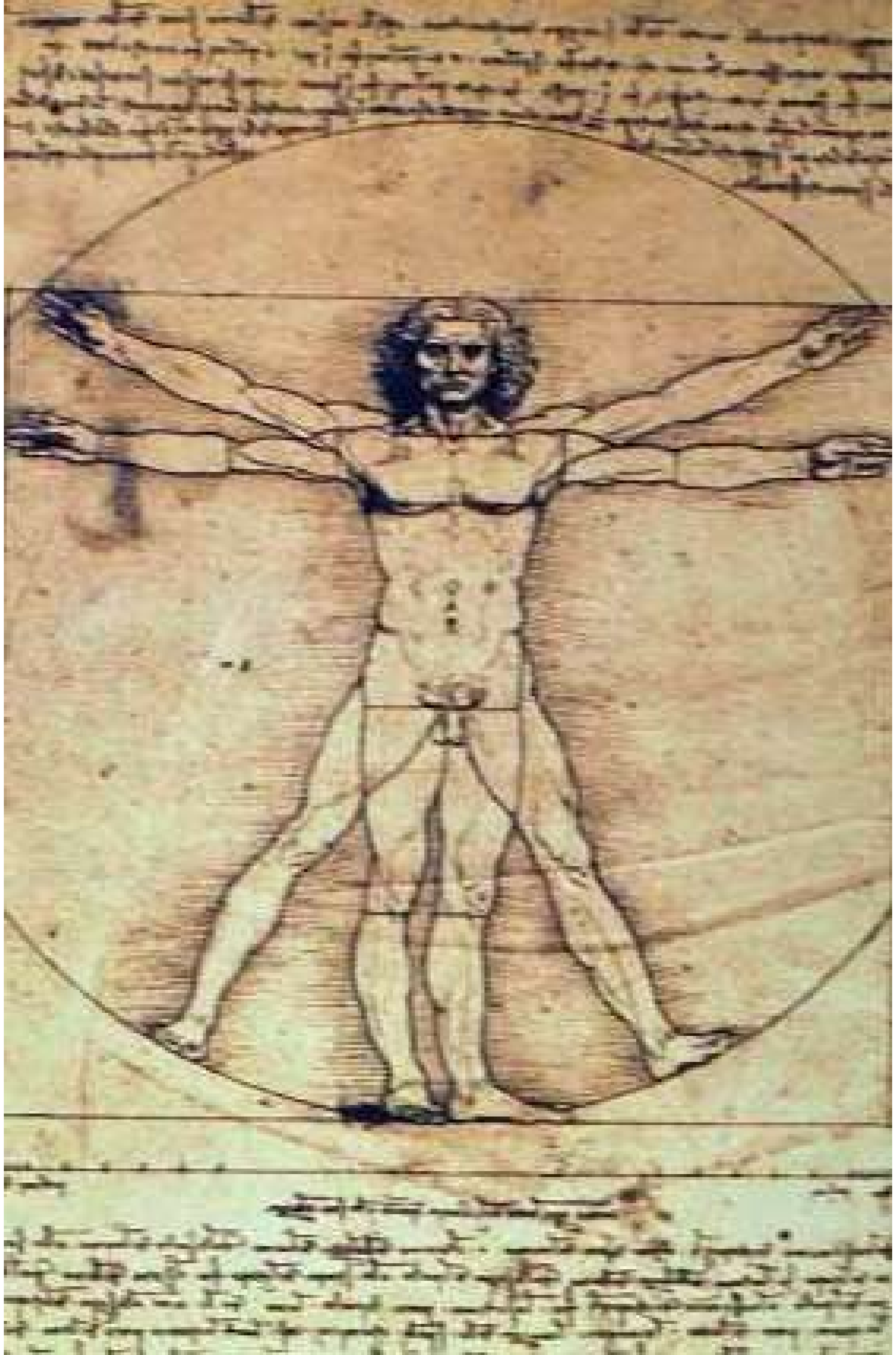
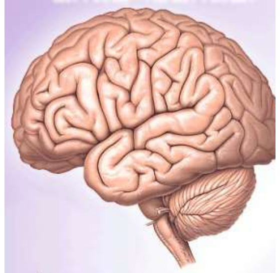
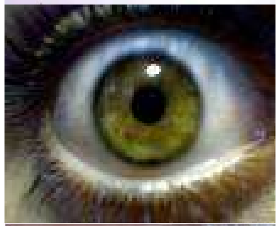


Interactive System インタラクティブシステム特論 (5)

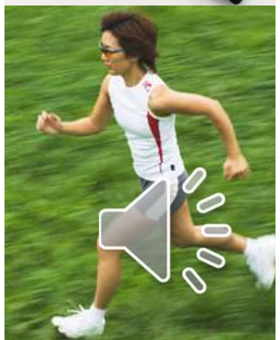
Hiroyuki Kajimoto
kajimoto@uec.ac.jp
Twitter kajimoto

Outline of the lecture

1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 聴覚、聴覚インタフェース／Auditory Interface
6. 触覚、触覚インタフェース／Tactile Interface
7. 力覚、力覚インタフェース／Haptic Interface
8. 移動感覚インタフェース／Locomotion Interface

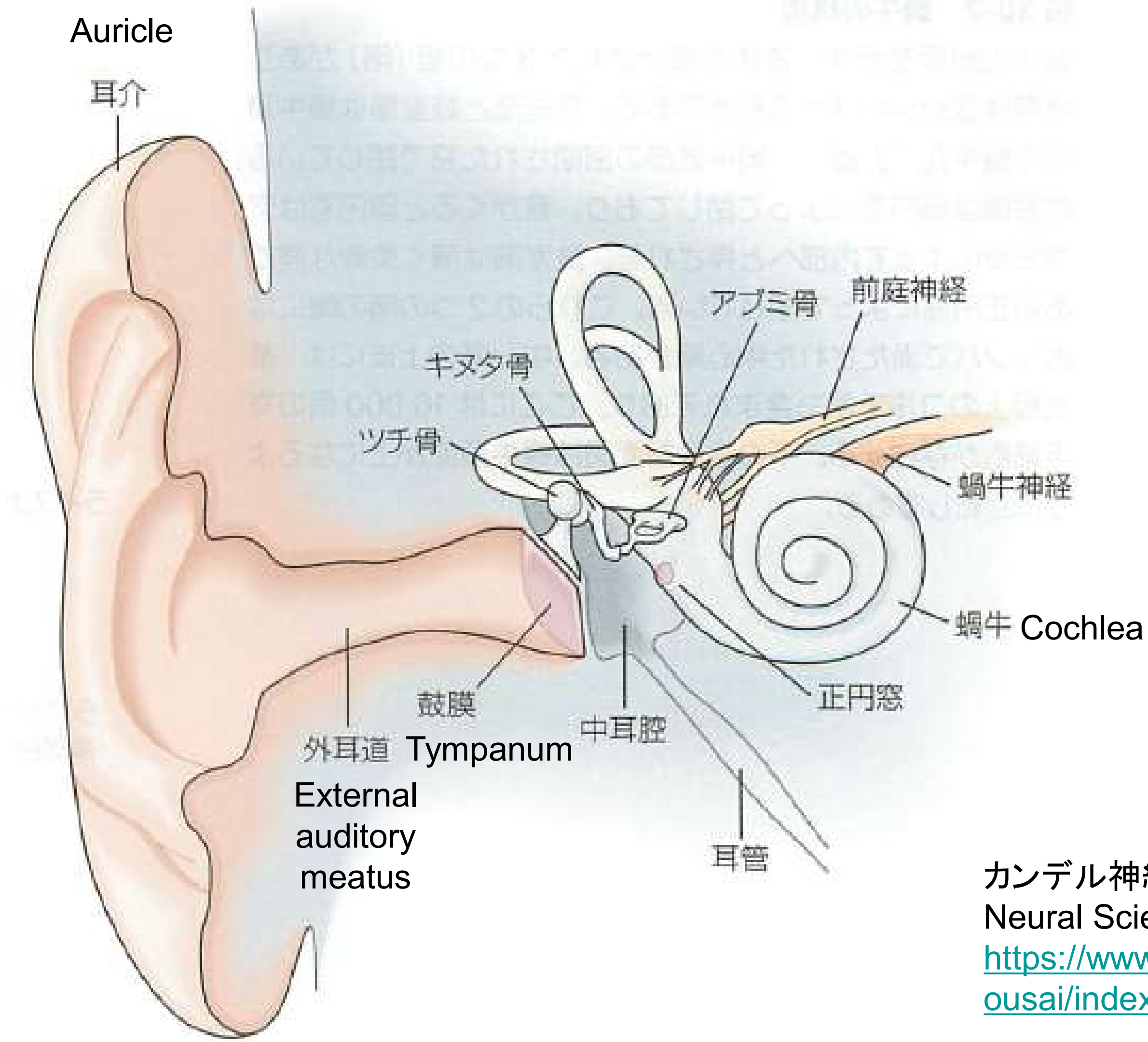




TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

Ear Mechanism



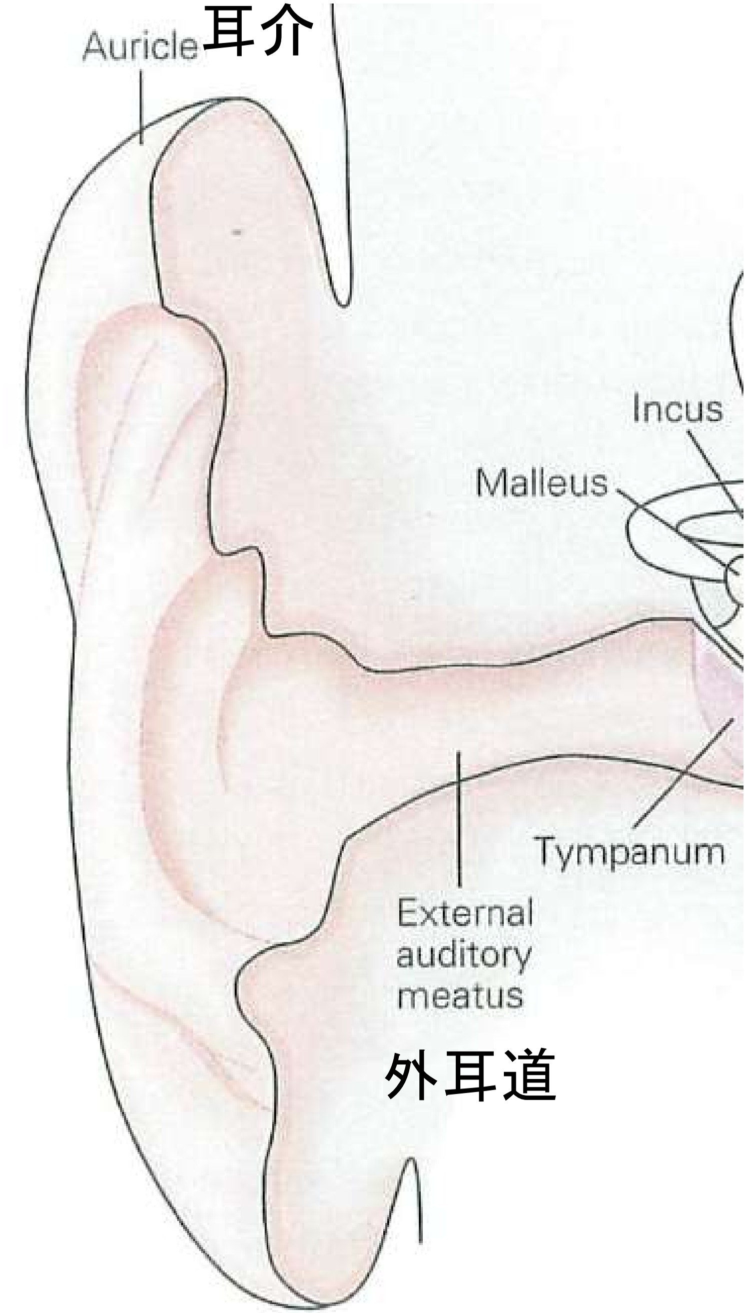
カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

External Ear 外耳 | Middle Ear 中耳 | Internal Ear 内耳

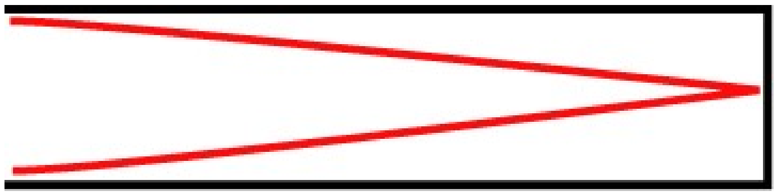
Journey of Sound to the Brain

https://www.youtube.com/watch?v=eQEaiZ2j9oc

外耳／External Ear



- 耳介／Auricle
  - 集音／Collection of sound
  - 方向定位／Directional sensation
- 外耳道／External Auditory Meatus
  - 共鳴管／A resonating pipe.
  - 2.5-3.5cm = 1/4λ
  - Lowest resonant freq. = 3-4kHz



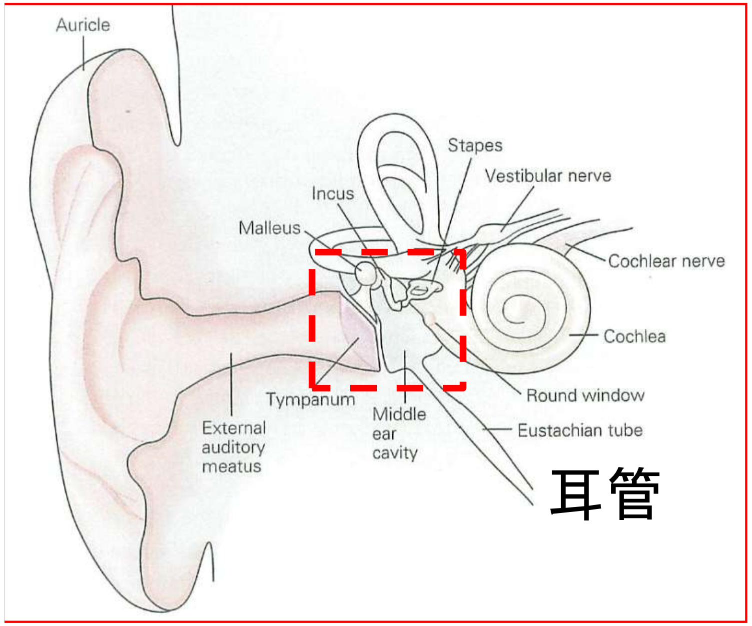
（CHI2015） Bodyprint: Biometric User Identification on Mobile Devices Using the Capacitive Touchscreen to Scan Body Parts Christian Holz, Senaka Buthpitiya, Marius Knaust

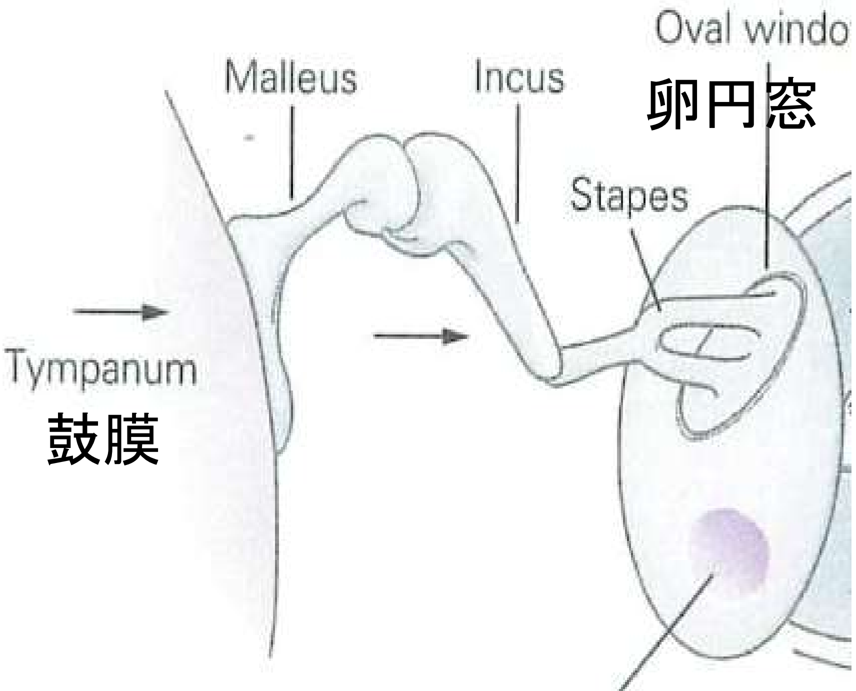
https://www.youtube.com/watch?v=JrK1wQjh980

マルチタッチ機能により身体各部を押し付けた際の魚拓をとる．特に耳の形を取ると認証に使える（実際歴史的には耳の形は指紋よりも先に犯罪捜査に使われていた）

Body print can be obtained by multi-touch smartphone and used for authentication. Especially, the shape of ear is the best (historically, it has been used in criminal investigations before fingerprints.)

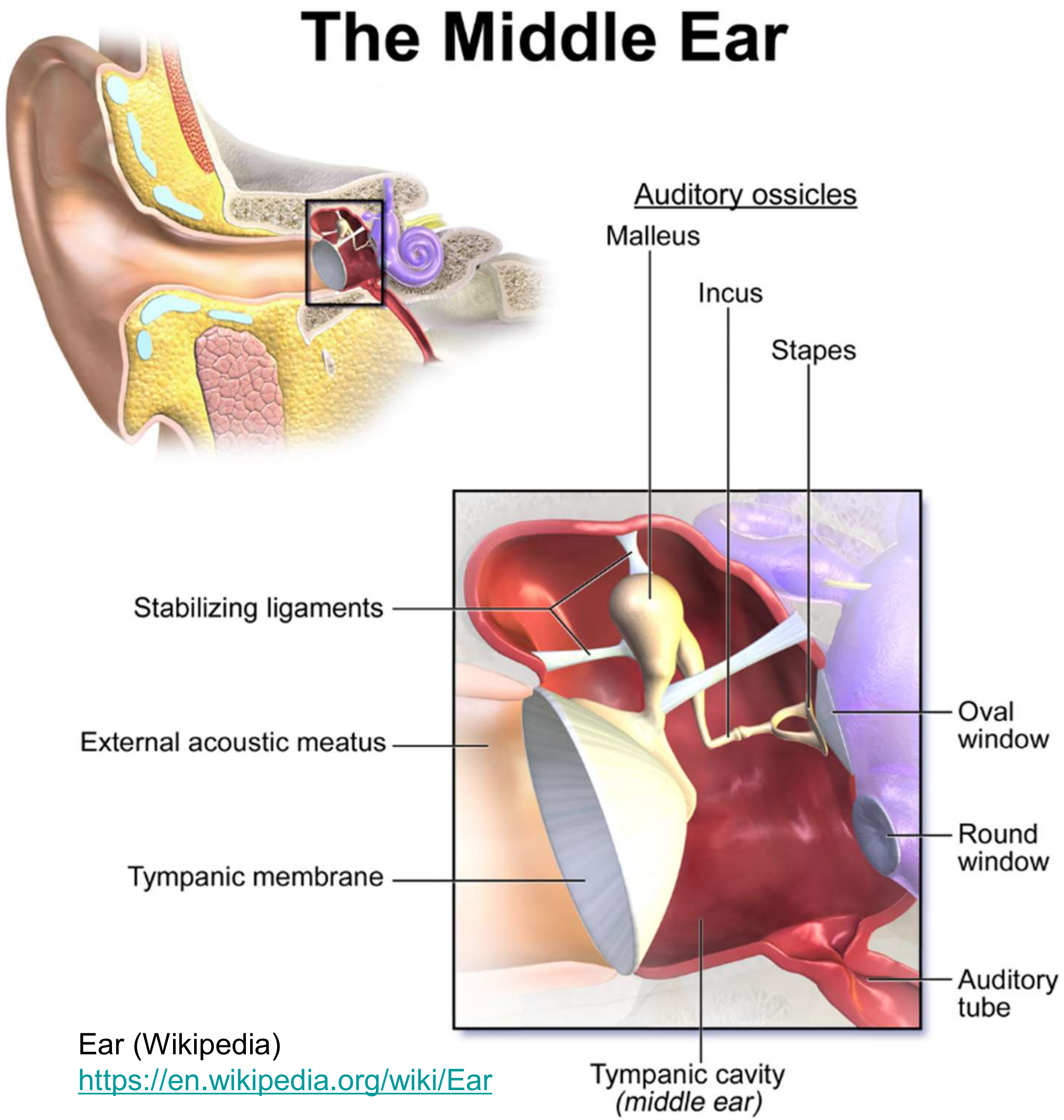
中耳／Middle Ear





- 鼓膜／Tympanum
  - 厚み／Thickness 0.1mm
  - 直径／Diameter 8-9mm
  - 知覚可能最小振幅／Min. Amplitude 0.12 μm
- 耳小骨／Ear ossicles (tiny bones)
  - つち、きぬた、あぶみ骨 Malleus, Incus, Stapes
  - 増幅／Amplification
  - 筋肉が付属：強い音で硬くなる反射(減弱反射) ⇒伝達を減衰／Connected muscle modulate transfer efficiency (attenuation reflex)
- 耳管／Eustachian tube
  - 気圧調整／Connected to throat and keeps air pressure

中耳における力の増幅／Lever Mechanism at Middle Ear

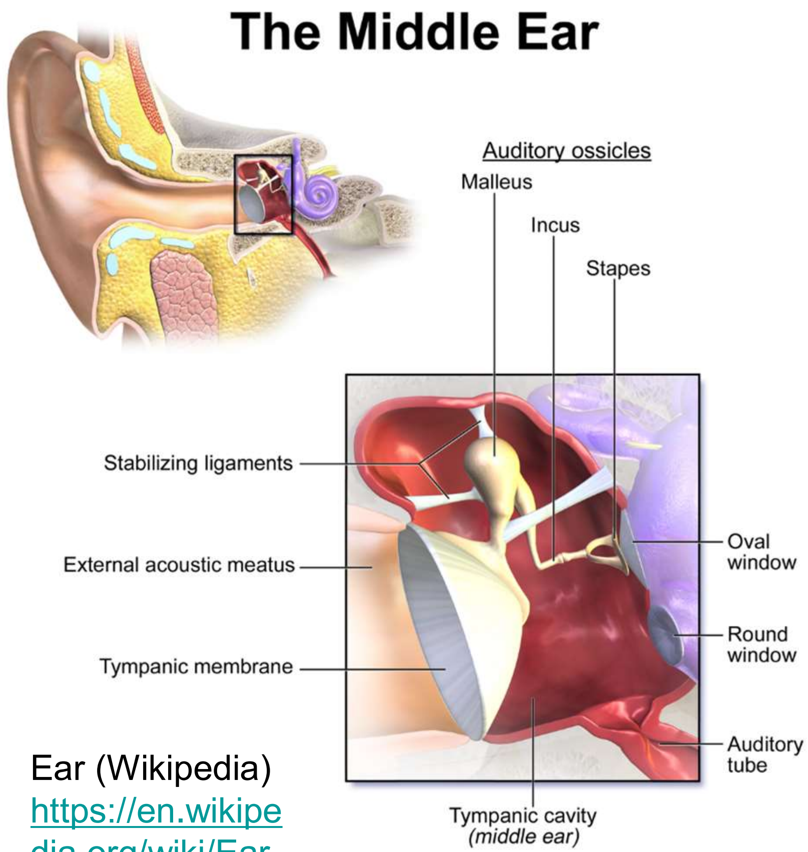


空気振動で液体を駆動？
How to drive Fluid by Air?

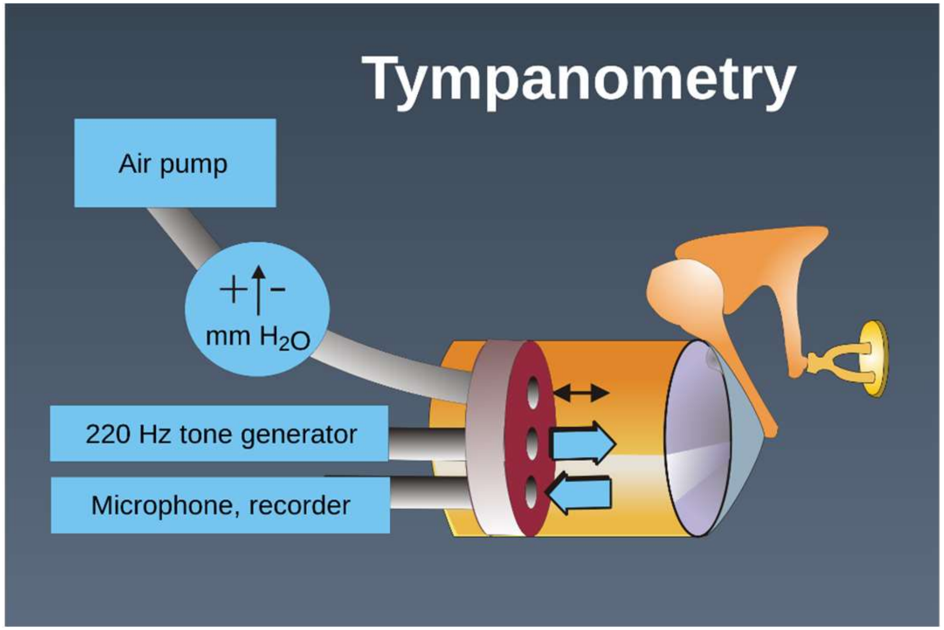
- Fluid has 4000x more impedance than Air (Most energy is reflected)
- Tympanum size is 17x larger than Oval Window.
- 3 Bones has 1.3x mechanical lever
- In total, force is magnified 22x.

Ear (Wikipedia)
https://en.wikipedia.org/wiki/Ear

中耳検査／Examination of Middle Ear



Ear (Wikipedia)
https://en.wikipedia.org/wiki/Ear

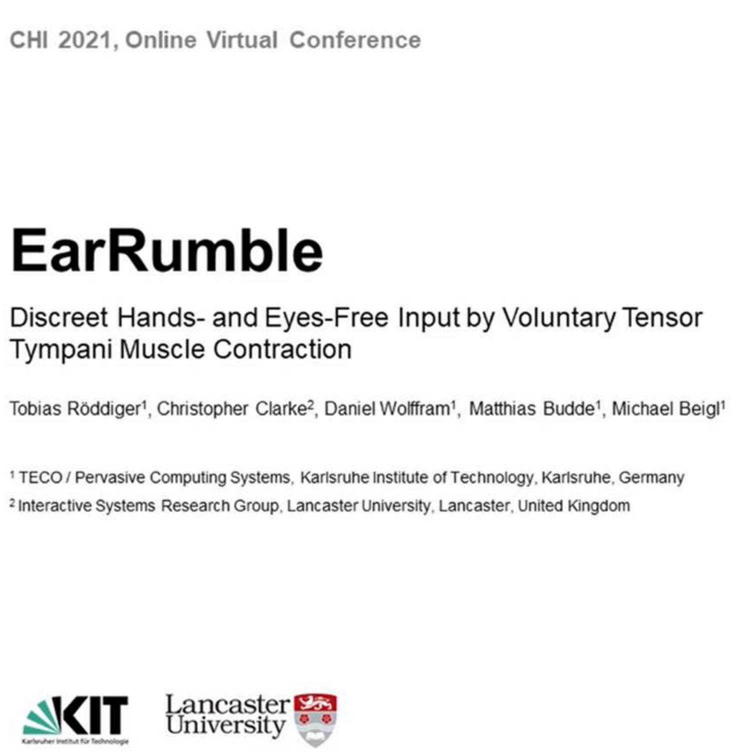


Tympanometry
https://en.wikipedia.org/wiki/Tympanometry

- 音を入れた際の反射音強度からインピーダンスを計測
  Impedance measurement by reflected sound
  - ティンパノメトリー／Tympanometry
    - 外気圧を変動させた際の鼓膜や耳小骨の振動のしやすさ(インピーダンス)を検査
      Measure tympanum’s impedance while changing external air pressure
  - 耳小骨筋反射検査／stapedial reflex
    - 鼓膜に大きな音を入力したときの減弱反射を鼓膜の振動のしやすさ（インピーダンス）で検査
      Measure tympanum’s impedance while inputting very large sound

(CHI2021) EarRumble: Discreet Hands- and Eyes-Free Input by Voluntary Tensor Tympani Muscle Contraction

Tobias Röddiger, Christopher Clarke, Daniel Wolffram, Matthias Budde, Michael Beigl

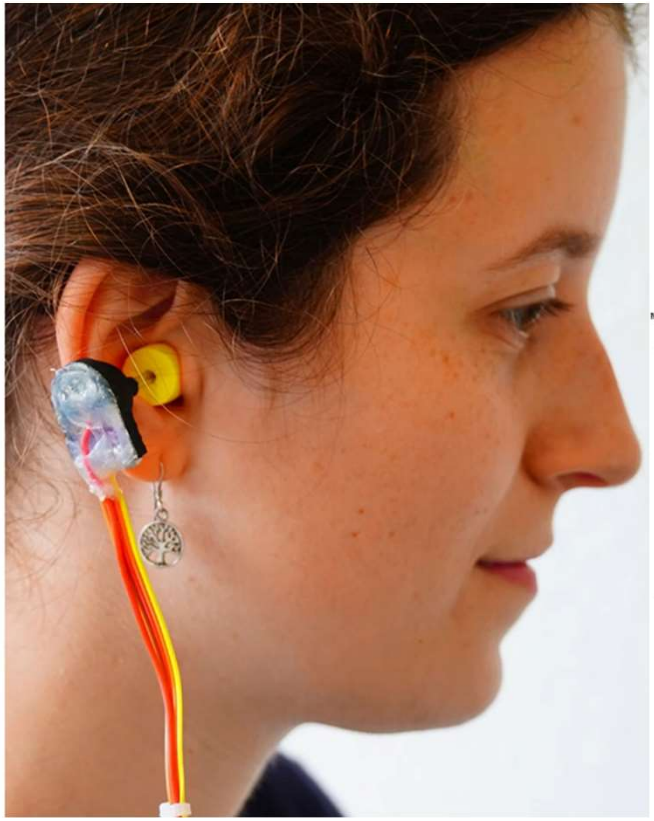

CHI 2021, Online Virtual Conference

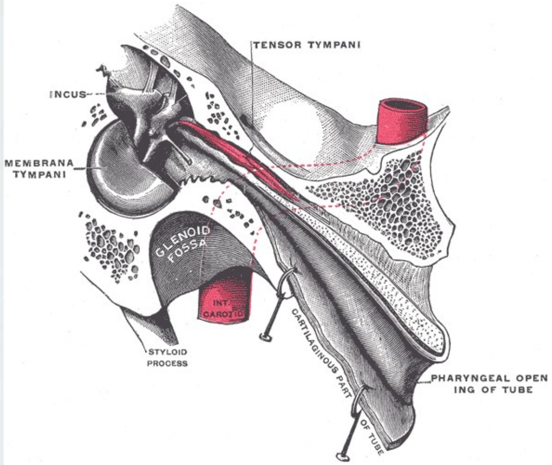
EarRumble

Discreet Hands- and Eyes-Free Input by Voluntary Tensor Tympani Muscle Contraction

