A Structural Model of Physiological and Psychological Effects on Adolescent Male Singing

Craig Denison

University of Miami, denisons4@me.com

Follow this and additional works at: http://scholarlyrepository.miami.edu/oa_dissertations

Recommended Citation

A STRUCTURAL MODEL OF PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS ON ADOLESCENT MALE SINGING

By

Craig Denison

A DISSERTATION

Submitted to the Faculty of the University of Miami in partial fulfillment of the requirements for the degree of Doctor of Philosophy

Coral Gables, Florida

August 2015
A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

A STRUCTURAL MODEL OF PHYSIOLOGICAL AND PSYCHOLOGICAL EFFECTS ON ADOLESCENT MALE SINGING

Craig Denison

Approved:

__________________________  ________________________
Stephen F. Zdzinski, Ph.D.    Don D. Coffman, Ph.D.
Professor of Music Education   Professor of Music Education

__________________________  ________________________
Corin Overland, Ph.D.        Rachel Lebon, Ph.D.
Assistant Professor of Professional Practice of Music Education   Professor of Jazz Performance

__________________________  ________________________
Julia Gerhard, D.M.A.        Dean of the Graduate School
Assistant Professor of Otolaryngology
DENISON, CRAIG (Ph.D., Music Education)

A Structural Model of Physiological and Psychological Effects on Adolescent Male Singing (August 2015)

Abstract of a doctoral dissertation at the University of Miami.

Doctoral dissertation supervised by Professor Stephen F. Zdzinski. No. of pages in text. (157)

The purpose of this study was to examine the relationship of Motivation, Affective State and Physiology on the vocal outcomes of Range, Registration Fluency, and Vocal Quality. Participants were members of community boys’ choirs from four states ($N = 196$). Surveys on motivation and mood provided the psychological data. Height, weight, and lung capacity measures provided physiological data. Sound data consisted of glides, speech and *messa di voces*. Data analysis included Pearson correlation analysis, exploratory factor analysis and two-step maximum likelihood structural equation modeling. Results indicated a strong effect of Physical Maturity on Registration Fluency. Correlations among observed variables height, age, and speaking pitch with ranges in upper and lower registers, intensity ranges and breathiness confirmed previous research on adolescent male singing. Motivation had a moderate effect on Range ($\beta = .13$). Speaking Vocal Quality strongly predicted Range ($\beta = -.22$). Physical Maturity had strong effect on Registration Fluency ($\beta = .27$). Physical Maturity outcomes predicted Range ($\beta = -.08$) indicated by multiple registers, which supported elements of both the Eclectic Theory (Cooksey, 2000a) and Expanding Voice Theory of voice change (Leck, 2009; Phillips, Williams, & Edwin, 2012; Williams, 2013).
Acknowledgements

I would like to express my gratitude to my wife, Dr. Maria Denison, who convinced me to go back to school, and has been an endless source of bright loving support throughout the dissertation process. I am also thankful for my sons, Zach and Caleb, who grew as I grew during this time, and supported me throughout my studies.

I am also grateful to the board, staff and families of Florida’s Singing Sons Boychoir, whose flexibility and support made this dissertation possible. I am especially grateful to the boys of the choir, whose interest in this study was such a unique source of joy.

This study would not have been possible without the interest and support of my choir colleagues. I am especially grateful to Julian Ackerley, Bryan Priddy, and the artistic staff of the San Francisco Boys Choir who arranged the data collection process.

I also wish to extend my deep appreciation my music education professors. Drs. Asmus, Abril, Coffman, Zdzinski, and Overland have provided thoughtful and challenging formative experiences for me. Their teaching will be a constant presence in my future work.

I’ve written thousands and thousands of words these past 4 years, and none of them are sufficient for expressing my gratitude to Dr. Zdzinski. From admission to research classes to the dissertation, he has been a steadfast supporter of my growth and the entire process was a distinct pleasure. Of course, it was not without its challenges, but he never doubted me, and for that I am wholly grateful.
Table of Contents

List of Figures .................................................................................................................. vii
List of Tables .................................................................................................................... ix

CHAPTER ONE STATEMENT OF THE PROBLEM ....................................................... 1
Criteria for Practitioners’ Decisions ............................................................................. 2
Vocal Ability .................................................................................................................... 2
Non-musical Factors ...................................................................................................... 3
Competing Theories ....................................................................................................... 3
Contemporary Eclectic Theory .................................................................................... 4
Expanding Range Approach ......................................................................................... 6
Theory Critiques ............................................................................................................ 9
New Tools for Understanding Boys’ Singing ............................................................... 11
Voice Measurement ...................................................................................................... 12
Structural Equation Modeling ...................................................................................... 13
Need for the Study ......................................................................................................... 14
Purpose and Research Questions ................................................................................ 15
Operational Definitions ............................................................................................... 16
Delimitations .................................................................................................................. 18
Vocal Registration ......................................................................................................... 19

CHAPTER TWO LITERATURE REVIEW .................................................................... 21
Contemporary Eclectic Theory of Voice Change (CET) ............................................. 21
CET development ......................................................................................................... 22
CET typology ................................................................................................................ 24
Evidence of validity for the CET ................................................................................ 26
Connecting the CET to practice .................................................................................. 27
The Expanded Voice Theory (EVT) ........................................................................... 28
EVT and Vocal Typology ............................................................................................. 29
Validity of the EVT ....................................................................................................... 31
Connecting EVT to practice ....................................................................................... 32
Vocal Outcomes ............................................................................................................ 34
Range ............................................................................................................................. 34
Registration Fluency .................................................................................................... 37
Vocal Quality ................................................................................................................ 49
Speaking Voice ............................................................................................................. 53
Tessitura ......................................................................................................................... 54
Predictors of Vocal Outcomes .................................................................................... 55
Motivation ...................................................................................................................... 55
Affective State. .............................................................................................................. 57
Personality ..................................................................................................................... 60
Singing Environment ................................................................................................... 63
Social Psychology .......................................................................................................... 63
Conclusion ..................................................................................................................... 65
CHAPTER THREE  METHOD ....................................................................................... 67
  Participants ....................................................................................................... 67
  Latent Variables ............................................................................................... 69
    Motivation and affective state ....................................................................... 71
    Physiology ........................................................................................................ 73
  Indicators .......................................................................................................... 73
  Vocal Outcomes ............................................................................................... 74
  Predictors ........................................................................................................... 79
  Procedure .......................................................................................................... 82
  Data Analysis .................................................................................................... 84
  Summary ............................................................................................................ 86

