

Light and Sound Perception

Perception

- Recognition and interpretation of sensory stimuli based chiefly on memory
- Insight, intuition, or knowledge gained by perceiving

Cognition

- The mental process of knowing, including aspects such as awareness, perception, reasoning, and judgment
- Generally a higher order mental process compared to perception
- Implies an interpretation of perceived data, possibly based on context or cultural factors

Perception

- Studying perception
 1. Environment
 - Existence independent of the perceiver
 2. Incoming stimuli
 - Origin with objects in the environment, detected by the perceiver
 - Sensory organs
 - Sensors attached to a computer
 3. Sensory surfaces and peripheral neurons
 - Process of conversion of stimulus into neural code before response can be generated
 - Storage of sensed data into a data structure
 4. Brain
 - Not available for study in humans
 - Simulated by CPU
 5. Effector systems
 - Physical and physiological stimuli that trigger different events in body
 - Pupil constricts in response to light
 - Camera may focus automatically without input from CPU
 6. Motor responses
 - Response to stimulus but may also affect stimulus
 - Sight is affected by eye movements and vice versa
- Optical and auditory illusions
 - Perceiving things that are not there
 - Escher's drawings
 - Bach's sonatas and partitas (perceiving two distinct violins when there is only one violin playing)

Light

- Nature of light

- Particle or wave?
- Behavior of waves
 - Basic waveform or sine wave
 - x axis represents wavelength or time
 - * Measured in nanometers (light) or seconds (sound)
 - y axis represents magnitude
 - Cycle
 - * One complete movement of a waveform
 - Hertz, or Hz – Unit of frequency or number of cycles per second
 - Amplitude of a wave
 - * Height of wave from equilibrium point
 - Phase
 - * Relative timing of cycles of identical waves
 - * Phase cancellation
 - Harmonics
 - * Waves related by arithmetic ratios
 - * Two or more waves may combine to form a complex wave
- Electromagnetic spectrum
 - Range of waveforms radiated from a source of energy
 - Includes visible light
 - Cosmic rays to Radio waves
- Speed of light
 - Could cause delay between transmission and reception
 - Change in speed due to different media (air vs water)
- Measurement of light
 - Candela
 - * Unit to measure the strength of light
 - * Also known as *candlepower*
 - Radiance
 - * Total amount of energy flowing from an electromagnetic source
 - * Measured in terms of watts
 - Luminance
 - * Measure of light strength perceived by human eye
 - * Only the energy in visible part of the spectrum
 - Brightness
 - * Relative measure to compare light emanating from two (or more) objects
 - * Subjective measure
 - * Lighted candle in a dark room compared to lighted candle in bright sunlight
 - Strength of light diminishes with distance as inverse of square distance
 - * Farther the projector from screen, larger and dimmer the image

- * Projectors rated in terms of *lumens*
- * Higher lumens allow the image to be seen in a normally lit room
- Reflection and refraction
 - Reflection – Bouncing light from a surface
 - Refraction – Altering the direction of light as it passes through a translucent medium
 - Total reflection – when almost all light is reflected from a surface
 - Total absorption – when almost all light is absorbed into a surface
 - Glare on computer screen
 - Cladding
 - * Internal reflection in an optic fiber cable
 - Focus using lenses

Color and color sensation

- What is color?
 - Behavior of objects to different wavelengths of visible spectrum
 - Objects appear to have color based on wavelengths of visible spectrum that they appear to reflect or transmit
 - Measuring color
 - Colorimetry
 - * Analysis of colors in terms of their spectral composition
 - * Quantitative determination of the depth of color of a substance
 - Color is measured by using instruments (spectroscope or colorimeter) to produce emission curves or remission curves
 - * The plot shows a graph of relative intensities of various colors in the spectrum
 - Other measures of color are chroma, saturation, value, lightness, and brightness
- Chroma or Hue.** Attribute of a visual sensation according to which an area appears to be similar to one of the perceived colors, red, yellow, green and blue, or a combination of two of them
- * Adding more of the same color may increase its intensity but does not increase its chroma
 - * If the dominant wavelength of a spectral power distribution shifts, the hue of the associated color will shift
 - * Black and white are *achromatic colors*
- Saturation.** Colorfulness of an area judged in proportion to its brightness
- * Amount of pure color contained in a chroma
 - * Runs from neutral gray through pastel to saturated colors
 - * More a spectral power distribution is concentrated at one wavelength, the more saturated will be the associated color
 - * You can desaturate a color by adding light that contains power at all wavelengths.
- Value.** Subtle difference between shades and tints of colors
- * Mixing black with a chroma gives another *shade* of the original
 - * Mixing white with a chroma gives another *tint* of the original
- Lightness and Brightness.** Help describe color differences and put color in context
- * Brightness or luminance

