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Formant Tuning in Gender Perception: Applications for Transgender Voice Training

Introduction:

In my first module assignment, I explored how formant tuning with vowels can aid in cross-training across genres. Some vowels were more suited to different types of music. I applied this to my own practice as a performer, as I wrote, programmed, produced, and performed in a cross-genre solo musical narrative show about my experience as a transracial adopted person. I explored how formant tuning and vowel modification can create different sounds suited for various genres, including classical, jazz, pop-rock, across American English, in my Module One assignment and my show. I discovered in my own lessons that my diction habits utilized some Korean speech features that showed up in my singing, though I do not know how to speak Korean, as well as some resonance strategies utilized, which were influenced by the regional accents I was raised with.

As I was teaching during the preparation for this project, I worked with many students with K-12 choral backgrounds to brighten their vowels to sound more authentically pop. Some clients had an easier time achieving the bright twang of musical theatre than others, and I noticed that one factor in a client was her New Zealand accent. Bright /i/ vowels came very easily to her as well as /ae/. She modified her vowels due to the resonance strategies used in her daily speaking habits, which correlates her accent to easily utilizing twang for singing The Wizard and I.

I also used formant tuning to assist a transfemme voice client modify their vowels to achieve a brighter range of vowels, to avoid a choral sound, which recalled a traumatic memory of church choral singing. I then came to the idea- could formant tuning have more applications aside from accents and genre?

Transgender voice training methods focus on pitch modification, as well as speech cadence and resonance strategies. However, especially for transfemme voices, pitch modification is limited. Utilizing formant tuning techniques could provide additional avenues to vocal authenticity, particularly when hormone therapy isn't accessible. This approach of adapting accent and cross-genre training methods offers transgender singers tools and options to find a voice most authentic to them during a time when gender-affirming care is at jeopardy.

Context:

In a world where gender affirming care is at risk for all ages, it is a crucial time to determine ways in which to support trans singers in the voice studio who may not be able to access gender affirming care. There are a variety of other reasons why an individual may need to stop gender affirming care, and there needs to be measures in place for those clients to feel supported in their voice studio while they may not have access to hormone replacement therapy. I currently have a client who is temporarily stopping hormone replacement therapy for family planning, but is struggling immensely with their gender identity and voice even more during this time. “Gender and history impact how we read the tone, velocity, and pitch of the voice, but they also shape parameters of where and when particular voices are invited to speak or expected to remain silent” (Ehrick, 2015). Transgender voices have been silenced due to stigma and phobia throughout history (Parker et al., 2022). This research study on trans voices is especially relevant considering the current political climate in the United States. There are almost 250,000 trans youth living in states that have either introduced or made legal measures, or laws were pending to ban access to gender-affirming care in the 2024 legislative session. This is slightly more than three-quarters of all trans youth ages 13-17 in the United States of America (Redfield et al., 2024). These bills negatively impact transgender youth by denying them medical care that is deemed best for them by healthcare professionals (Movement Advancement Project, 2024). The Movement Advancement Project (2023) also cites various tactics that target trans youth and adults from accessing care, criminalizing trans folk and their allies, and rolling back legal protections for trans people to exist in public and within American society. In 2023, almost two hundred bills were proposed, and twenty-six passed, but in 2024, over six hundred anti-trans bills were considered, and over fifty were passed in 2024. Eighty-seven bills were considered at the federal level last year (Trans Legislation Tracker, 2024). There has been a major rise in transphobia, and also the legal and societal protections of trans people in the United States since the beginning of the year.

This begs the question- what are other means in which teachers and pedagogues support clients and students in helping them develop and use a voice that is most authentic to them? There are other studies on formant tuning and gender perception; however, there is a limited amount of research done on transgender people in general, and even more limited in the field of voice. Considering the current state of transgender voice research, it is possible to draw upon a wealth of grey literature; however, there is white literature on gender perception and factors beyond the fundamental frequency.

Program of Study:

Aims:

- To develop and evaluate an organized pedagogical framework combining genre cross-training and accent work for transgender voice training

Objectives

- Acquire knowledge on how other factors aside from fundamental frequency play a role in how gender can be perceived in voice
- Identify and analyze existing literature that investigates how gender is perceived in voice

Learning outcomes

- Further understand what I have already been applying in my performance and teaching practices
- Broaden my knowledge of resonance strategies and formant tuning in contexts related to transgender voice training.
- Apply acquired knowledge to my studio as I teach students of various gender identities to find and use a voice that is tailored to their goals.
- Develop better practices and create a framework for students to use formant tuning at basic beginner levels

Methodology:

A rapid scoping review would be most appropriate for the time frame I have been provided for module 4. I aim to broadly scope the body of literature on how formants influence gender perception in the voice, and how to apply that information to transgender singers, which is a gap in the literature.

A comprehensive literature search was conducted between March and May 2025 using Google Scholar. Search terms included combinations of keywords such as “fundamental frequency,” “pitch,” “formant frequencies,” “gender perception,” “voice feminization,” “transgender voice,” and “voice therapy.” Boolean operators (AND, OR) were used to refine searches, for example: (“fundamental frequency” OR “pitch”) AND (“gender perception”) AND (“transgender”). I also searched for formants and singing. While I could have expanded the search terms in the initial search, I was able to continue to inquire about topics and themes as I gathered data from the

initial search using keywords such as (“cultural speech gender cues”) and (“vocal tract resonance”) AND (“accents”).

