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BMPF7013: Independent Study Module

Contents

Assessment 1 - Portfolio **3**
Introduction 3
Planned programme of study 4
Critical reflection 9
Assessment 2 – Written Assignment **14**
Introduction 14
Defining vibrato 14
Perception of vibrato 16
Theories of production 18
Volitional control 19
Straight tone 20
Use in choral singing 22
Use in musical theatre 24
Pedagogical approaches 26
Conclusion 29
References 30

Figures

Figure 1, Electronic database search 7
Figure 2, Assignment timescale 9

The use and suppression of vibrato in choral singing and musical theatre: a narrative literature review

ASSESSMENT 1 – PORTFOLIO

INTRODUCTION

I am the director of an adult female voice choir and also work part-time as a self-employed singing teacher specialising in musical theatre. I would like to explore the phenomenon of vocal vibrato and understand its definition, production and the complexities that surround this technique, particularly in musical theatre and choral settings. This deeper knowledge will help me to develop effective teaching practices in this area.

My interest in this study began while watching online lessons with Deric Rosenblatt, a New York-based musical theatre singing teacher with classical training and extensive experience in teaching Broadway performers. In his online subscription video series, Vocal Power Presents, he emphasises the use of "immediate natural vibrato" in warm-up exercises to release tension (2020).

This was the first time I had encountered such emphasis on vibrato. Despite having had lessons with eight classically-based singing teachers, I do not recall vibrato being mentioned during warm-ups or at any point in the lesson and I do not believe that it was because I was already singing with vibrato. As a choral singer, I am accustomed to singing with a straighter tone as desired by the choirs that I sing in, which has become my default.

Rosenblatt believes that finding the natural vibrato allows the voice to be free, whereas "straight tone is the result of holding" (2020). He acknowledges the importance of straight tone for stylistics reasons within songs, but emphasises starting with the most efficient, healthy and natural production before making stylistic choices.

I am curious to understand whether vibrato should be included in all warm-ups. This has also led me to seek a better understanding of the stylistic choices for vibrato within musical theatre and choral singing. I also acknowledge that my general knowledge of vibrato, including its definition, production, volitional control and teaching methods, is limited. Through this study, I aim to critically analyse existing data on vibrato to improve my understanding and enhance my pedagogical approach. I also hope to identify areas where further research is needed.

PLANNED PROGRAMME OF STUDY

Learning and development aims and expected outcomes

My overall aim is to gain insight into the current understanding of vibrato in order to be able to advise my students appropriately. More specifically, I aim to examine and critically analyse the current body of research on vocal vibrato in order to:

a) Define it, understand its production and volitional control;
b) Understand its uses within the main genres that I teach: musical theatre and choral singing;
c) Identify areas of controversy including vocal health implications for not using vibrato;
d) Explore information on pedagogical approaches;
e) Contribute to the ongoing discussion on this complex topic by producing a pragmatic literature review on vibrato for singing teachers in musical theatre and choral settings; and
f) Gain an understanding of any knowledge gaps and continuing challenges within this area of research and the possibilities for future research.

I expect that my learning outcomes will be:

a) A good understanding of vibrato and its challenges;
b) A knowledge of aesthetic uses and areas within musical theatre and choral singing;
c) The gaining of practical exercises for developing and maintaining a healthy vibrato;
d) An understanding of the potential influence this study will have on my teaching practice; and
e) The identification of ideas for my own future research.

Contextualisation of study

The inquiry framework guiding this study is pragmatism: an approach that acknowledges “the interconnectedness between experience, knowing and acting” (Kelly and Cordeiro, 2020, p. 1). This is relevant to my role as a practitioner researcher as I forge a path between theory and practice.

Within the paradigms that exist within social sciences, positivists believe in a single truth and at the other end of the spectrum, social constructivists believe in multiple realities (Guba and

Lincoln, 1994). In contrast, pragmatists are solution-based and define truth based on its "fruitful consequences" (Russell, 1959, p. 279). By adopting a pragmatic approach, I can gain relevant and actionable knowledge by integrating multiple approaches rather than being confined by one philosophical perspective (Rossman and Wilson, 1985; Feilzer, 2010).

Pragmatism "directs us to seek practical and useful answers that can solve, or at least provide direction in addressing, concrete problems" (Patton, 2015, p. E152). Therefore, I will be interpreting the data with the intention of informing action. While I will begin by examining peer-reviewed published literature, I will also include grey literature if it appears credible and aids finding answers. I will also need to make pragmatic choices regarding the inclusion and exclusion of literature in terms of the time constraints and limited resources that I have as a part-time researcher.

A pragmatic approach to research has been rebuked for its potential lack of rigour. In responding to the same criticism levelled at qualitative research, Meyrick describes a quality framework based on two key principles: transparency and systematicity (2006). I will be transparent in disclosing the process for the literature review and systematic in the collection and analysis of literature validating any departures from this approach. I will analyse the information and present a fair and balanced view that accurately reflects its context refraining from manipulating it to support a particular conclusion. It is important to note that this study is solely based on a literature review and does not involve testing of concepts on subjects in lessons, as ethical approval has not been obtained for such activities.

From an initial scoping of the research available on this subject, there is a large amount of information. In terms of existing literature reviews in this subject area, other than the reviews that are carried out as the initial part of a research project, I could only find one which was a systematic review of vibrato in group singing (Acosta Martínez and Daffern, 2022). This review provides a wide overview of the existing research without drawing any general conclusions or offering practical solutions. It does not cover non-vibrato singing, which is an important aspect of my study.

I acknowledge the existence of multiple types of vibrato within different cultures and musical styles and that they probably differ in their physiological attributes (Sundberg, 1994, p. 45). This literature review will be limited to focus on Western choral music and musical theatre, as my intention is to construct an evidence-based overview of the salient points to facilitate my work as a choral leader and in teaching musical theatre students within the UK. As it is estimated that there are over 40,000 choirs in the UK singing a wide variety of genres (Swann

and Edwards, 2017), in addition to the range of singing for musical theatre exams now available (Lambie, 2018), I hope that this overview will also be relevant for other teachers.

As I embark on this review, I hold certain assumptions regarding vibrato: I believe that the UK classical choral scene employs less vibrato compared with the US (Durrant, 2017, p. 224), although choirs like Sonoro actively promote its use (Ferris, 2016). I believe that the principal reasons choral singers are asked to minimise vibrato are blending, tuning and style, although I have never perceived an improvement in tuning or blending with less vibrato. In terms of my own singing, I am primarily a choral singer and while I do not feel that I am actively suppressing vibrato, I am aware that my voice tends to have a straight sound. In the realm of musical theatre, I believe that the legit style of singing likely incorporates vibrato in a manner similar to classical singing. I am also aware of the use of vibrato at the end of sustained notes, particularly during climactic moments in a song. I would assume that vibrato varies depending on the genre of music within the musical.

While I will include straight tone singing in my literature review, it is important to note that a historical musicology discussion of whether vibrato should be used in early music is beyond the scope of the study. Additionally, while I am open to considering all types of literature that offer potential solutions, I will not include anecdotal information from sources such as singing teaching blogs. Although these sources can be valuable, this study is already driven by anecdotal information suggesting that vibrato singing is healthier than non-vibrato singing. Therefore, my starting point will be peer-reviewed literature and once I have gained competence and confidence from this study, I may explore anecdotal data in the future.

Methodology

This narrative literature review will focus on peer-reviewed published literature and may also include grey literature such conference proceedings, dissertations and books written by vocal pedagogues and researchers.

A preliminary scoping search using the terms ‘vibrato’ AND ‘voice’ was carried out using Mendeley Online on 6 March 2023 to establish the appropriate guidelines for the full search. This search highlighted that www.mendeley.com and perhaps other databases do not respond to the use of Boolean operators.

Following on from this the following electronic databases were searched:

Electronic database	Search terms	Search dates	Notes
www.mendeley.com	vibrato	2018 to 13 March 2023	Downloaded all articles
Science Direct	vibrato AND voice OR sing OR vocal	2018 to 13 March 2023	Sorted by relevance and downloaded the top 100 articles, as the next articles did not seem relevant.
Science Direct	vibrato AND musical theatre OR musical theatre	2000 to 13 March 2023	Sorted by relevance and downloaded the top 30, as the next articles did not seem relevant.
Science Direct	vibrato AND choral OR choir	2000 to 13 March 2023	Sorted by relevance and downloaded the top 10, as the next articles did not seem relevant.
Google Scholar	vibrato AND voice* OR sing* OR vocal*	2018 to 13 March 2023	Sorted by relevance and downloaded the top 103 articles, as the next articles did not seem relevant.
Google Scholar	vibrato AND musical theatre OR musical theatre	2000 to 13 March 2023	Sorted by relevance. No downloads as it felt that the search did not uncover new relevant data.
Google Scholar	vibrato AND choral OR choir	2000 to 13 March 2023	Sorted by relevance. No downloads as it felt that the search did not uncover new relevant data.
Journal of Singing	vibrato	2018 to 13 March 2023	Downloaded all articles
Choral Journal	vibrato	2018 to 13 March 2023	Downloaded all articles

Figure 1, Electronic database search

The downloaded data was stored in Mendeley and I began skimming through the articles to remove duplicates and exclude irrelevant ones using abstracts and keywords. The exclusion criteria I used were as follows:

1. Inappropriate topics, such as articles that:
   a) did not pertain to the singing voice;
   b) were not related to Western classical or choral music, or musical theatre;
   c) focused on the synthesis of the digital singing voice, digital singer identification or singing voice transcription; or
   d) included the word “vibratory” instead of “vibrato”
2. Articles not written in English.

