Singing training for the tonally compromised

A practical exploration: capitalizing on neuroplasticity and alternative modalities for pitch-matching

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“I want to sing like the birds sing, not worrying who hears or what they think.”

-Rumi (1207-1273)

Why do we sing?

it's an essential part of our humanity.

"The singing maidens" of Pottery Mound, a reproduction by Thomas Baker of an 800-year-old Anasazi image

Anthropological

- Socializing
- Emotional communication
- Well-being

Biological

- Alert/avoid predators
- Mate selection
- Group cohesion
- Mother/infant bonding

Everyone should be able to sing*.

**but not everyone can…*

A voice teacher's dilemma.

- Singing is inherent to our humanity.
- Many people WANT to sing.
- Many people LOVE to sing.
- But they start voice lessons or join a choir and struggle to sing in tune.
- Some singers can match well for some pitches, but not others.
- The fear of failing or not being "good enough" is also a barrier.

It's not just beginners:

- Instrumentalists in musicianship classes can struggle with pitch matching in singing.
- Experienced singers can have pitch challenges in certain areas of their voice.

The are also special cases:

- Auditory processing issues, hearing aids, and cochlear implants can interfere with the desire to sing.
- Therapeutic singing has been used for Parkinson's, Alzheimers, and other disorders. Optimizing the experience includes pitch confidence.

How can we help?

How can we help?

Integrating ideas from the ***neuroscience of singing*** can help us ***design targeted pedagogy*** and ***streamline practice*** for these individuals.

Minding the gap!

I am NOT a neuroscientist.

I am a scientist, singer, and voice teacher
who has a passion for neuroscience.

There are some incredible neuroscience labs who study pitch processing, perception, amusia, and other musical cognitive processes:

Michel Belyk
Boris Kleber
Isabelle Peretz
Robert Zatorre
Gottfried Schlaug
Aniruddh (Ani) Patel
Diana Deutsch
John Sloboda
Simone Dalla Bella
Steven Brown
Petr Janata
Peter Pfordresher
Edward Chang

(and many more…)

—> all references listed in GRAY

What is singing?

?

Focus

Resonator

Vibrator

Activator

Thought

Action/Consequence

Feedback

(Physics, Physiology, and Psychology)

A voice teacher's dilemma.

How can we help?

Whether the singer is a beginner or advanced, the first step is diagnosing the problem.

Auditory *vs* Motor

(perception vs action)

Input → Output

(and everything in between…)

Our focus

"Poor-pitch singing"

= "*a failure to match pitches or pitch intervals within one semitone or more of the target*"

Pfordresher and Brown, 2007, 2009; cf. Dalla Bella et al., 2007; Wise, 2009

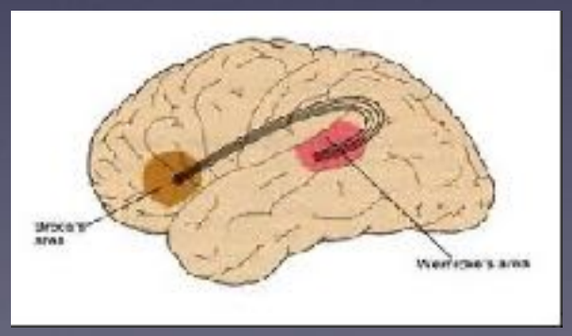
(or more loosely for our purposes, challenges with pitch matching or stability to various degrees)

"Tonally compromised"

Our focus

As opposed to ***amusia*** ("tone deaf") =

The inability to recognize musical tones or to reproduce them.
Amusia can be congenital (there are some well-studied genetic elements; *see Peretz*) or
acquired through brain damage.
Only ~4% (2.5%?) of the population are true amusics.



Proposed disruption in arcuate fasciculus (AF)

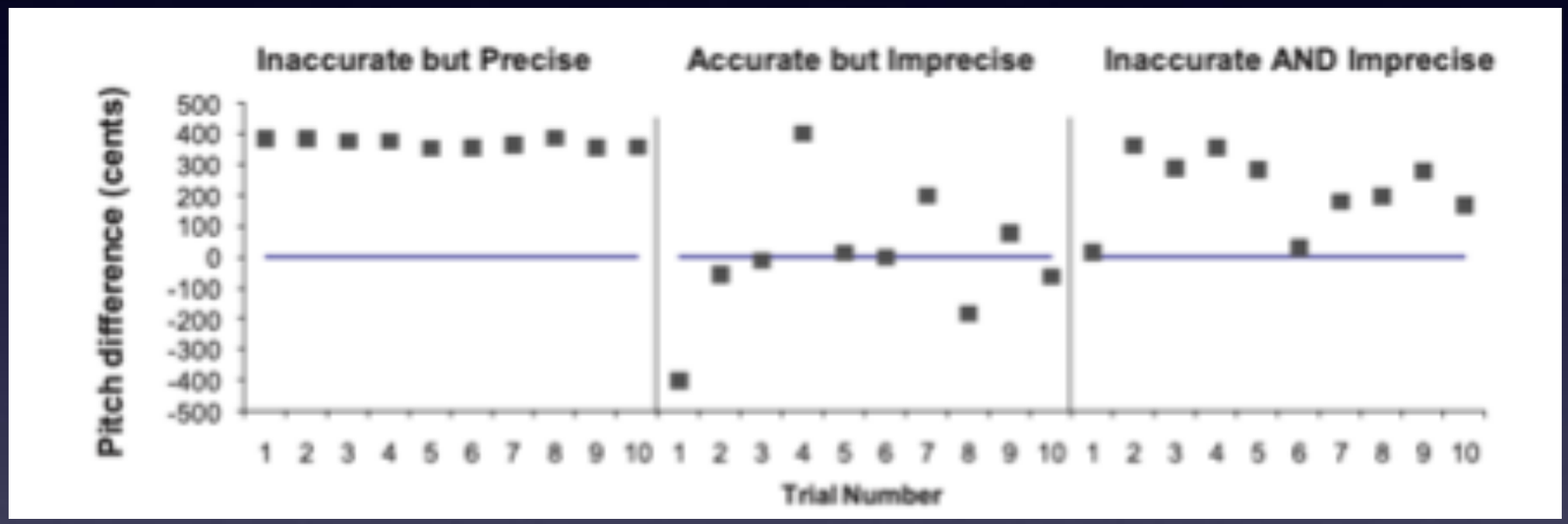
Many do not enjoy music, although some surprisingly do.

(some day, I would like to test some of these strategies on amusics though!! (:)

Pitch Accuracy *vs* Precision

Imprecise singing is widespread

Pfordresher PQ, Brown S, Meier KM, ***Belyk M***, Liotti M. J Acoust Soc Am. 2010;128(4):2182-2190. doi:10.1121/1.3478782



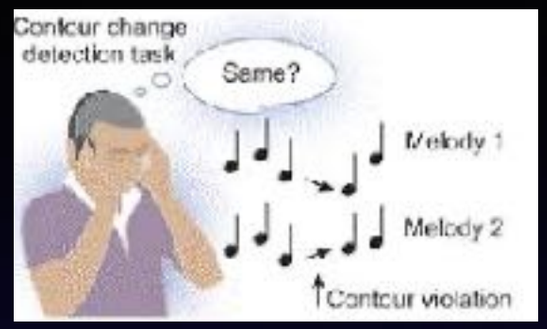
1 2 3

Accurate = at target
Precise = consistency

—> *"poor pitch"* singers fall within these 3 categories, but majority are (2)

Many methods to test pitch, i.e.:

Amusia: Montreal Battery for Evaluation of Amusia
http://www.brams.org/amusia-public/



Auditory Processing: Frequency Pattern Test (FTP)

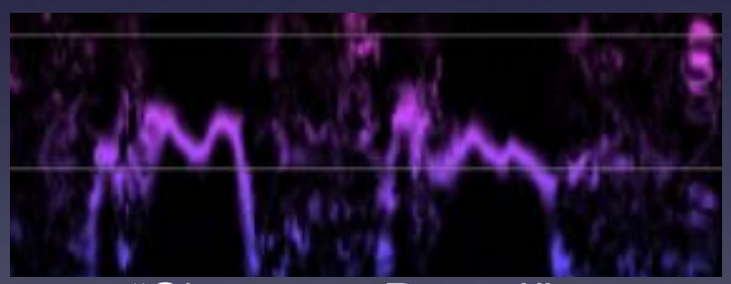
Singing: Sung Performance Battery (SPB)

(or design your own!
Voice teachers are creative at figuring out their students…)

<u>Side note</u>: pitch accuracy is only *one* element that can challenge a singer.

Singers can be good at matching pitch,
but there are other elements that require attention: timbre, rhythm, presentation, etc.

F#4 ←



“She Bang!”

→ F#4

“She Bang!”

He nailed it, despite be accused of being ‘tone deaf’!

However, PITCH MATCHING is a still critical first step for singing well…

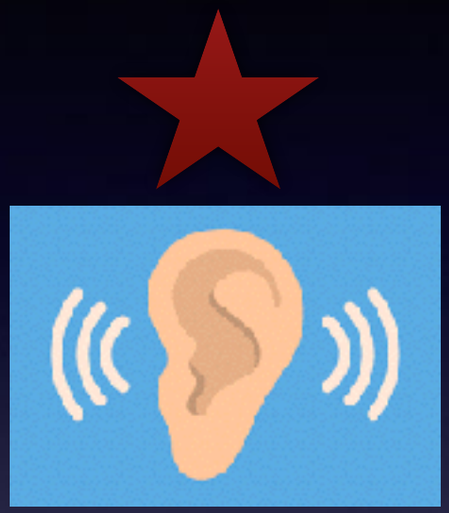
(which is why we are here!)

The other elements are for a DIFFERENT talk (:

How can we help?

Auditory *vs* Motor

(perception vs action)



Input → Output

(and everything in between…)

Most traditional strategies live here, even for clinical settings

Input

Google *'pitch matching'* or '*pitch training for singing*', etc. and the strategies involve some form of <u>ear training</u>.

- Ear training for singing expects individuals to identify pitches and intervals and sing them back ***<u>solely by listening</u>.***
- The sound input is typically a piano or teacher's voice.
- (The *feedback* focus for the singer is auditory as well).

But…

- Ear training strategies are not always successful.
- Negative results are not necessarily indicative of an unsolvable problem.
- We need to explore the many other pathways involved in pitch matching.
- We need to capitalize on ALL of the resources and data available to customize protocols for each individual case.

Input → Output

(and everything in between…)

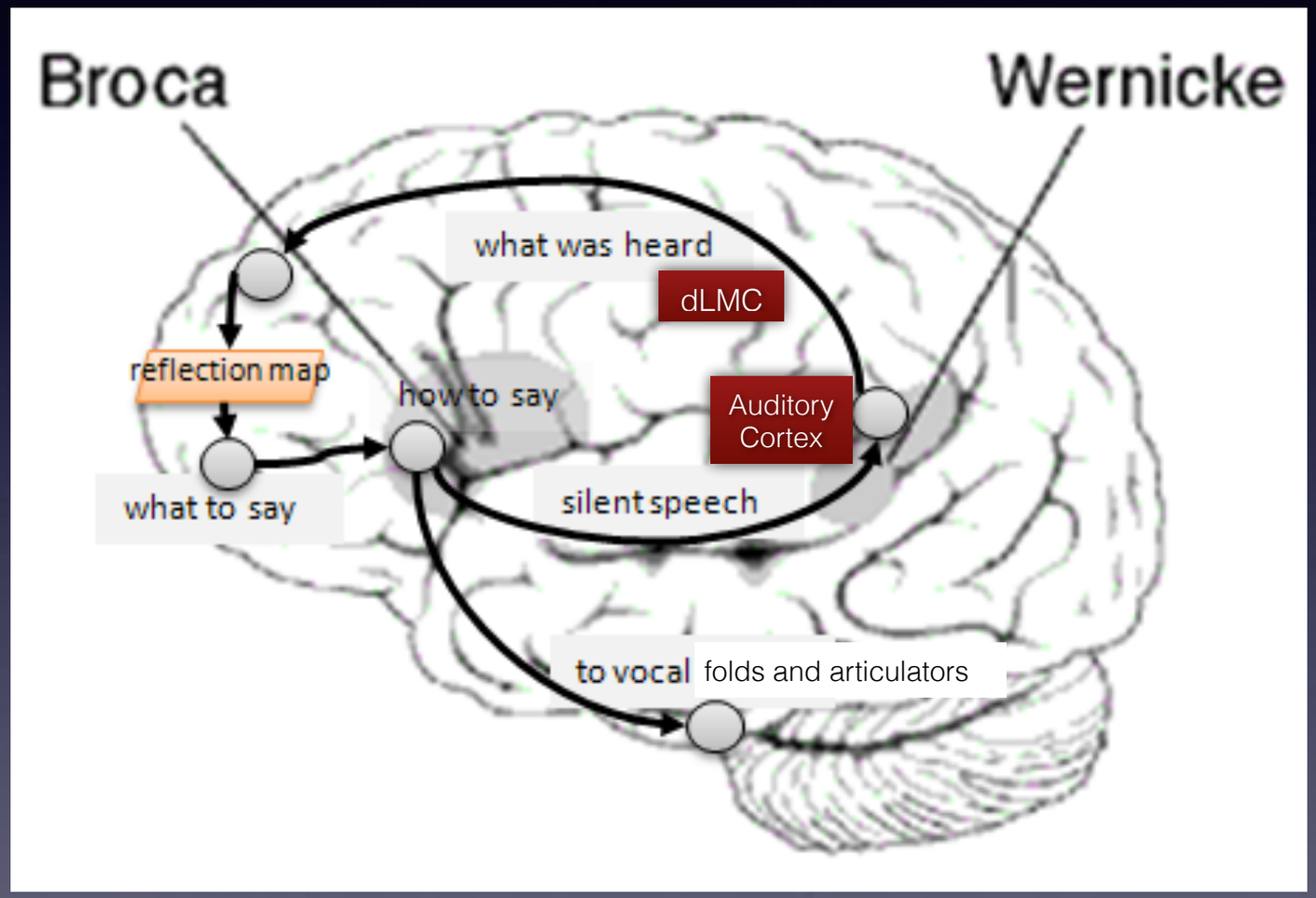
So…

Let’s look at a singer’s *brain*…

- Singing is a very complex motor task which involves the coordination of over 100 muscles.
- Given the intricate *sensorimotor* components, parsing out WHICH elements are interfering with pitch generation is critical.
- Teachers can capitalize on many avenues to facilitate pitch matching and strengthen connections.

Input → Output

(and everything in between…)



1. Auditory Input
2. Mental Processing
3. Vocal Pathway
4. Vocalization

Feedback

"Successful singing requires …

- ***perceptual skills*** *(pitch matching, interval reproduction, and fine-grained pitch discrimination ability),*
- ***cognitive abilities*** *(working memory, attention, and learning processes),* ***and***
- ***motor skills*** *(motor planning, motor selection, and motor execution).*

Difficulty singing in tune may reflect impairment in any or all of these abilities."

Loui, 2015

Pitch-matching intervention strategies

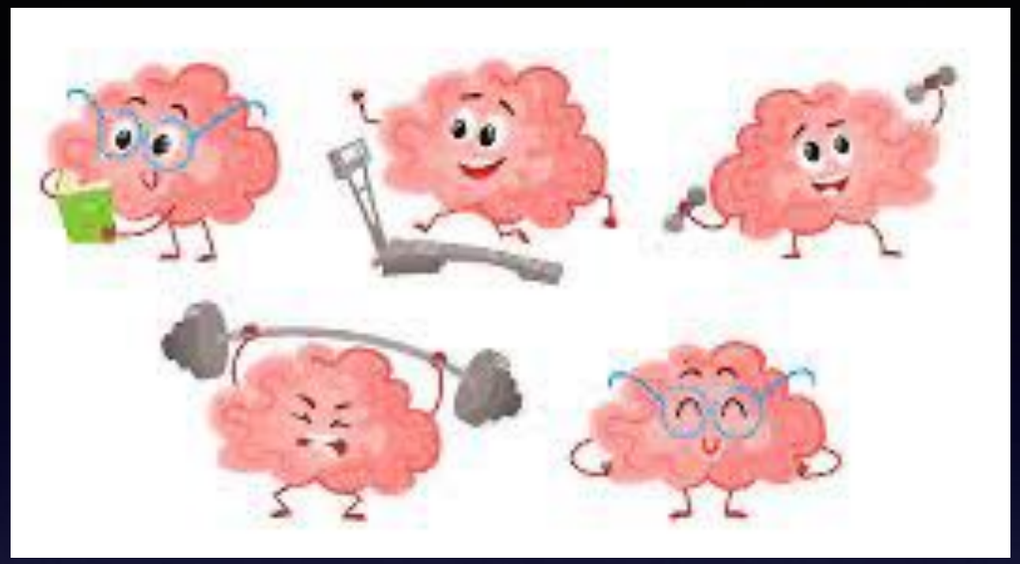
1 = Auditory inputs can be diversified, modified, and customized

2 = Memory and musical memory can be tapped

3 = Well-wired vocal motor skills, like speech, can serve as a template

***4 = The richest area to target is feedback: *visual biofeedback*, kinesthetic, and somatosensory elements**

Skills can be integrated for maximum impact.
E.g. visual biofeedback enhances independent results from other strategies.