I searched in Google Scholar using the search terms gender perception and formant tuning, which yielded 8,210 results. I later put in a date range to narrow down my search from 2000-2025, which yielded 7,710. As I have been reviewing the available literature, there were white literature results on formant frequencies and gender perception, often, quantitative studies measuring acoustical data, and quantitative tests on how sounds were perceived. As I dug deeper into the search results after page 3, the topics would delve into other topics that were somewhat related but not focused on the perception of gender or formant tuning. Those studies were in adjacent topics, taking into account other factors such as age, culture, language, and means of perception, even including hearing aid implants. Coming up with so many quantitative studies that essentially arrived at the same conclusions, I decided not to pursue any other search methods aside from my initial findings with Google Scholar, and only then sought to elaborate on related topics to contextualize the data. I could have utilized other search methods for those other topics; however, to consider word count and the scope of the project, I opted to use the studies Google Scholar found in my search.

This review seeks to answer my research question: “How does formant tuning influence gender perception in the voice, and how could these discoveries be applied to transgender singers? So I used the following criteria to include and exclude literature.

Studies were selected based on the following criteria:

- Published in peer-reviewed journals between 2000 and 2025 due to the rapid advances in technology, as well as research on a topic that was considered by society to be immoral or taboo in decades prior.
- Written in English
  Focus on quantitative acoustic analysis of voice characteristics related to gender perception
- Empirical research, including experimental, clinical, or observational studies.
- Some studies from previous to 2000 to contextualize. Since these studies are quantitative, there is more relevance to acoustical information than qualitative factors, which can change due to societal context.

I also included grey literature

- Grey source literature utilized in previous modules is referenced to explain and contextualize the white literature. There was also some grey source material I found from social media websites that proved to be insightful.
- Practitioner literature and website publications utilized in previous modules are referenced to give context to the white literature

Once relevant grey literature is selected, quality control is necessary to deem its validity in a systematic literature review. Scholarly studies such as Adams et al (2017) question the validity of evidence in grey publications, which tend to focus on conclusions rather than consider the research process to obtain the data and the methodical considerations to draw the conclusions. Grey literature is frequently excluded due to concerns about quality, accessibility, and the lack of peer review. However, the publication suggests that these concerns can be mitigated through high standards of evaluation criteria. In voice pedagogy, it is crucial to use white literature that has gone through a rigorous inclusion process; however, there are many resources for singers that are published using information from white literature in easily accessible formats.

I conducted a thematic synthesis by categorizing findings into major themes: gender perception in acoustical factors of the voice, factors that can alter gender perception in the listener, and their applications for trans voices. I drew out themes from the quantitative data, which measured fundamental and formant frequencies, listener perception, and drawing parallels to acoustical quantitative data from various fields, such as quantitative acoustical data in accent training and cross-genre training. As I undertake this research, I must consider my position as an insider as I design the research, analyze the information I acquire, and synthesize it. I do consider myself to be a nonbinary singer and voice teacher, working with trans voices in the studio.

Part 2: WRITTEN ASSIGNMENT AND CRITICAL REFLECTION

FORMANT TUNING: AN OVERVIEW OF ANATOMY AND VOWELS

The vocal tract is where the human voice resonates. The source of sound originates from the vibrating vocal folds, which cause the air in the vocal tract to vibrate at various pitches. These pitches are called formants. The space reaching from the top of the larynx and the back of the tongue is where the first formants resonate. The space above and in front of the tongue is where the second formants resonate. (Irene and Harris, n.d.). The lips affect both formants, especially the first. Rounded lips decrease both formants, and spread lips increase both formants. Articulation is often referenced as tuning the vocal tract shape (Bozeman, 2013). This is a very simplified descriptive model of vocal tract phonation to give a framework for formant tuning. Phonation of the human voice is much more complex.

The tongue is mentioned in the voice studio as another articulator; however, Johan Sundberg (1987) notes how the tongue plays a significant role in resonance. The shape and position of the tongue directly affect the second formant. A fronted tongue will increase the second formant, whereas if the tongue is moved further back, closer to the velar region, the second formant will decrease in pitch (Sundberg, 1987). When advanced, the tip of the tongue will raise the third formant, but when pulled back, the tongue will lower the third formant and raise the first formant by constricting the oral-pharyngeal resonating space (Sundberg, 1987).

Sundberg also notes that female singers seem to tune the first formant by adjusting the opening of the jaw. Measurements on female singers' jaw opening indicate it is systematically increased with the rising fundamental frequency (Sundberg, 1988). Irene and Harris (n.d.) suggest that when the jaw opens, the space behind the tongue decreases and the area in front of the tongue increases. This results in the increased pitch of formant 1 and the decreased pitch of formant 2. If the larynx is raised, both spaces in the vocal tract decrease, so the pitch of the first and second formants gets higher (Irene and Harris n.d.).