Since there was a substantial amount of data, my goal was to gather the most recent research through this search and then examine the frequently cited references to identify seminal works and other relevant older research. Due to fewer articles on vibrato in choral singing and musical theatre, I expanded the time frame for the initial search.

As I read through the selected articles, I evaluated the information and contemplated how I could apply it to my teaching practice. I organised my notes into themes, which I later summarised in the discussion below.

Timescale

	Step 1	Step 2	Step 3	Step 4	Step 6	Step 5	Step 7	Step 9	Step 10
Week commencing	**Agree topic with tutor and plan the timeline for project**	**Write rationale for area of study plus learning and development aims and objectives**	**Describe the literature review methodology**	**Source and read literature for area of study and organise relevant data**	**Tutorial**	**Write first draft of Assessment 2: Written Assignment**	**Write critical reflection of learning process**	**Amendments**	**Submit completed assignment**
16-Jan-23									
23-Jan-23									
30-Jan-23									
06-Feb-23									
13-Feb-23									
20-Feb-23									
27-Feb-23									
06-Mar-23									
13-Mar-23									
20-Mar-23									
27-Mar-23									
03-Apr-23									
10-Apr-23									
17-Apr-23									
24-Apr-23									
01-May-23									
08-May-23									
15-May-23									
22-May-23									
29-May-23									

Figure 2, Assignment timescale

CRITICAL REFLECTION

In this assignment, my goal was to gain a comprehensive understanding of the phenomenon of vibrato, its use in musical theatre and choral singing, and most importantly how I could apply this knowledge within my own choirs and teaching practice. Alongside the research, I kept a journal to record observations to help me reflect on this learning process. To structure this critical reflection, I will employ the reflective model developed by Driscoll (2007).

What?

I first became aware of my limited knowledge regarding vibrato while watching online lessons with a Broadway singing teacher: it was mentioned that singing with vibrato was considered healthier than singing without it. This notion intrigued me, as I had never explored this topic in my own singing lessons, and my default position in choral singing was to avoid vibrato unless required for stylistic reasons, believing it could affect the tuning of chords and was not a desirable trait in UK choral singing.

To gain a comprehensive understanding, I examined literature including peer-reviewed research articles and books written by voice researchers and teachers. These sources provided valuable insights into key concepts, such as the definition, characteristics and perception of vibrato. I also learned about some of the theories of production and discovered different ways in which singers can manipulate vibrato. During my research, I gained insights into singing without vibrato and considerations for the use of vibrato in musical theatre and choral singing. Additionally, I learned about pedagogical approaches for vibrato.

I found that the method of searching for recent research in electronic databases and then utilising citation mining to identify important older research was effective. Given the vast amount of research, it was impractical to include every study. However, by combining the most recent information with more seminal works, I felt that I achieved a good overview. Initially, I overlooked the relevance of articles on the synthesis of digital singing voice and excluded them. However, I noticed how useful that information could be when it appeared in some research that I had included. Although I do not believe the inclusion would have significantly impacted the literature review, I now understand that it might be worth considering these articles if I were to repeat the process.

It is important to recognise the existence of multiple types of vibrato within different cultures and musical styles and that they probably differ in their physiological attributes (Sundberg, 1994, p. 45). The majority of research on vibrato primarily focuses on Western classical music and it may not be directly applicable to musical theatre or choral contemporary repertoire. A limitation of the literature review and of the existing research lies in the scarcity of information relevant to these genres. In hindsight, it would have been beneficial to include information on vibrato from other cultures and genres, if available, to obtain more pertinent data.

During my reading, especially at the beginning, I found it overwhelming to grasp the various terms associated with vibrato. This was partly due to the fact that different concepts were described in multiple ways. For example, Isherwood (2009) uses the term amplitude instead of extent, even though amplitude usually has a different definition, and rhythm rather than rate. Shimmer is sometimes used to mean the consistency of extent (Becker and Watson, 2022) and sometimes the consistency of amplitude (Hakanpää, Waaramaa and Laukkanen, 2021). In addition, the use of abbreviations was not always easily comprehensible, even though they may have been defined. For instance, due to the desire to use psychoacoustic terminology, rather than using VR for vibrato rate, Anand *et al.*'s study used "f_{f0m}". (2012, p. 820.e19)

I believe that articles could be written with more clarity by using more standard terminology and only use abbreviations when necessary. I feel that it is inconsiderate to the reader to use jargon to be efficient or intellectually pretentious. In a previous assignment, I have written about how challenging I find academic writing and one of the most important things that I learned during this assignment was to try and express myself in a simple and straightforward manner and that as my knowledge increases I do not need to demonstrate that through the use of jargon.

As I progressed through the assignment, I not only expanded my understanding of vibrato but also developed a greater ability to question and critically evaluate the information I encountered. This evolution became particularly evident when exploring the topic of vibrato versus non-vibrato singing. The underlying driver of my research was the idea that singing with vibrato was inherently healthier than singing without it. At the outset as I began my reading, it seemed apparent that non-vibrato singing was unhealthy for the voice. I began to doubt my own competence as a singing teacher, feeling naïve for not having understood this basic concept. However, as I continued with my reading, I realised that it is not conclusive.
While singing with an even vibrato at a moderate rate and extent can be indicative of good technique and a healthy free voice, it does not mean that singing with a straight tone is inherently damaging. Limited research exists in this area, and while we understand the physiological signs of vocal fatigue, the link between non-vibrato singing and potential vocal harm is not conclusively established. This realisation prompted a heightened awareness of the need to critically examine the sources of the statements that we often repeat and the need to challenge assumptions and delve deeper into the evidence behind commonly held beliefs.

So what?

My primary goal is to apply the knowledge that I have gained from this literature review within my role as a choral leader and within my teaching practice. I am particularly keen to use the exercises that Nix (2014) suggests as I believe they help to encourage good vocal technique and natural production of vibrato as well as his tips for non-vibrato singing. During general warm-ups and within songs I will actively listen for vibrato and encourage its development as appropriate. I am keen to share the information I have learned with other choral leaders and singing teachers in addition to monitoring the ongoing developments in this area of research.

My expectation was that having explored the topic, I would have a comprehensive understanding of vibrato and if I was presented with concepts such as vibrato being healthy and non-vibrato being less healthy, I would have an evidence-based opinion. While my

knowledge has increased considerably, this is a topic that is still evolving. I realise that at this point in time we do not yet have the research to say conclusively that non-vibrato singing is a less healthy choice, although we could hypothesise that there is the potential for it to cause vocal fatigue.

Equipped with this newfound knowledge, I can confidently delve into reading anecdotal literature such as blogs and engage in meaningful conversations with other teachers on the subject. Previously I would have struggled with determining which information was credible and suitable for experimentation and would have felt unable to contribute.

What now?

As a consequence of this study, I have identified various learning areas that I am keen to pursue:

- In the article by Green *et al.* (2014), a quarter of musicals were in the pop/rock genre. However, the research data lacked insights into the use of vibrato within this type of musical. It would be beneficial to explore this aspect and gain a better understanding of vocal production and stylistic choices in pop/rock musicals, as well as how they compare or contrast with other types of musicals and with the actual pop/rock genre.

- One of the studies that captivated my interest the most was the recent investigation conducted by Becker and Watson (2022) on vibrato in female belt and legit singing in musical theatre. The selected songs for the belt mode of singing could all be classified as traditional belting. I am intrigued to further explore and compare these findings with vibrato in contemporary belting. As suggested at the end of study, it would be interesting to see the results of a similar study with male voices, although I acknowledge that there are debates surrounding the use of belting by male singers (Miles and Hollien, 1990, pp. 66–67).

- Titze (2002) indicated that vibrato diminishes at the extremes of the vocal range. I would like to gain a deeper understanding of where exactly this phenomenon occurs within the range.

- I was interested to read the research on vibrato and emotion. One of the limitations of the research was due to whether a singer is genuinely feeling an emotion or skillfully

feigning it and what impact that had on the results (Dromey et al.., 2015). It made me think about the difficulties that singers could experience portraying emotions genuinely in performance. I would like to explore how singers can portray emotions authentically without compromising vocal production or their mental health.

- Following on from the study by Moorcrooft, Kenny and Oates (2015) where breathing imagery impacted vibrato rate, I would be interested to know if breathing meditation had a similar effect.

Overall, this learning experience has been highly positive. I have experienced significant growth, transitioning from a state of limited knowledge to feeling competent and enthusiastic about applying my theoretical knowledge in my teaching practice.

