Human Computer Interaction for Game Design

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Prior studies in human perception and performance can help guide game design.

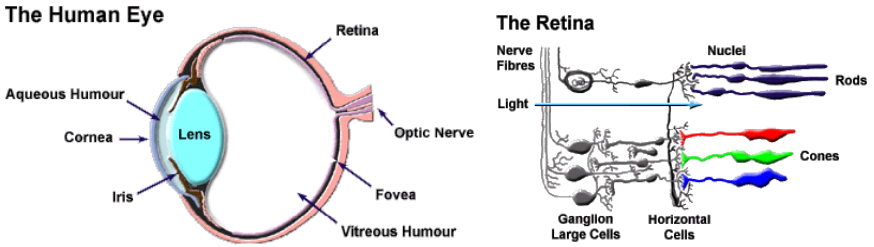
Human Perception System

- Obtain Information about environment through vision, audition, haptic/touch, olfaction, gustation, vestibular/kinesthetic senses.
- Human perception capability provides HCI design issues.

Vision

- Vision is one of the most important research areas in HCI because designers should know
  - What can be seen by users
  - What a user can see better
  - What can attract user's attention
- Vision
  - Physical reception of stimulus
  - Processing and interpretation of stimulus
  - No clear boundary between the two

Human Visual System



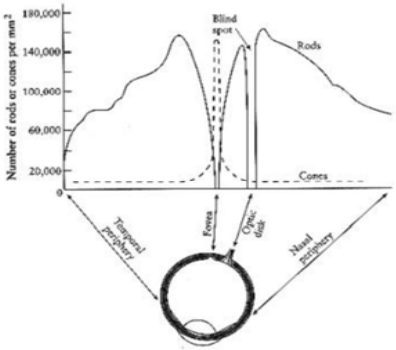
Human Eye

- Light is focused by the cornea and the lens onto the retina
- Light passing through the center of the cornea and the lens hits the fovea (or Macula)
- Iris permits the eye to adapt to varying light levels, controlling the amount of light entering the eye.
- Retina is optically receptive layer like a film in a camera
- Retina translate light into nerve signals.
- Retina has photoreceptors (rods & cones) and inter-neurons.

Photoreceptors (Rods & Cones)

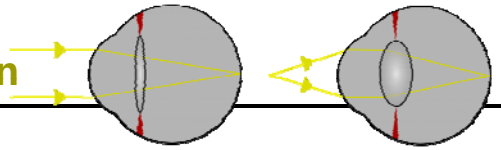
- Rods
  - Operate at lower illumination levels
  - Luminance-only
  - The most sensitive to light
  - At night where the cones cannot detect the light, the rods provide us with a **black and white** view of the world
  - The rods are also more sensitive to the blue end of the spectrum
- Cones
  - operate at higher illumination levels
  - provide better spatial resolution and contrast sensitivity
  - provide color vision (currently believed there are 3 types of cones in human eye, one attuned to red, one to green and one to blue)
  - provide visual acuity

Rods/Cones Distribution



- Fovea
  - only cone receptors with very high density
  - no rods
  - no S-cones (blue cones)
  - responsible for high visual acuity
- Blind Spot
  - no receptors
  - Axons of all ganglion cells pass through the blind spot on the way to the brain

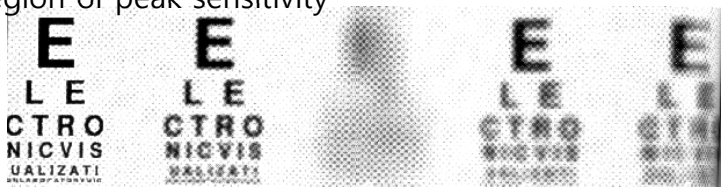
Vision Perception



- Accommodation
  - The process by which the eye increases optical power to maintain a clear image (focus) on an object as it draws near
- Visual acuity
  - Acuteness or clearness of vision, which is dependent on the sharpness of the retinal focus within the eye and the sensitivity of the interpretative faculty of the brain
- Contrast sensitivity
  - Typical band-pass shape peaking at around 4 cycles per degree with sensitivity dropping off either side of the peak
- Adaptation
  - The ability of the eye to adjust to various levels of darkness and light
- Color vision