Many singers notice that different vowels will resonate differently. They will feel secondary vibrations in different places in the body, due to the formants resonating at different pitches. The formants will resonate at different pitches due to the size and shape of the formant. Vowels in the teaching studio will often be described as closed or open, front or back. There are anatomical and

acoustic reasons for these adjectives. The first formant's frequency determines the "openness" or "closeness" of a vowel (Bozeman, 2013). Open vowels are considered open due to the position of the tongue being lower in the mouth, causing there to be more space (O'Connor, 2022). Closed vowels are considered to be closed due to the position of the tongue being higher in the mouth, resulting in less space in the mouth.

CORE ACOUSTIC PROPERTIES IN GENDER PERCEPTION

Fundamental Frequency

Longer vocal folds will have more mass and therefore vibrate at a lower rate. This results in people AMAB (assigned male at birth) tend to have longer vocal folds and vocal tracts. People AFAB (assigned female at birth) tend to have shorter vocal folds and vocal tracts, so the folds will vibrate at a faster rate, hence why pitch is the initial indicator of biological sex assigned at birth (Babel, McGuire & King, 2014).

Throughout all of these studies, the initial primary factor of gender perception tends to be the fundamental frequency (f_0). This is often correlated with pitch. Knowles & Little (2016) investigated how various acoustical factors, such as pitch and formants, altered a listener's perception of how cooperative the speaker is, as cooperation tends to be a quality perceived and associated with feminine traits. In the study, voices featuring a "feminine" range F0 were rated as more cooperative than those with masculinized F0, regardless of the speaker's assigned sex at birth.

The study by Gelfer and Schofield (2000) also concluded that voices perceived as female averaged a higher speaking fundamental frequency (SFF) compared to those perceived as male. The upper limit of SFF and ratings of femininity were correlated in the results, suggesting that higher pitch ranges are associated with perceptions of femininity in 'Male to Female' transgender voices. Houle & Levi (2021) showed that whispered speech reduces gender clarity, indicating how significant F0 and formants are to gender perception. Schmid and Bradley (2019) found that non-binary speakers F0 averaged to be right in between the mean F0 of cisgendered women and men, but the non binary speakers with more of a feminine gender identity had a higher SF0 and those with more of a masculine gender identity had a lower SF0. They also

found that both masculine and feminine speech cadence and intonation patterns were used across the nonbinary participants.

However, pitch varies across cultures. Natour and Wingate (2009) found that the fundamental frequencies of Jordanian Arabic-speaking adults are similar to adult Caucasian and African-American fundamental frequencies. However, for Jordanian Arabic-speaking AFAB participants, a higher trend in SF0 values was present than the Western participants. Average speaking pitches for English speakers are around 125 Hz for AMAB participants and 182 Hz for AFAB participants, whereas AFAB Chinese speakers' mean pitch is significantly higher at 297 Hz. In a study by Altenberg and Ferrand (2005), English speakers were used as the control group. The Russian/English bilingual group had a higher F0 in their English speaking. The other bilingual group that also spoke Cantonese had a slightly lower F0 in their Cantonese than in their English. Fundamental frequency does change depending on the language and cultural tendencies, and perception will change due to cultural expectations and norms. A study by Van Bezooijen (1995) concluded that in Japanese society, a higher pitch was more attractive for women, resulting in a higher SF0 than the Dutch women in the study.

Additional Formant Frequencies

Formant frequencies are measurements of vocal tract resonances in the oral cavity shape. F1 is associated with the tongue's height and position. F2 is associated with how front/back the vowel is. These frequencies are play a significant role in gender perception of the human voice, especially when F0 is at an intermediate pitch, and may not be classified as "high" (female) or low (male) (Gelfer & Bennett, 2013; Hillenbrand & Clark, 2009; Gallena, Stickels & Stickels, 2018). Raising the vowel formant frequencies, especially the second formant, directly changes how voices can be perceived as "not male," which is more feminine or androgynous, which correlates to the study by Schmid and Bradley (2019).

F2 is also a significant predictor of gender in voice. The higher the fundamental frequency and the F2, the voice is perceived as more feminine (Manny, 2014; Houle & Levi, 2021). Babel, McGuire, and King (2014) found that "for female voices, the largest contributor (of vocal attractiveness) was a principal component associated with higher second formant frequencies for /u/."

The study by Assmann, Nearey, and Dembling (2006) investigated how altering the formant frequencies and the fundamental frequency impact how the quality of naturalness is perceived

in a voice as well as the perceived gender. Acoustic features were altered with a vocoder, specifically the pitch (F0). The participants judged the spoken phrases as more natural when F0 and formant frequency patterns were consistent with natural patterns of speech. A more masculine perception was associated with sentences spoken with lower F0 and formant frequencies, while those with higher F0 and formant frequencies were perceived as more feminine. When the formant frequencies including the F0 were mixed up, this led to gender ambiguous results. Male speakers received higher masculinity ratings than those from female voices, even when factors were adjusted to match the other group, indicating that factors beyond F0 and formant frequencies contribute to perceived gender identity. Hardy et al. (2020) investigate the acoustic factors that can determine how a listener perceives masculinity and femininity, and also how “natural” or authentic the voice presents. In the study, they gathered speech samples from transgender and cisgender individuals reading the same text. The results concluded that it was mainly F0 that determined gender, but also F2 had a significant factor in how the trans women were perceived to be more feminine.