- Luminance of an object in the context of its surroundings
 - Attribute of a visual sensation according to which an area appears to emit more or less light
 - Radiant power weighted by a spectral sensitivity function that is characteristic of vision
 - Expressed in a unit such as candelas per meter squared
 - In practice normalized to 1 or 100 units with respect to the luminance of a specified or implied *white reference*
 - * Lightness
 - Amount of light reflected from an object
 - Perceptual response to luminance
- Trichromatic vision
 - Subtractive principle of color
 - * Mixing pigments results into a new pigment which absorbs (or subtracts) certain wavelengths
 - * Used in photographic films
 - Additive principle of color
 - * When colored lights are mixed together, they combine their wavelengths to form new colors
 - * Used in computer monitors
 - White light contains all colors
 - Perception of all colors
 - * Based on different proportions of three basic colors
 - * Different colors are perceived with different capability
 - * Red is perceived very well and is said to be dominant color
- Psychological aspects of color
 - Color is subjective and dependent on cultural background
 - It must be a primary consideration for multimedia developer
 - Colors are also associated with emotions (feeling blue)
 - Colors are also associated with temperature (blue for cold)
 - Pastels are taken to be relaxed and cheery
 - Darker colors convey stronger feelings like anger and depression
- Choosing and specifying colors for multimedia
 - We must choose colors that complement each other rather than contrast with each other
 - Easily specified by a “color wheel” to find contrasting colors
 - * Composed of two triangles with vertices as primary colors (RGB) and secondary colors (CMY)
 - * The secondary color opposite a primary color vertex is the one created by using the other two primary colors
 - * If the background color is given by $(R + G + B)$, the foreground color can be taken as $(\bar{R} + \bar{G} + \bar{B})$
 - Digitized pantone system
 - * Used in desktop publishing and multimedia production to compare colors
 - * Collection of known color samples
 - * Colors can be fine tuned by using the hexadecimal values of their components (look at Netscape color selection)
- Colors on computer monitors
 - RGB system

- * Each color identified as a mixture of primary colors using hexadecimal values
- * Color intensities are a function of graphic board and software and not of the monitor
- * Normally, each color is taken to be a number between 0 and 255, or between 0 and 0xFF
- * A board capable of displaying 24-bit color can show 256^3 or 16 million colors
- RGB color cube
 - * A 3D model to represent the RGB system
 - * Each color represented by its luminance on a scale of 0 to 1
- HSV system
 - * Hue/Saturation/Value
 - * Easily derived from RGB color cube
 - * Better definition of color, particularly for hardware designers
 - * V refers to luminance
- HLS system
 - * Hue/Lightness/Saturation
 - * Similar to HSV
 - * L refers to luminance
- CIE system
 - * Commission Internationale de l'Eclairage
 - * Allows any three colors to be used as primary colors
 - * Normally describes a luminance component and two chroma components
 - * Has a number of variants, such as L*a*b* system
 - * Can be easily converted to RGB (FAQ 18 on Colorspace FAQ)

Sound and visual communication

- Psychophysical aspects of perception
- Vision
 - Enabled by physical, psychological, and physiological processes
 - Physical process
 - * Generation, transmission, and reflection of light
 - Physiological process
 - * Transmission within the eye, hitting the rods and cones at the tip of optic nerve
 - * Impulses from optic nerve trigger physiological or neurological process in brain
 - Psychological process
 - * Allows to make sense of what is perceived
- Visual communication
 - Relies both on eye and brain
 - A picture is worth a thousand words
 - Important to the design of multimedia software
 - Multimedia designer as proactive communicator
- Images and meaning
 - Sense, feeling, tone, and intention

