Exploring Haptics to Augment Kinesthetic Learning in Singing

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Abstract

Singing involves complex body coordination and singing learners often struggle to interpret their internal sensations and feelings. This research explores haptic technology to enhance kinesthetic learning in singing. By integrating haptics to augment traditional instruction, this study aims to develop real-time tactile feedback tools to communicate internal bodily processes, improve muscle coordination, and enhance the learning experience. The findings will deepen the understanding of how we perceive and utilize our bodies in kinesthetic learning.

CCS Concepts

• **Applied computing** → *Interactive learning environments*; *Performing arts*; • **Human-centered computing** → **Haptic devices**.

Keywords

Haptic Feedback, Kinesthetic Learning, Wearable Technology, Singing Pedagogy, Motor Learning

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1 Introduction

Mastering singing is a complex process that requires mental focus, precise muscle coordination, and a clear understanding of how the voice works [17]. However, describing internal body sensations, like how muscles feel during singing, is naturally difficult [31]. This makes it hard for students to fully understand the instructions from teachers [11]. Additionally, discrepancies often exist between a teacher's perception of their kinesthetic movements and their actual use of the vocal apparatus [12]. This misunderstanding can cause beginners to struggle with interpreting internal sensations, leading to improper habits, anxiety, potential injuries, and sometimes even the premature end of their music studies [2, 17].

Haptic technology offers promising possibilities for improving how singing is taught. This technology is useful in conveying musical information and enhancing musical experiences [22, 36], as well as helping people learn physical movements [4]. An emerging field of *musical haptic wearables* explores "feeling" music through touch, improving accessibility and communication among diverse people, including music teachers and students [34, 35]. Singing relies on internal muscle movements that are invisible yet essential for producing voice [32]. Haptic devices offer a promising solution by helping students perceive and understand the sensations within their bodies during singing [14]. This opens the door to creative non-verbal ways of teaching body awareness in singing lessons.

In singing, research shows that somatosensory feedback (sensory information the body processes about its movements, position, and physical state, including the ability to sense muscle movement and breath control) is critical for improving vocal skills [2, 28]. Tactile sensations, for example, vibrations experienced during singing practices from lip or tongue trills, help singers develop better vocal control [17]. However, these natural vibrations are confined to specific parts of the body and can be difficult to perceive. This raises an important question: Can new haptic technologies, such as vibration-based tools, help singers better understand, communicate, and learn the physical sensations involved in singing?

Although haptic technology has shown potential, its use in music training is still in the early stages. Research has demonstrated its benefits for teaching instrument-based skills [33], but its application to singing is not well-studied [25]. My earlier research on haptic tools for singing has shown promising results, particularly in improving breath control, which is a key part of learning to sing [19, 23]. Building on this, my study will first explore specific challenges and opportunities related to how singers learn to feel and control their bodies. Then, I will focus on how haptic technology can address these challenges and enhance learning beyond what traditional methods can achieve. Since singing requires complex coordination across the body, this study will focus on breathing as the central physical process in vocal performance.

2 Context and Motivation

As a classically trained singer, I have spent decades refining my singing skills and improving body coordination. My passion for music began at age five, but early on, I faced challenges due to inadequate teaching methods that strained my voice. While some singers naturally develop strong mind-body awareness, many singers, including myself, require structured guidance to learn to sing effectively. One of my teachers used metaphors and described their bodily sensations during singing, but some of these explanations left me confused and eventually led to vocal strain. Only after finding a teacher who explained anatomy and body mechanics did I realize that singing could be a comfortable process rather than one filled with tension and nervousness. Inspired by this, my project aims to address these challenges by exploring how kinesthetic

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learning in singing can be enhanced through haptic augmentation. Ultimately, I hope my research helps both singers and teachers deepen their understanding of the body and improve learning and teaching methods.