Tobias Röddiger[1], Christopher Clarke[2], Daniel Wolffram[1], Matthias Budde[1], Michael Beigl[1]

[1] TECO / Pervasive Computing Systems, Karlsruhe Institute of Technology, Karlsruhe, Germany
[2] Interactive Systems Research Group, Lancaster University, Lancaster, United Kingdom



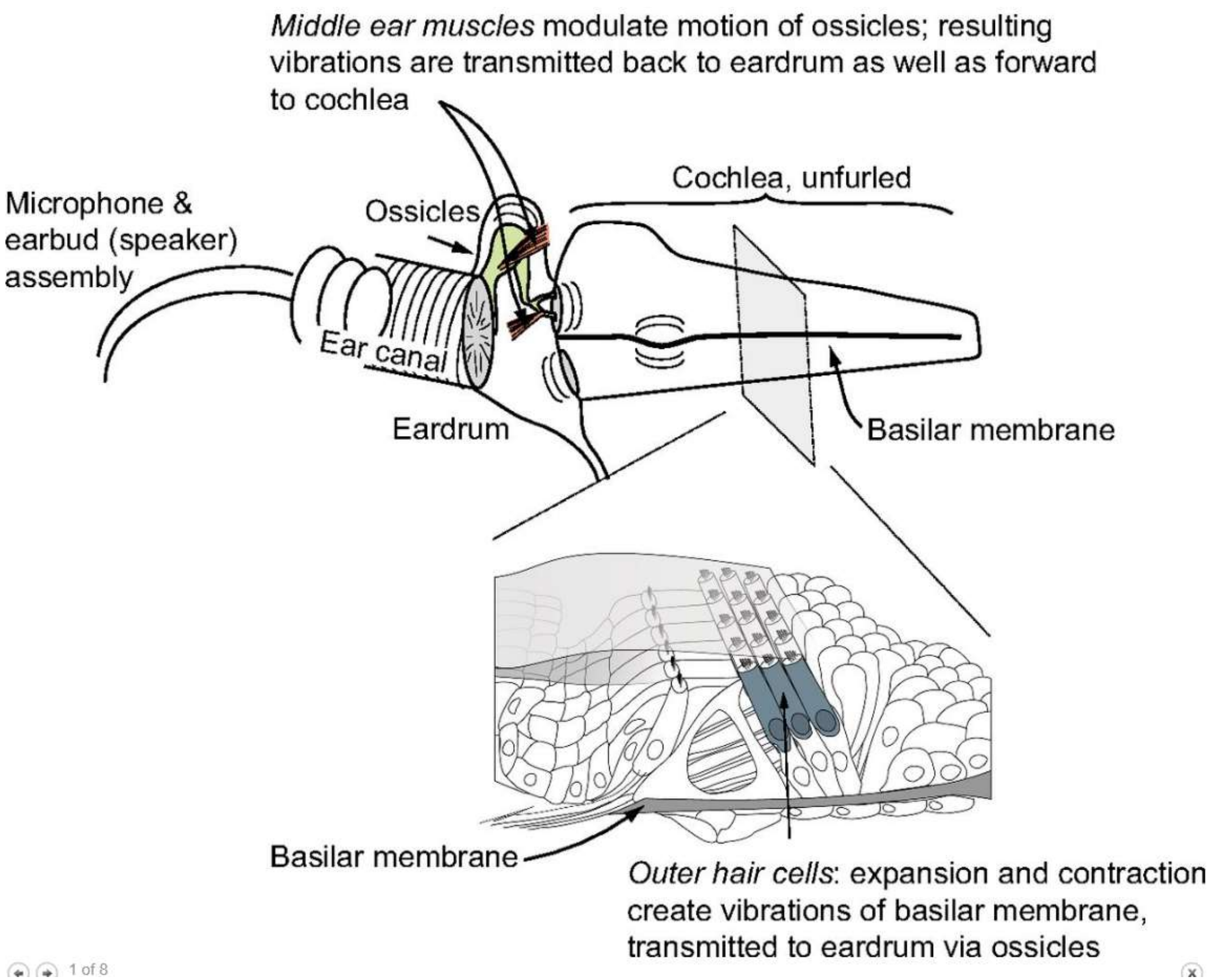


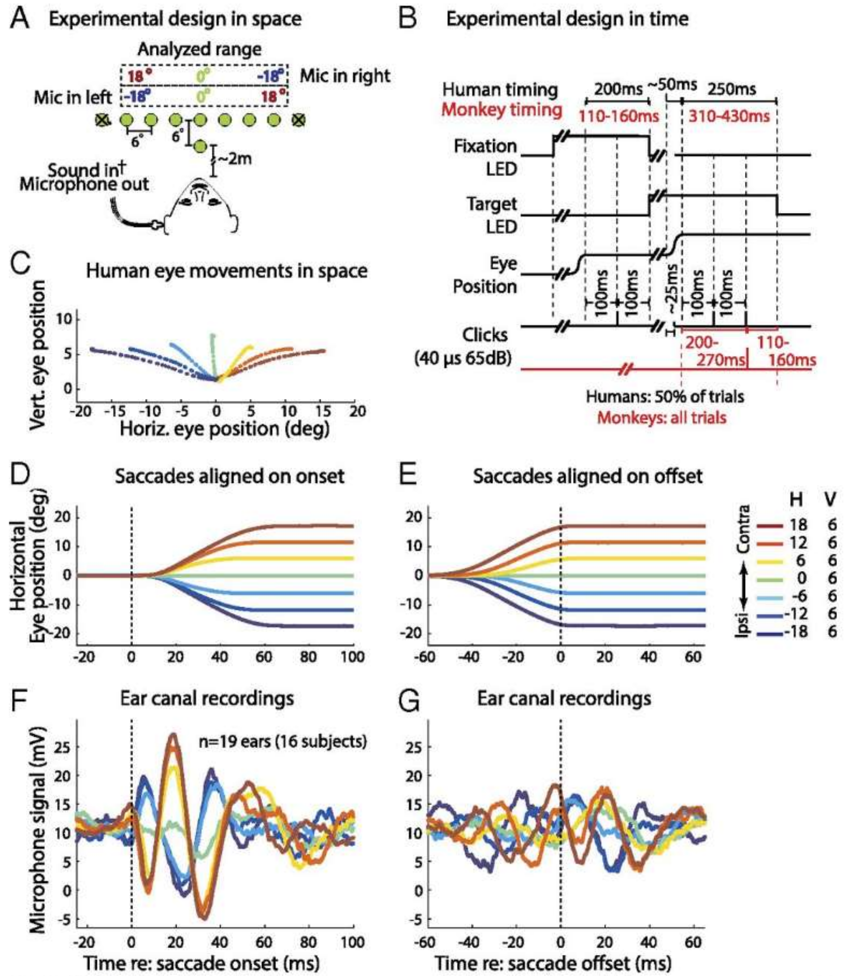
https://www.youtube.com/watch?v=dPTCJ4lt4CE&list=PLqhXYFYmZ-Vdsg4-okDWnptnyAs8HXjfN&index=20

- tensor tympani (鼓膜張筋：耳小骨筋の一つ)を任意に動かせる人がいる。その人達用の入力デバイスを空気圧センサを用いて作成
- There are people who can move their tensor tympani (one of the muscles of the ear) at will. Created an input device for these people using a pneumatic pressure sensor.

目の運動（サッケード）に応じて鼓膜に振動が発生？

Kurtis G. Gruters, David L. K. Murphy, Cole D. Jenson, David W. Smith, Christopher A. Shera, and Jennifer M. Groh: The eardrums move when the eyes move: A multisensory effect on the mechanics of hearing. PNAS2018 http://www.pnas.org/content/115/6/E1309

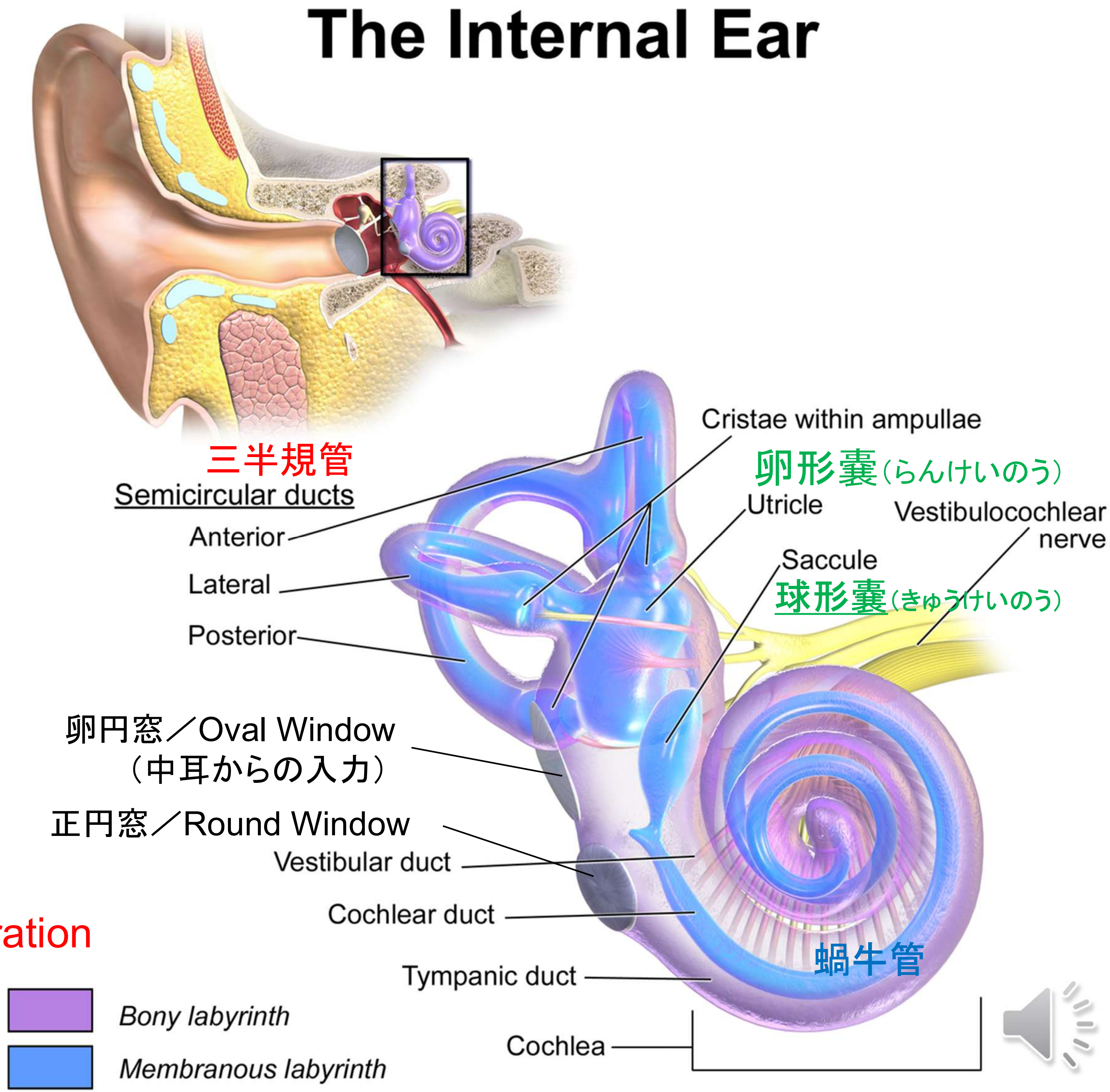




(from abstract) “These observations suggest that a vision-related process modulates the first stage of hearing. In particular, these eye movement-related eardrum oscillations may help the brain connect sights and sounds despite changes in the spatial relationship between the eyes and the ears.”

視覚がサッケードで劇的に変化する際に聴覚側に信号を送ることで視聴覚間の再対応付に役立てる？

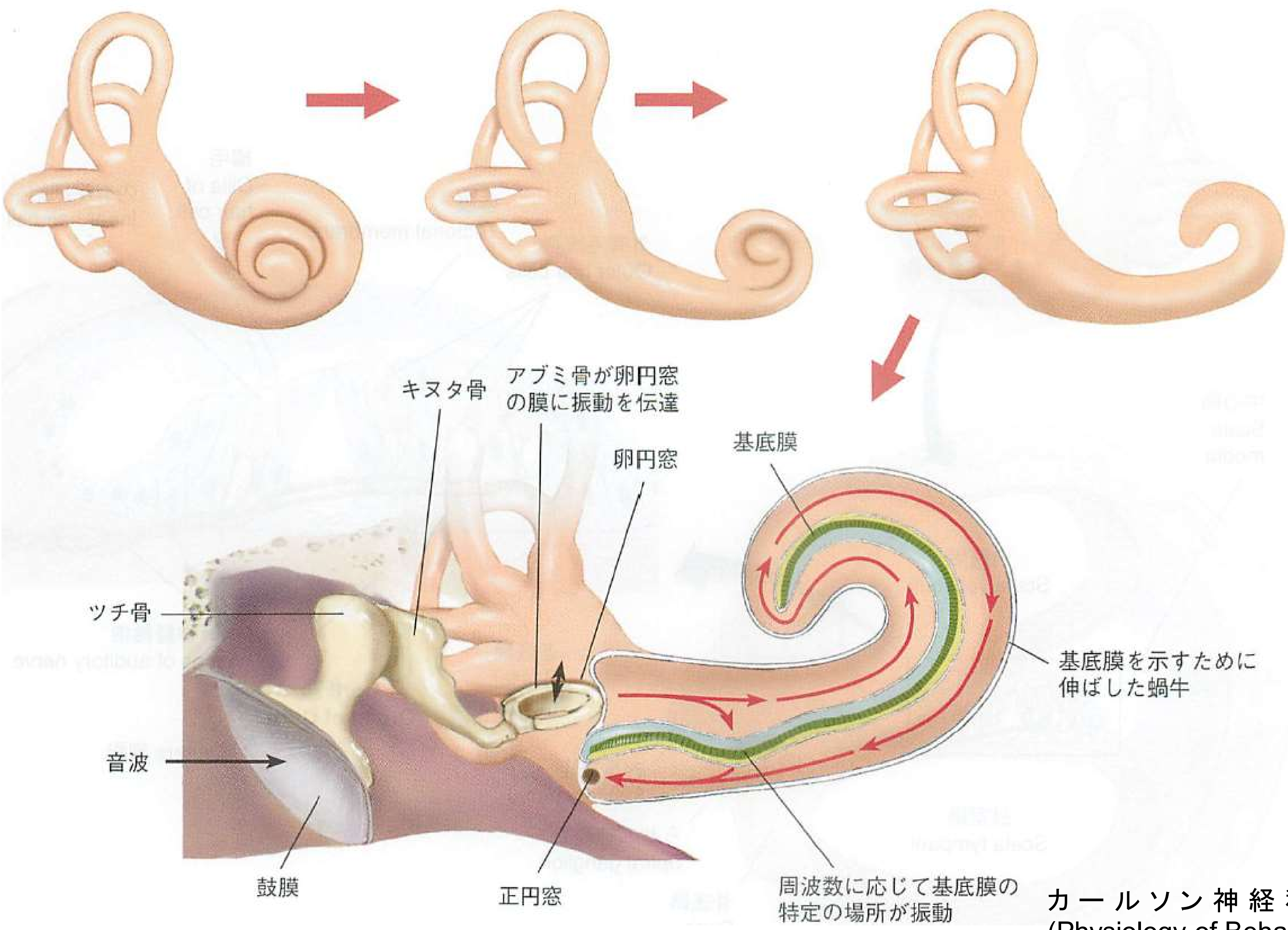
内耳
Internal Ear



Sensory Complex:

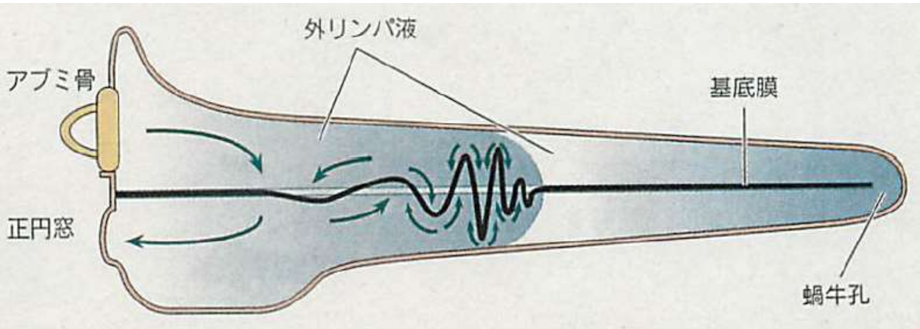
- Angular Acceleration
- Acceleration
- Sound

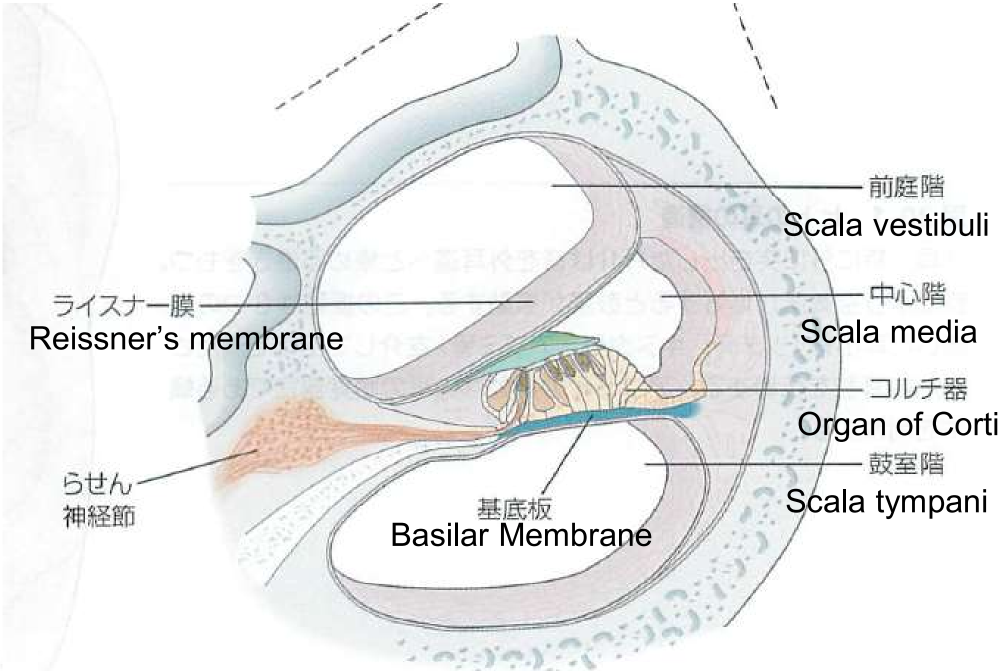
蝸牛管／Cochlear Canal = Snail Shape Tube

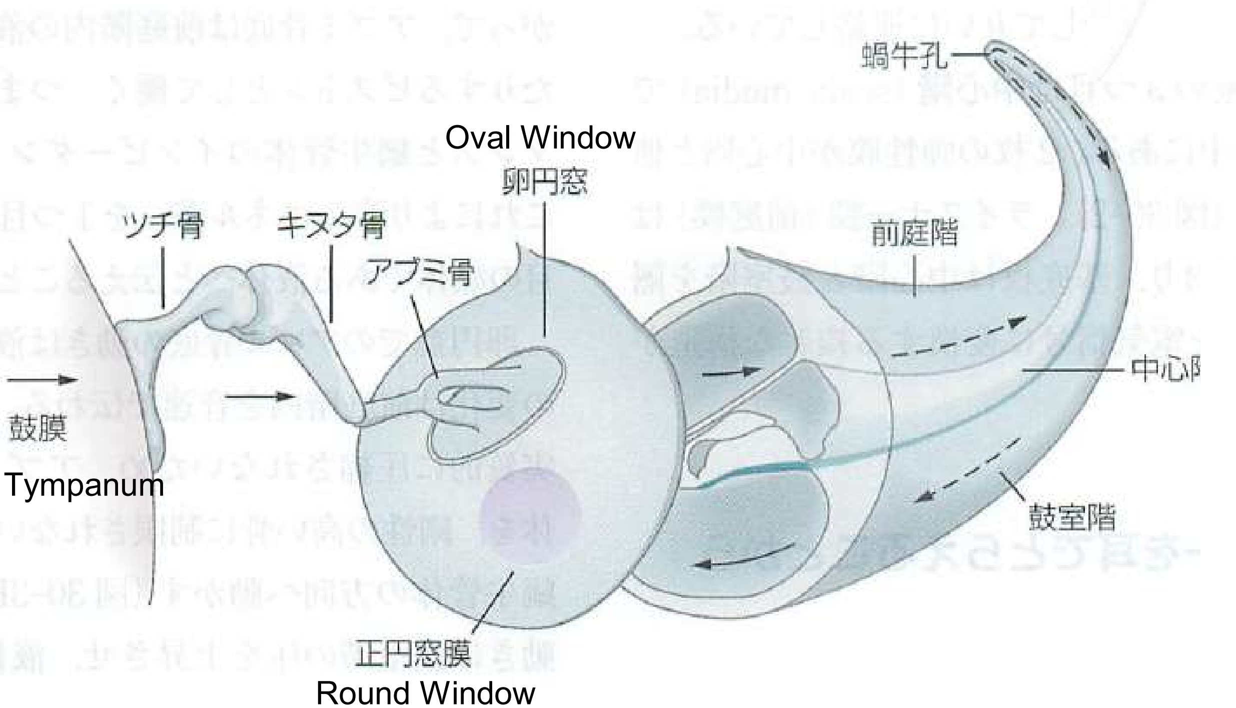


カールソン神経科学テキスト
(Physiology of Behavior)
https://www.maruzen-publishing.co.jp/item/b294439.html

蝸牛管は基底膜で上下に区切られる
The Tube is divided by Basilar Membrane





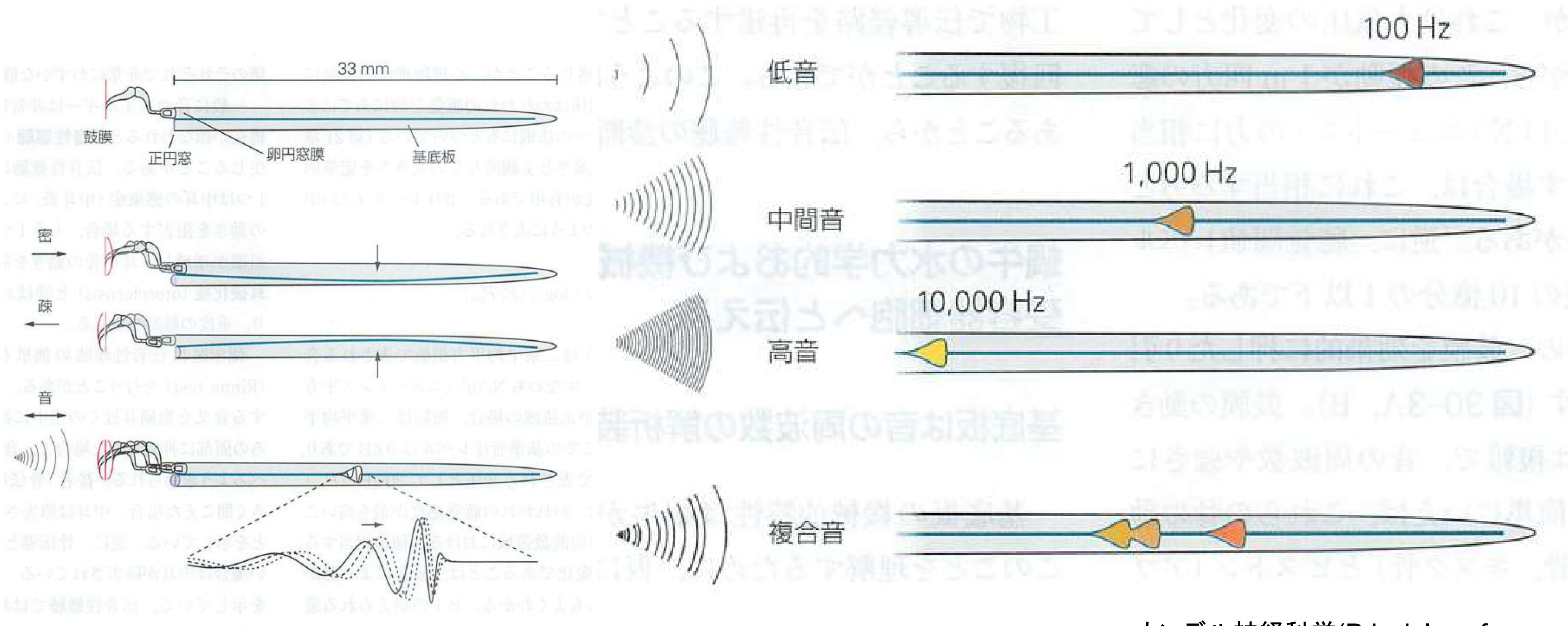


カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

卵円窓から入力。正円窓が膨れる
(水は体積変化しないため)

Input from Oval Window,
terminated at Round Window.
(Water volume does not change)

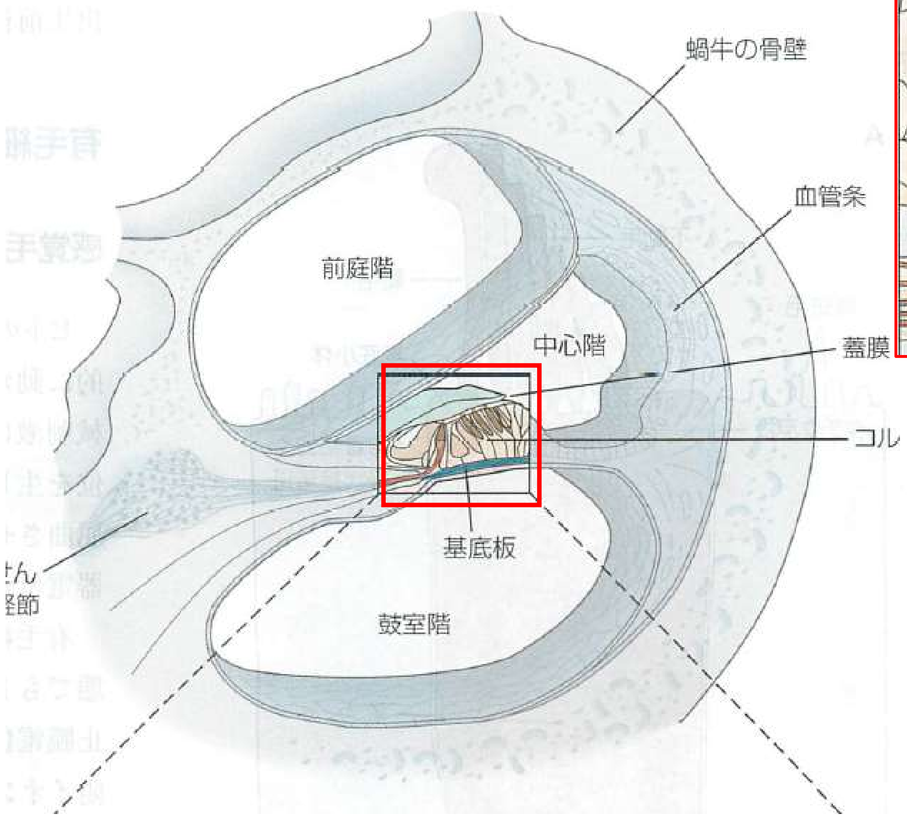
基底膜での周波数分解／
Frequency Analysis by the Membrane

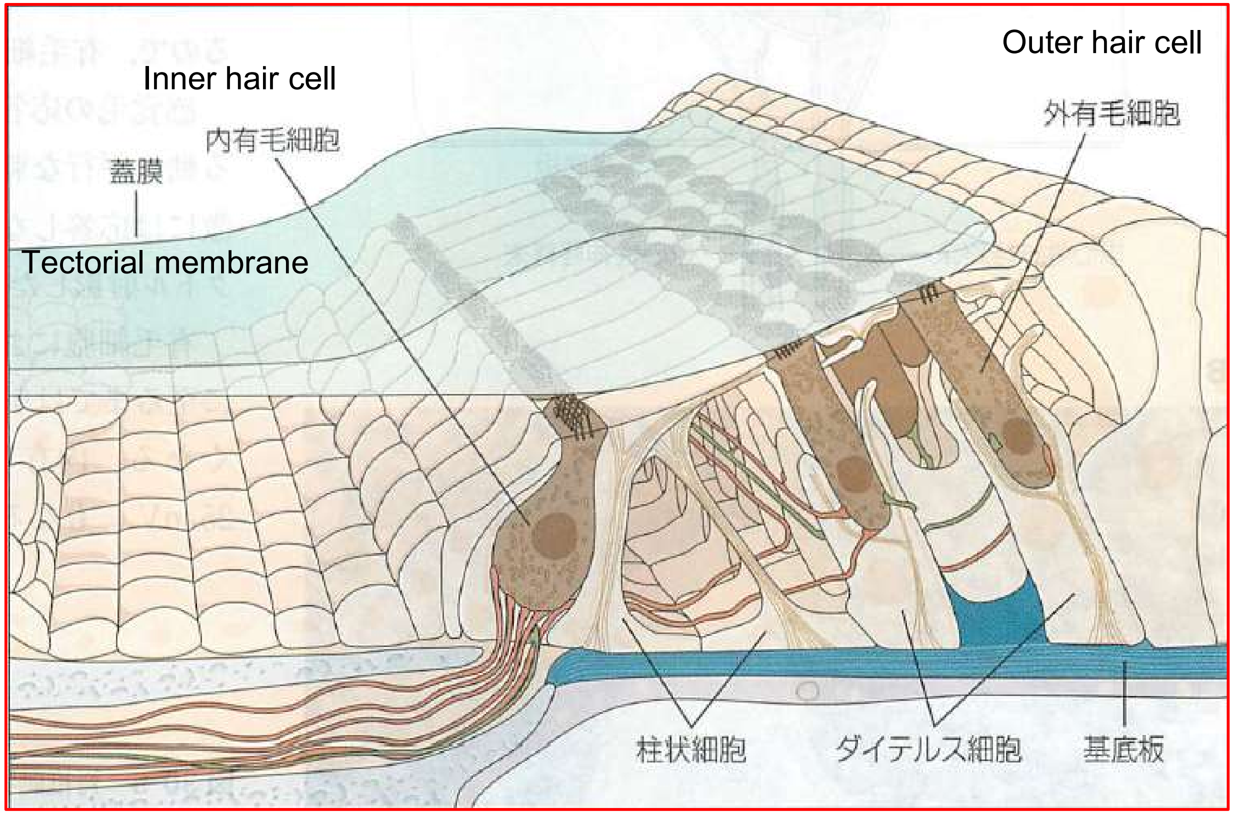


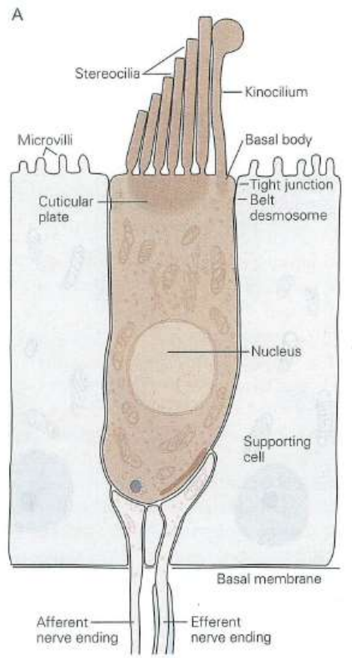
カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