- Sense of an image is the external reality denoted by it
- Feeling is the attitude conveyed by the image regarding the sense
- Tone is the attitude or message
- Intention is the effect it desires to produce in the viewer
- Importance of camera angles when taking a picture
- Still images
 - Visual alphabets
 - Basic graphic elements that make up a scene (color or shape)
 - Abstract representations
 - * Modern art
 - * Determine the nature of object from its visual representation
 - Concrete representations
 - * Development of cognitive ability
 - Kids can easily recognize the Golden Arches on a highway
 - * Discrepancies between concrete images and actual appearance of things represented therein
 1. Brightness level of images vs what is perceived by eye
 2. Range of colors perceived by eye is much wider than what can be captured in an image
 3. Pictures like outline drawings may not even contain information on brightness of objects
 4. Grayscale pictures have no color information
 5. Still pictures cannot produce the depth information
 6. No motion parallax in still pictures
 7. Pictures may not have the actual proportion of objects (think cartoons)
 8. Pictures may have major distortions (cartoons again)
 9. Pictures may omit features of their subjects (stick figures)
 - * Multimedia designers do not necessarily need the highest resolution level of images
- Form and shape
 - Visual art is based on form and shape, needed for effective communication
 - Usually generated by creativity of designer who should understand both aesthetics and technicality of computer graphics
 - Form
 - * Attributes of images recognized by brain
 - * Generally universal across cultures and history
 - Components of form
 - * Three components: dots, lines, shapes
 - * Three basic shapes: parallelograms, circles, triangles
 - * Characteristics of form and shape create impressions and associations in the minds of people
 - * Dot
 - Simplest graphical form
 - Basically a circle that has been filled in
 - Commands immediate attention anywhere in a visual frame
 - Becomes center of attention in the center of a frame
 - Dot placed to a side of a frame created tension through asymmetry
 - Two dots make the viewer divide attention between them

- Three or more dots make the brain create associations or perceive recognizable form through automatically filling in the lines
 - Hundred of thousands of dots placed together can form an image, as done in *pointillism*
 - Images on computer monitors, as well as digital images, are formed through placements of dots
- * Line
 - Occurs when dots are placed so close together that there appears to be no space between them
 - Perfectly straight lines generally do not appear in nature
 - Straight lines can be oriented in graphic images as horizontal, vertical, and diagonal
 - Bold lines convey strength and confidence
 - Curved lines give a sense of grace and airiness
- Basic shapes
 - * Parallelogram
 - Four sided figure with opposite lines that are parallel and equal in length
 - Balanced and symmetric parallelogram is called a square
 - Basic frame for an image is a rectangle
 - * Circle
 - Should be used sparingly
 - Draw viewer attention and may distract from the main message of the image
 - * Triangle
 - Most active and dynamic of shapes
 - Equilateral triangle conveys a sense of stability, serenity, and quiet purpose
 - Isosceles triangle pointing up resembles a church steeple and can evoke deep religious or serene feelings; in other directions, it can be used to draw attention like an arrow
 - * In some cultures, the triangles and circles may be construed as lewd symbols and therefore, must be used carefully while designing multimedia
- Graphic primitives
 - * Computer graphics object essential to the creation of images
 - * Three essentials: points, lines, and polygons
 - * Point
 - Has no substance or volume (dot has volume as tiny circle filled with solid color)
 - Represented as pixel on computer screen
 - Smallest unit of display that can be controlled by software
 - Hardware-based fundamental building block of computer graphics
 - * Line
 - Two or more pixels adjacent to each other
 - * Polygon
 - A closed figure of more than two sides in one plane
- Depth
 - Depth is not perceived by retina/eye but rather by brain
 - Illusion of depth in stereoscopic images due to two slightly different images traveling to brain
 - Sense of depth comes from
 1. Space
 - * Frame of image
 - * Open spaces enhance the feeling of depth
 2. Size