2.1 Kinesthetic Learning in Singing

Kinesthetic learning in singing involves developing body awareness and fine motor control, both essential for effective vocal performance. Key aspects of kinesthetic learning in singing include breath management (using related muscles effectively in inhalation and exhalation), posture (the way a singer holds their body), and forward articulation (using the mouth and vocal tract in a way that projects sound forward) [5]. Breathing serves as the foundation of singing and is often described as the power source for vocal production, yet it is one of the most challenging aspects to master [13]. Ineffective breathing techniques can restrict diaphragmatic function (the movement of the diaphragm, a key muscle in breathing) and make it difficult for singers to control their voice [8]. For trained singers, effective breath management becomes automatic, allowing them to focus on artistic expression [8].

Traditional singing lessons typically use descriptive language, vocal demonstrations, and listening exercises to teach students [11]. Teachers typically use metaphors or describe how singing "feels" based on their bodily sensations and experiences, which can confuse students who lack similar experiences [30]. This miscommunication can hinder progress and even lead to improper vocal habits and vocal strain [17]. Innovative approaches beyond traditional methods may address these challenges.

2.2 Haptics in Motor Training

In recent decades, technological advancements have introduced tools that use visual, auditory, and haptic feedback to promote motor learning and rehabilitation [18, 20, 29]. For example, robotic devices have shown promise in guiding motor learning through haptic feedback, allowing patients to learn movements without putting strain on therapists [20]. Traditionally, haptic training methods have involved physically guiding movements, which is effective in simple tasks but less common for complex activities [29].

Recent studies show that haptic systems enhance motor learning in complex tasks by providing real-time tactile cues that improve body movement awareness and performance [15]. Despite some inconclusive results, likely stemming from differences in haptic methods and participant backgrounds, the benefits of haptic guidance in motor training are are widely recognized [4]. Given the complexity of singing, which requires full-body coordination and precise activation of intricate muscle groups, exploring haptic technology in this context is a valuable next step.

2.3 Augmenting Singing Kinesthetic Learning

Technology-based augmented feedback has been shown to improve motor learning, particularly in complex tasks that use auditory, visual, and haptic cues [29]. Auditory feedback is beneficial in tasks that require precise timing and rhythm [27]. In singing, breathing guidance often relies on visual cues, such as animations or instructional prompts like "breathe deeply" [1, 23]. While visual feedback can aid understanding in some cases, it may also hinder learning by fostering dependency [24, 26].

Haptic feedback is suited for helping singers understand and control their body movements, especially breathing and coordination [19]. For example, Corsetto is a kinesthetic haptic garment designed to communicate a singer's vocal experiences to a listener through soft mechanical actuators that simulate key elements of singing, such as breathing and posture [7, 16]. Additionally, wearable tools like Body Lutherie foster empathy and a deeper understanding of the body as an instrument [10].

However, these haptic tools have limitations, as most are designed to replicate the bodily experiences of a single professional singer. This approach makes them less adaptable to individual learners with diverse needs, skill levels, singing styles, and body types. To better support singing education, haptic devices should be customizable, user-friendly, and suitable for a broad range of users, with their effectiveness rigorously validated.

3 Research Questions

The long-term goal of this research is to deepen the understanding of the singing body and to design, develop, and evaluate tools that enhance challenges related to kinesthetic learning in singing. My research focuses on addressing the following questions:

RQ1: What are the challenges and opportunities in augmenting kinesthetic learning for singers?

RQ2: Can haptic technology provide an effective and widely accepted solution for singers? How can it enhance traditional teaching methods to address key challenges in kinesthetic learning for singing?

4 Research Activities

The PhD research is organized into two main studies. The insights from each study will formulate how to go beyond existing singing pedagogy to support singing learning.

Study One - Understanding Challenges and Opportunities in Singing Pedagogy for Kinesthetic Learning (Completed, manuscript in preparation):

To answer **RQ1**, I conducted a qualitative study with three semi-structured focus groups, including eleven participants: seven singing students and four professional teachers. The students ranged from beginners to advanced levels, while the teachers, averaging 18.5 years of experience, represented a mix of genres. The focus groups discussed:

(1) Challenges faced by students or observed by teachers in respiratory and other kinesthetic aspects of singing.
(2) Common solutions, including current pedagogical approaches, tools, technologies, and potential innovations.