The use and suppression of vibrato in choral singing and musical theatre: a narrative literature review

ASSESSMENT 2 – WRITTEN ASSIGNMENT

Introduction

The aim of this study is to explore the current understanding of vibrato, its controversies and the implications for singing teachers in musical theatre and choral singing. While the subject has been researched for over 90 years (Dromey et al.., 2015), there remain many unanswered questions (Stark, 1999, p. 121). This narrative literature review will investigate how we define vibrato and its characteristics, its theories of production and volitional control. It will explore the stylistic use and considerations for vibrato and non-vibrato within Western musical theatre and choral singing. Finally, the study will look to suggest pedagogical approaches for the development and maintenance of vibrato in singers and ideas for future research.

Defining vibrato

Within the literature, Seashore's definition of vibrato is frequently used: "a periodic pulsation, generally involving pitch, intensity, and timbre, which produces a pleasing flexibility, mellowness, and richness of tone" (Seashore, 1932, p. 33). Seashore and his team, having developed specific instruments to measure vibrato, were responsible for extensive research on this phenomenon (Prame, 1992, p. 73; Hähnel and Martensen, 2019, p. 29). While Seashore's work is still highly regarded and forms the foundation of the body of research that we have on vibrato, some aspects of it have become outdated partly due to use of primitive technologies and partly because the research was conducted on singers of that era. For example, certain parameters of vibrato have evolved with singers since that time (Ferrante, 2011, p. 1683). Nevertheless, Seashore's definition has stood the test of time and continues to be employed because the acoustic description of vibrato has remained relatively consistent (Titze et al.., 2002, p. 2272).

My preference is for a similar, but more extended definition by Nix, which provides additional clarity and detail on the acoustic characteristics, but refrains from defining the perception of vibrato:

> a periodic oscillation of the f_0 (perceived as pitch) and all its harmonics, amplitude (perceived as apparent intensity or volume), timbre (a result of harmonics sweeping through vowel formants), subglottic pressure, closed quotient (the percentage of each vibration cycle the vocal folds are in contact), and formant frequencies. (2014, p. 411)

There are two principal ways that vibrato can be measured: by the extent and the rate of the oscillations. Vibrato extent is the distance by which the fundamental frequency is varied in the oscillation or how much the slight alteration in pitch is above or below the target pitch. (Sundberg, 1987, p. 163) This is usually measured in cents or semitones with 100 cents being equivalent to a semitone. A normative range for extent could be considered to be plus or minus 50-100 cents. This can be affected by loudness (Glasner and Johnson, 2022, p. 465). Extent can increase with training (Mitchell and Kenny, 2010) and with time: by examining recordings, Ferrante (2011) reported a general increase in extent for the soprano within Western classical music over the last century (1928-2009). It can also be affected by the choice of repertoire (Mitchell and Kenny, 2010, p. 427) and other factors that will be discussed throughout this review.

Extent is usually accompanied by an amplitude modulation, which is measured in decibels. The frequency and amplitude modulations can be in or out-of-phase with each other (Dromey, Reese and Hopkin, 2009).

Vibrato rate is the number of oscillations per second, which are measured in hertz (Hz). In contrast to extent, Ferrante (2011) reports a decrease in rate over the last century from approximately 7Hz to approximately 5Hz. This decrease is also evidenced in the writing of Sundberg and Titze: in 1987 Sundberg states that a rate of less than 5.5Hz “sounds unacceptably slow” (p. 164), but 21 years later Titze claims that 4.5-6.5Hz is an acceptable range (2008, p. 40). Furthermore, it has been shown that males voices have slower rates of vibrato than females (Shipp, Leanderson and Sundberg, 1980; Guzman et al.., 2012), age has an impact on vibrato and in particular a decrease in rate (Titze et al.., 2002, p. 2273) and training also has an effect on rate with Mitchell and Kenny observing a slight decrease over a two-year period.

In a small study conducted by Bretos and Sundberg (2003), it was observed that the rate of vibrato varies within a singer and changes with pitch. The study also recorded an increase in rate towards the end of a note in the final cycles of the vibrato. This finding aligns with the research by Ferrante (2011) and Prame (1992). Prame further contributes to the discussion

on reported rates of vibrato by highlighting that the rate can vary depending on the durationof a note “with shorter tones showing higher average rates than longer tones.” (1992, p. 83).

Vibrato can be measured by its consistency through the vibrato cycles. Sundberg believes that “the more regular the vibrato, the more skilled the singer.” (1987, p. 163). Consistency of rate is known as jitter, while shimmer is the consistency of vibrato amplitude or sometimes extent (Patel et al.., 2011, p. 94; Becker and Watson, 2022). Jitter and shimmer are described as a percentage with a low number signifying a more consistent approach. There has been less research in this area (Horii, 1989b; McHenry and Evans, 2022).

Perception of vibrato

Vibrato is perceived to be a result of a good singing technique (Howes et al.., 2004, p. 216) with classical singers developing vibrato “more or less by itself as voice training proceeds successfully” (Sundberg, 1987, p. 163). The goal for vibrato is that it “draws no attention to itself” (Titze *et al.*, 2002, p. 2272); for the listener to be “unaware of oscillating movements” (Reid, 2022, p. E142). More noticeable vibratos often occur when the rate and/or extent lie outside of the normative bounds. In addition, a delayed onset of vibrato was regarded as a less appropriate vibrato by voice teachers (Ekholm, Papagiannis and Chagnon, 1998).

When a vibrato is “appropriate”, it is considered a characteristic of vocal quality (Ekholm, Papagiannis and Chagnon, 1998) and a significant factor in achieving vocal beauty (Robison, Bounous and Bailey, 1994). The latter study involved a group of voice experts rating classical baritones and musical theatre female belt singers. The most beautiful voices, regardless of genre, had a high proportion of vibrato within their total singing time with an even approach and a moderate rate and extent. The consistency of vibrato as an indicator of vocal quality was also evidenced by Diaz and Rothman (2003). Sundberg believes that rate has a much greater impact than extent (1987, p. 165), which is corroborated by Anand *et al.*’s study (2012).

While it may be difficult for a listener to specifically perceive amplitude modulation within vibrato (Sundberg, 1994), it seems that it plays a fundamental role in producing a rich and natural sounding quality in voice synthesis experiments (Maher and Beauchamp, 1990). Although Howes *et al.* hypothesise that a high level of amplitude modulation would create a less appropriate vibrato for the listener (2004, p. 93).

The terms wobble, bleat and flutter are often used to describe less desirable vibratos. A wobble has a wide extent, usually greater than 50 cents, and with a rate less than 5Hz. In

contrast, a bleat or flutter has a narrow extent (less than 50 cents) and a fast rate of above 7Hz. A flutter can also be defined as out-of-phase amplitude and pitch modulation cycles (Nix, 2014, pp. 411–412).

Expressing emotion through vibrato

Reid believed that vibrato could serve as a "reflector" of emotions (1975/2022, p. 142). Seashore stated that it was "essential to the expression of feeling" (1967, p. 47), but questioned its ability to convey the specific kind of emotion. However, Seashore's opinion did not appear to be based on any evidence (Dromey *et al.*, 2015, p. 171).

Scherer *et al.* (2015) compared the expression of emotion in singing and speaking voices. The study suggested that opera singers utilise vibrato, especially when expressing intense emotions like anger, as their emotional freedom is limited by the predefined vocal line.

Howes *et al.* (2004) conducted a study where listeners accurately identified the conveyed emotion being conveyed in an operatic cadenza. The first part of this study also found a potential impact from emoting on vibrato: singers who were most successful in expressing "fear of death" had faster vibrato rates. Scherer (1995, pp. 236–237) states that if emotions can be accurately perceived from the voice, then they must affect the vocalization mechanism, resulting in observable difference in the acoustic patterns of sound waves.

In a study by Sundberg, Iwarsson and Hagegård (1994) a singer was asked to sing various song extracts in an emotionally neutral manner and then with expression. The expressive singing was categorised as either agitated or non-agitated. It was found that the agitated singing exhibited a greater extent of vibrato compared with the non-agitated or neutral singing. The agitated singing was also consistently louder than the non-agitated singing. This possibly suggests that the arousal of emotion may have led to a louder vocal response, which in turn contributed to an increase in vibrato extent.

Jansens, Bloothooft and De Krom (1997) found that angry and joyful singing contained vibrato, while sadness did not. Anger and joy were also associated with higher average sound pressure levels than sadness. This perhaps indicates that emotions indirectly influence vibrato through other parameters such as loudness. Guzman *et al.* (2012) demonstrated that emotions themselves do not seem to directly affect vibrato, but loudness does impact vibrato extent and jitter.

The research conducted by Dromey *et al.* (2015) involved sustained vowels, a more emotionally neutral song and a song with heightened emotions. By monitoring loudness and pitch, the researchers found that rate increased with higher levels of emotion, and the extent and stability of vibrato increased with the performance of songs rather than sustained vowels. This suggests that the act of performing songs, rather than solely experiencing emotion, may drive changes in vibrato.

Overall, there is some evidence supporting the idea that vibrato can assist listeners in identifying the emotion conveyed by a singer and that emotions have an impact on the voice. There appear to be two main challenges in this type of research: first, isolating the direct impact of emotion on specific parameters, and second, understanding whether the emotions applied within the studies are genuine and not skillfully simulated by the singer. These complexities warrant further investigation.