These strategies can *change your brain!*

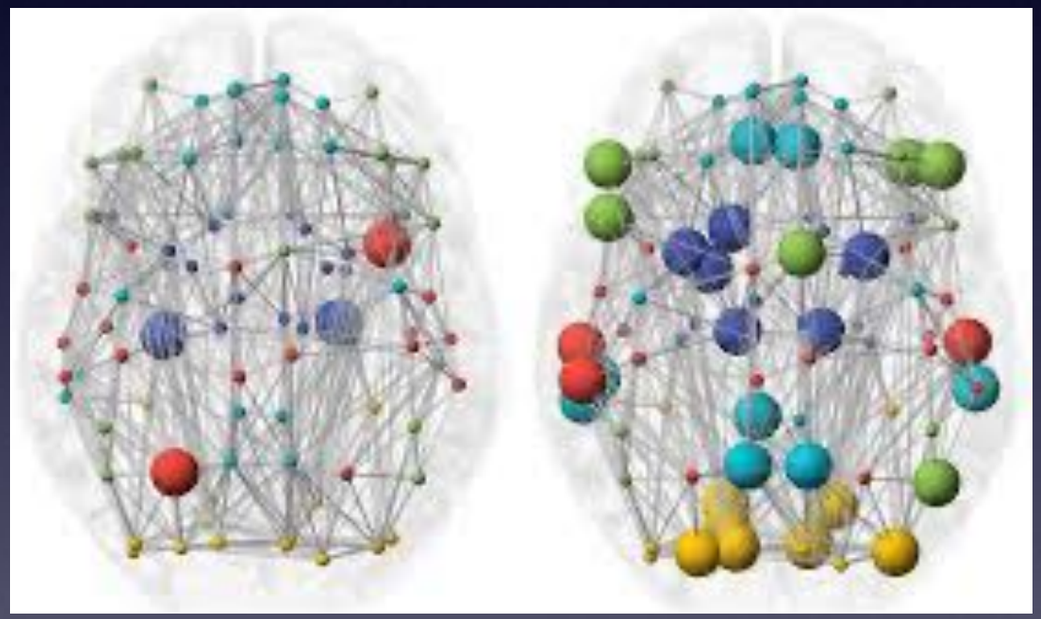
= **Neuroplasticity**

Utilizing multi-pronged targets for pitch matching enhances

NEUROPLASTICITY

across broader brain regions

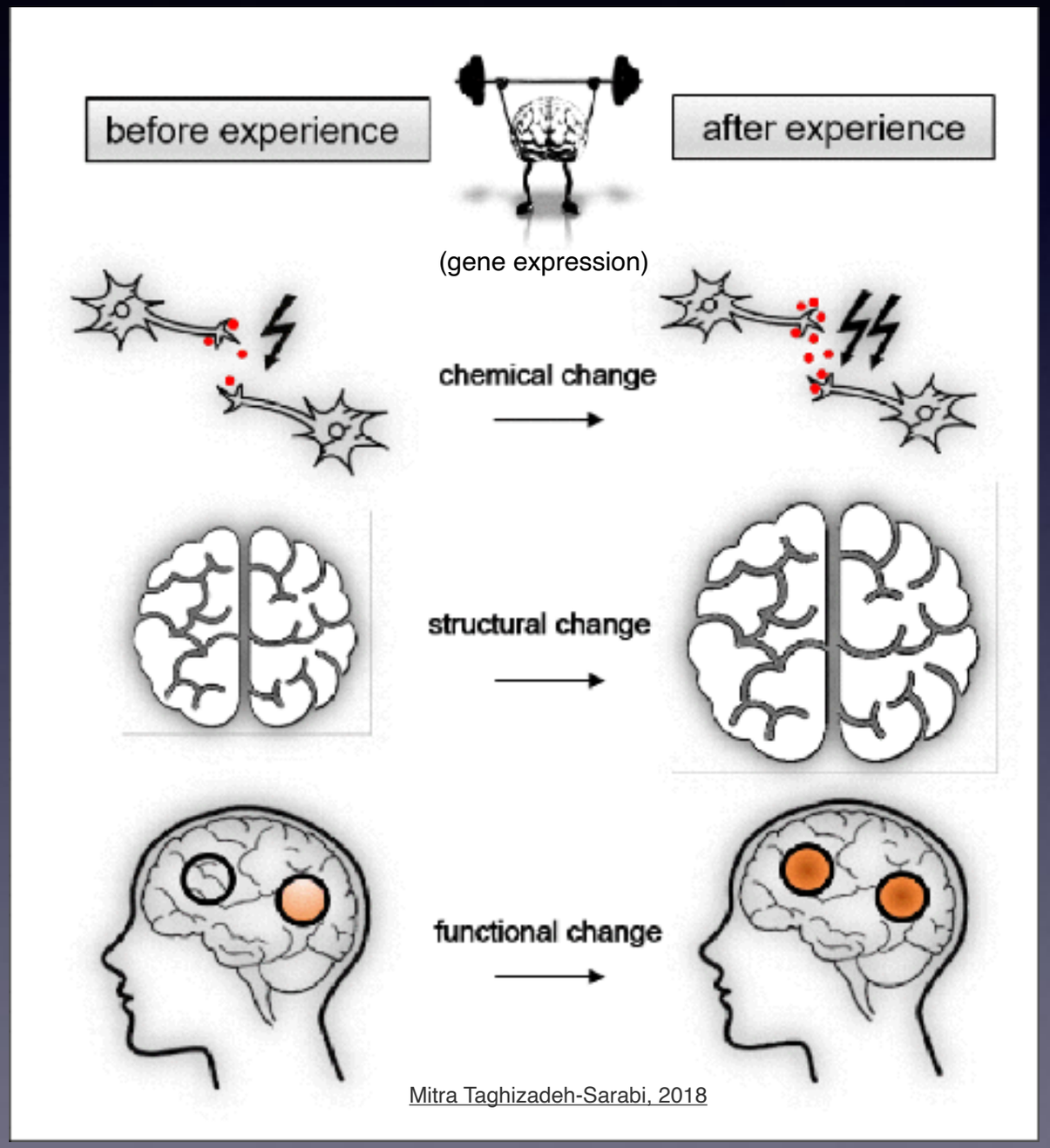
From this…. to this



Yan-Ling P, 2019

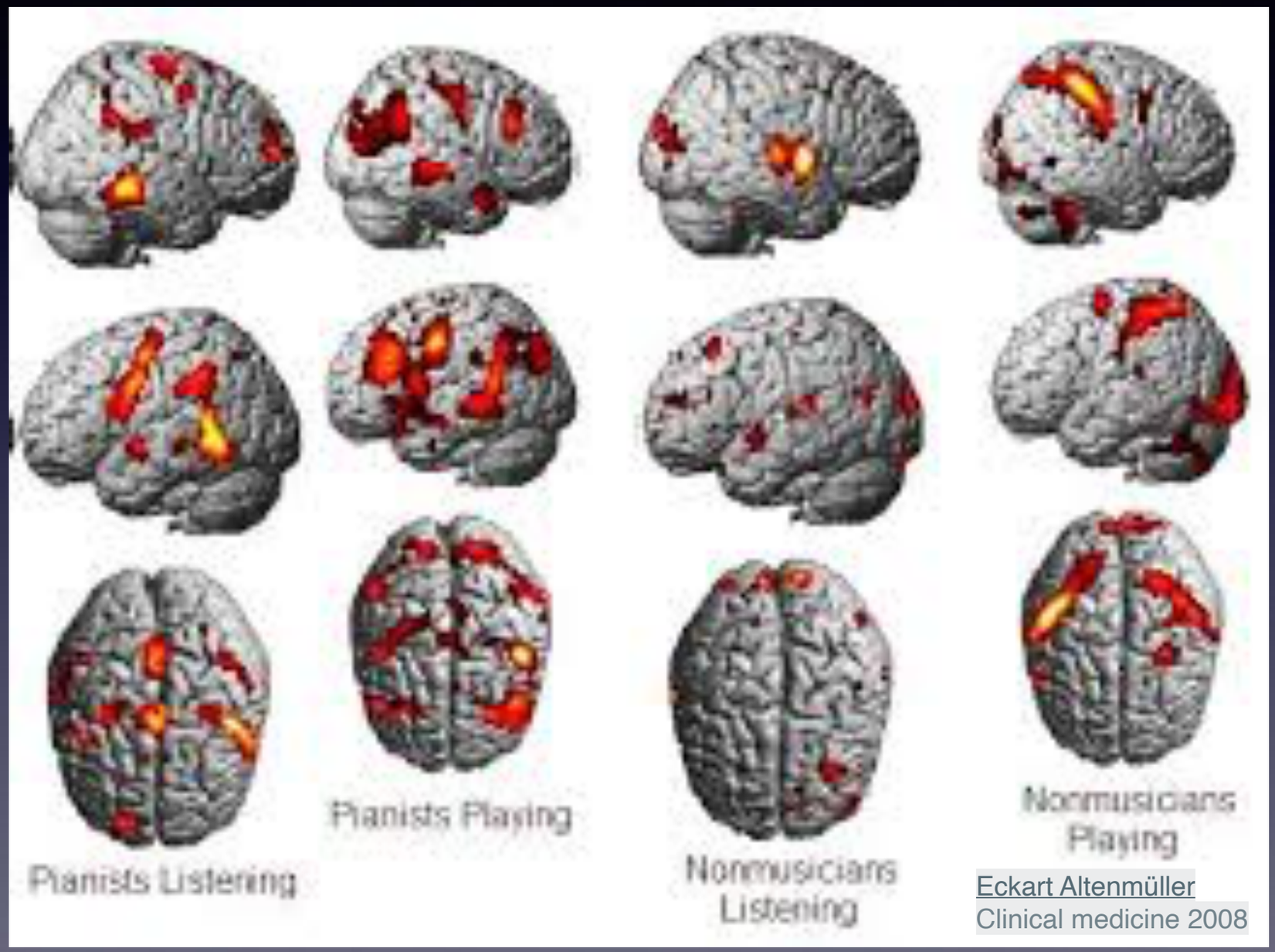
i.e. ear training alone

ear training PLUS
musical memory
visual biofeedback, etc.

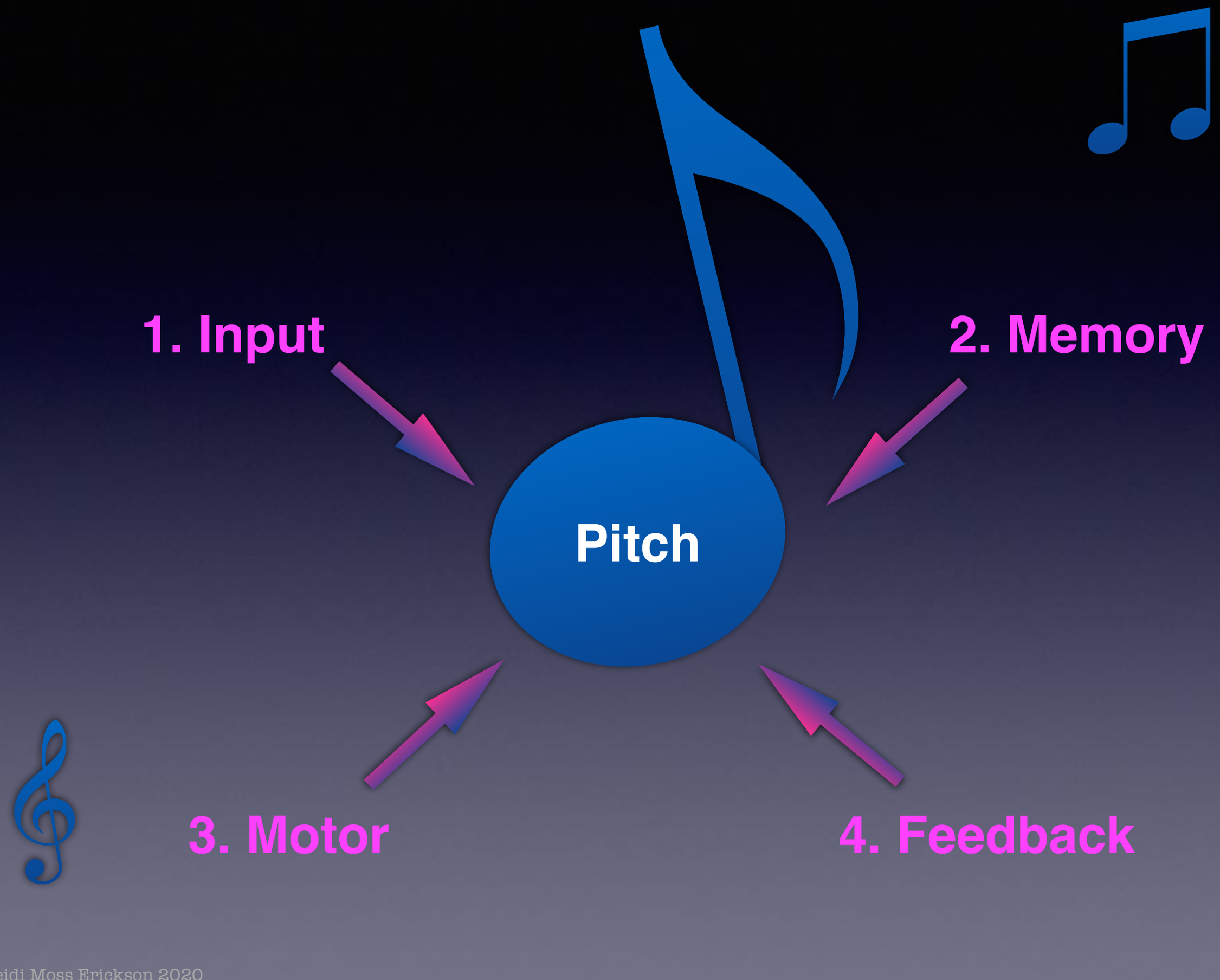


Mitra Taghizadeh-Sarabi, 2018

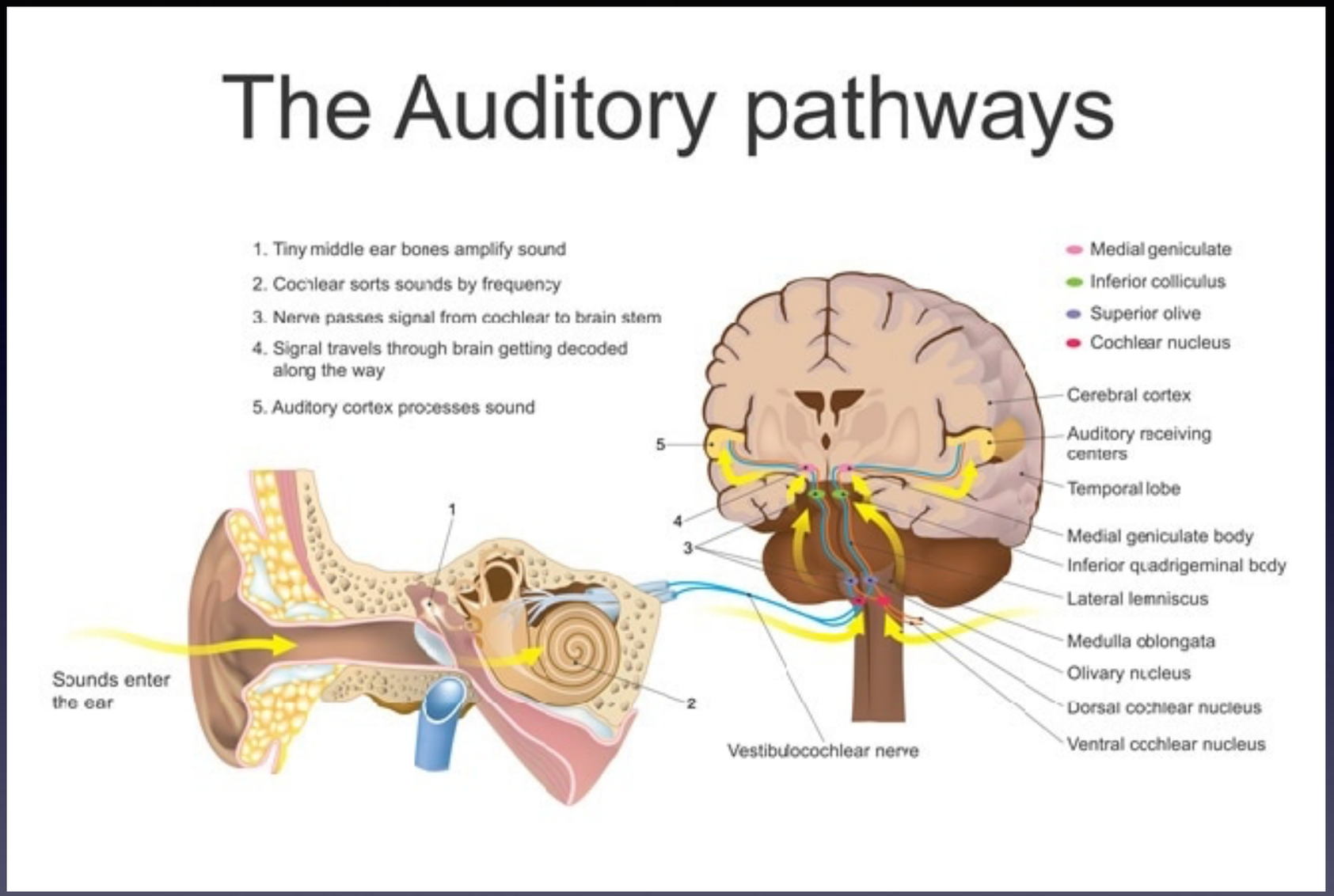
Practice changes your brain structure.
More inputs, more changes.