CHAPTER FOUR  RESULTS AND DISCUSSION ...................................................... 88
  Preliminary Data Analysis ................................................................................ 89
    Descriptive Analysis Results ......................................................................... 89
    Correlational Analysis Results ...................................................................... 94
  Exploratory Factor Analysis .......................................................................... 98
  Structural Equation Model ............................................................................... 101
    Measurement Model ....................................................................................... 102
    Structural Model ............................................................................................ 105
  Discussion ......................................................................................................... 106
    Combinations .................................................................................................. 110
    Models ............................................................................................................ 111
  Context of Participants and its Effect on Results ............................................ 112

CHAPTER FIVE  CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS ........ 114
  Conclusions ....................................................................................................... 120
  Recommendations for future study ............................................................... 122
  Limitations ........................................................................................................ 124
  Implication for practice .................................................................................... 125

References .......................................................................................................... 129

Appendix A  Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) ......... 143
Appendix B  Asmus’ Magnitude of Motivation in Music (AMMM) test items .......... 144
Appendix C  Director-Measure of Adolescent Voice (D-MAV) .............................. 145
Appendix D  Singer: Measure of Adolescent Voice (S-MAV) survey ................. 146
Appendix E  Positive and Negative Affect Schedule items and scale ..................... 149
Appendix F  Instructions for measuring lung capacity ........................................... 150
Appendix G  Physiological measure sheet (P-MAV) ............................................. 151
Appendix H  Instructions and script for sound collection ....................................... 152
Appendix I  Sentences for Sound Collection ...................................................... 154
Appendix J  Syntax for Confirmatory Factor Analysis ........................................... 155
Appendix K  Lower triangle covariance matrix ......................................................... 156
Appendix L  Syntax for Structural Model Analysis ....................................................... 157
List of Figures

Figure 1. Cooksey stages of adolescent male voice change ........................................ 5
Figure 2. Model of Cooksey typology on CET stages.................................................. 6
Figure 3. Range classifications of Leck students........................................................ 7
Figure 4. Model of vocal outcomes on Leck’s voice classification............................... 9
Figure 5. Proposed structural path model of singing in adolescent male voice............ 16
Figure 6. Initial measurement model of singing in adolescent male voice............... 18
Figure 7. Cooksey stages of adolescent male vocal development............................. 23
Figure 8. Cooksey stages of adolescent male vocal development............................ 24
Figure 9. Model of Cooksey typology applied to stages of vocal development........... 25
Figure 10. Barham’s categories and ranges of boys’ changing voices......................... 27
Figure 11. TKTS voice classification for junior high men.......................................... 29
Figure 12. Leck voice classification for expanding male voice.................................. 30
Figure 13. Model of EVT typology applied to Leck’s classification of voice parts...... 31
Figure 14. MacKenzie Alto-Tenor Plan. ..................................................................... 35
Figure 15. Cooper Cambiata Concept voice classifications....................................... 36
Figure 16. Swanson voice classification...................................................................... 36
Figure 17. Davison voice parts by grade ................................................................. 37
Figure 18. Thyroarytenoid and cricoid muscles. Superior view................................ 39
Figure 19. Posterior glottal chink ............................................................................. 52
Figure 20. Formant crossing denoting register change.............................................. 53
Figure 21. Proposed structural equation model ......................................................... 70
Figure 22. Proposed structural path model of vocal outcomes in adolescent males .... 71
Figure 23. Affective state as latent factor in isolation .............................................. 71
Figure 24. Physiology latent variable in isolation ..................................................... 73
Figure 25. Range indicators ..................................................................................... 75
Figure 26. Registration Facility indicators ............................................................... 76
Figure 27. Spectrum of head voice glide denoting register change.......................... 76
Figure 28. Spectral display demonstrating passaggio............................................... 77
Figure 29. Register overlap as seen in Leck ......................................................... 78
Figure 30. Vocal Quality latent indicators.............................................................. 78
Figure 31. Motivation indicators ................................................................. 80
Figure 32. Affective State indicators ........................................................... 81
Figure 33. Physiology indicators ................................................................. 81
Figure 34. Measurement model of vocal outcomes in adolescent males............ 85
Figure 35. Path model of vocal outcomes in adolescent males ............................ 86
Figure 36. Respecified model ......................................................................... 101
Figure 37. Measurement model using confirmatory factor analysis ...................... 104
Figure 38. Structural model with standardized path estimates ............................ 105
Figure 39. Correlation of lung capacity-intensity range by pitch ....................... 108
List of Tables

Table 1. Comparison of register nomenclature between CET and EVT .................. 41
Table 2. Physical Characteristics .......................................................................... 90
Table 3. Motivational and Affective Characteristics ............................................ 91
Table 4. Vocal Ranges ......................................................................................... 92
Table 5. Maximum, Minimum, and Range Intensities ........................................... 93
Table 6. Voice Quality of Reading ....................................................................... 94
Table 7. Pearson Bivariate Correlations of Physical Traits ................................. 94
Table 8. Pearson Bivariate Correlations of Motivation Domains ......................... 95
Table 9. Pearson Bivariate Correlations of Ranges ............................................. 96
Table 10. Comparison of Pearson Correlations of Age and Height to Intensity ...... 97
Table 11. Exploratory Factor Analysis with Varimax Rotation ......................... 100
CHAPTER ONE

STATEMENT OF THE PROBLEM

Today’s music educators find themselves in a moment of conflicting theories regarding male voice change. Put simply, one theory asserts a sequential lowering of the voice measured by single register singing (Cooksey, 2000a, 2000b). Another asserts a less predictable expanding voice range measured by multiple register singing (Leck, 2009a, 2009b). Both theories have been criticized (Freer, 2010a; Phillips, 2014) in writings, presentations, and workshops. In the midst of these theories teachers attempt to give boys a positive singing experience. One teacher expresses the concerns of many in an online discussion:

OK, [I’ve] done a lot of reading and read all the various experts’ take on the classification of the changing adolescent male voice. I have not found any reference to these few boys I have that have a WIDE range of around [2] octaves. There are no holes in their range. What in the world are they? [Their] range is not in Cooksey, Cooper, Swanson, McKenzie, Phillips, or Collins. (Hayashi, 2013)

Choral practitioners and researchers have explored adolescent male changing voice extensively over the past 50 years. Over this time, practitioners have set forth various methods, theories, and advice for managing young men’s singing based on their classroom and rehearsal experiences (Barham & Nelson 1991; Barham, 2009; Beery, 2009; Collins, 1996; Davison, 2011; Friddle, 2005; Leck, 2009b). Researchers have used systemized designs and tools to explain the voice change process (Cooksey, 1977, 1978, 1984, 2000b; Rutkowski, 1982; Thurman, 2012) and offer suggestions based on their findings.

Unfortunately, even though well-regarded systems have emerged over the last half-century, a shared understanding of boys’ voices between practitioners and researchers is elusive. In particular, research approaches and theories (Cooksey, 2000a;
Collins, 1993) do not seem to connect to the experiences and observations of many practitioners, or to the contexts in which they teach (Leck, 2009a; Phillips, 2014; Brown, 2010). This disconnect is especially pronounced in boys’ singing outside of schools, such as in community or church choirs.

