In Virtual Reality (VR)
    - Training
    - Gaming
  - In Cave Automatic Virtual Environment (CAVE): immersive environment where displays or projectors are directed to three to six walls of a room-sized cube
    - Military
- Associative learning:
  1. Releases odor when learning
  2. Releases the same odor when resting
  3. Facilitates learning

Olfactory Virtual Reality (OVR) Technology

U.S. Navy Combined Arms Virtual Environment (CAVE)

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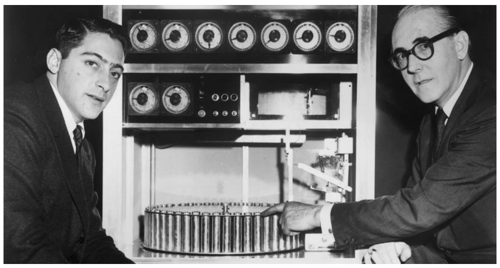
Smell in Entertainment & Well-Being

- 4DX film format allows films to be augmented with practical effects like motion seats, wind, strobe lights, snow, scents



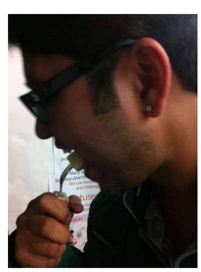
American film producer Mike Todd Jr (left), Swiss inventor Hans Laube, and the "Smell-O-Vision" machine, which produced smells in synchronization with action in a film. It was used for the 1960 film "The Scent of Mystery". Circa 1959, Photo by Hulton Arc

J. Amores, J. Wang, M. Dotan, P. Maes. 2019. Lotuscent: Targeted Memory Reactivation for Wellbeing Using Scent and VR Biofeedback. In IEEE EMBS Symposium and Workshop on Brain, Mind, and Body: Cognitive Neuroengineering for Health and Wellness.

Taste-based Interaction

- Entertainment
- Immersive systems
  - Virtual and augmented reality
- Culinary
- Healthcare and well-being

Screen Lckin' Good: Japanese Professor Invents a 'Lickable' Device that Lets You Taste What You See, EuroNews.Next (05/01/2022)



Hiromi Nakamura and Homei Miyashita. 2012. Development and Evaluation of Interactive System for Synchronizing Electric Taste and Visual Content. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12). ACM, NY, 517–520.

Smell & Taste in UI: Challenges

- Delivery time
  - How much time does it take to reach a smell to a person?
    - Can they be used to provide real-time feedback?
- Neutralization
  - How do you remove a smell or taste?
- Subjectiveness
  - Smell is associated with one's memory and experience, thus can have different interpretation and association
    - Cultural aspect
    - Personal experience

inclusive interaction lab