Theories of production

Our understanding of how vibrato is produced is still evolving and there have been many theories of which a number are included below. Within Western classical music at least, production is broadly understood "as a series of neurologically driven laryngeal and respiratory adjustments, being mainly characterized by rapid increases and decreases in activation of the cricothyroid muscle" (Dromey, Reese and Hopkin, 2009, p. 156).

In 1970, Vennard, Hirano and Ohala conducted a study using electromyography to analyse vibrato in the cricothyroid, lateral cricoarytenoid and vocalis muscles and in five extrinsic muscles (the digastric, thyrohyoid, sternohyoid, palatopharyngeus, and levator veil palatini) of four subjects. In addition, in one of those subjects they also studied the interarytenoid. They confirmed activity in the cricothyroid muscle for pitch increases and that activity in all other muscles (except the interarytenoid) for at least part of the time with "the intrinsic muscles alternating with the extrinsic in diadochokinesis" (1970, p. 20). Hirano, Hibi and Hagino reported oscillatory movement in surrounding structures, such as the laryngeal depressors, the lateral pharyngeal wall, velum, the base of the tongue and the epiglottis, using videoendoscopy (1995, quoted in Nix, 2013, p. 58).

Furthermore, Deutsch and Clarkson (1959) observed that auditory feedback was a significant contributor to rate. Shipp, Sundberg and Doherty (1988) conducted an experiment on delayed auditory feedback, which supported Deutsch and Clarkson's findings to a certain extent. While the rate did change significantly in some delay conditions, the changes were much smaller

compared with the previous study, which was hard to explain. Nevertheless, modifying auditory feedback appeared to impact the laryngeal muscles involved in vibrato rate. More recently, Lester-Smith *et al.* (2022) explored masked and delayed auditory feedback and found that rate was not affected, but its consistency and extent was influenced by masking. Overall, the gain of auditory feedback seems to affect vibrato, although there are inconsistencies in the results regarding rate across the studies.

Shipp, Leanderson and Sundberg (1980) hypothesised that vibrato was "produced by selective activation and inhibition of neural impulses in the critical muscles groups through the vocal tract." Then a possible connection between pathologic vocal tremor, such as in Parkinson's Disease and vibrato was observed (Ramig and Shipp, 1987). Titze *et al.* suggested that vibrato could be a "stabilized tremor" (1994, p. 215). Following on from this, it was proposed that vibrato may be caused by a long-latency reflexive negative feedback loop involving agonist-antagonist muscle pairs that can alter the length and tension of the vocal folds, such as the cricothyroid with the thyroarytenoid muscle. (2002)

In addition to recognising a "laryngeally mediated vibrato", Shipp, Doherty and Haglund also mention an alternative approach involving subglottic pressure fluctuations driven by abdominal contractions (1990, p. 303) This method is often employed in pop music (Sundberg, 1994, p. 56). Pre-pubescent children typically lack natural vibrato perhaps owing to the under-development of the vocal ligament. However, they can create a similar sound through laryngeal shaking, using the tongue root against the top of the larynx (Williams, 2019, p. 99) or by using the subglottic pressure approach.

Amplitude modulation can occur through vocal tract resonances and in addition there is evidence of it occurring at a laryngeal level (Horii, 1989a; Dromey, Reese and Hopkin, 2009). It can be a by-product of cricothyroid-driven frequency modulations, but also be achieved through this abdominally mediated approach. This could be a significant volitional method of creating amplitude modulation and vibrato in general (Shipp, Doherty and Haglund, 1990; Dromey, Reese and Hopkin, 2009).

Volitional control

According to Titze *et al.*, "vibrato frequency is less controllable by the singer than vibrato extent" (2002, p. 2273). However, a study by King and Horii (1993) showed that singers were able to better match rate to a target vibrato than extent. They also found that singers were

more successful in matching slower rates compared with faster ones. Additionally, Dromey, Carter and Hopkin (2003) demonstrated that singers could consciously change the rate in different vocal registers. Participants could increase the rate more in chest and mix and decrease more in the head register. It appeared that breath pressure could be used to make these adjustments with a decrease for slower rates and increase for higher rates. However, it remains unclear whether singers can make these changes without auditory cues and sustain them in the long term.

Mitchell and Kenny (2004) showed that extent could be increased, and the onset of vibrato could be adjusted using an improved “open throat” technique. Nix, Patinka and Titze (2020) found subtle decreases to rate and extent, as well as an increase in jitter, could be achieved by changing the mouth opening from its normal position in either direction. Hinkley (2021) demonstrated that singers can adjust their rate and extent to match an audio sample. The study found that undergraduate singers had more success than the high school subjects, suggesting that training has an impact on the ability to consciously control vibrato.

Current evidence suggests that singers can consciously make adjustments to vibrato. The extent of conscious control over vibrato without matching it to a target sample is an area that requires further research.

Straight tone

A straight tone, also known as non-vibrato, is often perceived as lacking vibrato. However, as Nix points out “slight fluctuations in pitch, intensity, or vocal characteristics occur in all singing” (2014, p. 413). Despite this, straight tone has gained a reputation for a flat quality of sound and is sometimes associated with poor technique and vocal fatigue.

The negative perception of straight tone may be influenced by pedagogues such as Miller and Vennard, who described it as “incessant mooing” (1986, p. 188) and “deplorable” (1990, p. 205). Vibrato, on the other hand, is often considered a good vocal technique, which can lead to the perception that straight tone lacks technique. However, Titze challenges this view by suggesting: “a vibrato-free voice might mean that the person has good [muscle] balance but they disengaged it somehow” (2000, quoted in Olson, 2008, p. 563).

According to Titze *et al.* (2002), straight tone is achieved not by decreasing the vibrato rate, but rather reducing extent. A study by Wooding and Nix (2016) on non-vibrato found that both extent and rate work together to create a perception of vibrato-free singing, with rate having

the strongest influence. It is believed that vibrato naturally decrease to straight tone at the high and low ends of the voice due to a reduction in the antagonistic activity of the cricothyroid and the thyroarytenoid, resulting in decreased oscillations (Titze *et al.*, 2002).

Straight tone has been stigmatised as an unhealthy singing approach. Singers are often discouraged from singing with straight tone due to concerns that it may damage the voice, as stated by Katok (2021, p. 9). However, conclusive evidence to support this claim is lacking (Sublett, 2009, p. 540; Nix, 2013, p. 65). Mabry writes:

> if the use of straight tones summarily destroyed voices, thousands of singers would have lost their voices by now, since the use of non-vibrato is prevalent in some musical styles and cultures. (2002, pp. 43–44)

Vocal fatigue can occur in the laryngeal muscles or the lamina propria of the vocal folds. The recovery time for muscle fatigue is relatively short, ranging from minutes to hours, whereas the recovery time for the lamina propria can take hours to days (Titze, 1999). The vibrations observed in surrounding structures during vibrato, as discussed earlier, may help alleviate tension in the vocal mechanism (Hirano, Hibi and Hagino cited in Nix, 2013, p. 58). Nix speculates that singing with vibrato may result in less laryngeal muscular tension than singing without vibrato. He further hypothesises that a reduction in glottal adduction during vibrato may lessen the impact on the lamina propria, potentially preventing vocal fatigue. The opposite could be true for non-vibrato singing (2013, p. 58). This is based on Gauffin and Sundberg's suggestion (1989) following a study by Iwata and Large (1971), which explained the lower airflow rates in vibrato singing as compared with non-vibrato due to increased glottal resistance.

McCoy describes an informal experiment regularly conducted by his students using electroglottography and spectrum analysis to compare singing with and without vibrato. He notes that there are typically three groups of singers when it comes to non-vibrato singing. The first group exhibits an increased closed quotient, indicating that they may be suppressing the vibrato by adducting at a laryngeal level. The second group shows a decreased closed quotient, suggesting that they are increasing airflow to achieve non-vibrato. The third group maintains the same closed quotient as when they are singing with vibrato. Although some singers in this group may have little vibrato in their sound, others are capable of turning vibrato on and off. This group tends to have lighter voices. According to McCoy, achieving a heathy straight tone requires "balanced, easy breath support, laryngeal freedom, muscular release in the articulators and the willingness to make a different sound quality." (2011, p. 299).

Elliott proposes that singers should adjust the pressure of the airflow to achieve non-vibrato (2006, p. 17). Katok, in his article, suggests using low subglottic pressure and low airflow to access straight tone. He also recommends using slides, as they are “free of vibrato since it does not stay on any one pitch long enough for it to oscillate.” (2021, p. 15)

To address the misleading connotations associated with terms like straight tone or non-vibrato, Sherburn-Bly suggests using the term “simple tone” instead (2007, p. 61). Sublett would like to change the use of the term ‘straight tone’ as an instruction, as she feels that it encourages tension, and she prefers the singers to think of it as purifying or focusing the tone. (2009, p. 542)

Straight tone is not necessarily unhealthy, but we have to be mindful of the possibilities of vocal fatigue as we continue to learn more about this technique. Perhaps research should focus on communities where non-vibrato is more widespread (Isherwood, 2009, p. 273).

