Examining Embodied Sensation and Perception in Singing

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ABSTRACT

This paper introduces my PhD research on the relationship which vocalists have with their voice. The voice, both instrument and body, provides a unique perspective to examine embodied practice. The interaction with the voice is largely without a physical interface and it is difficult to describe the sensation of singing; however, voice pedagogy has been successful at using metaphor to communicate sensory experience between student and teacher. I examine the voice through several different perspectives, including experiential, physiological, and communicative interactions, and explore how we convey sensations in voice pedagogy and how perception of the body is shaped through experience living in it. Further, through externalising internal movement using sonified surface electromyography, I aim to give presence to aspects of vocal movement which have become subconscious or automatic. The findings of this PhD will provide understanding of how we perceive the experience of living within the body and perform through using the body as an instrument.

CCS CONCEPTS

• **Human-centered computing** → *Auditory feedback*; **HCI theory, concepts and models**; **Interaction paradigms**.

KEYWORDS

Embodied interaction, movement perception, knowledge transfer, biosignals, lived experience

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1 INTRODUCTION

My research explores how internal interactions are learned and perceived within the body. Our interactions with our bodies are unique, and driven by our own individual life experience [48, 54, 59, 79, 117, 120], which makes understanding the sensations and perceptions of others incredibly difficult [86]. It is often challenging to describe our own tacit and wordless lived experience, even to ourselves [103]. To understand more of how individuals perceive their actions and how this perception is shaped through experience, my PhD work focuses on a specific artistic practice – how vocalists learn to sing and the connection between a vocalist and their body, which is also their instrument. Like other technical crafts and musical arts, singing requires refined, precise control over the voice as a tool; however, singing presents a useful interaction model to study because this well-defined control is completely internal. To the vocalist, their voice is largely present in sensations occurring within their own body [51, 61]. Understanding the rich internal connection with the voice can provide insight into how we understand our own bodies, particularly as we engage in well-defined interaction learned over long periods of time [14, 96]. Through exploration of the voice, I aim to address larger questions present in HCI of how perception is shaped through experience, and we can communicate sensory-based interaction and practice between different bodies.

Going forward, I will refer to sensation, perception, and experience as related yet distinct concepts. ***Sensation*** is the most difficult to define, as it is an ambiguous and often wordless state of consciousness, but I use it to refer to the way of feeling in the body or having bodily awareness through the senses during an interaction. I use ***Perception*** to refer to how we *believe* we interact, whatever that truth may be for us based on our sensations; this perception is further informed through ***Experience*** of being in the world, the ongoing relationship between the world and what we learn from it, and how this changes the way we interact.

2 CONTEXT & MOTIVATION

I view myself firstly as a musician and artist, in addition to being an HCI researcher. My personal background is in vocal studies; I work as a vocal educator and have been a semi-professional vocalist since I was 15 years old. I have personally experienced a long-lived interaction with my voice, ranging from feelings of complete understanding and connection between mind and voice, to complete detachment from my instrument and subsequent alienation within my own body. My research aims to expand on how we understand and connect with our bodies during artistic and creative practice. As well, I want to understand more of how lived experience and feedback from the world around us helps to inform our action and intention with our bodies, and how this experience can be understood and can be communicated effectively for both our own understanding and to the understanding of others.

This relationship with the voice is formed over years of practice and often formal training with another vocalist teacher, as well as through the lived experience of using the voice in a personal and daily way [1, 79, 88, 91, 93]. Vocal practices are somewhat difficult to master at the start, as they require us to perform normal, every day

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tasks such as breathing, standing, and vocalising in a very specific way. However, as with most learning experiences, the act of singing becomes internalised and unconscious over time [83]. These formerly difficult tasks become embedded in larger action paths and require less attention [40, 43, 44, 48, 83, 89, 97]. Due to the covert nature of the voice, this precise control is mostly learned through abstract teaching methods [61]. Typically, a voice teacher will use metaphorical references to convey vocal technique to their students. Despite the subjectivity of conveying one's personal sensory knowledge and experience, vocal pedagogy has been successful for hundreds of years through the use of abstract teaching methods.

