HOW FAR ARE WE IN UNDERSTANDING NEUROSCIENCE AND VOICE

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Introduction: The fluency and the reliability of voice production depends on a mechanism that links motor commands and sensory feedback, as the main signal processing. Studies of the neural organization of fMRI identifies regions where activity during speech production is modulated and where predicted outcome is regulated. We have earlier studied phonetograms of young brain damaged people, showing no intensity modulation of frequency in a two octave test. We have also found a relationship between measurements of high speed films and pharmacological treatment in dystonia patients, showing that these methods might assist in diagnosing brain defects related to voice.

Objectieve/Conclusion: The focus here is to get on to understand how neuroscience aspects can help us in voice treatment documentation. This presentation seeks to show how far we are (Figure 1-4).
The understanding of the vocal folds, the voice physiology and brain regulation is important and has many future aspects for qualified voice education as well as pathology. We refer to three groups of techniques of music training (Rhythmic auditory stimulation (RAS), Patterned sensory enhancement (PSE), Melodic intonation therapy (MIT) and neurological music therapy (NMT)) that has some evidence and need for further documentation. Still in the future genetic and hormonal regulation of voice should not be forgotten in combination with neuroscience.

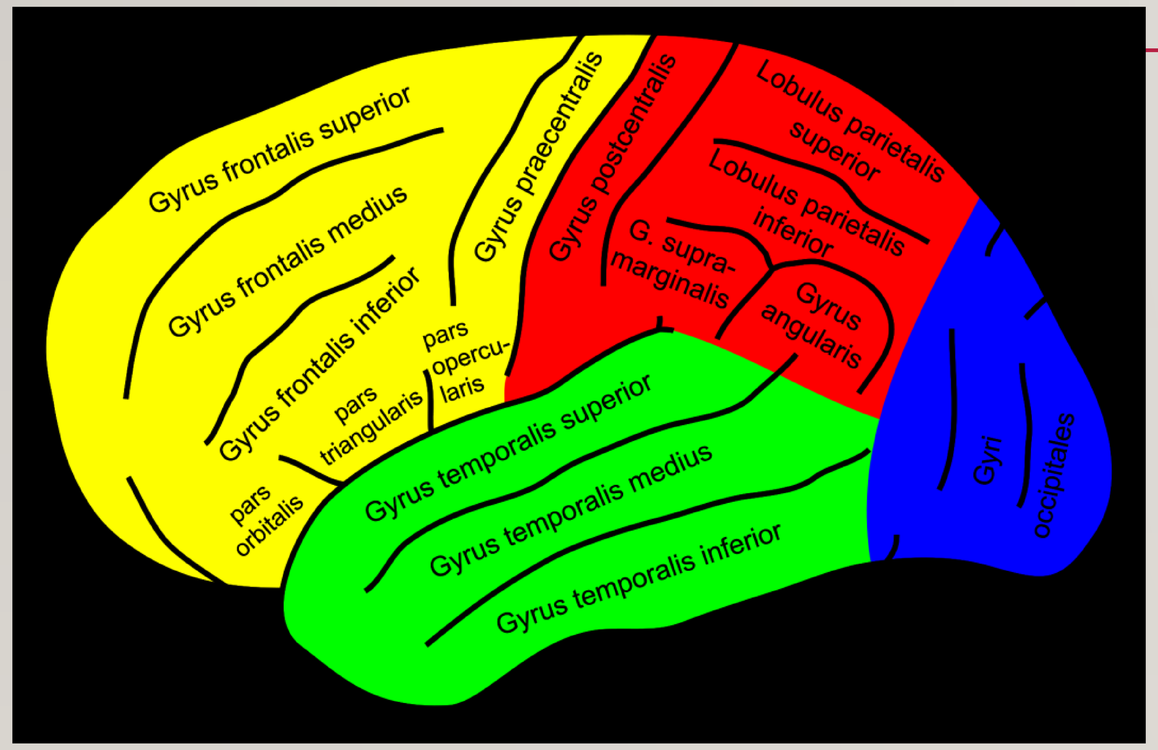

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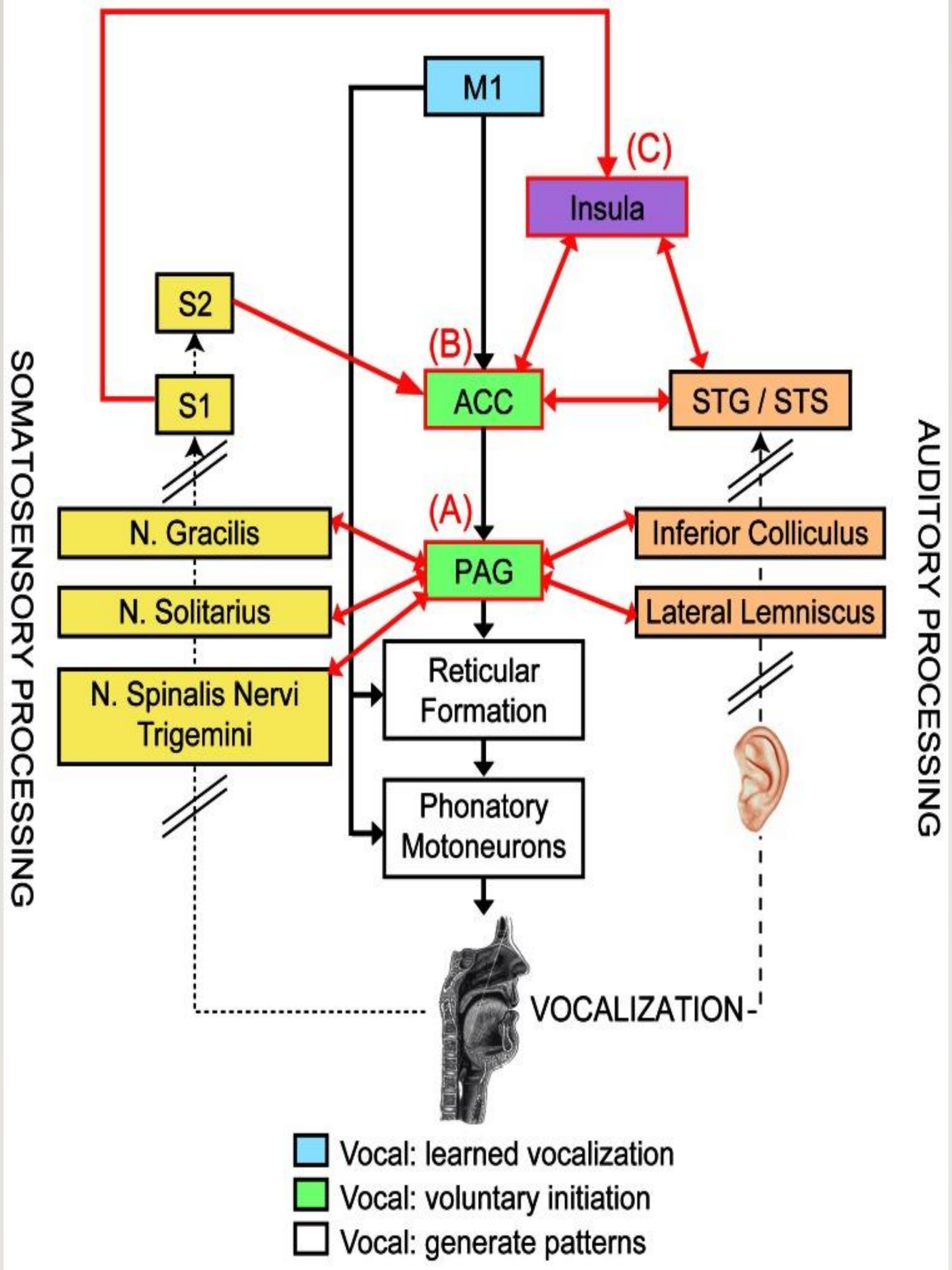
Figure 1) Superior temporal and middle temporal gyri activation during voice function

The middle temporal gyrus and inferior temporal gyrus serve language and semantic memory processing Middle temporal gyrus and inferior temporal gyrus gray matter volumes were measured in 28 healthy male subjects by using high-spatial-resolution MRI.

Superior temporal gyrus:

- The superior temporal gyrus contains the primary auditory cortex, which is responsible for processing sounds. Specific sound frequencies map precisely onto the primary auditory cortex.
- This auditory (or tonotopic) map is similar to the homunculus map of the primary motor cortex.
- Specialized for processing combinations of frequencies.
- Specialized for processing changes in amplitude or frequency.
- Essential structured involved in auditory processing as well as in the function of language in individuals.
- Is an important structure in the pathway consisting of the amygdala and prefrontal cortex, which are all involved in social cognition processes.