Use in choral singing

> Experts offer a wide range of view points regarding vibrato in choral singing, from those who believe in a free, soloistic vibrato to those who advocate a minimal vibrato or even straight tone. [...] Given the polarity of these opinions, with healthy vocal technique and sound quality in the balance, it behooves choral conductors to learn as much as possible about the phenomenon of vibrato. (Walker, 2006, p. 37)

Choral singers often have different experience levels of singing training. In a study involving 1124 choral singers from the UK, Germany and Australia, it was found that only 42% of them had received singing lessons. Looking at two ends of the training spectrum, Brown, Rothman and Sapienza (2000) found that one consistent difference between professional singers and non-singers was the existence or lack of vibrato. This suggests that there could be a variation of vibrato between members of a choir depending on their singing training.

Choral singers are often required to adjust their vibrato, including singing without vibrato for the purpose of intonation, blend and adherence to historical or stylistic requirements, such as in early music (Sublett, 2009; Galante, 2011; Nix, 2013). However, this can lead to disagreements between choral directors and singing teachers. Some teachers, as discussed, believe that singing with minimal vibrato can be unhealthy and furthermore can hinder a singer’s development as a soloist (Goodwin, 1980; Nix, 2013).

Intonation

Vennard argues that a misconception emerged in choirs “that perfect intonation was impossible except with straight tone.” (1967/1990, p. 206) How does vibrato actually affect our perception of tuning? In a pitch-matching study conducted by Hinkley (2021), participants were tasked with imitating phrases that were in tune, sharp or flat in addition to either having vibrato or minimal vibrato. The results showed that responses to phrases with vibrato were more accurate in terms of tuning compared with phrases with minimal vibrato. Titze supports the idea that vibrato “helps stabilize the pitch” by regulating the inherent oscillations present in the voice (2008). In addition, Warren and Curtis (2015) demonstrated that the use of vibrato reduces the impact of mistuned singing. These findings challenge the notion that straight tone is necessary for the perception of perfect intonation in choirs.

Blending

Blending could be considered a crucial aspect of choral singing (Daffern, 2017) and could be defined as the avoidance of “one voice ‘sticking out’” (Emmons and Chase, 2006, p. 150). Choral directors often view vibrato as a characteristic that needs to be managed to achieve blend (Daffern, 2017). In a study by Man (2014) comparing choral and solo singing, all participants believed that they needed to adjust between the two modes, with 50% citing blend and 37% citing vibrato. The participants exhibited an increased rate, extent and duration of vibrato in their solo singing compared with their choral singing. This finding is supported by research indicating that vibrato extent is generally reduced in choral singing compared with solo singing (Rossing, Sundberg and Ternström, 1987). Another study showed some synchonisation of vibrato between choral singers who employed vibrato (Jers and Ternström, 2005).

In a study on ensemble blending, singers often identified “vibrato as key factor they they were trying to control.” (Daffern, 2017, p. 385.e28) The research demonstrated that singers made conscious efforts to decrease vibrato to improve blend. However, the overall adjustments made by the singers in this study, with perhaps the exception of the soprano’s vibrato extent, were not as significant as they themselves perceived them to be.

Goodwin (1980) discovered in his study, where sopranos used various methods to achieve blend by reducing the adverse effect caused by certain partials switching on and off, that one of those ways was by reduced vibrato. However, the success of this method is dependent on the spectral characteristics of the individual singer’s voice.

The study on professional opera chorus singers is often quoted as being an example where vibrato was not adjusted for group singing. While this study is interesting and provides insights into ensembles, it perhaps does not directly apply to choral singers. It is important to note that an opera chorus and a choir have different requirements and potentially are comprised of a different type of singer. As Titze states “opera choruses, composed often of solo singers with ample ring, may therefore not exhibit the timbral unity that one hears in choruses composed of non-opera singers.” (2008, p. 40) and the study concludes by hypothesising that an opera chorus singer requires a similar timbre to opera soloists (Reid *et al.*, 2007).

An interesting study by Ekholm (2000) compared a soloistic approach to choral singing with a blended approach and raises the point of whether it is necessary for a choir to blend. This perhaps brings further contention between choral conductors and singing teachers, as the results showed that the teachers tended to prefer the fullness, freedom and vibrancy associated with the soloistic approach, while choral conductors favoured the lightness, clarity and control in the blended singing mode.

A final point to consider is that instead of actively manipulating the vocal production of choral singers to achieve blend, an alternative approach could be a combination of voice-matching and spacing. The voice-matching technique, associated with Weston Noble, involves arranging singers next to others with whom their voices naturally blend (Giardiniere, 1991, p. 5). The second aspect to consider is the spacing of singers. Research suggests that a spread spacing arrangement can contribute to an improved choral sound, both for listeners and singers (Ekholm, 2000; Daugherty, 2003).

Use in musical theatre

Musical theatre performers require versatility as are required to perform in different voice qualities and styles. There are three dominant voice qualities in musical theatre: legit, mix and belt. The term legit comes from legitimate and is associated with a head voice dominant style closely associated with the classical tradition. (LoVetri, Saunders-Barton and Means Weekly, 2014; Bourne and Kenny, 2016; Becker and Watson, 2022) The definition of belt continues to evolve. In 1990, Miles and Hollien defined belting as “unusually loud, heavy phonation that exhibits little-to-no vibrato [and] a high level of nasality” (p. 69). Voice pedagogues have distinguished between traditional and contemporary belting: traditional belting incorporates vibrato and is prevalent in pre-2000 musicals. It typically encompasses a range up to D5 and is chest voice dominant producing a full sound with open vowels. In contrast, contemporary belting makes little use of vibrato, it is usually higher than D5 incorporating some degree of

head voice and closed, narrow vowels (Roll, 2014). Mix falls in between legit and belt and is dominated more by speech sound, but easily connects into the higher voice. In addition to these voice qualities, musicals are dominated by a range of styles such as pop, rock, blues, jazz and rap. Frequently a singer will move from one style to another within one show. (LoVetri, Saunders-Barton and Means Weekly, 2014; Bourne and Kenny, 2016; Becker and Watson, 2022)

In a study conducted by Bourne and Kenny (2016) 12 leading musical theatre voice teachers were interviewed to gather their perceptions of different voice qualities within the genre. Most teachers agreed that vibrato was a component of the belt sound, but typically with less vibrato than legit singing. Only one teacher expressed the opinion that belt singing did not involve vibrato, while two others noted that it depended on the type of belt being used. Specifically, “pure” belt and “full-on belt” were perceived as lacking vibrato, while “belt mix” incorporated vibrato, usually occurring at the ends of phrases. Regarding legit singing, some teachers mentioned the inappropriateness of an uneven, obtrusive, “over-wide” vibrato or wobble.

In a recent study by Becker and Watson (2022), the use of vibrato in legit and belt performances was compared among five established female musical theatre performers. It was observed that both voice qualities had a higher proportion of notes sung without vibrato compared with those sung with vibrato. The belt extracts had a lower proportion of notes with vibrato compared with the legit extracts. Additionally, it was noted that the duration of vibrato within a note was generally longer in legit singing. The average rate was slower for belt performances and most singers had a wider average extent in the legit performances although this difference did not achieve statistical significance. There was also no notable difference in terms of cycle-to-cycle consistency. It is worth mentioning that all the belt songs analysed in this study fit into the traditional belting category according to Roll’s definition. It would be interesting to explore a comparison with contemporary belting styles and with male voices, although it is debatable if male voices commonly employ belting techniques (Miles and Hollien, 1990).

Another study that predominantly focused on traditional belting was conducted by LeBorgne *et al.* (2010). 20 musical theatre students were rated on seven potential characteristics of belting while singing two vocalises and six excerpts from musical theatre songs. It was determined that ring and vibrato were the “most deciding” parameters to characterise elite belting. All of the singers and raters believed that vibrato was a part of belt sound and it was suggested that belt vibrato could be closer to jazz vibrato. All of the songs were pre-2000, but

arguably “Someone like you” could be categorised more as contemporary belting and the vocalises did extend to E5 which is in the contemporary belting range.

Echternach *et al.* (2014) examined the vocal tract shape of one musical theatre female singer whilst producing two different styles of vibrato: the classical style involved less adjustments of the vocal tract than the jazzy vibrato: the position of the larynx and the diameter of the supralaryngeal area exhibited significant and pronounced changes during the execution of jazzy vibrato. However, with only one subject, it is difficult to make generalisations from this study.

These studies contribute to our understanding of vibrato usage in musical theatre. However further research is needed on sub-styles of belt and within mix in addition to the male voice. Research also does not reflect on the pop/rock genre of musicals which accounted for 25% of the job postings in Green *et al.*’s survey of musical theatre audition listings in a six-month period in 2012-13. (2014) Given the significance of this percentage, further research is need to explore the use of vibrato in this genre.