To facilitate idea generation, we used Mural [21] for card sorting, enabling participants to collect and edit notes collaboratively on a web-based canvas. Additionally, body mapping [3] was employed to help participants illustrate their kinesthetic awareness and singing learning processes on blank body outlines (as Figure 1 shows).

Through thematic analysis, I identified three main challenges that singers of various skill levels face: *Difficulties in Muscle Coordination and Adjustment*, *Challenges in Identifying and Managing Muscle Tension*, and *Struggles with Register Transitions and Airflow*

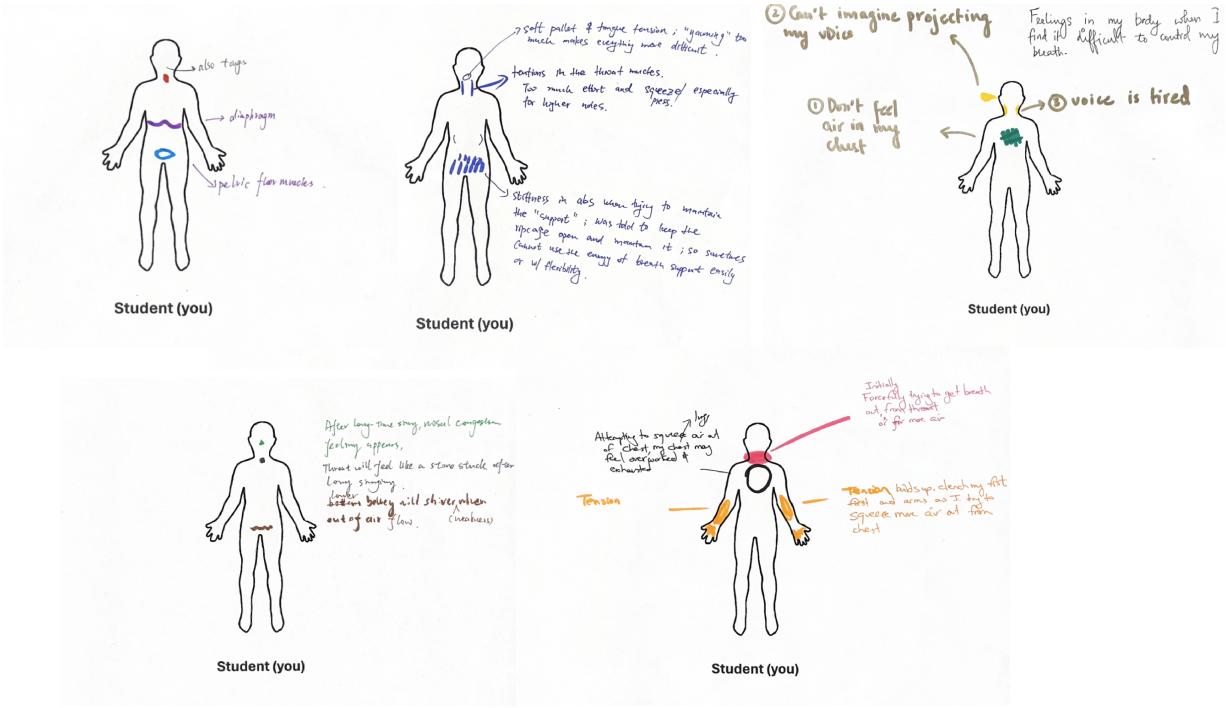

Figure 1: Examples of participants' body mapping drawings illustrating the kinesthetic singing problems they identified in *Study One.*

Control[1]. Participants also suggested solutions, which I grouped into four key pedagogical interactions (teaching strategies) and two primary technological interventions (ways technology could assist in learning).

Given my focus on wearable haptics, these findings lead to my next research question, **RQ2**, which investigates how haptic technology can address the challenges identified in singing pedagogy and enhance traditional teaching methods to improve learning outcomes.