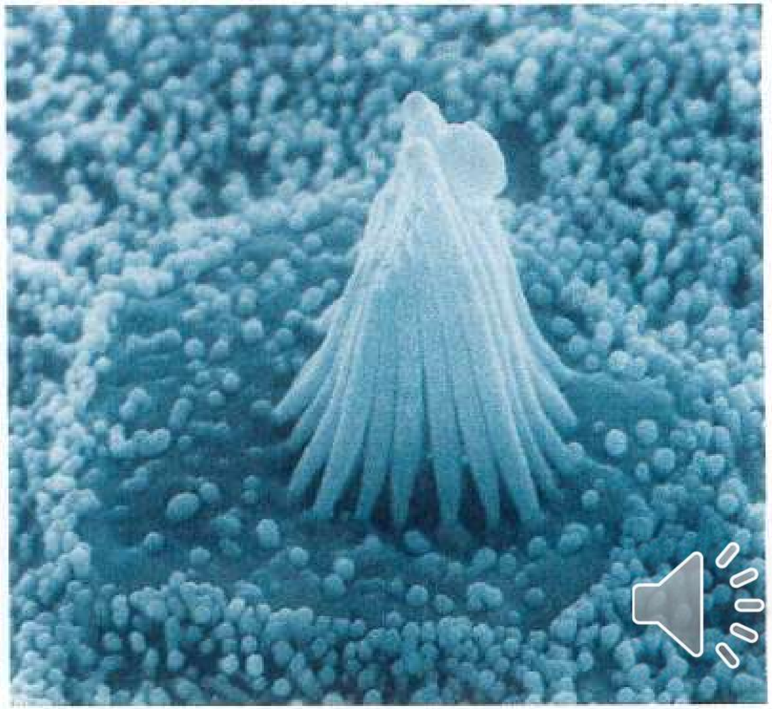
- Lower Frequency = Go Deeper
- Frequency is Converted to Spatial Pattern

基底膜上の有毛細胞
Hair Cell on the Membrane



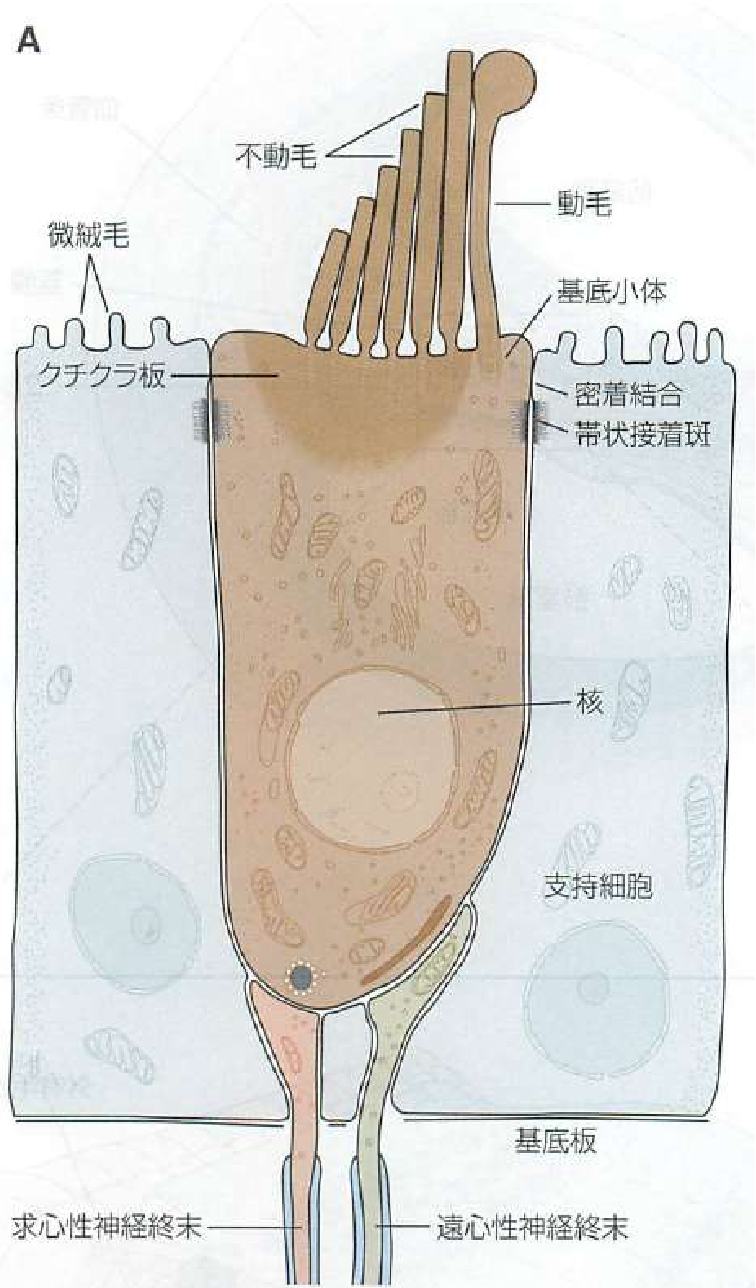


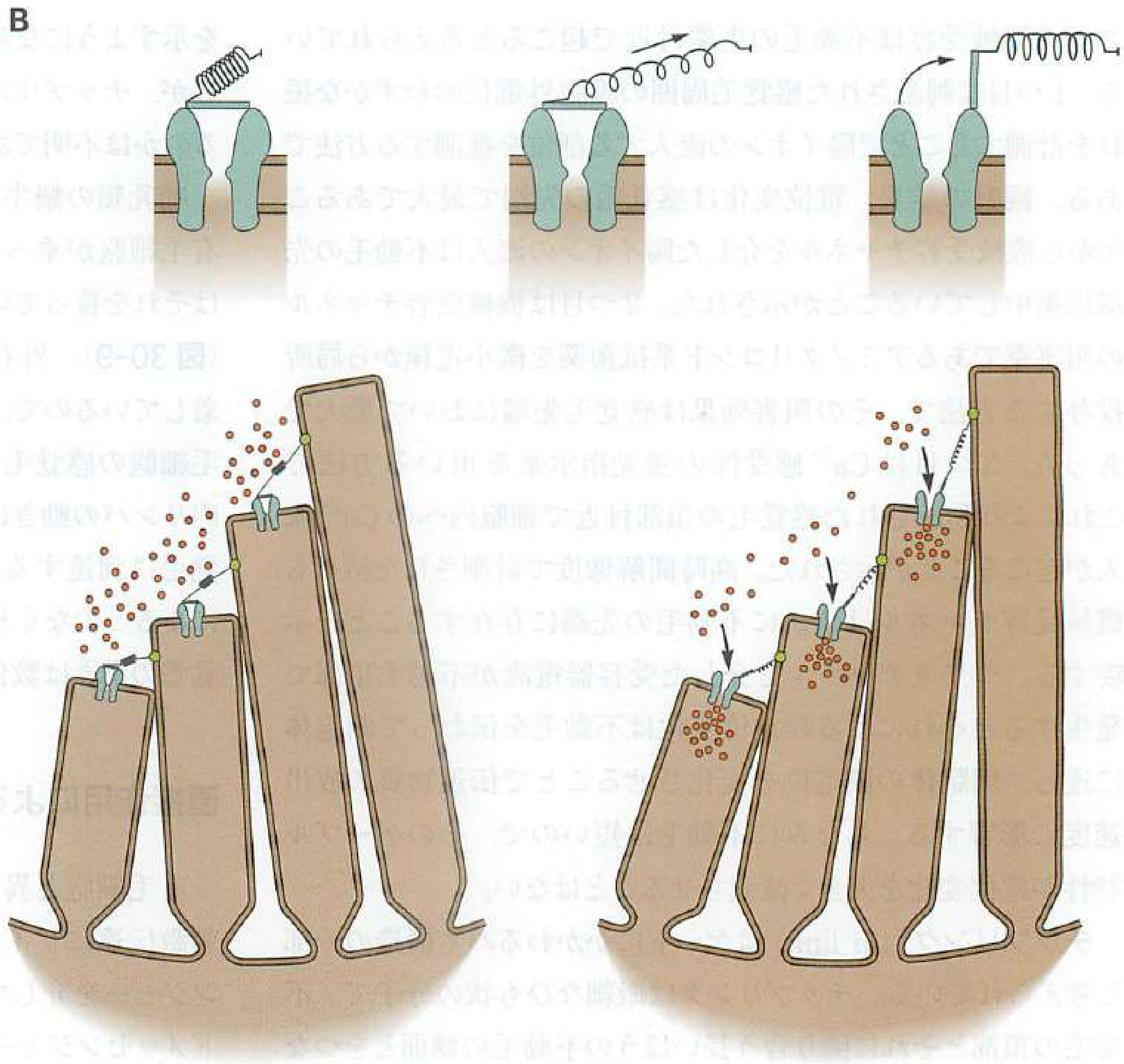




カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

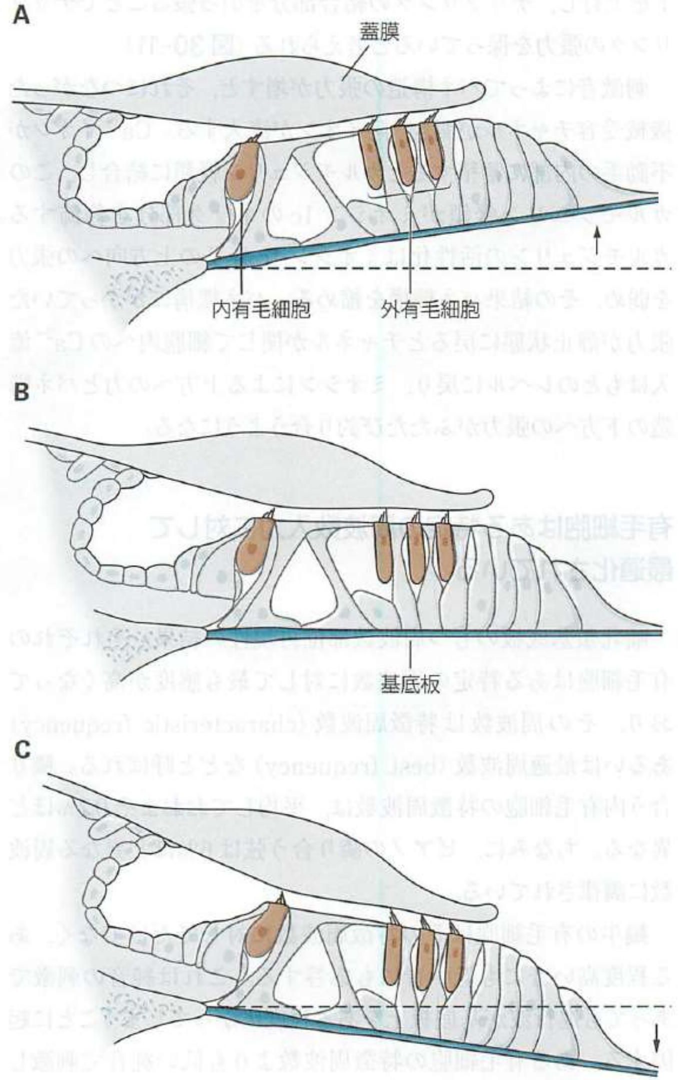
有毛細胞と機械的チャンネル開閉
Mechanical Channel on the Hair Cell

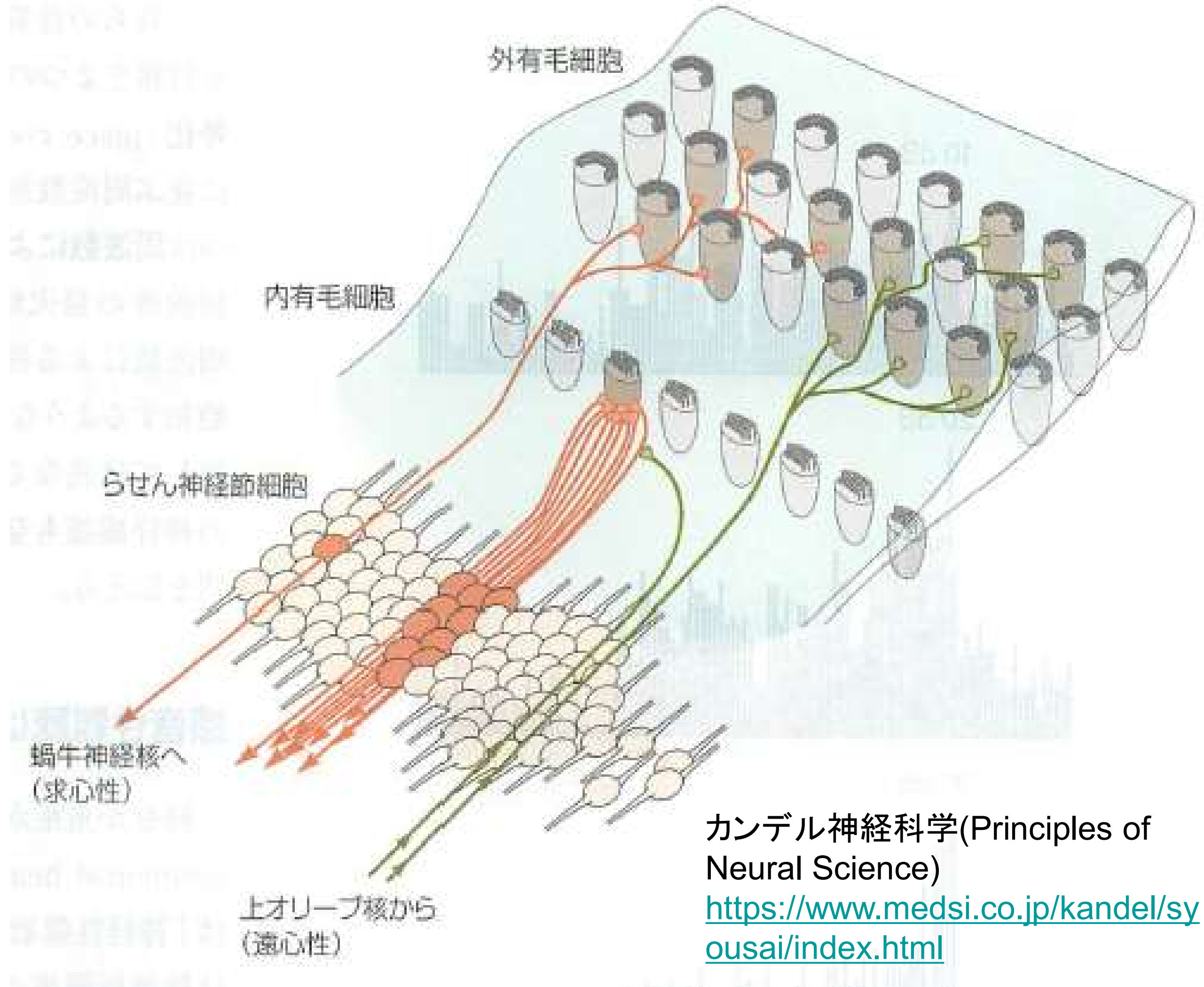




カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

内有毛細胞と外有毛細胞 Inner and Outer Hair Cell

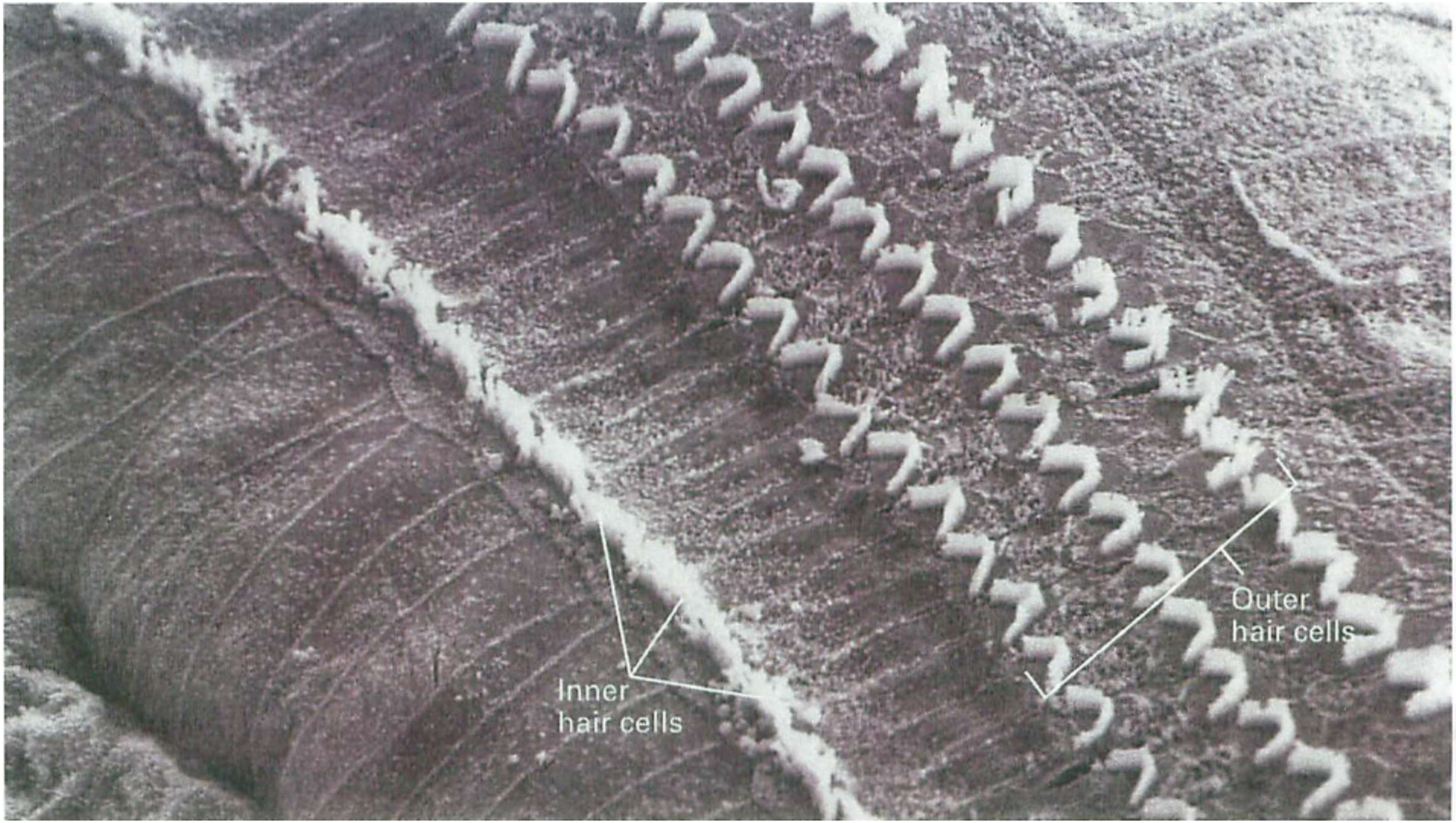




カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

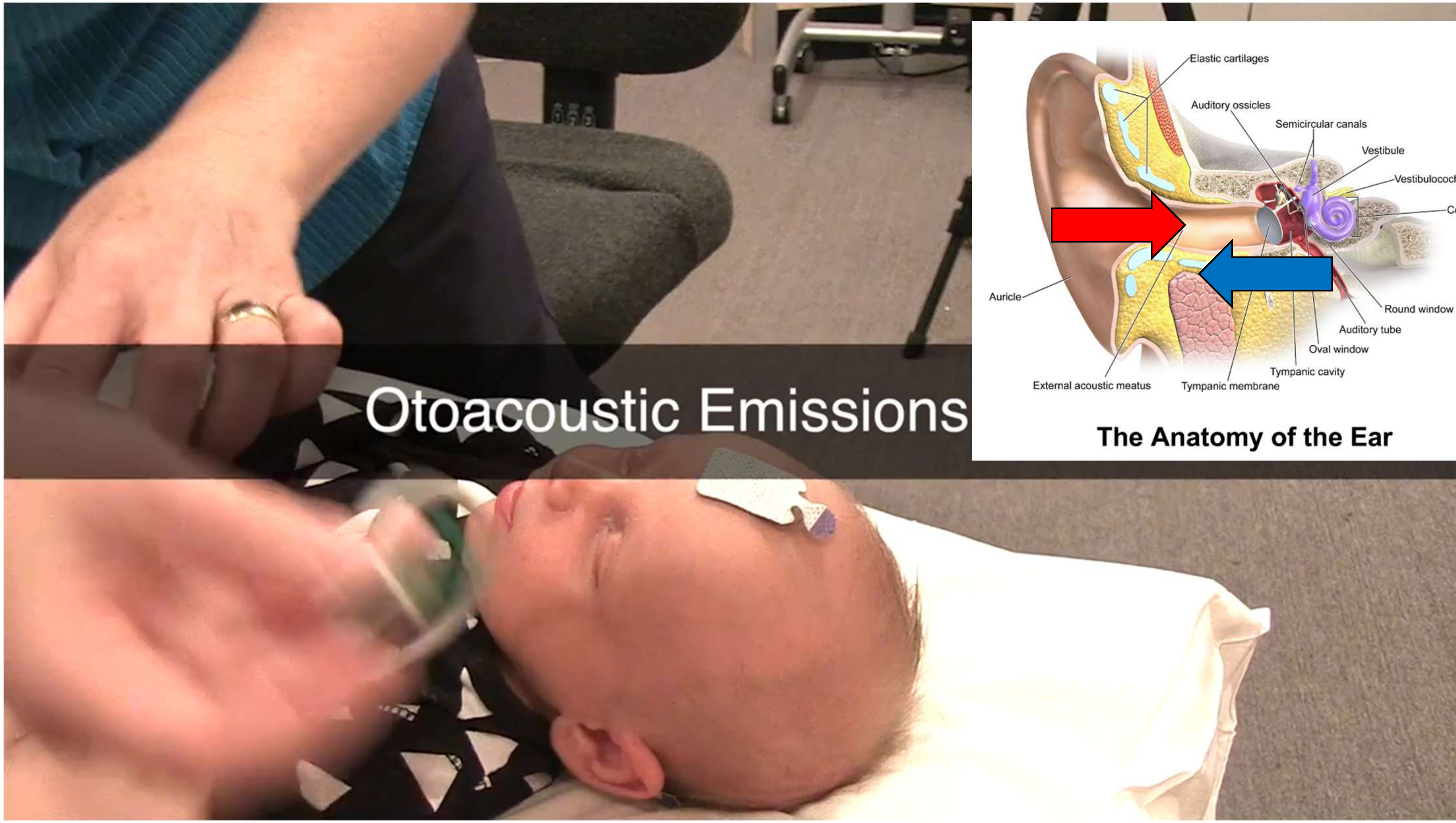
- Inner Hair Cell：Single Line. Sensory Nerve is Connected
  - About 3500. Not connected to tectorial membrane
- Outer Hair Cell: 3 Lines. Actuating Nerve is Connected
  - About 12000. Hair tip is connected to tectorial membrane
  - Works as actuator to adjust inner hair cell sensitivity.

内有毛細胞と外有毛細胞／Inner & Outer Hair Cell



カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

耳音響放射／Otoacoustic Emission, OAE



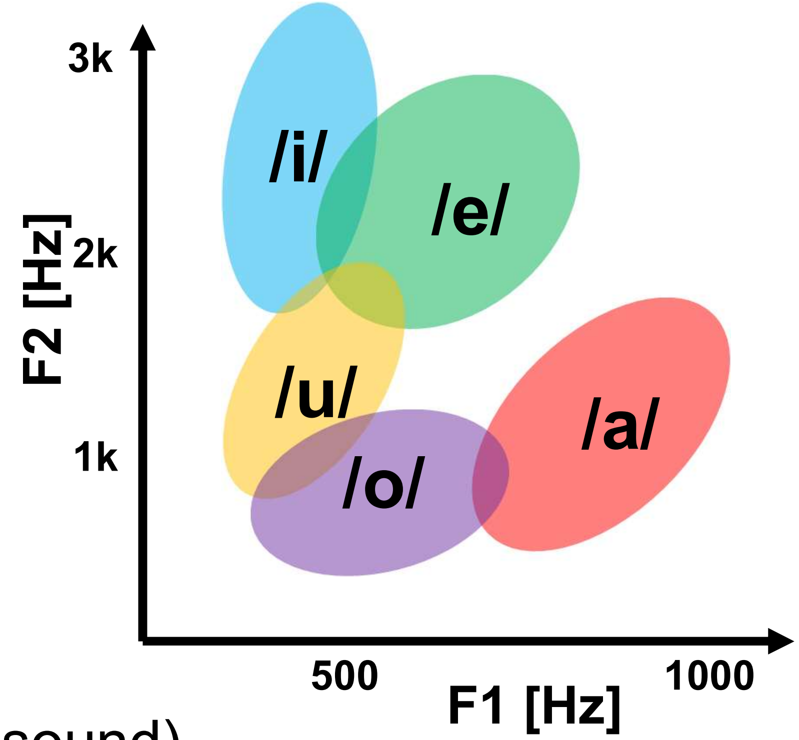
https://www.youtube.com/watch?v=c9BmtEFNuCo Hearing Test - Otoacoustic Emissions Test

- 蝸牛が自ら音を発する。外部音に対する反応としても、無音時にも自発的に。外有毛細胞の活動による。/ Cochlea emits sound by itself, both as a reaction to external sound, and without external sound. Due to outer hair cells
- 聴覚系の検査のために用いられる。Used as an examination tool.

TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

音は周波数分解されて知覚される／
Sound is analyzed by Frequencies.

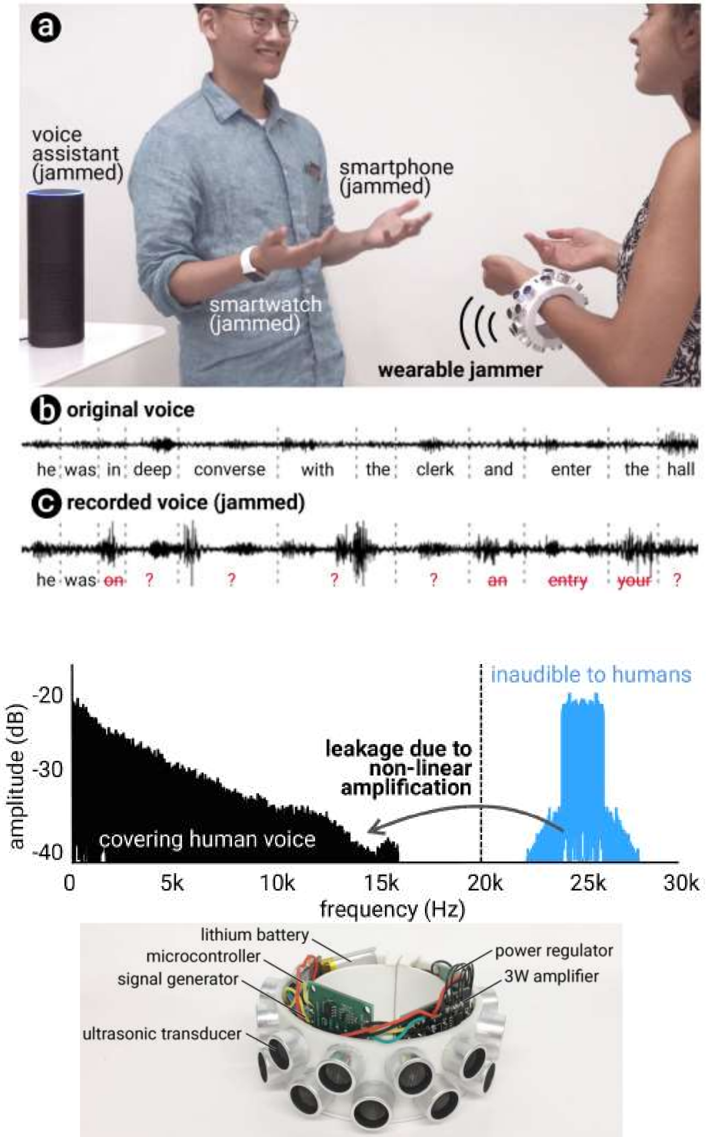


- 20Hz～20kHz (Higher than 20kHz = ultrasound)
  Become worse with aging
  - especially upper limit becomes lower.(“Mosquito Noise”)
- Sound is analyzed by Frequencies.
  - Ex. Formant
    - Vowel is analyzed by “two major peaks”.
      - First Formant: 500～1000Hz
      - Second Formant:1500～3000Hz

（参考）しゃべるピアノ

Speaking Piano http://www.youtube.com/watch?v=muCPjK4nGY4
Talking Piano https://www.youtube.com/watch?v=-6e2c0v4sBM

(CHI2020) Wearable Microphone Jamming
Yuxin Chen;Huiying Li;Shan-Yuan Teng;Steven Nagels;Zhijing Li;Pedro Lopes;Ben Y. Zhao;Haitao Zheng



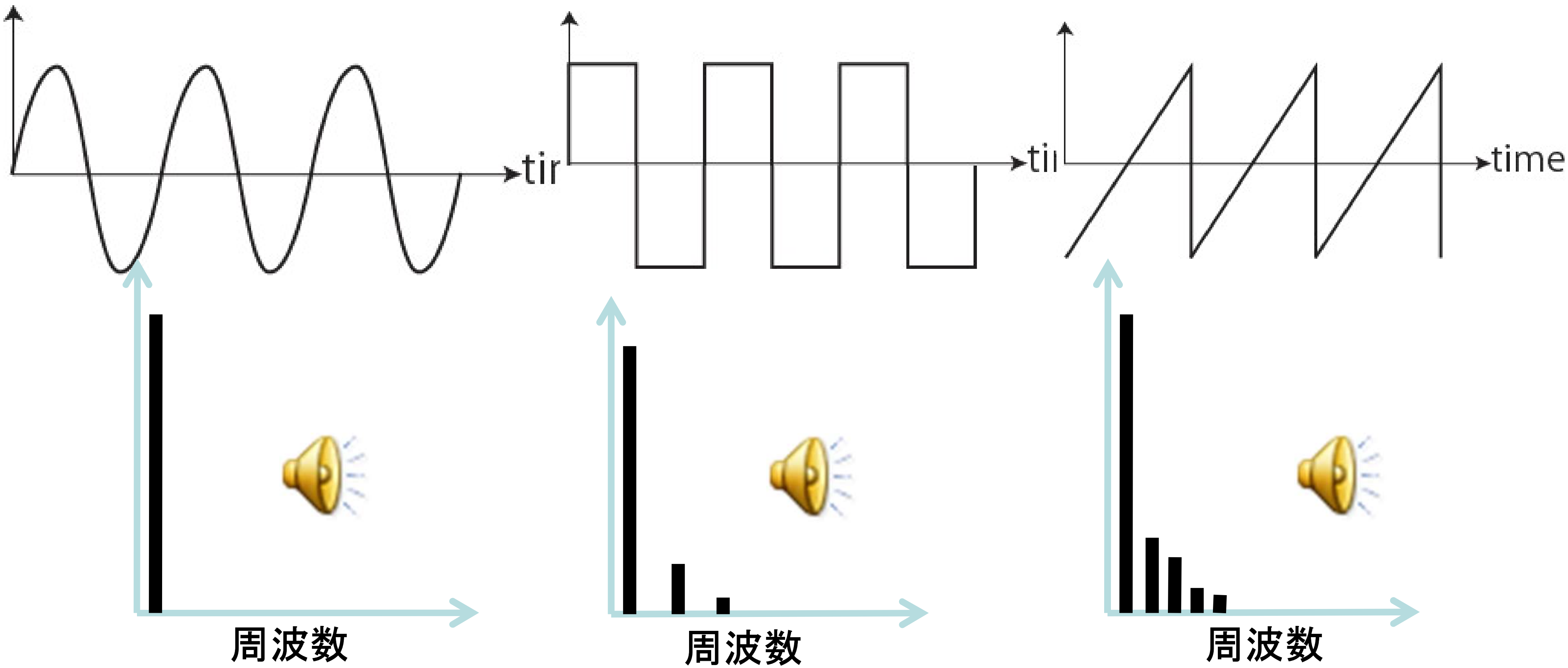
- https://www.youtube.com/watch?v=qogp8b52uOg
- ギリギリ非可聴の超音波を流す。サンプリングによって周波数が折り返され、可聴域信号として記録される。これによって音声の記録を妨害する。

(CHI2021) PrivacyMic: Utilizing Inaudible Frequencies for Privacy Preserving Daily Activity Recognition, Yasha Iravantchi, Karan Ahuja, Mayank Goel, Chris Harrison, Alanson Sample

https://www.youtube.com/watch?v=0e3Hbzr7p6I&list=PLqhXYFYmZ-Vdsg4-okDWnptnyAs8HXjfN&index=294

- 非可聴領域の音がユーザの行動の推定にどれだけ使えるか調べた⇒使える。
- ということで、可聴域の音を録音せず、非可聴域のみで動作させることでプライバシーに配慮した生活場面認識システムが出来た。
- Investigated how much non-audible sounds can be used to estimate user behavior.
- Able to create a privacy-conscious life scene recognition system that does not record sounds in the audible range and operates only in the non-audible range.

