


6. Sound, Language, Thought & Sense Integration

How do I know what I think till I hear what I say?

Aim

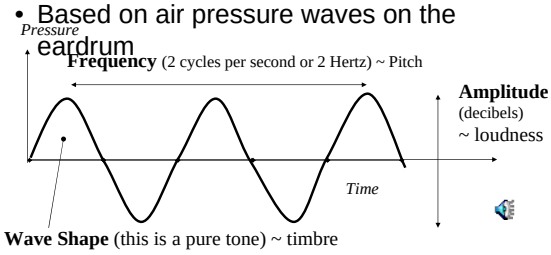
How does the brain represent sound and other sense information and combine it?

How does this affect the design of HCI systems?

Sound?

Gregory: Hearing, p303

- Closely connected to emotions
- Based on air pressure waves on the eardrum



Loudness

- Measured in decibels = Log of air pressure
  - Double *loudness* = +10db = x10 *air pressure*
  - 1 db = just detectable , 60-70db = conversation, 100 db or above = uncomfortable
- **Loud** sounds can threaten, be unpleasant or embarrass, so *volume control is critical*:
  - A real estate shop's computer sales system is too loud, & has no volume control, the user response is:
    - Says "Is it talking to the whole neighborhood?"
    - Steps back a few paces embarrassed, then walks away

Pitch

- Pitch is the wave *repetition rate* (frequency)
  - From 20Hz (very low) to 20,000Hz (very high)
  - Each musical note has a certain pitch
- *Application:*
  - *Low* sounds imply large men or animals, large instruments, or strength, e.g The Terminator & Darth Vader have low voices
  - *High* sounds associate with women or children, small instruments (piccolo) or animals, and hence harmlessness,
  - Lower pitched voices/sounds *if bad* are more threatening, *if good* are more reassuring
  - Higher pitched voices threaten less harm but can be taken less seriously

Timbre

- Most sounds are not pure sine waves
- *The "shape"* of the sound wave distinguishes a piano and a violin (at the same pitch and volume)
- *Applications:*
  - Each person's voice has a unique *timbre.* We deduce many things from it, e.g. gender, age, culture, race, country, status and more
  - *Choose a voice to fit the context* (e.g. adult voice for a child tutorial but child voice for a child game)

Fourier analysis

Gregory: Fourier

- *Complex sounds* can be broken down into *pure sine waves,* which recombine into that sound
- The ear can *carry out a fourier analysis* - hear a chord as a combination of notes, not a new note (cf the eye cant do this as different light frequencies can combine to give a new color, e.g. yellow)
- We can hear many *frequencies in one sound*
  - Sounds with high frequencies in them sound "sharp"

The ear - a frequency analyzer

- Parts
  - *Eardrum*: membrane vibrates with air pressure changes
  - *Inner bones*: amplify vibration (adjustable to volume)
  - *Cochlea*: a fluid filled spiral.
    Its basilar membrane base vibrates
    - Like a guitar string to match the frequency (for low sounds)
    - In different places for different frequencies (for high sounds)
    - Sensitive hair cells along the basilar membrane create sound
    - With age we lose ability to hear higher frequencies, as those cells are lost and not replaced
- *Application:* Lower frequencies are heard better by everyone

Harmony - frequency combinations

Gregory: Music, p499

- As combining light frequencies gives colors, so combining sound frequencies gives chords
- Some frequencies "go together" harmoniously, as some colors do
- All music uses *the octave* frequency scale, even animals respond to it
- Must stay with the same octave of notes, or "key"
  - *Major* keys are happy and joyful
  - *Minor* keys are sad and plaintive

Attention and sound

- Sudden volume or pitch *changes* get attention
- For sound, *time order* is critical, listen to the "tada" sound played in reverse
- *Application:* Sound easily catches attention as the channel is often free (cf visual)
  - This sound "says" there is an error
  - Dont use speech while people are reading (listening and reading use the same language channel!)
  - Listening is about *four times slower than reading*

Music

Gregory: Music

- Music involves:
  - *Rhythm*: loudness pattern over time.
    The most basic form of music, e.g. drums
  - *Melody*: frequency patterns over time, e.g. a tune
  - *Harmony*: frequency combinations e.g. chords and accompaniment
- Gestalt principles of proximity and simplicity also apply to sound patterns
- *Application:* Music is a universal "language" that affects every type of person - it creates *mood*

Foreground and Background

- *Sounds*
  - B/G: No pattern or steady rhythmic one (e.g waves), quiet, soothing
  - F/G: Sudden loud noises, varying patterns
- *Music*
  - B/G: Repetitive, harmonic changes (e.g muzak, store music)
    - Repetitive but sharp more mellow, harmony Ideal
  - F/G: Strong rhythm, catchy tune, clear sharp notes
- *Speech*
  - B/G: many people talking (a hubbub)
  - F/G: Single speaker almost always gets attention

