A Model Human Cochlea

Emoti-Chair,

Emoti-Bands,

Emoti-Pads…

Designing and Experiencing Audio-Tactile Displays

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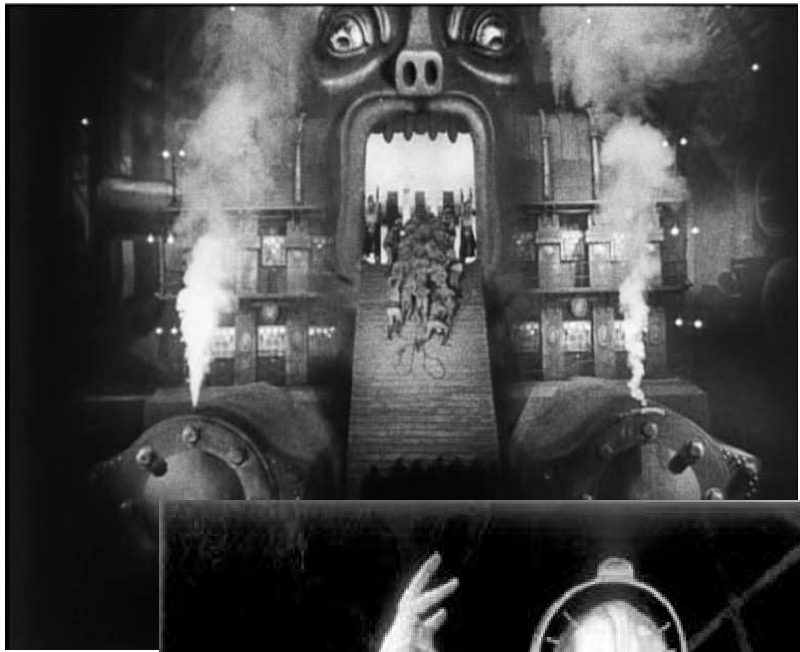
Music in Film



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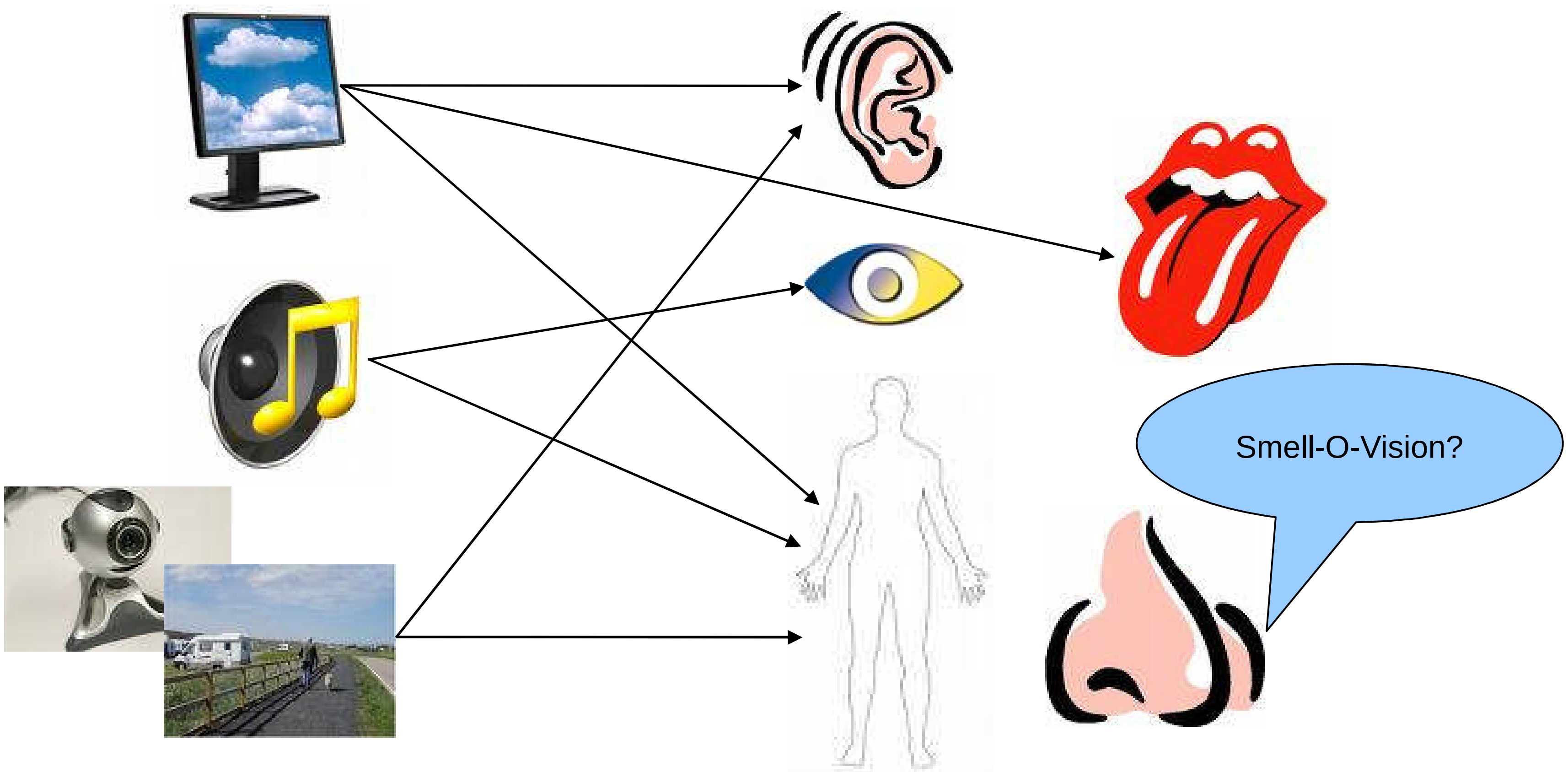
Inclusive Design

