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Cognitive insights and implications of singing: actions, proprioception, and perception in vocal performance.

Juanita Leal

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Mary Pappert School of Music

Mentor: Dr. Zvonimir Nagy

Juanita Leal

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Introduction:

Studies in vocal performance have suggested the interdependence of cognitive reactions and performative proprioception. This interdependence indicates an introspective self-evaluation process during the act of musical performance. When affected by singers' judgment of vocal production, self-evaluation and perceptive processes potentially change due to implicit competitive roles in the music performance environment.

Singing can affect a person's body in many ways, beginning with the brain's responses when completing this task in different environments. Likewise, singing can relieve stress, stimulate the immune response, release endorphins, and improve overall mental health and mood[1]. The process of singing also gets affected by the primitive parts of our brain that send responses to stimuli that it might sense as dangerous. For example, being stared at by an audience. The relationship between cognitive processes and singing leads to the following questions: what are the specific cognitive functions and processing when singing, and how does each person perceive their singing voice? How does the singer respond to vocal performance within the critical artistic and academic environment? What makes the

[1] Stanborough, R. 2020, November 10. *10 Ways That Singing Benefits Your Health. https://www.healthline.com/health/benefits-of-singing*

brain relate the sound it senses to our bodies, and what cognitive process is involved in judging said sound?

In this project, I delve deeper into the ways the brain recognizes aspects of vocal sounds, how it reacts to the process of singing, and how it can identify them as its own in two different environments: the controlled practice space and the variable performance space. By reflecting on existing research and conducting a series of interviews with college voice students, I aim to understand how they perceive their voices during the act of vocal performance and whether they notice a change in said perception while they think they are being judged. In the end, I will compare the results of my interviews with the literature reviewed to determine whether perceptual aspects of singing map onto the results that researchers have found.

Cognitive studies on singing:

Singing is as complex a process as is reasoning, thinking, and memory storage. What all these tasks have in common is that they are distributed across different parts of the brain. It has been studied that while a person is singing, the left temporal lobe, right temporal lobe, frontal lobe, occipital lobe, and parietal lobe become active to coordinate the number of single processes that are required when completing this task.

> The *temporal lobe,* located above the ear, is the most significant for hearing. It contains the part of the brain known as the auditory cortex. […] The *frontal lobe*, located behind the forehead, is associated with executive functions, learning, memory, and planning. It contains the motor cortex and is implicated involuntary muscle motion, which would include altering the pitch or timing of a note. […] The *occipital lobe* at the back of the head is associated with vision and is relevant to singing from the standpoint of processing signals of moving lips, facial expression, and bodily rhythmic motion of fellow choristers or a choral leader, or checking in a mirror one's posture and motor behavior when practicing. The *parietal lobe*, on the top, […] is well-positioned to receive and integrate information from the different senses: auditory, visual, tactile, skin receptors, kinesthetic (motion perception), and proprioceptive (position of muscles and joints). It contains the sensory homunculus, a distorted map of the body representing sensory responsiveness, with disproportionate space dedicated to sensations from the vocal tract (tongue, lips, pharynx),

> as well as the nose, eye area, and fingers/hand. (Cohen, A. J., Levitin, D., & Kleber, B. 2020, pp. 2-3)

As explained by Levitin, Cohen, and Kebler in *Brain mechanisms underlying singing* (2020), there is a hierarchically organized brain system that has parallel pathways for both controlled vocalization and voluntary fine-motor control of emotional voice production. These two pathways consist of: first, activation of the *larynx/phonation* area of the motor cortex that trigger movement by the different sets of muscles that manage the vocal fold closure generating sound when the air passes through them; and second, the activation of a brain region that plays an important role in autonomic function, motivated behavior, and behavioral responses to threatening stimuli – the periaqueductal gray (PAG). Said pathways are connected to limbic structures that are involved in emotional vocalization and voice initiation (like the amygdala, hypothalamus, and hippocampus), and while simultaneously activated, they could potentially generate an emotional response in a singer experiencing any degree of performance anxiety. This reaction would explain why the performer could go through a lack control over his or her voice while singing in front of an audience.

Singing requires the coordination of three complex cognitive processes in addition to what has been mentioned above: forming a mental model of the song that will be performed; making the laryngeal adjustments necessary for accurate pitch production, as well as timbrical representation of the model in mind; and auditory and motor feedback to determine whether the targeted sounds are reached and making modifications if it has not.