Eckart Altenmüller
Clinical medicine 2008



1. PERCEPTION: impact of auditory input



- Left ear better for musical pitch (right auditory cortex)
- Schneider and Wengenroth (2009) differentiated between two types of listeners:
  - holistic (or fundamental)
  - spectral listeners
  - (But it really is a continuum of the two…)

1.

“Do you hear what I hear?”

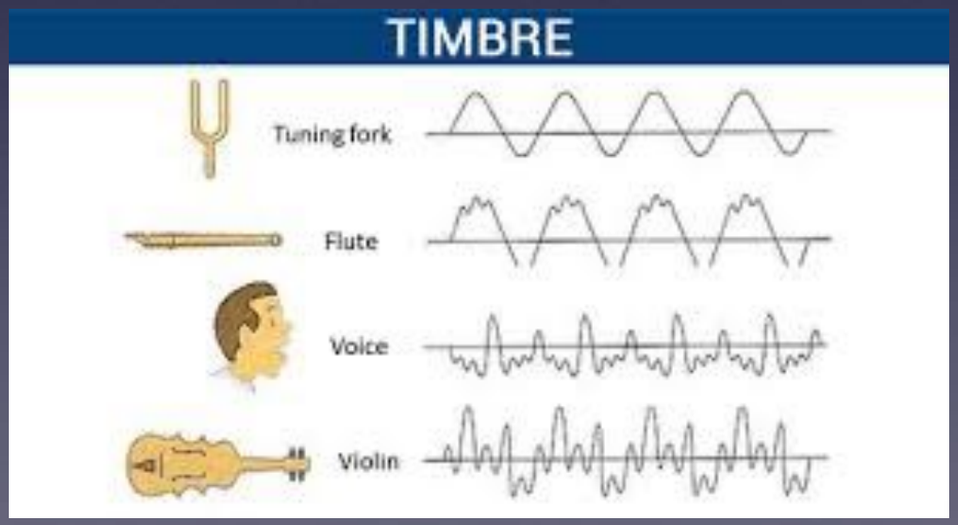
TIMBRE: spectral and temporal elements

“Timbre, the perceptual quality or color of a sound, is defined as everything by which a listener can distinguish between two sounds with the same loudness, pitch, spatial location, and duration.

For instance, it is differences in timbre that allow us to distinguish a violin from a guitar, or one vowel sound from another.

Among the typical adjectives that fall under the category of timbre are “brightness”, “clarity”, “harshness”, “fullness”, and “noisiness””.

Allen EJ, Moerel M, Lage-Castellanos A, De Martino F, Formisano E, Oxenham AJ. Encoding of natural timbre dimensions in human auditory cortex. Neuroimage. 2018;166:60-70. doi:10.1016/j.neuroimage.2017.10.050

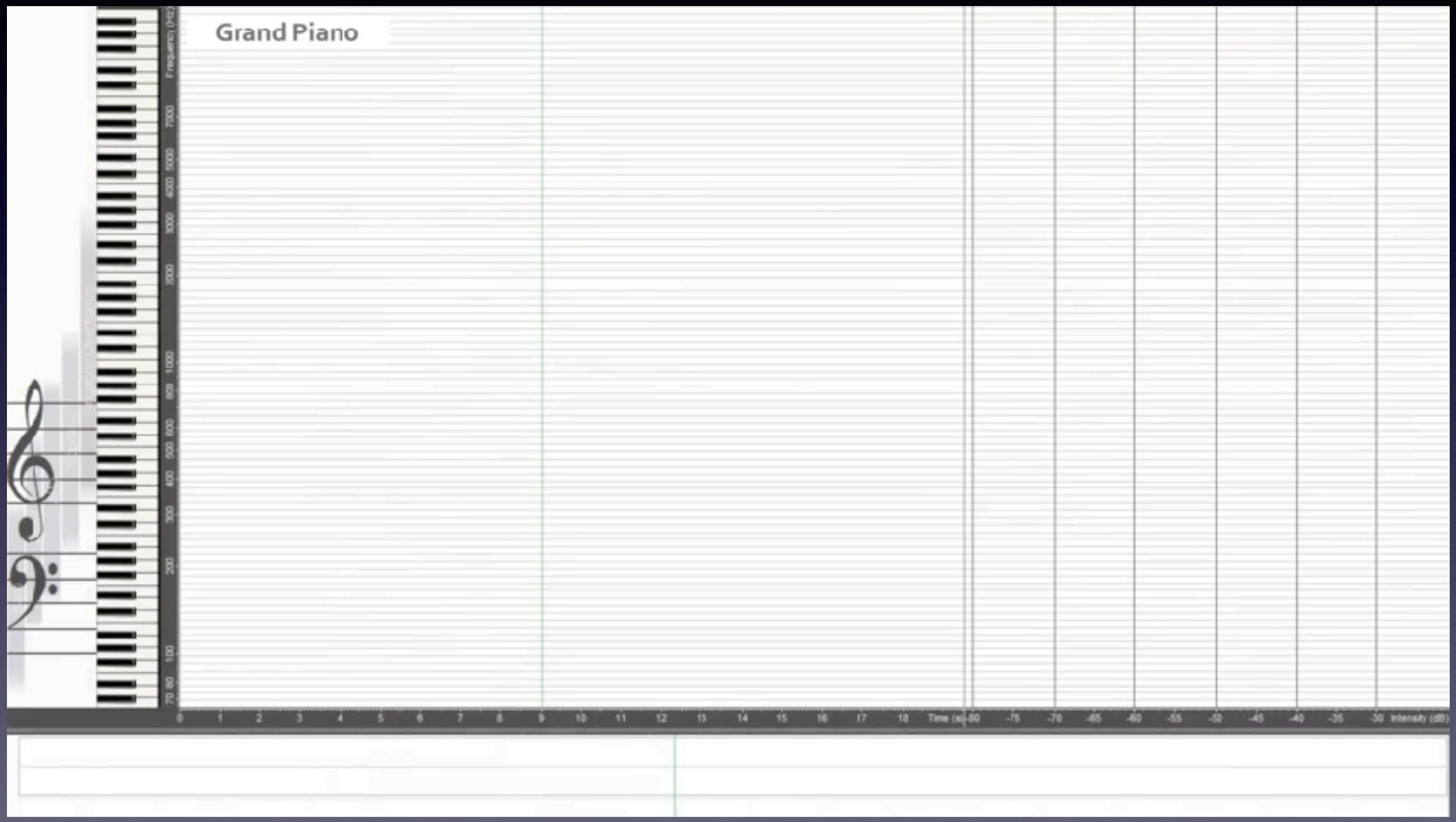


During auditory perception, the human brain analyzes both time and frequency simultaneously.

1.

TIMBRE

Wide-ranging, distinctive elements

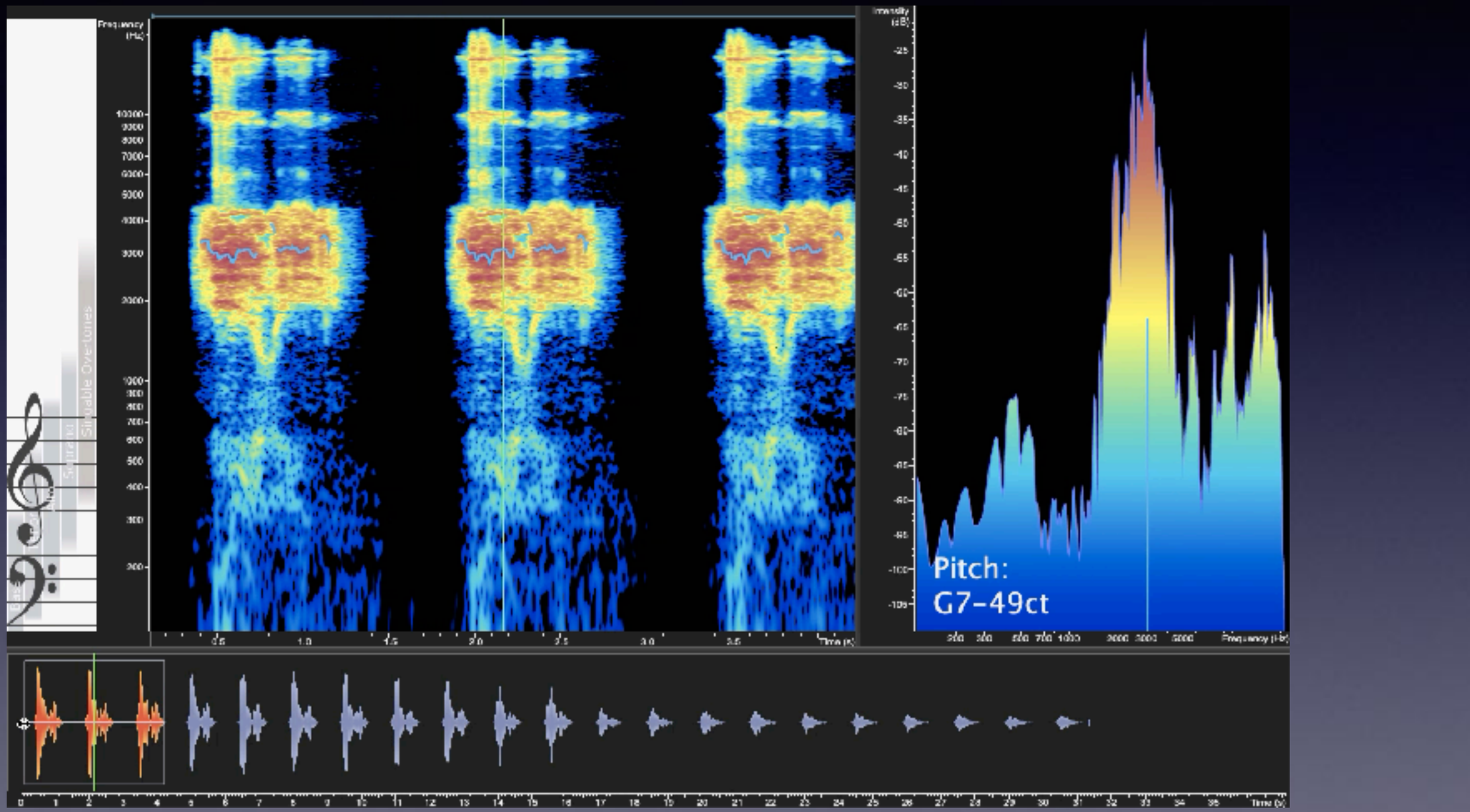


Did they all sound identical in pitch? Did any sound sharp/flat? (e.g. sitar?)

1.

Individuals differ in their auditory processing

“Laurel/Yanni”

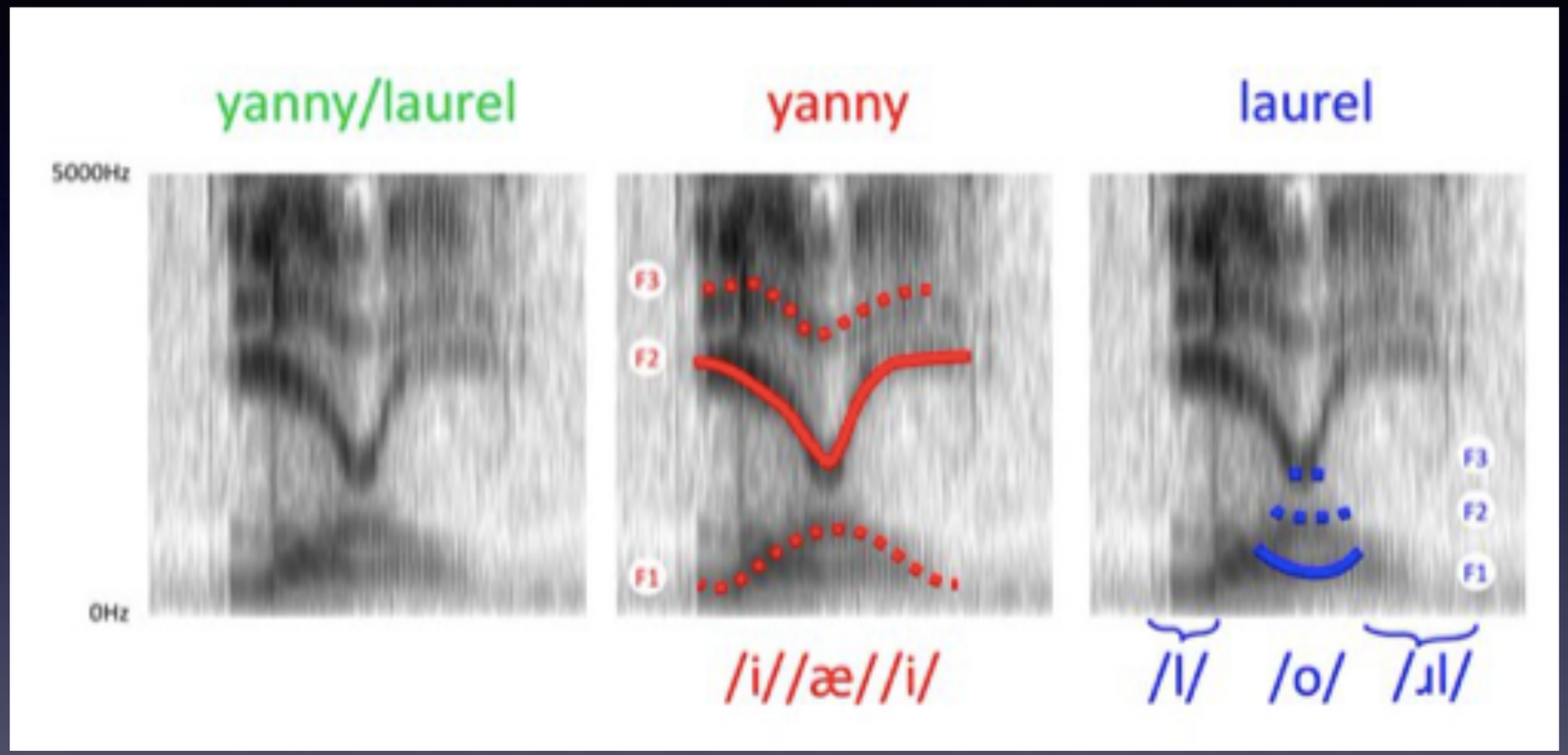


Raise your hand when you hear LAUREL clearly with a pitch/human voice sound.
Is everyone the same?

1.

An Aural Illusion

The mystery of overlapping formants…



In BOTH scenarios the BRAIN had to:

1) **DECIDE which was important and which to block out**
2) **FILL-in missing INFORMATION**

1.

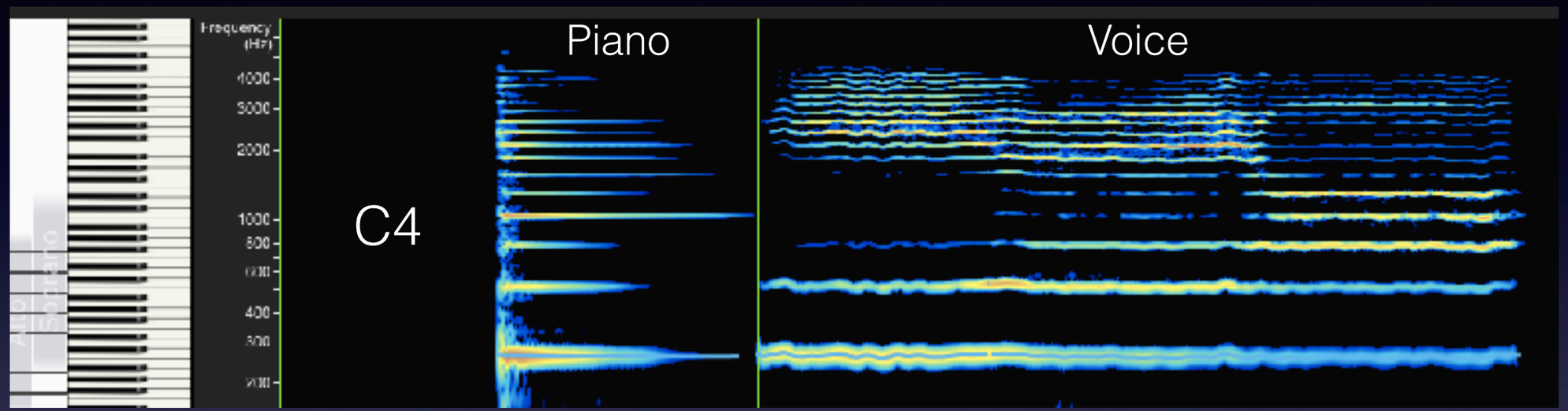
Individuals differ in their auditory processing…

…experiment with different inputs!