- * Depth perception due to relative size of objects
- 3. Color
 - * Warm-colored objects appear closer than cool-colored objects
 - * Larger differences between light and dark tones make the objects appear closer compared to neutral tones
- 4. Lighting
 - * Depth due to difference in light intensities and shades
- 5. Texture gradients
 - * Ripple effects in a pond or wind created ridges on a sand dune
 - * Depth cues due to the effects appearing closer together
- 6. Interposition
 - * Placement of one object in front of another
- 7. Time
 - * Depends on cultural interpretations
- 8. Perspective
 - * Technique of creating the perception of three dimensionality in an image rendered in two dimensions
- Three major perspective forms
 1. Illusionary perspective
 - * Seeming convergence of parallel lines
 2. Geometrical perspective
 - * Placement of nearer objects in lower part of the frame and distant objects in upper part of the frame
 3. Conceptual perspective
 - * Multiview perspective in the same image
 - * Emphasis on important objects (by size) to provide conceptual cues
- Images in motion
 - Movement linked to color, form, and depth
 - Four basic types of movement
 1. Real movement
 - * Objects in motion in real world
 - * Corresponds to analog technology (seconds hand in an analog clock) rather than digital technology (changes a number every second)
 2. Apparent movement
 - * Still image or a series of still images appear to move
 - * Underlying basis for motion pictures
 - * Occurs due to persistence of vision
 - * Time for brain to receive and process an image
 - * Applications may demand frame rate of 30 or 60 frames per second which can become difficult even with fast machine if we take bandwidth into consideration, or the applications may require streams to be uncompressed in real-time
 - * Physical causality
 - Transfer of energy from one object to another, causing a change in speed and direction
 - * Launching effect
 - An object is the cause of motion of another object, with the latter being said to be launched
 - * Entraining effect

- An object passes close enough to another object to influence the latter
- Viewer may not perceive causality but views the movement of two objects as isolated events
- Missing frames (in case of reduced frames/sec) should not contain information that can cause causality

3. Graphic movement

- * Motion of eyes or path followed in scanning an image
- * People tend to scan left to right and top to bottom but may scan different in some cultures
- * Some elements like color, size, and placement of objects may affect or command a viewer's attention

4. Implied movement

- * Illusion of movement in a still image, without any movement of image itself
- * Achieved by high contrast line placement and/or complementary colors (visual vibration)
- * Basis for *op art* (optical art)

- Text and typography

- History of writing

- * Petroglyphs or rock graphics



- Symbolic representations to convey a message or idea
- Pictograph – Picture of some object in real world (check the site: <http://www.mazinaw.on.ca/fobecho/nanabush>.)
- Ideograph – Representation of ideas; may not be easy to decipher across cultures

- * Cuneiform

- Originated by Sumerians



* Hieroglyphics

- Came from Egypt
- Consists of several hundred picture signs broadly classified into phonograms (sound or group of sounds) and ideograms



* Logograms

- Created by Chinese
- A character in writing which represents a word as a whole
- Artistic/pictorial method of representation