Individual differences

- As some people are color blind, so some cannot hear certain notes or tunes
- People prefer different styles
  - rhythm (e.g heavy rock music)
  - melody (e.g. pop music)
  - harmony (e.g. orchestra), or
  - All combinations
- *Application:* Choose music style to suit the audience

Gregory: Binaural hearing

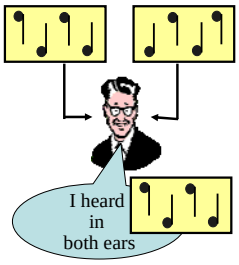
Binaural hearing

- Each ear gets slightly different signals
- By the difference we locate sound in space
  - For low frequencies, we use time or phase differences (up to one millionth of a second)
  - For high frequencies, we use loudness difference
- *Application:* Stereo sound allows 3D localization analyzers to operate, i.e. adds another experience channel to listening

Gregory: Auditory illusions

Auditory illusions

- Alternating high/low tones in each ear heard as high in one and low in the other
- Switch earphones - same result!
- Dominant LH processes right ear notes only
- But location involve a separate channel, and uses the higher frequency note
- Same sounds usually come from the same source



Gregory: Phonetics

Phonemes

- Phonemes, the basic sounds of speech, vary with the sounds around them (*context effect*)
- Not defined by spelling, e.g.
  - Same Chinese characters are pronounced differently (e.g. Mandarin vs Cantonese)
  - Some cultures have sounds that others don't (English "th" and "r', German umlaut, Chinese tonal vowels)
- Cultures recognize foreigners by how they talk
- *Application:* Use a native speaker for familiarity
- Or a foreigner for the exotic (e.g New York vs Scottish vs Japanese English) Was that the same person as before??

- Bough
- Rough
- Cough
- Through
- Dough

Gregory: Frish, p278

Signals and communication

- Frisch discovered the "language" bees used to tell other bees where the honey was
  - Direction was their "dance" direction relative to the hive axis angle to the sun
  - Distance was the dance type (round or waggle) and speed
- Any action can be a *signal if sender and receiver process it the same way*
- *Application:* Communication problems arise when *sender and receiver don't process the same signal the same way* e.g. men vs women, young vs old
- *Language* is just a common way of processing signals

Gregory: Body language, p99

Body Language

- In conversations, people synchronize behaviors
  - Sit the same way (postural congruence)
  - Use hands the same way
- Signals *rapport:* that they think, act and feel the same way
- *Application:*
  - People ask of your web site "Is this me?"
  - They judge, is it like me, or done by people like me?
  - In web site design, *identify target audience and show congruence to them,* e.g. business web sites need "business colors"

Gregory: Language: learning word meanings, p421

Formal Language

- In language, arbitrary word *signals symbolize* ideas
- Language must be *learned*
  - Because word forms vary with language
    - Mensa, table, mesa
  - Cf. Instinctive sounds are the same everywhere
  - Speech has *both* learned words and instinctive sounds
  - *Application:* Use universal natural sounds to cross language barriers *Wake up!*

Words and ideas

- *Words* represent ideas.
  - Ideas are not words
    - Babies *know* things before they can *say* them
  - Ideas start broad then are discriminated into sub-concepts, giving conceptual hierarchies
    - Child call a ball, a balloon, an egg, the sun all "Ball"
- Language begins with contextual help
  - e.g. "Mummy shoes" means "Where are my shoes?" or "Help me put on my shoes", depending on the situation *context*
  - Only after 4years do words have meanings apart from the present situation, and only after 11years do children analyze ideas
- Application: Context menus are easier to use

Gregory:Language areas in the brain p425

Language and meaning

- The analysis of *language* signals (sound or vision) into *ideas and meaning*, is done by specialized areas of the LH
  - Broca's area: Damage seriously affects speech but can leave melodies unaffected
  - Wernicke's area: Damage affects the connections between words and ideas, i.e. their meaning
- The analysis of *meaning* is a distinct *channel* with *analyzers,* just like color etc

Gregory: Concepts, p157

Concepts

- A concept is an idea that *represents* a defined *experience*
  - Concepts can *connect* to other concepts (*association)* e.g. baby ~ cuddly, fish ~ cold
  - Concepts can *contain* other concepts (*abstraction)* e.g dog < animal < thing
  - Concepts can *imply* other concepts (*analysis)* e.g. falling ~> landing
- Concepts are the building blocks of conceptual *thinking,*
  - Thinking is a generic system to model anything (cf spatial models, which only model space)
- Concepts can link in a *conceptual structure*