1.

Piano

Most used for ear training, but timbrally very different from voice.



/i/ /e/ /a/

Filtered Harmonics: to reduce interfering frequencies

C4

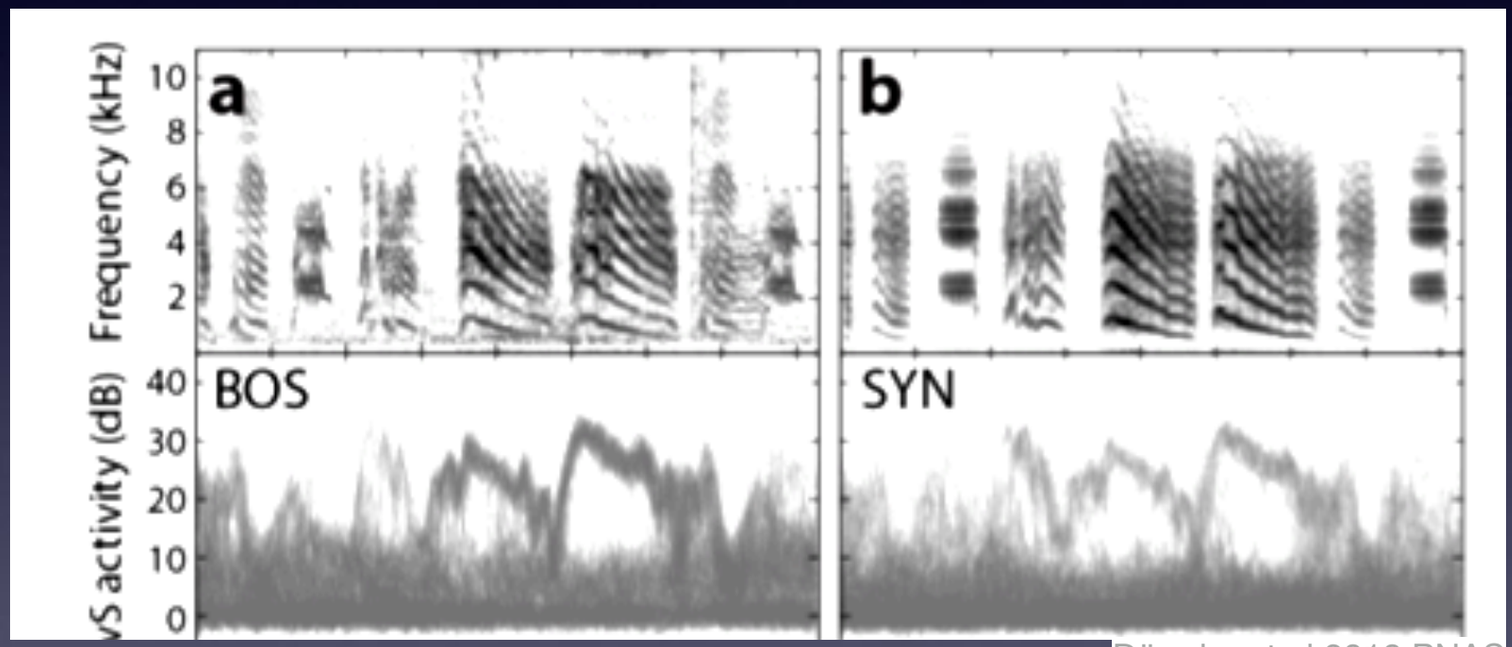
H1-3 only
(No fundamental!)

1.

Voice

- Our brains are wired to mimic voices best (=*vocal learning*).
- Our brains also show a greater sensitivity to sounds of human voice
- Our motor areas are activated for vocalization when we hear a voice:

Sleeping bird experiment



Döppler et al 2018 PNAS

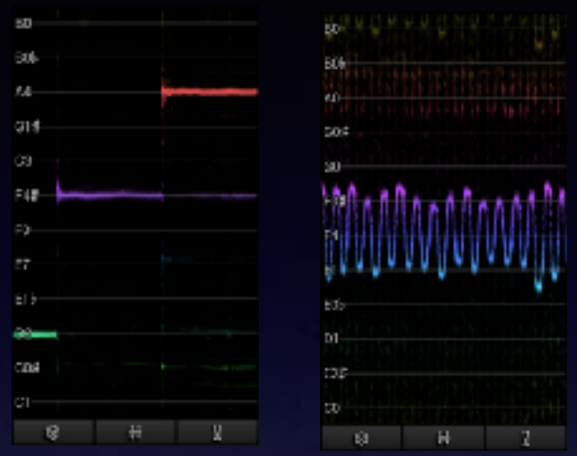
- Our brains have a special processing area for voice = temporal voice area (TVA)

(Belin et al. (2000)

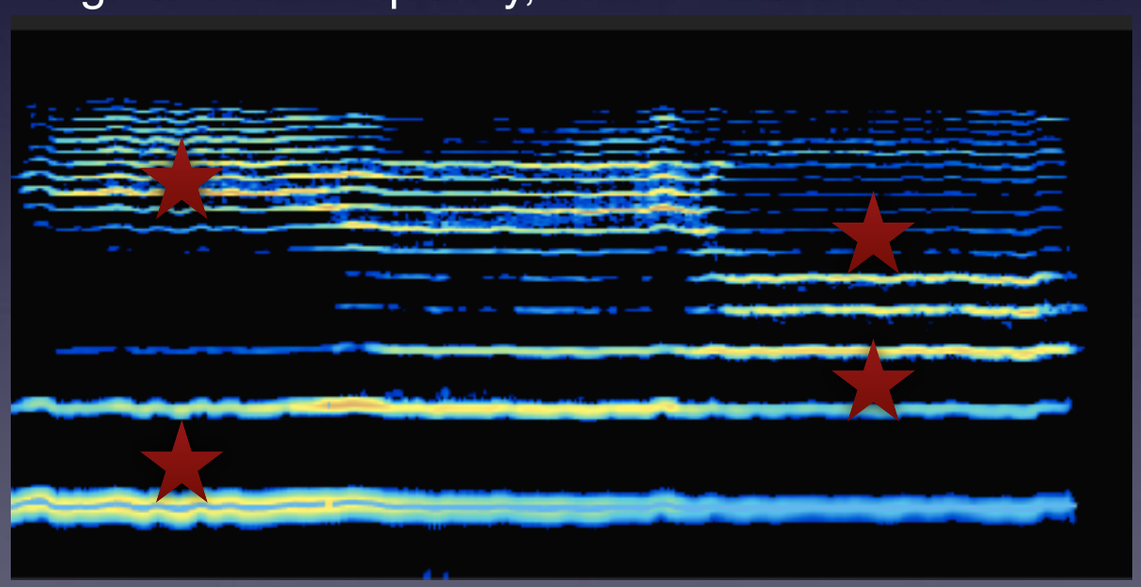
1.

Voice

- Input pitch with the same *octave* and *type* tends to be the most successful
- Straight tone better than vibrato (vibrancy can give pitch ambiguity)



- Consider vowel formants: a singer can latch on to augmented frequencies:
  e.g. /a/ used frequently, but F1/F2 are close and can boost competing frequencies/confuse the listener



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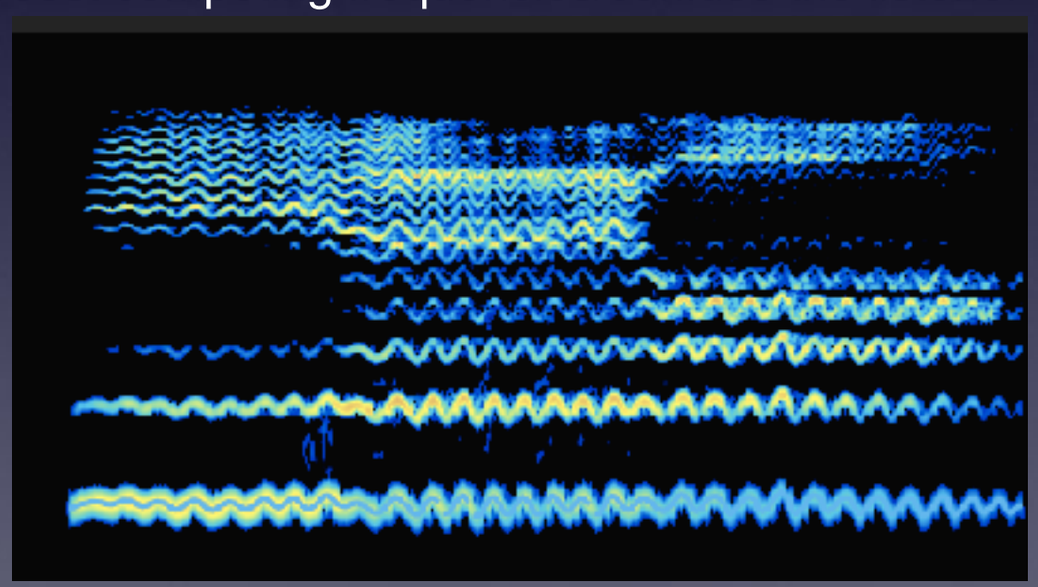


/i/ /e/ /a/

- The voice can also be filtered like the piano sample

1.

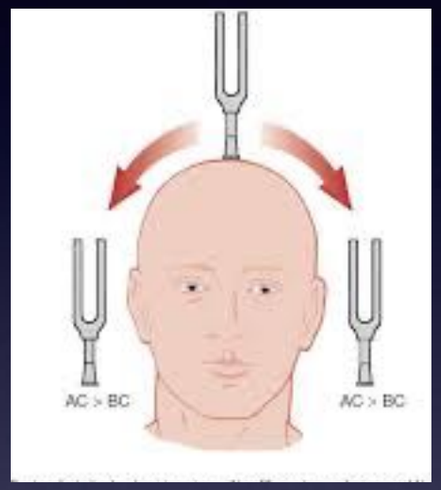
Other inputs/auditory contexts to consider:

- Effects of group singing: being near colleagues on pitch can help
- Bone conduction: bypassing canal
- Accompaniment: help or hurt?
- Sine tones:

C4 sine tone

- ASTC: sine tones have vowel-like qualities

Ian Howell, NEC



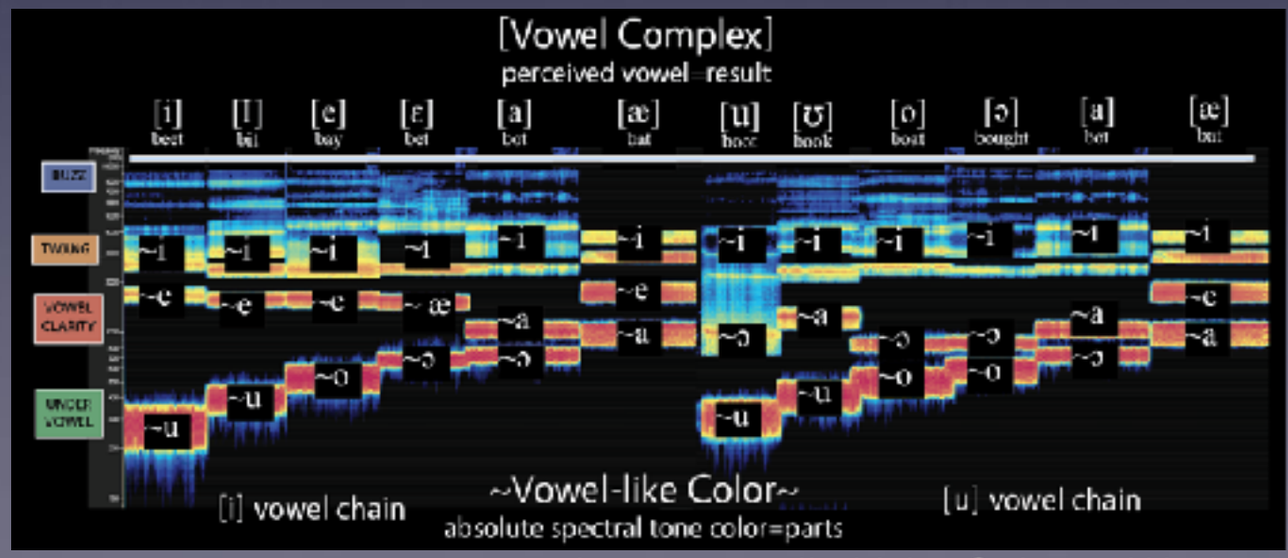
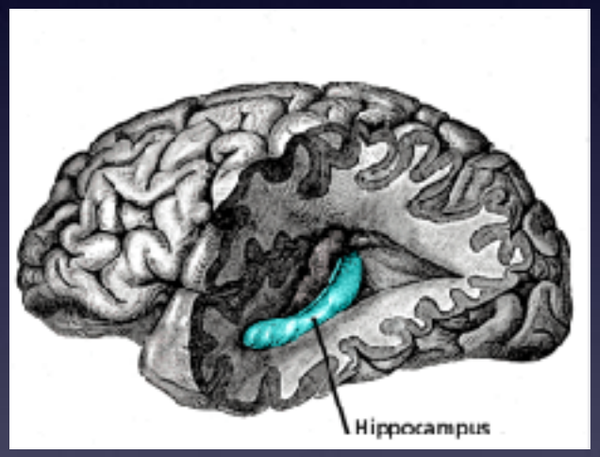


Image credit: VoiceScienceWorks

2. MEMORY

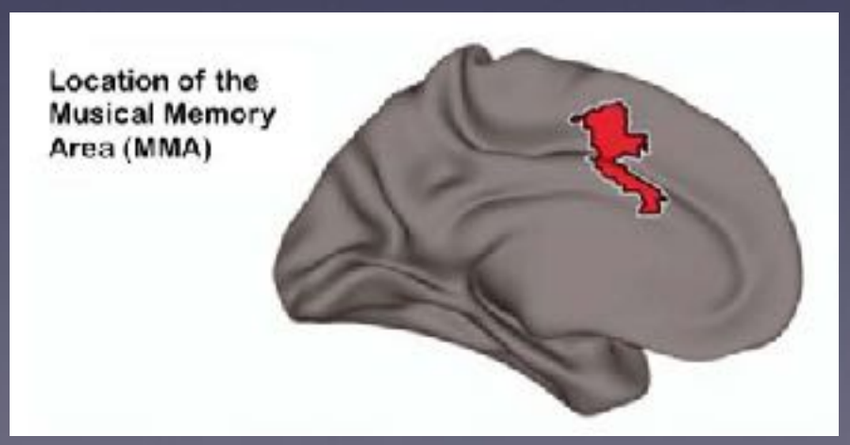
Using musical and episodic memory to retrieve pitch information.
Pitch memory can be short term or long term and are separated in the brain (Schlaug (2003)
These pitch memories can be used as reproducible starting points.

- Sing common songs like “Happy Birthday”
- Sing songs from very impactful personal times: e.g. teenage pop songs
- Practice musical imagery: clearly audiate, hum (activates motor) (Halpern 1989)



Episodic memory: *hippocampus*
Neurons represent the *experience* of the pitch changing.

Aronov, D., Nevers, R. & Tank, D. Mapping of a non-spatial dimension by the hippocampal–entorhinal circuit. *Nature* **543,** 719–722 (2017). https://doi.org/10.1038/nature21692



Musical Memory= MMA is *separate* from the hippocampus and the temporal lobe (which are necessary for long-term memory function).

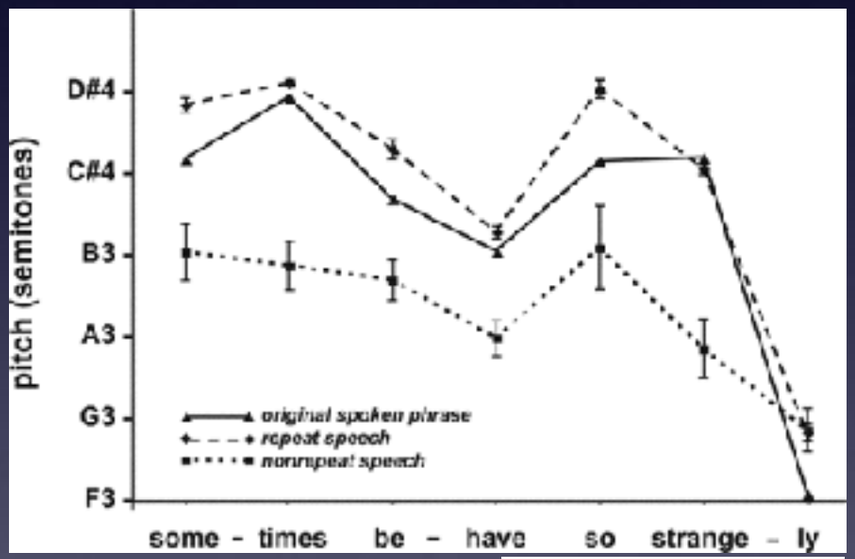
“(pre motor and sensorimotor areas)…more active when participants heard well-known songs compared to recently known or unknown songs”.

