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The use of vowel-based intonation
techniques by amateur choral singers

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PROJECT PROPOSAL

PROJECT TITLE

The use of vowel-based intonation techniques by amateur choral singers

THE CONTEXT

As the choral director of an amateur upper voice choir that is looking to specialise in competitive singing, I am constantly in search of strategies that will improve the group's performance. The choir consists of 17 singers with varying amounts of choral experience ranging from novices to those who have sung in choirs for approximately 15 years. My own experience includes running several previous choirs and a decade as a soprano in a London symphonic chorus. In addition, I am planning to become a full-time singing teacher this year, as I move away from my current role in asset management.

THE JUSTIFICATION

Intonation plays a pivotal role in the overall performance of a choir. It has been consistently highlighted as a primary concern during daily rehearsals as noted by Ganschow (2014) and further emphasised by Hensley in his 2021 article on the criteria for festival adjudication. One consideration for determining the quality of intonation is a singer's use of vowels (Sundberg, 1987, p. 143; Howard, 2023). There are two principal considerations (Howard, 2023):

- (1) Auditory pitch, which was the subject of my Module 5 desktop-based project (Lindsey, 2023). In this approach, while the fundamental frequency remains the same, spectral changes could lead to a perceived enhancement in intonation particularly in homophonic chords (Nix, 2012; Howard, 2023, p. 2). Although work by Hagerman and Sundberg (1980) and Ternström and Sundberg (1988) together with the concept of the "pitch of the missing fundamental" (Plack and Oxenham, 2006, p. 13) suggest that formant tuning could be used effectively this way, it is challenging to state the efficacy of this method without comparative evidence of ensembles singing with and without it.

(2) Intrinsic pitch of vowels, which concerns variations in the fundamental frequency as a result of changes of vowel. This has been evidenced not only in spoken language (Whalen and Levitt, 1995) but also in a study of choir leader pedagogy students (Ternström, Sundberg and Colldén, 1988) and professional choral singers (Howard, 2023).

Howard describes these vowel-based techniques as “somewhat subtle” (2023, p. 1), which perhaps suggests that they could be more suited for advanced choral singers. My proposed study seeks to understand whether it is possible to adopt these strategies to develop the intonation of less experienced choral singers. This is driven by a desire to elevate the performance of my choir in competitive settings.

THE INTENDED IMPACT

This project will explore the practical application of vowel-based tuning methods within amateur choirs, aiming to recognise the developmental needs of choral singers and directors and create a pedagogical approach for their effective implementation in group rehearsals and one-to-one settings. I plan to create an educational resource based on the knowledge acquired during this project, complementing the artefact produced in Module 5. I anticipate that these “subtle” techniques (Howard, 2023, p. 1) may not be relevant for the objectives of every amateur choir, but I hope that it will be of relevance to amateur choirs that strive for detailed excellence and a competitive edge in performances. Additionally, this project also looks to identify gaps in the existing literature on choral intonation and vowel usage and to uncover new areas for research.

More specifically, in this assignment, I seek to gain a better understanding of the concept of the intrinsic pitch of vowels, particularly with regards to less experienced choral singers. While differences in the fundamental frequency have been observed for different sung vowels (Ternström, Sundberg and Colldén, 1988; Howard, 2023), I would like to understand how these pitch variations are perceived by musicians, particularly those at an adjudicator level. Sundberg, Ternström and Colldén stated that on average it did not “appreciably affect the intonation of a singer” (1988, p. 191). However, there were some vowel pairs in this study that elicited more significant differences and I am aware that there is the possibility that less experienced singers may also produce a greater degree of variation in the fundamental frequency.

Furthermore, I aim to explore the development of choral singers’ listening skills, as a result of Howard’s assertion that the professional singers in his study are adept at tuning “through finely honed careful listening” (2023, p. 2). The Sundberg, Ternström and Colldén study (1988) further underscores this by demonstrating

the importance of auditory feedback when singers are compensating for the variations caused by the intrinsic pitch of vowels. I would like to understand audiation (Jordan, 1987, p. 9), the process of hearing music in the mind, how we learn to improve those skills and are there ways that we can improve the opportunity for auditory feedback, for example, in the way that a choir stands.

THE OUTLINED INTENTION

This project will employ a grounded theory approach utilising both qualitative and quantitative data (Chun Tie, Birks and Francis, 2019) with participation by choir members, choral directors and possibly choral composers, if relevant at that point in the data collection.

Initially, I aim to investigate the response of less experienced choral singers in a similar experiment to that conducted by Sundberg, Ternström and Colldén (1988). I plan to recruit approximately eight volunteers from my choir to participate in recording sets of vowels pairs in early May 2024. On an individual basis, participants will be instructed to smoothly transition between pairs of vowel sounds whilst attempting to maintain a consistent pitch level. They will choose a comfortable pitch in their vocal range for each pair of vowels. Each participant will undergo two 10-minute recording sessions, separated by approximately one hour. The purpose of conducting two sessions is to assess whether participants perform better in the second session after the “training” effect of the first round. This design mirrors the rounds of testing and the interval between them in the Sundberg, Ternström and Colldén’s study. A total of nine vowel pairs will be utilised. To ensure participants clearly understand the target vowel sounds, they will listen to spoken demonstrations of the vowels. The demonstration tracks will sourced from: http://www.vowelsandconsonants3e.com/chapter_1.html# (Ladefoged and Disner, 2012). Recordings will be captured using a Rode NT-USB microphone, my Mac and GarageBand software. Subsequently, I will analyse these recordings in VoceVista to evaluate the accuracy of the fundamental frequency. After analysing this data, I may repeat this procedure with further volunteers from my choir.

Continuing on from this, I plan to explore the perspectives of choral conductors regarding intonation and vowels in amateur choirs. Conductors will be selected through theoretical sampling for semi-structured interviews. Following each interview, the data will be analysed, and additional conductors will be recruited and interviewed until data saturation is achieved. Depending on the findings, further exploration of this topic may involve semi-structured interviews with choral composers. All of these interviews will be scheduled to occur via Zoom in May and June 2024. For recording purposes, I will use my Mac in conjunction with Otter.ai

software to capture the interviews accurately. I will send the transcripts to the participants for their review and validation. Furthermore, following the analysis of the data from the vowel pair testing, to determine whether any results hold auditory significance for trained musicians at the level of an adjudicator, a subset of recordings (potentially featuring a single vowel pair) will be provided to the conductors in advance of their interview. They will be asked if they discern a difference in pitch as the vowels transition in each recording.

Finally, I will conduct a literature review to explore concepts that are raised in the semi-structured interviews and as a result of the vowel pair testing, in addition to understanding how singers can optimise their listening skills. The collected data will be analysed and then presented in a written report and presentation. Furthermore, this research will assist me in developing an educational tool for use in choirs. The research is scheduled for submission and presentation in September 2024.

Timeline

See Appendix 1 for the intended timeline of this project.

THE ETHICS AND INSIDE RESEARCH

Before the study begins, I will clearly communicate to all participants the type of data I plan to collect, their expected contributions, the amount of time required from them and how the collected information will be used (Costley, Elliott and Gibbs, 2010, p. 32). Each participant will need to sign a consent form to participate (Denscombe, 2003, p. 53).

The anonymity of participants' data is crucial to prevent any potential harm to their reputations, that of the University or my own as the researcher (Denscombe, 2003, pp. 141–143). To protect privacy, each participant will receive a unique identifier. Both the identifiers and the research data will be securely stored in password-protected Google cloud storage to ensure confidentiality. Choir members will be aware of which singers are choosing to take part in the testing, but the data that is provided on their participant information form and their recorded data will be confidential.

Given my dual role as both the researcher and the choral director of the choir from which the vowel pair testing participants are from, I am aware of the unique challenges this presents (Costley, Elliott and Gibbs, 2010, p. 25). I will employ rigorous methodological approaches to ensure the integrity of the research, which includes

establishing clear boundaries between my roles as a researcher and as a choral director. A primary concern is that participants might feel their musical abilities are being evaluated, potentially affecting their future in the choir. I will reassure them that this is not the case. While anonymisation techniques will be used to shield participants' identities from external parties, fully anonymising data from myself will be complex due to my familiarity with the choir members and their voices. Nevertheless, I strive to foster an open and honest culture within the choir, where members feel comfortable sharing concerns. Participants will be reminded that they have the right to withdraw from the study at any time without repercussions. I will also assure participants that they are not being evaluated in terms of their membership within the choir.

I have opted to employ grounded theory as the guiding methodology for this research emphasising a data-driven and inductive approach. It is therefore important for a researcher to “suspend ... their own beliefs temporarily for the purposes of research” (Denscombe, 2003, p. 102) and I will endeavour to do so. Ultimately, while the potential impact of my role as an insider researcher is acknowledged, careful consideration and methodological safeguards will be applied to minimise negative effects.

PERSONAL LEARNING OUTCOMES

By the end of this module, I anticipate achieving a deeper understanding of the nuanced relationship between vowel sounds and intonation in choral settings, particularly for amateur singers. Additionally, I aim to better understand how to develop the listening skills of choir members for the enhancement of intonation. I will translate these insights into a concrete actionable strategy that can be applied in rehearsal and performance contexts. I expect that this knowledge will also be able to be applied within singing lessons.

PROJECT REPORT

The use of vowel-based intonation techniques by amateur choral singers

INTRODUCTION

Intonation, which can be defined as the accuracy with which a pitch aligns with the intended target note, is a key focus for choirs, especially those involved in competitive singing (Swannell, 1992, p. 560; Ganschow, 2014; Hensley, 2021). I direct an amateur choir that has been active for three years with a current focus on competing in festivals. The choir consists of 17 cisgender females aged 20 to 60, with diverse backgrounds and varying levels of musical experience. My goal for the choir is to enhance both the individual and collective skills of the singers to improve their overall performance, which includes accuracy of intonation. One method of enhancing intonation is through a choir's use of vowels (Sundberg, 1987, p. 143; Howard, 2023).

A vowel can be defined as a speech sound that forms part of a syllable and is produced with relatively little obstruction to the outward breath flow (Ladefoged and Maddieson, 1990, pp. 93–94). From an articulatory perspective, vowel differentiation is primarily determined by tongue and lip positions. These changes in the vocal tract lead to changes in the formant frequencies (Sundberg, 1987, p. 76). From an acoustical perspective, vowel sounds are differentiated principally by their first and second formants, F_1 and F_2 . (Peterson and Barney, 1952; Carlsson and Sundberg, 1992, p. 256). The human voice produces complex tones containing a series of harmonics, which are multiples of the fundamental frequency (f_o). A formant will boost the sound of a harmonic that is close in frequency (Bozeman, 2017, p. 86).

Pitch can be understood objectively in terms of the fundamental frequency, which is measured in hertz (Hz). However, in complex tones as produced by the voice, where the tone consists of multiple frequencies providing further auditory cues, pitch can be regarded as a “perceptual attribute” (Bendor and Wang, 2006, p. 391). The presence of the harmonics in the sound has been shown to aid pitch discrimination Click or tap here to enter text. (Moore, Glasberg and Peters, 1985), even in the absence of the fundamental frequency: the “pitch of the missing fundamental” is a phenomenon, where the fundamental frequency is not sounded, but listeners still detect it as the pitch of the sound due to the presence of the harmonics (Plack and Oxenham, 2006, p. 13). This indicates the importance of harmonics in pitch perception and consequently intonation.