Study Two - Exploring Haptics to Enhance Kinesthetic Learning Beyond Traditional Pedagogy (In progress): This study addresses **RQ2** by exploring whether and how haptics can enhance the traditional pedagogy methods. Building on insights from Study One and personal experiences with singing lessons, including those of three singers (myself included), I am developing a wearable suit equipped with interchangeable Electrical Muscle Stimulation (EMS) and vibrotactile actuators targeting key muscle areas. A mobile app will provide real-time control and customization of the actuators, allowing adjustments to vibration intensity, patterns, and timing. The signal processing and communication parts build on my previous research with MappEMG, a system designed to map muscle activity to real-time vibrotactile feedback, offering tactile cues to enhance kinesthetic learning [22].

[1]Muscle coordination and adjustment refers to controlling the muscles used in singing, such as those in the throat, diaphragm, and face; muscle tension relates to the tightness that can strain the voice or hinder singing; registers are distinct ranges of vocal pitches, like chest voice and head voice, while airflow management involves controlling the breath to sustain and shape the voice.

Once the wearable suit is developed, I will explore how haptics can augment the traditional pedagogical interactions identified in *Study One* through mixed-method experiments. Qualitatively, I will use autoethnography [9] and body mapping [3, 6] for self-observation and reflective investigation of embodied experiences by singing learners. Quantitatively, I will measure muscle activity and analyze singing recordings to compare performance with and without haptic feedback, focusing on changes before and after using the suit.

5 Timeline

I am currently in my third year of PhD studies at the Schulich School of Music, McGill University, affiliated with the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT). Before beginning my PhD, I contributed to several projects, including publications at the 2021 and 2022 International Conference on New Interfaces for Musical Expression (NIME), which helped lay the groundwork for designing wearable breathing guidance tools for singing. In my first year of doctoral study, I developed MappEMG [22], an EMG processing system that maps data from a portable EMG device (BITalino) to vibrotactile devices. This project demonstrated the potential of haptic feedback in enhancing teacher instruction and identified possible applications for biofeedback pedagogy tools. MappEMG was presented at the International Conference: ArtsIT, Interactivity & Game Creation in 2023 and serves as the foundation for future system designs in signal acquisition, processing, transmission, and haptic mapping.

In my second year of doctoral study, I conducted an extensive literature review across various fields, including NIME, HCI, haptics, wearable technologies, voice science, bioengineering, robotics, music education, respiratory physiology, and embodied cognition, which enabled me to pass my comprehensive exam the same year. I also completed *Study One*, identifying key challenges and technological opportunities for expanding beyond traditional singing pedagogy, which has shaped my research direction moving forward.

Currently, I am preparing the manuscript from *Study One* for submission this fall. Over the next three years, I will focus on *Study Two*, building on the MappEMG system and my previous work in haptics and singing. Throughout this process, I am actively engaging with voice communities, such as the Pan American Vocology Association and The Voice Foundation, as a student member. I also plan to collaborate with local music schools to engage more singing learners and evaluate the practical use of the system in singing lessons.

Participating in the TEI 2025 graduate consortium will allow me to connect with researchers in the areas of tangible, embodied, and embedded interactions, aligning closely with my research interests. This opportunity will provide valuable interdisciplinary feedback on my initial study and guide the next stages of my PhD research.

6 Expected Contributions

This interdisciplinary research aims to make three key contributions. First, it bridges traditional pedagogy with haptic technology to possibly create more effective, embodied learning experiences by enhancing body awareness, improving pedagogical communication, and potentially elevating singing techniques. These advancements could extend beyond singing to instrumental practice, composition, and performance. Second, it broadens the application of haptics to singing education contexts, fostering the development of more sensitive and interactive haptic systems. Finally, by exploring the kinesthetic learning in singing, this research can help deepen our understanding of how tactile sensation, perception, and metaphor interact in augmenting embodied interaction. These insights can benefit the designing of new embodied interfaces in areas such as sports training, dance, and rehabilitation.

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