- Deaf and hard of hearing viewers
  - No access to music
  - Unlike speech, music is often indicated as symbols
- Valuable information is lost
- Experience is degraded
- ASID attempts to address these problems

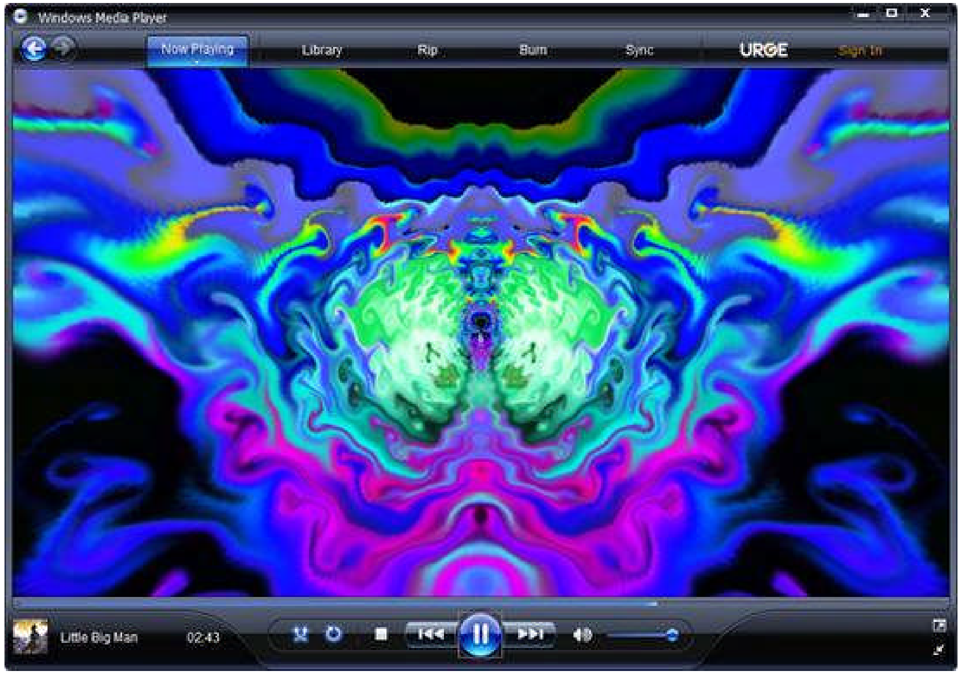
+ Crossmodal Displays

- Presenting information intended for one modality using the perceptual channel of another.



Sensory Substitution

- Translate, interpret, transform, or otherwise map characteristics of one sensory modality onto another



Parameters

Form factor: Chair

Tactile Perception

Tactile devices

Mapping Modalities

- Audio perception: 20Hz – 20kHz
- Tactile perception: 10Hz – 1000Hz
- Can't alter original music without first understanding emotional content
- Need vibrotactile device that can handle music
- Piano music (orchestra) 27-4100Hz
- Music is not only pure tones: timbre, harmonics…
- Psychophysics focus on single-point contact
- Ambient experience not primary information comprehension