Jacobsen, J. H., Stelzer, J., Fritz, T. H., Chételat, G., La Joie, R., and Turner, R. 2015. Why musical memory can be preserved in advanced Alzheimer’s disease. Brain 138:2438–50. doi:10.1093/brain/awv135

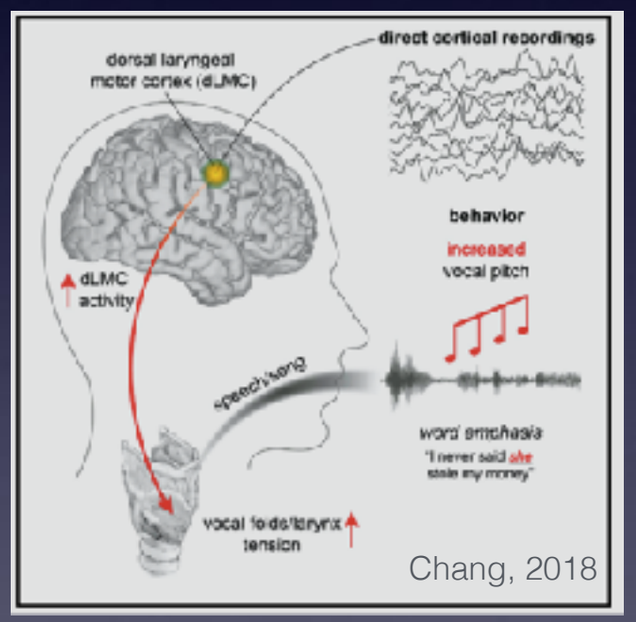
—> This is why people with Alzheimers or dementia retain musical memory: it stays intact!

3. MOTOR

- Singing is a complex motor task which involves coordination of >100 muscles.
- Some pitch matching issues are NOT at the input nor auditory processing level, but at the motor coordination level.
- Speech is a pitch-motor activity we do all of the time and can be used as a starting point.
- Prosody can facilitate interval contours (e.g. question, emphasis).



From Deutsch (2003).



Chang, 2018

- Emotional gestures and intentions can also emphasize pitch elements of speech.

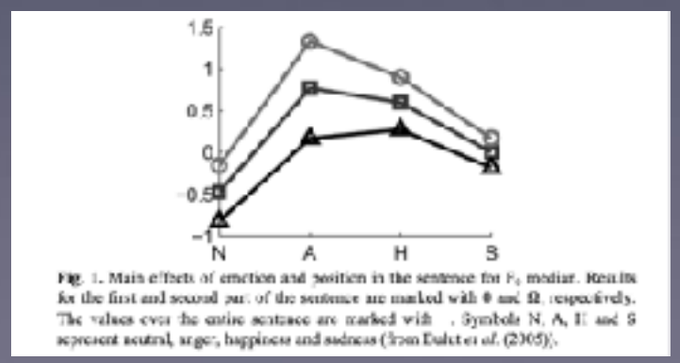
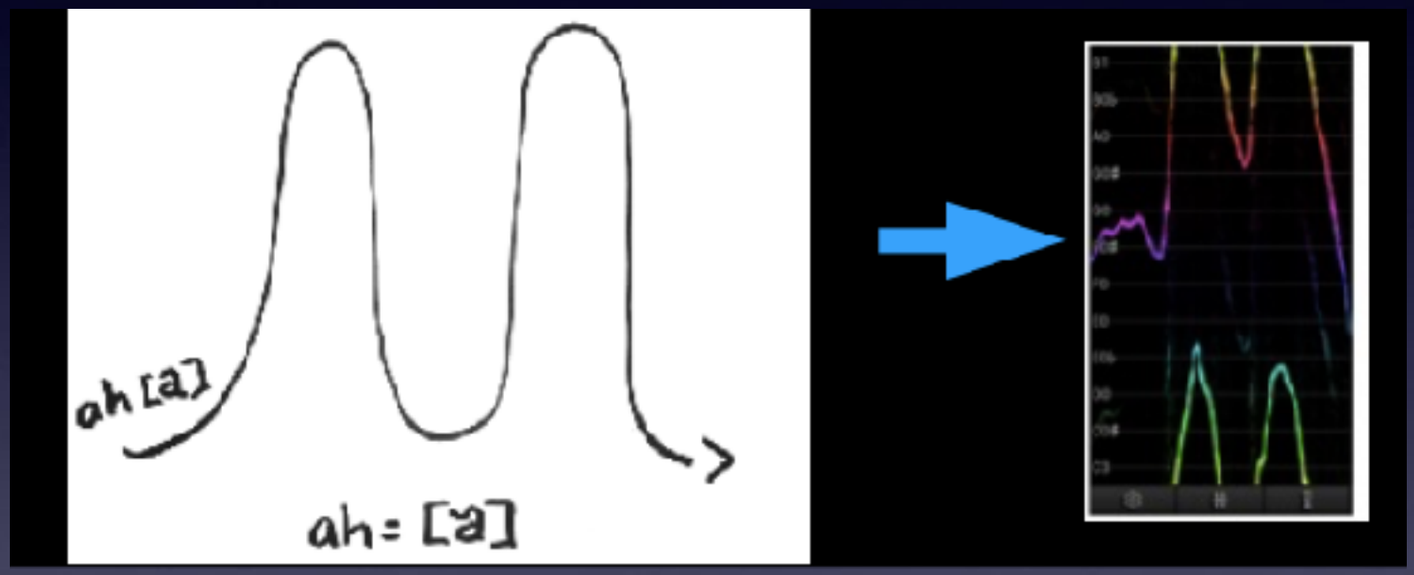


Fig. 1. Main effects of emotion and position in the sentence for F_0 median. Results for the first and second part of the sentence are marked with θ and Ω, respectively. The values over the entire sentence are marked with . Symbols N, A, H, and S represent neutral, anger, happiness and sadness (from Bulut et al. (2005)).

3. MOTOR

- *Voiced sighs* can also give ideas of pitch contour and range without having to "target". Stop and sustain randomly to give singer idea of sustained pitch.
- For higher ranges, /u/ vowel helps to carry voice through acoustic registrations in the sigh. (e.g. 'overvowel' idea from Ken Bozeman)



- /u/ and owl mimicry is also good for extensions: allows for fold lightness and efficient airflow without thinking technically.

*4 = VISUAL BIOFEEDBACK

The most impactful strategy for a wide-range of singers

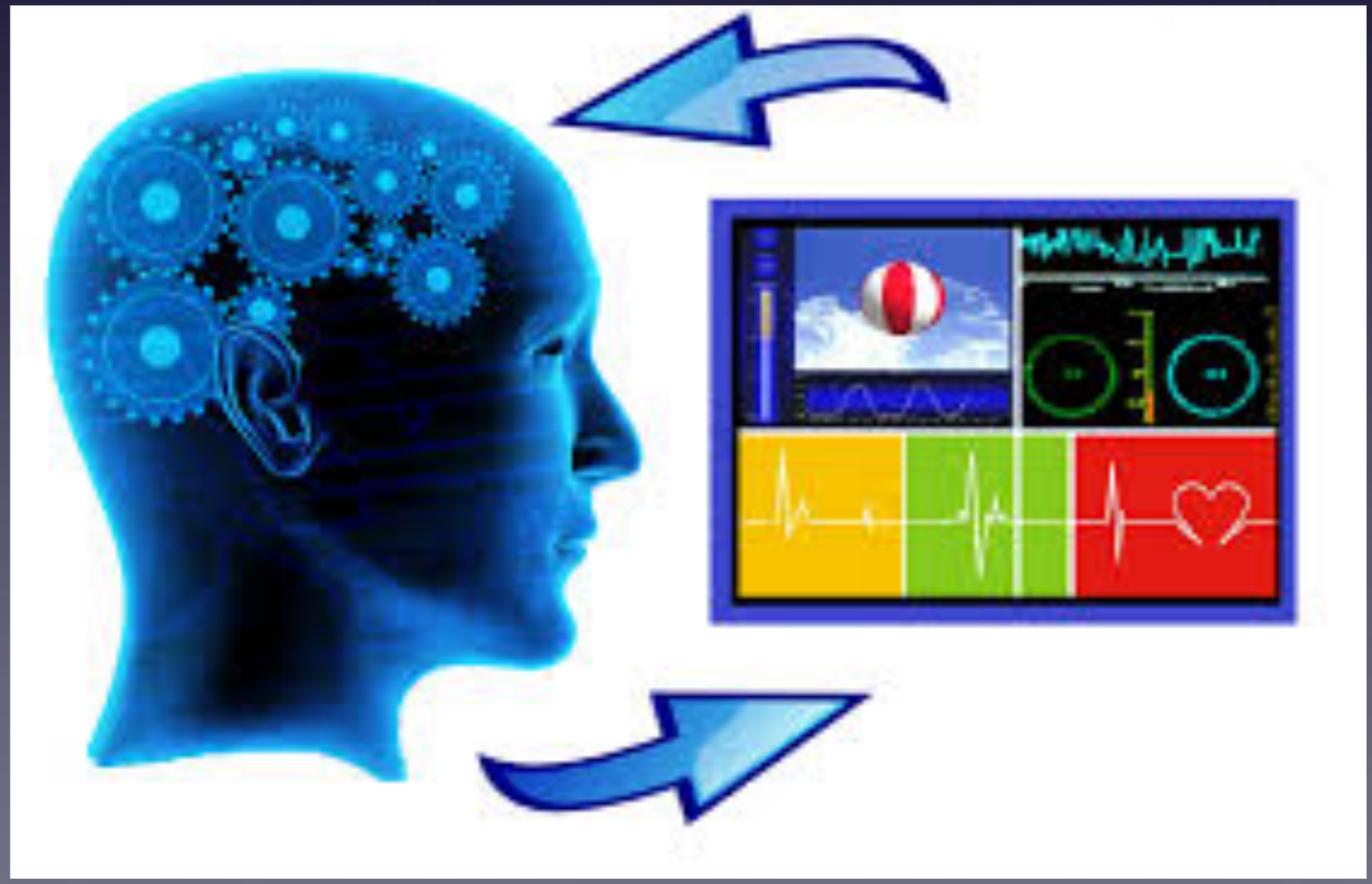
(upcoming JOS paper:

"Mobile Applications and Biofeedback in Vocal Pedagogy")

4*.

Biofeedback

The process of gaining greater awareness of many ***physiological*** functions using instruments that provide information on the *activity* of those same systems, with a goal of being able to *manipulate them at will*



4*.

Biofeedback

Models of feedback-learning indicate that the criteria necessary for success both neurologically and psychologically are:

1. **Perceptibility**= the subject can perceive the bio-signal
2. **Autonomy**= the subject can self-regulate the output
3. **Mastery**= the subject can exert control over the bio-signal
4. **Motivation**=the subject is satisfied by the outcome
5. **Learnability**= the biofeedback enhances the subject's knowledge

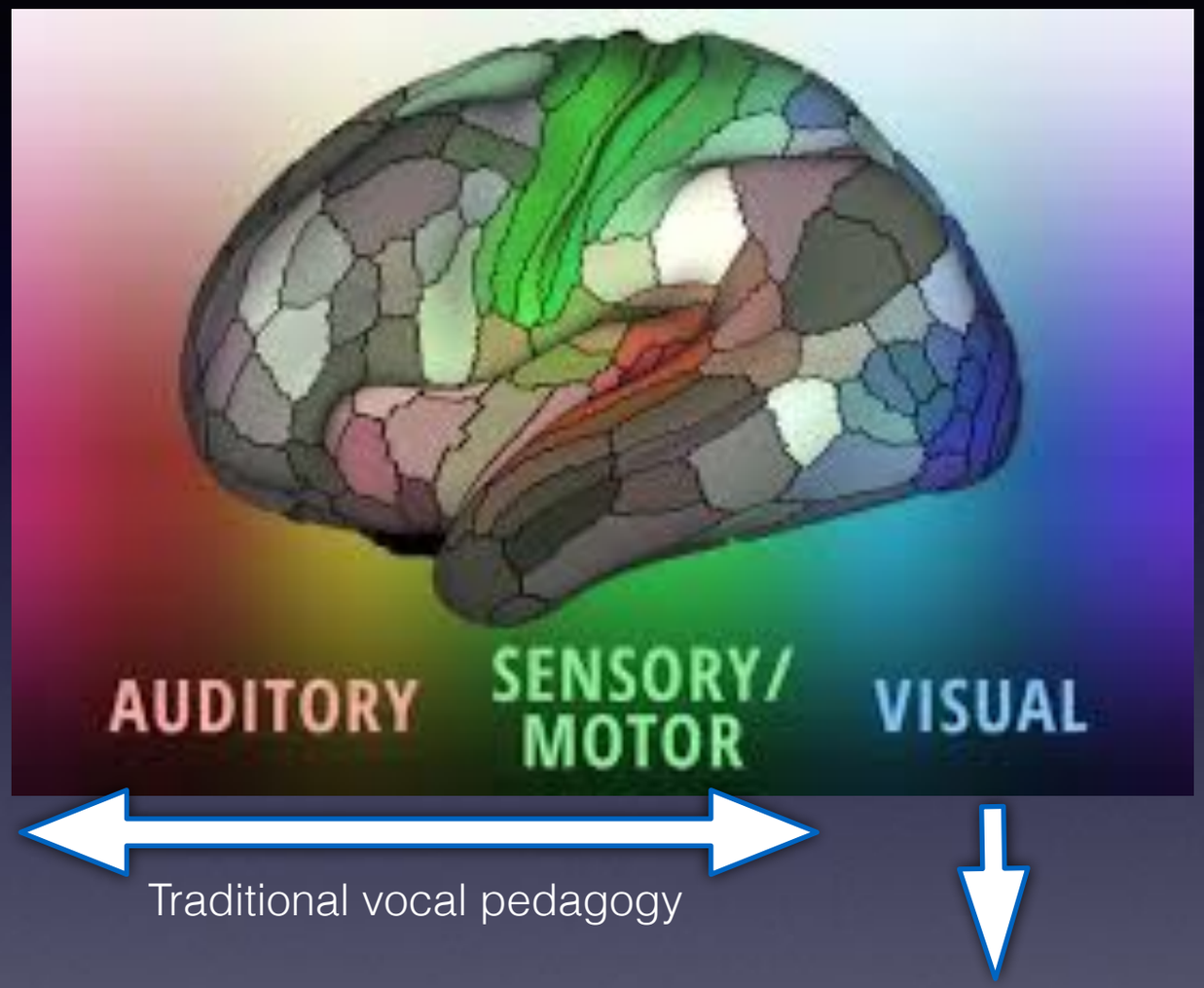
—>Singing and Pitch-Matching fit these requirements

4*.

Visual Biofeedback:

Associating *sound* with *sight*

- Inputs from different parts of brain yield more connections, processing, and integration.



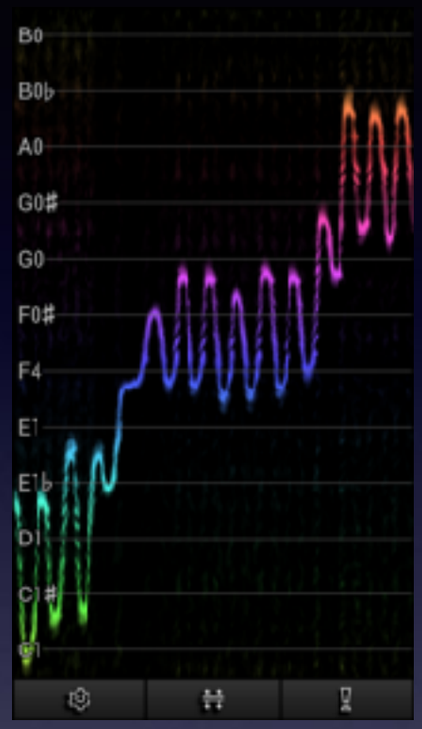
- Singers who struggle with auditory or somatosensory feedback can use an additional, unrelated feedback source to target pitch

4*.

Mobile Applications or Computer Software

Simplest interface:

- Linear graph
- fundamental pitch only
- Color-coded for Hz
  (adds another biofeedback dimension)



PitchLab

VoceVista
(beta)

THANK YOU, BODO MAASS!

4*.

Real-world examples…

4*.