Visual Acuity

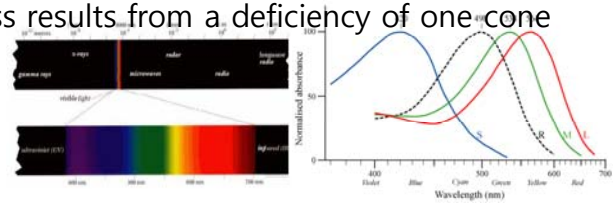
- Visual Acuity is measured as the angle subtended by the human eye.
- Snellen fraction 20/X where the viewer sees at 20 feet detail that the average person can see at X feet.
- 20/20 vision corresponds to recognizing letters that are 5 minutes of arc.
- A resolution of about 5 arcmin is necessary to get to the region of peak sensitivity



20/20 CRT 20/40 HMD 20/425 BOOM 20/85 CAVE 20/110

Color Vision

- Human perceive electromagnetic energy having wavelengths in the range 400 nm ~ 700 nm as visible light.
- There are three types of cones, referred to as S, M, and L. They are roughly equivalent to blue, green, and red sensors. Their peak sensitivities are located at 420 nm, 534 nm, 564 nm.
- Color perception results from the simultaneous stimulation of the 3 cone types.
- Colorblindness results from a deficiency of one cone type.



Temporal Resolution

- The real world doesn't flicker. CRTs do flicker because the image is constantly being refreshed.
- We perceive flickering if the image on CRT isn't refreshed fast enough.
- Rate above which the human eye can no longer recognize discontinuous changes in brightness as a flicker.
- 31.25 Hz for most humans. Some can see up to about 50Hz.

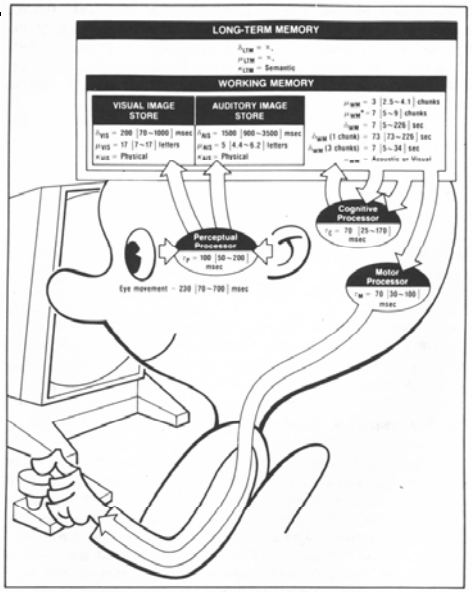
Frame rates

- Frame rates in video games refer to the speed at which the image is refreshed - typically in frames per second (FPS).
- If the video games has no animation, high frame rates are meaningless.

Visual Perception Implications

- Putting a lot of detail in the interface at the perimeter of a first person shooter's display screen might be a waste.
- Notice that in a driving game, it is very difficult to admire the scenery and drive competitively at the same time. Sometimes it's more fun to watch the game than play it.
- Video game monitors should ensure that they are set at refresh rates higher than this rate. Typically 60Hz is used in monitors.
- Highest quality monitors today refresh at 120Hz (at most).
- Most consumer monitors refresh at about 60 to 80Hz.
- Some games claim several hundred frames per second. This is impressive but ultimately not perceivable by the human.
- Plus, if graphics are not synchronized with the vertical blank of the screen- image will appear to tear even at high frame rates.
- So for optimal graphics presentation you synch the frame rate with the refresh rate so that image buffer swaps occur ONLY during vertical blank cycle.

Human Processor Model



- The Psychology of Human-Computer Interaction by Stuart Card.
- Many experiments dating back to the 1960s to predict how quickly humans can detect and respond to a stimulus.
- E.g. User sees a sequence of random characters on the screen and is asked to press a button every time he sees an A.

Human Processor Model

- Human Processor Model by Card, Moran, Newell (1983)
  - Uses the cognitive, perceptual, and motor processors along with the visual image, auditory image, working memory, and long term memory storages.