At present, my research can be broken into two parts: 1) Understanding how vocalists perceive their body-instrument and how this understanding is articulated to others, and 2) Capturing and externalising biosignals through sonification as a way to examine and interact with internal movements and unconscious action. By sonifying these normally soundless movements, I explore the existing relationships vocalists have with their bodies and provide new interactions with physiology through this biofeedback. In order to understand how abstract experiences are learned and then executed through physical movement in singing, I will first unite relevant research from music educators, philosophers, and designers on how we are able to interact with our bodies in both abstract and tangible ways.

2.1 Communicating Experience

Vocal pedagogy has developed over time without the use of technology mediation and with limited understanding of vocal anatomy or physiological mechanics [9], yet voice teachers have been able to convey technique to their students. This is largely done through their own understanding of the voice and the sensations and internal feedback within the body [19–21]. Vocal teachers must therefore be able to articulate their perception of living in and working with their body to their student, who will have a different and unique experience in their own body [15, 19, 21, 36]. HCI research, such as that focusing on somatic experience [57, 73, 86, 87, 115] and phenomenology [10, 30, 32, 93, 103–105, 107] has long focused on the difficult task of developing and exploring different ways to convey such subjective and personal experience to others [86, 87, 103]; for vocal teachers, this transference of internal sensory experience is done largely through abstract representations [51, 61].

Here, I am speaking of metaphor in a contemporary sense [68, 69]; that is, metaphor is anything which aims to increase understanding of the complex and often wordless target understanding domain through representation in an understandable and experience-based way [15, 19, 21, 36]. For instance, it is difficult to describe what supported breathing through engaging the diaphragm during singing feels like. This movement and its internal feeling is not common in everyday breathing, so it will be unfamiliar to beginner students. Teachers may use metaphors such as having their student imagine there is a balloon or a tire inside of their abdomen, which is inflating and expanding, or use arm gestures to mimic this imagined inflation away from the body in a visible movement. Of course, the diaphragm neither inflates nor expands, but these representations map understandable visual references of familiar objects, external movement, and paired gesture to the difficult-to-describe sensations of the diaphragm's contraction and release. In this way, metaphor helps to provide tangibility to our tacit and often wordless experience of living in our bodies [61, 100, 122] and is considered to be essential in the teaching of sensorimotor coordination needed for singing [19, 23, 39, 41, 42, 49, 51, 98].

2.2 Forming Musical Imagery

These abstract representations form mental imagery of what an action should feel, look, or sound like when performing it (imagery can take the form of any sense, so this can also include taste and smell in some applications) [15, 36, 37, 74]. This knowledge comes from previous experience in practice [36, 65, 114] and of existing in the world [17, 69], as well as tacit knowledge of our bodies [86, 103, 106, 108]; in this sense, a mental image may be formed of the metaphorical representations encountered during the learning process. Musical mental imagery is important to help musicians plan and recall their motor coordination [11, 28, 36, 65, 70, 92], know when their experience does not match the expectation of their movement and make changes [8, 50], and add emotional expression into their performance [3, 15, 53, 72]. Musicians and other practitioners of detailed and complex crafts spend time practicing this imagery. This can include working in spaces which mimic their performance environments [124], repetition of tasks, and experimenting with their actions to create accurate images of how their intention and behaviour impacts the results on their craft.

With familiarity of these action-result chains, musicians learn what to expect from their interaction. Overtime, practice becomes more internalised [48, 83, 117] and smaller details, such as the feelings and movements needed to engage in an activity like supported breathing, become automatic and require less attention [83], leaving more room for creative focus and applying these skills in big-picture focus. Less active monitoring leads to a feeling that the musician and their instrument work as one [2, 113, 118, 119]; for vocalists, this embodied relationship is even more personal as the voice is a viewed as being a source of both personal and musical identity [1, 88, 94]. This relationship changes over time with new knowledge [2, 59] and experience and operates in a highly entangled and cyclical way [2, 27, 29]; the musician performs according to their existing knowledge and then learns from that performance to further shape and refine their knowledge over and over again [48, 59], continually evolving and changing both the performer and performance over time [11, 29, 31, 32, 54, 67, 117, 120].