- * Alphabet

- Created by Phoenicians
- Greeks introduced vowels

- Modern 26-letter alphabet came into existence in 14th century
- Web site: <http://victorian.fortunecity.com/vangogh/555/Spell/pic-logo.htm>
- Typography
 - * Mechanical reproduction of words
 - * Combination of technology and art
 - * Printing press and Gutenberg
 - * Calligraphy (illuminated manuscripts)
- Typefaces
 - * Also known as fonts
 - * Refers to the design of letters, numbers, and other characters
 - * Used to communicate the feelings (tone, mood, and attitude) behind text
 - * Spelling Microsoft as Micro\$oft, or μ \$
 - * Increase the visual impact, and send message about content
 - * Inappropriate use can distract the audience
 - * Typeface design
 1. Serif
 - Small strokes at the end of each letter
 - Decorative in nature
 - Add visual character and interest to the overall appearance
 - Functional as they guide reader perception through the text
 - Commonly used for message text
 2. Sans serif
 - No serifs on letters
 - Used in display types
 - May add elegance or impact to a visual message
 - Not well suited for large blocks of text
 - Work best when surrounded by a lot of whitespace
 - * Specialty fonts, like decorative and *SCRIPT* fonts
 - Used to convey elegance and formality
 - Ornate calligraphy used for invitation cards
 - Handwritten message may indicate informality
 - Dingbats used to spice up a message with visual punctuation
 - * Type style
 - Variation in weight and stroke
 1. **Bold** – Authoritative voice or emphasis; use with restraint as it can make a page look dense
 2. *Italic* – Used for emphasis (quotation, humor, irony), or introduction of new ideas or concepts
 3. ***Bold italic*** – Combination of above two
 4. SMALL CAPS – Mostly for abbreviations
 - Lesser used styles such as shadow, outline, and underline
 - Type weight
 - Width of a letter and its stroke thickness
 - Stroke thickness is indicated by the concept of *stress* – variation in thickness of strokes that make up a single letter
 - Serif typefaces have more stress (more variation in vertical and horizontal strokes) than sans serif typefaces
 - Type size

- Measured in points, with 72 points to an inch
 - Used to indicate the importance of message, or message component
- x-height
 - Height of lowercase letters without ascenders
 - low x-height gives the appearance of more white space between lines
- Check out the Unix utility `xfontsel`
- Text alignment
 - * Justification (justified (both ends)/left/right/center)
- Special effects
 - * Reverse type (flip background and foreground colors)
 - * Screen type (add gray color to background)
 - * Use of boxes to convey relevant information

Sound

- Effectively used in many successful films
- Sound production
 - Created as a sound wave by a physical process
 - Tuning fork
- Harmonics and wave analysis
 - Frequency perceived as pitch
 - * Greater the frequency, higher the perceived pitch
 - * Sounds produced by violin have a higher pitch compared to those produced by bass
 - Amplitude
 - * Intensity or loudness of sound
 - Harmonics
 - * Waves with frequencies related by arithmetic ratios
 - * Can be added to pure tones by using electronics
 - * The same notes sound different on different instruments due to different harmonics generated by instruments
 - * Different harmonics of different instruments are a result of different physical structure and different method of generating sound vibrations
 - * Distinctive sound of instruments, known as *timbre*, is created due to a number of harmonics and intensities in relation to the fundamental tone
- Propagation of sound
 - Sound waves get altered by the medium of transmission, as well as the presence of other objects in the environment that reflect and absorb sound waves (acoustics)
- Sound and the environment
 - Environment allows people to determine the distance and direction of a sound source (in ideal conditions)
 - Reflection of sound waves from objects causes multiple representations of original waves
 - Interference from the same or different objects may change the frequencies in the wave, or their pattern of radiation and distribution

- * Ripples in a still pond due to two or more objects thrown into water
- Sound travels at a speed of 1050 feet per second through air (slow compared to light at 186000 miles per second)
- When sound is generated in a room, directly radiated wave strikes the ears of the listener first (*direct sound*) and then, the first reflection of the sound from objects (*early sound*)
- Reverberation
 - * Reflections from the early sounds (double, triple, quadruple reflections)
 - * Multiple reflections continue till the waves are attenuated
 - * Effectively, listener receives more sound energy compared to direct sound (guiding principle behind auditoriums)
 - * Sound waves should not escape the auditorium or be absorbed too soon
- Diffraction
 - * Ability of sound waves to travel around objects in the path
- Sound and motion
 - Doppler effect
 - * Wavelength of the sound waves is affected by motion
 - * The horn of a vehicle increases in pitch as it moves towards the listener
 - * Occurs due to relatively slow speed of sound through air
 - * Only occurs for objects that are traveling reasonably fast compared to listener (at least 20 or 30 mph)
 - Contributes significantly to the sense of motion and reality in a scene or multimedia production