Zarate, J. M., 2013: *The Neural Control of singing*, Frontiers in Human Neuroscience. Review 7: 237

Figure 2) Motor and sensory control systems of voice production

The vocal motor control hierarchy starts with the generation of complete vocal patterns from the reticular formation and phonatory motor neurons (white boxes) the next highest level of control (green boxes) stems from the anterior cingulate cortex (ACC) and periaqueductal gray (PAG), which can initiate and emotionally motivate vocal responses.
The highest level of vocal control comes from the primary motor cortex (M1, blue box; its modulatory brain regions are not depicted), which is responsible for producing learned vocalizations.
Somatosensory feedback (arrow) from various receptors distributed throughout the vocal tract is processed in the ascending somatosensory pathway (yellow boxes, left; black slanted lines indicate that only selected regions of this pathway are shown) and transmitted to the primary and secondary somatosensory cortex (S1, S2).
Auditory feedback (arrow) from the vocalization is processed by the ascending auditory pathway and auditory cortical regions (orange boxes, right).
Potential neural regions that integrate sensory feedback processing with vocal motor control are indicated with red-outlined boxes, and their shared connections are represented by red arrows: **(A)** the PAG, **(B)** ACC, and **(C)** the insula (in purple, classified as a higher-order associative area).

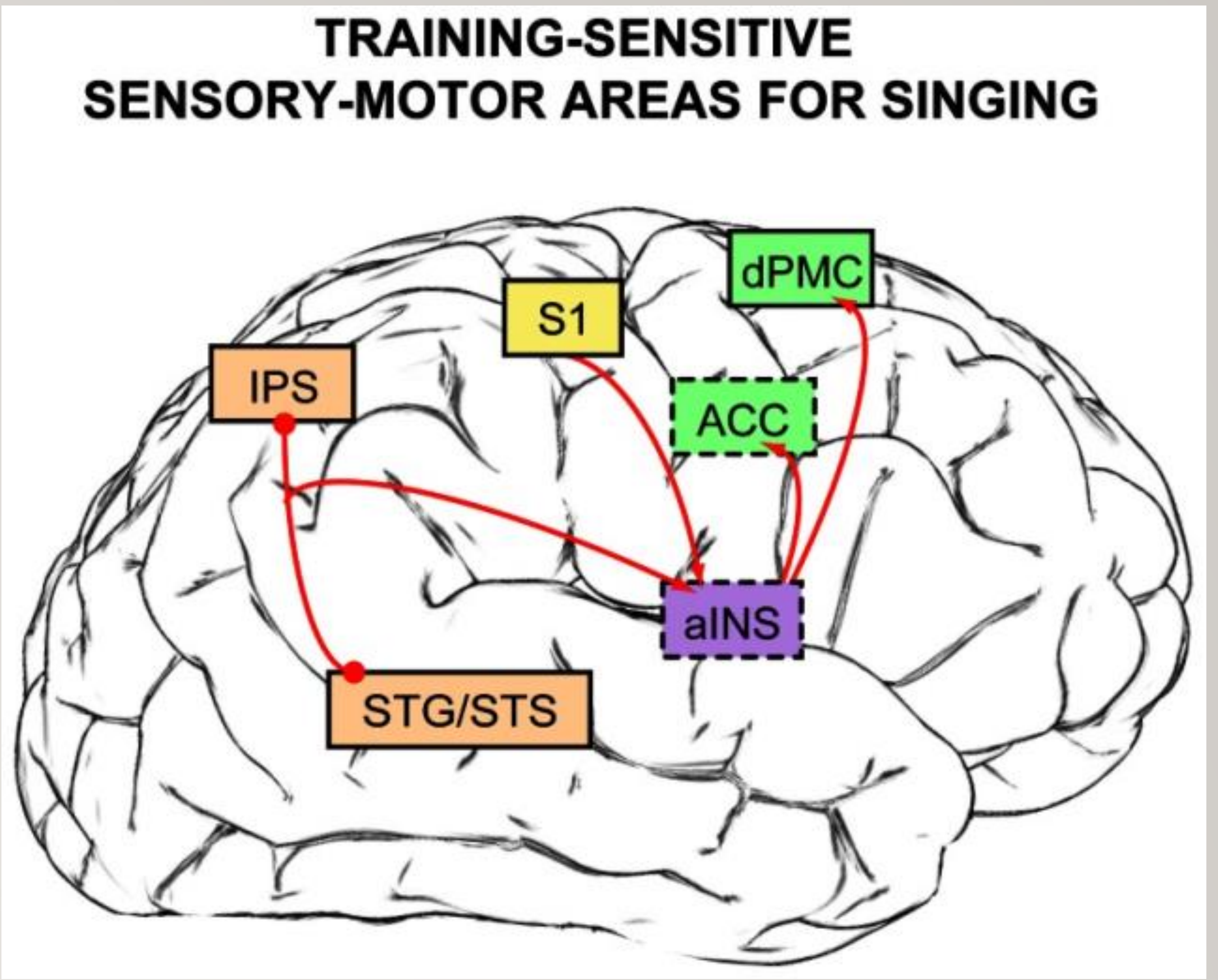


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Figure 3) Within the functional network, cortical substrates are specific for the sensory-motor control of singing pitch sensitive to the amount of vocal training which have been identified as *IPS for auditory processing* and *transformation for motor output* (orange box), *S1 for somatosensory processing* (yellow box), *anterior insula* (both for auditory-motor integration and somatosensory feedback gating; purple box), and premotor regions for vocal motor preparation and response initiation (dPMC and ACC; green box)

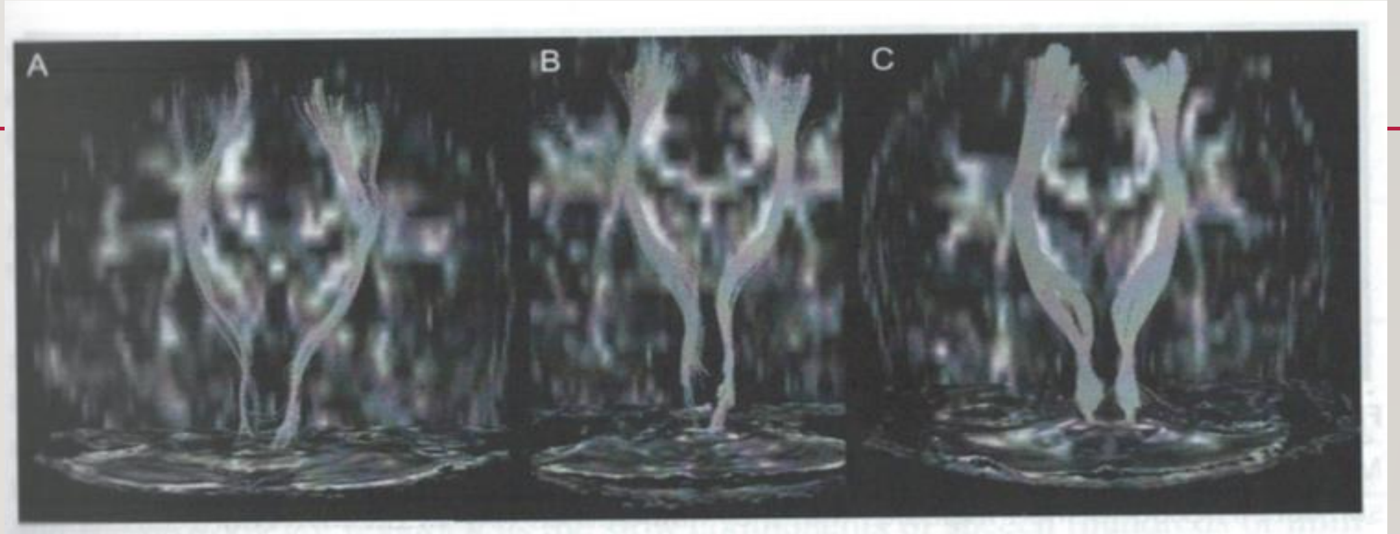

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Figure 4) With training musicians get many afferent stimula to the brain, which results in that the brain adapts - and improves the corticospinal tract which is a descending efferent motor pathway carrying signals from the brain down the spinal cord to the target muscle or organ.
A: Corticospinal tract of a non-musician child.
B : Corticospinal tract of a non-musician adult.
C: Corticospinal tract of a adult musician.

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