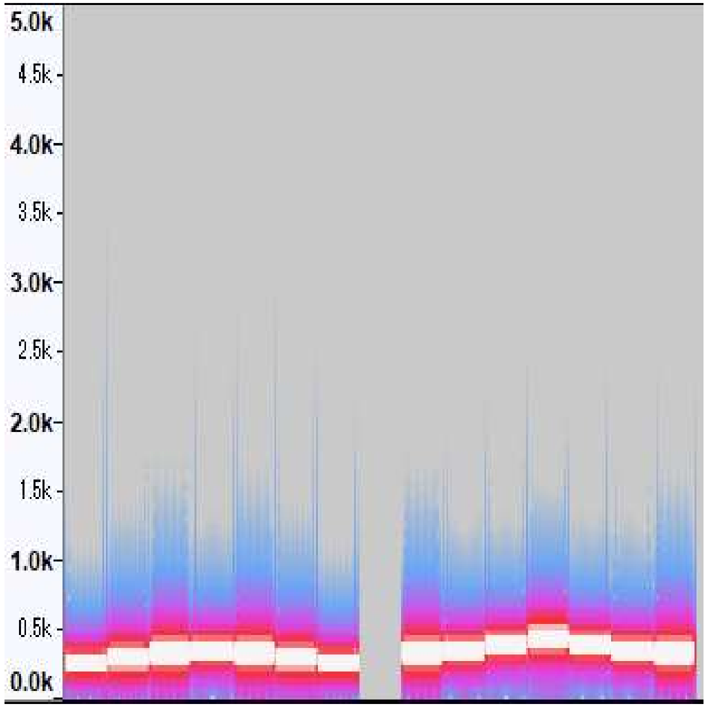
倍音構造の知覚／Perception of Harmonic Structure

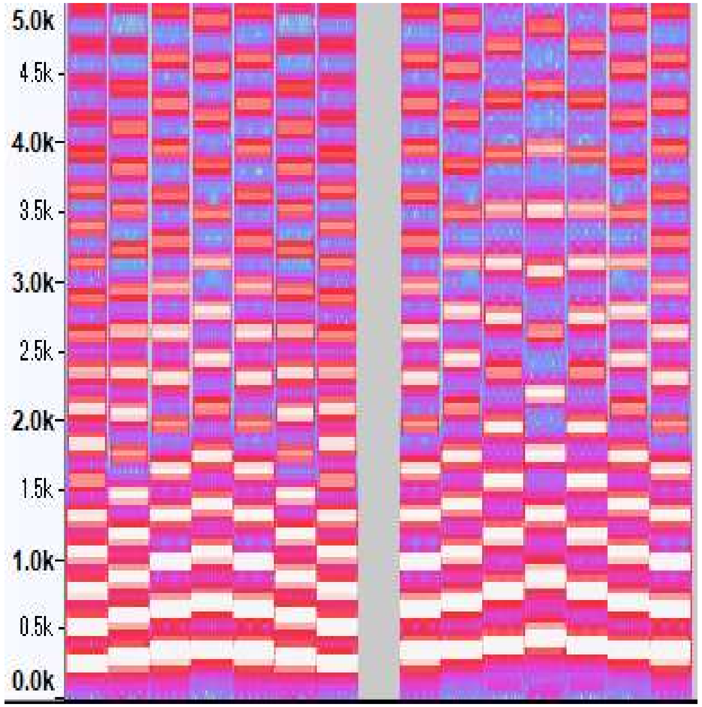


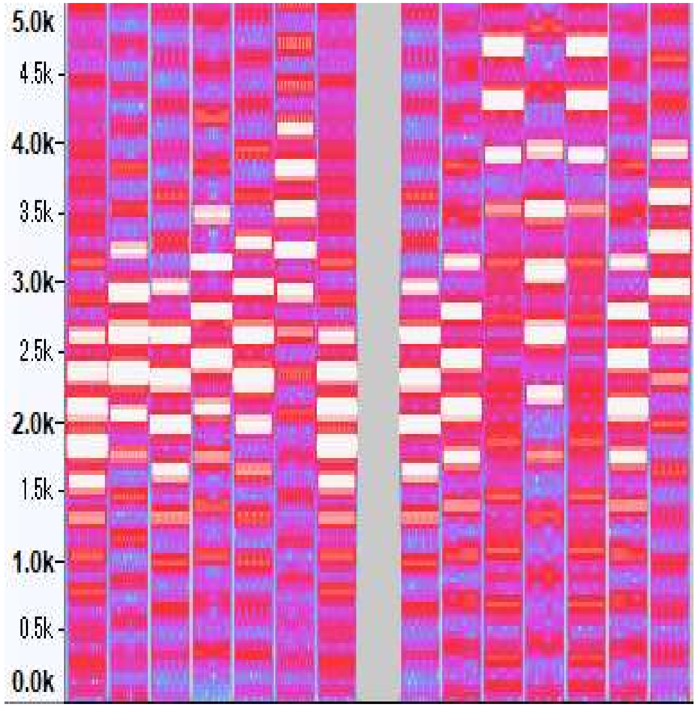
これらを人は､｢音色は違うけれど同じ｣と思える

We Perceive these sound as the same pitch, altough tone is different.

ミッシングファンダメンタル現象/ Missing Fundamental







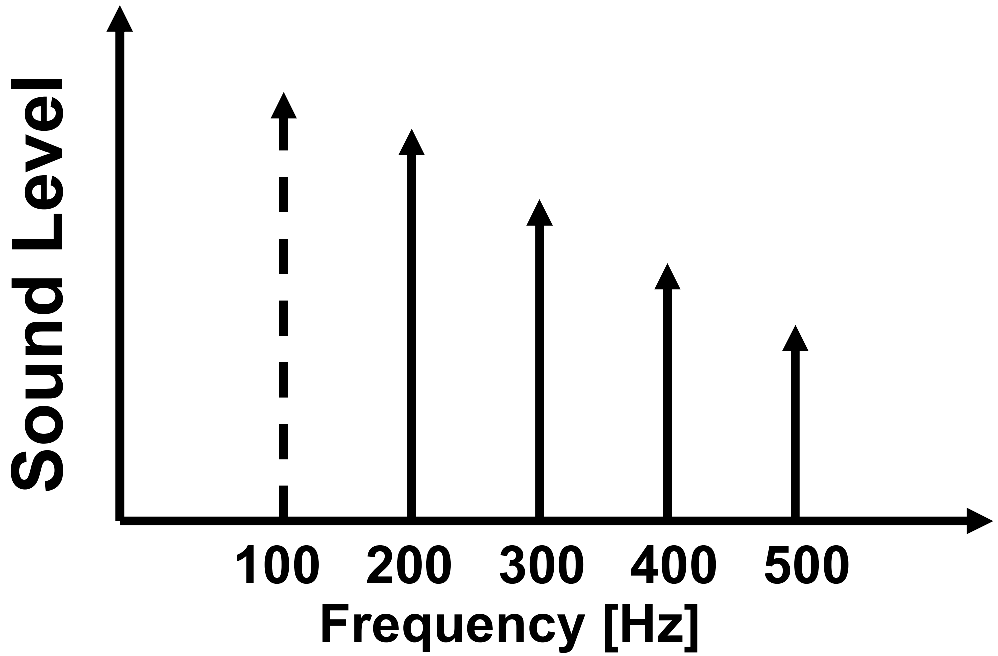
基底音が無くても、倍音成分の間隔で基底音を知覚できる

Without basis frequency, we perceive it by harmonic structure.

http://www.brl.ntt.co.jp/IllusionForum/a/missingFundamental/ja/index.html

このページは錯視・錯聴についてまとまっているのでチェック

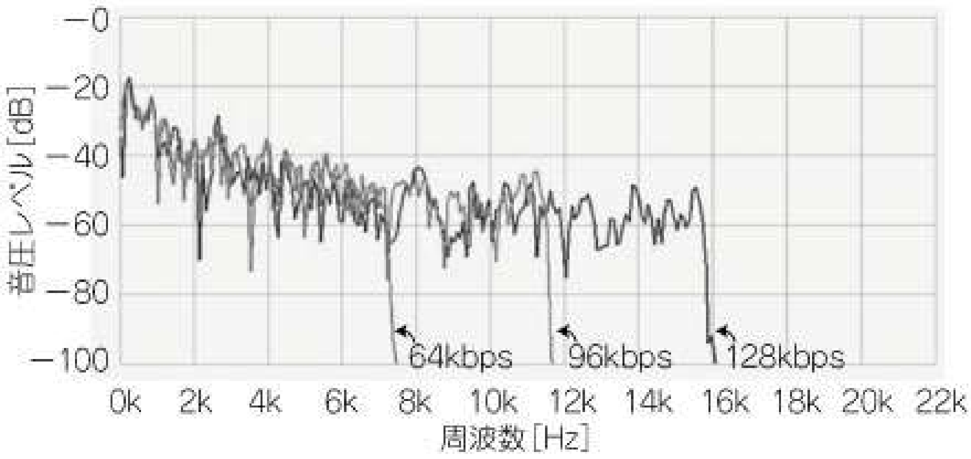
ミッシングファンダメンタルの応用
Application of Missing Fundamental

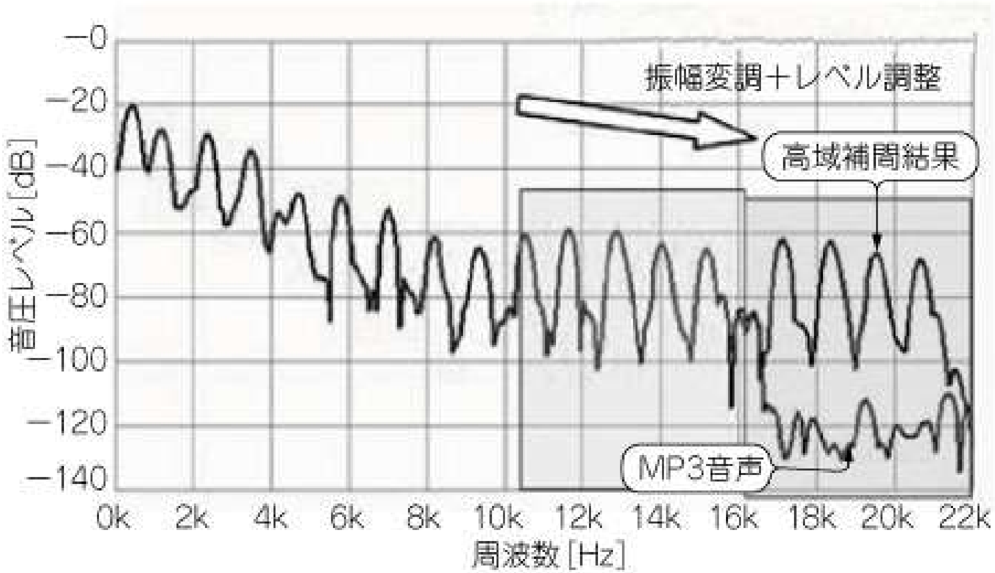


小型スピーカは低周波を出しにくい。Small speaker can’t output low freq.

200Hz以上で、100Hzの倍音を聞かせると、100Hzの基音が聞こえる。
薄型テレビ（特に内蔵スピーカの特性が悪くなりがち）で採用。
Outputting 200,300,… frequency sound, we perceive 100Hz basis freq.
Thin TV (which has small speaker) applies this method.

倍音構造の応用
Application of harmonic structure





http://www.kumikomi.net/archives/2009/08/dsp.php?page=1

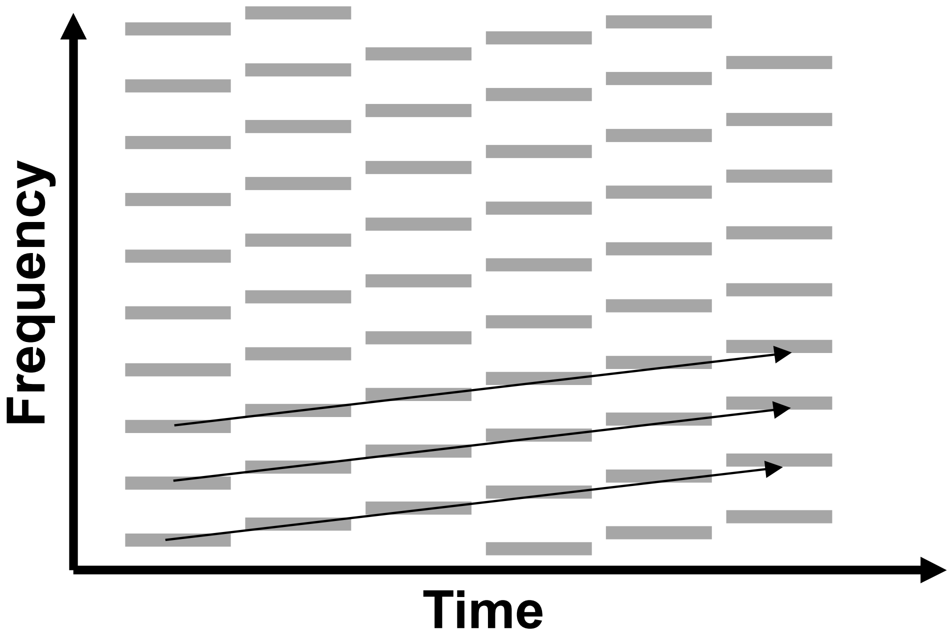
MP3等の圧縮では高周波領域カット→自然に聞こえない場合ある。
再生時、「楽器音には倍音構造がある」ことを利用、周波数を拡張。

As compression such as MP3 cuts off high freq., harmonic structure of musical instrument is utilized for compensation.

無限音階(シェパードトーン)/ Shepard Tone

YMO LOOM(1981)

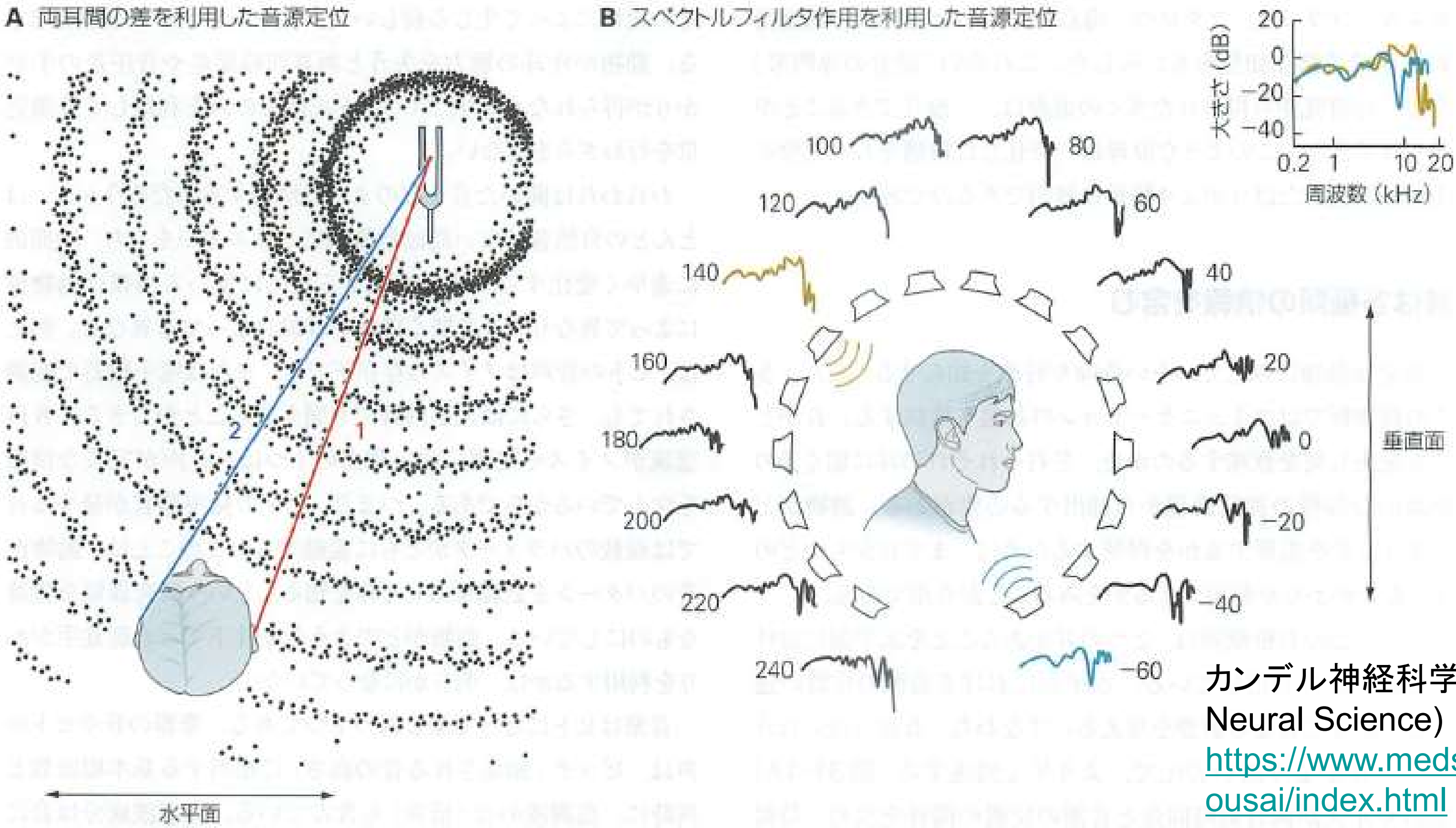
https://www.youtube.com/watch?v=sP4V6jiNj18



人間が周波数構造をパターンとして知覚していることを利用、主観的には無限に上昇する音を作ることができる。

Utilizing human perception of spectrum structure, infinitely rising (falling) sound can be generated.

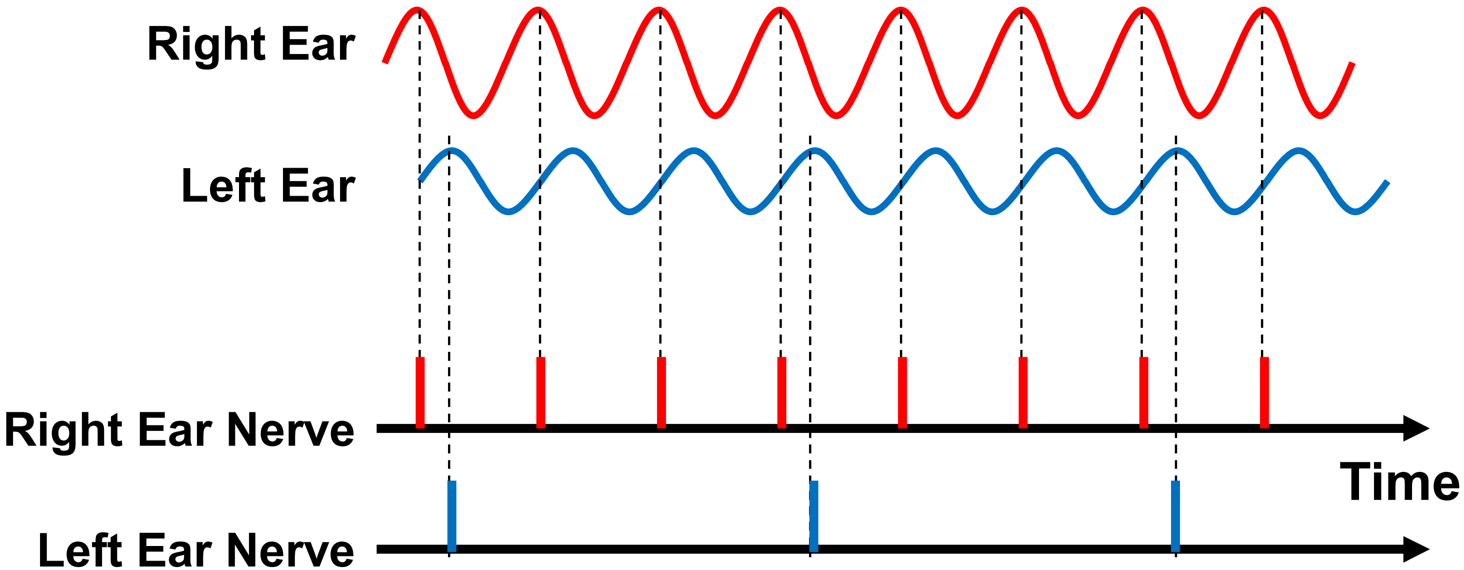
音源定位／Sound Position Localization

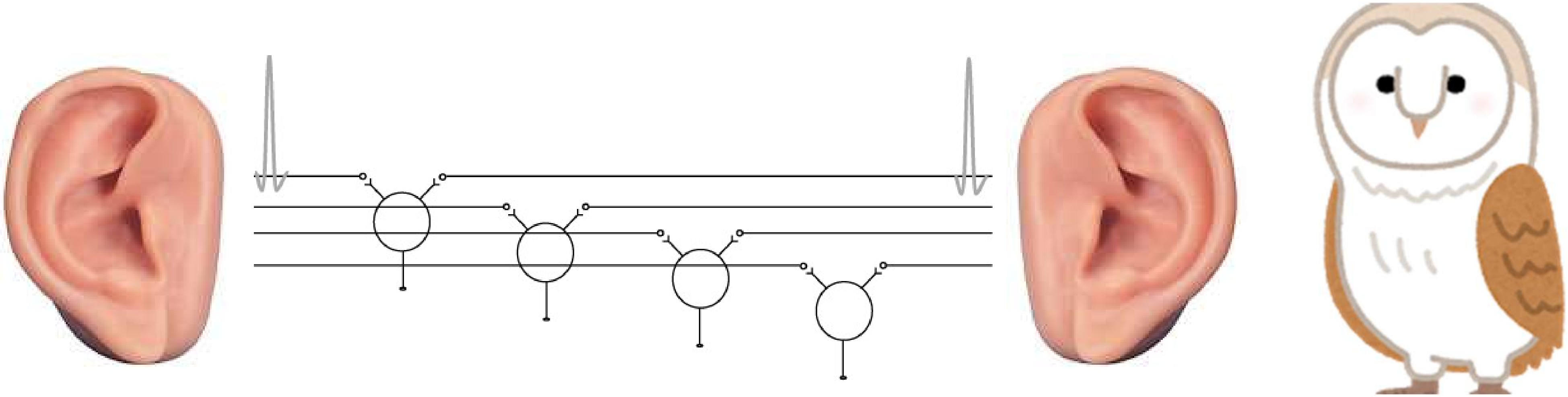


カンデル神経科学(Principles of Neural Science)
https://www.medsi.co.jp/kandel/syousai/index.html

- 両耳の差／Difference of two ears
  - 20～2kHz 時間差、位相差／Temporal (Phase) Difference
  - 2kHz～ 強度差／Amplitude Difference
- 上下方向の定位:耳介による音色変化
  Earlobe filters the sound, so that sound tone changes with vertical position.
  - 純音の定位は不可能。未経験の音の定位も難しい
    Pure tone localization is impossible. Inexperienced sound is also difficult

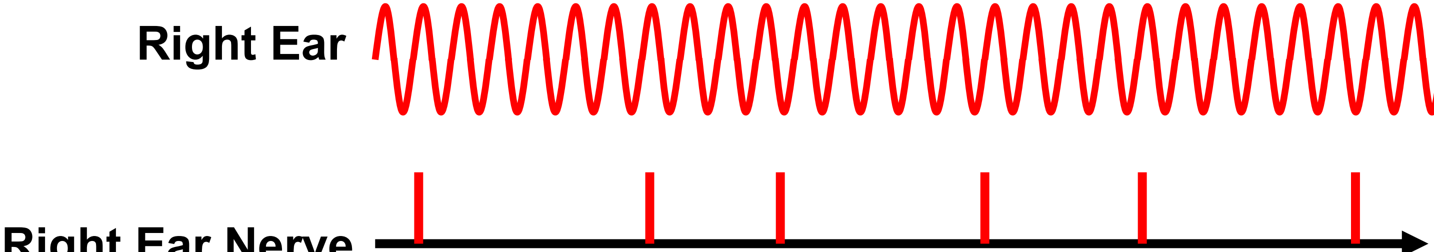
音源定位と神経コーディング(低周波）／
Sound localization and nerve coding (low frequency)

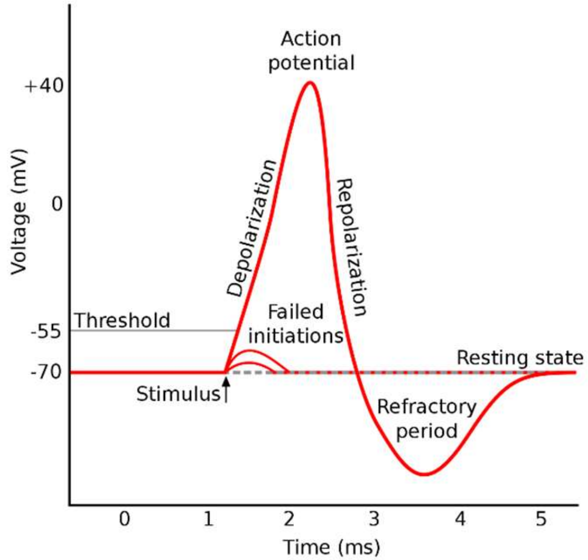




低周波における位相固定された活動 → 音源定位に神経活動のタイミングが使える
Nerve activity is phase-locked for low frequency, so the timing can be used for localization.

音源定位と神経コーディング（高周波）／
Sound localization and nerve coding (High Frequency)





Action potential (Wikipedia)
https://en.wikipedia.org/wiki/Action_potential

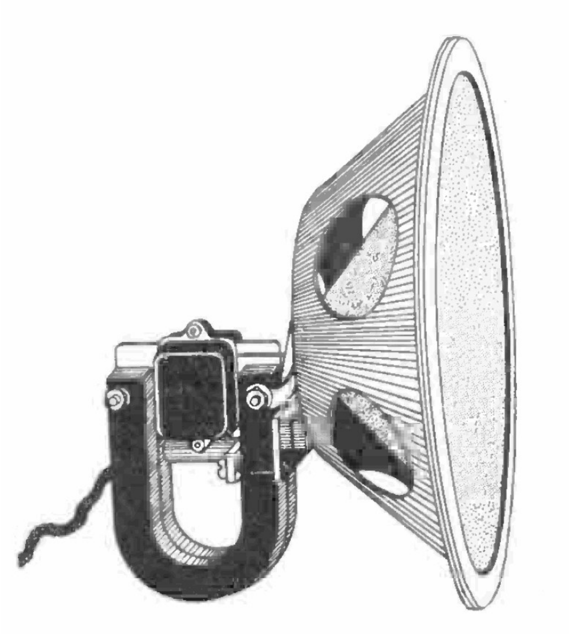
一周期の時間が神経の不応期より短いためランダムに近い活動→タイミングが使えないので強さだけが頼りになる。
逆に高周波は直進性が高いため、左右耳間の音圧差が大きい。

As one cycle is shorter than nerve’s resting period, nerve activity is random and only intensity can be used for localization. The high-freq sound is more direct, so sound pressure difference between the two ears is large.