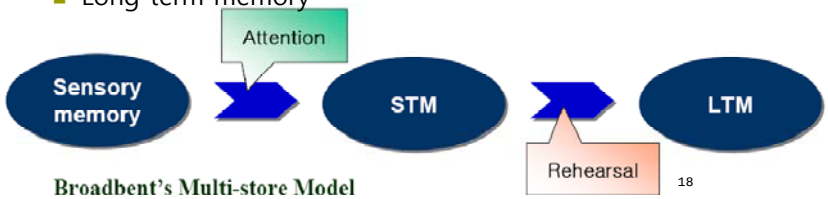
	Visual image storage	Auditory image storage	Short-term memory	Long-term memory
Capacity	17(7-17) letters	5(4.4-6.2) letters	3(2.5-4.1) chunks	∞
Decay	200(70-1000) msec	1500(900-3500) msec	7(5-226) sec	∞
Encode	Physical	Physical	Acoustic, Visual	Semantic
Processing cycle time	100(50-200)msec		70(30-100)msec	

Human Processor Model

- **The perceptual processor:**
  - takes input from the eyes and ears and drops it into two temporary memories, the visual image store and the auditory image store.
  - As a computer hardware analogy, these memories are like frame buffers, storing a single frame of perception.
- **The cognitive processor:**
  - operates on data from all the memories, including long-term memory, and puts its results back in the working memory.
- **The motor processor:**
  - takes instructions from the working memory (which you might think of as RAM, although it's pretty small), and runs those instructions on the muscles.

Human Memory

- Human memory is in every level of human processing
  - Encoding: type of things stored
  - Storage: Sensory/Short-term/Long-term memory
  - Retrieval
  - Forgetting: Decay, Interference, Retrieval failure
- Three types of memory
  - Sensory memory (sensory buffer)
  - Short-term memory (working memory)
  - Long-term memory



Broadbent's Multi-store Model

Sensory Memory

- **Visual image storage** is an image frame from the eyes.
  - Encoded as physical image
  - Size ~17 (7-17) letters
  - Decay ~200 (70-1000) msec
- **Auditory image storage** is a buffer for physical sound.
  - Encoded as physical sound
  - Size ~5(4.4-6.2) letters
  - Decay ~1500 (900-3500) msec
- **Intentional attention passes information in sensory memory to short-term memory.**

Short-Term Memory

- **Short-term memory (a.k.a. working memory)** is a scratch pad for mental process.
- When you read, you have to remember the foregoing words or sentences to understand the meaning.
- Higher access time (~70 ms), but faster decay (~200ms)
- **Small capacity: 7 ± 2 "chunks"**
- Chunking depends on presentation and on what you already know.
- **Maintenance rehearsal fends off decay.**
- **Interference causes faster decay.**

Long-Term Memory

- Long-term storage of information
- **Huge capacity, and little decay**
  - Long-term memory is apparently not intentionally erased; they just become inaccessible.
- Two types of long-term memory
  - Episodic memory – memory of event in a serial form
  - Semantic memory – a structured record of facts & association between concepts
- Rehearsal
  - Maintenance rehearsal (repetition) appears to be useless for moving information into long-term memory.
  - **Instead, elaborative rehearsal moves chunks from Working memory to long-term memory by making connections with other chunks.** Elaborative rehearsal lies behind the power of mnemonic techniques like associating things you need to remember with familiar places.

Long-Term Memory

- Remembering
  - The amount of learned is proportional to the amount of time.
  - Learning is more effective when it is distributed in time.
  - Concrete words are easier to remember.
  - Meaningful sentences are easier to remember – because one projects them on human semantic knowledge
- Forgetting
  - Memory decays logarithmically (Fast initially, but slowly later)
  - Retroactive interference: A new memory trace tends to overwrite an existing, similar memory traces
  - Proactive interference: A new memory trace is harder to remember if there is older but similar kinds of memory traces.
  - We tend to remember positive information better.
  - More emotional events are easier to remember.