Issues

- Audio perception: 20Hz – 20kHz
- Tactile perception: 10Hz – 1000Hz
- Can't alter original music without first understanding emotional content
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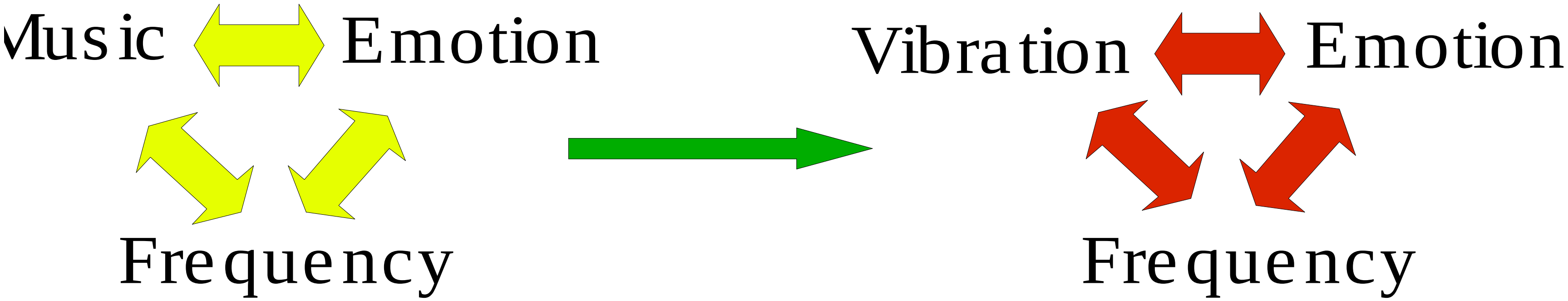
Voice Coils

- **Pros:**
- Offer complete set of vibrations from the music
  - Speakers used in night clubs for deaf communities to provide musical vibrations for dancing
- Do not require alteration of audio signal to cause vibrations
- Low cost vibrotactile devices
- Presents entire audio signal

- **Cons**
- Only most prominent frequencies can be detected
- May be fragile for prolonged use
- Little knowledge about vibrotactile properties