**Criteria for Practioners’ Decisions**

Effective practitioners apply several criteria in understanding the singers in their classroom: vocal ability and non-musical criteria. This understanding can influence their decisions on lesson content, repertoire, part assignment, and leadership roles.

**Vocal Ability**

Practitioners principally consider four elements considering vocal ability: range, tessitura, vocal registration, and vocal quality (Cooksey, 2000a, Leck, 2009a). **Range** is a compendium of pitches available to an individual singer. **Tessitura** is the comfortable range of pitches nested within the total range of a voice (Cooksey, 2000b). **Vocal quality** in adolescence is often assessed by presence of breathiness, roughness, and strain (American Speech-Language-Hearing Association, 2006; Cooksey, 2000b). **Vocal registration** is a complex function of the larynx commonly understood as a group of pitches that share timbral similarities (Baken & Orlikoff, 2000; McCoy, 2012).

Many choral teachers make most of their decisions for repertoire, part assignment, and group membership based on range (Barham & Nelson, 1991; Barham, 2009; Davison, 2011; Phillips, 1992). In fact, for many teachers, range is the only criterion considered. Empirical research into adolescent male voices supports an understanding of the voice that goes beyond range (Cooksey, 2000b, Leck, 2009b), and other teachers and directors
consider the tessitura, quality, and registration of a boy’s voice as supported by the research literature.

**Non-musical Factors**

Many teachers also consider non-musical factors found within an individual: personality (Kemp, 1996; Lounsbury, 2003, 2009), vocal physiology (Cooksey, 2000a; Thurman, 2012), musical environment (Zdzinski, 1996; Zdzinski, in press), social maturity (Ashley, 2009; Shepherd, 1983), mood (Linnenbrin, et al., 2011), motivational set (Asmus, 1994; Freer, 2012), and prior singing experiences (Freer, 2009a, 2009b; Harrison, 2010; Kennedy, 2002, 2004). While perhaps not measured formally, these considerations often inform teachers’ decisions for group membership and voice part. Although these factors are valuable in certain performance outcomes, their effect on vocal outcomes is not yet established.

Non-vocal factors like motivation and personality inform teacher decisions, but these factors are often perceived intuitively rather than measured. We do not know what degree of influence these factors have on vocal outcomes or the extent of their effects. This study seeks to uncover and express some of these possible non-musical factor effects on the vocal outcomes of range, registration fluency, and vocal quality.

**Competing Theories**

A chief concern of this study was how some of the aforementioned factors (personality, vocal physiology, singing environment, motivation, and mood) might contribute to a new understanding of the two principal approaches to male changing voice: those associated with John M. Cooksey’s Contemporary Eclectic Theory (1977b,

**Contemporary Eclectic Theory**

In the decade before 1973, three divergent approaches to classifying and describing the male changing voice emerged: (a) Cambiata Concept by Irwin Cooper, (b) Alto-tenor Plan of Duncan McKenzie, and (c) The Frederick Swanson Theory (Cooksey, 1977a; Freer, 2010a; Leck, 2009). These theories differed principally in their understandings of the rate of voice change, the classification of voices, and nomenclature of voice parts. More detail on these three theories will be addressed in Chapter 2 of this study.

These three approaches plus Cooksey’s are commonly mentioned in literature reviews of adolescent singing voice (Collins, 1992; Cooksey, 1977a; Freer, 2010; Leck, 2009a). Of the four, Cooper’s Cambiata Approach and Cooksey’s CET are best known due in part to the organizations that support and propagate both systems. Cooksey worked with the Minnesota-based VoiceCare network (www.voicecarenetwork.org), writing and conducting numerous clinics and workshops around the world until his death in 2012. His work continues in the writings of his collaborators and colleagues, Leon Thurman and Graham Welch. The Cambiata Institute (http://music.unt.edu/cambiata/), founded by Cooper’s student Don Collins and continued by Alan McClung, now fosters and extends Cooper’s theories and research. While differences in application between Cooksey and Collins exist (Collins, 1993), the similarities in their treatment of range, tessitura and register warrant treating them as a single theoretical structure.
Cooksey wrote four articles for *The Choral Journal* on male changing voice (1977a, 1977b, 1977c, 1978), the first of which compared the theories of Cooper, McKenzie, and Swanson. His second article used results from several studies in Europe to form his Contemporary Eclectic Theory (CET) of male voice change (Cooksey, 1977b; Phillips, Williams & Edwin, 2012). His use of the term “eclectic” referred to bringing the three theories of Cooper, McKenzie, and Swanson into a single, synergized theory. Cooksey’s resultant theory asserted that adolescent male voice change was a sequential and predictable lowering of vocal pitch. His CET described a five-stage (1977b, 2000a) classification of voice change displayed as measurements of range (Figure 1).

![Figure 1. Cooksey stages of adolescent male voice change. Adapted from Cooksey, 2000b.](image)

Cooksey devised a typology that guided classification of voice change throughout his research (1977b, 2000a). Maturational stages and voice classification guidelines were identified and defined using

- total pitch range;
- tessitura (most comfortable singing pitch range);
- voice quality (degree of constriction, breathiness, and spectral configuration);
- register development; and
• average fundamental frequency of speech samples (Cooksey, 2000a, p. 722).

These criteria in combination were used to determine stages of voice change (Cooksey, 1977b, 2000a). Cooksey applied these stages to practice in order to determine the appropriate voice part for individual singers (Barham, 2001; Cooksey, 2000b). From this typology, a model can be derived where CET voice class corresponds with Cooksey’s stages (Figure 2):

![Figure 2. Model of Cooksey typology on CET stages. Derived from Cooksey typology 1977b, 2000a.](image)

In the decades following the initial articles on CET (1977a, 1977b, 1977c, 1978), several validations of this theory emerged through replication (Cooksey, 1984, 2000b; Cooksey, Beckett & Wiseman, 1985; Rutkowski, 1982) and external predictive measures (Cooksey, 1993; Cooksey & Welch, 1998; Hollien, 2012; Thurman, 2012).

**Expanding Range Approach**

Despite the validity evidence for CET, it has not been universally embraced. Experienced directors of children and boychoirs have been particularly resistant. This is
due in large part to their feelings that Cooksey’s findings did not reflect these directors’ experiences with young male voices. Such feeling is likely due to the social context of public school singing and single vocal registration. Consequently, the children’s choir conductor Henry Leck asserted an approach to male voice change based on his experience that entailed an expansion rather than a lowering of range (2009a). His classification of these voices was not by stages like Cooksey, but rather by voice parts divided into registers (Figure 3).

Figure 3. Range classifications of Leck students (Leck, 2009a).