This leads to two key considerations regarding how vowels may affect choral intonation. Firstly, vowels could influence choral intonation through auditory pitch perception, which involves how we hear and interpret pitch, as described above. It is hypothesised that changes in vowel formants, which alter the spectral content of sound can enhance or diminish certain harmonics, thereby affecting the perception of intonation, particularly in choral homophony (Hagerman and Sundberg, 1980; Ternström and Sundberg, 1988; Nix, 2012; Howard, 2023, p. 2). My Module 5 project (Lindsey, 2023) explored this potential for formant tuning in detail. The project concluded that this concept still requires further testing.

The second consideration involves the intrinsic pitch of vowels, which refers to variations in the fundamental frequency that occur due to vowel changes, primarily resulting from articulatory adjustments (Ternström, Sundberg and Colldén, 1988). This phenomenon, observed universally in spoken language, shows that high vowels such as /i/ have a higher fundamental frequency than low vowels such as /a/ (Whalen and Levitt, 1995). The most widely accepted explanation is the tongue-pull theory: as the tongue rises to produce a higher vowel, it pulls on the larynx through the connecting hyoid bone, increasing the tension in the vocal folds which results in a higher pitch (Ohala and Eukel, 1987; Chen, Whalen and Tiede, 2021). Recent research has shown that the jaw also plays a significant role particularly in the lowering of non-high vowels (Chen, Whalen and Tiede, 2021). It has been suggested that a “jaw-push” occurs when the mandible lowers pushing into the thyroid cartilage and hyoid bone decreasing the tension of the vocal folds (Erickson, Honda and Kawahara, 2017). The concept of intrinsic pitch has been observed in studies of choral singing, although the subjects were choral pedagogy students and professional choral singers rather than amateur singers (Ternström, Sundberg and Colldén, 1988; Howard, 2023). While it was reported that this effect does not “appreciably affect the intonation” of singer who is studying choral pedagogy, it was also suggested that it could have a greater impact within the context of a choral chord (Ternström, Sundberg and Colldén, 1988, p. 191).

There appears to have been no studies using amateur choral singers as participants for either of these concepts. Howard describes these techniques as “somewhat subtle” (2023, p. 1) and notes that they require “well-honed and practiced listening skills over a long period” (2023, p. 2), implying that they may be more suitable for advanced singers. While I acknowledge that the proactive approach of formant tuning is an advanced concept, a study in spoken language suggests that the intrinsic pitch of vowels is “an involuntary effect” (Bush, 1981, pp. 173–174; Ternström, Sundberg and Colldén, 1988, p. 191). This means that amateur singers could be unknowingly

altering the fundamental frequency without the technical skills to compensate for it. Both Ternström, Sundberg and Colldén (in a singing study) and Bush both provide evidence that this frequency shift can be compensated for through listening. Therefore, I feel compelled to explore this vowel-based intonation consideration within my own choir, which brings me to the following research questions:

- How does a change in vowel impact the fundamental frequency of amateur choral singers?
- Is this change aurally significant enough for choral competition adjudicators to notice?
- How can I develop the listening skills of amateur choral singers to make vowel-based techniques relevant in improving intonation?

This project will investigate how the intrinsic pitch of vowels impacts the intonation of amateur choirs and will explore methods for developing the listening skills of choir members (and choral leaders) to improve intonation. I will create an educational resource to aid this process, serving as a companion reference guide to the one I developed for Module 5 (Lindsey, 2023). The UK has a strong tradition of amateur choral singing (Durrant, 2017, p. 229) and while these subtle strategies may not seem relevant to all amateur choirs, I hope this study will be valuable for those seeking to achieve a high level of precision in performances and will identify gaps in current research. From a personal perspective, I intend to deepen my understanding of my own choir members and their abilities and to develop my own listening skills, as I work to develop theirs.

METHODS AND FINDINGS

The paradigm guiding this mixed methods study is social constructivism, which encompasses an ontological belief in multiple realities, an epistemology that is subjective and co-constructed and an axiology that places values at the centre of the research process (Guba and Lincoln, 1994). This framework is ideal for this study that seeks to explore the human experience and perspectives of those involved in choral singing. Specifically, the project employs quantitative and qualitative data directed by grounded theory, an inductive and iterative approach where theory evolves directly from the data (Payne, 2007, p. 70; Chun Tie, Birks and Francis, 2019) with “data collection and analysis are concurrent activities” (Payne, 2007, p. 73). This method allows the research to evolve as the researcher gains a deeper understanding of the key elements, making it well-suited to this study, as it aligns the findings closely with the participants’ experiences rather than being driven by a pre-existing hypothesis (Payne, 2007, pp. 69, 73).

My original proposal for this project included four methods: a vowel pairing test with amateur choir singers; semi-structured interviews with choral conductors (and possibly composers) to understand their perspectives on intonation and vowels in amateur choirs; sending a subset of recordings from the vowel pairing test to the conductors to assess whether they perceived a difference in pitch between vowels, akin to what a competitive adjudicator might discern; and a literature review to explore the development of listening skills and any concepts raised in the interviews and vowel pairing tests. Based on the results of the vowel pairing tests, I decided to change the second method from interviewing conductors to interviewing the participants who had taken part in the tests. This decision, explained further below, was made to better understand the quantitative data. In addition, I found research that provided a way to assess how audibly significant the changes in fundamental frequency were in the vowel pairing tests (Nikjeh, Lister and Frisch, 2008). This allowed me to interpret all 144 tokens of data (rather than a smaller subset that would have been a reasonable amount for the conductors to assess) thereby deepening my understanding.

Therefore, this study employs three research methods with the aim of achieving triangulation and a richer context (Easterby-Smith *et al.*, 2021, p. 80). Each method and its focus were determined by the data produced in the previous method. Consequently, this report is structured as follows:

- Method and findings for strategy one: vowel pairing tests with amateur choral singers
- Method and findings for strategy two: interviews with amateur choral singers
- Method and findings for strategy three: literature review on the development of listening skills

Following this, the reference guide (see Appendix 9) was developed with a pragmatic approach, which integrates experience, knowledge and practical application (Kelly and Cordeiro, 2020) to elicit actionable takeaways. Pragmatism is useful in my role as both a practitioner and a researcher, as it is not constrained by one philosophical stance or one method (Rossman and Wilson, 1985; Feilzer, 2010). It therefore enhances the relevance of my research and contributes to both academic knowledge and practical solutions.

Ethics

Before conducting the research, I received ethical approval from the University and a letter of approval from my employer (see Appendices 2 and 3). In addition, I provided all participants with

detailed information about the nature of the project, the data I intended to collect, their involvement and how the data would be handled (Costley, Elliott and Gibbs, 2010, p. 32). Each choir member signed a consent form for the vowel pair testing and for the interviews (see Appendix 4) (Denscombe, 2003, p. 53). Ensuring participant confidentiality was a priority, as any disclosure could potentially cause reputational harm to the singers, the choir, the university, or myself as a researcher (Denscombe, 2003, pp. 141–143). To protect their identities, all participants were assigned a unique reference; this identifying information was securely stored in password-protected Google cloud storage. In addition, the names of the singers and identifying details were redacted from the data, which was also stored in password-protected Google cloud storage.

Regarding insider-researcher considerations, all eight participants are members of my choir. I am conscious of the potential harm that could result from revealing data, even anonymously, within the organisation. I have not shared the findings with anyone, although I may discuss the project in broad terms if asked in the future. All participants were volunteers and knew that they could withdraw their participation and their data at any time and there was no pressure to participate. I work hard to foster a supportive culture within the choir and I reassured the participants that their participation is not an evaluation of their choir membership in any way (Costley, Elliott and Gibbs, 2010, p. 31).

1 VOWEL PAIRING TESTS WITH AMATEUR CHORAL SINGERS

Method

Design

The objective of this initial strategy was to use a quantitative approach to assess the extent to which less experienced choral singers can maintain the fundamental frequency when changing vowels, and how audibly noticeable this is to both musicians (including instrumental and vocal musicians, such as adjudicators (The British and International Federation of Festivals for Music, 2024)) and non-musicians (who may represent concert audience members or amateur singers without musical training). The participants were members of my choir and are detailed below in Figure 1. This section of the study is based on part of an experiment by Ternström, Sundberg and Colldén (1988), in which they examined how experienced choral singers compensated for changes in fundamental frequency when altering vowels. They concluded that, although most

vowel changes did not significantly alter pitch, certain vowel pairs (such as /i/ to /ε/) led to more substantial changes, potentially affecting choral intonation.

Participants

Eight adult females, all members of my upper voice choir, participated in this study. The entire choir of 17 singers was informed about the research, and eight members volunteered. They were provided with information about the study and signed a consent form (Appendix 4). As part of the form, they confirmed that they were amateur choral singers and indicated the number of years of choral experience that they have had.

Participants	S1	S2	S3	S4	S5	S6	S7	S8
Choral experience (years)	12	3	4	13	25	4	1.5	20

Figure 1, Choral experience of participants

Apparatus

The audio was recorded with a Rode NT-USB microphone. Each participant was asked to stand with their mouth 12cm away from the pop shield ensuring the logo on the pop shield was aligned with their mouth. The microphone was connected to a MacBook Air via USB to record the participants directly in the voice analysis software, VoceVista Video Pro (Version 5.7.1.7261). This software was used to calculate the mean fundamental frequency of each vowel. Spoken demonstrations of the vowel sounds were played using http://www.vowelsandconsonants3e.com/chapter_1.html# (Ladefoged and Disner, 2012) on the MacBook Air.

Procedure

The procedure involved participants listening to two spoken vowel sounds played sequentially (produced by a recorded male voice). Participants were instructed to sing the first vowel “at a comfortable pitch” (Ternström, Sundberg and Colldén, 1988, p. 187), and then switch to the second vowel sound without altering the pitch. Each vowel pair was initially played twice, but could be repeated at the participant’s request, as the focus was not on their ability to replicate the sound. Participants were asked to replicate the vowel sounds as accurately as possible. They had the

freedom to change to the second vowel at any time, but were encouraged to maintain the first vowel for at least a full second. Participants were also instructed to transition between the vowels quickly and without a gap in the sound, and to pre-imagine the pitch they intended to sing. Additionally, they were asked to sing with a straight tone, minimising any vibrato. All of these instructions were given in order to more accurately capture any change in the stabilised frequency of each vowel and were similar to the instructions given by Ternström, Sundberg and Colldén (1988).

A few informal trials were conducted to familiarise the participants with the task. The study included nine vowel pairs, as detailed in the section below. Participants were expected to run through all pairs once, but there were occasions when they struggled to sing the correct vowel sound, to transition smoothly without a gap or to sing with minimal vibrato, necessitating repetition, as detailed in the Findings. In some cases, where there was a recognisable large frequency difference, participants repeated the pair, although the first attempt is the result that was recorded in the discussion below. The full results with all attempts are presented in Appendix 5 for transparency. After completing the first round, participants took a break of approximately 45 minutes before repeating the procedure with each vowel pair reversed. The purpose of repeating the procedure was to determine whether the singers' performance improved with experience. Data was then analysed using Microsoft Excel and IBM SPSS Statistics (Version 29.0.2.0 (20)).

Vowels

The Ternström, Sundberg and Colldén study utilised 12 pairs of vowels that “were chosen so as to involve systematic changes in articulatory parameters, such as jaw and lip opening, and tongue shape.” (1988, p. 187) They chose vowels that were part of the Swedish language, and participants were provided with Swedish carrier words to illustrate them. As my choir is based in the UK and currently only sing in English, I selected seven vowel pairs from the Swedish study that are also used in BBC English (Ladefoged and Disner, 2012, p. 48). These are listed below in Figure 2. The concept of a standard form of English in the UK is widely debated. This study identifies BBC English as a standardised variant, which is similar to a modern version of Received Pronunciation (RP) and is sometimes referred to as Standard Southern British English (SSB) (Deterding, 1997; Ladefoged and Disner, 2012, p. 45). Additionally, I chose two vowel pairs that occur within English diphthongs (Ladefoged and Disner, 2012, p. 48). As described above, I used

a recorded demonstration track for the vowels, allowing choir members to target the same sound, regardless of their accent or native language.