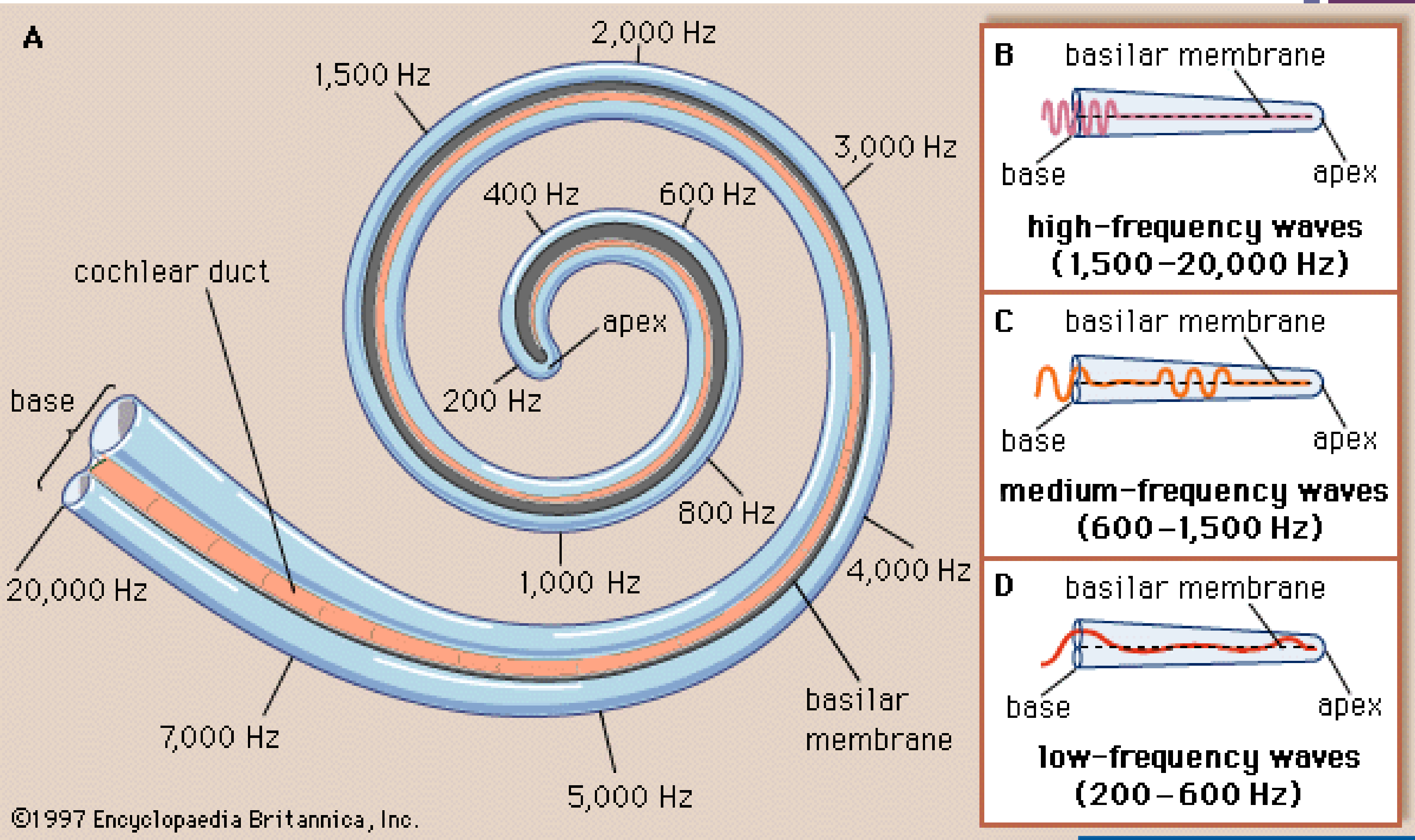
Mapping



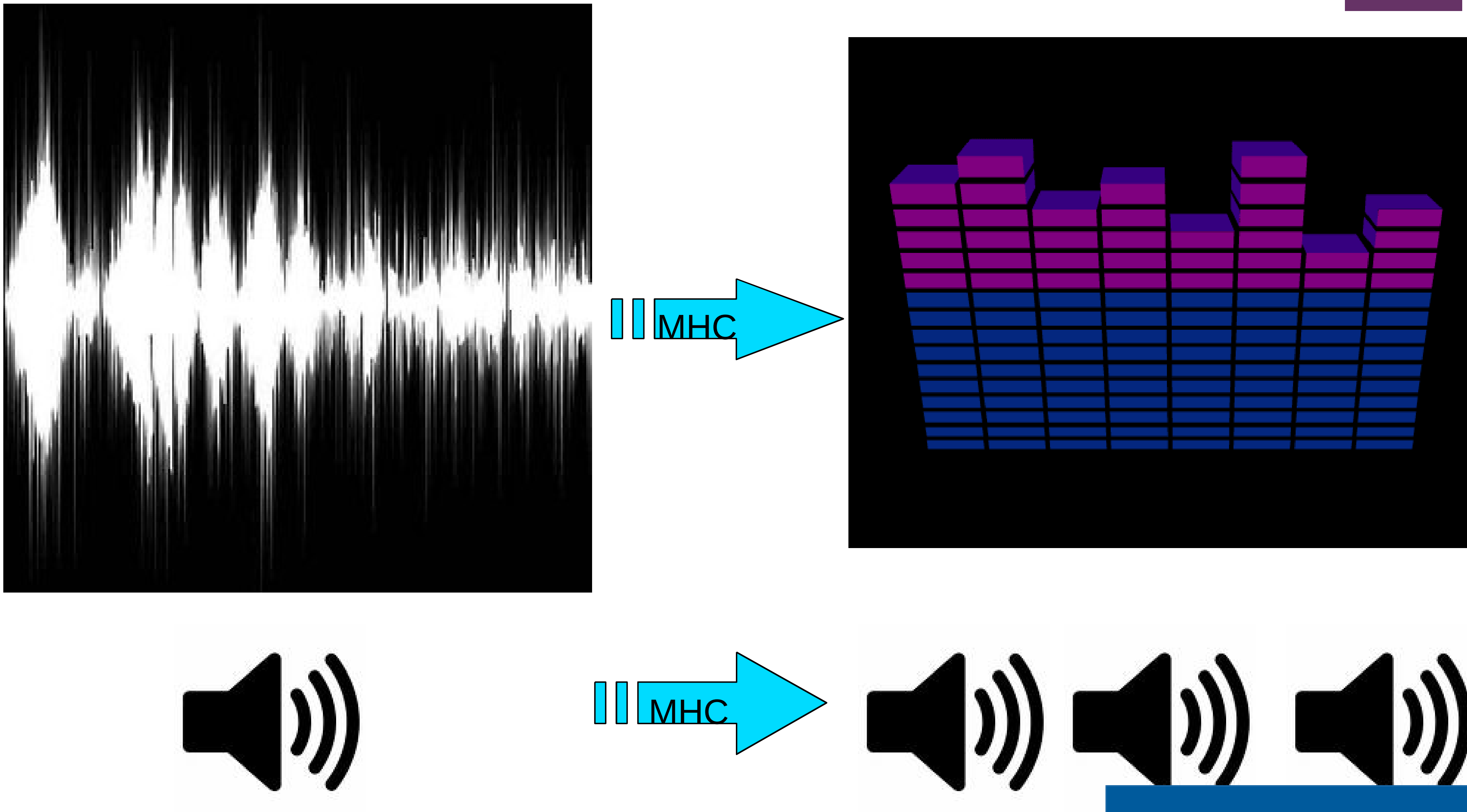
- How do we model this sensory substitution?
- Consider human hearing as a model
- Found the following:

Need

Human Cochlea Model



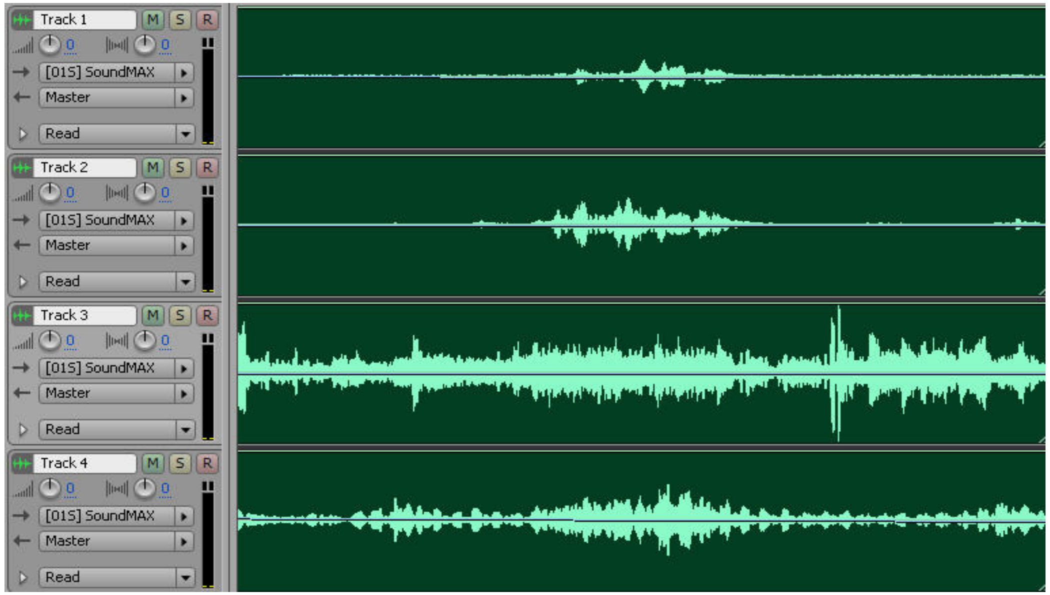
+ Model Human Cochlea (MHC)