Gallena, Stickels, and Stickels (2018) investigated how raising vowel formant frequencies (F_1–F_3) influences listeners' perceptions of gender in speech. The researchers took samples spoken by an adult male speaker raised the formant frequencies of vowels (/i/, /æ/, /ɑ/, and /u/) in increments until they matched those typical of a female speaker. The F0 was held constant at a gender-ambiguous level. Listeners then classified each sample as male, female, or gender-neutral. The results indicated that raising the whole range of formant frequencies shifted listeners' perceptions from male to feminine or gender neutral. This was evident in vowels such as /a/ or /ae/, which have a high F1. This indicates that the qualities of a high F1 tend to be associated with resonance that is perceived as more masculine, but the pitch of the other formats can alter that perception.

Idsardi and Zetland (2019) identify that:

> “This formant spacing can be attributed to the high vowels (for example in "goose" and "geese"), which have a constriction in the velar to palatal region of the mouth. For these vowels, the first formant is the result of the system acting as a Helmholtz resonator, which has a resonance based on the area of the constriction and the volume of air in the cavity behind the constriction. This means that vocal tracts of substantially different lengths can nevertheless closely match an F1 resonance in the high vowels.”

This information can be utilized to alter and tune the F1 resonance and create distance between the F1 and F2. Cartei, V. and Reby, D. (2015) found that formant spacing, particularly between F1 and F2, is a significant factor for gender perception in pre-pubertal children's voices. F0 is not as reliable a factor in gender perception since there tends to be less variation of F0 pitch in that age range. The study found that AMAB children's voices had wider formant spacing compared to AFAB children. This is due to larger vocal tract sizes in males, even at a pre-pubertal age. The size of the vocal tract correlates with the distance between the first (F1) and second (F2) formants, and a wider spacing was perceived as more "male." In contrast, female children's voices had more narrow formant spacing, likely due to smaller vocal tracts. This smaller spacing between the formants was perceived as more "female." This is confirmed by Deepawale et al. (2008), who determined that the space between the first three formants varies in frequency. The findings show that the energy between the adjacent formants for people AFAB is smaller than people AMAB. Depending on the vowel, the energy difference is evident between second and third formants for males and females.

A study by Mount and Salmon (1988) found that increasing fundamental and other formant frequencies of the subjects' speaking voice, specifically F2, can be achieved by altering tongue placement. When the therapy concluded, the subject had almost doubled the Hz of the pitch of her speaking voice in sustained vowels. F2 values for /i/,/a/, and/u/ also indicated an increase in frequency. The subject was perceived as a male over the phone, even after 4 months of GAVT (gender affirming voice therapy). However, as the F2 values began to increase after more practice, around 6 months later, and the subject reported that she was perceived as a woman on the phone.

Transgender women's voices can attain feminization but still tend to differ from cisgender female voices on some acoustic features, such as F_0 and voice quality measures (Schwarz et al., 2018). While F0 is significant in the initial perception of gender, another contributing factor tends to be not fundamental pitch but the spacing between F1 and F2. Additionally, Doyle et al. (2024) found that speech intelligibility was not compromised by formant-shift modifications, affirming the practicality of GAVT (Gender-Affirming Voice Therapy).

ADDITIONAL QUALITIES FOR GENDER PERCEPTION

Pitch variation and the range of semitones also play a role in gender perception (Hancock et al., 2014). Greater variation in pitch tends to be perceived as a feminine speech trait (Knowles &

Little, 2016; Gelfer & Mikos, 2005; Hillenbrand & Clark, 2009). Hancock et al. (2014) emphasize that intonation also cues gender perception. Transfemme speakers who used more of an upward intonation cadence were more likely to be associated with feminine qualities. This finding highlights how prosody is a critical component of voice feminization therapy.

Other vocal quality elements, such as breathiness and smoothness, can enhance femininity (Manny, 2014; Martinho et al., 2024). This factor of voice quality in the women can indicate youthful larynges or as a generally feminine attribute. (Babel, McGuire & King, 2014). Breathy female voices tended to be rated as more attractive, hence, more natural.

Gorham-Rowan & Morris (2006) concluded that a significant increase in MFDR (Maximum Flow Declination Rate) was observed in AFAB voice production. The study sought to explore the physiological functions of trans women as they seek to feminize their voice. The study shows that a more abrupt glottal closure can aid in the perception of a voice sounding more feminine. Specifically, physiological changes such as increased maximum flow declination rate (MFDR) contribute to a more abrupt glottal closure characteristic in feminine voices.

Physiological differences in voice production have been observed between genders. Linville (1996) reported that in stroboscopic evaluation, adolescent men rarely exhibited glottal gaps, while adolescent women showed higher rate of glottal gaps. Similarly, Sodersten, Hertegard, and Hammarberg (1995) found that more than half of their female participants had a posterior chink glottal configuration. These anatomical differences can influence acoustic features such as breathiness, a marker of vocal femininity. Such characteristics influence listener judgments.