First vowel	Second vowel	Reason for selection
/ɔ/	/a/	Vowel pairings used in Ternström, Sundberg and Colldén study (1988)
/u/	/ɔ/	
/u/	/a/	
/i/	/ɛ/	
/ɛ/	/a/	
/a/	/i/	
/i/	/e/	BBC English diphthongs
/ɔ/	/ɪ/	
/a/	/ʊ/	

Figure 2, Selected vowel pairings

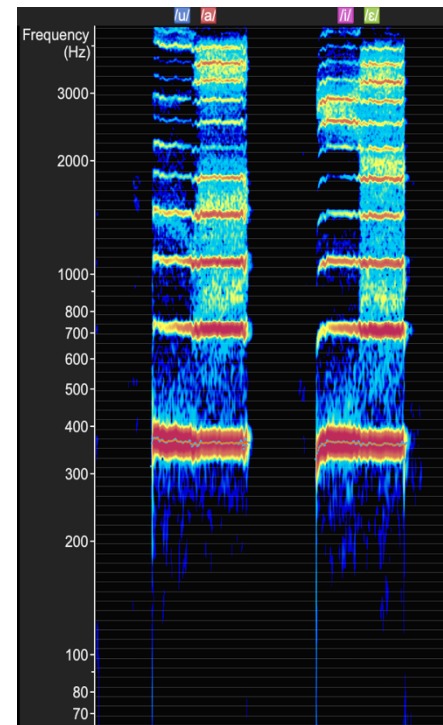


Figure 3, S4: Spectrograms of /u/ to /a/ and /i/ to /ɛ/ (Source: VoceVista Video Pro)

How the vowels were measured

VoceVista was used to measure the mean fundamental frequency of each vowel within a pair (see Figure 3). By using the spectral display, the mid-point of the vowel change could be marked. A 0.2 second segment was then marked on either side of the midpoint to account for the transition between the vowels, ensuring a more accurate and stable reading of the frequency of each vowel without any interference from the transition. As shown in Figure 3 above and 4 below, 0.5 seconds before and after the allocated transition period were marked on VoceVista and the software determined the mean fundamental frequency of both vowels for these periods. The length of 0.5 seconds was chosen to avoid the onset of the first vowel and the offset of the second vowel, ensuring the measurement of the most consistent part. Figure 5 shows how the fundamental frequency could vary at the onset and the green line shows the point at which the vowel was measured from. On occasion, when the participant did not sustain a particular vowel for long enough to use this method, either the transition period or the 0.5s of vowel measurement was reduced, depending on which approach allowed for capturing the more stable part of the vowel

(this is marked in the full results in Appendix 5). An alpha level of 0.05 was used in the statistical analysis below.

First vowel					Second vowel				
Start of vowel (time varies)					Measured (0.5s)	Trans (0.2s)	ition (0.2s)	Measured (0.5s)	End of vowel (time varies)

Figure 4, Measured sections of vowel pairs

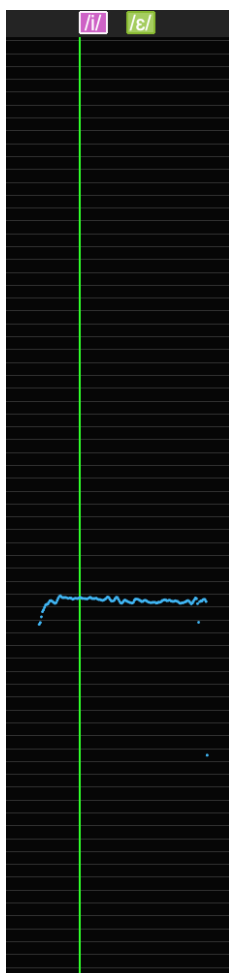


Figure 5, S4: Fundamental frequency of /i/ to /ε/ (Source: VoceVista Video Pro)

I should note at this point that there is no measure of accuracy in terms of the vowel sounds that were produced, other than auditory recognition on the day. It is possible to analyse the first and second formants in VoceVista, but this felt beyond my current level of expertise (Deterding, 1997, p. 49).

Findings

The measurements of the mean fundamental frequencies for each vowel can be viewed in Appendix 5. Figure 6 shows how much the fundamental frequency changed for each participant's demonstration of the 18 vowel pairs. It is the percentage difference between the mean fundamental frequency of vowel one and vowel two (shown to two decimal places). The difference is represented as a percentage rather than in hertz, as the latter could be misleading due to the logarithmic nature of pitch (Howard and Angus, 2017, p. 134). A negative percentage indicates that the frequency decreased from the first vowel sound to the second, while positive percentages indicate the opposite. Figure 6 records the first attempt made where the participant transitioned without a gap between the vowels, without excessive vibrato and with the correct vowel sound.

	First round								
	ɔa	ʊɔ	ua	ɪɛ	ɛa	ai	ie	ɔɪ	au
S1	0.30%	-2.06%	-2.06%	-1.50%	-0.71%	-0.11%	-0.89%	13.38%	13.65%
S2	0.39%	-0.12%	0.27%	1.01%	0.69%	0.87%	-0.95%	0.04%	0.74%
S3	0.16%	-0.65%	-1.32%	-0.05%	-0.07%	0.61%	-0.75%	10.88%	12.20%
S4	0.03%	-0.56%	-0.77%	-1.19%	-0.25%	-0.19%	-0.77%	0.59%	-0.92%
S5	-1.03%	1.67%	0.68%	-1.40%	0.70%	1.39%	-0.53%	0.35%	1.45%
S6	0.68%	-0.28%	-2.58%	-0.71%	-0.24%	-1.17%	1.80%	0.24%	0.60%
S7	-0.74%	-0.74%	0.16%	-0.51%	0.85%	1.64%	-0.27%	0.82%	0.88%
S8	-1.00%	-3.46%	-2.70%	-3.35%	-0.73%	4.13%	-0.12%	2.46%	13.03%
	Second round								
	əʊ	ɔu	au	ɛɪ	æɪ	ia	ei	ɪɔ	ʊa
S1	-0.03%	-0.81%	0.19%	0.10%	1.29%	-0.32%	0.16%	-0.09%	-10.35%
S2	-0.31%	-0.94%	0.50%	0.25%	1.45%	0.51%	1.63%	-1.19%	-0.54%
S3	0.07%	0.83%	0.50%	0.55%	0.31%	-0.93%	0.98%	-10.47%	-13.10%
S4	0.47%	-1.07%	-0.01%	0.09%	-0.33%	-0.05%	0.24%	-0.12%	0.18%
S5	-1.27%	0.53%	1.31%	0.21%	0.24%	-0.16%	0.05%	-0.81%	-1.69%
S6	0.22%	3.85%	1.21%	-0.04%	-0.64%	-1.12%	1.03%	-12.67%	-1.56%
S7	0.52%	0.59%	1.09%	2.07%	1.45%	-2.81%	0.78%	0.12%	-0.07%
S8	-0.05%	1.47%	2.05%	2.30%	1.74%	-0.23%	2.20%	-13.79%	-2.19%

Figure 6, Percentage difference between the mean fundamental frequencies of each vowel in a pair

Furthermore, Figure 7 below lists the mean and standard deviation for each vowel pairing, produced using IBM SPSS Statistics. The smallest mean differences were observed for /ɛ/ to /a/ at 0.0294% and the largest mean difference was for /a/ to /ʊ/ at 5.2027%. The lowest standard deviation was for /a/ to /ɔ/ and highest was again for /a/ to /ʊ/. This indicated that /a/ to /ɔ/ showed low variability between participants and a better ability to maintain the frequency when

transitioning between these vowels, with the opposite being true of /a/ to /ʊ/. On an individual token basis, the smallest difference of -0.01% was recorded on /a/ to /ʊ/ by S4. The largest difference was for /ɔ/ to /ɪ/ at -13.79% by S8. It is hard to precisely compare the data with the Ternström, Sundberg and Colldén's study (1988), which represents the data in a different way. The largest mean difference in their study was /i/ to /ɛ/ which was the second largest mean difference in this study (out of the vowel pairs that were replicated from the Ternström, Sundberg and Colldén study). In the future in the context of rehearsals and performances, this could be a vowel pair to be more acutely aware of particularly on a sustained, homophonic chord. Their smallest mean difference was /u/ to /ɔ/, which was relatively large in our study. However, their second smallest difference was /ɔ/ to /a/, which was the second smallest in this study too.

	N	Minimum	Maximum	Mean	Std. Deviation
ɪɔ	8	-13.79%	0.12%	-4.8765%	6.23399%
ʊa	8	-13.10%	0.18%	-3.6630%	5.09416%
ua	8	-2.70%	0.68%	-1.0405%	1.33229%
ie	8	-3.35%	1.01%	-0.9636%	1.26414%
uɔ	8	-3.46%	1.67%	-0.7751%	1.48970%
ia	8	-2.81%	0.51%	-0.6364%	1.01293%
ie	8	-0.95%	1.80%	-0.3091%	0.90290%
ɔa	8	-1.03%	0.68%	-0.1505%	0.67118%
aɔ	8	-1.27%	0.52%	-0.0463%	0.56609%
ɛa	8	-0.73%	0.85%	0.0294%	0.63672%
ɔu	8	-1.07%	3.85%	0.5558%	1.62750%
aɛ	8	-0.64%	1.74%	0.6902%	0.90816%
ɛi	8	-0.04%	2.30%	0.6902%	0.93898%
au	8	-0.01%	2.05%	0.8566%	0.68167%
ei	8	0.05%	2.20%	0.8835%	0.75043%
ai	8	-1.17%	4.13%	0.8955%	1.59709%
ɔɪ	8	0.04%	13.38%	3.5939%	5.36120%
au	8	-0.92%	13.65%	5.2027%	6.47036%

Figure 7, Mean and standard deviation for each vowel pairing (Source: IBM SPSS)

Returning to the largest and smallest mean differences of this study, the distance between the vowels in each pair on the International Phonetic Association (IPA) vowel chart (Figure 8) would indicate that a large change may be expected for /a/ to /u/ and a small change for /ɛ/ to /a/. Perhaps, on the basis of the IPA chart, we would have expected an even bigger change for /a/ to /u/. A possible reason for this is explained in the analysis of the data in the “Influence of spoken demonstration vowels” section. However, as noted in my Module 5 project (Lindsey, 2023), the IPA chart is “not a direct mapping of tongue position” (International Phonetic Association, 1999) and even if it was there are no fixed articulatory positions for each vowel (Nicholson, 2017, p. 124). Therefore, the IPA chart is not a precise way of judging the degree to which there are articulatory changes between vowels, but we can get a general sense of whether we would expect the frequency to increase or decrease. The mean value listed in section 7 suggests that overall the frequency moved in the direction that we would expect.