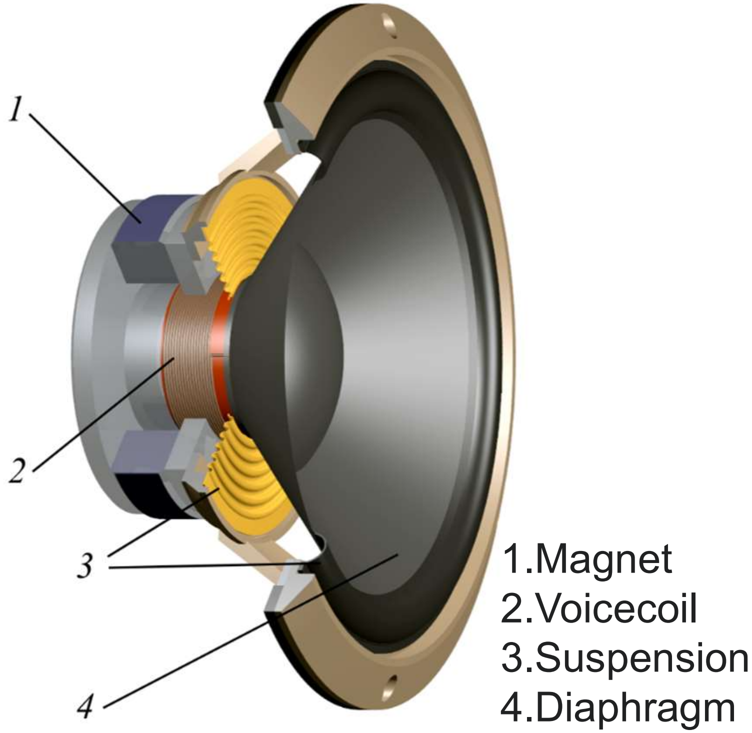
TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
   1. Auditory Devices
   2. 3D Audio
   3. Synthesis of Auditory and other sensations
   4. Auditory sensation and welfare engineering

電磁誘導型スピーカ＆マイク
Moving coil type speaker & microphone



Moving Iron Speaker (1870s)
https://en.wikipedia.org/wiki/Moving_iron_speaker



Loud Speaker (Wikipedia)
https://en.wikipedia.org/wiki/Loudspeaker

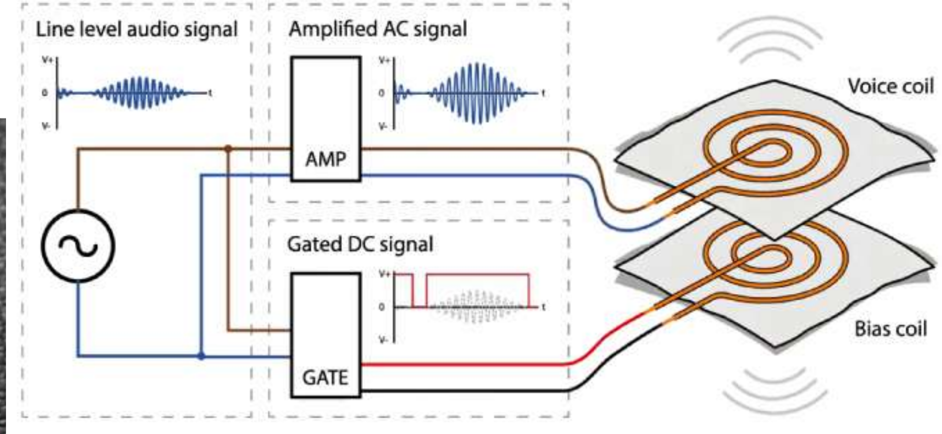
Microphone (Wikipedia)
https://en.wikipedia.org/wiki/Microphone

低コスト・ロバスト・湿気に強い

多くスピーカに用いられる。通常は磁石を固定，コイルを振動(ムービングコイル形)（最初期は逆）。コイルは非常に軽く、高周波駆動可能

Utilizing electromagnetic induction. Ordinary, magnet is fixed, coil is vibrated. The coil is light-weight and, can be driven quickly.

（UIST2020) Sonoflex: Embroidered Speakers Without Permanent Magnets
Thomas Preindl, Cedric Honnet, Andreas Pointner, Roland Aigner, Joe Paradiso, Michael Haller

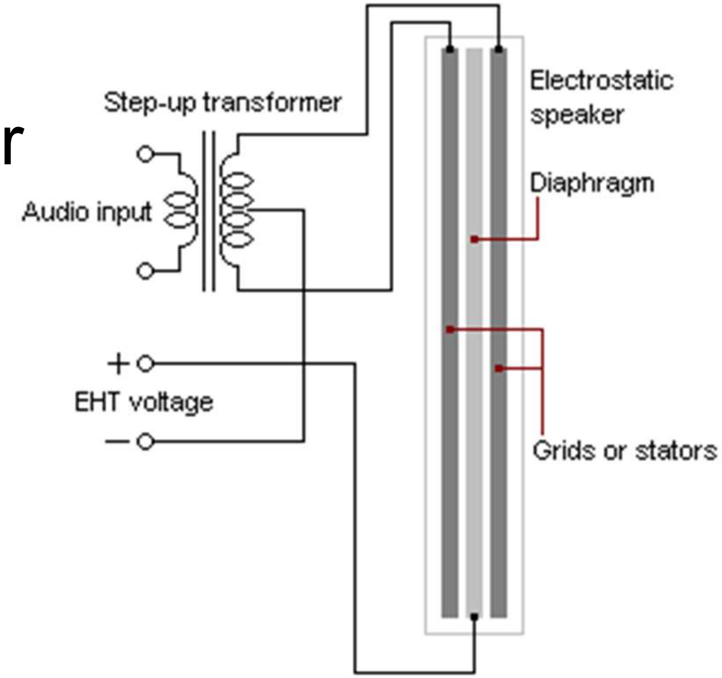


https://www.youtube.com/watch?v=5coB7Ekreac

- 布(服)に縫い付けるスピーカ。磁石を不要とするために2つのコイル構成とする。
- A loudspeaker that is sewn onto cloth (clothing). Two coils are used to eliminate the need for magnets.

コンデンサマイク･スピーカ
Capacitance type microphone & speaker

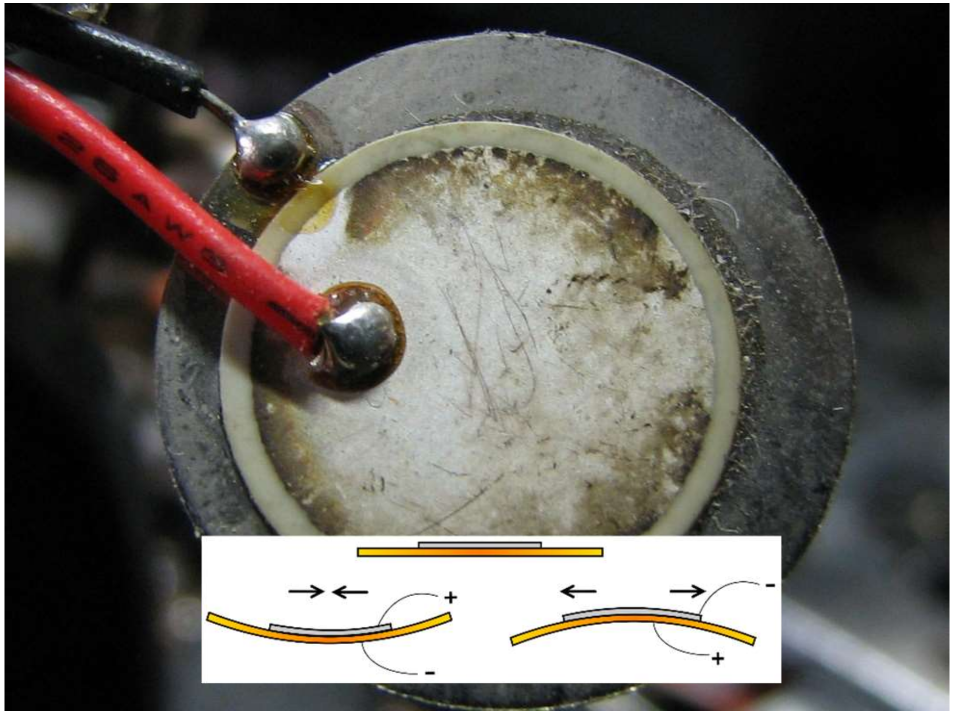
Microphone (Wikipedia)
https://en.wikipedia.org/wiki/Microphone



Electrostatic loudspeaker (Wikipedia)
https://en.wikipedia.org/wiki/Electrostatic_loudspeaker

- コンデンサマイク/ Microphone
  - 2枚の電極板距離の変化による静電容量変化を検出/ Detecting distance between two plates by measuring capacitance
  - 共振周波数が高いため可聴域ではフラットな特性。一般的に高性能。/ High resonant frequency means flat frequency charactestics.
- コンデンサスピーカ
  - 2枚の電極板に加える電圧の変化による電極板距離の変化により空気を駆動/ Distance between two plates is altered by applying voltage
  - 平面全体を駆動可能なため，平面型スピーカなどに用いられる/ Large plane is driven, enabling large thin speaker

圧電スピーカ／マイク Piezoelectric speaker/microphone

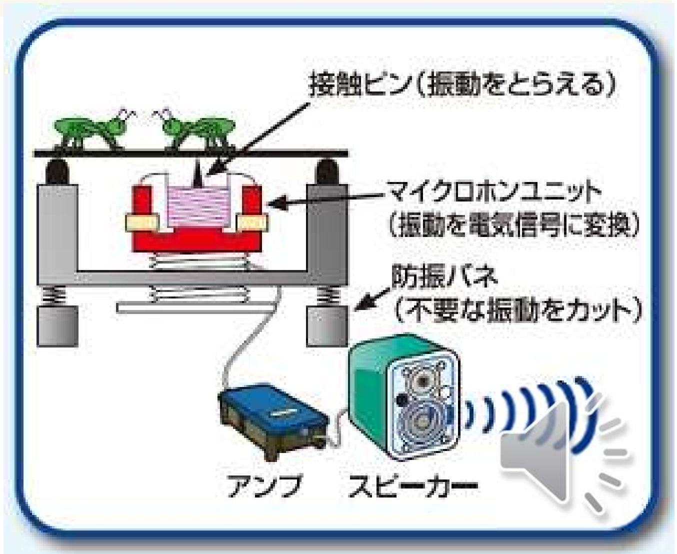


Piezoelectric Speaker
https://en.wikipedia.org/wiki/Piezoelectric_speaker

Crystal microphone or piezo microphone
https://en.wikipedia.org/wiki/Microphone

- 圧電素子（ピエゾ）を用いたスピーカ／マイク。メタルのダイアフラムをピエゾの伸縮で湾曲させて音を発生。非常に小型・安く作れるのでブザー等に利用。
  A speaker/microphone that uses a piezoelectric element (piezo). A metal diaphragm is bent by the expansion and contraction of the piezo to generate sound.
- マイクはコンタクトマイク（楽器、計測用）として多用される。
  Used as a contact microphone.

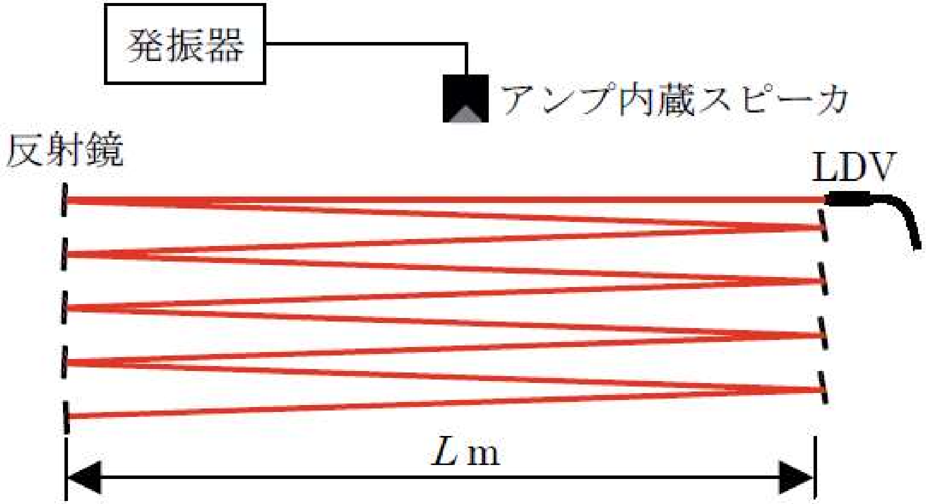
（参考）NHKの昆虫マイク



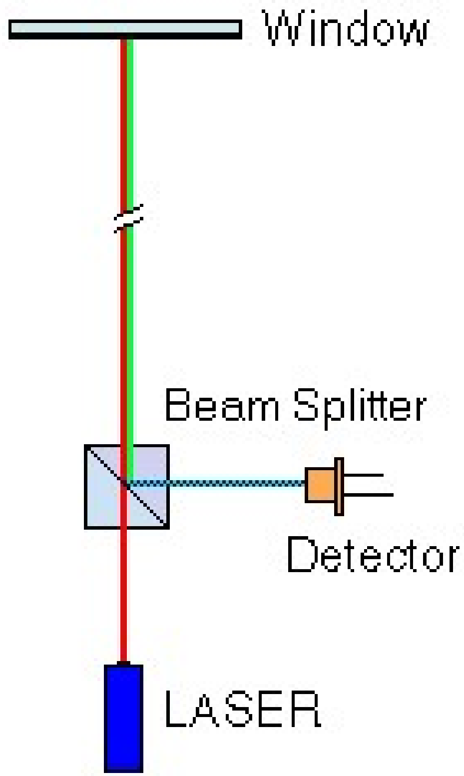
NHK for School 個体を伝わる音
https://www2.nhk.or.jp/school/movie/clip.cgi?das_id=D0005401124_00000

https://www.nhk.or.jp/strl/labo/voice-technology/

(参考)レーザーマイク / Laser microphone



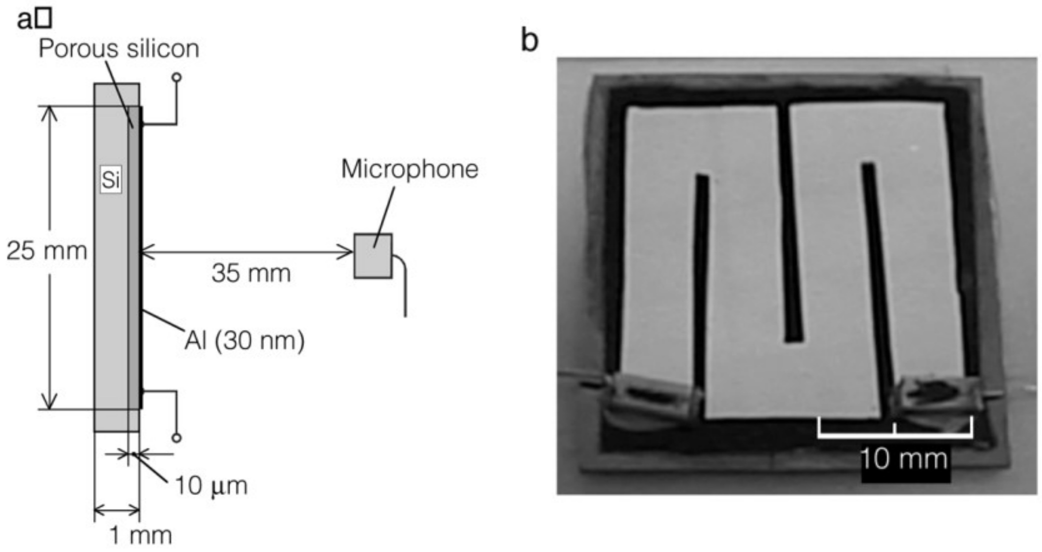
ドップラー効果方式(滝沢他2003,
http://www.acoust.rise.waseda.ac.jp/publications/happyou/asj/asj-takizawa-2003march.pdf



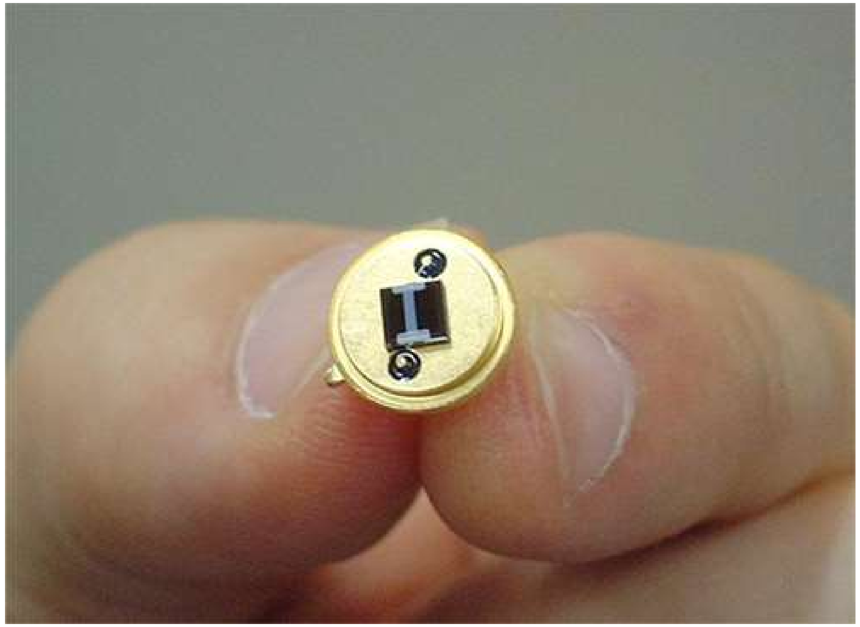
干渉計による振動検出

- レーザー光での検出：マイク自身による音伝達阻害がない。
  Detecting by laser. Ideally no “microphone”
  - ドップラー効果方式。粗密変化を測定
    Doppler effect. Measures density change
  - 干渉計方式。光路長変化を測定
    Interferometer. Measures distance change

(参考)温度スピーカ Thermo Speaker



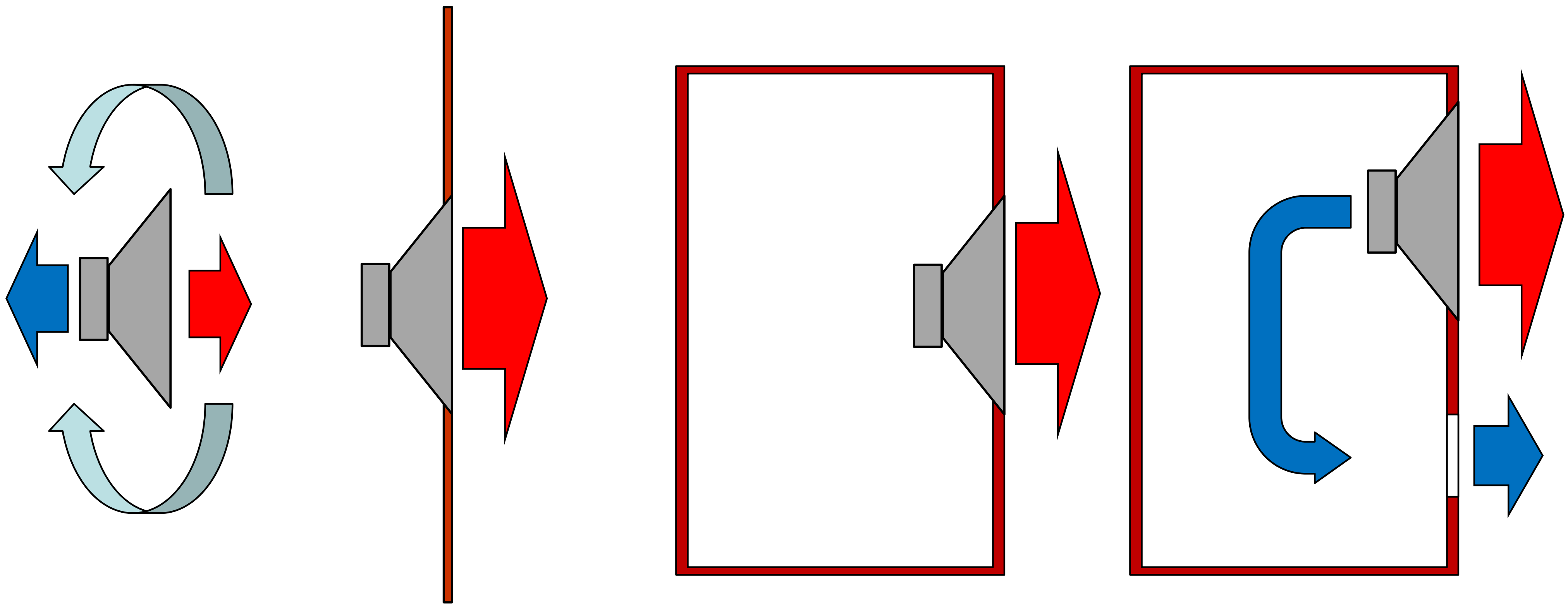
H. Shinoda, T. Nakajima, K. Ueno, and N. Koshida: Thermally Induced Ultrasonic Emission from Porous Silicon , Nature, 400, 853 - 855, August 26, 1999.



カンタム14、周波数0.1kHz-100kHzの広帯域小型スピーカーを開発(2010.6.25)
http://www.nikkan.co.jp/news/photograph/nkx_p20100625.html

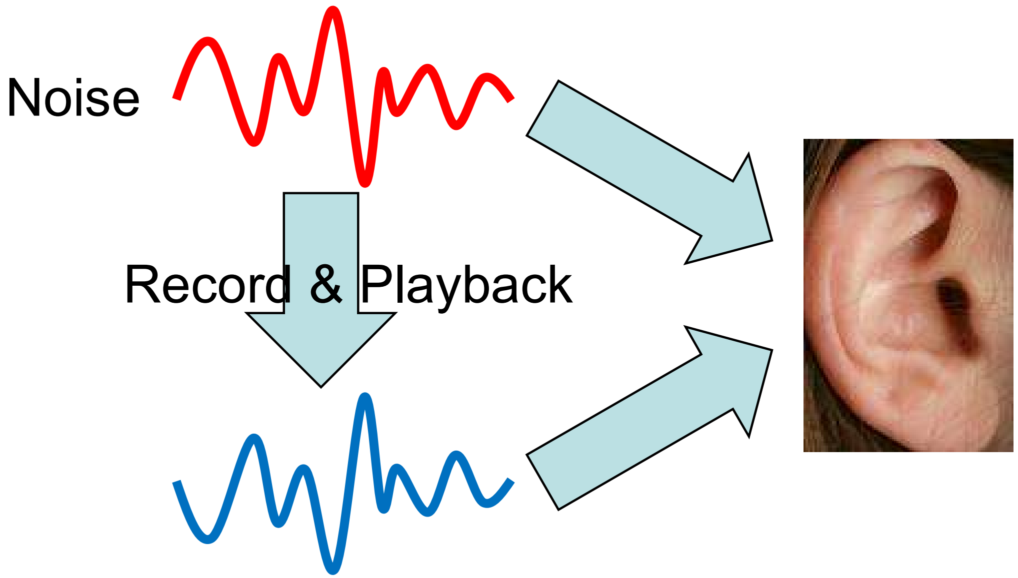
- 微小世界では温度も高速
  Heat transfer is fast enough in a small world.
- 電流によりジュール熱を生じさせ，熱による膨張で音を発生させる.
  Joule heat expands air around the device

スピーカボックスの役割 Role of speaker box



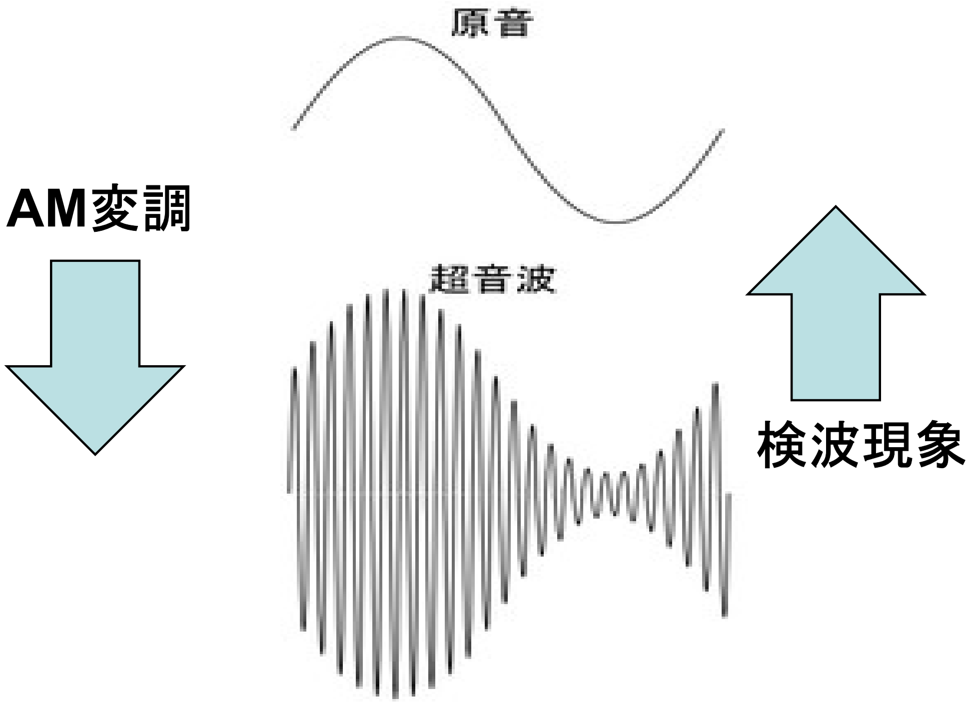
- スピーカ表裏で生じる逆位相の音圧による打ち消し効果を抑制
  Positive & negative pressures are sumultaneously produced by speaker.
  Box avoid the effect
- ボックスの共振特性を利用して苦手な低音を増強
  Box has resonant frequency → Enhance low frequency
- バスレフタイプ:特定の周波数の音を増強
  Bass-reflex type: Enhance certain frequency

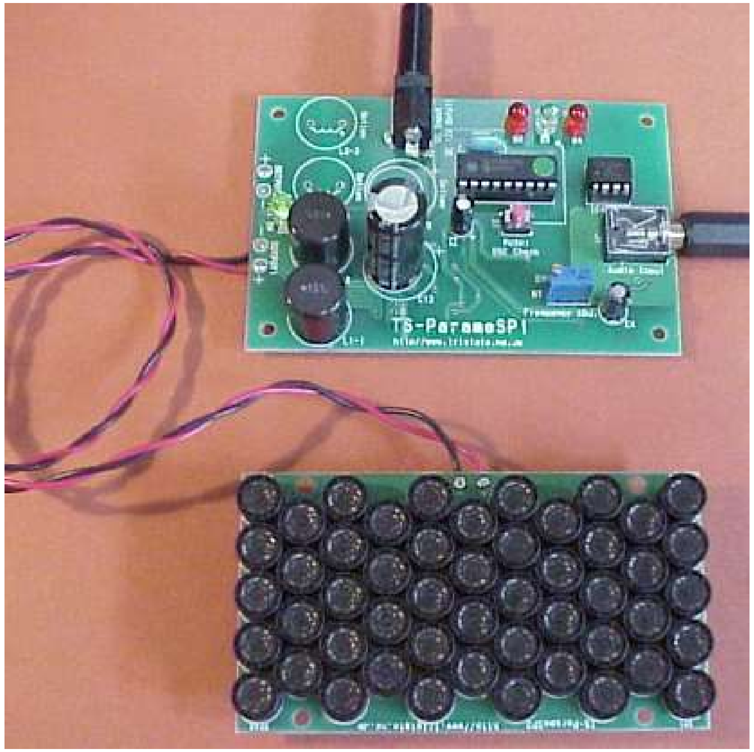
アクティブノイズキャンセリング／Active Noise Cancelling



- 外からの音と逆相の音を出すことで効率よく音を消去
  Negative sound cancels external sound.
- 低周波は得意。高周波は苦手
  Low frequency components are easy to cancel.
- 記録場所と再生場所が近いほうが楽に実現→ヘッドフォンは理想的
  Microphone and speaker should be closer. Headphone is ideal.
- 実は原理的にはスピーカボックスを外すようなもの
  The principle is actually similar to “removing” speaker box.