Hardy et al., 2020; Martinho et al., (2024), measured vocal tract length and pitch, vocal qualities such as jitter (frequency variation) and shimmer (amplitude vadriation), and formant frequencies (F1-F4), and concluded that the combination of all of these factors played a role in gender perception. A study by Schwarz et al. (2018) revealed significant differences between the two groups across various acoustic measures, such as fundamental frequency (F0), jitter, shimmer, and voice turbulence index. Transgender women exhibited lower mean F0 compared to cisgender women, and their voices were characterized by low volume and consistent cadence. These results suggest that transgender women can achieve voice feminization through glottal adaptations, although their voices may still differ from those of cisgender women in certain acoustical aspects.

Donai & Lass (2015) concluded that high-frequency spectral cues (from high-pass filtered vowels) also supported accurate gender identification. Female and child voices typically have higher spectral energy due to shorter vocal tracts and higher fundamental frequencies. Spectral tilt, which is defined as the slope of the high-frequency energy drop-off, varies by age as well as sex. High-frequency energy can reflect tension in the voice, breathiness, and emotional states such as anger or excitement.

Articulation of fricatives like /s/ can contextualize other aspects of a person's sociolinguistic style (Zimman, 2017). Zimman elaborates, "In this way, the voice as a gendered mechanism is constructed through the same processes of 'stylistic bricolage' one observes in linguistic variations. With the development of a low-pitched voice, a high frequency /s/ can result in the perception of a gay or queer male (as explained in Zimman 2013)." While analyzing a couple of many features in how speech patterns are intertwined with societal expectations and aspects of gender, noting the correlation between fundamental frequency and /s/ provides another layer of nuance in how femininity or masculinity is characterized in the voice.

CONTEXTUAL AND LISTENER-BASED INFLUENCES

While there are significant findings on patterns of formants, it is imperative to consider other contextual factors of perception that can influence the listeners. Pernet, Belin & Jones (2014) concluded that gender and phoneme processing seem to be separated at the early stages of processing auditory information. The brain relies on different acoustical cues. Findings conclude how specific these neurological processes are for various speech and linguistic factors. Further analysis revealed that vowel formant frequencies were primarily used to distinguish voice gender, whereas consonant formant frequencies were used for phoneme categorization. This suggests that various acoustic features are emphasized depending on the categorization task. This is important to take into consideration, especially considering factors about how intonation and speech melody also influence gender perception. As noted previously, greater use of upward intonation patterns and larger semitone ranges is associated with perceptions of femininity, indicating that prosodic features are important in gender communication beyond static acoustic measures (Hancock, Colton & Douglas, 2014). These features are influenced by a variety of linguistic and social constructs. Brown et al. (2020) found that gender perception tended to be stable across different listener demographics. The study concluded that ratings of gender perception of a transmasculine speaker are not significantly influenced by varying

listener age or gender minority status if the group size is reasonable. This finding suggests that voice-based judgments of gender may be consistent across different listener demographics

Transgender and non-binary listeners used more diverse acoustic criteria in judging voice gender, especially in expressive speech tasks. Martinho et al. (2024) found a correlation between the gender perception of the voice and the context of the listener and the speaker. Transgender and non-binary judges displayed a greater range in their observations compared to cisgender and speech language pathologist subjects. Groups of judges utilized more varied acoustic measurements when analyzing the speech of transgender and non-binary subjets in the samples than compared to the cisgender speakers in the study.

Visual cues also provide significant context in voice perception. On a social scale, the conclusions suggest that people do not perceive a voice in isolation. Instead, listeners tend to interpret voice characteristics such as gender, vowel sounds, and even sexual orientation are influenced by how the listener visualizes the speaker. These implications are crucial for understanding how people interpret gender in speech and are crucial for understanding the flexibility of gender perception in different contexts. (Burgering, M.A., van Laarhoven, T., Baart, M. and Vroomen, J., 2020)

METHODS OF TRAINING FORMANT TUNING

Biofeedback and Visual analysis automations

Kumar et al. (2011) and Deepawale et al. (2008) discuss how using systems of classification of pitch and formant data can analyze and give feedback on acoustic information that correlates with gender perceptions. These automation models can inform analysis tools and potential applications in transgender voice care.

An article by Deanna Kawitzky and Tara McAllister (2018) notes that the variations in the frequencies of formants in people assigned male or female at birth directly contribute to how others perceive the voices as masculine or feminine. This study explored whether “visual-acoustic biofeedback” is effective in assisting transgender women achieve typical formant values of cisgender women. The study also investigated the shift influences the perceived femininity in speech. The study by Kawitzky and McAllister (2018) investigates the use of visual-acoustic biofeedback to assist transgender women in achieving formant frequencies typical of cisgender women, specifically focusing on the second formant (F2). Participants were prompted to produce vowels while aligning their F2 with a target shifted

upwards (feminized target), or using control conditions such as unshifted formants, or formants shifted downwards. During the short term training, both transfemme women and cisgender men showed a significant difference in F2 frequency across the conditions. Listeners were blind folded so they could not utilize visual cues, rated higher F2 values as more feminine. This indicates that increasing F2 contributes to the perception of femininity in speech. The study's results show that biofeedback can be utilized as a valuable tool in gender affirming voice therapy for transgender women. Researchers in the study did note that a larger sample sizes is necessary in further research to draw concrete conclusions.