Stabilizing Pitch

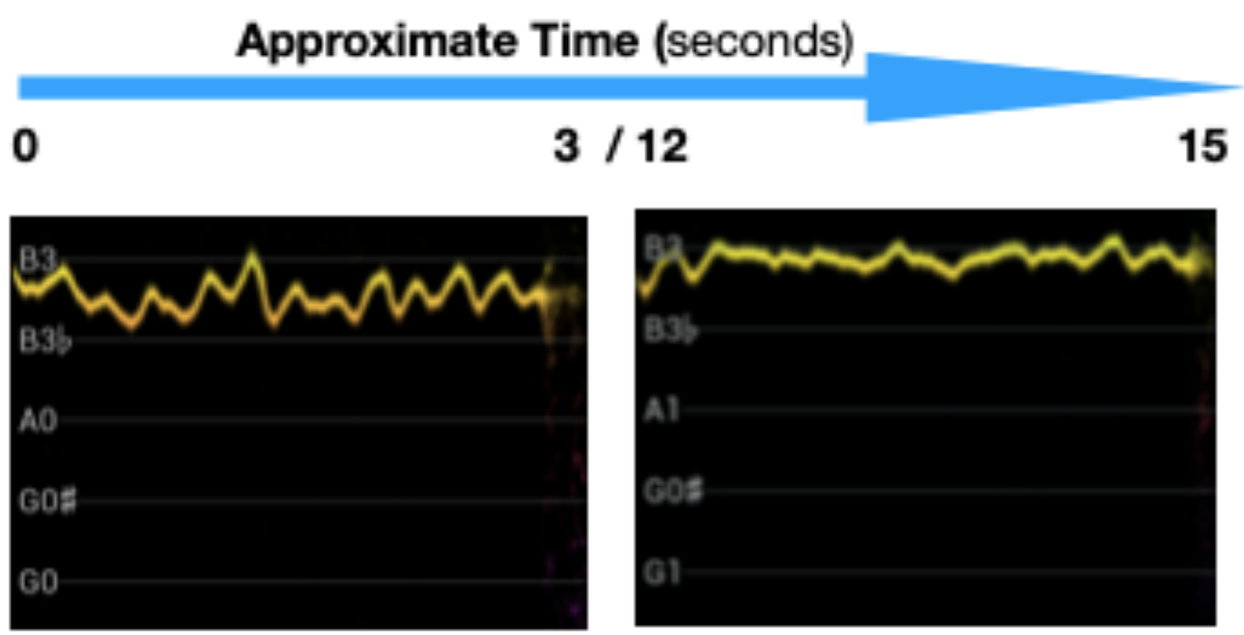
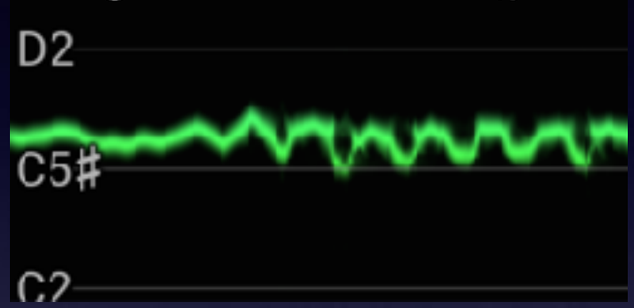


FIGURE 3A. PITCH STABILITY using *PitchLab*.
13 year old female stabilizes B_3 in real time using visual biofeedback only. Sound not necessarily continuous and breaths not represented nor indicated.

4*.

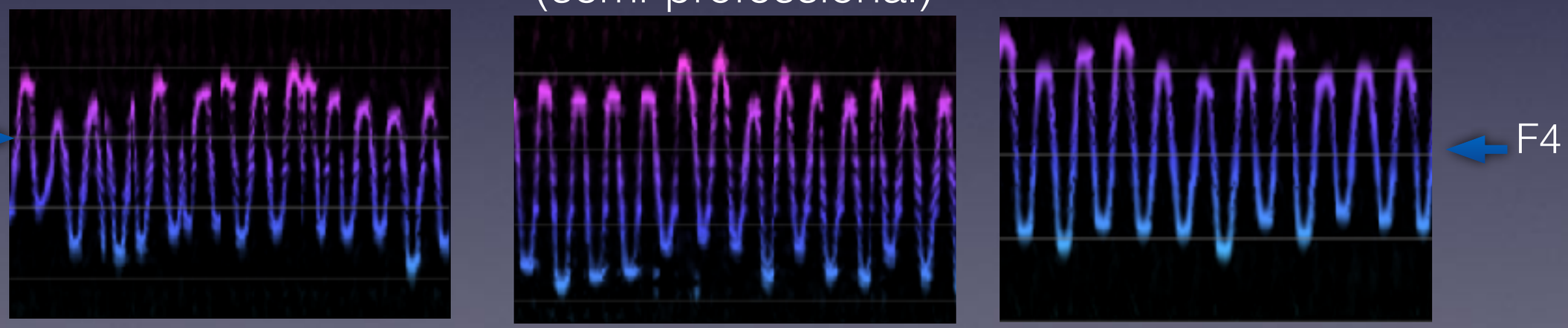
Vibrato and Pitch

straight to vibrant (young)



below pitch/unstable->below pitch/more stable->center of pitch/stable
(semi-professional)

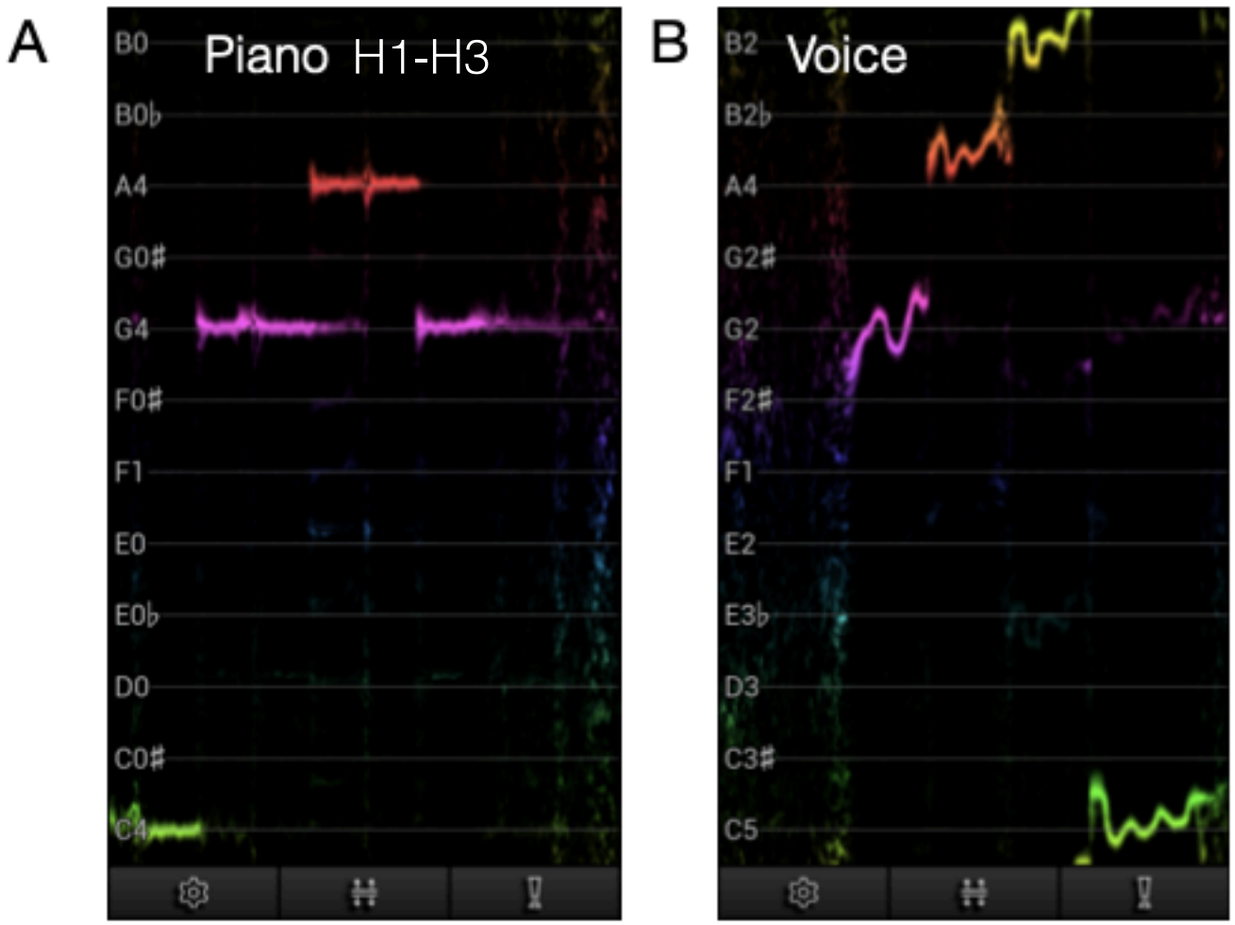
F4



F4

4*.

Pitch Matching: using *Improvisation*



C3. G3. A3 3 G3 G3. ~ A4. ~C4.. ~C4.

Figure 11. COCHLEAR IMPLANT PITCH-MATCHING IMPROVISATION EXERCISE
A 72 year old Ci patient with precious musical experience but had severe pitch-matching loss, improvising on select pitches on the piano. These results were after approximately two month's work on pitch-matching around C_3.

(this work in conjunction with Charles Limb, MZHF grant)

4*.

Other feedback elements…

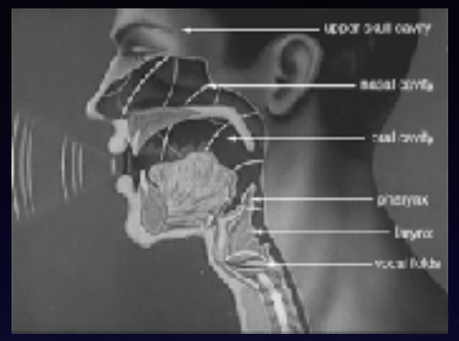
(OR things that just free the brain from trying so hard…)

4*.

Let's PLAY!

—>capitalizing on fun, alternative strategies that result in positive vocalizations

- Somatosensory

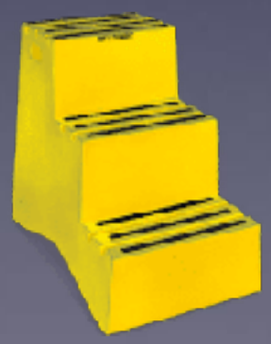


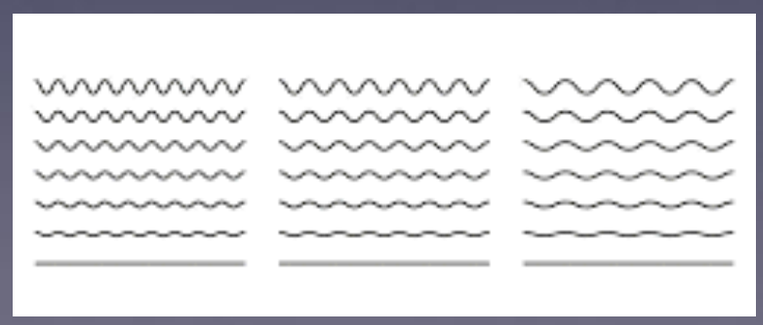
Draw this.....Do this.....Feel This!

- Distraction

Do this.....Or this!

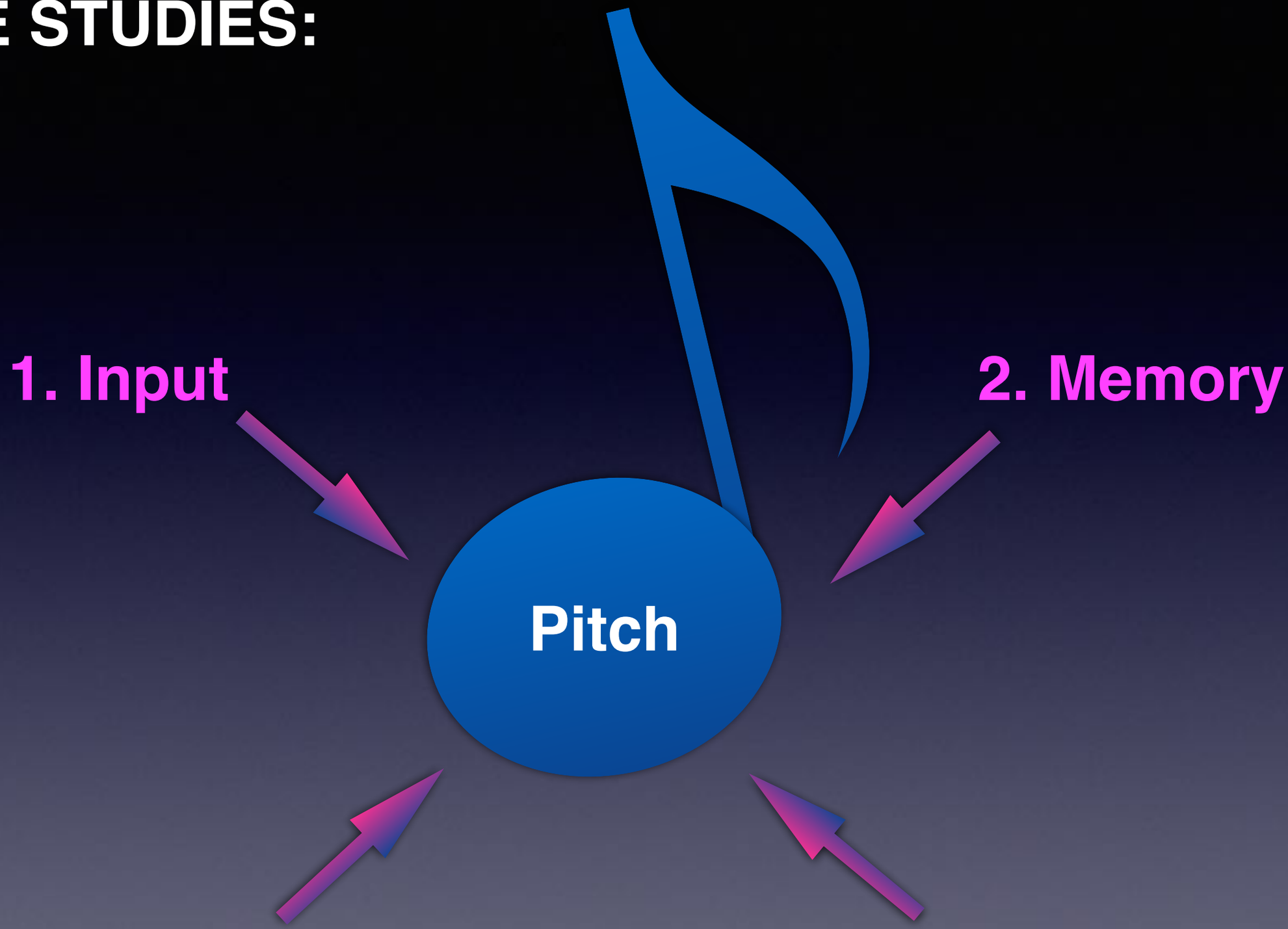
- Imagery





Imagine this.....or this.....or THIS!

CASE STUDIES:



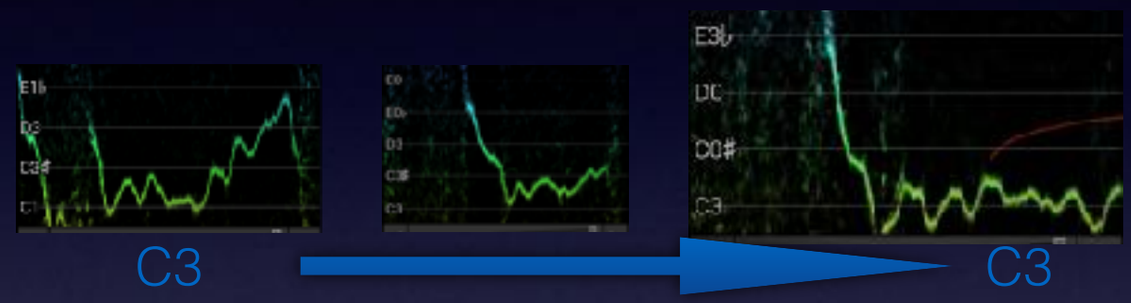
“Gio”, Tech Worker at Google

Goal: To sing a Russian rap song well for karaoke night

Pitch test: Every note played on piano resulted in same, very low Hz response (*precise, not accurate*)

Strategy

- Started in Speaking range (**3**): *“Hello!”*



- C3 became reproducible
- Interval training around C3: in lesson and practice at home using *visual biofeedback* (**4**)
- Input sounds from a pre-recorded low male voice (**1**): much better than piano or my voice.
- Pitch-matching became dependable after about 4 weeks
- Learned “Caro mio ben” AND Russian rap song for Google recital (;

Conclusion

- This case was a clear indication that his brain heard pitches well when he wasn’t singing, but the mind to motor coordination was challenging.
- In addition, real-time feedback of his own voice wasn’t reliable.
- He matched pitches better with a voice in his own range rather than a piano or female voice.
- Given those issues, pitch matching ability resolved quickly using visual biofeedback (**4**), modifying audio input (**1**) and speech/motor correlation (**3**).