Pedagogical approaches

Developing good vocal technique

Vibrato can serve as an indicator of good vocal technique, as Coffin pointed out by stating that “You will know when things are right because there will be free-flowing vibrato.” (1980, p. 14) General vocal technique training can have an impact on vibrato, as Mitchell and Kenny demonstrated (2010). However, a study by Mendes *et al.* did not show training to have an impact (2003). It is worth noting that while both studies were similar and were carried out over four semesters, the exact time frame is unclear. Mitchell and Kenny clarified that their study spanned two years, while the other study by Mendes *et al*. at the University of Florida was not explicity stated. The university’s academic calendar consisting of three semesters per year suggests that the study could have been conducted over a shorter time period. In addition, the singers may have received different amounts or quality of instruction between the two studies.

In this spirit of vibrato being a consequence of good singing, Nix has developed a number of exercises to promote “a flexible, spontaneous, artistically appropriate vocal production” for both vibrato and straight tone singing (2014, p. 414).

Correcting problems

Where problems exist with the vibrato, the suggestion is that a teacher should start by checking:

1. the alignment of the body;
2. breathing issues in terms of an unsteady airflow, high or uneven breath pressure; or
3. the “extrinsic musculature” such as an overly high or low larynx, tongue or jaw tension.

Vowel modification and adjustments of airflow can also help (Nix, 2014, pp. 415–417).

LeFevre (2017) pinpoints tension in the tongue as a possible cause of defective vibratos such as wobble, bleat and an intermittent straight tone and prescribes a series of exercises for retraining the tongue. For the correction of a wobble, Titze *et al.* suggests some anecdotal advice: “singing soft and high and by strengthening laryngeal muscles” and a bleat by “singing in the midrange, using muscle relaxation exercises and establishing a balanced vocal quality” (2002, p. 2273).

A study by Moorcroft and Kenny (2012) showed the potential benefit of vocal warm-ups in improving vibrato rates: a 25-minute warm-up produced significant changes for classical female voices. Improvements were observed in the cycle-to-cycle consistency of rate within a note and between notes and rates were moderated with faster rates decreasing and slower rates increasing. Similar results in consistency and moderating fast and slow rates were achieved by using breath imagery (Moorcroft, Kenny and Oates, 2015). It was particularly successful for the two singers with the fastest rates, who perhaps not coincidentally also had the least experience. Both of these studies require larger sample sizes and testing on male voices before these results can be generalised.

Straight tone

In a survey conducted by Nix (2013), 350 singers were asked whether they had received explicit instruction in vibrato. The majority (59.4%) responded that they had not, and any mention was only indirect. The same question was asked of non-vibrato singing and again the majority (62%) said no, it was only mentioned indirectly. For those who had received instruction, the source of vibrato instruction was predominantly from a voice teacher (70.4%), while non-vibrato was primarily from a choral director (53.2%). The results indicate a lack of explicit instruction for a significant portion of singers and in terms of straight tone, choral

directors carry the weight of responsibility for imparting information on a technique that still requires much further research.

It is important that voice teachers maintain open communication and work with choral directors to support them in the achievement of their desired choral sound (Olson, 2008, p. 562). When working with singers that are using straight tone both parties should be vigilant in looking for warning signs of vocal fatigue. These signs may include changes in overall vocal quality, reduced dynamic range, difficulties in singing softly, changes in vocal pitch range, challenges in transitioning through registers breaks, unexpecting voice cracking, increased effort required to sing or speak, discomfort with the larynx during speaking or singing and discomfort outside of the larynx. (Nix, 2013, p. 61)

Improving aural skills

Part of a study by Howes *et al.* (2004) involved 14 singing teachers with national/international reputations. They were asked to listen to 11 recordings of the same cadenza performed by different well-known professional female singers. The purpose was to gather their perceptions of vibrato rate, extent and onset. The study found that there was no correlation between the recorded and perceived onset of vibrato. Moreover, the correlations between perceived extent and rate were only moderate, with extent showing slightly more accuracy. Similar findings regarding the lack of correlation for rate, extent and jitter were observed in a study by Stern and Nix (2021), but this time focusing on male singers. The listeners involved musicians and non-musicians and interestingly the less musically trained listeners had the highest correlations between their perceptions and the measured vibrato characteristics.

Anand *et al.* noted that if we are able to connect “perceptual judgments to acoustic measurement” it would be possible to develop a useful teaching framework (2012, p. 820.e25). Voice software tools like Madde or VoceVista could be valuable in supporting such a pedagogical approach. In a YouTube video (2021), Nix demonstrates how teachers can use voice synthesis tools to improve their identification of vibrato characteristics by training their listening skills to discern isolated adjustments of rate and extent. In addition, it is useful for comprehending the in and out-of-phase impact of amplitude oscillations with pitch modulations (McCoy et al., 2021).

Conclusion

The objective of this literature review was to provide a comprehensive overview of the current understanding of vibrato and the ramifications for singing teachers in the realms of musical theatre and choral singing.

Vibrato is a complex phenomenon that continues to be a subject of ongoing research and exploration. Many aspects of this topic still lack definitive conclusions, leaving room for extensive future investigations. One obvious and important area for further research is gaining a deeper understanding of the various acoustic parameters of vibrato and the physiological mechanism involved in its production.

While it is known that certain aspects of vibrato can be consciously controlled, more research is needed, especially in terms of volitional control without a specific vibrato target. Emotions appear to influence vibrato and singers can use vibrato to convey emotions to an extent, but this is not conclusive. Exploring a simulated emotions elicit the same response as genuine emotional arousal would be particularly interesting. In the context of musical theatre, it would be beneficial to examine contemporary belting and its relationship with vibrato, as well as potential variations in vibrato production across different voice qualities and genres, specifically within the pop/rock genre of musicals.

Regarding choral music, it is worth reconsidering the use of straight tone for tuning and blending purposes. Exploring alternative approaches or determining when straight tone is truly necessary can contribute to improved choral sound. While there is no conclusive evidence indicating that minimal vibrato is detrimental to vocal health, it is important to be mindful of potential contributions to vocal fatigue and to continue investigating this area.

Incorporating vibrato as an indicator of good vocal technique within warm-ups and repertoire selection appears to be a valuable teaching practice.

References

Acosta Martínez, G. and Daffern, H. (2022) 'The Role of Vibrato in Group Singing: A Systematic Review: The Role of Vibrato in Group Singing', *Journal of Voice* [Preprint]. Elsevier Inc. Available at: https://doi.org/10.1016/j.jvoice.2022.11.004.

Anand, S. *et al.* (2012) 'Acoustic parameters critical for an appropriate vibrato', *Journal of Voice*, 26(6), pp.820.e19-820.e25. Available at: https://doi.org/10.1016/j.jvoice.2012.06.004.

Becker, A.S. and Watson, P.J. (2022) 'The Use of Vibrato in Belt and Legit Styles of Singing in Professional Female Musical-Theater Performers', *Journal of Voice* [Preprint]. Available at: https://doi.org/10.1016/j.jvoice.2022.07.018.

Bourne, T. and Kenny, D. (2016) 'Vocal Qualities in Music Theater Voice: Perceptions of Expert Pedagogues', *Journal of Voice*, 30(1), pp. 128.e1-128.e12. Available at: https://doi.org/10.1016/j.jvoice.2015.03.008.

Bretos, J. and Sundberg, J. (2003) 'Measurements of vibrato parameters in long sustained crescendo notes as sung by ten sopranos', *Journal of Voice*, 17(3), pp. 343–352.

Brown, W.S., Rothman, H.B. and Sapienza, C.M. (2000) 'Perceptual and acoustic study of professionally trained versus untrained voices', *Journal of Voice*, 14(3), pp. 301–309. Available at: https://doi.org/10.1016/S0892-1997(00)80076-4.

Coffin, B. (1980) *Overtones of Bel Canto*. Metuchen, NJ: Scarecrow Press.

Daffern, H. (2017) 'Blend in Singing Ensemble Performance: Vibrato Production in a Vocal Quartet', *Journal of Voice*, 31(3), pp. 385.e23-385.e29. Available at: https://doi.org/10.1016/j.jvoice.2016.09.007.

Daugherty, J.F. (2003) 'Choir Spacing and Formation: Choral Sound Preferences in Random, Synergistic, and Gender-Specific Chamber Choir Placements', *International Journal of Research in Choral Singing*, 1(1), pp. 48-59.

DeLeo Leborgne, W. *et al.* (2010) 'Perceptual findings on the broadway belt voice', *Journal of Voice*, 24(6), pp. 678-689. Available at: https://doi.org/10.1016/j.jvoice.2009.02.004.

Deutsch, J.A. and Clarkson, J.K. (1959) 'Nature of the vibrato and the control loop in singing', *Nature*, 183, pp. 167–168.

Diaz, J.A. and Rothman, H.B. (2003) 'Acoustical comparison between samples of good and poor vibrato in singers', *Journal of voice*, 17(2), pp. 179–184.

Driscoll, J. (2007) *Practising clinical supervision: a reflective approach*. London: Bailliere Tindall.

Dromey, C. *et al.* (2015) 'The effects of emotional expression on vibrato', *Journal of Voice*, 29(2), pp. 170–181. Available at: https://doi.org/10.1016/j.jvoice.2014.06.007.

Dromey, C., Carter, N. and Hopkin, A. (2003) 'Vibrato rate adjustment', *Journal of Voice*, 17(2), pp. 168-178. Available at: https://doi.org/10.1016/S0892-1997(03)00039-0.