Accents and Formants

The need for resonance in any genre is to allow the initial vocal fold phonation to reverberate in the vocal tract. A great way to introduce a studio application is by merely speaking. Challenging the student to imitate the "voices" the teacher will make by playing around with different accents such as British, Australian, American Southern, American TransAtlantic, American Midwest. These accents will help them play around with different vowel sounds since various accents require different shapes of the mouth and therefore resulting in different vowel sounds (Hero and Houston, 2023). Accents and dialects can have an impact on how speech is approached, and how it can be used as a framework to help trans people and singers discover and familiarize themselves with formant tuning.

Ghorshi, Vaseghi, and Yan (2008) conducted a study comparing evaluations on cross-gender speech recognition. The results indicate that accent differences influence speech models to an extent comparable to gender differences. Additional findings indicate that the second formant (F2) is the most influential resonant frequency in accent perception, with male speakers showing a similar pattern. This supports the argument by Weber et al. (2001) that F2 plays a critical role in accurately classifying accents. F2 also falls within a frequency range characterized by relatively higher energy concentrations. The first formant (F1) is considered the next most important factor in accent classification. Both F2 and F1 values are key determinants in identifying accents. Babel, McGuire, and King (2014) found that, "This pattern of /u/-fronting is characteristic of Californians, especially younger females, and here it was found to be important to the attractiveness of the voice." Transfemme singers can modify their vowels to achieve more perceived naturalness to their voice, especially since the /u/ vowel correlates with F2. Another study by Chan, Hall, and Assgari (2016) explored how vowel formant frequencies and durations influence the perception of foreign accents. Using synthesized speech, they

manipulated the formant frequencies and durations of the vowels /æ/, /ʌ/, and /a/. They programmed variations that simulated native English and Spanish-accented speech sounds. Native English listeners then rated these sounds for clarity and strength of accent. In their study, changes in F2 for /a/ and /ʌ/ altered both ratings of comprehension and accent. By manipulating F2 values away from native English norms, perceived accentedness, which shows the significance of F2 vowels in accent perception.

A method ranked the normalized distances between formant frequencies across accents, and it identified F2 as the most significant formant in conveying accent identity, followed by F1. Yan, Q., Vaseghi, S., Rentzos, D. & Ho, C.-H., et al. (2007) investigated the acoustic characteristics distinguishing British Received Pronunciation (RP), General American, and Broad Australian English accents, focusing on formant frequencies and their trajectories. **First Formant (F1):** Australian vowels exhibit lower F1 values compared to British and American vowels. I have found this to be true with voice clients from New Zealand, which have similar vowels to Australian English. **Second Formant (F2):** Australian vowels have higher F2 values, while British vowels show intermediate values. Formant modifications significantly influence accent perception. Australian vowels are changed to target British formant values, resulting in a perceived British accent, while there were some slight deviations due to prosody, etc.

This is also true for gender perception as well, per previously referenced literature. As discussed before, of the formants that are not the fundamental frequency, F2 is the strongest predictor of gender perception, followed by F1. Using this information to contextualize the evidence presented previously about how the second formant is most significant in gender perception advocates for the validity of using accent training techniques to alter F2 and F1 values in gender affirming vocal training and therapy.

Cross-Genre Training as a framework for formant tuning

Formant frequencies directly affect voice timbre (Sundberg, Thalen, 2015). This indicates crossing between different styles of vocal music would require one to alter formant frequencies by means of the articulators and resonators. Various shapes of the mouth create a general resonance. Changing the laryngeal height (vertical) or altering pharyngeal width can fine-tune this basic resonance in a precise manner (Wilson, 1997). Latimerlo and Popeil (2012) note the three possible positions of the pharynx: wide for classical and R&B, constricted for country and

rock, neutral for pop, musical theater, and jazz (Wilson, 1997). The positions of the vocal tract alter the sound considerably and therefore can help the singer adjust to singing in different genres (Cardon, 2021).

Vowel modification is typically used to help singers reposition their anatomy to sing vowels in higher parts of their range (O'Connor, 2022). Shirlee Emmons notes, "With the aid of vowel modification, singers will have fewer intonation problems, better resonance across their ranges, more carrying power, easier production of forte and piano, clearer diction, and… a much better blend" (n.d.) This would mean vowel modification can also be used to help singers achieve different sounds for different genres as well. As singers attempt to discover varying resonance sensations, they can use different vowels to discover where sensations should be. As previously discussed, different vowels alter the space and therefore frequency of each formant. Vowels with low first formants are closed, such as /u/ or /i/. Vowels with high first formants are open like /ɛ/, /ɔ/, or /ɑ/. The second formant is why vowels are perceived as front or back because front vowels have a high second formant while back vowels have a low second formant (Bozeman, 2013). The /ʉ/ vowel has lowered pitch in both formants due to both spaces in the vocal tract being enlarged (Irene and Harris n.d.). This is also because the /u/ vowel requires a lower larynx. Front vowels /æ/ and /i/ have a higher larynx height than /u/. Front vowels such as /i/ also have typically higher frequencies than vowels /ɑ/, /ɔ/, /ʉ/. An explanation for the lower larynx position in /a/ may be that lowering the larynx assists the tongue to move back into the pharynx since it is connected with the hyoid bone (Moisik et al, 2019). Irene and Harris (n.d.) also note that "If the tongue is retracted and the muscles by the hyoid bone are contracted, it can contract the space around the larynx, making free vibration impossible for the larynx." Lisa Popeil and Gina Latimerlo outline how to achieve different sounds in their book Sing Anything. They instruct singers to sing on a different vowel for each genre and make specific changes to the larynx, pharynx, tongue, jaw, and soft palate. While students at first may struggle to be distinctly aware of a high or low positioned larynx, wide or narrow pharynx, and high or low tongue, they can create those positions with vowel sounds they are already familiar with. Students can use the shape of these vowels as a template to modify other vowels they sing, so they can use appropriate diction and resonance for each genre.