Case Study: **“Carl”**

(one that warmed my heart)

MZHF Grant: Cochlear Implant/HA Choir

Dr. Charles Limb, UCSF

(known for his studies on the brain during jazz improvisation)

Dr. Indre Viskontas, SFCM

Heidi Moss Erickson, SFCM

- **Normal Cochlea: 17,000-23,000 hair cells**
- **CI: 16-22 channels**
  - **Each channel encompasses a large receptor region**
  - **Optimized for SPEECH COMPREHENSION**
  - **Hz outside of speech formants (F1/F2) less clear**
  - **Sensitive to noise**
  - **Most cannot discern pitch within a major third**

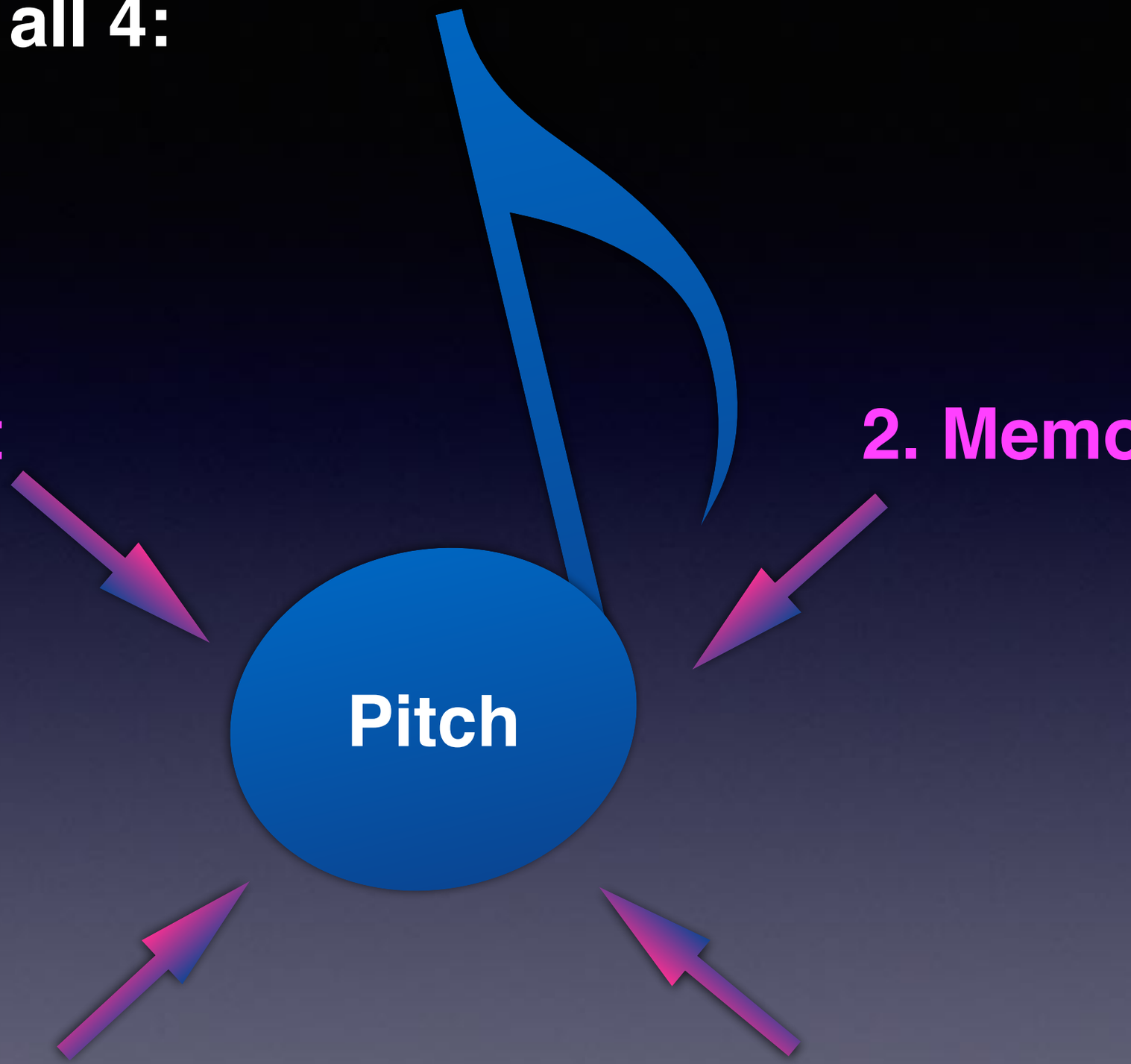
Case Study: “Carl”

(one that warmed my heart)

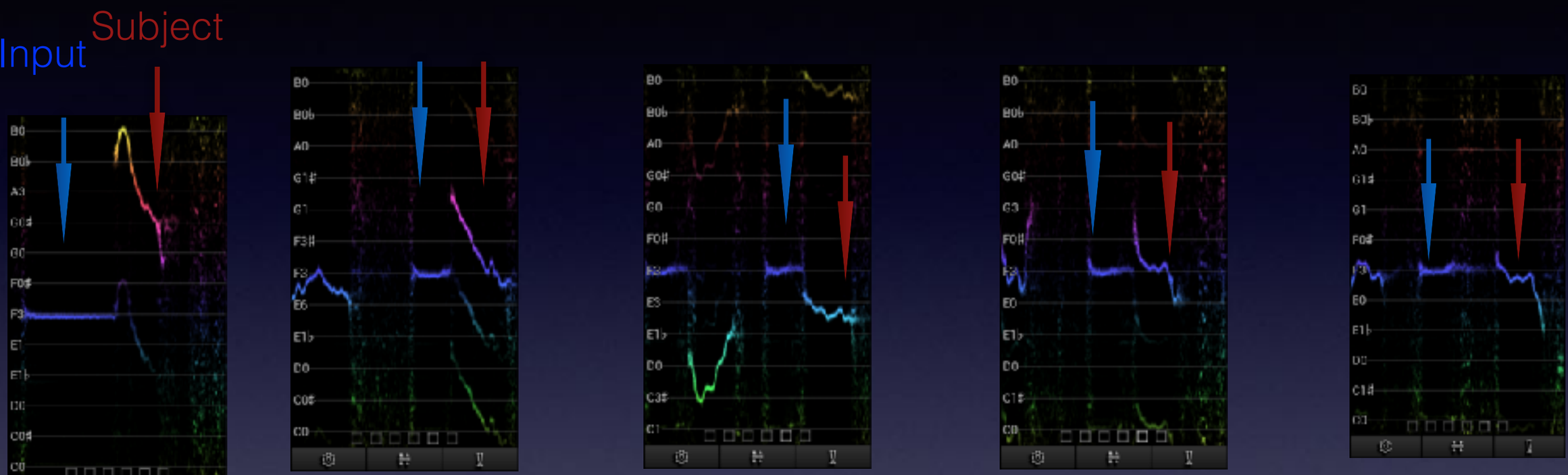
- 73 year old male (in 2018)
- Lost hearing over 30 years ago:
  - worked at SF Airport
  - engine blew up near head without hearing protection
  - complete hearing loss-> legally deaf
- Prior to hearing loss played in an amateur blues/club band
- DEVASTATED by loss and inability to listen to, appreciate, or perform music
- Bilateral, 16 channel CI implants around 1995
- He waited over 30 years, to try and sing again via this study
- Initial tests: he could not match pitch nor aurally discern pitches within a major third
- Lower frequencies (fundamental of his voice type) particularly hard
- I worked with him every week one-on-one for 3 months

So what happened???

‘Carl’ needed all 4:



Visual Biofeedback Case Study

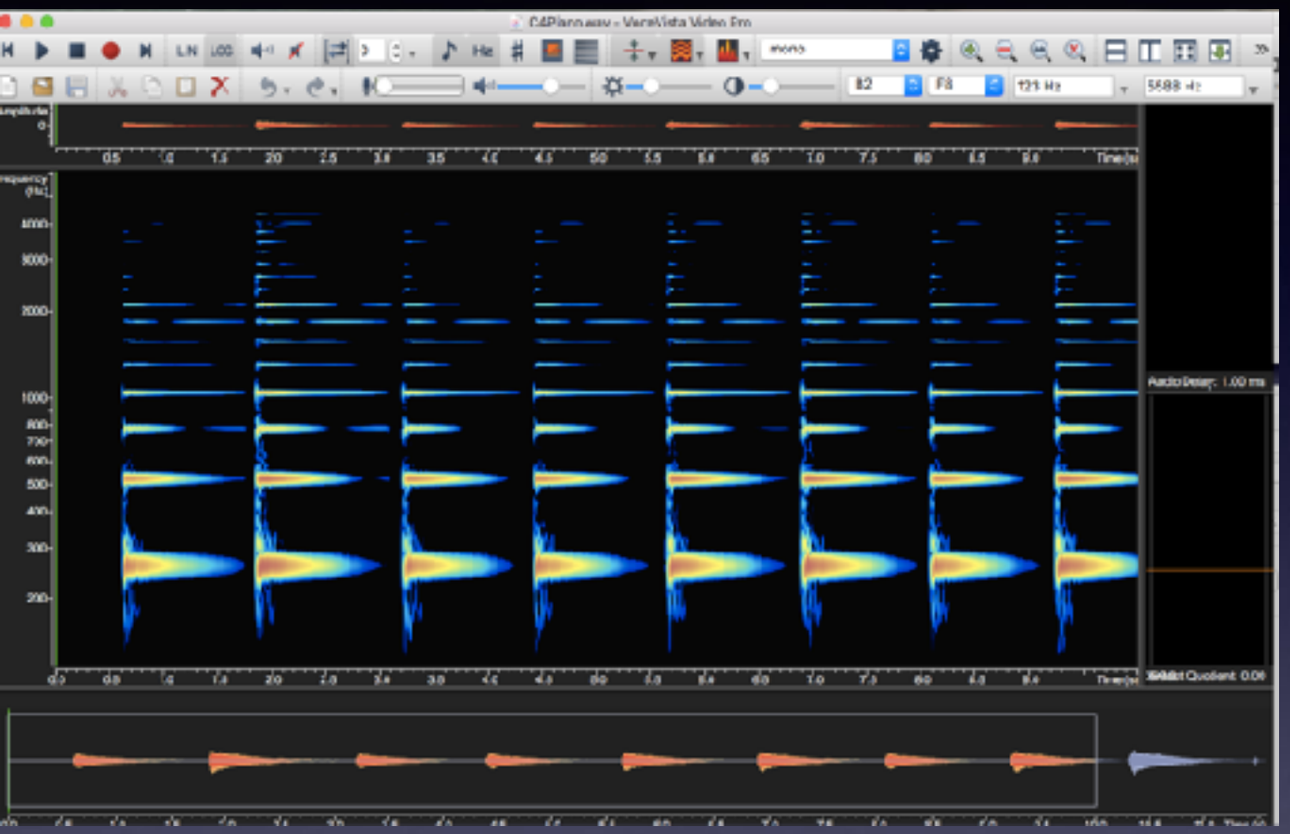


- Input: F3 on piano, filtered piano, male voice, or filtered male voice
- Speak AND sing while looking at app
- Common: overshoot/undershoot/no stability (slide)
- I would give up/down hand signals to refine
- Mental and kinesthetic awareness increased
- Finally was able to stabilize reproducibly ~2 months
- Reinforce as much as possible

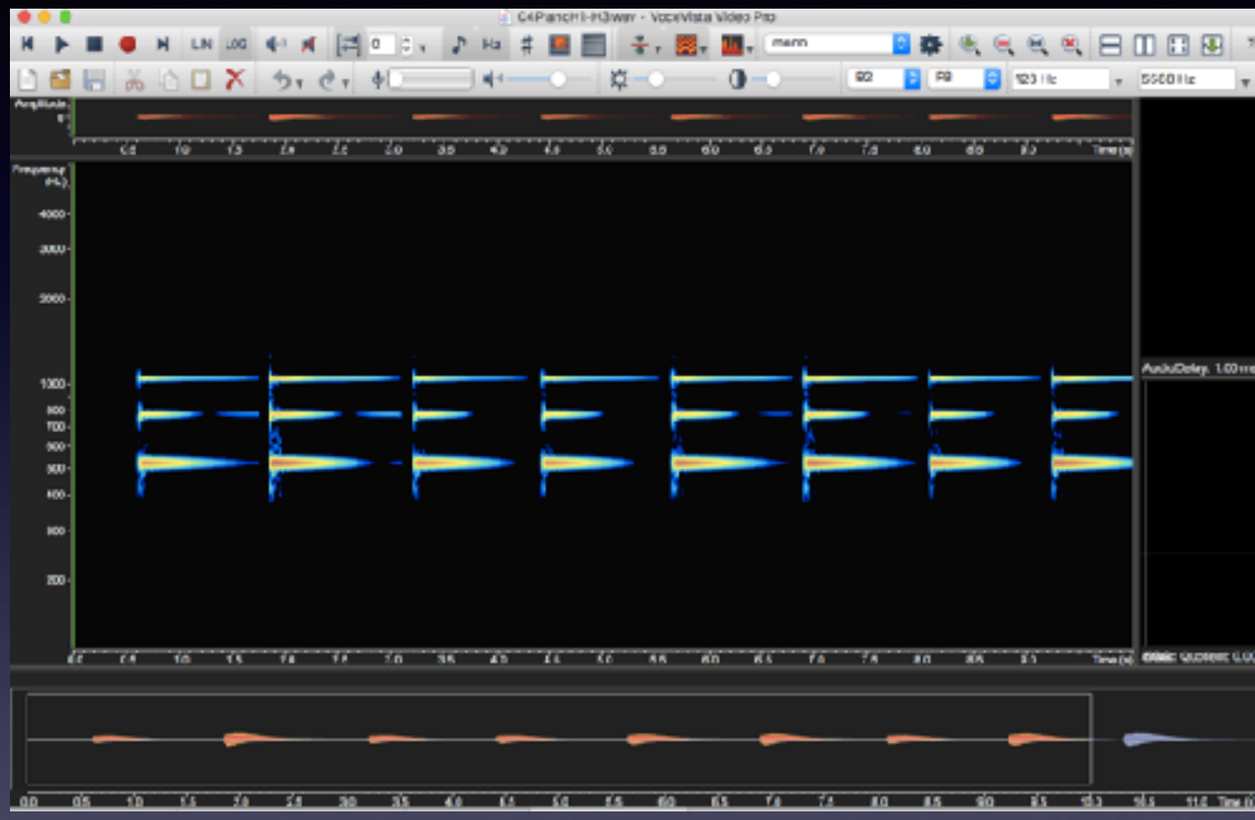
Reduce Input Hz

To reduce noise/capitalize on enhanced Hz:
CI optimized to discern speech/formants