Long-Term Memory

- Retrieval
  - Recall: Accessing memory items or attributes associated the current item in mind.
  - Recognition: Completion of a memory item from a partial clues.
  - Recall is possibly more complex process than recognition.
  - Categorization makes retrieval easier.
  - It is difficult to distinguish whether information decays or retrieval of information becomes harder.
  - Visualization helps memorization and retrieval.

Results- and ramification for video games

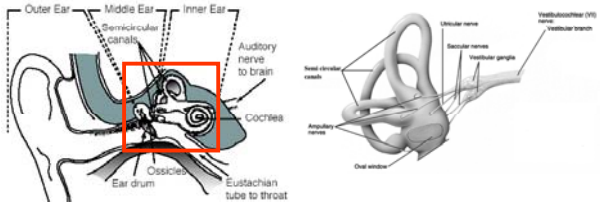
- Perceptual processor: T_p ~100(50-200) msec
  - If you have movement in your game that is slower than 10 frames/sec, viewer will not perceive this as an animation.
- Cognitive processor: T_c ~70(30-100) msec
- Motor processor: T_m ~70(25-170) msec
  - In a button masher game you cannot expect the average player to be able to push buttons in rapid succession faster than 70ms.
- Total: 240 [105~470] msec
  - In a fighting game, the average player will not be able to see a punch and block it faster than 200ms. (ie if you graphics update is at 30 frames/second [ie 33ms] and if there are fewer than 6 frames of animation in a punch, then the user won't have enough time to see and block it)
  - If they are experts they may be able to react as fast as 105ms- but no faster.

Results- and ramification for video games

- Eye Movement: T_e ~230(70-700) msec
  - Try to keep frequently used info in the center of the screen rather than in the periphery.
- Effective working memory is 7 +/- 2 items. In this some long term memory is involved.
  - A unix command with fewer than 7 arguments
  - A menu with fewer than 7 commands
  - A dialog with fewer than 7 choices
- In practice average person can keep about 3-4 items in his/her head at a time.
- For RPGs, if you have many quests for a player, you should keep an automated journal that the player can refer back to later- especially if the player might only play the game once a week.

Simulator Sickness

- Symptoms
  - Nausea, Blurred vision, Difficulty concentrating, Headache, Drowsiness, Discomfort, Dizziness, Fatigue
- Causes
  - Conflict between visual system and vestibular system
  - The organ of the inner ear containing three semicircular ducts at right angles to one another
  - Responsible for maintaining the body's orientation in space, balance, and posture; regulates locomotion and other movements and keeps objects in visual focus as the body moves.



Remedies for Simulator Sickness

- Close your eyes.
- Or take a walk around the block if you can do it without falling over.
- Break the illusion of motion by NOT covering your entire field of view with the game screen. (ie sit back so that you can see the edges of your monitor- *your mother was right!)*
- Do not play in a dark room- for the same reason as above.
- Avoid scenes where you are rolling about the Z axis.
- Higher frame rates can actually INCREASE the sense of motion.
- But the jarring effect from lower frame rates can cause eye strain.

Seizures

- Japan – 6:50pm Dec 16, 1997: 685 people (310 boys, 375 girls), most of them children, simultaneously felt ill from watching Pokemon show. 150 were hospitalized.
- Cause was a red/blue flashing at 12Hz from one of the video game worlds in the show.
- Formerly it was known that:
  - Rapid light/dark changes or alternating high-contrast patterns cause nerve cells in the brain to fire electrical impulses more rapidly than usual.
  - In people with photosensitive epilepsy this lead to muscular convulsions or loss of consciousness.
- Pokemon incident "discovered" a new type of seizure :
  - Chromatic sensitive seizure –Red/Blue flashing

Seizures

- 1993 – Advertisement in UK had fast moving computer graphics images. Caused a # of complaints from viewers & 3 cases of seizures.
- 1994 – Independent Television Commission, which regulates commercial TV in UK, limited the rate of flash to three per second.
- Flashing images, especially those with red, should not flicker faster than 3Hz.
- If the image does not have red, it still should not flicker faster than 5Hz.
- Flashing images should be displayed for a total duration of less than two seconds.
- Stripes, whorls and concentric circles should not take up a large part of a TV screen.