Therefore, not only does singing require the brain activity that is fixed to configure the muscular activity to produce sound, but it also involves processes behind proprioceptive, perceptive, and kinesthetic responses to gain a better understanding of how the task is being accomplished. These processes rely on the *somatosensory cortex,* which transmits feedback from the vocal tract, larynx, and respiratory systems while the *auditory cortex* provides information from auditory feedback, helping the brain connect the different parts of the brain that account for the recognition of one's sound.

Likewise, voice teachers widely discuss the importance for a singer to be able to recognize and internalize the kinesthetic aspect of voice production to make structural changes in the

production of the sound. These changes aim to develop a strong technique, which would be the ultimate tool to gain an effective muscle memory that would not be strongly affected by the activation of the PAG while performing.

For better clearance of the aspects that this research is covering, the definitions of *kinesthesia, proprioception,* and *perception* are the following:

- **Kinesthesia:** the ability to sense the position and movement of different parts of the body using sensory receptors (proprioceptors) in joints, limbs, and muscles. Kinesthesia is a key component in muscle memory and hand-eye coordination and its discovery led to the study of proprioception.

- **Proprioception:** although used interchangeably with kinesthesia, proprioception refers to "the sense of relative positioning of neighboring parts of the body". Part of the functions of proprioception includes the perception of joint position and movement, muscle force, and effort.

- **Perception:** the process of becoming aware of objects or processes using the senses.

Subjects:

For this research, five classically trained singer subjects in their first or second years of master's degrees were asked to record two videos, as well as answer a three-part questionnaire regarding the perception of their voice. For the two videos, the singers have been told to record one piece of their choosing in two different settings: the first, in a practice session where they did not feel pressured; and the second, a formal recording of a said piece that was going to be sent to a hypothetical panel of juries that would evaluate their performance[2]. The purpose of the questionnaire is to determine various aspects regarding the perception of their voices:

[2] It is important to clarify that the singers believed that the recordings were in fact sent to the panel of juries.

1. How they perceive characteristics of their sound regardless of what other people have told them about their voice.

2. What they have been told about their voices and how this can affect perception and proprioception of their sound when singing.

3. What part do kinesthetic and proprioceptive aspects play in the perception of their voices.

4. Whether their perception of their voice is changed when being in an anxiety-inducing situation when performing.

Results:

General aspects of their perceptive experiences:

The first part of the questionnaire was a review of general aspects that a singer might take into consideration when referring to his or her own voice. These include how they would describe their own voice, the impact of auditory perception, what other people have expressed they hear in the singer's voice, and what perceptive aspects help them relate the sound they are hearing to the sensation of their bodies.

For the most part, the singers seem to be able to describe with precision what sound characteristics are found in their voices and can use lingo that helps them on determining what type of voices they have. Although they all confirm hearing these qualities, there is a psychological aspect that reflects on what they hear compared to what they wish to hear while they are performing. Often, this makes them change their vocal technique to achieve what they want to hear, resulting in tension and less effectiveness in the projection of the sound.

Though most subjects answered that they do feel like auditory perception is important, they all agree on the fact that the kinesthetic and proprioceptive aspects are more reliable to determine what is happening with their technique. Most of them replied that sometimes they have believed they sounded "good", but they felt tension in their phonatory and articulatory system while singing. Nevertheless, the way they relate the heard sound to the

production of sound in their bodies relates to the characteristics they associate with “good singing”, which might mean they still focus more on what they want to hear. Aspects like vibrato, brightness, and projection seem to be the key for the singers to relate what they are hearing to kinesthesia and proprioception while performing.

Their mental state, while they are practicing or performing, is a determining element that affects their perception of their voice. Other components like validation from an external listener, how they are feeling emotionally, and the self-critical process of comparing their voices with other peoples’ also affect the perception of their sound. However, there seems to be a direct connection between what this group of singers perceives in their voices and what other people have expressed that they sound like.

The kinesthetic aspect of technical difficulties while singing, the psychological component of being self-conscious because of an external opinion (usually after singing), and the confidence in learning the music were the recurring aspects that determined the sensation of not having “sounded good” in a specific situation. Whereas the perception of “good singing” refers to how well they knew the music, how much in control over the muscle behavior of the instrument they have, and how connected they were to the character they were interpreting.

When answering the question “how do you perceive that your voice gets affected when performing in an environment where you might get nervous?”, three of the five subjects described a feeling of constriction in the muscles of the larynx, as well as a diminishing projection in the sound. For the remaining two subjects, one of them has noticed a “shake” over her entire body due to anxiety, and the other one answered that she does not struggle with being nervous while singing.

After recording the practice:

The second and third parts of the questionnaire aimed to gain insight into what perceptive aspects were in play while the subjects were practicing and how these aspects could vary when filming the recording that was to be sent to a hypothetical panel of juries.