Listening and Auditory Communication

- Listening is hearing a sound and paying attention to it
- Reception of sound
 - Ear receives complex waveforms and brain deciphers them
 - Habituation
 - * Phenomenon exhibited by about 85% of all auditory neurons
 - * Neurons do not get excited unless there is a change in stimulus
 - * Unless a sound is renewed, ear becomes deaf to it
- Perception of pitch
 - Perception of pitch is a psychological property and is closely related to the frequency of sound wave (physical property)
 - Humans can detect frequencies between 20 to 20000 Hz
 - Pitches above 16000 Hz are perceived as hiss
 - With age, perception of higher frequencies is lost and sensitivity to pitches may change across the spectrum
 - Implication of age-related perception changes is important to multimedia developer for target audience
 - Ear does not respond well to low frequencies at low volumes
 - Sounds at different frequencies should be rendered at different intensities to compensate for nonlinear frequency/volume relationship
- Measurement of sound
 - Sound source radiates acoustic energy, with its magnitude as power output of the sound source

- Acoustic power is measured in terms of *acoustic watt*
- Human ear can discern about 350 different levels of sound intensity
- Threshold of pain
 - * Pain experienced by hearing some sound at close range
 - * Generally about 1 acoustic watt of sound energy
- Threshold of sound
 - * The minimum energy level that can be perceived
 - * About 10^{-12} acoustic watt for humans
- Large perceivable range of hearing makes acoustic watt an inconvenient measuring unit
- Decibel, or dB
 - * Measurement of *sound pressure level*
 - * Based on ratios and logarithms to reduce the wide range of numbers
 - * The range from threshold of sound to threshold of pain is represented by 0–120 dB
- Hearing is nonlinear
 - * Doubling the acoustic power of a sound source does not necessarily double its apparent loudness
 - * Decibel scale takes the nonlinearity into account, and is based on powers of 10
 - * Decibels have no inherent value, and there must be a comparative number
 - 0 dB does not mean the absence of sound (it is the threshold of sound)
 - A sound pressure level of 100 dB (in a concert) implies that it is about 100 dB greater than the threshold of sound, and about 20 dB less than the threshold of pain
- Decibels are appropriate for describing the sound pressure levels because of similarity to human hearing process
 - * A 1 dB change in sound pressure is almost impossible to detect
 - * Average human hears difference in loudness in 3 dB increments; to generate a slight change in perceived loudness, power must be doubled
 - * To double the perceived loudness, sound pressure level must be increased by 10 dB, requiring 10 times the original power
- Perception of sound
 - Physical aspects of sound – volume, duration, attenuation, frequency
 - Abstract qualities – warmth, brightness, roughness, hollowness
 - Meaning assigned to sound
 - * No meaning exists at the physical aspects or abstract qualities level
 - * Perception is a result of mental processing
 - Localization
 - * Locate sources of sounds, in the presence of distractions
 - * Enabled by two ears to perceive the direction and distance
 - Identification
 - * 4000 Hz of bandwidth sufficient for voice grade communication in telephone systems
 - * Enables the recognition of voice of people known
 - * People make identification using a number of cues such as elements of tone and timbre, rate of speech, attack and decay, and psychology based attributes such as warm, rich, and tinny
 - * Contextual variation
 - Same kind of sound events at different times produce different acoustic waves
 - * Four approaches to contextual framework of constancy in perception

1. Prototype or template solution
 - Listener develops ideal representations and compares them with the sounds actually heard
 - Appears to be used by humans but difficult to reproduce on machine
 2. Feature or attribute solution
 - Abstract critical features that distinguish among the possibilities
 - Features assumed to be abstracted by brain
 - Many sounds are too complex to have their physiological representation in neural circuits
 3. Higher-order variable solution
 - Time-varying complex acoustic properties that uniquely identify an event
 - Higher-order variables may be directly perceived and identified by brain
 - Problem in identifying the unique higher-order variables for each sound source and event
 4. Innate systems
 - Distinct brain structures that process sounds and yield invariant precepts
 - Innate systems are autonomous and independent of other perceptual processes
- * Sufficient bandwidth and sufficient fidelity should be employed to ensure that sound is identifiable
 - Music psychology
 - * Ubiquitous to all cultures
 - * Structural complexity like grammatical complexity of language
 - * Important for multimedia developer to understand how people hear and process sounds to best advantage
 - * Improper sound can have a negative effect on the production