All Video Games Now Include a Standard Warning…

- **WARNING: READ BEFORE PLAYING**
- A very small percentage of individuals may experience epileptic seizures when exposed to certain light patterns or flashing lights. Exposure to certain patterns or backgrounds on a computer screen, or while playing video games, may induce an epileptic seizure in these individuals. Certain conditions may induce previously undetected epileptic symptoms even in persons who have no history of prior seizures or epilepsy.
- If you, or anyone in your family, have an epileptic condition, consult your physician prior to playing. If you experience any of the following symptoms while playing a video or computer game -- dizziness, altered vision, eye or muscle twitches, loss of awareness, disorientation, any involuntary movement, or convulsions -- IMMEDIATELY discontinue use and consult your physician before resuming play.

Theories / prior studies can only tell you so much about game design because they were designed to answer a specific question that might not be the same question you are asking, like:

"how do I make my game more fun for more gamers?"

In this case FEEDBACK is crucial

4 Important Criteria for Feedback

1. The feedback should accurately represent the opinions of the target gamers. Your own impressions or your group's impressions do not qualify.
2. The feedback should arrive in time for the designer to use it. If the feedback is perfect, but arrives too late the feedback isn't that helpful.
3. The feedback should be sufficiently granular for the designer to take action on it. Not general theories.
4. The feedback should be relatively easy to get. Need to estimate how much it costs you to get the feedback and weigh it against how valuable the feedback will be. Spending $100K to determine if the sports car in the game should be red or blue is not worth $100K.

2 Common Sources of Feedback: Professionals and Gamers

- Professionals:
  - Group members: satisfies criteria's 2,3,4.
  - External consultants (game journalists, gurus): Satisfies criteria 3. Maybe 1 and 2.
  - Problem is that game developers and journalists know the area too well. Similar to how film critics judge the film as terrible but the public loves it.
- Non Professionals:
  - Newsgroups, fan mail: satisfies criteria 1 but requires a prototype to already be developed. This makes it difficult to satisfy criteria 2. Satisfies criteria 4 since fans are always very vocal. But sometimes difficult to satisfy criteria 3.
  - Acquaintance testing: friends & neighbors. Satisfies 1, 3 and 4. But not 2.
  - Focus groups: typically done by publishers. Costly and typically comes late in the development phase- too late.
- Challenge is to come up with a feedback system that works on all 4 criteria.

Approach by Microsoft Game Studios

- Usability research (small sample observational studies)
- Playtest research (large, structured questionnaire studies that focus on the first hour of game play.)
- Reviews from user-testing specialists.

Usability Research

- Small sample observational studies
- Originates in the field of applied psychological and Human Computer Interaction research.
- Goal: discover problems that the dev team was unaware of, and to understand the thoughts and beliefs of the participant and how they affect their interaction with the game.
- Over the course of 2-3 days, 6-9 participants come to Microsoft for individual 2-hour sessions.
- Each participant spends some unstructured time exploring the game prior to attempting a set of very specific tasks.
- Common measures include: comments, behaviors, task times and error rates.

Playtest Research

- Large, structured questionnaire studies that focus on the first hour of gameplay.
- Originates from psychology in the fields of judgment and decision-making.
- Goal: Gauge participants' attitudes, preferences, and some kinds of behavior, like difficulty levels.
- Sample sizes are relatively large (25-35 people) in order to be able to compute reliable percentages.
- Each person gets just over 60 minutes to play the game and answer questions individually on a highly structured questionnaire.
- Participants rate the quality of the game and provide open-ended feedback on a wide variety of general and genre-specific questions.

Reviews from User-Testing Specialists

- Specialists have a lot of experience watching users play games and listening to their complaints and praises.
- Specialists can identify early on, mistakes that development teams typically make and correct them.

Focus Groups

- If used at all, are used for early feedback on ideas.
- Not very good for evaluations.
- Group nature of focus groups makes it difficult to get useful individual opinions about a game.