C3



C3 H2-4

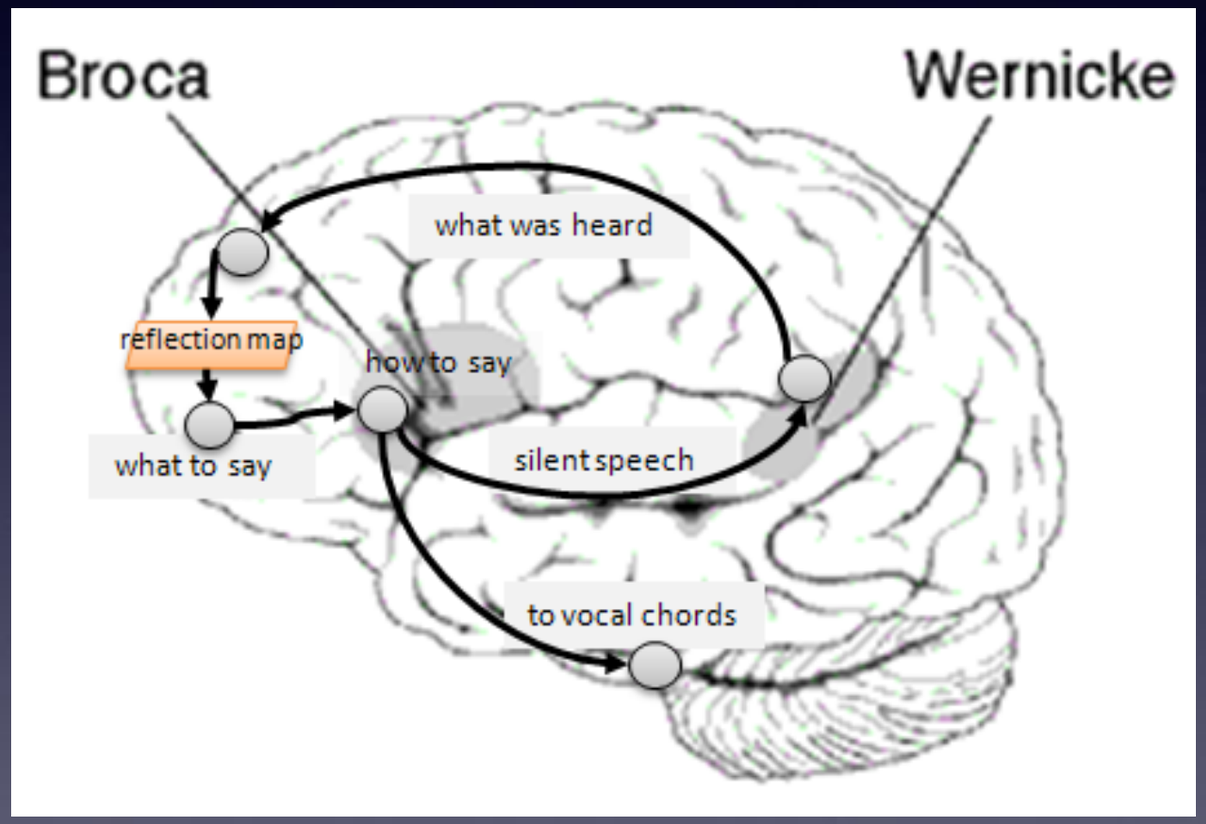


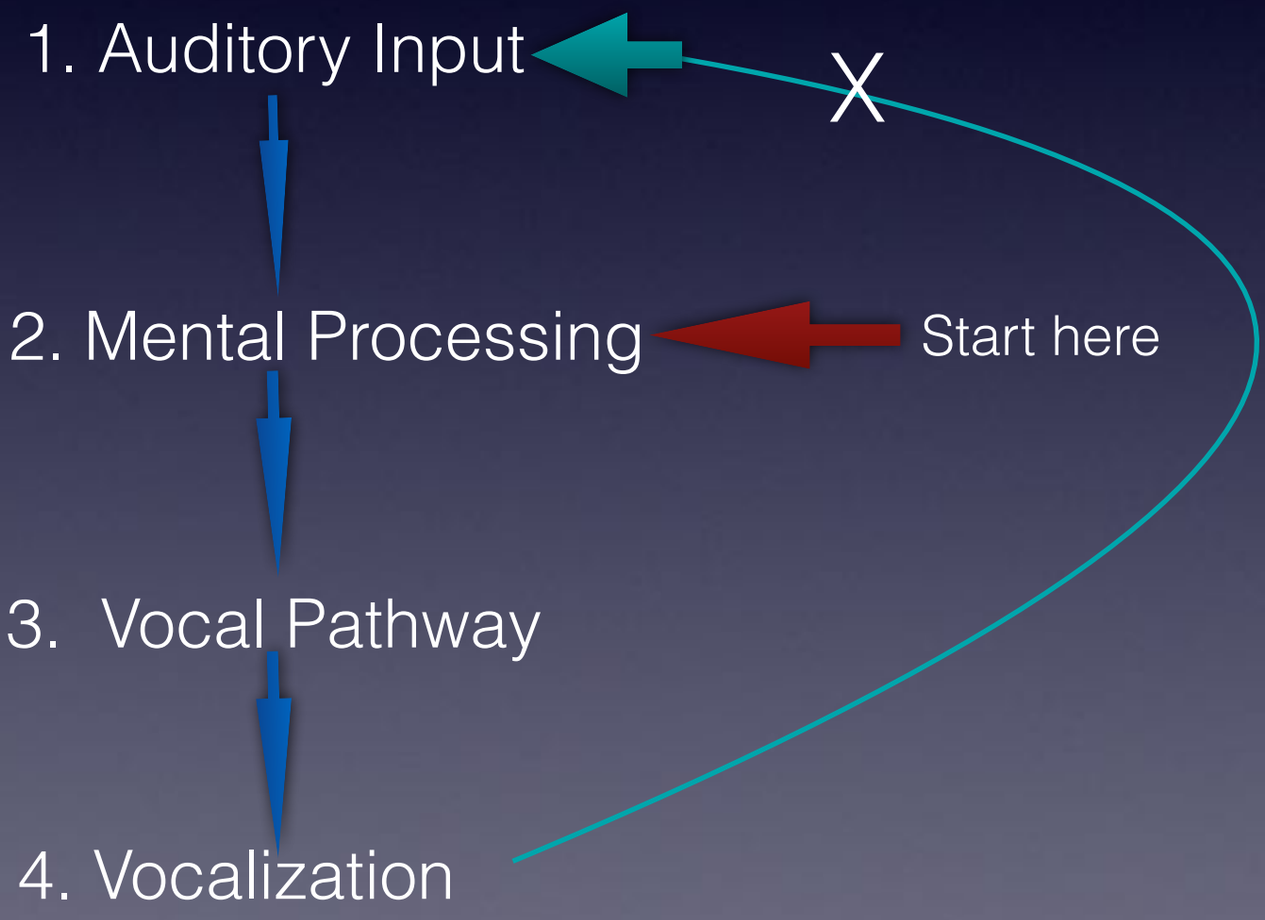
->helped tremendously!

No fundamental!!!
The brain interpolates
(psychoacousics)
“Carl” preferred this input
(CI optimized for F1/F2)

Mental Intention

->could we capitalize on his MEMORY of songs he learned prior to hearing loss?





Mental Intention

Case Study

“Fly me to the moon…”

His favorite song…But can no longer listen/sing because to HIS ear, sound very off and wrong…

I asked him to sing *wearing earplugs* so there would be minimal conflicting feedback.

It was PERFECT.

His MIND remembered. His VOICE remembered. His EARS just couldn’t hear it!

Goal: Increase reproducibility
USE as template for new music: relationships

Mental Intention

Case Study

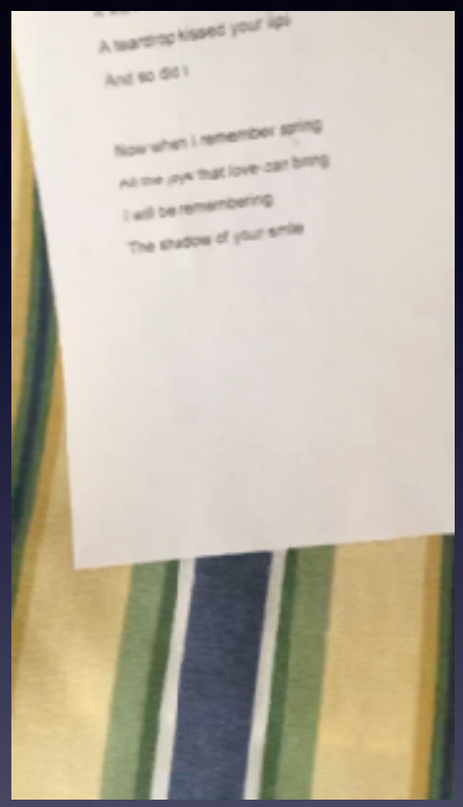
“Fly me to the moon…”

—> after 3 months:

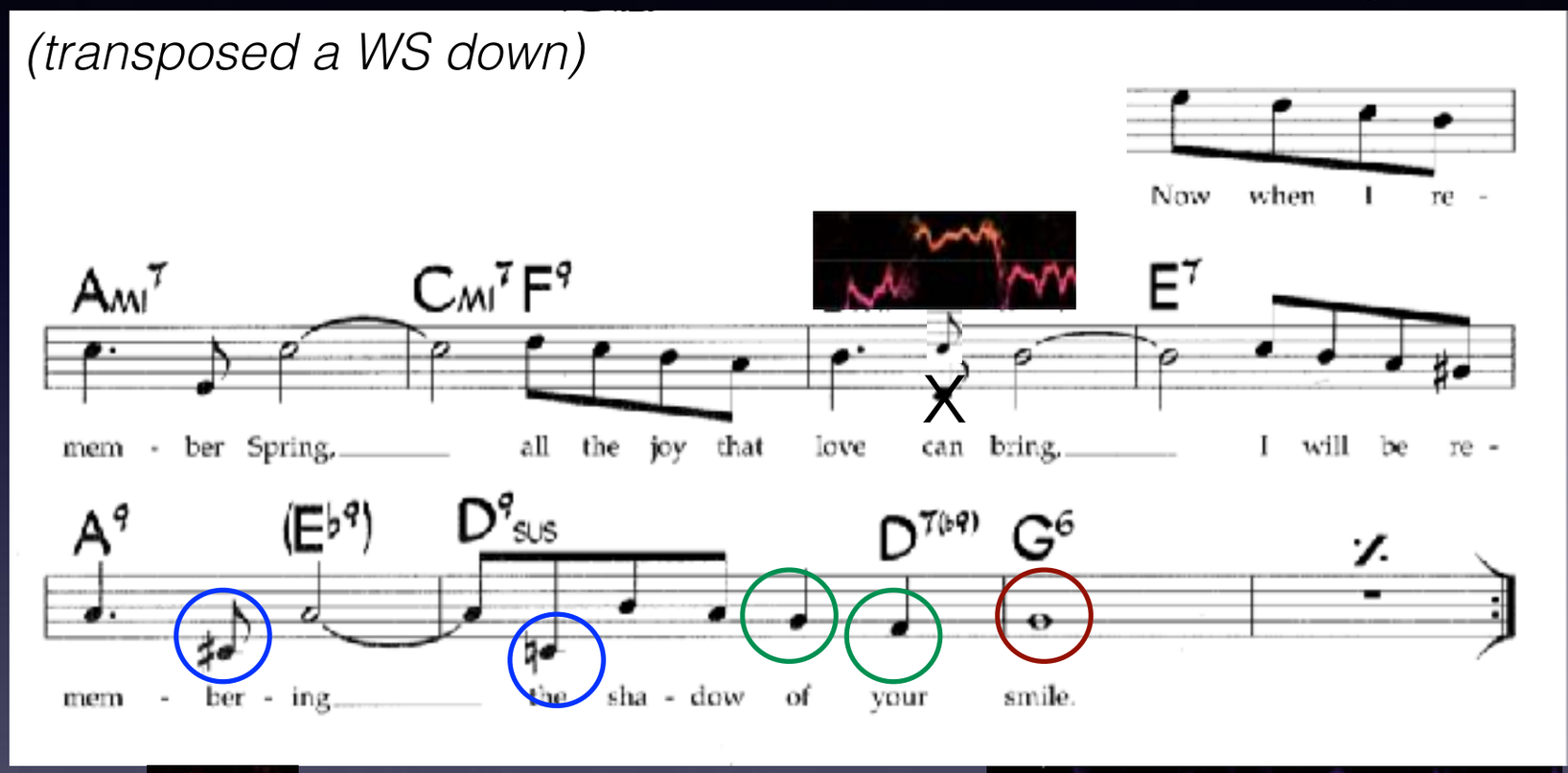
- Pitch matching more reliable
- Sang “Fly me to the moon” without fear
- Began to RECOGNIZE the song!
- Could learn new songs easier
- Emailed me asking me for choirs to join (:

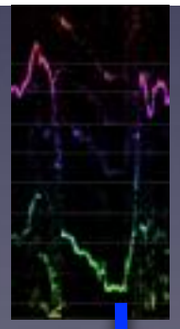
“Carl”, a CI Patient: 2 year follow up:

“Shadow of your smile”: familiar pre-CI, but never sung.
No longer needs feedback!
NOTE: semitones and natural corrections to target!!

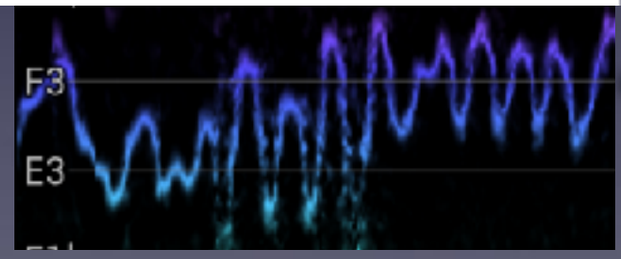


(transposed a WS down)





“-ber” targeted

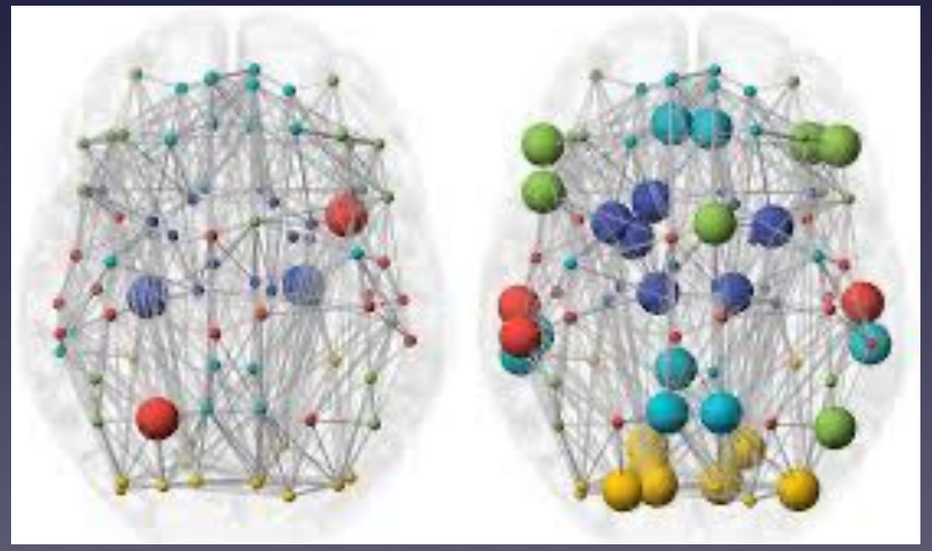


F3!

“smile” evened out naturally

“Carl”, a CI Patient: 2 year follow up:

- His brain re-wired.
- He now discerns pitches *within* a major third, including challenging semitones.
- He no longer needs visual biofeedback.



From this…. to this

- “Carl” said he LOVES to sing again.
- He joined a regular choir at Christmas last year.
- We cannot give up on these singers!
- The joy of music is immeasurable.

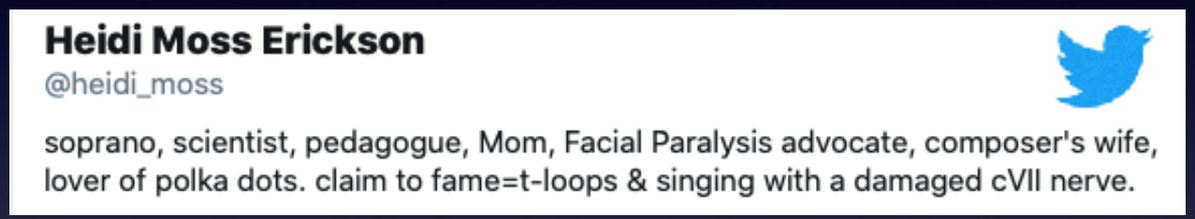
Everyone should be able to sing*.

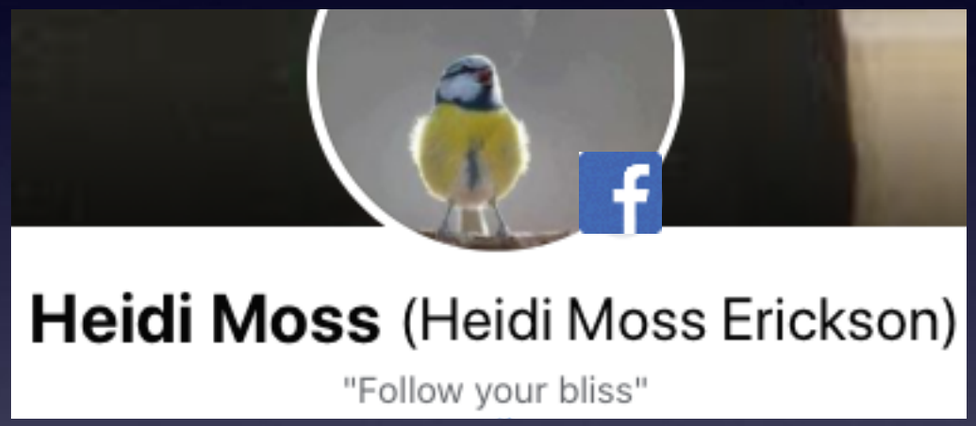
**but not everyone can…however, we can help!*

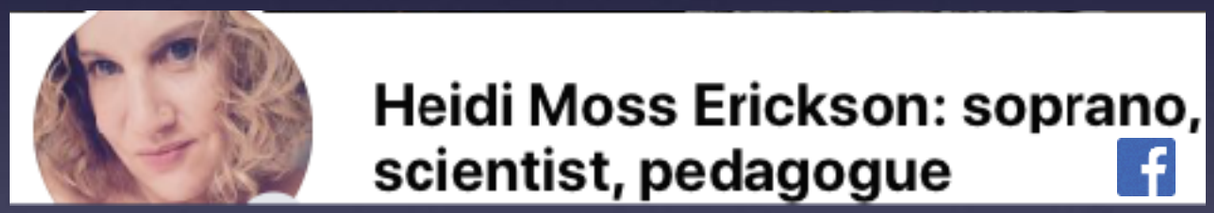
We are lucky to have a brave…

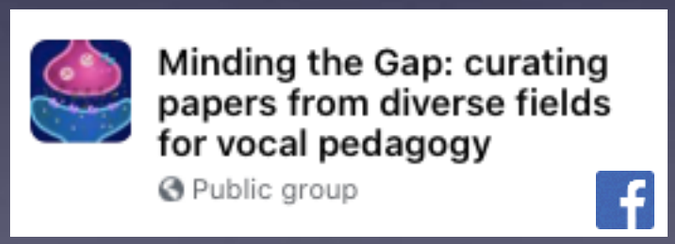
CONTACT ME!!
I like making new friends…

hmoss@sfcm.edu
bellscanto@gmail.com









(website under construction: www.heidimosserickson.com)

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Lab members

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