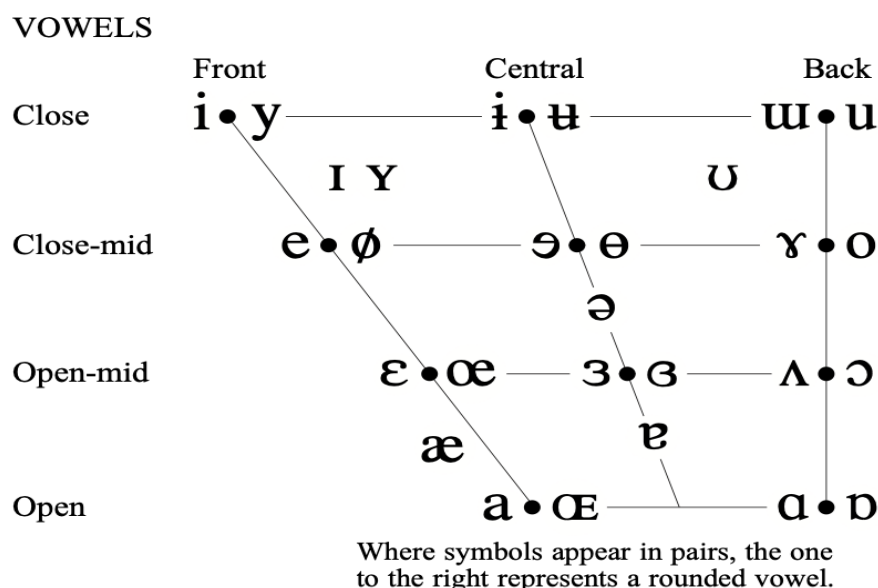


Figure 8, IPA Vowel Chart(International Phonetic Association, 2020)

Discussion

Audible differences

Various studies have shown that musicians’ abilities to discriminate between frequencies from an auditory perspective is superior to non-musicians (Spiegel and Watson, 1984; Kishon-Rabin, *et al.*, 2001; Micheyl *et al.*, 2006; Nikjeh, Lister and Frisch, 2008). The threshold at which frequencies

can be discriminated in known as the difference limen for frequency (DLF) (Kishon-Rabin et al, 2001, p. 125). In analysing the results of this study, I have used the DLFs from Nikjeh, Lister and Frisch's research, which are 1.35% for musicians (including instrumental and vocal musicians) and 3.19% for non-musicians. The reason for this choice is that this study was particularly relevant as an indicator because it used complex tones rather than pure tones and as discussed above the presence of harmonics makes an impact on pitch discrimination. The selected pitches used in the study were in the female mid-vocal range (261.63-392 hertz) which were similar to the "comfortable" pitches chosen by the participants in this study. The results of this current study were marked in accordance with these DLFs, as can be seen in Figure 9 below.

	First round								
	ɔa	uɔ	ua	ie	ɛa	ai	ie	ɔɪ	aʊ
S1	0.30%	-2.06%	-2.06%	-1.50%	-0.71%	-0.11%	-0.89%	13.38%	13.65%
S2	0.39%	-0.12%	0.27%	1.01%	0.69%	0.87%	-0.95%	0.04%	0.74%
S3	0.16%	-0.65%	-1.32%	-0.05%	-0.07%	0.61%	-0.75%	10.88%	12.20%
S4	0.03%	-0.56%	-0.77%	-1.19%	-0.25%	-0.19%	-0.77%	0.59%	-0.92%
S5	-1.03%	1.67%	0.68%	-1.40%	0.70%	1.39%	-0.53%	0.35%	1.45%
S6	0.68%	-0.28%	-2.58%	-0.71%	-0.24%	-1.17%	1.80%	0.24%	0.60%
S7	-0.74%	-0.74%	0.16%	-0.51%	0.85%	1.64%	-0.27%	0.82%	0.88%
S8	-1.00%	-3.46%	-2.70%	-3.35%	-0.73%	4.13%	-0.12%	2.46%	13.03%
	Second round								
	əɔ	ɔu	au	ɛi	æɛ	ia	ei	ɪɔ	ua
S1	-0.03%	-0.81%	0.19%	0.10%	1.29%	-0.32%	0.16%	-0.09%	-10.35%
S2	-0.31%	-0.94%	0.50%	0.25%	1.45%	0.51%	1.63%	-1.19%	-0.54%
S3	0.07%	0.83%	0.50%	0.55%	0.31%	-0.93%	0.98%	-10.47%	-13.10%
S4	0.47%	-1.07%	-0.01%	0.09%	-0.33%	-0.05%	0.24%	-0.12%	0.18%
S5	-1.27%	0.53%	1.31%	0.21%	0.24%	-0.16%	0.05%	-0.81%	-1.69%
S6	0.22%	3.85%	1.21%	-0.04%	-0.64%	-1.12%	1.03%	-12.67%	-1.56%
S7	0.52%	0.59%	1.09%	2.07%	1.45%	-2.81%	0.78%	0.12%	-0.07%
S8	-0.05%	1.47%	2.05%	2.30%	1.74%	-0.23%	2.20%	-13.79%	-2.19%
	Exceeded DLF for musicians					Exceeded DLF for non-musicians			

Figure 9, Percentage difference between the mean fundamental frequencies of each vowel in a pair categorised by DLFs

This means that in 73% of the 144 tokens (8 participants x 18 vowel pairs), the difference between the frequency of the first vowel and the second vowel would not have been noticeable to a musician, let alone a non-musician. However, 10% would have been noticeable to a musician and 17% would have been noticeable to a musician and a non-musician (see Figure 10). In terms of vowel pairs, we can see that /ɔ/ to /a/ and its reverse pair, plus /ɛ/ to /a/ had no noticeable differences, which is in line with the standard deviation measurements in Figure 7. There were

seven vowel pairs that had differences only noticeable by a musician. Notably, /ɔ/ to /ɪ/ and /a/ to /ʊ/ and their reverse pairs had multiple instances of frequency differences that would have been audibly evident to non-musician and musicians. These are the vowel pairs that were chosen as examples of English diphthongs.

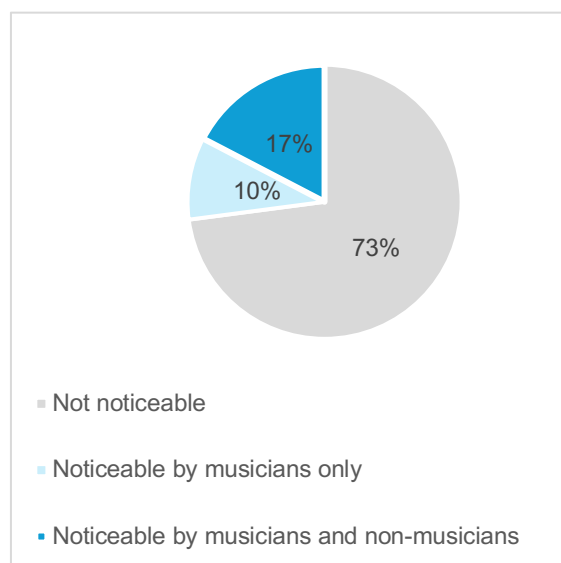


Figure 10, Pie chart showing the perceptibility of vowel changes

On initial inspection of individual performance in Figure 11, we can see that one participant (S4) had no vowel pairs with a noticeable difference in frequency, three other participants had between two and five instances where their difference would have been noticeable by a musician. Four participants (S1, S3, S6, S8) had between two and five instances where their frequency difference

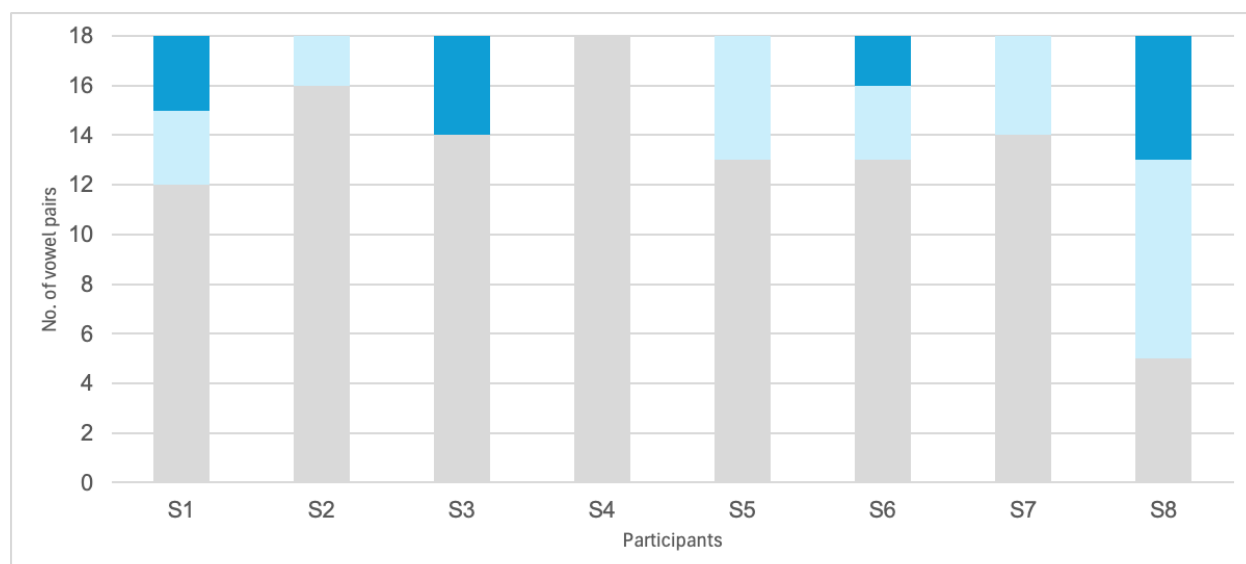


Figure 11, Audible differences for each participant

would have been noticeable by a non-musician in addition to a musician. Notably, 72% of S8's tokens would have been noticeable by a musician.

A Pearson correlation analysis on IBM SPSS (see Figure 12) revealed that there was a moderate positive, but insignificant correlation between the number of years of choral experience and the number of noticeable tokens ($r = 0.444$, $n = 8$, $p > 0.05$) for each participant. In this case, we cannot conclude that years of choral experience positively impact on the ability of the singer to maintain the fundamental frequency while changing vowel.

		Choral experience (years)	Noticeable tokens
Choral experience (years)	Pearson Correlation	1	0.444
	Sig. (2-tailed)		0.270
	N	8	8
Noticeable tokens	Pearson Correlation	0.444	1
	Sig. (2-tailed)	0.270	
	N	8	8

Figure 12, Pearson correlation of participants' choral experience and noticeable tokens (Source: IBM SPSS)

Influence of spoken demonstration vowels

As previously mentioned, the study utilised recorded spoken demonstrations of the vowels to guide participants in targeting the correct vowel sounds. Recordings were chosen over carrier words to account for the participants' diverse accents. Although I anticipated that the recorded male voice, speaking between 90.22 and 104.43Hz, might prompt participants to select a lower note in their range, I did not consider that the fundamental frequency of the spoken vowels could affect the singers' abilities to maintain a consistent fundamental frequency as they transitioned between vowels. Figure 13 shows the correlation between the change in fundamental frequency of the spoken vowels and those produced by the participants. The results reveal a highly significant correlation for S1, S3 and S8 with p-values less than 0.01 and a significant correlation for S5 and S6 with p-values less than 0.05 (although S5 is at the borderline of being insignificant with $p = 0.049$ and S6 is at the borderline of being highly significant with $p = 0.011$). However, S2, S4 and S7 showed no significant correlation, with S4 being the least correlated. If I were to repeat this experiment, I would record the vowel sounds at approximately the same fundamental

frequency. Nonetheless, it is intriguing to observe the impact of an external reference for these choral singers, suggesting the need for further development of the participants' listening skills and perhaps their inner hearing abilities.