Dromey, C., Reese, L. and Hopkin, J.A. (2009) 'Laryngeal-Level Amplitude Modulation in Vibrato', *Journal of Voice*, 23(2), pp. 156-163. Available at https://doi.org/10.1016/j.jvoice.2007.05.002.

Durrant, C. (2017) 'The framing of choirs and their conductors: a UK perspective', in F. Abrahams and P. Head (eds) *The Oxford Handbook of Choral Pedagogy*. Oxford: Oxford University Press, pp. 221–236.

Echternach, M. *et al.* (2014) 'Vocal tract shapes in different singing functions used in musical theater singing-a pilot study', *Journal of Voice*, 28(5), pp. 653.e1-653.e7. Available at: https://doi.org/10.1016/j.jvoice.2014.01.011.

Ekholm, E. (2000) 'The Effect of Singing Mode and Seating Arrangement on Choral Blend and Overall Choral Sound', *Journal of Research in Music Education*, 48(2), pp. 123-135.

Ekholm, E., Papagiannis, G.C. and Chagnon, F.P. (1998) 'Relating objective measurements to expert evaluation of voice quality in Western classical singing: Critical perceptual parameters', *Journal of Voice*, 12(2), pp. 182–196. Available at: https://doi.org/10.1016/S0892-1997(98)80038-6.

Elliott, M. (2006) *Singing in style: a guide to vocal performance practices*. New Haven: Yale University Press.

Emmons, S. and Chase, C. (2006) *Prescriptions for choral excellence*. New York: Oxford Unviersity Press.

Feilzer, M.Y. (2010) 'Doing mixed methods research pragmatically: Implications for the rediscovery of pragmatism as a research paradigm', *Journal of Mixed Methods Research*, 4(1), pp. 6–16. Available at: https://doi.org/10.1177/1558689809349691.

Ferrante, I. (2011) 'Vibrato rate and extent in soprano voice: A survey on one century of singing', *The Journal of the Acoustical Society of America*, 130(3). Available at: https://doi.org/10.1121/1.3621017.

Ferris, N. (2016) 'We need to talk about vibrato', *Classical Music*. Available at: https://www.rhinegold.co.uk/classical_music/need-talk-vibrato/ (Accessed: 1 March 2023).

Galante, B. (2011) 'Vibrato and choral acoustics: Common voice science issues for the choral conductor', *The Choral Journal*, 51(7), p. 67.

Gauffin, J. and Sundberg, J. (1989) 'Spectral correlates of glottal voice source waveform characteristics', *Journal of Speech and Hearing Research*, 32(3), pp. 556–565. Available at: https://doi.org/10.1044/JSHR.3203.556.

Giardiniere, D. (1991) *Voice matching: a perceptual study of vocal matches, their affect on choral sound, and procedures of inquiry conducted by Weston Noble*. PhD dissertation. New York University.

Glasner, J.D. and Johnson, A.M. (2022) 'Effects of Historical Recording Technology on Vibrato in Modern-Day Opera Singers', *Journal of Voice*, 36(4), pp. 464–478. Available at: https://doi.org/10.1016/j.jvoice.2020.07.022.

Goodwin, A.W. (1980) 'An Acoustical Study of Individual Voices in Choral Blend', *Journal of Research in Music Education*, 28(2), pp. 119-128

Green, K. *et al.* (2014) 'Trends in Musical Theatre Voice: An Analysis of Audition Requirements for Singers', *Journal of Voice*, 28(3), pp. 324–327.

Guba, E. and Lincoln, Y. (1994) 'Competing paradigms in qualitative research', in N. Denzin and Y. Lincoln (eds) *Handbook of qualitative research*. Thousand Oaks, CA: Sage, pp. 105–117.

Guzman, M.A. *et al.* (2012) 'Influence of emotional expression, loudness, and gender on the acoustic parameters of vibrato in classical singers', *Journal of Voice*, 26(5), pp. 675.e5-675.e11. Available at: https://doi.org/10.1016/j.jvoice.2012.02.006.

Hähnel, T. and Martensen, K. (2019) 'How Thomas A. Edison shaped today's singing ideal: Tracking his ambiguous concept of tremolo by analysing archival documents and sound recordings', *Empirical Musicology Review*, 14(1–2), pp. 22-49. Available at: https://doi.org/10.18061/emr.v14i1-2.6689.

Hakanpää, T., Waaramaa, T. and Laukkanen, A.M. (2021) 'Comparing Contemporary Commercial and Classical Styles: Emotion Expression in Singing', *Journal of Voice*, 35(4), pp. 570-580. Available at: https://doi.org/10.1016/j.jvoice.2019.10.002.

Hinkley, S.P. (2021) 'Effects of vibrato and pitch-varied vocal models on acoustic measures of high school and undergraduate singers' vocal performance', *International Journal of Research in Choral Singing*, 9, pp. 1–21.

Horii, Y. (1989a) 'Acoustic analysis of vocal vibrato: a theoretical interpretation of data', *Journal of voice*, 3(1), pp. 36–43.

Horii, Y. (1989b) 'Frequency Modulation Characteristics of Sustained /a/ Sung in Vocal Vibrato', *Journal of Speech, Language, and Hearing Research*, 32(4), pp. 829–836. Available at: https://doi.org/10.1044/jshr.3204.829.

Howes, P. *et al.* (2004) 'The relationship between measured vibrato characteristics and perception in Western operatic singing', *Journal of Voice*, 18(2), pp. 216–230. Available at: https://doi.org/10.1016/j.jvoice.2003.09.003.

Isherwood, N. (2009) 'Vocal vibrato: new directions', *Journal of Singing*, 65(3), pp. 271-283.

Iwata, S. and Large, J. (1971) 'Aerodynamic Study of Vibrato and Voluntary "Straight Tone" Pairs in Singing', *The Journal of the Acoustical Society of America*, 49(1A_Supplement), pp. 137–137. Available at: https://doi.org/10.1121/1.1975892.

Jansens, S., Bloothooft, G. and De Krom, G. (1997) 'Perception And Acoustics Of Emotions In Singing', *Proceedings of the 5th Eurospeech,* Rhodes. Available at:

https://www.researchgate.net/publication/2655381.

Jers, H. and Ternström, S. (2005) 'Intonation analysis of a multi-channel choir recording', *TMH-QPSR*, 47(1), pp. 1–6.

Katok, D. (2021) 'Healthy minimization of vibrato', *The Choral Journal*, 62(4), pp. 8–19.

Kelly, L. and Cordeiro, M. (2020) 'Three principles of pragmatism for research on organisational processes', *Methodological Innovations*, 13(2), pp. 1–10. Available at: https://doi.org/10.1177/2059799120937242.

King, J.B. and Horii, Y. (1993) 'Vocal matching of frequency modulation in synthesized vowels', *Journal of Voice*, 7(2), pp. 151–159. Available at: https://doi.org/10.1016/S0892-1997(05)80345-5.

Lambie, S. (2018) 'Marking Musical Theatre', *Music Teacher*, 97(9), pp. 31–33.

Lefevre, C. (2017) 'Tongue Management, Part 2', *Journal of Singing*, 74(1), pp. 51–55.

Lester-Smith, R.A. *et al.* (2022) 'The effects of masked and delayed auditory feedback on fundamental frequency modulation in vocal vibrato', *Journal of Voice* [Preprint].

LoVetri, J., Saunders-Barton, M. and Means Weekly, E. (2014) 'A brief overview of approaches to teaching the musical theatre song', in S. Harrison and J. O'Bryan (eds) *Teaching singing in the 21st century*. Dordrecht: Springer, pp. 53–68.

Mabry, S. (2002) *Exploring Twentieth-Century Vocal Music*. New York: Oxford University Press.

Maher, R. and Beauchamp, J. (1990) 'An investigation of vocal vibrato for synthesis', *Applied Acoustics*, 30(2–3), pp. 219–245. Available at: https://doi.org/10.1016/0003-682X(90)90045-V.

Mann, L.M. (2014) 'Effects of Solo and Choral Singing Modes on Vibrato Rate, Extent, and Duration Exhibited by Undergraduate Female Singers', *IJRCS International Journal of Research in Choral Singing*, 5(1), pp. 26–38.

McCoy, S. (2011) 'The Choir Issue, Part 1', *Journal of Singing*, 67(3), pp. 297–301.

McCoy, S. *et al.* (2021) *Practical Science in the Studio, Part 3: 'High-Tech' Strategies*, *Journal of Singing*, 77(5), pp. 633-643.

McHenry, M.A. and Evans, J. (2022) 'Maintaining Professional Performance Viability With Age', *Journal of Voice*, 36(5), pp. 668–672. Available at: https://doi.org/10.1016/j.jvoice.2020.08.012.

Mendes, A.P. *et al.* (2003) 'Effects of Vocal Training on the Acoustic Parameters of the Singing Voice', *Journal of Voice*, 17(4), pp. 529-543.

Meyrick, J. (2006) 'What is good qualitative research? A first step towards a comprehensive approach to judging rigour/quality', *Journal of Health Psychology*, pp. 799–808. Available at: https://doi.org/10.1177/1359105306066643.