Composition of Microsoft User-Testing Group

- 15 fulltime user-testing specialists
- 3-5 contract specialists
- 3 fulltime support staff.
- Almost all user-testing specialists at least 2 years of graduate training in experimental psychology, or equivalent experience in applied psychology and are gamers.
- In 2001- tested approximately 6500 participants in 235 different tests, on about 70 different games. 23 were non-Microsoft products.
- From 1997 to Jan 2002- group has produced 658 reports on 114 products (53 Microsoft, and 61 non-Microsoft products) representing the opinions of more than 15,000 hours of consumer reactions to games prior to their release.

Hardware Interfaces

Joysticks

- Joysticks were the predominant gaming interface for almost a decade.
- But they proved difficult for games requiring fast response.
- So the stick shrank and the result is the gamepad.
- But joysticks-proper continued to evolve.
- Today's joysticks are mainly used for flight simulation or robot driving games.
- Force feedback sticks have their own CPU and cooling fan.

Gamepads

- Multipurpose device.
- Combination of digital and analog joysticks.
- Initially intended for platform games.
- Small joystick allows for quicker movements than arm-based flight joysticks.
- Button placement is designed to maximize the # that a player can press at the same time.
- Expectation is that today's gamepads come with vibration capability.

Belkin Nostromo Speedpad N50

- Interesting innovation.
- FPS do not play well on gamepads.
- Too many keys and too little precision.
- Gamers typically use the keyboard and a mouse on their computer.
- Speedpad is used in conjunction with mouse.
- Isolates important game keys alleviating the need to take eyes off the screen.

Belkin Nostromo Speedpad N52

- Next generation responds to user feedback:
- Able to press more than 3 keys at a time.
- More keys so that D-Pad could be used for item selection rather than as a movement control.
- Most FPS gamers are more familiar with WASD mapping for movement rather than D-Pad.

Microsoft Gamevoice

- Useful for hands-busy, eyes-busy environments.
- Good for commands that take a lot of effort to operate- e.g. commander on a submarine.
- Humans are forgiving of each other when mistaking speech; humans are also more flexible when interpreting speech. So we tend to scrutinize computer systems more when they fail.
- Cognitive load is high when using speech. Difficult to talk and think at the same time.
- 30 years to attempt to put speech into fighter jet cockpits have failed.

Speech Used for Game Play

- Speech recognition system is programmable to press a key on the keyboard.
- Unfortunately few games have enough key bindings to make this possible.
- Also used as an internet voice chat during multiplayer gaming. This is probably the better use for voice.
- Voice command either via free speaking or push-to-talk to prevent accidental triggering.
- Delay introduced in waiting for the system to confirm detected command, so Not good for single commands especially in fast paced games- like 1st person shooters.
- Faster to press a key than to say it.
- Good for chain of commands.
  - e.g. Red Alert = target enemy, increase front shields, charge weapons, increase speed to half impulse.

Essential Reality P5 Glove

- Infra-red emitters on glove.
- Camera performs 3D position and orientation tracking
- Resistive bend sensors
- Arm fatigue (guerilla arm) prevents use for more than 5 minutes.
- Researchers in the VR community have known this for over a decade.
- Calibration is needed for each individual.

E-dimensional Stereoscopic Shutter Glasses

- Technology has been in existence for more than 10 years. (Stereographics Corporation designed them mainly for Chemistry)
- Field sequential stereoscopic at 60Hz (30Hz per eye)
- Each eye goes opaque by polarizing each lens.
- Synchronization is either via a cable or via infra red emitter and receiver.
- 4 graphics buffers:
- Rear left, rear right, front left, front right
- Draw to rear, swap both.
- 30Hz is too slow- flickering is very noticeable.
- The ones used in the CAVE are 120Hz (60Hz per eye).
- Players only able to tolerate flicker for brief periods of time.
- Stereo enabled by graphics cards are stereo driver enhancements for DirectX.
- Only works on CRTs- not LCD screens becoz LCDs are polarized screens.

Criteria for a successful hardware interface

- Must allow a player to use the interface for long periods of time without fatigue or discomfort.
- Gamers can play on a computer or a console for hour(s).
- Devices must provide a noticeable advantage over existing controls.
- Device must be affordable- $25-50 range.
- Device must be robust- withstand aggressive use.

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