パラメトリックスピーカ／Parametric Speaker





http://akizukidenshi.com/catalog/g/gK-02617/

- 可聴音をAM／FM変調し、超音波周波数に移動
  Audible sound is translated to high freq. sound by AM/FM
- 空気と物体の界面で検波、可聴音に戻る
  Demodulation at boundary between air and object.
- 指向性が極めて高い→インタラクティブシステムに向く
  Beam can be very narrow→applications for interactive systems

パラメトリックスピーカ

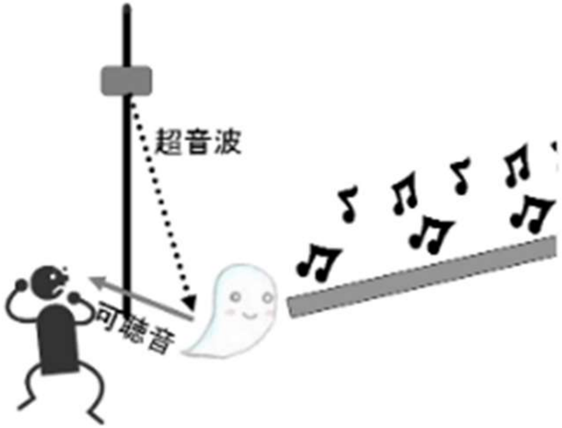
LRAD（Long Range Acoustic Device）

LRAD (Wikipedia)
https://en.wikipedia.org/wiki/Long_Range_Acoustic_Device

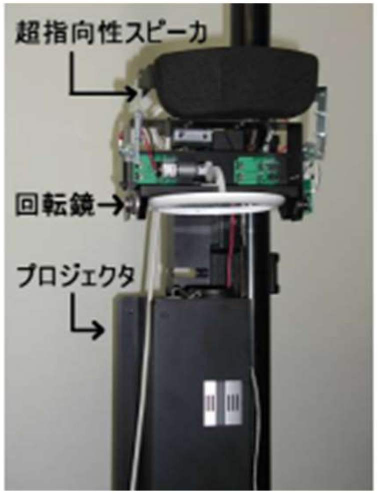
http://www.youtube.com/watch?v=iFzPkxIwVXI

パラメトリックスピーカの原理を用い、音エネルギーを遠くに飛ばす

パラメトリックスピーカーで「モノから声を出す」
Parametric speaker to “speak out of things”

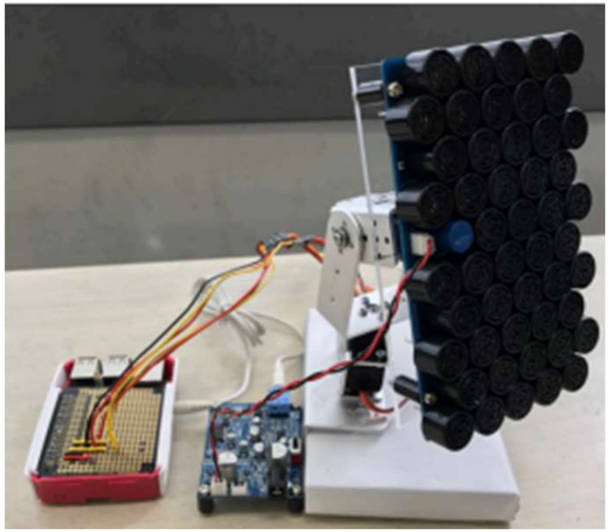


山本他：探し物支援のための超音波を用いた誘導システ ム CoCo, ヒューマンインタフェースシンポジ ウム 2007
https://slideshowjp.com/doc/279285/%E6%8E%A2%E3%81%97%E7%89%A9%E6%94%AF%E6%8F%B4%E3%81%AE%E3%81%9F%E3%82%81%E3%81%AE%E8%B6%85%E9%9F%B3%E6%B3%A2%E3%82%92%E7%94%A8%E3%81%84%E3%81%9F%E8%AA%98%E5%B0%8E%E3%82%B7%E3%82%B9%E3%83%86%E3%83%A0-coco

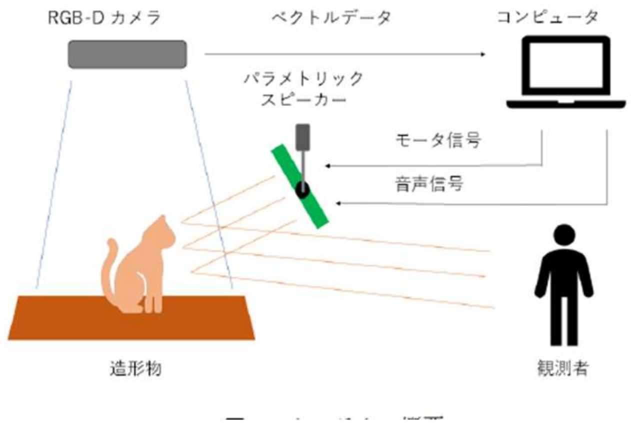


山本他：CORON: 実空間移動型エーシェント提示システ ム, インタラクション 2008, pp.37-38, 2008.
http://www.interaction-ipsj.org/archives/paper2008/interactive/0061/paper0061.pdf

中垣他：指向性スピーカを用いた空間拡張デバイス SonalShooter の基礎検討(2011)
http://www.interaction-ipsj.org/archives/paper2011/interactive/0221/1LNG-7.pdf

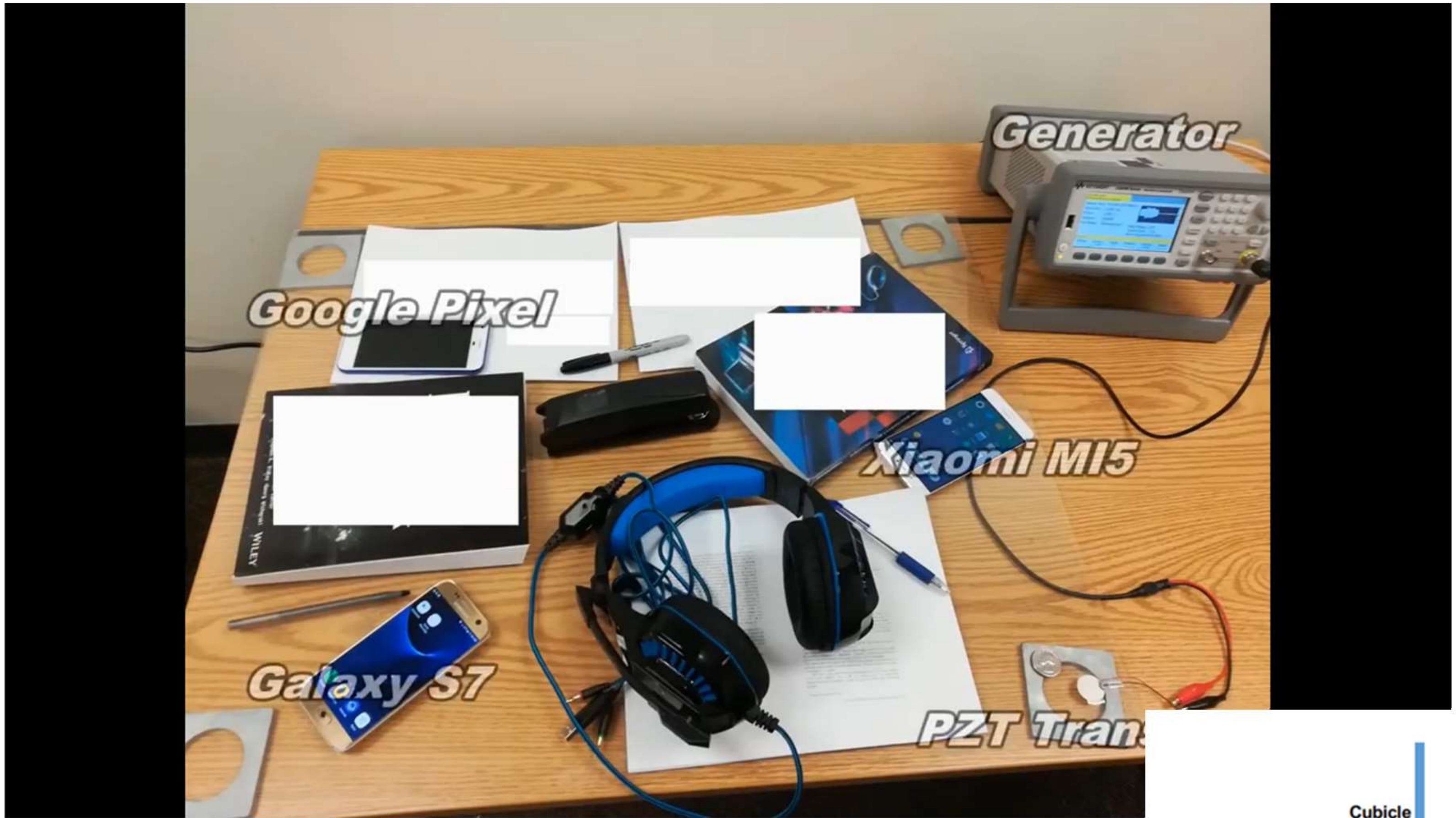


池田他：パラメトリックスピーカを用いた 対象を追尾する音声広告システム(2017)
http://www.interaction-ipsj.org/proceedings/2017/data/pdf/1-501-08.pdf

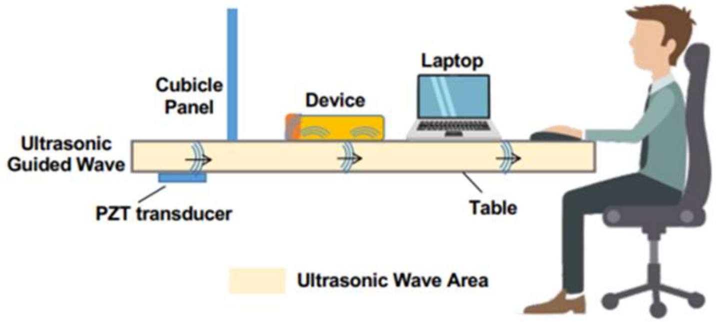


大田他：パラメトリックスピーカを用いた砂の造形物に対する音像生成(2019)
https://ipsj.ixsq.nii.ac.jp/ej/?action=repository_action_common_download&item_id=199428&item_no=1&attribute_id=1&file_no=1

(NDSS2020) SurfingAttack: Interactive Hidden Attack on Voice Assistants Using Ultrasonic Guided Wave



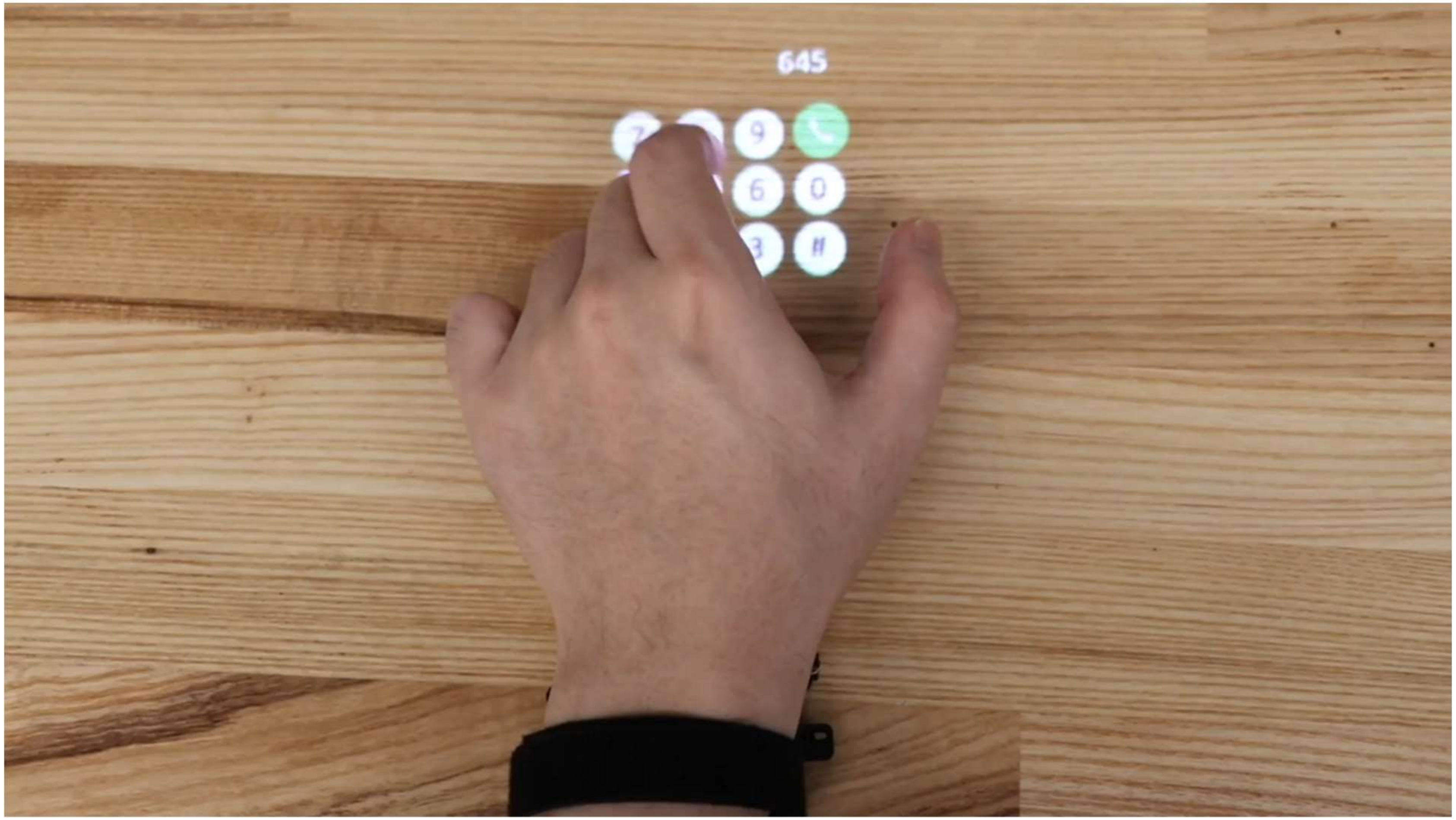
https://www.youtube.com/watch?v=pQw2zRAqVnI



変調をした超音波信号を机に伝搬させ、机の上においたスマートフォンに音声入力してしまう。

The modulated ultrasonic signal is transmitted to a desk, and voice is input to a smartphone placed on the desk.

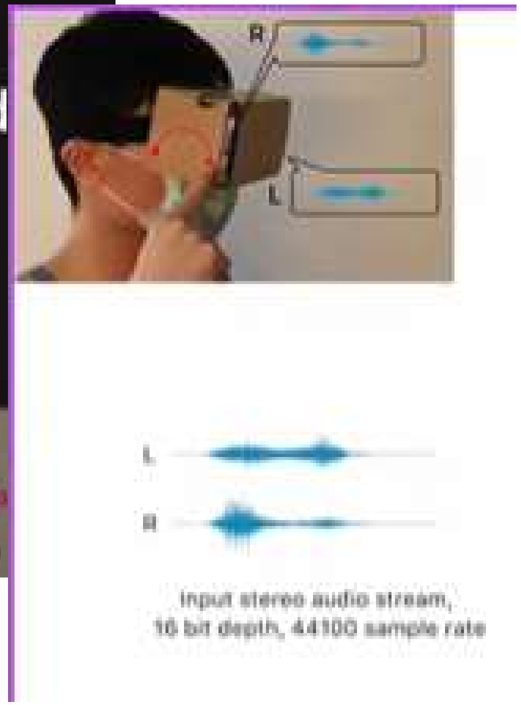
(UIST2020) Acustico: Surface Tap Detection and Localization using Wrist-based Acoustic TDOA Sensing
Jun Gong, Aakar Gupta, Hrvoje Benko



https://www.youtube.com/watch?v=ZyXd3KjN07A

- 手首部分にセンサ。空中の音センサと表面振動センサを配置。これによってタップ時の音源位置を推定出来る。
- Sensor at the wrist. Aerial sound sensor and surface vibration sensor are placed. This allows the position of the sound source at the time of tapping to be estimated.

(IEEEVR2021) Taizhou Chen, Lantian Xu, Xianshan Xu, Kening Zhu
GestOnHMD: Enabling Gesture-based Interaction on the Surface of Low-cost VR Head-Mounted Display



https://youtu.be/ob7y6ms48fc?t=21205

- 低コストHMD用の低コストジェスチャ入力。マイクを使ってこすった音を拾う。
- Low cost gesture input for low cost HMDs. Use a microphone to pick up rubbing sounds.

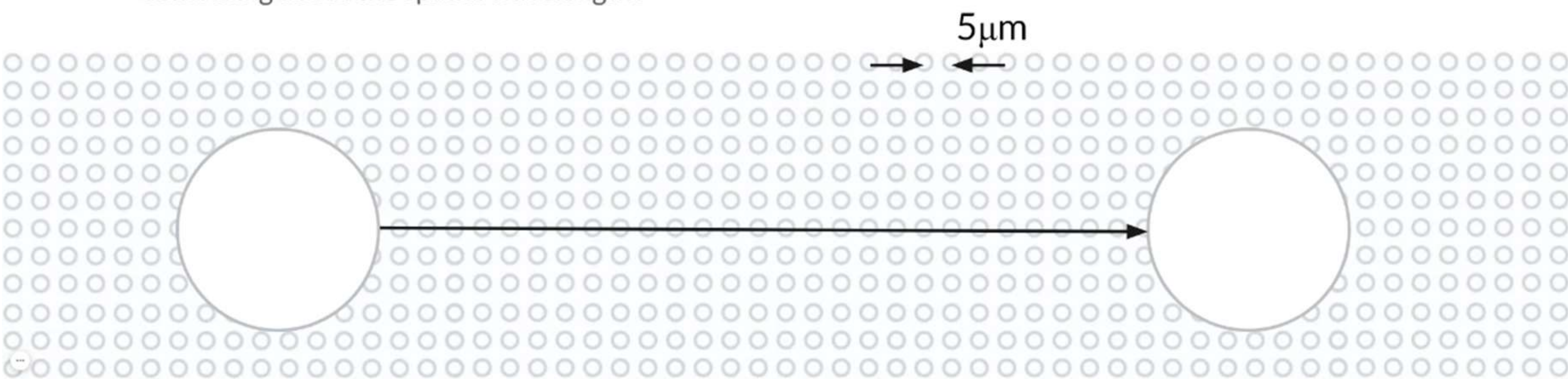
(CHI2022) TriboTouch: Micro-Patterned Surfaces for Low Latency Touchscreens Craig Shultz, Daehwa Kim, Karan Ahuja, Chris Harrison

TriboTouch Principle

When two objects slide against each other, friction creates vibrations that are related to:

1. The average spatial wavelengths of the surfaces
2. The sliding velocity between the objects

We can sense these vibrations with a piezo, and infer information about sliding velocity by knowing something about the spatial wavelengths



https://www.youtube.com/watch?v=LMq2n3g8Hf0&list=PLqhXYFYmZ-VcAoFsLTdH9hF26jsFkvs2B&index=524

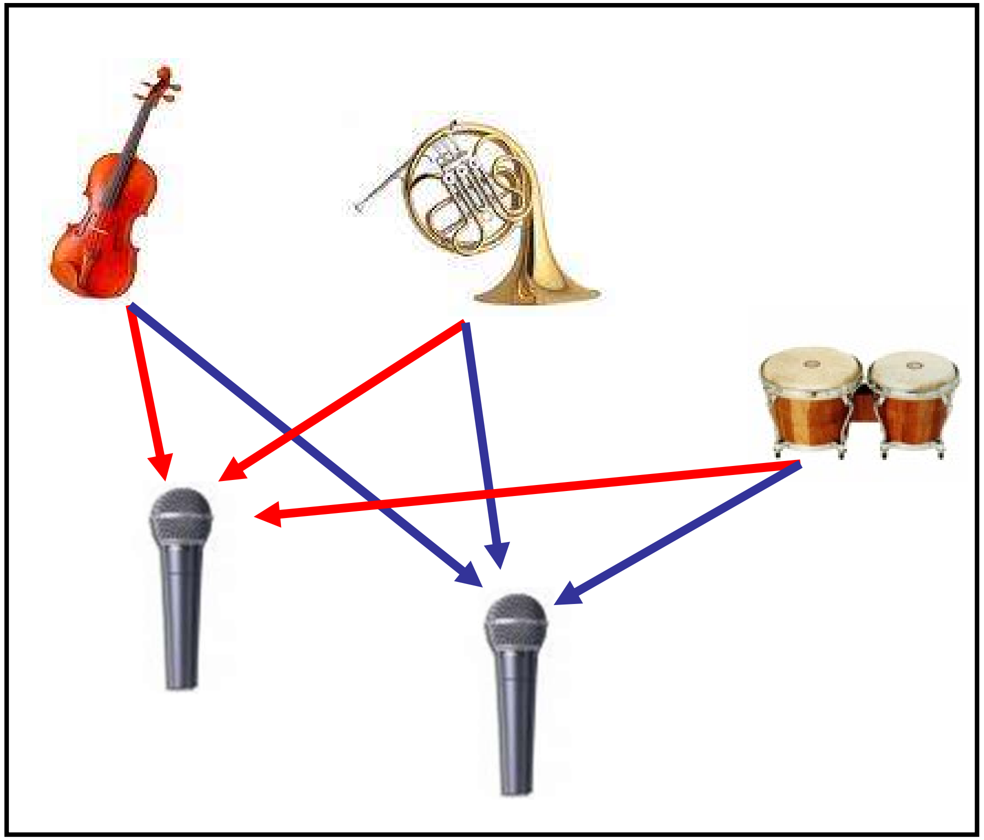
タッチ画面に微小な凹凸パターンをつけ、音を発生させることで指の移動速度を算出、タッチ精度を上げる

Calculates the speed of finger movement and improves touch accuracy by applying a minute uneven pattern to the touch screen and generating sound.

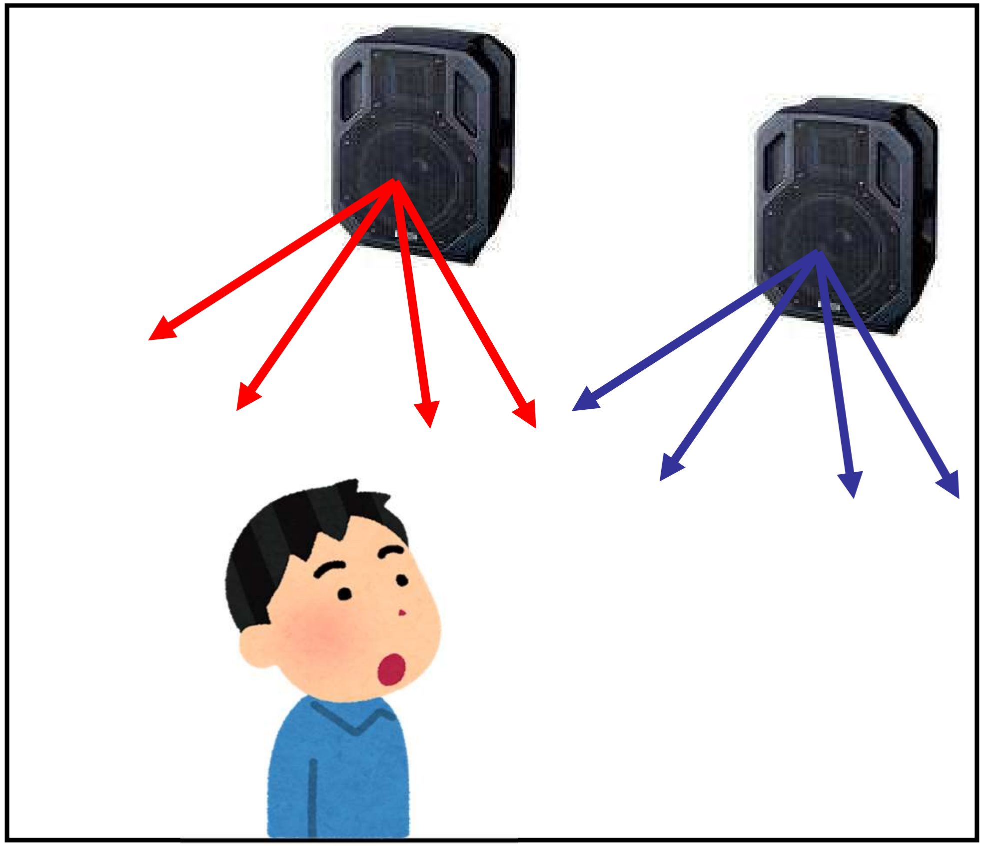
TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

Ordinary Recording and Playing



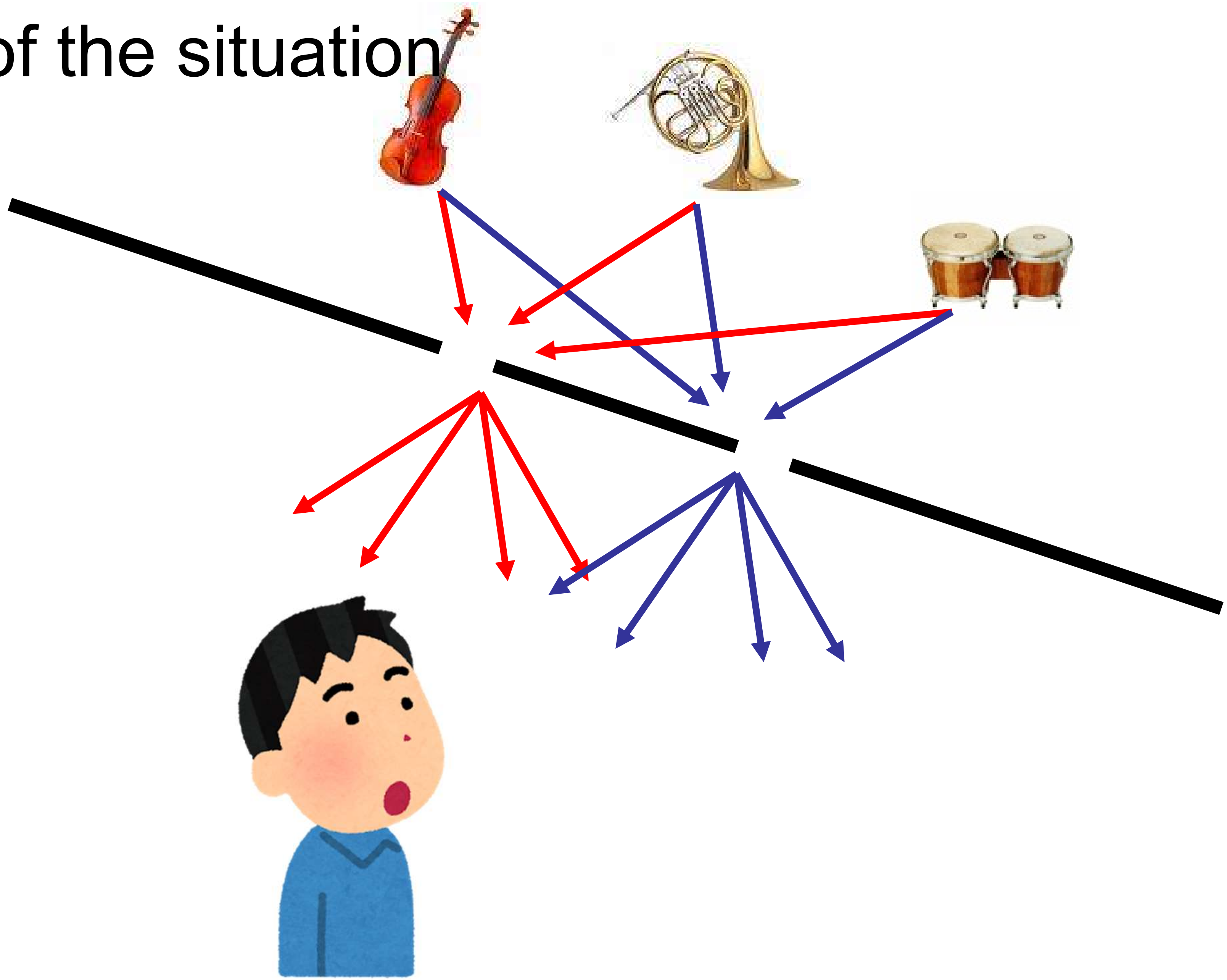
Record: by two microphones



Play: by two speakers

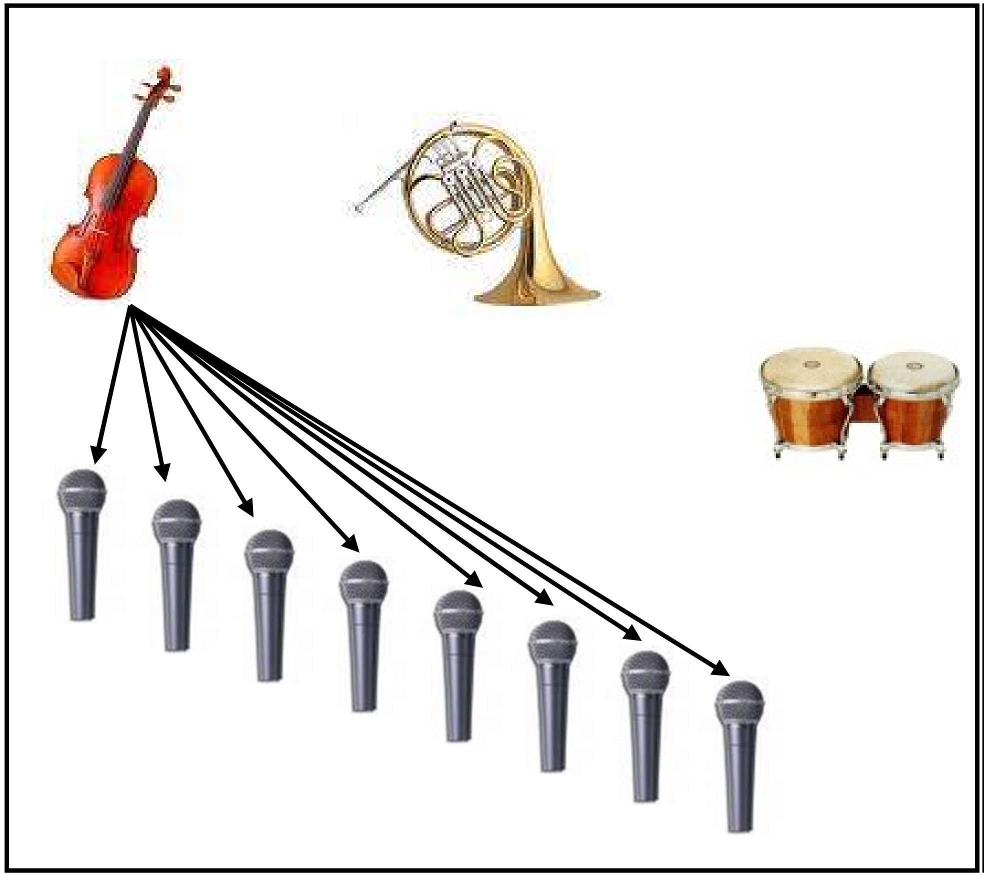
WHY is it OK?