Correlations										
		S1	S2	S3	S4	S5	S6	S7	S8	Spoken
S1	Pearson Correlation	1	0.211	.878**	0.042	0.406	0.126	0.242	.551*	.812**
	Sig. (2-tailed)		0.401	0.000	0.870	0.095	0.619	0.333	0.018	0.000
	N	18	18	18	18	18	18	18	18	18
S2	Pearson Correlation	0.211	1	0.399	0.045	0.275	0.268	0.201	0.465	0.278
	Sig. (2-tailed)	0.401		0.101	0.858	0.270	0.283	0.424	0.052	0.263
	N	18	18	18	18	18	18	18	18	18
S3	Pearson Correlation	.878**	0.399	1	-0.094	.522*	.528*	0.247	.757**	.948**
	Sig. (2-tailed)	0.000	0.101		0.710	0.026	0.024	0.323	0.000	0.000
	N	18	18	18	18	18	18	18	18	18
S4	Pearson Correlation	0.042	0.045	-0.094	1	-0.215	-0.127	0.137	-0.063	0.015
	Sig. (2-tailed)	0.870	0.858	0.710		0.391	0.615	0.588	0.803	0.952
	N	18	18	18	18	18	18	18	18	18
S5	Pearson Correlation	0.406	0.275	.522*	-0.215	1	0.232	0.344	.473*	.470*
	Sig. (2-tailed)	0.095	0.270	0.026	0.391		0.354	0.162	0.047	0.049
	N	18	18	18	18	18	18	18	18	18
S6	Pearson Correlation	0.126	0.268	.528*	-0.127	0.232	1	0.106	.703**	.582*
	Sig. (2-tailed)	0.619	0.283	0.024	0.615	0.354		0.676	0.001	0.011
	N	18	18	18	18	18	18	18	18	18
S7	Pearson Correlation	0.242	0.201	0.247	0.137	0.344	0.106	1	0.363	0.217
	Sig. (2-tailed)	0.333	0.424	0.323	0.588	0.162	0.676		0.139	0.388
	N	18	18	18	18	18	18	18	18	18
S8	Pearson Correlation	.551*	0.465	.757**	-0.063	.473*	.703**	0.363	1	.736**
	Sig. (2-tailed)	0.018	0.052	0.000	0.803	0.047	0.001	0.139		0.000
	N	18	18	18	18	18	18	18	18	18
Spoken	Pearson Correlation	.812**	0.278	.948**	0.015	.470*	.582*	0.217	.736**	1
	Sig. (2-tailed)	0.000	0.263	0.000	0.952	0.049	0.011	0.388	0.000	
	N	18	18	18	18	18	18	18	18	18

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Figure 13, Pearson correlation between the change in fundamental frequency of the spoken vowels and those produced by the participants

Impact of experience

Ternström, Sundberg and Colldén concluded “that the subjects increased their Fo stability in the second run”. While two of the participants in this study said that the second round was “easier” (S1 and S8), on first inspection by counting the number of times the DLF was exceeded in the first round compared to the second round there appears to be very little difference (Figure 14).

	First round	Second round
Exceeded DLF for musicians	12	13
Exceed DLF for non-musicians	8	6
Total	20	19

Figure 14, Number of times the DLF was exceeded by round of testing

To understand this in a more detailed way, a paired samples t-test was carried out in IBM SPSS (Figure 15). This compared the first round vowel pair with its second round reverse pair, for example, /i/ to /e/ with /e/ to /i/. This test was focused on whether the difference between the first and second vowel of each pair reduced in the second round. This test does not focus on whether the frequency was higher or lower than the previous vowel, just purely on the size of the gap between the vowels, regardless of whether it ascended or descended. Therefore the mean difference listed below is different to the mean listed in the table above, as the table above did account for whether it 2.06% above the previous vowel or -2.06% below. In this test we are only concerned with the 2.06% gap not the direction of the movement.

		Paired Differences					t	df	Significance	
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				One-Sided p	Two-Sided p
					Lower	Upper				
Pair 1	ɔa - əɔ	0.17283%	0.42517%	0.15032%	-0.18262%	0.52828%	1.150	7	0.144	0.288
Pair 2	uɔ - ɔu	-0.07088%	1.71100%	0.60493%	-1.50132%	1.35955%	-0.117	7	0.455	0.910
Pair 3	ua - au	0.45907%	0.97663%	0.34529%	-0.35741%	1.27556%	1.330	7	0.113	0.225
Pair 4	ie - ei	0.51373%	1.01783%	0.35986%	-0.33719%	1.36466%	1.428	7	0.098	0.196
Pair 5	ɛa - aɛ	-0.40234%	0.45499%	0.16086%	-0.78272%	-0.02195%	-2.501	7	0.020	0.041
Pair 6	ai - ia	0.50051%	1.52917%	0.54064%	-0.77790%	1.77893%	0.926	7	0.193	0.385
Pair 7	ie - ei	-0.12336%	0.96870%	0.34249%	-0.93322%	0.68649%	-0.360	7	0.365	0.729
Pair 8	ɔɪ - ɪɔ	-1.31257%	7.99852%	2.82790%	-7.99950%	5.37436%	-0.464	7	0.328	0.657
Pair 9	au - ua	1.72374%	3.92139%	1.38642%	-1.55462%	5.00211%	1.243	7	0.127	0.254

Figure 15, Paired samples t-test to compare the performance of the first round of testing with the second round for each vowel pair (Source: IBM SPSS)

In reviewing these results, we are looking for a positive t-value to indicate that the difference on the first round was higher than the difference in the second round. We have five out of nine positive values. However, only one of the nine results was regarded as significant /ɛ/ to /a/ and the reverse with $p < 0.05$, this t-value was negative indicating that the difference increased between the first and second round. These results do not show any sense of improvement between round one and round two, despite singers indicating that they found the second round easier. Maybe this sentiment was more a reflection of familiarity with the task.

Further information

Additionally for transparency, there is one instance of a gap between vowels where no further attempt was made and was only seen as part of the analysis. This was S5 moving from /ε/ to /a/ as seen in Figure 16.



Figure 16, S5: Fundamental frequency of /ε/ to /a/ (Source: VoceVista Video Pro)

Next steps

A decision to interview the vowel pairing participants instead of the conductors was made to prioritise understanding the factors that influenced the results. Additionally, I was interested to discover if there were any insights to be gained from the more successful participants (S2, S4 and S7) that could help improve the performance of the other singers. Notably, S2 and S7 have the lowest amount of choral experience and yet performed well in this task in comparison with S8 who has a significant amount of choral experience. The interviews aimed to better understand the

choral experience of the participants in more detail than tenure and to determine whether other aspects of the participants' musical backgrounds, neurodiversity, hormonal factors or understanding of intonation or vowels contributed to the outcomes.

2 INTERVIEWING AMATEUR CHORAL SINGERS

Method

Design

This second research method involved interviewing the participants who took part in the vowel pair testing. This was to better understand both the participants and their test results in order to better address the research questions. This qualitative section of the research was more specifically guided by phenomenology, which “focuses on how life is experienced” (Denscombe, 2003, p. 97). Some of the key elements of phenomenology that I have been mindful to adhere to during this research are:

1. to present relevant experiences as true to the original as possible including data that may appear to be “self-contradictory, irrational or even bizarre” (Denscombe, 2003, p. 101).
2. the concept of intentionality, which requires consideration of both the “what” and the “how” of an experience, seeking to explore both what the experience is and the feelings or meanings that the participants attach to that experience (King, Horrocks and Brooks, 2019, p. 231).
3. epoché or bracketing, which involves the suspension of pre-existing assumptions and biases (King, Horrocks and Brooks, 2019, p. 232). In this project, this includes my acknowledgement of existing opinions about choir members, their strengths and weaknesses, and my assumptions and knowledge about their backgrounds. It is important for me to not bring my preconceived ideas about these choir members into the study and that I allow the data to speak for itself (Denscombe, 2003, p. 102).

Participants were interviewed using a semi-structured format, a primary method in phenomenology that encourages participants to discuss areas of importance to them. This

method allows for both predefined and spontaneous questions if required, which works well to fully understand each individual choir member whilst also providing some consistency between interviews (Denscombe, 2003, p. 103).

Participants

The participants were the same eight participants from my choir that completed the vowel pair testing in section one. All eight participants were asked if they would be happy to take part in additional research, they were provided with new information sheets for this section of the research and all signed new consent forms (see Appendix 4).

Procedure

The interviews were conducted on Zoom and lasted between 17 and 53 minutes. The variation in length was primarily due to the participants' level of engagement and the detail of their responses. The questions were arranged in three broad topics covering the participants' backgrounds, knowledge of vowels and knowledge of intonation. The interviews were recorded on Otter.ai using an iPhone SE and initially transcribed using Otter.ai. The transcriptions were then reviewed line-by-line, making detailed corrections to ensure they were accurate verbatim accounts of the interviews to the level of the "actual words spoken" (King, Horrocks and Brooks, 2019, p. 193). This transcription process served as the first stage of analysis, allowing familiarity with the data (Langdridge and Hagger-Johnson, 2009, p. 377). During this process and in the subsequent coding, memos were created of notable moments within the interviews (Saldaña, 2021, p. 58). Each interviewee verified the transcription for accuracy.

Following initial familiarisation, three types of coding were then employed to analyse the data:

1. ***In Vivo coding***: This type of coding uses "a word or short phrase from the actual language" in the collected data (Saldaña, 2021, p. 137). These excerpts capture the participants' perspectives directly and were particularly useful for understanding their definitions of terms and for presenting a phenomenological authentic account of the participants' experiences. The first application of this code used a direct quote from the text, while subsequent applications reflected similar sentiments, even if the exact words

differed. In this study, an *in vivo* code that was used was “*shapes on the inside of your mouth*” to describe vowels. All *in vivo* codes were listed in inverted commas.

2. **Initial coding:** This approach is also called open coding and it allows the researcher freedom to code the data without restrictions in order to see where the data leads. This seemed appropriate for the overall grounded theory approach of this project and because it can be used to analyse the interview data of these participants in conjunction with the use of *in vivo* coding (Saldaña, 2021, p. 148). An example of descriptive coding used in this study was *no formal singing training*.
3. **Structural coding:** This type of coding involves labelling data with broader categories, typically using a phrase that corresponds to a specific topic. These codes act as anchoring points (Saldaña, 2021, p. 130). In this study, structural codes included *musical experience*, *musical development*, *health*, *reflecting on testing*, *knowledge of vowels* and *knowledge of tuning*. Each extract of the text was marked structural code followed by a descriptive or *in vivo* code, for example, *musical development: “self-educating”*.

The online qualitative coding software, Delve (<https://app.delvetool.com/>), was used to manually mark the codes in the interview text. The coding process began with *in vivo* and descriptive codes for the interviews with S1 and S2, followed by structural coding, which helped maintain the context for the codes. The remaining six interviews were then coded using all three types of codes. The interviews were reviewed three times, with each review focusing on consolidating and refining the codes further. Finally, all the codes were exported into Microsoft Excel for categorisation and theming using the system suggested by King, Horrocks and Brooks (2019, pp. 203–209). The categorisation was initially influenced by key themes identified in the memos, recurring codes, and the structural coding, and then subsequently overarching themes arose from the categories. See the Appendices 6, 7 and 8 for the full interview transcriptions, a list of codes, their categories, sub-themes and themes plus an audit trail showing the first two stages of the categorisation and theming process.

Findings

Results

Analysis of the data uncovered two central themes: **contexts of learning** and **technical areas of development**, each with a number of sub-themes as can be seen in Figure 17 below.



Figure 17, Themes and sub-themes

Contexts of learning

This theme contains data that reveals that the participants have a range of backgrounds, training and personal circumstances, which have the potential to influence each member's approach to singing, the choir and the vowel pair testing. In addition, the data revealed the prioritisation of individual needs vs the choir's needs and the participants' appetite for self-development. Each of the sub-themes will be discussed in turn.