Sensory Substitution Models

- Separating the audio signal into multiple vibrotactile devices

- Two models:
  - Track Model
  - Frequency Model

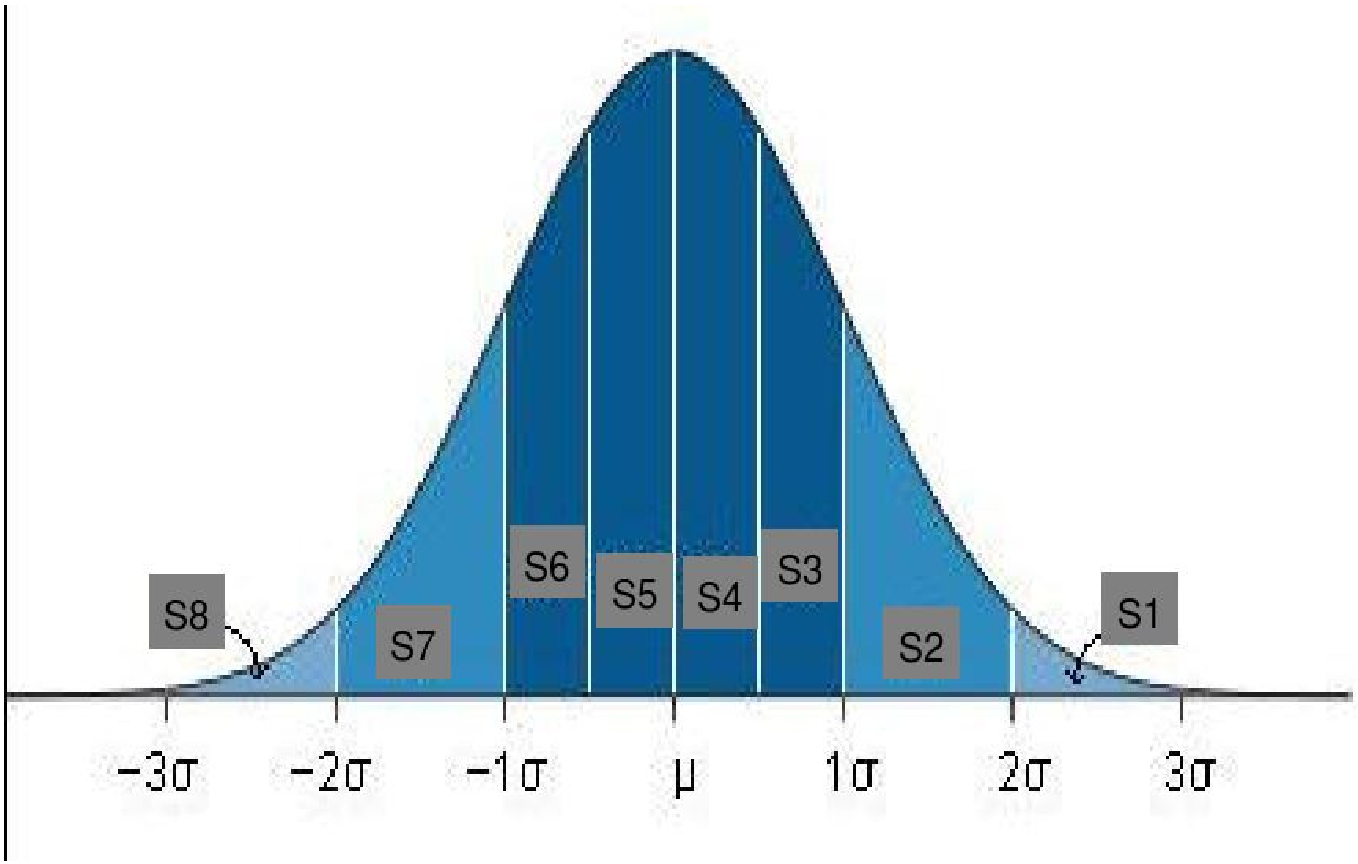


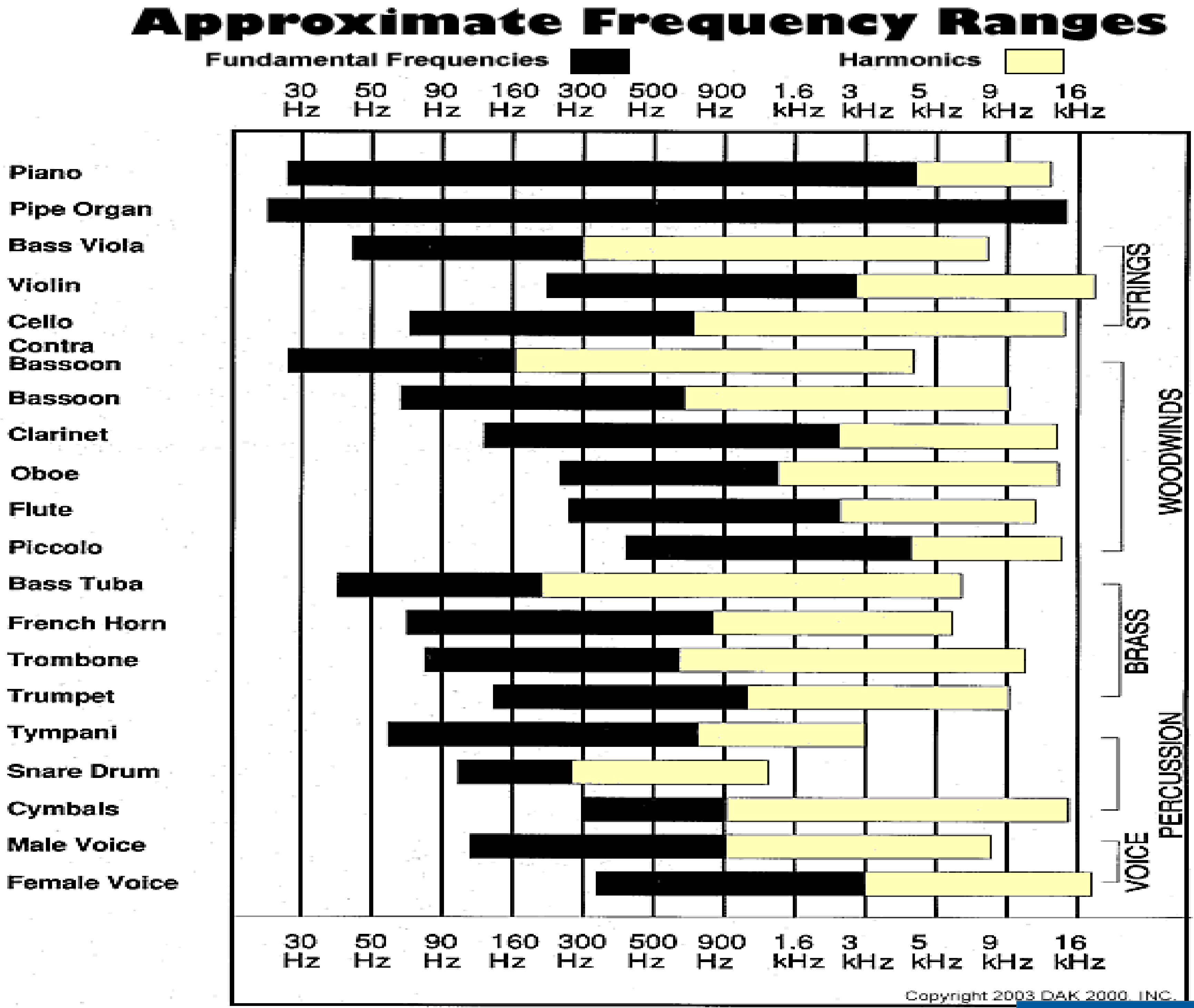
+ Track Model

- Requires source separation
  - Instruments represent individual signals
  - Intuitive approach
- MIDI
  - facilitates the separation of instruments into different tracks
- Problem: number of instruments do not always map onto number of speakers
  - Can't always access tracks from existing music