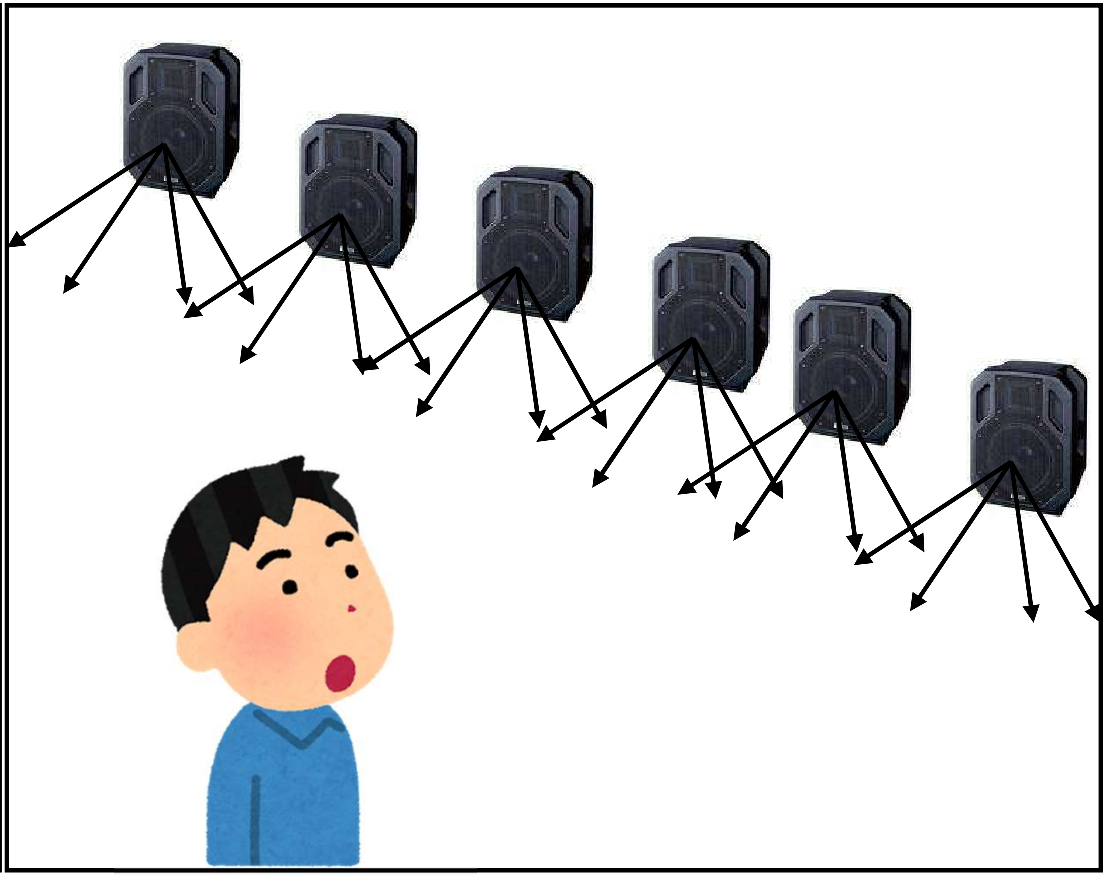
Analysis of the situation



•**Equivanent to Listen "through two holes on the wall".**
•**Limited Naturalness, but almost OK.**

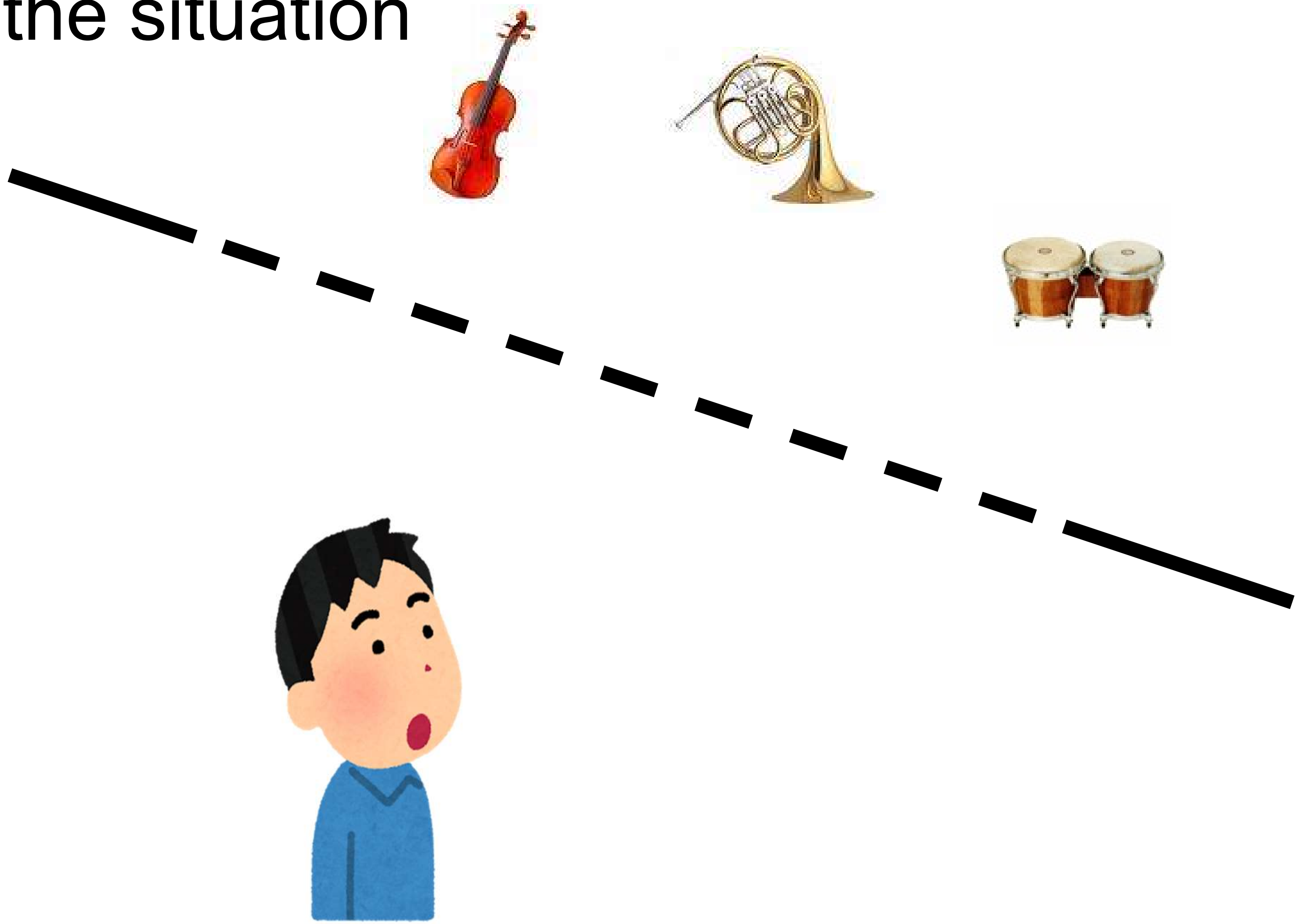
Money solves the problem





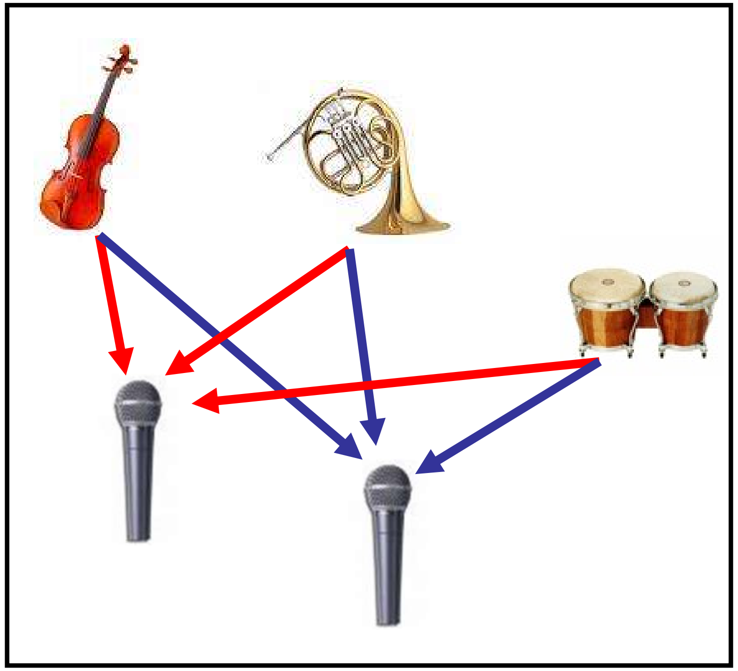
Recording: N microphones **Playing: N speakers**

Analysis of the situation



- “Holes” on the wall become numerous.
- Sufficient number of holes destroy the wall

What about Headphone?

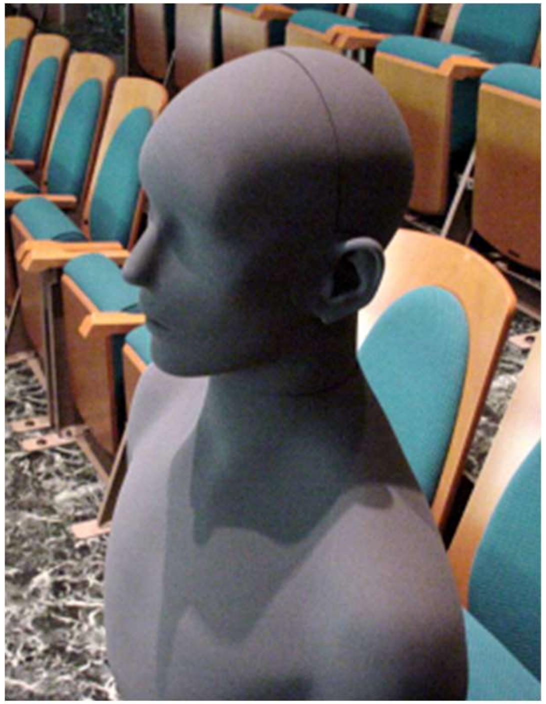


Normal Recording

Playing by Headphone

- Many information about Sound Source Position is Lost.
- Sometimes, Sound is Perceived as “Sound from Inside Head.

Binaural Recording



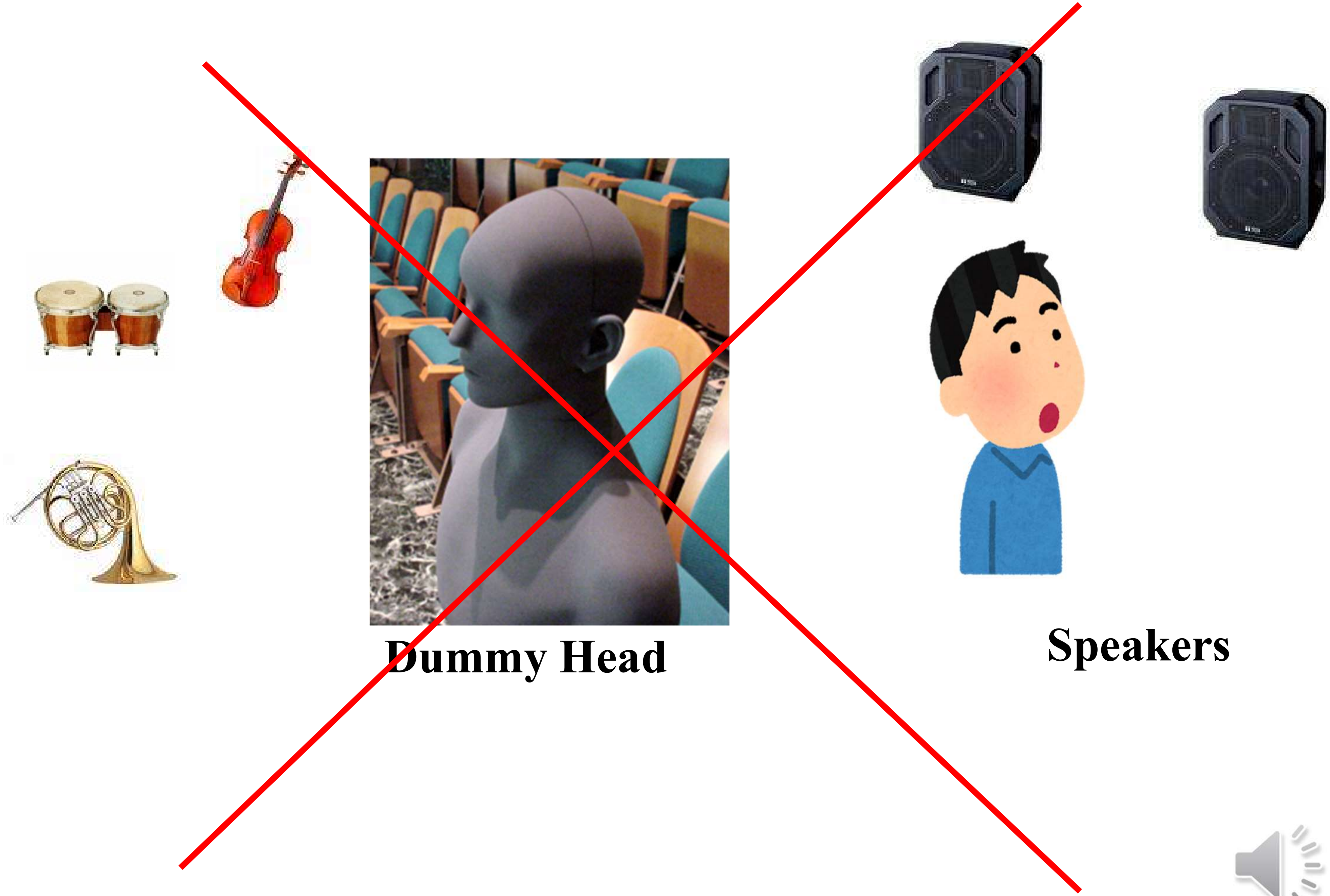
Dummy Head

Head Phone

Perfect Sound Localization,
Because All Three elements are replayed.

- Temporal Difference
- Amplitude Difference
- Frequency Change by Earlobe.

Vice Versa



We've heard of something similar...

- Headphone＝HMD
- Speakers＝Ground Fixed Type Display



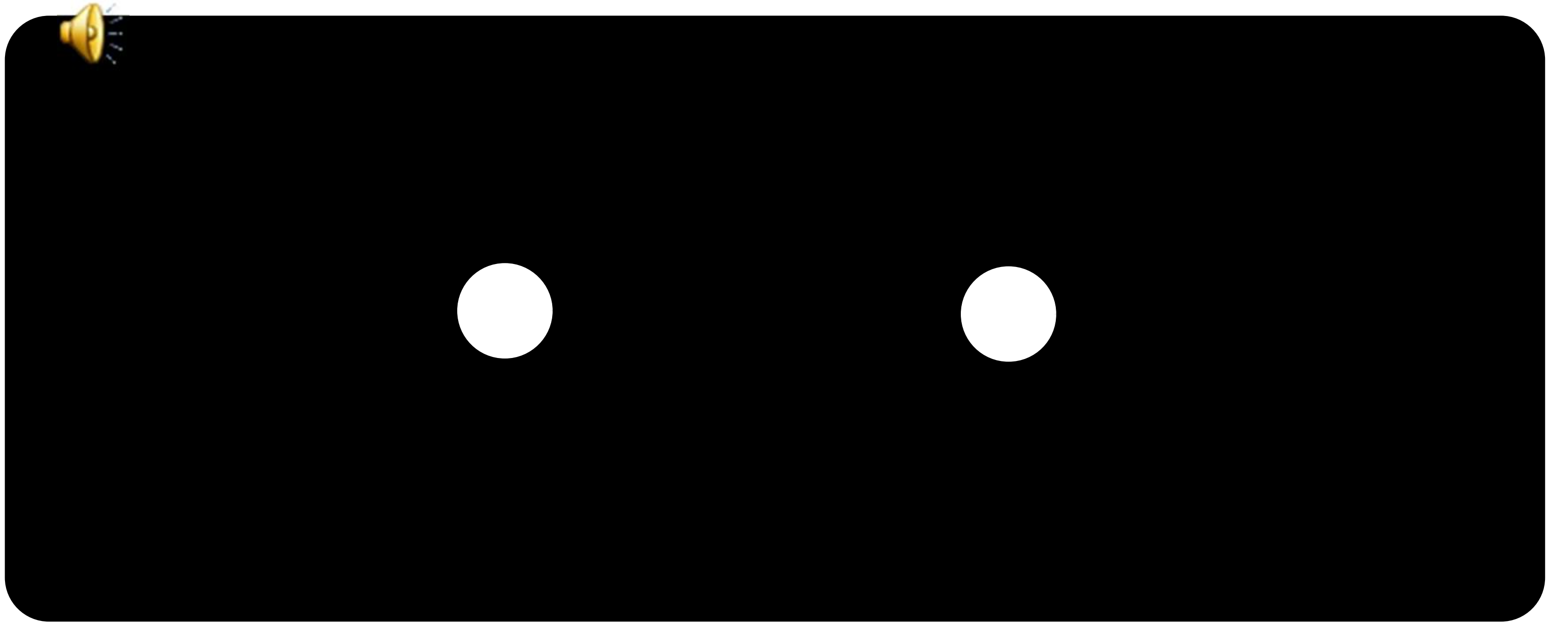


Review: HMD and Camera for it.

TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
   1. Auditory Devices
   2. 3D Audio
   3. Synthesis of Auditory and other sensations
   4. Auditory sensation and welfare engineering

視覚と聴覚の融合
Synthesis of visual and auditory sensations

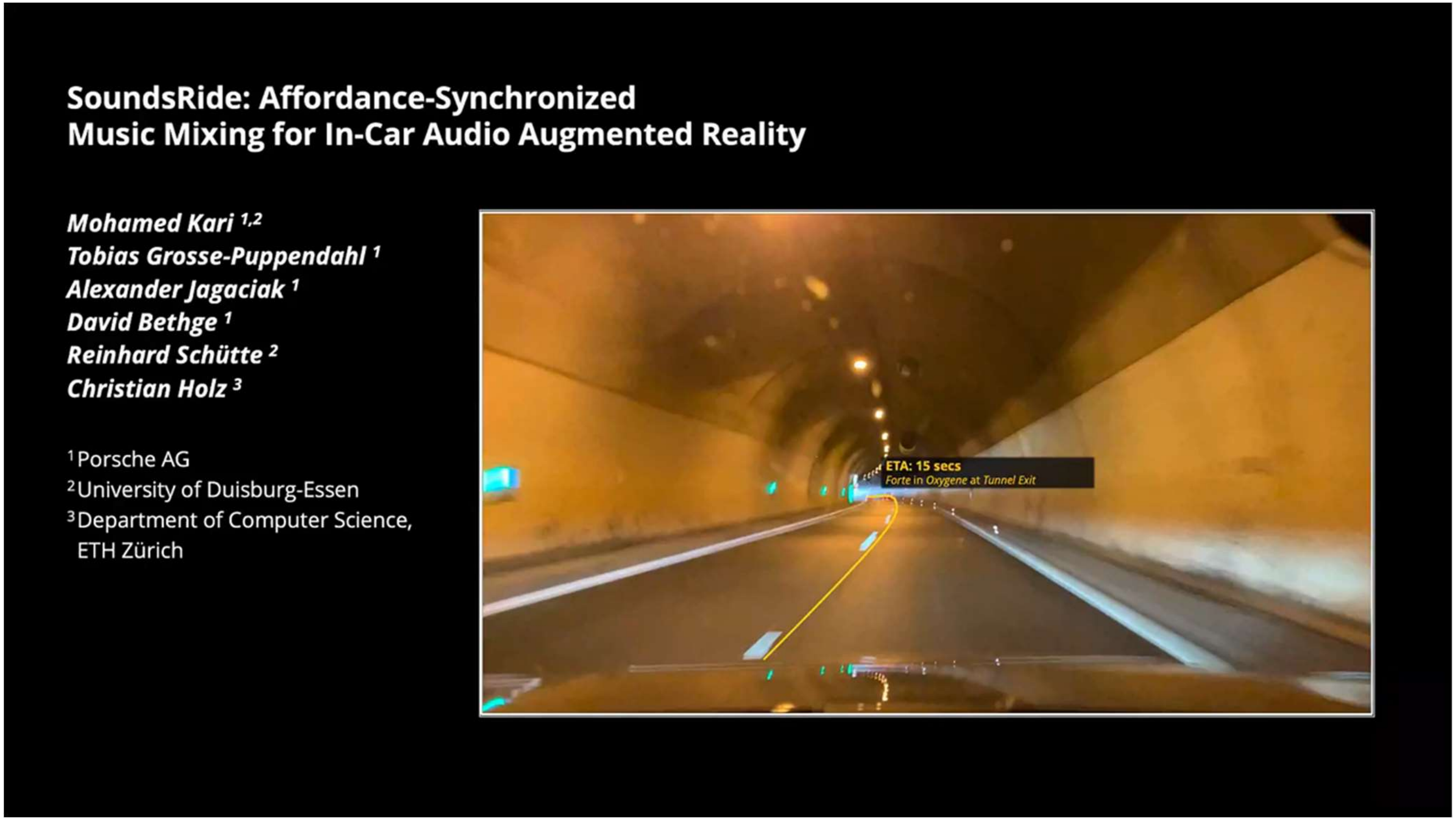


- 破裂音で左右のボールの動きが変わる
  Click signal produces collision-reflection feeling

マガーク効果／*McGurk effect*

Visual “Ga-Ga”+ Audio “Ba-Ba” -> Sounds like “Da-Da”
Close your eyes -> Ba Ba Open your eyes -> Da Da

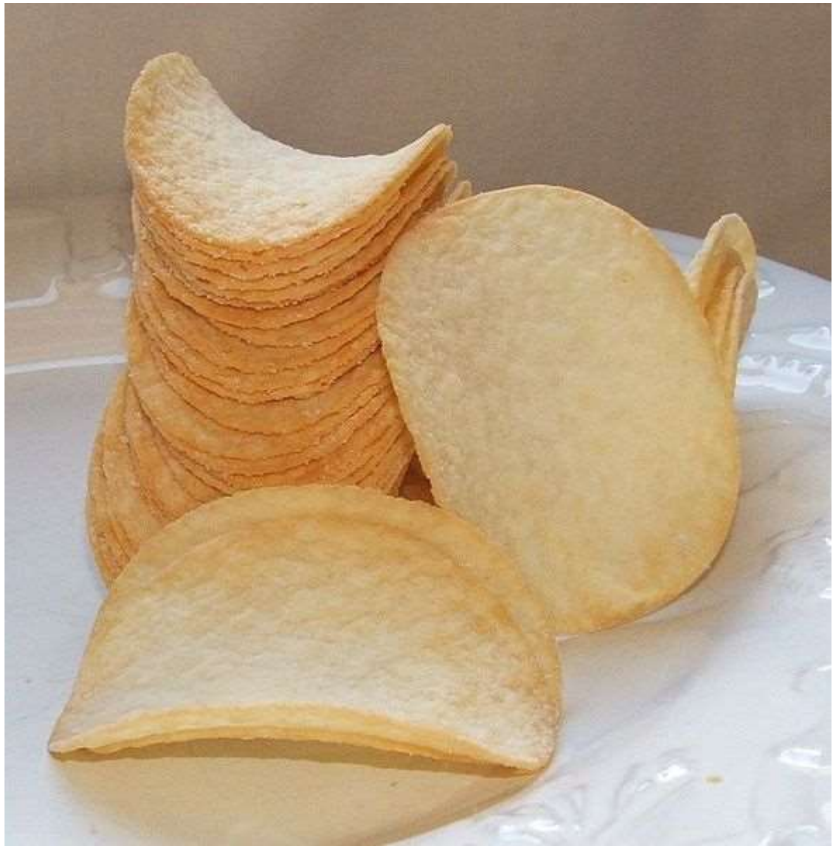
(UIST2021) SoundsRide: Affordance-Synchronized Music Mixing for In-Car Audio Augmented Reality Mohamed Kari, Tobias Grosse-Puppendahl, Alexander Jagaciak, David Bethge, Reinhard Schütte, Christian Holz



自動車のBGMを、走行予想に合わせて調整する
Tailor the background music of the automobile to the driving forecast.

https://www.youtube.com/watch?v=tRqZnFnS6d4&list=PLqhXYFYmZ-VeKUIuttbQWomTQ-oXF6PLf&index=49

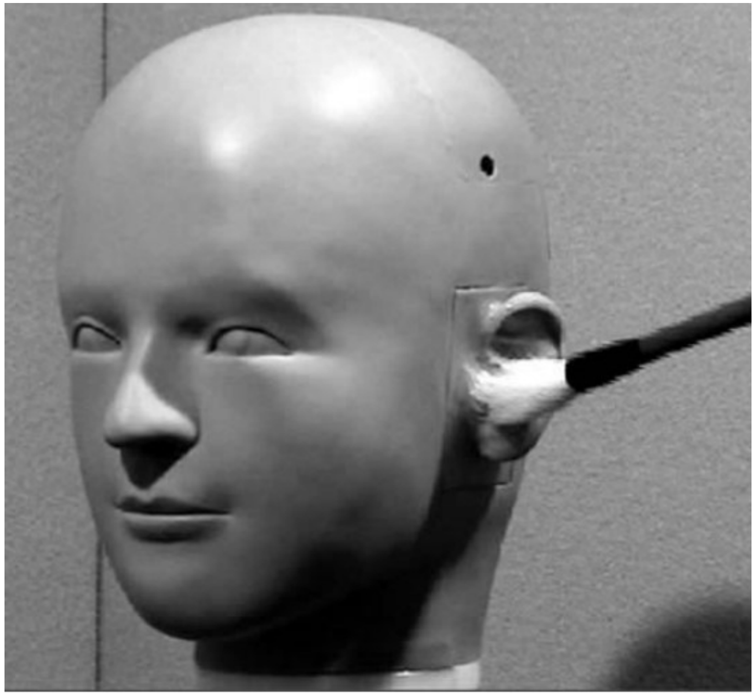
味覚と聴覚の融合
Synthesis of gustatory and auditory sensations



- ポテトチップスのサクサク音は味覚に影響する
  Crisp sound of potato chips alters taste
- IG Novel Prize for Nutrition 2008

Zampini, M., & Spence, C. (2004) The role of auditory cues in modulating the perceived crispness and staleness of potato crisps. Journal of Sensory Studies, 19, 347-363.

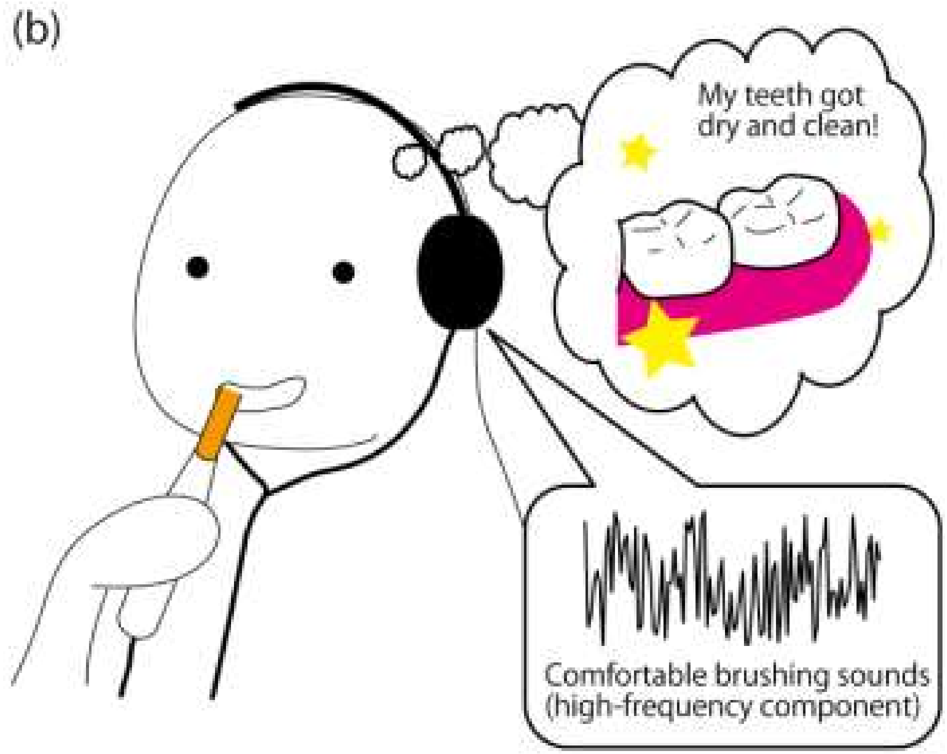
触覚と聴覚の融合(1/2)
Synthesis of tactile and auditory sensations

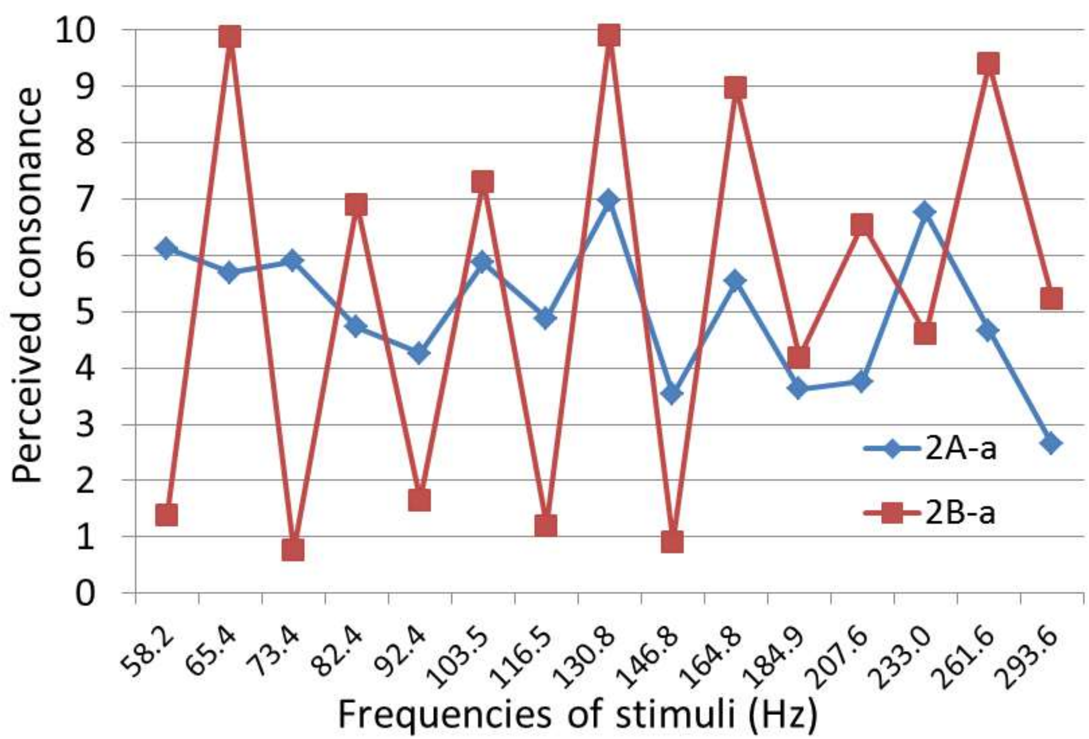


- Parchment-skin illusion(羊皮紙錯覚): 手の感触が音によって変化．両手をこすり合わせている時に，その音を変化させて被験者に提示⇒高音域増幅で手の感触が滑らか・乾燥。高音域減衰で粗・湿感。
  Jousmaki, V et al.: Parchment-skin illusion: sound-biased touch, Curr. Biol, 1998

- ダミーヘッドの左耳に挿入したマイクロホンで，耳を筆でくすぐった時の音を録音、この音をヘッドホンで 提示すると耳にくすぐったさを感じる.
  北川：多感覚錯覚から見る身体のリアリティ、VR学会誌2005 http://www.brl.ntt.co.jp/people/kitagawa/pdf/399kitagawa.pdf

触覚と聴覚の融合(2/2)
Synthesis of tactile and auditory sensations





- 歯磨き音の高周波／低周波強調⇒「清潔感」「努力感」が強調される
  By modifying sound, tooth-brushing became more satisfactory.
  T. Hachisu, H. Kajimoto: Augmentation of Toothbrush by Modulating Sounds Resulting from Brushing, in Proceedings of the Advances on Computer Entertainment Tecnology (ACE) 2012, pp.31-43, Kathmandu, Nepal.

- 触覚と聴覚を同時に呈示⇒「和音」に相当する周波数関係の時に「しっくり」する
  “Consonance” relationship is found between tactile and audio sensation.
  R. Okazaki, T. Hachisu, M. Sato, S. Fukushima, V. Hayward, and H. Kajimoto: Judged Consonance of Tactile and Auditory Frequencies. IEEE World Haptics Conference, April 14-17, 2013,

TODAY's TOPIC

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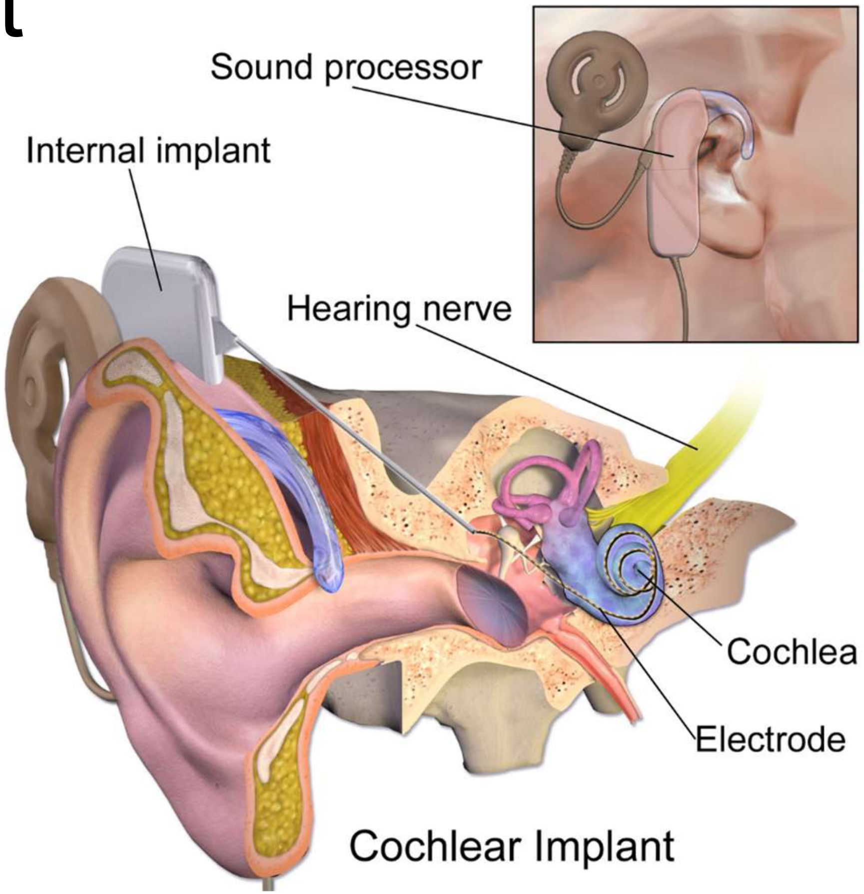
音と福祉工学／Sound in Welfare Engineering

- 聾唖者のサポート／Supporting deaf and mute
  - 人工内耳／Artificial inner ear
  - 人工咽頭／Artificial pharynx
- 視覚障害者のサポート／Supporting visually impared
  - 感覚代行／Sensory substitution
  - 視覚障害者の障害物知覚／Obstacle avoidance ability of the blind
- 高齢者のサポート／Supporting elderly
  - 補聴器／Acoustic aid
  - 骨伝導スピーカ

人工内耳／Cochlear implant



Cochlear implant (wikpedia) https://en.wikipedia.org/wiki/Cochlear_implant

- 歴史：ボルタが最初に50Vを耳内部にかけた。／History: Volta first applied 50V inside ear (around 1800).
- 体外：マイク，スピーチプロセッサ，送信コイル／External body: microphone, speech processor, transmission coil.
- 体内：受信コイル、アンプ、電極／Internal body: receive coil, amp, electrodes
- 電極は8～22対．蝸牛に挿入され，感覚神経を電気刺激．音として感じる／8 to 22 electrodes are inserted to cochlea, stimulating sensory nerves directly.