A classical singer will use a broad range of vowels, especially when singing in various languages such as Italian, German, French, Spanish, English, Russian, etc. However, classical

singers tend to use darker vowels than the typical CCM singer (Wilson, 1997). Chiaroscuro refers to the balance of lightness (chiaro) and darkness (scuro) of vocal tone color (Vala, 2021), which results in a balanced timbral quality (Miller, 2004). Voice teachers have concluded that classical singers can achieve a darker tone by lowering the larynx relative to pitch (Wilson, 1997). This impacts the energy patterns between formants. Lowering F1 and F2 also has the effect of creating a spectral distance between the formants which define the vowel (F1 and F2) and formants often referred to as the "singer's formant cluster" (F_3, F_4, and F_5). The distance between those formant clusters allows the listener to more clearly distinguish unique timbre in a singer's voice, which also assists in individual voice distinction. In classical singing, a low larynx/wide pharynx can help the singer attain the traits associated with the genre. The /o/ vowel, which is round and has space in the mouth, promotes a very lifted soft palate and a rounding of the lips to keep the "scuro" in the chiaroscuro. This vowel can be used as a template for keeping the sound typical of classical singing. This correlates with more masculine vocal qualities, which assists in accessing that resonant "boom" like call-quality typical of masculine voices. It may be beneficial for a transmasculine singer to sing a classical piece, which can require more rounded vowels typical of the "scuro" in chiaroscuro, which will lower the fourth formant, resulting in a more masculine perceived voice.

The /o/ vowel is characterized by an elevated back tongue, resulting in a large space behind the tongue and a smaller space in front of the tongue (Irene and Harris, n.d.). As mentioned previously, this results in a low formant 1 and a high formant 2. Using the /i/ vowel as a reference of how a high F2 frequency feels would help give an anchor point to shape other vowels accordingly. The /a/ vowel is formed by a neutral-low tongue position, increasing the space in front of the tongue while decreasing the space in the back, resulting in a high formant 1 and low formant 2. Brightening the vowel to /ae/ would help raise F2, which correlates with more feminine qualities. For Belt Musical Theatre styles, the authors direct the singer to create an /ae/ vowel with a half-lifted palate. The difference between /a/ and /ae/is a widening of the mouth and lifting of the tongue, creating a brighter sound. The brightness of the /ae/ and the nasality of the half-lowered palate will give the twang resonance desired by belt singers. To achieve that color for the rest of the vowels in this style of singing, widening the mouth into a smile and showing the teeth, which Popeil and Latirmerlo call the "Molar Mouth." Even rounder vowels, such as /u/, sung with a wider mouth, will create that brassy belt quality characteristic of the genre. Kate Cardon also agrees and suggests singers use "Bright vowels and more nasality than allowed in other styles" (2021). This results in raising the F2, so utilizing the /ae/ vowel can

help singers modify other vowels to a “brighter”, more “forward” placement. Encouraging transfemme singers to try a musical theatre piece would be beneficial in raising the second formant, which can assist in creating a sensory marker for the singer, who can recreate similar resonance strategies to have their voice be perceived as more femme.

CONCLUSION:

Gender affirming voice therapy and training involves not only increasing or decreasing F0 but also modifying formants and vocal fold physiology (Gorham-Rowan & Morris, 2006; Schwarz et al., 2018). While elements such as fold closure and speech patterns play a role in gender perception, formants are a significant element in gender perception. These studies highlight a multi-dimensional approach to voice feminization/masculinization and how to approach gender affirming voice training and therapy. While pitch (F_0) is a primary and powerful cue for gender perception, vowel formants and intonation patterns significantly enhance the listener’s perception of gender, especially in ambiguous pitch ranges. For transgender women, voice feminization requires adjustments not only in pitch but also in vocal tract resonance and prosody, with biofeedback emerging as a promising technique to facilitate these changes. For transgender men, hormone replacement therapy can help the fundamental frequency, but formant tuning can also help them utilize a more authentic voice. Further research can be done in transgender voice studies in general, as there is still a gap in the body of knowledge. However, there are enough studies with similar results that indicate formant tuning is integral to gender perception, and various patterns can determine how one perceives gender. The potential impact of this for transgender voices is significant because these tools and techniques can help individuals explore the full range of their voice, not just in fundamental frequency and pitch, but also the other acoustical factors that play into the resulting sound. While there are limitations to these quantitative studies, especially considering how cultural, social, and linguistic factors in how the voice is perceived, they do provide consistent data about acoustical patterns on how the voice functions. Clinicians should thus address both physiological vocal fold function and acoustic resonance, which holistically approaches the perceptual, physiological, and speech strategies tailored to individual needs (Kim, 2020). Future research recommendations would include contextualizing this quantitative data in qualitative studies about how this impacts transgender voices and insights into their experiences as they utilize these strategies.