2.3 Externalising Internal Movement

To understand this internal relationship and the vocalist's perception of their body, I have attempted to take these embodied behaviors which are unconscious and not in active focus and bring them to a noticeable, external perspective. My work has focused on the use of surface electromyography (sEMG) as a way to provide this externalisation. sEMG senses the electrical neural impulses which are responsible for muscle contraction [12]. I have chosen to work with sEMG as it can provide information about movement which is not visible by other methods [63], such as motion capture, and also those which are unconscious to the subject [24, 25]. These neural impulses occur when our bodies prepare to move and act as a trigger for movement [109]. Tanaka describes sEMG as being

the "input" to a movement, rather than the output [111]. This impulse occurs, albeit at a very low voltage, when we simply imagine moving [33, 63, 78, 95] and also before we are aware of movement [109]. For these reasons, sEMG can be a useful tool in observing movement from an "internal" view, where we focus on the innate preparation our bodies perform before we physically move.

sEMG has been used in a variety of HCI [4, 13, 47, 66, 71, 112, 116, 123] and specifically musical applications [16, 25, 60, 64, 75, 76, 85, 95, 96, 109–111] and is desirable both for its responsiveness and noisy ambiguity [12, 24, 25]. Use of sEMG in performance studies has allowed musicians to explore the relationship between their actions and sound and react to technology in an exploratory way [24, 109]. These interactions, like other experiences, form new imagery and perceptions of the relationship between movement and sound without pre-existing understanding of interaction [35, 101], calling attention to subconscious movement [25, 96] and leading performers to move in a variety of new ways which previously would not have given the same feedback [24, 60, 64, 75, 76, 85]. The ambiguity of sEMG also allows performers to explore their existing knowledge in understanding different cause-and-effect relationships in the interaction [24, 25, 96]. These perceptions of ambiguous interactions reflect the performer's perception of their movement and influence over the interaction [84].

2.4 Research Questions

Given the understanding of interaction with the body from these different contexts, I have focused on addressing the following research questions:

- How do vocalists use musical imagery and abstract metaphor representations (including linguistic metaphor and gesture) to relate to their body-instrument?
- How does the externalisation of internalised practice, done through sonification of sEMG, influence a vocalist's behavior and intention?
- How can biofeedback through sEMG influence perception and understanding of resulting physiological movement?

3 METHODOLOGY

The first section of the research involved interviewing voice teachers to understand how they talk about, represent, and teach sensation and action to their students. The second portion focused on how externalising these internal actions through sound can help singers to question their movement, intention, and perception of their voice; first, a circuit for measuring sEMG from the laryngeal muscles was created. Then, I conducted extensive autoethnographical study of my interaction with sonification of my own muscular movements while singing. The remainder of the PhD will involve combining these tasks, allowing singers to interact with the sonified movements of their body and observing how their action and perception of their singing change with this new form of feedback.

3.1 Teaching Vocal Fundamentals

To understand how voice teachers relate their own experience to evoke similar sensations in their students, I have conducted a semi-structured interview with voice teachers from a variety of stylistic backgrounds. The interviews focus on the metaphors – language, gestures, and other abstract representations – they use to teach fundamental vocal pedagogy, including supported breathing, posture, sound production, and sound shaping. The interviews were analysed using thematic analysis [6, 7] which revealed a variety of ways in which metaphors convey fundamental vocal technique to students, and how teachers use tacit understanding of the body and experience of other every day interactions outside of singing to evoke sensations for their students. Additionally, the study utilised several self-report questionnaires for mental imagery ability, including the Movement Imagery Questionnaire 3 (MIQ-3) [121] for visual and kinetic imagery and the Bucknell Auditory Imagery Scale (BAIS) [45], as well as the Goldsmiths Musical Sophistication Index (Gold-MSI) [80, 81] to assess general musical experience and basic demographics of the teachers. This was done to determine whether the kinds of metaphors used had any correlation with the teacher's ability to use imagery of the same modality.