Leck’s retention of upper register distinguished his approach from Cooksey’s, which omitted that register from classification. Although Leck did not name this approach, reviewers and writers are increasingly referring to this as the Expanding Range Theory or Expanding Voice Theory (Ashley, 2013; Ashley & Mecke, 2013; Brown, 2010; Phillips, Williams & Edwin, 2012).

The term “approach” rather than “theory” was supported by music education researcher Kenneth Phillips, who aligned himself with Leck but called his work the Extended Range Approach (ERA) to voice change (2004). In his book Directing the
Choral Music Program, Phillips described different to approaches male voice change as “schools of thought,” and refers to practices arising from Cooksey’s research a part of the “limited range school” (Phillips, 2004). He lists Cooksey, Cooper, and McKenzie as members of that school. Although the use of the term “theory” may be debatable among some music researchers, this study will refer to Leck’s and Phillips’ approach as Expanding Voice Theory (EVT) to be consistent with the literature on boys’ singing, including Phillips later writing (Ashley, 2013; Ashley & Mecke, 2013; Brown, 2010; Phillips, Williams & Edwin, 2012).

This study treats both approaches as theory. While Cooksey’s theory was testable and is supported by empirical research, questions of registration fluency and tessitura remain. Specifically, clear operational definitions of both vocal registration and tessitura are not available. As a result, the recommendations for practice emerging from that research constitute an approach based on limited information. Still, Cooksey provided a valuable framework of inquiry that yielded important empirical information. While not expressing his approach as theory, Leck’s approach was clearly based on a framework of understanding that can be tested for statistical validity. Since both represent a system of ideas that can be empirically examined, this study will both measure and report statistical analyses that will address both theories.

From Leck and Phillip’s literature on voice classification, a model of the Expanded Voice Theory (EVT) can be derived where voice class refers to register ranges by voice part (Figure 4):
Figure 4. Model of vocal outcomes on Leck’s voice classification. Derived from Leck 2009 and Phillips 2014.

Theory Critiques

The two theories and their accompanying models have several conspicuous differences. First, CET is a systematically measured, generalized, and validated theory of male voice change based on research that has extended through the past four decades. EVT, however, is newly specified and less defined. As a result, less contemporary empirical research on EVT exists. Also, Cooksey and Cooper focused on general public school contexts, while Leck’s approach to EVT emerged from praxis in community choir contexts. These different contexts merit serious consideration, particularly when vocal registers are taken into account. As singing is socially situated, its meaning and norms vary. Male upper register singing is often viewed as beautiful and desirable in community choir contexts (Ashley, 2013; Ashley & Mecke, 2013; Beet, 2005; Brown, 2010; Phillips, Williams & Edwin, 2012; Phillips, 2014), and reprehensible in society-at-large (Ashley, 2013). Such a difference could exert enormous psychological influence on the vocal outcomes.
Phillips does support EVT with some recent empirical research (Emge, 1997), but the bulk of the literature he cites in support of extended range is based in praxis (Phillips, 2014). Another difference between CET and EVT is the theories’ divergent views on the predictability of voice change as expressed in developmental stages (Cooksey, 1977b, 2000a). In EVT, classifications and range charts address the changing voice in parts rather than stages. In fact, Phillips explicitly questions whether the male voice change is indeed sequential and predictable (2004, p. 116).

The two models each offer unique strengths. The CET model provides a clear and specific typology of classification that can assist teachers in preparing repertoire and curricula for singing. It explains the physiological process of voice change in scientific detail and provides practical suggestions that can be applied across a wide variety of contexts. The EVT model, however, describes a centuries-long approach to boys’ singing applied to adolescence. It allows for experience and conditioning in multiple register singing that can be applied to a wide variety of musical genres and contexts. While CET prepares young men for lifelong singing also, EVT provides more pitches and timbres through its use of greater composite range and multiple vocal registers.

Like Cooksey in 1977, today’s music education researchers and teachers find themselves in a moment of seemingly conflicting theories regarding male voice change. Some have begun to express a desire for another synergy of theory that brings together the appealing and relevant qualities of both CET and EVT (Ashley, 2013; Williams, 2013). In fact, it has been argued that both theories might be right (Ashley, 2013; Williams, 2013). A new synergistic theory on male voice change would echo Cooksey’s
approach when he devised the CET in 1977, and the development of a model that can inform such a theory is the intended result of this study.

**New Tools for Understanding Boys’ Singing**

Current developments in music and education research could make this the right moment for a synergistic model. New questions informed by currents in sociology (Ashley, 2009; Welch, 2011), psychology (Lounsbury, Tatum, Gibson, Park, Sundstrom, Hamrick, & Wilborn, 2003) and qualitative methodology (Ashley, 2010; Freer, 2009a, 2009b) have yielded a richer understanding of adolescent male singing. Due in part to these studies, how a person feels about his singing is an increasingly important consideration. Researchers and authors are reporting contexts of male singing outside the traditional general music and choral paradigms (Harrison, Welch & Adler, 2012). Qualitative research has revealed boys’ preferences for singing and how they feel about the role of singing in their lives (Abrahams, 2012; Ashley, 2010; Freer, 2009, 2010b; Kennedy, 2002, 2004). The effect of these considerations on specific vocal outcomes, however, is not clear.

Martin Ashley asserts: “Whatever may be thought, [these studies] seem to suggest that a boy’s own will-power, allied to his social understanding of how other boys think and act, is the most important variable in boys’ singing that is currently available . . .” (Ashley, 2010, p. 144). A model that takes into account affective state and motivation could clarify such a strong assertion, and would provide an empirical understanding of psychological variables and their effect on vocal outcomes. This study will measure affective state and motivational trait variables to understand the magnitude of their effect on the specific vocal outcomes of range, registration fluency, and vocal quality.
Voice Measurement

In addition to new research methodologies, technological instruments for voice measurement are cheaper and more accessible. Free software such as Praat (Boersma & Weenink, 2013), and more advanced tools like Voce Vista-Pro (Boersma & Weenink, 2013; Miller, 2008) and voice range profile analysis (Boersma & Weenink, 2013; Herbst 2013) are providing unprecedented richness, access, and reliability in vocal assessment. Also, where once a single machine with a single function measured and printed data, a personal computer can now record, measure, and analyze vocal sound, analyze the data, and report the findings.

Praat displays spectrographs, which reveal components of a complex sound as harmonics, much in the same way that a prism breaks light into a color spectrum (McCoy, 2012). The distribution and intensity of harmonics in a vocal tone are formed by the variable resonance of the vocal tract, the flexible acoustic chamber of the voice. A singer’s intrinsic anatomical properties, coupled with conscious alteration of the vocal mechanism, create the acoustic effects of these formants. In a spectrograph, the components of frequency, intensity, and time, are presented for each formant of a tone by a grayscale display. The darker the formant’s display, the greater is its intensity. Spectrographs display the frequencies in Hertz (Hz), intensities in decibels (dB), and time occurrences in seconds of both the formants and the fundamental pitch ($F_0$).