While practicing, most of the singers perceived their sound as “normal” (the description often used after this word referred to “not being the best they had sounded but also not the worst”) and described feeling comfortable during the practice session. They linked the vocal outcome to a series of tensions or lack of breath support.

The general answer in terms of liking the performance of their voice referred to the awareness of tension and the ability to solve it, as well as the level of connection to the character in the piece. However, the discomfort with the practice session had to do with not feeling like the muscles were free enough or liking the tonal outcome.

When it comes to the frequency with which their voices respond to the target outcome in terms of performance while practicing, three out of the five singers responded that their voices respond to what they aim in a 40% to 50% ratio, since it is hard for them to figure out the muscular behavior right away. The other two responded that their voices respond to what they aim to do 85% of the time while they are practicing.

After recording the piece for the panel of juries:

Overall, the subjects rely mainly on auditory feedback, kinesthesia, and proprioception to determine what the vocal outcome was while performing the piece. The first two subjects described their bodily sensations a lot more, as opposed to subjects C through E, which relied mostly on auditory feedback. Subject D did do two recordings and most likely answered the questionnaire after hearing the recording, which was not ideal – since the goal of the research is to gain insight into what singers are perceiving in real-time.

There seems to be a great influence of psychological aspects (how secure they were while performing, insecurities about recording themselves, and the emotional response that the piece had on them) on the kinesthetic, proprioceptive, and auditory aspects of their perception. Frequently during the questionnaire, the subjects would describe what their train of thought was while performing and how this connected to the other aspects.

Even though all of the subjects answered that their voices did do what they were looking for in the performance, there were descriptions of difficulty in maintaining the aimed vocal production. Likewise, the average response in their muscle behavior while performing is

60% to 85% accuracy between what the singers intended to do and what the vocal outcome came to be while performing onstage.

When asked how often their voices responded to what they wanted to do interpretively while performing in general, subjects A and B answered that they did not feel like the thought of being judged affected their performance. However, subject A did emphasize the fact that she did not feel bothered about this because it did not represent a grade. Subjects C through E did notice that their performance was being affected by a light performance anxiety product of the thought of being judged.

Conclusions:

The answers to the questionnaire that the singer-subjects had to fill suggest three main factors that influenced the perception of their voice. The first was the auditory feedback, the second was the kinesthetic and proprioceptive aspect, and the third was the psychological standpoint.

Based on the results, one of the main conclusions of the study refers to the importance of the psychological aspect of singing. Although auditory perception, kinesthesia, and proprioception were influential factors in the singers' perception of their vocal production and the capability to relate the perceived sound to the interoception of the instrument, psychological aspects such as what they relate to "good singing", what they have been told their voices can and cannot do and how they "wish to sound like" play the most important part in how they perceive their voice. In fact, it seemed to have the most impact on how performance is judged by performers themselves in any of the instances.

Whenever the subjects seemed to be insecure about musical qualities like rhythm and pitch, the answers to the questionnaire leaned towards laryngeal tension and lack of auditory attention. This suggests a connection between musical accuracy and both auditory and kinesthetic perceptions of the performance in the practice session as well as the performance.

The third conclusion according to the answers of the singer-subjects seems to be that auditory perception, although helpful and relevant in pitch accuracy, sometimes might not

be a trustworthy tool when it comes to an effective technique, since it is largely influenced (as stated previously) by a psychological desire to adjust the natural sound of their voices to what they consider “beautiful”.

Singers seem to be more aware of the correlation between kinesthetic-proprioceptive capacity and auditory feedback when their vocal production is less coordinated than when they are having moments of better technical effectiveness. This means that while each singer perceived a more intensive need for technical polishing, the association between their bodily sensations and the sound they heard as a result of these sensations was clearer to them; as opposed to when they described their signing as particularly “good”.

It is suggested to remake this study in an environment where the singers cannot control the outcomes entirely (i.e. record themselves, hear the recordings) to get more accurate results in terms of what they perceive in real-time. Likewise, it is also suggested to remake this study by incorporating contemporary commercial music singers and a broader number of subjects.

Topics of discussion:

- Since the subjects’ concept of how their voice “should sound like” is also largely influenced by what other people have told them about their voice, is there a need for a voice teacher to provide verbal feedback on what a singer sounds like?

- Is it better to let the student develop a strong technique based on how comfortable they feel while singing and how effective this sound might be onstage without the descriptive aspect of said sound?

- Would it be more helpful to tell a singer what their voice is like *after* they have developed a stronger technique to help them with repertoire choices instead of biasing their perception over their voice *before* they have achieved the desired technical goal?

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