Results suggest that, rather than adopting teaching practices based on their own imagery ability, teachers tend to identify with particular teaching styles that were successful for them and rebuke the kinds of metaphors which were used by teachers they did not get along with or did not understand. Additionally, the interview data reveals that many teachers cannot explain why certain metaphors work or why they are able to experience particular sensations through them. Many metaphors were copied verbatim from their own teachers or from other voice educators, and often reference other life experiences outside of singing [17, 105, 119] Many of these metaphors are widely used amongst teachers across continents and even in different styles of singing; I was familiar with the vast majority of the metaphors from my own voice lessons with other teachers in the past. The initial findings of this study suggest that metaphors work as an approximation of a sensation. There is not a perfect way to communicate how a sensation feels; rather, the ambiguity of understanding seems to be what allows for the transfer of the knowledge from the teacher, by allowing the student to interpret the metaphor within their own body and experience. Teachers work through self-reflection [54, 56, 82] to find understandable metaphors and pass them along as if they were a code to unlocking these sensations in others. By finding a relatable likeness for the otherwise indescribable feeling, we can evoke similar understanding in different bodies.

3.2 sEMG and Sonification

To connect with the internal experience of the singer, or to help the singer better connect with actions they have internalised, the second portion of the research aims to externalise and draw attention to internal movement. I have designed a circuit for capturing sEMG signals of the surface-level laryngeal muscles, which work to position the larynx during singing [46, 102]. Although there are commercially available sEMG platforms which may be suitable, such as the such as the MyoWare Muscle Sensor (Advancer Technologies)[1] or BITalino,[2] I have designed a circuit for this research for two main reasons: 1) More flexible electrode placement on smaller muscles, and 2) More accessible technology for other researchers or designers, offering low cost (appx. $40 USD) and

[1] http://www.advancertechnologies.com/p/myoware.html
[2] https://bitalino.com/

open-source schematics. The board itself is derived from the open-source Advancer Technologies EMG Circuit v7.1.[3].

The sEMG data has been sonified as a source of external feedback with which the wearer of the device can interact [5, 22, 52, 58, 62, 77, 116]. This sonification has provided control of digital instrument synthesis, such as the frequency of the carrier used in a ring modulator applied to the vocal signal and the centre frequency of filtered noise. These sonificatons were used in improvisation exercises as a way of experimenting with the movements of the larynx, which normally would be soundless. After a few iterations of the circuit and living with the device for nearly a year, I have also designed a small PCB of the circuit, VoxEMG, which can be used for further application[4].

Additionally, the design of the VoxEMG circuit was done in an autobiographical sense using my lived experience working with my own voice [26, 38, 55, 82]; the muscles I chose to measure in the end and the practice of singing sEMG was shaped by my own awareness of how my body moves, where the activations were stronger and often more unexpected, and how I wanted to interact with them [99]. At the time of writing, I have spent about 30 months working the system into my own vocal practice and have uncovered ways in which the technology and my interaction have shaped each other [26, 34, 82, 120]. From this first-person interaction, I have uncovered a number of surprising reactions and effects of having worked with the system. For instance, many of my movements were occurring in a subconscious and soundless way and only once I began to sonify them did I start to feel their activity [18, 90] – this was the case for sonifying and singing with the movements of the suprahyoid muscles, which move with the tongue and help to shape the oral cavity [46]. I found these muscles "made sound" when I was engaging in supported breathing (the tongue drops on inhalation and to shape the sound before singing). I could not identify the source of the sound at first, as this movement is something which I have internalised over time. While I currently do not think of the different movements needed to breathe during singing, this was something which I needed to learn over time. Teachers first worked to make this action very obvious and get me to focus on this motion. This focus on different movements of the body which was also apparent in the instruction examined through interview study. Over time and with practice, the action needed less and less attention. By sonifying it, I found I was suddenly aware of this motion again. Overall, I found that working with my body through this external presence helped me to examine aspects of my movement which were not previously or recently considered. Through highlighting different elements of body-based technique, we can encourage movement and awareness and work to strengthen the relationship between the artist and their body.