Future Recommendations and Practical Applications:

This would be integrated into my practice in the studio by checking in with my clients about how they feel about their voice as we develop resonance strategies by using accents as a framework for altering formant frequencies. I would also gather data on their perspective as they sing in various genres, and see how they respond to using that resonance strategy in a genre-based setting. I would be obtaining qualitative data in the studio based on the quantitative data I researched in this study. I would also devise a framework for vocalieses and suggest repertoire plans for a transfemme singer, a transmasc singer, and a nonbinary singer, drawing upon the data from this literature review. Further collaboration can be done with the TRANScend Ambassadors, an ensemble of transgender and gender non-conforming voices I sing with, to employ these methods with other colleagues, and consulting with our director, Dr. Felix Graham, about best practices in incorporating these frameworks for resonance strategies.

Critical Reflection:

Schön's reflective model appealed to me during my process of cross-training, as I had learned a lot from experimentation and experience, but found a lot of research to expand upon what I already learned. I initially began this topic as a way to expand upon my learning process. I also noticed parallels from my process of learning to Gibbs' reflective cycle (1988). For this study, I took these steps in the reflective cycle as a process of finding an issue, reflecting upon why I felt there was an issue, then taking steps to solve the issue and learning how to apply my discoveries to other areas of my musical life in my journey crossing genres. Then I took that a step further, and hypothesized how gender and formants are correlated.

With reading selections from Bozeman's book, I learned why I made those initial discoveries about why the /i/ vowel sounds and feels brighter (2013). Upon discovering the "voice science works" website, Irene and Harris gave an easily understandable explanation for formants, which is to be considered grey literature, but still accurate and informative. This is where Gibbs' next step of analysis comes into my process (1988). I recognized gaps in my knowledge about formants and acoustics, and then continued my research around that as well. I discovered how vowels and diction relate to aspects of singing in different genres of vocal music, and I also learned about formants and resonance. In continuing to analyze, I learned why those things

were intertwined, then sought out how to apply it based upon what I knew previously with a more informed perspective.

As I was working on this paper in my formative assignment, I began to apply formant tuning methods that I was learning in my coursework to my studio practice, by having students widen or round the lips and see how that would alter the vowel, and how that sound would apply in various contexts, such as range and genre. I also researched methods by teachers such as Lisa Popeil and Kari Ragan, and found their methods of teaching various genres to align with the findings of Sundberg, Miller, Bozeman, and Titze, concluding that my evidence was concrete. I was able to move onto the next step in Gibbs' reflective cycle and draw conclusions (1988), especially after reading Laterimo and Popeil's book, Sing Anything. The last step in Gibbs' model is to reflect upon my actions and come up with a new plan. As I created my personal development plan, I thought about my goals as an educator and performer, and the steps I needed to take in order to improve. By creating an action plan with measurable goals, I was able to continue the cycle of learning in action and reflecting on the action I took. In accomplishing my goals I set out in my formative assignment of being a cross genre performing and teaching artist, I was able to reflect upon my experience as a transracial adopted person, and apply that to a need that I saw arise in my teaching studio- affirming and assisting my transgender voice clients in their voice journey.

Quinn (2000) notes all the common themes in reflective work, which include retrospection, self-evaluation, and reorientation. I continued the cycle and applied the work I did in my formative assignment and my third module assignment, combining the two in order to complete this desk based review of literature on formants and gender perception. Pollard's model of reflective practice outlines a process of observation, analysis, and evaluation, which results in informed action (Warwick, 2007). By utilizing the quantitative data correlating acoustical formant patterns with test results on how gender was perceived, these studies observed, analyzed, and evaluated the subjects in the studies, but many of these studies merely implied a proposed plan for informed action. With this reflective practice, I can observe the data, analyze the findings, and evaluate the effectiveness of a teaching framework using accent and cross-genre training for gender affirming voice training, which is the informed action.

After reflection, I was careful to ensure that I did not delve into “compassion” fatigue as I researched this topic, which I took great care of in module 3. The semi-structured interview format I used to gather data in module 3 required recalling past psychologically stressful/traumatic experiences and asking questions about private information, such as health treatment can be of risk to the participants (Amir, Badour, and Freese, 2009). However, the desk-based nature of this literature review and drawing upon data from mostly quantitative studies resulted in not encountering that potential liability, which I observed from my reflection. However, I did have to strategize self-care as I researched marginalized communities, especially as there are very real acts of violence occurring towards the trans community in the United States of America. Barry Kerzin, MD, adjunct professor of psychiatry, says, “There’s no such thing as compassion fatigue, just empathy fatigue.” He goes on to make the distinction that compassion is a desire to relieve suffering, whereas empathy is the adoption of another’s suffering (Lloyd, 2023). I am currently working with a Compassion Focused Therapist (a modality of therapy I learned about through a Voice Study Centre lecture), and have been actively working on maintaining boundaries as a person, a performer, and an insider researcher to take action for positive change and not adopt the suffering of those I care about.

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