A voice range profile (VRP), formerly know as a phonetograph (Baken & Orlikoff, 2000), measures the sound pressure level intensity, generally heard as loudness. While it also displays pitch, a VRP shows the range of intensities from softest to loudest on a single pitch across a range of pitches from lowest to highest.
**Structural Equation Modeling**

A structural equation model can offer a new lens through which to understand the diverse factors of vocal outcomes and individual traits. Structural equation modeling examines not only direct effects, but also indirect effects, while holding other effects constant (Keith, 2006). For example, even though there may be no evidence of a direct effect of extroversion on range, once it is mediated through motivational set, an indirect effect might be observed. Furthermore, the extent of that effect’s influence can be expressed through the resultant coefficients. In this way we can address questions like, “If a boy favors extroversion, and has received extensive vocal training, to what extent can I expect he will have a wide range holding all other factors constant?” This way of showing relationship and the extent of those relationships can be valuable to teachers of boys’ singing.

Furthermore, the relationship between the vocal outcomes of range, registration, vocal quality, speaking pitch, and tessitura can be clarified. More specifically, we can know to what extent they covary. A richer understanding of this relationship could guide vocal evaluation processes. For example, if tessitura and range vary together and share the same predictors, a teacher may not have to evaluate both to get the information needed. This can save valuable time for the teacher of a choir of 100 singers.

Structural equation modeling (SEM) provides a framework in which to express commonly understood latent factors with greater quantitative specificity (Keith, 2006). For example, Registration Fluency is a skill that boychoir conductors might observe and desire, but are unable to measure as an isolated phenomenon. For them, boys who possess high Registration Fluency smoothly sing from one fully realized register to another; those
with low registration fluency cannot. Directors may know it when they hear it, but they cannot express the observation in a way that others can understand with any specificity. In SEM, this unmeasured fluency can be a latent factor, something that can’t be directly measured but is expressed through a group of measures. Latent factors will be particularly helpful in providing a means of understanding other qualities and their effects like physiology, motivation, and mood on singing. Most importantly, latent factors combine many variables into a more reliable and understandable construct than if each measure was considered separately.

One of the strengths of SEM is its graphic representation of relationships between variables. Its figures show the direction, type, and degree of relationships between and among factors and indicators. Knowing what relates, and what does not relate is the first step in understanding the value of SEM. Seeing the direction and strength of those relationships is the next step.

**Need for the Study**

The need for study arises from two principal concerns. First of all, among practitioners, teacher educators, and researchers, no unified theory for boys’ singing exists. This is likely due to the absence of sociological and psychological considerations in the quantitative research. As a result, disagreement is common (Freer 2010a; Leck, 2009a). This is a particularly important consideration in teacher education. A good educator needs a complete understanding of boys’ voices in order to make an informed decision appropriate to the context for singing. Knowing a single approach is insufficient for the possible contexts in which prospective teachers may find themselves.
The second concern is that the influence of extra-musical factors on vocal outcomes has not been empirically measured and modeled. The SEM model in this study includes psychological and sociological factors not provided by CET and EVT. Secondly, a model with good fit could emerge and describe the relationships and qualities of factors in boys’ singing with greater specificity.

The competing theories to boys’ singing and voice change between the CET- and EVT-based approaches are problematic for researchers, practitioners, and future teachers in establishing a comprehensive understanding of boys’ voices. Like Cooksey’s theory development in the 1970s, an SEM model could uncover relationships between factors that will lead to a new theory that arises from consideration of contextual variables.

**Purpose and Research Questions**

This study evaluates the relationship of several latent factors to vocal outcomes. These factors include non-vocal factors of

- Physiology;
- Affective State; and
- Motivation.

The vocal outcomes reflect Cooksey’s typology of

- Range;
- Registration Fluency; and
- Spoken Vocal Quality.

The purpose of this study was to examine the effects of Physiology, Affective State, and Motivation on Range, Registration Fluency, and Vocal Quality in the form of a predictive model.
By framing the purpose of relating individual traits to vocal outcomes in structural equation modeling, several questions emerged:

1. What interrelationships existed within and among the following latent variables: (a) Physiology, (b) Motivation, (c) Affective State, (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

2. What combination of variables and latent factors of (a) Motivation, (b) Physiology, and (c) Affective State best predicted the latent vocal factors of (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

3. What model of the variables best predicts vocal achievement in adolescent males?

In order to begin investigating a possible theoretical structure for boys’ singing, a structural path model of the latent factors was created from this study’s research questions (Figure 5):

![Figure 5](image)

*Figure 5. Theoretical structural path model of vocal outcomes in adolescent males.*

**Operational Definitions**

*Physiology* included the measured variables of height, weight, and lung capacity (Cooksey, 2000b). The latent variable of *Motivation* included measured variables of self-concept of ability, commitment, comparison to others, and value of ensemble (Asmus,
The latent variable of *Affective State* was indicated by the measured variables of positive and negative affect (Thompson, 2007; Watson, Clark & Telegen, 1988; Watson & Clark, 1999).

*Vocal Range* was treated as a latent variable whose measurements included absolute range, and range extremes across registers, (Cooksey, 1977, 2000b; Denison, 2013; Leck, 2009a). The latent variable *Registration Fluency* was informed by several measurements. The first was the absolute range of pitch overlap of the upper register and the lower register. The second was the range of a middle register as defined by the spectral change from upper to lower register in a descending pitch glide. Additional considerations of Registration Fluency were the consistency of the slope line through the passaggio and the range of the phonational gap (Denison, unpublished; Leck, 2009a; Phillips, 2004; Willis & Kenny, 2008). Absolute range of falsetto (head voice) and modal voice (chest voice) were also intended to indicate Registration Fluency.*Vocal Quality* was a latent variable informing a perceptual measure (ASHA, 2006) and acoustic measures of jitter, shimmer, harmonicity, intensity, and formants (Baken & Orlikoff, 2000; Miller, 2008; Herbst 2013). *Speaking Pitch* was expressed in reading and conversational speech (ASHA, 2006).
The measurement model for the initial SEM was as follows:

**Figure 6.** Initial measurement model of vocal outcomes in adolescent male voice.

**Delimitations**

All mentions of the voice and singing will be in reference to those of adolescent males in pubertal transition, unless noted otherwise. The terms *voice change*, *vocal mutation*, and *vocal transition* are diverse terms used in methodological and research literature that refer to the same phenomenon: hormone induced alterations in the vocal mechanism that occur at puberty. In this study, the term *voice change* will be used.