Thinking

Gregory: Thinking, how it can be taught, p774

- *Formatory thinking* just links or associates ideas
  (e.g. memorizing words or dates for an exam uses formatory analyzers)
- *Abstract thinking* forms higher, more *holistic* ideas, from concrete more ones
  (e.g. no one has ever seen a "three" as it is abstract. Mathematics needs abstract thinking - it cant be done by formatory analyzers)
- *Analytical thinking* can derive and assess conceptual relations by logical argument
  - e.g. People are stupid, Socrates is a person, therefore Socrates is stupid
  - Socrates is somebody, somebody is stupid, therefore Socrates is stupid; Illustrate **faulty arguments**

Gregory: Internal models, p387

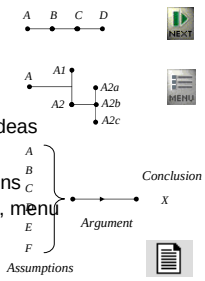
Document Structure

- A document's structure enables readers to form *a conceptual structure* – an idea mental model
- It has headed sections, sub-sections and paragraphs with no headings
  - Each with an idea theme.
  - Each with a beginning, middle and end (to introduce, to say and to conclude)
  - Frame/color/style sections to highlight them, e.g. quotes

Tell them what you are going to tell them, tell them it, then tell them what you just told them Army guideline

Application

- Types of idea relations
  - *Associative* (ideas link to ideas) e.g hypertext connections
  - *Abstract* (ideas contain ideas) e.g. a heading hierarchy
  - *Analytical* (ideas imply ideas) e.g. ideas plus argument give new ideas
- *Types of document structure*
  - *Associative* e.g hypertext connections
  - *Abstract* e.g. headings, tabs if linear, menu hierarchies, breadcrumbs
  - *Analytical* Usually mainly text



Gregory: Remembering, p679

Remembering

- How to memorize information?
  - Simplest method is *repetition*
- *Embed* concepts in a conceptual structure - so one part leads to another
  - E.g. remember the alphabet letters in sequence
  - Mnemonic: Every good boy deserves favor
  - Recall the part by recalling the whole
- Sensory memory is based on *impact* based on change
  - E.g. Say it LOUDLY or UnUsUally to remember it

All analyzers remember!

- Things will be remembered if
  - Repeated (rote learning)
  - They have sensory impact (clear, bold, obvious)
  - They have emotional impact (see later lesson)
  - They have conceptual impact
    - Link into existing conceptual structures
    - Provide strong argument based on agreed facts
  - Can use sensory modality to retrieve conceptual modality (e.g. Mnemonic like KIS, or KISS)
- Understand how people think to fit with their structures, cf showing a "red flag" to a bull

The KIS principle

- *KIS = Keep It Simple* (army version KISS)
- To communicate effectively
  - Use *words* whose meaning is clear and simple, especially for children (cf children's color preferences),
  - For example, children struggle with idea of someone who is both good *and* bad
- *Examples*
  - Reduce the number of words
  - Reduce the length of the words
  - One idea per sentence
  - Use the local background context (borders, graphics, colors etc) to support the meaning structure

Content analysis

Abstract → ***Detail***

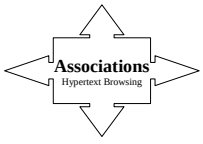
Headings → Sections → Paragraphs → Sentences

Sequence

Beginning *(issue, problem, interest, purpose)*

Middle *(information, argument)*

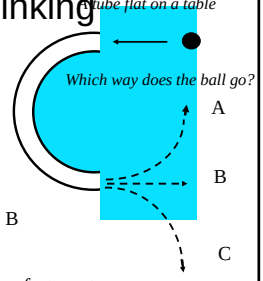
End *(summary or conclusion)*



Links to *appendices, more information, other sources)*

Analytic thinking

- Not easy or intuitive- *usually it hurts*
- Avoid *premature closure* from other more intuitive processes



Bob cycles to from A to B at 10mph, how fast must he cycle back to average 20mph for the whole trip?

Answers: B, He cant

Applications

- To help users process document content:
  - *Priming*: Declare key ideas like site purpose early, to prepare or "lead into" them
  - *Attention*: The first sentence can be critical to keep (or lose) attention. *Manage* attention
  - *Chunking*: Group same ideas in the same paragraph or section. Put in a logical sequence
  - *Minimalism*: Remove anything unnecessary to now!
  - *Contextual*: Add menu options based on object selected
  - *Consistency*: Avoid contradictions (e.g. bad spelling contradicts claims for "professionalism!)