Background

The participants in this study have varied levels of formal music training and experience, as can be seen below. While all sang in their school choirs and some had additional choral experience, only one participant has received one-on-one singing lessons and five participants have played instruments. None of the participants were aware of changes in their singing voices due to hormonal factors. In reflecting on the recent vowel pair testing, participants highlighted the variation in difficulty and the significant mental effort required. Introducing the participants individually at this point in the report of this small-scale study provides useful context for beginning to understand the participants further:

S1 played piano and recorder as a child and reached grade three or four in music theory. She sang in school choirs and continues to sing as an adult, but has had no formal singing training. She has no physical health issues. S1 found the testing interesting, with the level of difficulty varying.

S2 grew up in a musically immersive environment with a variety of instruments available to her, primarily playing the recorder and piano. Though reluctant to sing, she participated in school choirs and eventually sang in a band. She reports no physical health issues affecting her singing.

In terms of the testing, S2 enjoyed the process and focusing on something that she “take[s] for granted”, with difficulty levels varying.

S3 has the highest level of formal qualification in music within the group, having studied music at university, in addition to having played guitar and piano to an advanced level. She sang in school, church and university choirs, but has not completed any formal singing training apart from some breathing training that utilised singing. She has back issues which can affect her singing. S3 noted of the testing that some vowels were easier to produce at different pitches.

S4 has had no formal training, but sings regularly as a soloist in addition to her choral and musical theatre experience. She is conscious to follow a strict vocal hygiene regime approaching performances, particularly as she has nasal polyps and suffers from catarrh. She does not play any instruments. S4 emphasised the need for “really concentrating” during the testing.

S5 has had singing lessons, although on a limited basis, and had aspired to be an opera singer before relocating to the UK. She sang in her school choir and later in auditioned adult choirs and as a soloist, but does not play instruments. She believes her voice has changed due to factors like pregnancy, weight gain or age, making breathing more difficult and high notes harder to reach. S5 found the testing interesting, but sometimes difficult to recreate the vowel sounds accurately.

S6 has had no formal singing training, but sang in school and adult choirs. She feels her voice has deepened, possibly due to age. Although she initially did not recall any instrumental experience, she later remembered an attempt to play the piano. S6 found the testing “slightly easier the second time around” due to knowing what to expect. She felt that her performance improved when not focused on matching the pitch of the spoken demo tracks, and pre-imagining the sounds made it easier.

S7 pursued higher grades in piano and theory grades as an adult and has taught piano. She also plays the flute and violin and has performed in a woodwind ensemble as an adult. She sang in a school choir, but primarily played the piano for it. She has had no formal singing training. S7 considered the testing “fairly straightforward” but noted the need for intense concentration.

S8 teaches piano and has run a children’s choir. She has not had one-on-one singing lessons, only choir-based training. She sang in a children’s choir and a school choir and continues to sing

chorally as an adult. S8 described the testing as challenging and interesting. She found remembering the task requirements and recreating the vowel sounds difficult at times.

Cognitive processes

Neurodiversity: During the interviews, S2 disclosed that she was being assessed for Autism Spectrum Disorder (ASD), while S5 revealed that she was being evaluated for Attention Deficit Hyperactivity Disorder (ADHD). S3 expressed a belief that she has ADHD, although had never been formally diagnosed and S8 described herself as “a little bit neurodiverse, but I've never been diagnosed”. Therefore, there are no confirmed cases of neurodiversity among the participants, but during the interviews there were descriptions of symptoms that affected singing or music learning that could possibly be related to these conditions in some cases, such as anxiety, confidence issues and difficulty maintaining focus (National Health Service, 2021, 2022). The other four participants (S1, S4, S6 and S7) identified as neurotypical.

Learning challenges and strategies: S2 and S4 both discussed their awareness of how fluctuating confidence levels affect their singing. S2 described her challenges when singing in a quartet, explaining that she feels she has to “segment her mind into doing different things” when managing the multiple tasks of performing for the audience, engaging with the other quartet members and singing all at the same time, which leaves her feeling “on tenterhooks”. S4 and S5 spoke of nerves or anxiety being the cause of sharp singing and S5 and S8 talked of nerves and the impact on their breathing. S3 also shared that her low self-esteem, which she attributes to having undiagnosed ADHD, and how this has impacted the time it takes her to learn music, leading to a negative experience at university and affecting her confidence in singing. To address these challenges, S3 uses colour coding to help her learn music, perhaps indicating an adaptive and proactive approach to overcoming her challenges.

S2 and S5 both discussed their struggles with maintaining focus during rehearsals, while S3 mentioned her tendency to drift between choral parts. S2 noted her fascination with patterns, which she believes enhances her aural skills. S1 and S4 emphasised the importance of repetition in learning music, while S7 highlighted the role muscle memory plays in accurately targeting the correct notes in familiar music. S5 mentioned that she “found it easier to learn by doing” and although she does not read music, she compensates with a strong memory.

Individual versus choir

This sub-theme encapsulates perspectives that highlight the influence of the group on the individual, conflicts between individuals and the group and the need for leadership.

Individual before choir: Regarding vowel unification, S4 expressed the view that more experienced choirs would strive to create a unified sound and would be adopting a common approach to vowel production. Despite recognising this practice, S4, who is one of the more accomplished singers as reflected in the vowel pairing test results, expressed reluctance to proactively blend her vowels with others at this point in time. She felt that she has confidence in her own technique and is unwilling to compromise her approach:

I wouldn't say that other choir members influence my singing generally. In the current choir that I'm singing in... no. I don't think currently, our choir is at a stage where I'm thinking about blend. And maybe I should do, but I'm not because I think everybody's just doing their own thing ... There are a lot of people that haven't sung for very long and just a little bit inexperienced. But there's some that's not either, so it's not everyone but I would say because of that I'm not going to change ... I think I have more experience to know how I think it should sound and therefore I don't tend to listen. (S4)

Some of the participants were not very conscious of unifying vowels with the choir, instead focusing more on their individual performances (S2, S5 and S8). S5 later refined this view, perhaps echoing a sentiment similar to S4's stance that others should adjust to match her:

In the sense of making the same sounds, absolutely, we should all blend together ... I don't really mind how you get there, as long as your sounds matches with mine and we all do the same thing at the same time. The important thing is to blend.

Influence of others: Alternatively, perhaps S5 was simply expressing a view similar to S3, where she is not particularly aware of how other singers produce vowels, but still tries to blend with them. S8 felt that unifying vowels would positively influence the choir's overall sound, though it may be challenging for individuals. S7 noted that while she did not focus on vowel unification, she might be influenced by singers "doing a good job" and would align with the group under direction.

Regarding intonation and the influence of others, S3 and S6 believed other choir members could influence their tuning, while S5 felt that other singers would not have an impact on her tuning.

Leadership: The data further suggests that singers believe effective vowel production and tuning improvements depend on direction from the choir leader. S4 noted that singers can interpret vowels in different ways, indicating a need for leadership. S1 mentioned that she would modify vowels under direction and felt that tuning is "more disciplined when you're within the choir", adding that her tuning would improve with guidance. S3 felt that by unifying vowels within their section, that their hearing of it within the section might not be the same as the conductor or audience's perceived sound at the front.

Motivation for improvement

The interview data reveals a spectrum of attitudes regarding motivation towards improvement from those more content with the status quo to others ambitious to advance their skills to enhance the individual sound or for the collective sound of the choir.

Lack of proactivity: Some choir members seem to express a lack of proactive engagement towards their musical development or perhaps a sense that they do not know what they do not know, as shown in comments like "it's not really something that I take too much notice of" (S1) or the passive approach to vowel modification where S8 said that "I just sing it as it comes out my mouth" (S8). Despite this, there is a sense from participants of compliance and willingness to act on external direction to improve. S8 responded to a suggestion with "I will do that. I'll try that" and at the end of the interview reflects by saying that:

"we all just want to sing for pleasure and it just sort of comes out your mouth ... And I think it is really good to dissect it a bit because ... that's what makes us ... a better choir."

S1 speaks about improving tuning and vowel modification under direction and working on tuning by going "over it, over and over again", but overall her interview reflects a person that has not thought about it and is not proactively seeking improvement.

Volition: From S3, S5 and S6, there is a sense of trying to improve with deliberate actions such as listening carefully to unify vowels or to blend, noticing the mouth shapes of others to improve

their own sound, writing the required vowel sound on the sheet music or actively seeking help. Furthermore, some choir members conveyed intellectual curiosity and a more active desire to challenge themselves evidenced by comments such as “how far I could go” (S2), “wanting to ... stretch my brain” (S7) and “I don’t think we can ever stop” (S4) with reference to vocal development. S4 describes their approach as “self-educating” but is intending to start singing lessons, while S2 expresses genuine enjoyment and a sense of fascination in learning.

Technical areas of improvement

There were three significant areas for technical development: aural skills, vowels and intonation.

Aural skills

Perceptions of aural ability: The data on the participants’ backgrounds highlights a varied range of aural skills. Five participants (S1, S2, S3, S7 and S8) have received formal aural training in the past, primarily as part of their lessons in preparation for instrumental exams, though the frequency, level and recall of this training varies among them. S2, S3 and S7 have all been educated at a grade eight aural level, with S2 notably receiving consistent aural training throughout her instrumental lessons, making the process “straightforward” for her. In contrast, S3 “struggled” due to insufficient practice, but now finds it easier attributing this improvement to extensive listening stating “I’ve learned to hear the different pitches in my head now, whereas that was what was lacking when I was very young”. S7 found aural “okay” and also had consistent aural lessons from a young age and continued this training as an adult while preparing for her grades six to eight piano exams. S8 was educated to grade 6 piano and S1 to grade three or four; both recognise that they must have received aural training as part of their lessons, though they struggle to recall specific details. S8 currently teaches aural skills as part of her piano instruction.

Additionally, S3 learned tonic solfa as a child in choir and practised intervals using that system, which helped her develop sight-singing skills. S5 claimed to have an ability to identify notes without external references. During this interview, she demonstrated this skill twice, accurately once and inaccurately the other time. She also emphasised her strong memorisation skills, which may suggest that her ability to recall notes might stem from muscle memory related to familiar songs rather than having perfect pitch. S4, who lacks instrumental experience, speculated that this may have impacted her aural abilities. She mentioned that she “learn things a lot by ear” and

has noticed that her awareness of tuning has improved over time, although she might have difficulty detecting slight pitch variations.

Listening within choir: Listening was frequently mentioned as a method for improving intonation including the use of external references such as rehearsal tracks, pianos, accompaniments and tuning forks. S7 suggested listening to the harmony. S1, S2 and S8 suggested that singing in tune means singing the same as each other and six out of the eight participants spoke of listening to the other choir members as a way to improve tuning. S7 said that she ‘just really think[s] about it’, while S3 and S8 more specifically speak of hearing the sounds in their heads. In terms of unifying vowels, S1 and S8 noted that they prioritised listening for the correct pitch over vowel matching, while S3 mentioned that she “listen[s] very carefully to try and pick up the same sort of sounds”.

Vowels

Definition of vowel: Perspectives of the term vowel varied, with five of the participants noting the graphemes a, e, i, o and u, while S2 described them as “shapes on the inside of your mouth” and S4 noting that vowels can “change the sound completely”. Vowels were also described as having no distinct start or end, and their articulation involves breathing and the use of the tongue. Vowels reminded S6 of Julie Andrews and the phrase “how now brown cow” and S5 and S2 of the instruction to “open your mouth”. The complexity of vowel sounds was acknowledged with S2 describing the written form as a way of “reducing down something that’s really, really complex”, recognising that while there are principally five written vowels, there are theoretically an infinite number of vowel sounds that require guidance for a choir to sing in the same way.