人工内耳／ Cochlear implant

www.youtube.com/watch?v=UQFxkhFiLAM
人工内耳で音楽を～音程判別への挑戦

人工咽頭／electrolarynx

電動式人工喉頭　ユアトーン
http://www.first-med.co.jp/products/yourtone.php

Communication after laryngectomy.mov South East Coast Laryngectomy Support Groups (UK)
https://www.youtube.com/watch?v=R4azcU6i2lE, https://en.wikipedia.org/wiki/Electrolarynx

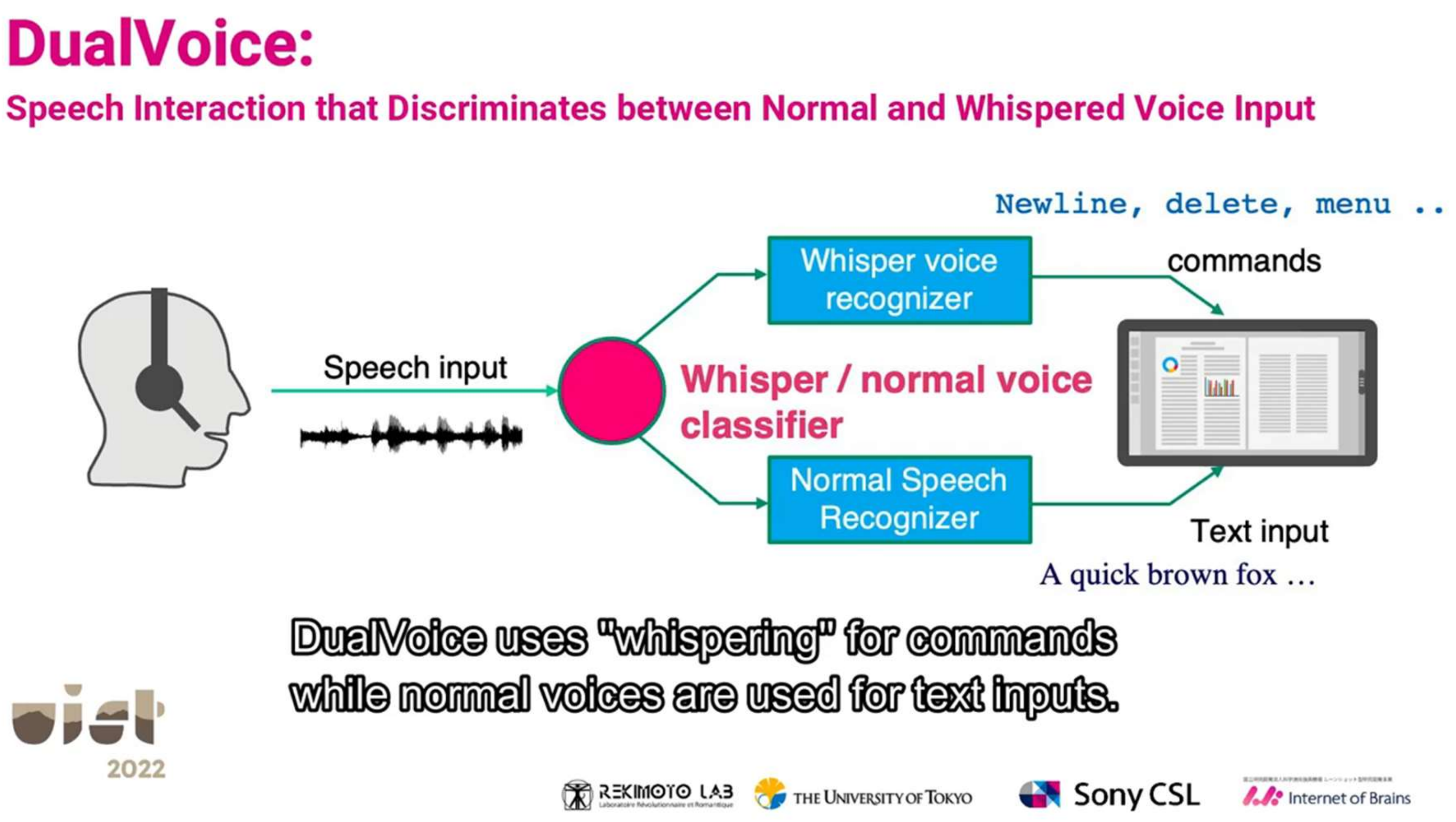
- 咽頭ガン等で咽頭の摘出→声の元となる振動を作れない
  Pharynx is removed for cancer→Vibration cannot be generated
- 人工咽頭：振動により声の元を作る.
  Artificial pharynx: Generate vibration, as a source of voice

(UIST2018) SilentVoice: Unnoticeable Voice Input by Ingressive Speech
Masaaki Fukumoto

https://www.youtube.com/watch?v=t41BtT9V_W4

- 吸気による音声入力を提案. 全く声が外にもれない.

(UIST2022) DualVoice: Speech Interaction that Discriminates between Normal and Whispered Voice Input
Jun Rekimoto



https://www.youtube.com/watch?v=5On80Jk-2_Y&list=PLqhXYFYmZ-VdaPIMTFVH5K5brMDJCIfAn&index=42

通常の音声で文字を入力し、ささやき声でコマンドを入力することで、音声認識を利用した文書作成の誤認識や編集の問題を解決する新しい音声対話手法を提案

Proposes a new speech-input method that solves the problems of misrecognition and editing of documents using speech recognition by using normal speech to input text and whispered commands.

感覚代行1／Sensory Substitution 1

Sonic Guide

vOICe

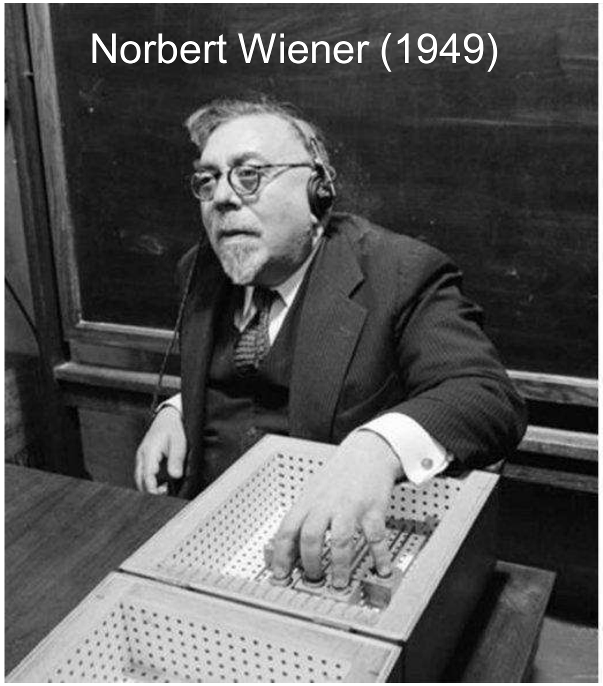
聴覚による視覚代行

Substitute visual sensation by auditory sensation

vOICe

http://www.youtube.com/watch?v=I0ImSYP7OcM

感覚代行2　触覚による聴覚代行／Sensory Substitution 2
Substitute auditory sensation by tactile sensation



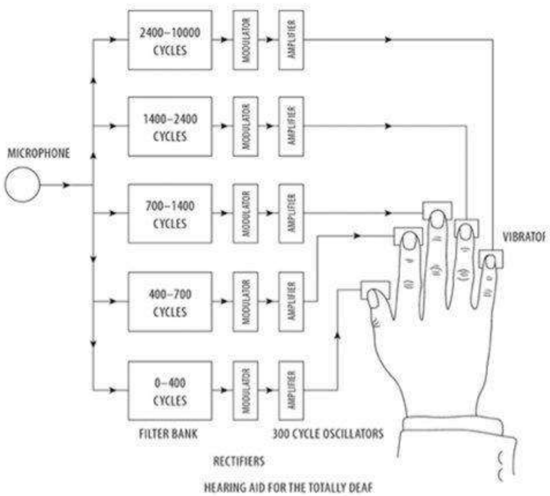
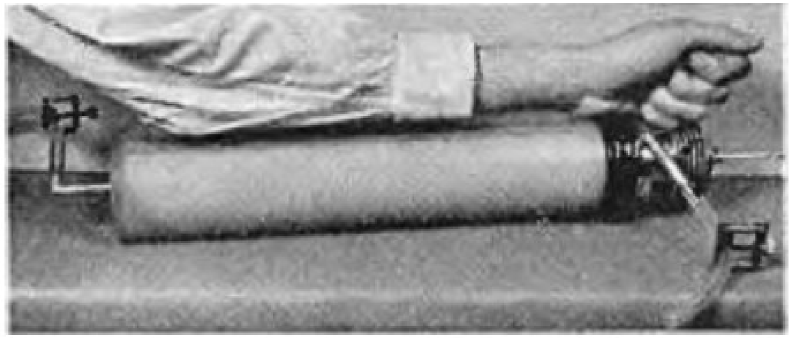
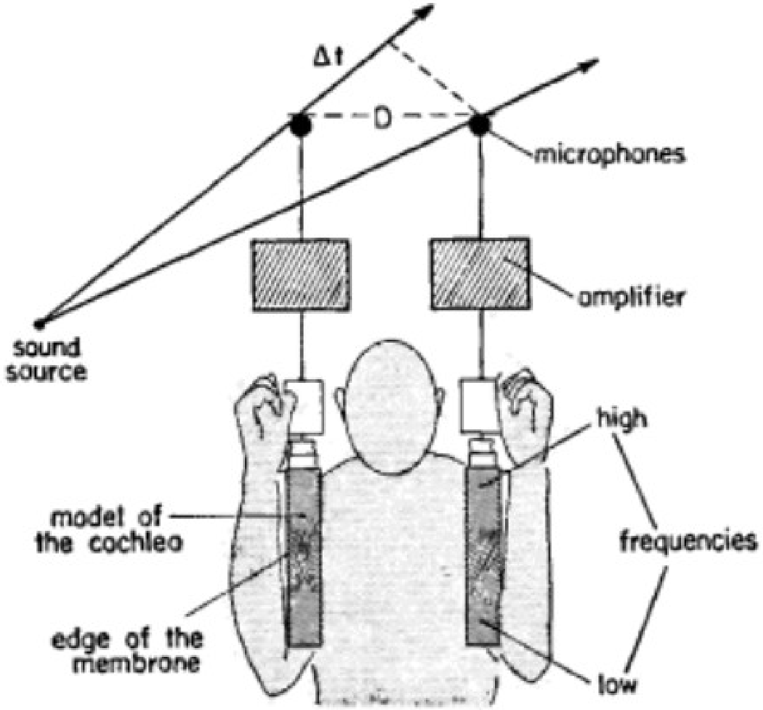


FIGURE 5. Designed and built by Norbert Wiener's cybernetics group at MIT in 1949, the hearing glove reproduced sound patterns as tactile sensations on the fingers of one hand. Wiener designed the device as a prosthesis and as a means to investigate the cybernetic principles of aural systems. From Norbert Wiener, *The Human Use of Human Beings: Cybernetics and Society* (Boston: Houghton Mifflin, 1950). Reprinted by permission of Houghton Mifflin Harcourt Publishing Company.





https://www.jstage.jst.go.jp/article/jasj/31/3/31_KJ00001454074/_pdf/-char/ja

G.v. Bekesy(1955) Human Skin Perception of Traveling Waves Similar to Those in the Cochlea

触覚で音を聞く。基本アイデア：周波数分解して皮膚に分布提示

Frequency components are presented to different position of the skin, like cochlea.

視覚障害者の障害物知覚
Obstacle sensation of the visually impaired

- アクティブセンシング／Active Sensiong
  反響音の知覚による定位（エコロケーション）／
  Perceive location by sound “echo” (echolocation)

- パッシブセンシング／Passive Sensing
  周囲雑音の強さ、音色の変化により定位
  簡単には「音響的影」／
  Perceive obstacle by noise reduction (acoustic shadow) and change of tone color

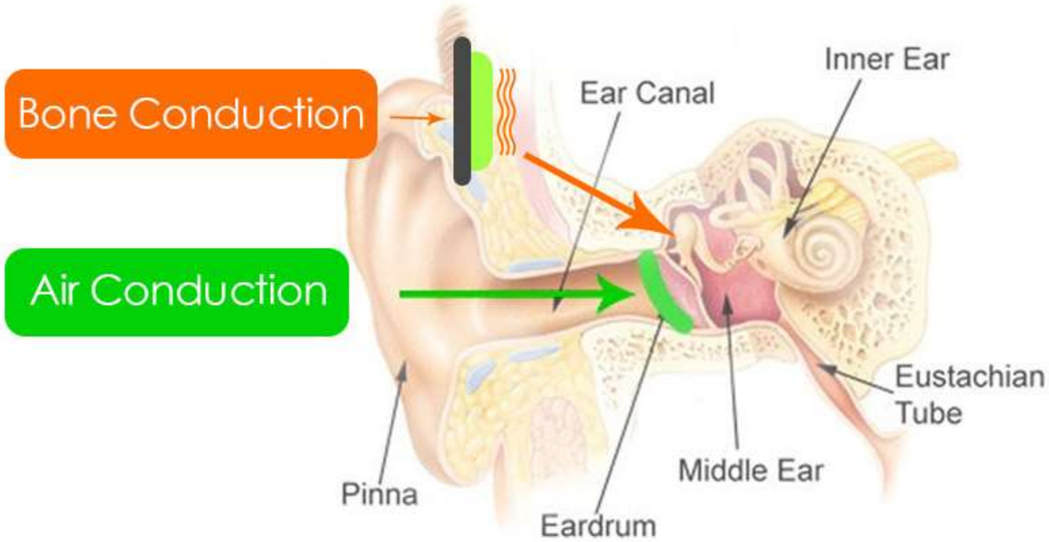
エコロケーション／Echolocation

Blind Kid uses Echolocation to "See"
http://www.youtube.com/watch?v=YBv79LKfMt4

音響的影の提示による障害物検知
Obstacle avoidance by presenting acoustic shadow

松尾他：音響的影の提示による気配感覚の増強，日本バーチャルリアリティ学会 第12回大会論文集2007.

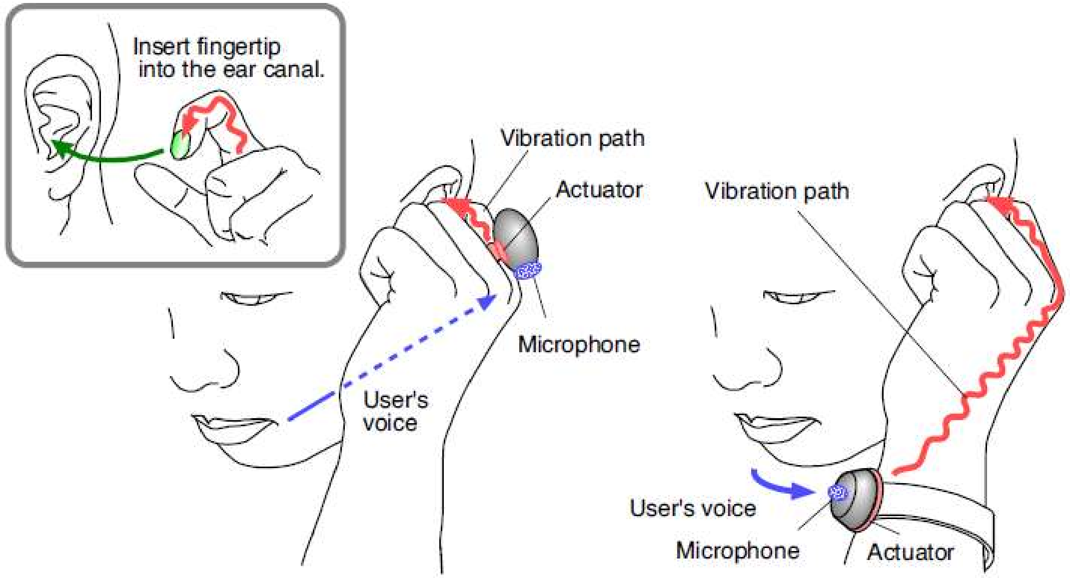
高齢者のサポート：骨伝導
Supporting elderly: hearing aid and bone conduction



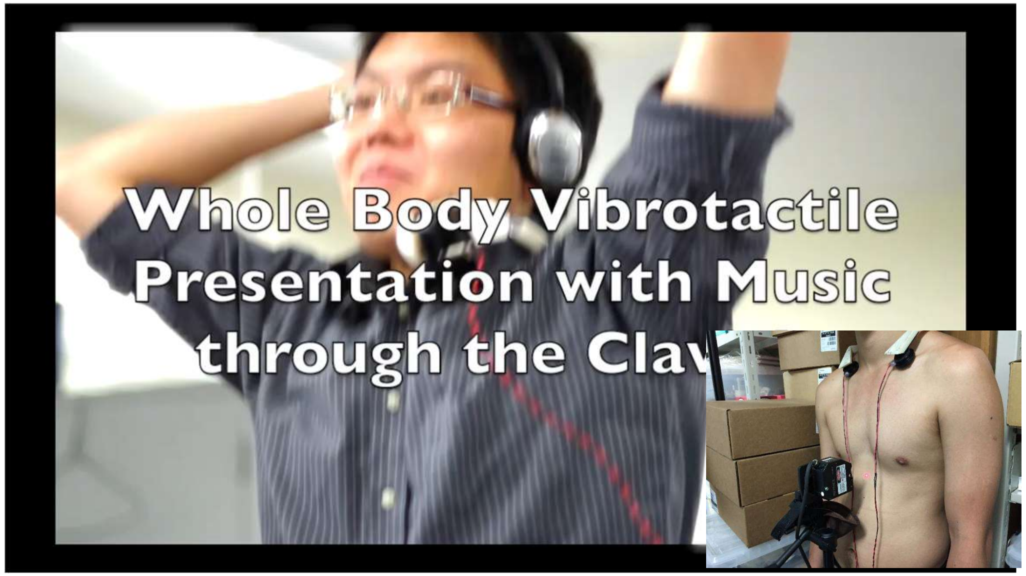
Bone conduction (Wikipedia) https://en.wikipedia.org/wiki/Bone_conduction

- 骨を振動させて音を伝える／
  Inner ear is directly vibrated by bone conduction
- 特に外耳，中耳に問題がある難聴で威力を発揮／
  Effective if problems are in external ear or middle ear.

Other ideas related to bone conductions



Fukumoto, A Finger-Ring ShapedWearable HANDset based on Bone-Conduction, ISWC2005
https://ieeexplore.ieee.org/abstract/document/1550779



R. Sakuragi, S. Ikeno, R. Okazaki, H. Kajimoto: CollarBeat: Whole Body Vibrotactile Presentation via the Collarbone to Enrich Music Listening Experience, ICAT2015

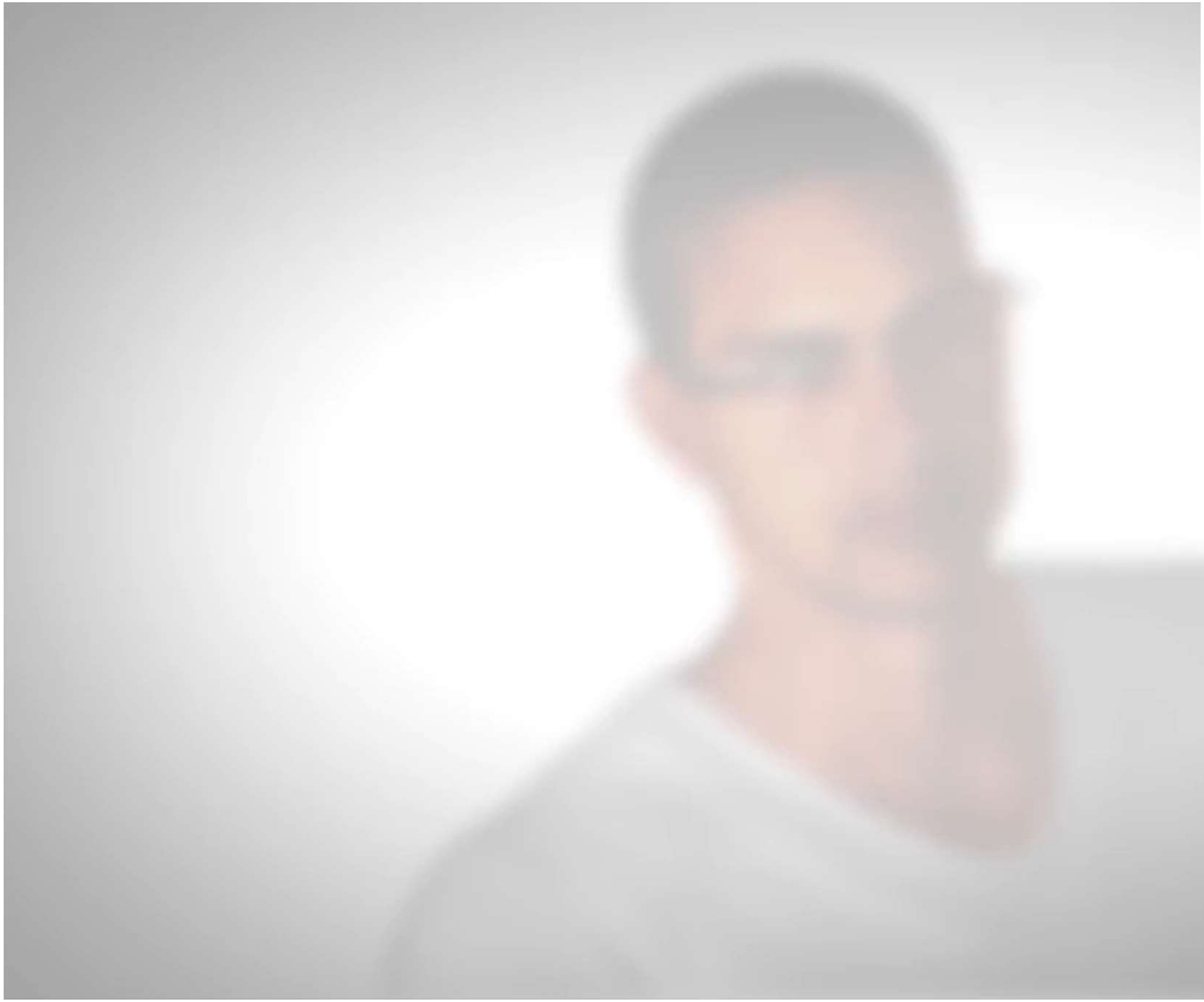
ORII Smart Ring: https://orii.io/
https://www.youtube.com/watch?v=Xwbn-Dpw_3E

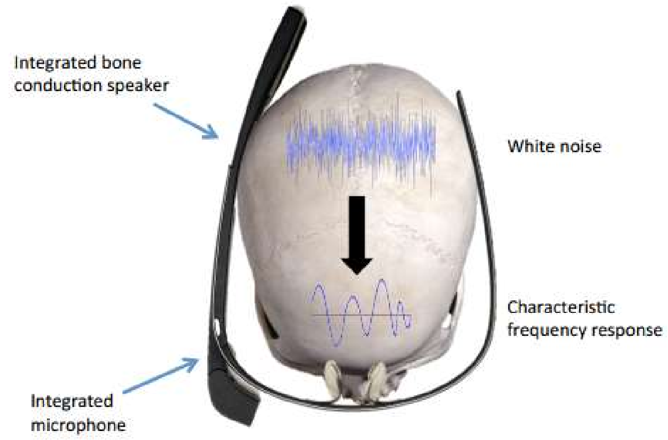
The Bone Fone: Radio Shack's Attempt At Making Collarbones Musical

By James Grahame

The Bone Fone was a floppy fabric covered tube that housed an AM/FM radio and two speakers. It was designed to be warn around the neck like a scarf, with the speakers resting on your collarbone. The idea, of course, was that sound was transferred directly from the little speakers into your body. I played with one briefly as a kid, but can't recollect what it felt or sounded like. It was marketed through Radio Shack, and I'm beginning to wish that I'd kept my dad's copies of their catalogs from the early 1980s.

(CHI2016) SkullConduct: Biometric User Identification on Eyewear Computers Using Bone Conduction Through the Skull, Stefan Schneegass, Youssef Oualil, Andreas Bulling





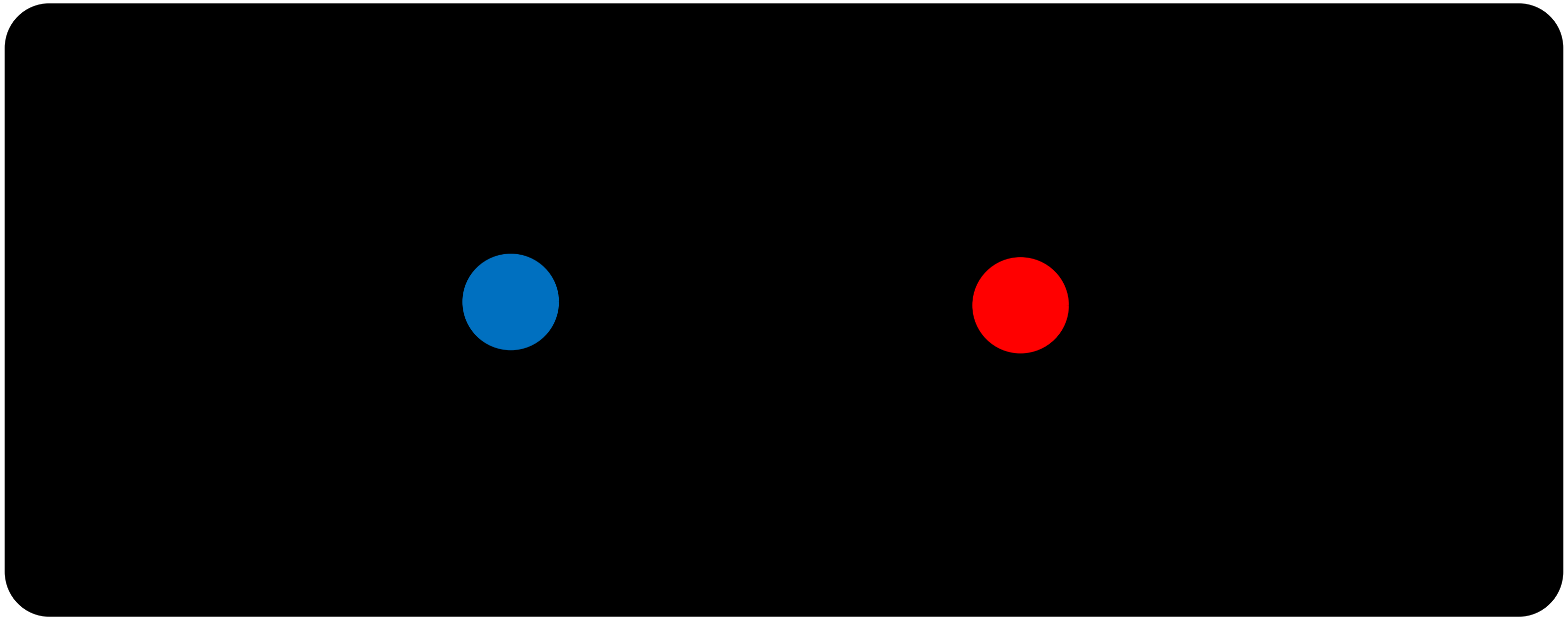
https://www.youtube.com/watch?v=5yG_nWocXNY
後頭部から入力して前頭部で出力する骨伝導の特性によって個人認証.

小テスト：一週間以内に提出
Mini Test: Submit in one week

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. 耳介の役割について説明せよ Explain role of auricle
2. 外耳道の役割について説明せよExplain role of external auditory meatus
3. ティンパノメトリーについて説明せよExplain Tympanometry
4. 耳小骨筋反射について説明せよ Explain Stapedial Reflex
5. 内耳基底膜の働きについて説明せよ Explain role of basilar membrane.
6. 内耳有毛細胞の働きについて説明せよ Explain role of hair cells on the basilar membrane.
7. 耳音響放射について説明せよ Explain otoacoustic emission
8. フォルマントについて説明せよ Explain formant
9. ミッシングファンダメンタル現象について説明せよ Explain missing fundamental phenomenon
10. 無限音階について説明せよ Explain shepard tone
11. 低周波音の音源定位の方法について説明せよ Explain localization by low frequency sound.
12. 高周波音の音源定位の方法について説明せよ Explain localization by high frequency sound.
13. 上下方向の音源定位について説明せよ Explain localization of vertical sound position.
14. パラメトリックスピーカについて説明せよ Explain parametric speaker
15. マガーク効果について説明せよ Explain McGurk effect
16. 人工内耳について説明せよ Explain cochlear implant.
17. エコーロケーションについて説明せよ Explain echolocation

実験レポート：視覚と聴覚の融合
Report: Synthesis of visual and auditory sensations



- 授業で紹介した現象の色付き版。赤と青の円を往復運動させる。
  - 交差した瞬間にクリック音を鳴らした場合と鳴らさなかった場合／交差した瞬間に色を入れ替える場合と入れ替えない場合、の2x2=4条件でどのように知覚するか観察する。
- 使用環境はパワーポイント等のスライドでも、Processing等でもよい。レポートでは図を載せ、結果を述べる。
- The red and blue circles are made to move back and forth.
  - Observe how they are perceived under the following 2x2=4 conditions: with and without clicking sound at the moment of intersection, and with and without switching colors at the moment of intersection.
- The environment can be PowerPoint slides, Processing, etc. In the report, include a diagram and describe the results (no need to attach the environment used).