Gregory: Touch p778

Touch

- Involves *skin receptors* for:
  - Light touch (hairs)
  - Pressure
  - Vibration
  - Pain
  - Temperature
- We detect *changes*, e.g. put one hand in cold water and one in hot. Now put both in tepid water. It seems "hot" to one hand but "cold" to the other

Gregory: Localization of Brain Function and cortical maps, p436

Cognitive map of touch

- Somatosensory brain areas processing touch are not equal
- Much of the skin gets little processing, while the lips say get a lot
- A *signal's cognitive impact* depends on the *processing produced*, not the signal size

Gregory: Taste p767

Taste

- Tongue recognizes *types of dissolved molecules*
  - Primary tastes are salty, sweet, sour and bitter?
  - But some tastes are none of these (Japanese *umami)*
  - Different types of primary taste, e.g. soya salty vs brine salty
- With smell, taste guides food selection and good diet
  e.g. avoiding rotten food
- Depends on a varying *sensory baseline* of saliva (x10) and current mouth content (x100)
  - Fasting sensitizes taste, eating desensitizes it
  - Each taste affects the next one (e.g. wine)
  - With a purified baseline, tasters can distinguish once from twice distilled water

Gregory: Smell p719

Smell

- Nose recognizes *types of airborne molecule*
- Smell connects to older brain parts, not the neocortex of the intellect
- Smells enervate, or stimulate, the body directly
- Their impact is often overlooked in science
  - Relationships - Deodorants, perfumes, air fresheners
  - Eating - Flavors of foods come largely from smell
  - Danger - Detection of leaking gas
- Individual differences, women may be more sensitive than men
- No satisfactory classification scheme

Applications

- Few IS applications at this time for other senses ..
  - *Scratch'n'sniff* screen covers?
  - Touch screens where you *feel* the screen?
  - *Motion theatre chairs* for a full roller coaster experience
  - A *pain port* for more realistic action gaming?
  - *Galvanic skin response* "truth channel" for communication?
  - *Brain wave (EEG)* links to bypass the senses middle man?
- "Primitive" senses are simple but can have powerful effects, e.g. a bad smell

Gregory: Cross-modal sensory integration p173

Sensory Integration

- Is there a "common sense" place where sense experience is integrated?
  - e.g. can you recognize a seen object by touch?
    - Yes - cross-modal sensory integration occurs
    - No - each sense has its own autonomous analyzers
- In young children and animals, cross-modal sensory integration is weak (no real need)
  - e.g. baby grabs what its hand feels but still watches say a face
- Language/concepts act as cross-modal bridges, connecting sensory analyzers

Gregory: Blindness recovery from p94

Example - recovery from blindness

- Blind subject received corneal grafts at 52 years
  - Could learn to see CAPITALS, as he had learned their shapes by touch
  - Could not recognize lower case letters (which he had not learned by touch)
  - Unaffected by Necker cube illusion. Looking out a window several stories up, he thought the ground outside was touchable (no depth processing)
  - Had to touch a familiar object (a lathe) first to see it, "Now that I have felt it I can see it"

Application - preferred channels

- People have different *preferred channels* that act as "gatekeepers" for all other processing
- For those who prefer/attend *meaning*
  - Give valid information
  - Avoid fact errors or logical inaccuracies (red flags!)
  - Provide a summary overview early
  - Use a logical idea sequence
  - Use terms unambiguously, correctly and literally, not metaphorically or colorfully

Summary

- Sound analyzers process signal frequencies into sound patterns over time (notes) while visual analyzers for patterns over space (objects)
- Concept analyzers process language into ideas in a conceptual structure
- Language is the cross-modal bridge of the senses, linking sense modality analyzers
- Associative "thinking" is fast and simple but often wrong
- Analytical thinking gave us modern science but it is non-intuitive as the brain was not designed to think!

Homework

- The following are key readings for this lesson:
  - *Hearing*, Basic mechanics of the ear
  - *Binaural hearing* - basis of stereo
  - *Language, learning word meanings* - distinguish concepts from words
  - *Thinking, how taught* - Distinguish analytical thinking (difficult) from formatory thinking (easy) and read the examples
  - *Language areas in the brain* - Skim, but recognize there are distinct areas that have particular functions in language and thought
  - *Remembering* - Learn how to remember things and to make things memorable
  - *Touch, taste and smell* - briefly review so you can see the same principles operate. Understand how these senses are more pervasive and less specific compared to sight and sound
  - *Cross-modal sensory integration* - Read the examples, and understand the role of language and thought in bridging the senses

Next:

- Even given every type of visual processing to every level there is still something missing!
- What is it?
- User interaction and *navigation*
  - "Where am I?"
  - "What do I do?"