Sung versus spoken vowels: Participants noted that sung vowels tend to be more open and sustained compared to their spoken version, with some mentioning the need to “sing it in a more posh way” (S8) or avoid regional accents, such as the Essex accent, when singing. S5 observed that in opera, in particular, that there can be a loss of clear diction due to open vowels. Additionally, S7 expressed that pronunciation choices in singing could be influenced by the style of the song and that singing often requires more conscious attention to vowel articulation. In contrast, S3 felt that her spoken vowels were more precise than her sung vowels, but this seemed due to external pressures to speak using Received Pronunciation (RP).

Changing vowels: Six of the participants identified changes in mouth shape and three mentioned tongue position as physical adjustments made when changing vowel. Other physical changes included adjustments in chin position (S3), the face (S2) and palette (S5). Participants were asked about the unification of vowels within choral sections. This was seen as beneficial contributing to a better and more blended sound and clearer diction. S4 commented that a more experienced choir would “figure out what the best way to sing something would be”. Suggestions for improving vowel unification included offering guidance, improving general technique, demonstrating the difference it could make, providing IPA “cheat sheets” or reference words for vowels, singing together more frequently and participating in training such as workshops. Some participants noted that higher voices approach vowels differently to lower voices. When asked whether they had ever tried changing how they sang a vowel to improve the sound, S4 spoke extensively about her experience of vowel modification, which she does “literally all the time”, especially in her higher range. No other participants discussed this concept, except for S5 who mentioned that “The more you open, the easier it becomes for you to reach a specific note.” Beyond vowel modification, participants also mentioned breathing and alignment adjustments as methods to enhance vowel quality.

Intonation

Perspectives on intonation: Participants defined “in tune” singing as being on “the right tune”, “singing on pitch” and being “in harmony to the other parts”. S7 added that “that’s the standard”. Conversely, “out of tune” singing was described as “discordant or dissonant” (S3), “not good” (S6), involving incorrect notes or minor pitch deviations and unintentional key changes. S2 commented that it was natural to “lean” flat or sharp. S3 said, “We weren’t singing what was written” reflecting a view of a number of the participants that being “out of tune” is regarded as being on an entirely different note from the intended one, as opposed to being “a little smidge out” (S7), which is a more subtle deviation from the centre of the intended pitch. S5 and S6 also commented that being on the wrong pitch did not automatically classify as being “out of tune” because it still might harmonise and “sound nice” (S6). S5 similarly classified “in tune” singing as “smooth and enjoyable”.

Singing in tune: Participants identified various causes of poor intonation including breathing issues and vocal register challenges. S4 commented that for her “sharpness is an accident”, often caused by nerves. S4 also highlighted the increased difficulty of staying in tune on a harmony

line, where more focus is required compared to singing the melody. To maintain accurate tuning, participants suggested several strategies: starting on the right note, reviewing the sheet music, warming up properly and occasionally changing the arrangement to better accommodate an individual's voice. As mentioned in the Aural Skills section above, listening was a crucial element of maintaining intonation for all participants. S2 spoke of her strategy of listening and questioning "Did that sound about right?" To correct flatness, participants recommended aiming slightly above the note and brightening the vowel, while improving sharpness involved softening the sound or calming nerves. S2 and S7 both mentioned simply adjusting the pitch slightly up or down to correct intonation. There were two comments about vibrato and its impact on tuning: S7 mentioned hearing that "vibrato helps to ... mask" poor tuning, while S4 acknowledged the general debate on whether vibrato affects the intonation of choral singing.

S5 initially spoke confidently saying "I think I'm always in tune" and described pre-emptively altering arrangements of songs to avoid issues. She also commented "I don't find it hard either whether I am a cappella or if I'm with a track" to stay in tune. However, as the interview progressed, S5 revealed that her intonation had become less reliable over time. She recounted a past experience in a choir: "the director was always trying to double check with me if the pitch was correct ... she always trusted me that she could count on me on a clean performance". Now S5 feels that she is "struggling to keep the note" and expressed sadness and frustration, saying "it is the end of the day for me, because I always thought I was a strong singer." She partly attributed her current challenges to nerves and breath control and has sought help from a singing teacher.

Discussion

Explaining the results of the vowel pairing tests

As a reminder of the participants' performance in the vowel pairing tests, please see Figure 11 on page 23. S4 demonstrated the strongest performance, closely followed by S2 and S7. S5's performance was similar to S7 in terms of the noticeable differences, but she was notably influenced by the spoken vowel demonstrations. S3 performed well, except for difficulties with four vowel pairs; she was also significantly influenced by the spoken vowel tracks. S6 and S1 had similar performance levels, while S8 performed the worst among the participants. S1, S8 and S6 were additionally all influenced by the spoken vowels.

As previously noted, there was no correlation between choral experience and performance in the vowel pairing test. In this qualitative section, the singers provided more details about their backgrounds, which added complexity to the results, regarding S3 and S8. Despite their significant musical experience, both experienced some of the larger measurements of difference in the test. Neurodiversity may be a contributing factor; S3, has low self-esteem with regards to music due to negative experience at university linked to neurodiversity. S8 mentioned possible neurodiversity but did not provide much detail. There were similarities in the qualitative data between S3 and S8, leading to an expectation of a similar performance. There appears to be more to understand about S8, who was fairly reserved during the interview in comparison with the other participants. Participants S2, S3 and S7 all had advanced aural training, though S3 admitted to struggling in the past, feeling more confident now. Both S3 and S6 believed other choir members could influence their tuning, while S5 felt unaffected by other singers. S6, with limited choral experience and minimal musicianship, is closest to a beginner among the participants. Therefore, her results seem understandable.

The interviews revealed a striking pattern: S2, S4 and S7, who were more successful in matching vowel frequencies, all expressed, explicitly or through choice of language, a strong desire to improve. In addition, S2 gave a sense of a well-rounded education in music mainly through instrumental lessons and playing, while S7 had taken on advanced level grades in adulthood to stretch herself. In terms of vocal technique, S4 seemed to have put the most effort into developing her vocal technique followed by S5.

Success in the tests appears to be a combination of vocal technique, musicianship/listening skills and personal motivation. It is possible that S4's edge comes from having honed her listening skills through both choral and solo singing, with vocal technique further enhancing her abilities. In contrast, S1's apparent lack of motivation, vocal knowledge and aural skills may have negatively impacted her performance. S5, who performed fairly well, does not have English as her first language, which may have influenced her difficulty in producing certain vowels.

Development plan

Several key areas for the choir to focus on have emerged from the data:

1. **Desire to learn and the ability to focus:** These two factors were significant for several choir members. As Holding notes, effective learning cannot occur until a person first “attends” (2012, p. 324). Further research on how to enhance these aspects within the choir is needed.
2. **Individual development:** The testing and the interviews has shown the importance of spending time with the choir members on an individual basis to talk to them, to understand them better, to understand their needs, to be able to discuss concepts, use VoceVista with them and help them with vocal technique such as S5’s challenges with registers and tuning.
3. **Vowels:** Use of my Module 5 reference guide with the choir to focus on vowel articulation, modification, the use of IPA and diphthongs. This will help to standardise vowel production across the choir.
4. **Intonation:** After discussing intonation with individual singers, it would be useful to have a collective discussion with the choir. Using some of the questions from the interviews, we should work together to define what it means to sing in tune and explore the factors that positively or negatively impact intonation.
5. **Listening skills:** The next immediate step is to focus on improving listening skills. Many participants emphasised their reliance on listening during the interviews, and the vowel pairing tests indicated in two ways that listening is key: some singers’ listening abilities influenced their performance negatively by being influenced by an external reference and auditory feedback is crucial for compensating for frequency changes. I am particularly interested in exploring the role of inner hearing in this context.

3 LITERATURE REVIEW ON AURAL IMAGERY

Method

To conduct this narrative literature review, I began by focusing on peer-reviewed sources. My initial exploratory search took place on Mendeley Online on 15 July 2024 using the following keywords “audiation”, “aural imagery” and “inner hearing”. These keywords guided the subsequent searches on the following platforms Science Direct, Journal of Singing, Google Scholar and the Choral Journal. A substantial number of articles were listed in the results on Google Scholar and Science Direct. To manage this, I sorted the Science Direct results by relevance and reviewed the top 100 articles. On Google Scholar, I focused on articles published between 2014 and 2024, reviewing the most relevant ones until the content began to lose relevance to my study. The final search was conducted on 26 July 2024. The data collected from

these searches was organised in Mendeley, enabling me to efficiently screen and remove duplicate entries. After this initial filtering, I was left with 136 articles that required further examination. I assessed each article's relevance to my study by reading the abstracts and skimming the articles, where necessary. In addition, I examined frequently cited references to identify further publications.

I established the following exclusion criteria, omitting publications that:

1. Pertained to music therapy, hearing loss or impairment, kindergarten, rhythm-only audiation, music aptitude tests and audiation of written word
2. Were conference proceedings
3. Were not written with regards to Western music
4. Were not written in English or did not have an available English translation

In addition to peer-reviewed sources, I also incorporated grey literature, when it was considered credible, valuable and relevant, and particularly where peer-reviewed sources were lacking. This included books by experts in choral leadership. The findings are summarised below.

Findings

Aural imagery

Seashore remarked that the ability to “hear and feel all the effects of every detailed element before he has written down a note or sounded it out ... is the outstanding mark of a musical mind” (Seashore, 1938, p. 5). Many terms have been used for the skill of the “mind’s ear” (Seashore, 1938, p. 5), such as auditory imagery, aural perception, musical perception and subvocalisation (Gerhardstein, 2002, p. 103; Brodsky *et al.*, 2003). One term that has gained widespread use in music is audiation (Gerhardstein, 2002), for example:

Singing plays a central role in music education as it promotes the development of inner hearing or audiation. The ability to audiate is an essential skill in performing, analyzing, improvising, and composing music. (Houlahan and Tacka, 2024, p. 386)

Audiation is the ability to hear and process music in the mind without any external sound. It's a term coined by the lecturer, author, researcher and teacher, Edwin Gordon (Gordon, 1999, p. 41). The term itself has evolved over time: in 1975, it began simply as "hearing music as compared to aural perception, which suggests just pure sensory reaction to sound". The definition then expanded to include comprehension and a number of types and stages of audiation. Gordon was keen to emphasise that audiation is not simply "aural perception ... It is a cognitive process by which the brain gives meaning to musical sounds." Gordon argues that students may struggle with intonation because, while they might recognise they are out of tune, their lack of audiation ability prevents them from correcting the issue effectively. (Gordon, 1980, p. 25).

Audiation is a valuable term that has increasingly come to be used as a synonym for inner hearing, as in the quote above. However it originally served as a central concept in both Gordon's Music Learning Theory (MLT), which is a sound before symbol educational approach (Crump Taggart, 2016, p. 188), and the music aptitude tests that he developed (Gerhardstein, 2002, p. 115). MLT has been the subject of criticism. Although it appears to be aimed more at other aspects than the concept of audiation (Gerhardstein, 2002, p. 116). Gordon details eight types of audiation:

1	Listening to familiar or unfamiliar music
2	Reading familiar or unfamiliar music
3	Writing familiar or unfamiliar music from dictation
4	Recalling and performing familiar music from memory
5	Recalling and writing familiar music from memory
6	Creating or improvising unfamiliar music while performing or in silence
7	Reading and creating or improvising unfamiliar music
8	Writing and creating or improvising unfamiliar music

Figure 18, Types of audiation (Gordon, 1980, pp. e27-28)

The types that appear relevant to choir rehearsals and/or performances are types one, two and four. Type one involves hearing and understanding music, whether familiar or new, while it is being performed. Type two involves silently hearing and comprehending the sounds while reading written music. Type four refers to mentally recalling and performing music that has been previously heard. Trusheim shows how audiation can be used more extensively and "go far beyond tonal and rhythm patterns [to] tone color, volume and nuance". He comments on how brass players are able to imagine "an idealized sound with a high degree of vividness and detail", which then guides their performance.