Miles, B. and Hollien, T. (1990) 'Whither Belting?', *Journal of Voice*, 4(1), pp. 64–70.

Miller, R. (1986) *The structure of singing*. New York: Schirmer Books.

Mitchell, H.F. and Kenny, D.T. (2004) 'The impact of "open throat" technique on vibrato rate, extent and onset in classical singing', *Logopedics Phoniatrics Vocology*, 29(4), pp. 171–182.

Mitchell, H.F. and Kenny, D.T. (2010) 'Change in Vibrato Rate and Extent During Tertiary Training in Classical Singing Students', *Journal of Voice*, 24(4), pp. 427-434. Available at: https://doi.org/10.1016/j.jvoice.2008.12.003.

Moorcroft, L. and Kenny, D.T. (2012) 'Vocal warm-up produces acoustic change in singers' vibrato rate', *Journal of Voice*, 26(5), pp. 667.e13-667.e18. Available at: https://doi.org/10.1016/j.jvoice.2011.10.007.

Moorcroft, L., Kenny, D.T. and Oates, J. (2015) 'Vibrato changes following imagery', *Journal of Voice*, 29(2), pp. 182–190. Available at: https://doi.org/10.1016/j.jvoice.2014.06.002.

Nix, J. (2013) 'Vibrato and Non-Vibrato Singing: Who teaches it? How do they teach it? Does it make a difference?', *Choral Journal*, 53(9), pp. 57-66.

Nix, J. (2014) 'Shaken, not stirred: Practical ideas for addressing vibrato and nonvibrato singing in the studio and the choral rehearsal', *Journal of Singing*, 70(4), pp. 411–418.

Nix, J. (2021) *Using Madde to train perception of vibrato* [video]. Available at: https://www.youtube.com/watch?v=rw4G9x_tM_0 (Accessed: 1 April 2023).

Nix, J., Patinka, P.M. and Titze, I. (2020) 'Changes in Vibrato Rate, Vibrato Extent, and Vibrato Jitter in Soprano Voices in Response to Changes in Mouth Opening: A Pilot Study', *Journal of Singing*, 77(2), pp. 213-218.

Olson, M. (2008) 'Vibrato vs. nonvibrato: The solo singer in the collegiate choral ensemble', *Journal of Singing-The Official Journal of the National Association of Teachers of Singing*, 64(5), pp. 561–564.

Patel, S. *et al.* (2011) 'Mapping emotions into acoustic space: The role of voice production', *Biological Psychology*, 87(1), pp. 93–98. Available at: https://doi.org/10.1016/j.biopsycho.2011.02.010.

Patton, M. (2015) *Qualitative research and evaluation methods: integrating theory and practice*. 4th edn. Thousand Oaks: Sage.

Prame, E. (1992) 'Measurements of the vibrato rate of ten singers', *STL-QPSR*, 33(4), pp. 73–86.

Ramig, L.A. and Shipp, T. (1987) 'Comparative measures of vocal tremor and vocal vibrato', *Journal of Voice*, 1(2), pp. 162–167. Available at: https://doi.org/10.1016/S0892-1997(87)80040-1.

Reid, C. (1975/2022) *Voice: Psyche and Soma*. Digital edn. New York: New Digital Printing. (Originally published in 1975)

Reid, K.L.P. *et al.* (2007) 'The Acoustic Characteristics of Professional Opera Singers Performing in Chorus Versus Solo Mode', *Journal of Voice*, 21(1), pp. 35-45. Available at: https://doi.org/10.1016/j.jvoice.2005.08.010.

Robison, C., Bounous, B. and Bailey, R. (1994) 'Vocal Beauty: A study proposing its acoustical definition and relevant causes in classical baritones and female belt singers', *Journal of singing*, 51(1), pp. 19–30.

Roll, C.K. (2014) *Female musical theater belting in the 21st century: a study of the pedagogy of the vocal practice and performance*. PhD dissertation. Columbia University.

Rosenblatt, D. (2020) *Vocal Power Presents* [video]. Available at: https://vocalpowerpresents.nyc (Accessed: 25 January 2022).

Rossing, T.D., Sundberg, J. and Ternström, S. (1987) 'Acoustic comparison of soprano solo and choir singing', *Journal of the Acoustical Society of America*, 82(3). Available at: https://doi.org/10.1121/1.395281.

Rossman, G.B. and Wilson, B.L. (1985) 'Numbers and Words: Combining Quantitative and Qualitative Methods in a Single Large-Scale Evaluation Study', *Evaluation Review*, 9(5), pp. 627–643. Available at: https://doi.org/10.1177/0193841X8500900505.

Russell, B. (1959) *Wisdom of the west*. London: Rathbone.

Scherer, K.R. (1995) *Expression of Emotion in Voice and Music*, *Journal of Voice*, 9(3), pp. 235-248

Scherer, K.R. *et al.* (2015) 'Comparing the acoustic expression of emotion in the speaking and the singing voice', *Computer Speech and Language*, 29(1), pp. 218-235. Available at: https://doi.org/10.1016/j.csl.2013.10.002.

Seashore, C. (1932) *The Vibrato*, *University of Iowa Studies in the Psychology of Music*. Iowa City: University of Iowa.

Seashore, C. (1967) *Psychology of Music*. New York: Dover Publications.

Sherburn-Bly, R. (2007) 'On the Voice: Straight Tone in the Choral Arts: A Simple Solution', *The Choral Journal*, 47(8), pp. 61–69.

Shipp, T., Doherty, E.T. and Haglund, S. (1990) 'Physiologic factors in vocal vibrato production', *Journal of Voice*, 4(4), pp. 300-304. Available at: https://doi.org/10.1016/S0892-1997(05)80045-1.

Shipp, T., Leanderson, R. and Sundberg, J. (1980) 'Some acoustic characteristics of vocal vibrato', *J Res Sing*, 4, pp. 18–25.

Shipp, T., Sundberg, J. and Doherty, E.T. (1988) 'The effect of delayed auditory feedback on vocal vibrato', *Journal of voice*, 2(3), pp. 195–199.

Stark, J. (1999) *Bel Canto: A History of Vocal Pedagogy*. Buffalo, NY: University of Toronto Press.

Stern, R. and Nix, J. (2021) 'Listener Ratings of Male Singer Technical Ability', *Journal of Voice*, 35(3), pp. 501.e1-501.e9. Available at: https://doi.org/10.1016/j.jvoice.2019.11.004.

Sublett, V. (2009) 'Vibrato or nonvibrato in solo and Choral singing: is there room for both?', *Journal of Singing-The Official Journal of the National Association of Teachers of Singing*, 65(5), pp. 539–544.

Sundberg, J. (1987) *The Science of the Singing Voice*. Northern Illinois University Press.

Sundberg, J. (1994) 'Acoustic and psychoacoustic aspects of vocal vibrato', *STL-QPSR*, 35(2–3), pp. 45–68.

Sundberg, J., Iwarsson and Hagegård, H.H. (1994) 'A singer's expression of emotions in sung performance', *STL-QPSR*, 35(2–3), pp. 81–92. Available at: http://www.speech.kth.se/qpsr.

Swann, M. and Edwards, C. (2017) *Big Choral Census by Voices Now*. Available at: http://voicesnow.org.uk/wp-content/uploads/2017/07/Voices-Now-Big-Choral-Census-July-2017-1.pdf (Accessed: 1 March 2023).

Titze, I.R. *et al.* (1994) 'Interference between normal vibrato and artificial stimulation of laryngeal muscles at near-vibrato rates', *Journal of Voice*, 8(3), pp. 215–223.

Titze, I.R. (1999) 'Toward occupational safety criteria for vocalization', *Logopedics Phoniatrics Vocology*, 24(2), pp. 49–54. Available at: https://doi.org/10.1080/140154399435110.

Titze, I.R. *et al.* (2002) 'A reflex resonance model of vocal vibrato', *The Journal of the Acoustical Society of America*, 111(5), pp. 2272–2282.

Titze, I.R. (2008) 'Getting the Most from the Vocal Instrument in a Choral Setting.', *Choral Journal*, 49(5), pp. 34-41.

Vennard, W. (1967/1990) *Singing: The mechanism and the technic*. Revised edn. New York: Carl Fischer. (This edition originally published in 1967)

Vennard, W., Hirano, M. and Ohala, J. (1970) 'Laryngeal synergy in singing', *The NATS Bulletin*, 27(1), pp. 16–21.

Walker, G. (2006) 'Vibrato, science, and the choral singer', *The Choral Journal*, 47(6), pp. 36–46.

Warren, R.A. and Curtis, M.E. (2015) 'The actual vs. predicted effects of intonation accuracy on vocal performance quality', *Music Perception*, 33(2), pp. 135–146. Available at: https://doi.org/10.1525/MP.2015.33.2.135.

Williams, J. (2019) *Teaching singing to children and young adults*. 2nd edn. Oxford: Compton Publishing.

Wooding, R. and Nix, J. (2016) 'Perception of Non-Vibrato Sung Tones: A Pilot Study', *Journal of Voice*, 30(6), pp. 762.e15-762.e21. Available at: https://doi.org/10.1016/J.JVOICE.2015.10.005.