Frequency Model

- Separate audio signal into unique frequency bands





Approximate Frequency Ranges
Fundamental Frequencies
Harmonics
30 Hz
50 Hz
90 Hz
160 Hz
300 Hz
500 Hz
900 Hz
1.6 kHz
3 kHz
5 kHz
9 kHz
16 kHz
Piano
Pipe Organ
Bass Viola
Violin
Cello
Contra Bassoon
Bassoon
Clarinet
Oboe
Flute
Piccolo
Bass Tuba
French Horn
Trombone
Trumpet
Tympani
Snare Drum
Cymbals
Male Voice
Female Voice
STRINGS
WOODWINDS
BRASS
PERCUSSION
VOICE
30 Hz
50 Hz
90 Hz
160 Hz
300 Hz
500 Hz
900 Hz
1.6 kHz
3 kHz
5 kHz
9 kHz
16 kHz
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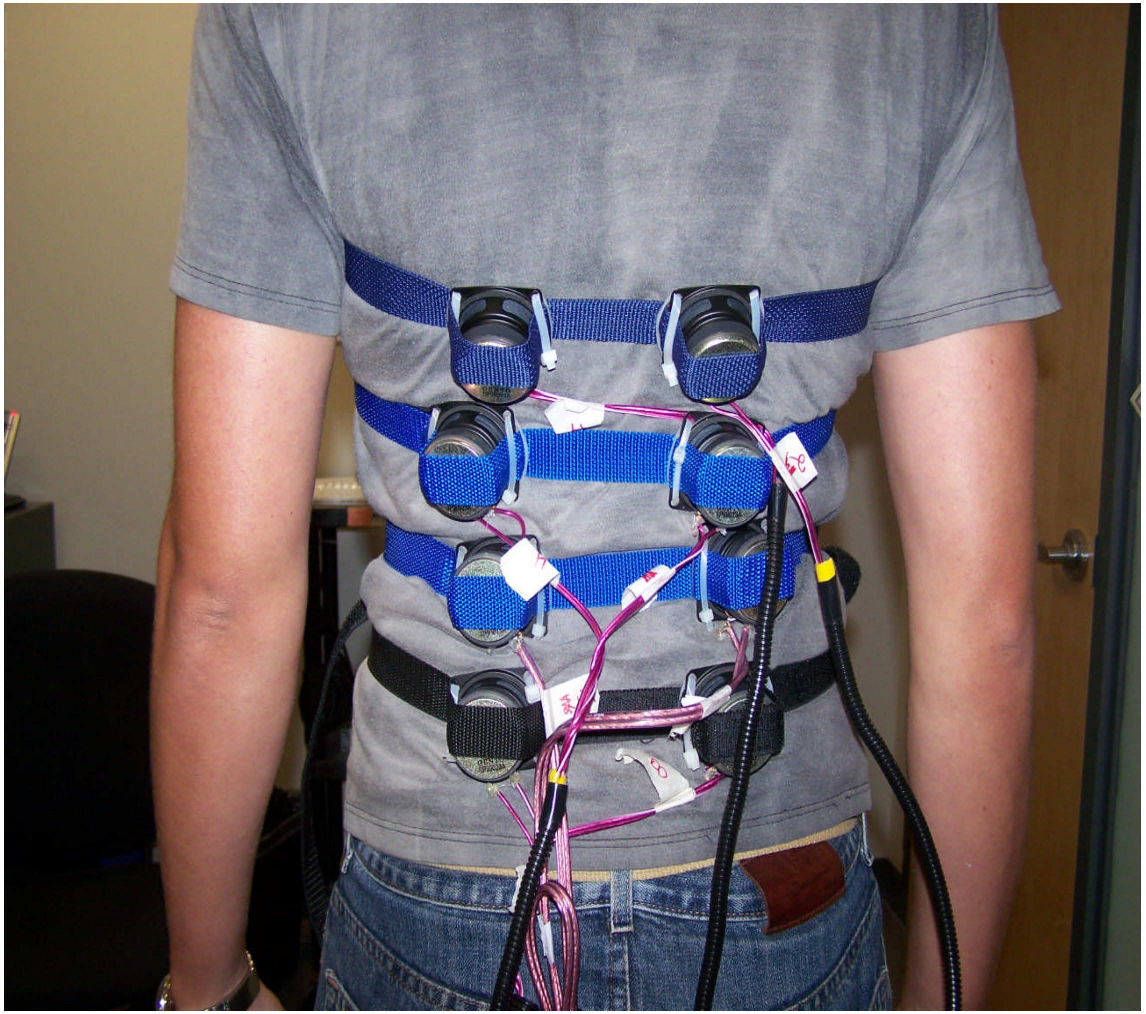
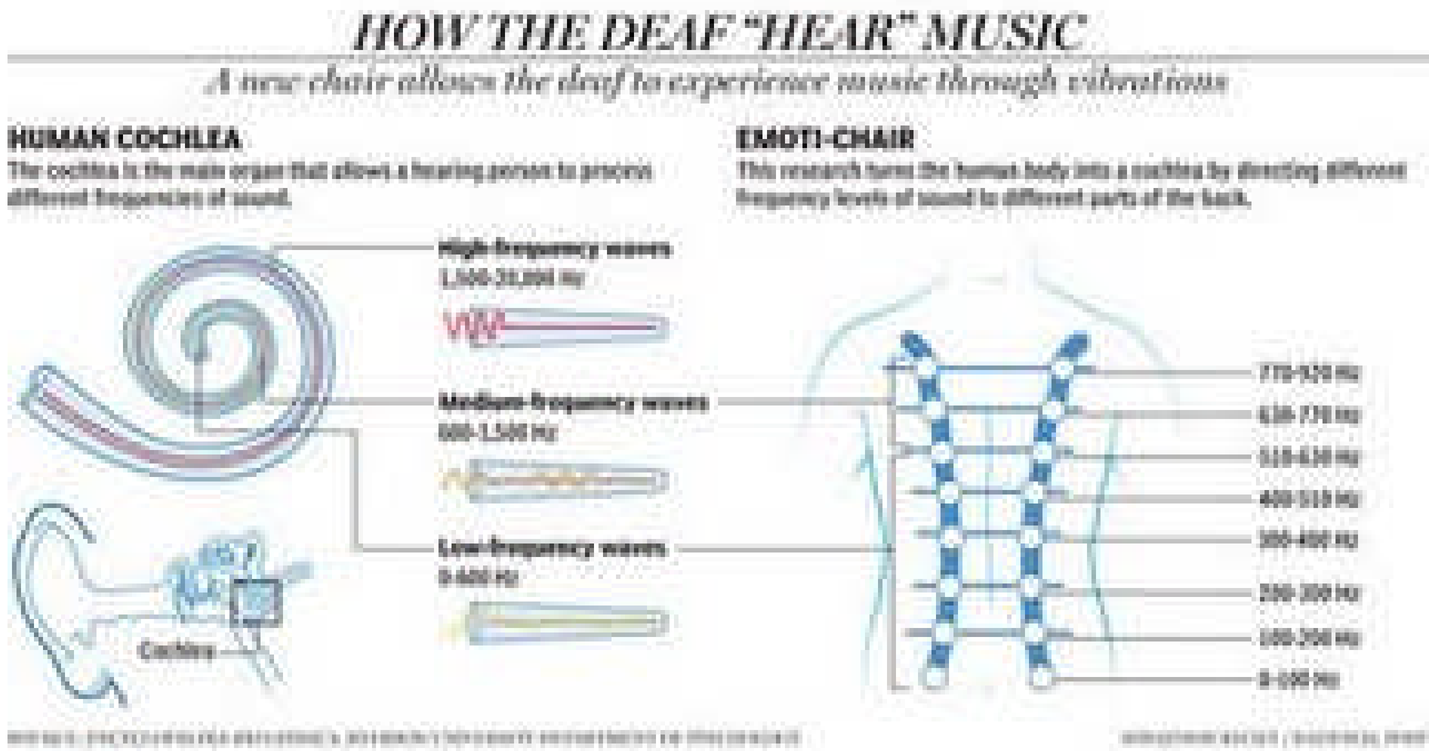
Prototype 0, 1



+ Prototype 2.0

+ Physical Considerations



Tactile Music Perception

- Mechanoreceptors:
  - Sensors on the skin:
    - Most located in the non-hairy (glabrous) skin
    - Pacinian -> fast vibrations
    - Meissner -> texture changes
    - Merkel -> sustained touch
    - Ruffini -> tension
    - Hair cells (cochlea) -> air pressure waves
      - Most sensitive mechanoreceptor

Optimal Placement of Sound on Skin

- Higher frequencies requires more sensitivity
- Fingertips, palms, feet, lips…and other glabrous skin most sensitive to vibrations
  - Locate highest frequencies where skin is most sensitive
  - Lowest frequencies do not need high sensitivity skin

Hands on session begins!

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