3.3 Future Work

The final study will aim to unite these two threads, using the sonified biofeedback to both explore and disrupt the vocal practice and the relationship the vocalists have with their body-instrument. This study will aim to expand my autoethnographical study to observing other vocalists. The sonification will provide external feedback to the usually soundless movements of the small muscles active in singing. The aims for the study will be to observe how vocalists play with the sonification of their intention and action in a freeform exploration, as well as to observe how behavior changes when given specific tasks to perform. Using different metaphorical language, similar to that used in the vocal tradition, to guide the interaction will help to determine how the abstract image of movement, combined with auditory feedback, lead to different perceptions of interaction with the body. It is the aim that the sonification can function as a metaphor itself, by mapping audible sound to the increase the understanding of movement. The goals of this study will be to understand what happens when we begin to externalise or bring attention to actions which are largely unconscious or have become embedded in larger action paths [25]. I will examine what behaviours the vocalists perceive are causing change in sonification, and whether the introduction of certain sound qualities to the vocal interaction, such as a creaky or squeaky sound being attributed to the laryngeal muscle movements, will influence the vocalists' perception of their own movement qualities [84]. As in my own exploration of singing with my sonified muscles, I want to see if the vocalists find smaller movements they did not realise they were making and how this discovery changes the perception of how the body works to create sound. It will also be interesting to see if it is possible to encourage movement of these muscles by making their presence part of an external, audible feedback interaction.

4 RESEARCH TIMELINE

I am currently in my third year of PhD study at Queen Mary University of London. In my first year I began conducting the extensive literature review of recent work in the variety of fields I have attempted to unite in this PhD and presented here. This has been continued through the duration of my research work. As well, I began to construct a device for measuring sEMG signals from the extrinsic laryngeal muscles [95, 96]; with the COVID-19 pandemic in my second year of PhD study, I have focused on further development of the sEMG circuit, leading to the creation of the VoxEMG board briefly discussed here, and an autoethnographical study of my use with it over the year [96]. Additionally, I conducted the interview studies with vocal teachers regarding how they describe their experience of singing to students through metaphor.

Currently, I have presented an initial verification of the method for sEMG sensing at the 2020 International Conference for New Interfaces in Musical Expression (NIME) [95] and my autoethnographic study using and living with the system for a year at the 2021 TEI Conference [96]. I have compiled the resources for the open-source VoxEMG board and how-to for DIY sEMG sensing in a repository; I hope to publish a larger article on developing similar sensing platforms next year. Additionally, a portion of the interview study of metaphor communication in vocal pedagogy has been submitted for publication. With my final year remaining, I will focus on finalising and publishing the full interview findings. I will also be designing the final study for my PhD to involve other vocalists using VoxEMG to interact with the sonification of their internal laryngeal movements, now that it is becoming possible for us to sing together again.

[3] advancertechnologies.com/p/muscle-sensor-emg-circuitkit-bronze.html
[4] The full open-source design and schematics for VoxEMG can be found here: https://github.com/courtcourtaney/voxEMG

It is my hope, through the TEI Graduate Student Consortium, to receive feedback on the final study design and analysis and to share the current research with others who may be interested in incorporating sEMG and other sonification to their work.

4.1 Contributions

Although this work is focused on a specific interaction and practice, the understanding of the embodied relationships which exist in many other activities will likely be of interest to others; the refined and lengthy practice which forms the relationship between a vocalist and their body-instrument is not unique to vocalists, but to many artistic practices such as dance and craftwork. Additionally, the understanding of the perception of the body and its movement formed through experience, and how this impacts the way in which we talk about our body, is key to giving attention to individuality in interaction design. Particularly, the understanding of how metaphor acts as a conduit to relate one individual's experience to another in their own body is useful to discern and and describe sensation in similar application. As well, I hope that the open-source designs for the VoxEMG, presented and discussed here, can be useful to others who wish to use sEMG in their research.

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