Gordon also lists six stages of audiation from “momentary retention” to “anticipating and predicting tonal patterns and rhythm patterns”, which are “presumed” (Gordon, 1980, p. e31) because “there is no way to confirm directly types and stages of audiation through experimental research” (Gordon, 2011, p. 25). There is difficulty in studying the cognitive process of inner hearing as there “is lack of a reliable method whereby such internal processes can be teased out and examined” (Brodsky *et al.*, 2008, p. 428). These three studies show that there is a similar process occurring when music is imagined as to when it is perceived or a score is interpreted in reality. Halpern (2001) reviewed evidence showing that similar brain regions are involved in processing perceived and imagined auditory sounds. The supplementary motor area is triggered for internally generated music. Brodsky *et al.* showed that phonatory and manual motor processing occur during notational audiation, where a score is being interpreted internally. Vuvan and Schmuckler (2011) explored an aspect of auditory imagery to see if we can mentally construct tonal images as accurately as we perceive external music. Their findings suggest are able to present tonal hierarchies as a mental representation and therefore that auditory imagery and auditory perception work in similar way.

Movable-do

Movable-do solfège is a way of teaching sight-singing and therefore ear training, as there is evidence that the development of aural skills is linked to sightreading (Grutzmacher, 1987; Kopiez and In Lee, 2008). In a study of Kentucky-based choirs, 79% believed that sight-singing had helped their choir’s intonation (Floyd and Bradley, 2006). Movable-do focuses on sound before symbol emphasising the role of the degrees of the scale promoting an increased awareness of relative pitch (Schüler, 2021, p. 84). It is a system by which terms are assigned to each degree of the scale. This can either be solfège syllables such as do, re, mi or the numbers 1 to 7. In this system, in a major scale, the tonic is ‘do’ or 1, so if it was D major, ‘do’ would be D, but if the music was in E major ‘do’ would be E (Floyd and Bradley, 2006, p. 70).

US school choral classes spend much time sight-singing due to its inclusion in the US music education programme and because it is often a requirement of state choral competitions (Henry, 2004, p. 206). Much of the following research has been based on this population. Movable-do and its associated system of movable pitch numbers are the two more commonly used systems of teaching sight-singing in the US (Floyd and Bradley, 2006; Kuehne, 2007; McClung, 2008). In

terms of success, Henry and Demorest (2004) found that there was no significant difference between movable and fixed-do (an alternative system by which the solfege syllables do not change with tonality). In a further study in 2005 they found that movable-do was significantly better. However, there were factors such as the consistency of method that may have undermined this result, so it is somewhat inconclusive.

Hand signs, created by John Curwen, accompany each degree of the scale and may reinforce sight-singing through kinaesthetic learning (McClung, 2008, p. 255). See the reference guide in Appendix 9 for descriptions of these hand signs. While some choirs incorporate them, others do not (Floyd and Bradley, 2006, p. 75). McClung (2008) found that students using the hand signs did not achieve significantly better results overall, though he noted that some students may benefit from their use, while others may find that it negatively impacts them. Conversely, a study by Killian and Henry (2005) revealed that participants with high and medium accuracy were significantly more likely to use hand signs.

Other factors contributing to success in sight-singing include preparation time and individual practice. Killian and Henry (2005) found that students with high and medium-accuracy benefitted from 30 seconds of preparation, while low-accuracy singers showed no improvement. High-accuracy participants often had individual voice lessons, played instruments and practised sight-singing individually. Low-accuracy singers, however, often lacked focus. Additionally, success was linked to having a director who conducted individual tests, emphasising that group achievement does not necessarily reflect individual progress in sight-singing (Middleton, 1984; Henry and Demorest, 1994). Middleton warned of the risk of relying solely on group reading success, as strong individual readers are essential.

The reference guide includes some resources for getting started with movable-do. More than half of the participants in Kuehne's study used a published method to teach sight-singing with the most popular method being "The Sight-Singer" by Audrey Snyder (1993). This book is now out of print and has been superseded by the choral sight-singing books "Sight on Sight" by Audrey Snyder (2007, 2011)— these come in two volumes with teacher and student editions plus a CD. They use movable-do as the basis for the books. It is aimed at children, and it makes use of American terminology for rhythms. Alternatively, the National Youth Choir of Scotland (NYCOS) have created a musicianship programme in three levels: bronze, silver and gold, which also makes use of movable-do (2024). NYCOS also offer workshops to develop choral leaders in this method.

The reference guide also includes pictures of the Curwen hand signs with a video demonstrating how to learn them, plus a tonal ladder for picturing the relationships between the solfège symbols/pitch numbers.

Harmonic context

Gordon relates audiation to language, emphasising that it involves comprehension rather than pure imitation: “audiation is to music what thought is to language” (Gordon, 1999, p. 42). Gordon argues that developing the ability to audiate is similar to learning a language, where immersion through listening and reading builds a foundation before advancing to speaking and writing. He emphasises the importance of constructing an “audiation vocabulary”, which is a mental catalogue of generalised musical knowledge and stylistic conventions. As this vocabulary grows, it enhances a musician’s ability to predict and understand musical structures with greater accuracy, leading to more refined and intuitive musical comprehension.

Numerous studies have indicated that a tonal context can improve the perception and understanding of pitch (Graves and Oxenham, 2017, p. 1). Killian and Henry (2005) found that singers who practised by establishing the key before starting by singing the tonic triad were more successful at sight-singing. Boyle and Lucas (1990) found that college students performed better in sight-singing when provided with a harmonic accompaniment rather than singing a cappella, especially in the early stages of learning to sight-sing. However, Lucas (1994) later discovered that middle school students performed better with unaccompanied melodies than with added harmonic context, contradicting Boyle and Lucas’s earlier findings. This could be due to the age and lack of experience of the participants, as 12-year-olds are yet able to “perceive the tonic-dominant relationship” (Lucas, 1994, p. 212).

James Jordon, professor and conductor at Westminster Choir College, has “found that when singers are taught intonation through a harmonic structure, their individual growth as musicians is greatly deepened.” (2017, pp. 52–53) He advocates a learning method which makes use of chimes to play the dominant of the tonality as the choir are practising. Jordan comments that “learning to both sing and audiate in tune with others in a harmonic context ... should be the focus and pedagogical goal” (2022, p. 25). Francès (1985) highlighted the significance of tonic and dominant degrees of the scale and that familiar patterns improve success with unfamiliar ones in sight-singing. Jordan writes, perhaps anecdotally, that “mature and experienced musicians

'naturally' audiate the dominant function note, and we tend to assume the audiation of the dominant occurs in less-skilled musicians." (2022, p. 27) Lucas suggests that "until harmonic perception skills are fully developed, students may be distracted by ... a tonal harmonic accompaniment" (1994, p. 212). The reference guide lists his book, *Intonational Solfege* (Jordan *et al.*, 2022), which contains teaching strategies, exercises and recordings in multiple tonalities and modes that develop singers for hearing the dominant. The dominant should be sounded with an instrument or app that does not produce complex tones to limit the confusion of harmonics. The book specifically recommends Malmrk ChoirChimes stating the design creates a purer tone. These are handheld chimes that can be bought individually or in a set and are shown in the reference guide.

Choral spacing

If a singer is using an external harmonic context to improve audiation and singing, an additional consideration is how the spacing of a choir could impact on a singer's ability to listen. A choral singer needs to be able to hear both their own voice and the rest of the choir in a balanced way. If their own voice is masked, it can lead to mistakes in pitch. Masking can occur when choir members are positioned close together. Conversely, if the rest of the choir is difficult to hear, timing issues may arise in addition to other elements, such as pitch and vowel formation, that the qualitative data in this study reveals that my choir singers listen for (Ternström, 1999).

In Daugherty's study (2003) of a choir of 20, similar in size to my own, it was reported that in terms of the spacing that was best to be able to hear the singers' own voices, 95% of participants thought that spread spacing worked best with a preference for circumambient spacing. In particular, the higher voices (sopranos and tenors) had a preference for a circumambient formation. In terms of how the singers were best able to hear the sound of the choir as a whole, 55% preferred spread spacing with a near even split between lateral and circumambient. That meant that 45% of the choir preferred to be in close spacing to achieve this aim. In a later experiment, Daugherty, Manternach and Brunkan (2013) examined choral spacing together with riser height testing two heights of risers. Choir members preferred the higher risers and spread spacing for hearing themselves and the lower riser height with close spacing for hearing the other choir members.

Ternström (1999) found that the ideal self-to-other ratio (SOR) varies among voice types with sopranos preferring a higher SOR than basses. From all the above research, it is clearly difficult

to find a structure that balances the needs of different singers and their SOR requirements. Ternström also lists additional suggestions of using sheet music to reflect the sound of a singer or for a singer to block an ear to hear their own voice more clearly. Adams (2019) suggests that the most effective method to determine if a setup will work for a specific choir in a specific environment is to experiment and that even if it does not change the overall sound, it may however alter how the choir members listen. A graphic representation of Daugherty's choir formations are included in the reference guide for inspiration during experimentation.

CONCLUSION

This research aimed to determine whether subtle vowel-based techniques can be used to enhance the intonation of amateur choral singers. The vowel pairing tests revealed that while the fundamental frequency was always affected, the aural impact was often minimal with 73% of frequency changes categorised as unnoticed. However, certain vowel changes were significant enough to be detected even by non-musicians, perhaps highlighting a gap in the choir members' listening skills where they have not compensated for the vowel change. Additionally, the influence of the spoken demonstration tracks on some choir members also indicated a need for an improved inner hearing, as participants had been instructed to pre-imagine the note that they were about to sing. Notably, choral experience did not significantly correlate with the vowel pairing test results. These findings led to semi-structured interview with the participants, which uncovered diverse backgrounds and varying perspectives on what it means to sing in tune and how vowel production is understood. The literature review provided valuable insights into audiation and the development of listening skills, supporting the need for targeted training both in rehearsals and on a one-to-one basis with singers.

The research had its limitations: the unexpected impact of spoken vowel demonstrations on the results suggest that future studies should be more controlled. The study's small scale with participants of varied backgrounds and abilities limits its generalisability (Denscombe, 2003, p. 36). In addition, these findings are particularly relevant to amateur choirs aiming for high-level singing, but may not apply to all amateur choirs, especially those not committed to the long-term process of teaching sight-singing (Lucas, 1994, p. 214) to a group with mixed music reading abilities.

From a personal perspective, this research underscored the value of spending individual time with choir members to discuss their backgrounds, develop vocal technique and musicianship skills, address specific challenges and strengthen relationships. Future research could explore the impact of methods such as sight-singing using movable-do and the use of a harmonic context on adult amateur singers with varying levels of musical literacy. Current studies often focus on school students, and while Jordan's use of dominant chimes at Westminster Choir College has proven effective, it would be interesting to examine their effectiveness for amateur adults. Additionally, it would be valuable to understand how long it takes to develop sight-singing skills in a choir that meets twice a week, compared to the school choirs in the US who often meet more frequently (Kuehne, 2007, p. 125).

In summary, vowel changes do affect the fundamental frequency of amateur choral singers, they are usually not significant enough for an adjudicator to notice. Movable-do, singing with a harmonic context and experimenting with choir spacing appear to be beneficial in developing listening skills and intonation in choirs, but the effectiveness of the first two elements with adult amateur singers with varying levels of musical literacy remains inconclusive.

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