This study was intended to be broadly applicable to a variety of contexts through its consideration of social and psychological variables. As such, its findings are intended to be relevant not just to music education research, but also to middle school teachers, children’s and boys’ choir directors, and voice pedagogues of adolescent men. For our purposes, the term *teacher* will be used to denote all those who instruct, teach, or lead young male singers. This includes those who refer to themselves as conductors, directors,
teachers, or pedagogues. Boychoir will be used to describe an ensemble of either just boys or a composite of boys and men.

**Vocal Registration**

Registration is a complex aspect of singing for all singers, not just for young men. In order to understand the two theories of CET and EVT, some clarity on the terminology of register is required. A vocal register has been described as a “series of consecutive, homogeneous tone qualities, the origin of which can be traced to a special kind of biomechanical (muscular) action” (Ware, p. 281). While this definition is generally agreed upon, “theories, and opinions abound as to their number, names, impact . . . and even their very existence” (McCoy, 2012, p. 143). The use of three registers, (upper voice, mixed/passaggio voice and lower voice) as per the Italian school of singing has generally served as a starting point in the conversation (Miller, 1986, p. 313), and has been extended to discussion of the adolescent singer by proponents of multiple register singing (Phillips, 1992, p. 16).

Perhaps the most accurate representation anatomically is the use of the terms thick-fold and thin-fold production (Williams, 2012). Thick-fold production describes well the dominant anatomical mechanism of singing in chest voice, while thin-fold addresses the mechanism of the falsetto or head voice. A smooth transition from thick to thin characterizes and implies a middle register.

In this study, (a) falsetto, thin-fold production will be generally referred to as *head voice*, (b) thick-fold production as *chest voice*, and (c) middle mixed voice as *passaggio*. While these terms are anatomically dubious, singers, pedagogues and
practitioners commonly understand them. These terms will make understanding easier as the study gets more complex, especially in Chapter 4.
CHAPTER TWO
LITERATURE REVIEW

The purpose of the study was to examine the effects of Motivation, Physiology, and Affective State on vocal outcomes of Range, Registration Fluency, Vocal Quality, and Speaking Pitch. From this examination, a theoretical model emerged whose construction was informed by preexisting research and pedagogical schools of thought. This theoretical model was applied and compared to the research and individual schools of thought. This chapter examines the development and validation of the Contemporary Eclectic Theory (CET) and the Expanding Voice Theory (EVT) followed by an examination of the approaches leading up to and associated with these theories.

Once the approaches are delineated, each of the latent factors will be reviewed starting with the outcome factors: Range, Registration Fluency, and Vocal Quality. A review of relevant literature on the predicting latent factors of Motivation, Affective State, and Physiology follows.

Contemporary Eclectic Theory of Voice Change (CET)

“There is little doubt that the most comprehensive analysis of vocal metamorphosis during adolescence in the English speaking literature is still considered to be that of John Cooksey.” (Ashley, 2013, p. 5) This assertion is widely accepted by researchers. Studies, papers, and presentations on changing voice regularly include mention of his work. His empirical research brought a rigor and validity to the discourse on boys’ voices that “cannot be ignored” (Thurman & Welch in Cooksey, 2000b, p. 821).
CET development

In 1977, Cooksey began a series of four articles setting forth a “contemporary, eclectic theory of voice change” (Cooksey, 1977a, p. 13). The first article examined the approaches of Irwin Cooper (Cooksey’s teacher), Frederick Swanson, and Duncan McKenzie. While differences between the approaches were initially noted, Cooksey’s article emphasized eight points of agreement and commonality: (a) voice change is related to the onset of puberty, (b) current repertoire literature is not suitable to the changing voice, (c) voice change is unpredictable, (d) one can expect to find voices in different stages of growth in a group of boys ages 12-15, (e) rates of voice change vary, (f) individual and group voice testing is necessary, (g) teachers should help students understand their voice change, (h) good vocal habits are important (Cooksey, 1977a). These commonalities provided for Cooksey the foundation he sought to develop his theory.

In his second article (1977b), Cooksey used data from two European studies: one in the former Czechoslovakia (Nadir, Zboril & Sevicik, 1965) and the other from Austria (Frank & Sparber, 1970). The Czechoslovak study of 100 boys in a boarding school was a longitudinal examination of vocal maturation. The researchers tested boys from ages 11-16. Singing and speaking voice, as well as physical characteristics of height, weight, and laryngeal dimensions were measured every four months. These changes were then correlated “with the development of the primary and secondary sexual characteristics, and concomitant anatomical developments in the larynx, body height and weight . . .” (Cooksey, 1977b, p. 8). Cooksey noted the value of the study’s controlled environment, offering the instructors of singing “some valid insights into the complex process of
adolescent voice mutation." (Cooksey, 1977b, p. 8). The authors of the Czechoslovak study identified three apparent stages in their conclusions: beginning, middle, and end of voice change. Cooksey used the resultant mean speaking pitches, mean upper limit of ranges, and mean lower limit of ranges of their data to infer that male vocal mutation could be indexed into developmental stages. While Cooksey did not specifically say that he sought to replicate the Czechoslovak study, it appears to have offered a valuable guide to developing his methodology.

The studies from Austria by Frank and Sparber appeared to validate components of the Czechoslovak voice change study, and Cooksey’s inference about stages. Their first study (1970) of 5000 7 to 14 year olds also delineated three stage groupings. The second study (\(N = 130\)) identified three registers, as well as three different vocal timbres. From the Austrian data, the Czechoslovak data, and his own empirical experience, Cooksey theorized five stages of male changing voice development: (1) before mutation, (2) beginning of mutation (midvoice I), (3) high mutation (midvoice II), (4) end of mutation (new baritone), and (5) settled voice (1977b, p. 12; Figure 7)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage I</td>
<td>Before mutation</td>
</tr>
<tr>
<td>Stage II</td>
<td>Beginning of mutation</td>
</tr>
<tr>
<td>Stage III</td>
<td>High mutation</td>
</tr>
<tr>
<td>Stage IV</td>
<td>End of mutation</td>
</tr>
<tr>
<td>Stage V</td>
<td>Settled voice</td>
</tr>
</tbody>
</table>

![Figure 7. Cooksey stages of adolescent male vocal development delineated by range (1977b).](image)
CET typology

In developing his five stages in 1977, Cooksey identified and described markers of vocal typology in each stage. These markers were (a) range, (b) register, (c) vocal quality, (d) speaking pitch, and (e) tessitura. He addressed this same vocal typology decades later with greater specificity in two chapters he wrote for the *Bodymind* series (Cooksey, 2000a, 2000b).

The first chapter of *Bodymind* (2000a) reports a longitudinal study of male voice change Cooksey conducted in 1985 (Cooksey, Beckett & Wiseman, 1985). The participants in the study were 86 boys in Orange County, CA. who were evaluated over three years. Sonographs of their singing were collected as they progressed through CET’s five stages of voice change and analyzed using the five markers of Cooksey’s vocal typology. Results were generally congruent with Cooksey’s previous classification (Figure 8).

![Figure 8: Cooksey stages of adolescent male vocal development delineated by range (2000a).](image-url)
Cooksey’s 2000a chapter clarified his definitions of vocal typology from 1977:

Maturational stages and voice classification guidelines were identified and defined using the following criteria:

1. total pitch range
2. tessitura (most 'comfortable' singing pitch range);
3. voice quality (degree of constriction, breathiness, and spectral configuration);
4. register development; and
5. average fundamental frequency of speech samples (p. 721).

From Cooksey’s typology and classifications, a model can be derived (Figure 9). Testing such a model would be challenging as it has many paths that would require normal distribution, high statistical power, and large sample size. Reducing these paths would increase the parsimony of the model, which is statistically desirable.

![Figure 9. Model of Cooksey typology applied to Cooksey stages of vocal development.](image-url)
Evidence of validity for the CET

Leon Thurman (2012) cites several points of evidence for validity of the CET. The first was a connection of Cooksey’s stage to Tanner’s stages of genital growth (1969) demonstrated in a Welsh study (Harries, M. L., Walker, J. M., Williams, D. M., Hawkins, S. M. & Hughes, I. A., 1997). This study of 26 non-chorister boys analyzed speaking and singing fundamental frequencies and categorized by Cooksey’s stages. The assigned stages were compared to Tanner’s stages and saliva testosterone levels. Participants were also asked to sing “Happy birthday” at a comfortable pitch of their choosing in the modal range. The results showed good correlation between the Cooksey’s and the other classifications. This study offered external validity of the Cooksey’s stages, especially as Tanner’s stages on genital development are so widely accepted as standard (Cooksey, 2000a; Thurman, 2012).

Thurman (2012) and Cooksey (2000a) also cite a pilot replication study by Rutkowski (1985) as evidence of generalization validity. The participants ($N = 10$) were classified in the sixth grade according to Cooksey’s stages. A five note scalar passage was used for the testing, with each participant starting at speaking pitch. Range, voice quality and tessitura were noted. The process was repeated five months later in the seventh grade and again in the eighth grade. Results showed a progression through the Cooksey stages at ages slightly earlier than his 1977 projections.

Both of these studies cited for validity had small sample sizes drawn from a narrow population, and the reports are not clear on what statistical techniques were used to address that limitation. Measurements were taken in the lower modal register (chest voice) in both studies, which narrowed their applicability.
Connecting the CET to practice

While the connection of Cooksey’s analyses, theory, and findings to subsequent research is strong (Thurman, 2012), their adoption to practice has varied. Choral method textbooks and practitioner articles have shown a diverse treatment of these theories. This diversity can be seen in the range and tessitura figures these writings often provide and generally fall into two categories of classification: developmental growth stages, and voice parts (Phillips, 1992; Collins 1993; Garretson, 1998; Brinson & Demorest, 2014).

Many authors adapt Cooksey’s stages to their own particular understanding of voice parts. Barham and Nelson’s approach is typical:

Cooksey’s categories provided us with much food for thought. Many of the ideas and concepts expressed in [my] book are based on his research. However, with extensive testing and in-class application, we reduced the six categories to four and modified them slightly to approximate more nearly what we found in our work. (p. 7, 1991; Figure 10).

Figure 10. Barham’s categories and ranges of boys’ changing voices (1991).

Such modifications are offered specifically to guide repertoire selection and assign voice section (Davison, 2011; Phillips, 1992). Cooksey also combined stages into a single voice part. Although he retained the names of stages to voice parts, his combining of stages indicates a flexibility that is often not mentioned in literature on Cooksey (1999, p. 27).
Other texts address his work chiefly as an approach among several others, offering less detail and little to no discussion of specific stages or their application to repertoire (Phillips, 2004; Ward-Steinman, 2010; Reed, 2008). Vocal registration and vocal quality in adolescent men’s voice are seldom discussed in these textbooks, neither are they addressed in a way that resemble the detailed, systematic expressions of range and tessitura of Cooksey’s research. A notable exception is Kenneth Phillip’s second edition of *Teaching Kids to Sing* (2014), which devotes a section to registration in boys’ voices.

The diverse treatment of Cooksey’s research in the choral pedagogy literature could be due to the diversity of contexts for boys’ singing. These different contexts are often socially constructed and provide important information not applied in CET.

Clearer definitions and measurement of registration, vocal quality and tessitura could strengthen the relevance of the CET model to other contexts. Affective and social factors such as affective state, trait, motivation, and environment may contribute valuable information that could assist in connecting CET research to teacher education and practice.

**The Expanded Voice Theory (EVT)**

In 2010, the children’s choral conductor and pedagogue Henry Leck described his dissatisfaction with adolescent male voice classifications which he felt were based on narrow range and chest register. He felt that these classifications were not congruent with what he was encountering in his young men’s singing (p. 49). Furthermore, he described the repertoire informed by a CET approach as “not very musically fulfilling and … somewhat contrived” (p. 56). Over time, he “discovered that if a boy sings from his high
voice to his low range consistently and continues to sing in the old voice while developing the new, the [register] break eventually disappears” (p. 49). In his program, young men were able to access a three-octave range of multiple vocal registers that could be applied to repertoire and performance. For Leck, a pedagogical approach that allowed for more than one register and a larger range had more satisfying results artistically and educationally.

Kenneth Phillips echoed Leck, stating that, “a knowledge of proper vocal registration is the key to understanding the male changing-voice process” (2013). His method, Teaching Kids to Sing (TKTS), also followed an expanded range approach based on an EVT framework (Phillips, Williams & Edwin, 2012). Like Leck, Phillip’s principal expression of classification is by voice part range (Figure 11).

**Figure 11.** TKTS voice classification for junior high men (Phillips, 2014).

**EVT and Vocal Typology**

Leck’s classification of young men’s voices differed from CET in several ways. First, it included multiple register singing. A two-register approach of upper and lower voice was reflected in Leck’s classification, which expressed two sets of registers: one set for young basses and the other set for young tenors (Figure 12). Second, his chart is not an expression of sequential stages.
Leck’s registers overlap by at least a perfect 5th, implying a range of mixed registration that Leck desired (2009, p. 52). Some called this overlap the middle voice (McCoy, 2012); others, including Cooksey, called this overlap the passaggio. The latter is consistent with studio voice pedagogy nomenclature (Miller, 1986; Vennard, 1967). It is not reported in Cooksey’s research results or measured specifically in his data collection (2000a), but he does mention it in his descriptions of voice classifications (2000b).

Figure 12. Leck voice classification for expanding male voice (2009a).

Leck devotes the bulk of his attention to range and register in his writing on adolescent male voices. Little to no attention is drawn to other elements. For example, Leck does not mention mean speaking pitch in his writings. He briefly mentions vocal quality as a component of individual vocal assessment, but it is not clearly defined or applied (Leck, 2009b). The term “tessitura” appears several times in Leck’s book; it is not defined but appears to function principally as an alternate expression of range.

Phillips provides more detail in his treatment of the elements of the vocal typology. He discourages use of a mixed middle register (2004, p. 117; Phillips, Williams & Edwin, 2012), particularly for those boys whose new baritone chest register is limited to pitches below 293 Hz (D4). Vocal quality is described by Phillips in TKTS (2014) as having on average a light sound with a “husky or breathy quality.” In that same text,
Phillips lists ranges and tessituras by adult male voice parts (tenor, baritone, bass) and educational level (junior high, senior high).

When considering Leck and Phillips together as a part of EVT, a model can be derived that can represent the theory (Figure 13). The model is leaner than the Cooksey model, but some variables shown to be relevant by the literature are not included in EVT.

![Figure 13](image_url)  
*Figure 13. Model of EVT typology applied to Leck’s classification of voice parts.*

**Validity of the EVT**

Leck points to performances by his choir, the Indianapolis Children’s Choir as well as other ensembles as evidence of validity for his approach (2009). His choirs have toured worldwide, and are regularly invited to American Choral Directors Association conferences. The organization’s high school level group (SATB) performed most recently at the American Choral Directors Association National Conference in Dallas (2013) after a competitive selection process. Leck has indicated that his high school men’s successful performances validate his approach (H. Leck, personal communication,

The practice of retaining the upper register in male voices during transition is supported by medical voice researchers (Sataloff & Spiegel, 1991), as well as by vocal pedagogues (Striny, 2007). Phillips identifies several early researchers (Joseph, 1959; Mayer & Sacher, 1964; Swanson, 1959) and practitioners (Herman, 1988; Swanson, 1977) working within the EVT paradigm. Phillips also cites his own research (1992) and that of his students (Emge, 1997) in support of EVT. An EVT approach can also be found in a few practice articles for music educators (White & White, 2001). Most conductors of community boys’ choirs in the United States also identify with the practices of EVT (J. Ackerley, M. Anderson, K. Berg, K. Fox, S. Holmes, J. Litton, personal communication, February, 2012).

**Connecting EVT to practice**

The EVT inclusion of multiple registers, however, yields its own unique techniques that differ from CET:

Henry Leck encourages boys to sing whatever part they wish, and they are empowered to sing whatever voice part most comfortably serves them. There are times, however, when a boy is unable to apply this skill. Leck then hears the boy to determine if his head register is usable and to ascertain the overall range. From there, he prescribes a detailed singing plan for the boy. This may include singing one piece in head register and then another in chest register. The prescription may also include jumping from a soprano II part for a page, to an alto I part for one or two phrases, and then to a baritone part. This process allows the boy to find the best places for him to sing comfortably. By switching from the head register in one piece to chest in another, the boy extends his range and minimizes fatigue. In contrast, by singing the same part constantly, the boy only employs a range of little more than an octave. It is helpful for the boy to use both registers by switching parts in the same composition so that he is set up for success. (Brown, 2010, pp. 62-63)
Adapting music to adolescent male voices seems to be an accepted and common practice in both the CET and EVT (Holtgreve, in Freer, 2008). Several techniques have been identified as effective means of adapting written music to a group of boys’ voices (Barham, 2001). Octave displacement, transposition, swapping parts, doubling parts, and writing a new part have been successfully used to adapt music to fit adolescent males’ voices (Dilworth, 2012; Herman, 1988).

Such techniques do appear in the most choral method texts; Cooksey recommends it in his text for teachers (1999). A study by Killian (2003) surveyed choral music educators ($N = 337$) at state conventions on their techniques used to accommodate limited range changing voice male singers. A checklist of strategies were presented to the participants who were instructed to check all that apply: (a) select only upper voice singers, (b) rewrite parts, (c) octave transpose, (d) separated choirs by gender, (e) assign boys non-singing responsibilities, and (f) other. Response totals indicate widespread use of octave displacement and part rewriting for school settings with singers in the high mutational stage (approximately grades 5-8). Analysis by state, however, showed that the some strategies grouped by locale. Killian stressed caution in interpreting and generalizing the results since the participants were not randomized and geographic location of teaching appeared to confound the results. Regardless of the approach, the continuing need for adaptive techniques seems to call into question an emphasis on strict classification (Freer, 2008) and has elicited calls for new paradigms of singing for adolescent men (Hower, 2006, p. 65).
Vocal Outcomes

In structural equation modeling, a theoretical model is tested for fit to the sample data collected. In the proposed theoretical model of this study (Figure 5, p. 16), the vocal latent variables were the outcomes. The model’s vocal outcomes of Range, Registration Fluency, and Vocal Quality reviewed in this chapter mirror Cooksey’s typology.

Range

Range is by far the most quantified and examined and continues to dominate the delineation of boys’ voices during voice change. The Contemporary Eclectic Theory’s (CET) stages of voice change have consistently been delineated by range (Cooksey, 1977a, 1977b, 1977c, 1978, 1986, 2000b; Rutkowski, 1982). When CET voice stages are combined into voice parts, they are also expressed by range (Cooksey, 1999). EVT writers also show voice parts and registers that are differentiated by their range (Leck, 2009a, 2010; Phillips, 2014). Regardless of theory or approach, range is the primary means of expression and measure for most studies and methods (Ashley, 2013; Barresi & Bless, 1984; Cooper & Kuersteiner, 1970; Freer, 2009c; Harries et al., 1997; Hollien, 2012; Killian & Wayman, 2010; MacKenzie, 1956; Phillips & Doneski, 2011; Swanson, 1977; Thurman, 2012; Williams, 2010, 2012, 2013).

The primacy of range in delineating approaches to changing voices can be seen in the work of six theorists on male voice change: (a) Duncan McKenzie, (b) Irwin Cooper, (c) Frederick Swanson, (d) Cooksey, (e) Leck, and (f) Phillips. The first three, McKenzie, Cooper and Swanson have been called “three great American pioneers of changing voice theory” (Collins, 1993, p. 152) for their early role in encouraging boys’ singing through their voice change.
The earliest modern expression of adolescent male ranges is generally ascribed to Duncan McKenzie (1956). His understanding of voice change is referred to in the literature as the alto-tenor plan (Collins, 1992). As can be seen in Figure 14, the alto-tenor voice part somewhat resembles Cooksey’s mid-voice range and is placed between the alto and tenor ranges. In the figure, we can also see a narrowing of range in both the alto-tenor and tenor voice parts. While McKenzie allowed for larger ranges and multiple registers in other contexts, his alto-tenor plan and its range charts were intended for schools singing in modal chest register.

![Figure 14: MacKenzie Alto-Tenor Plan (Collins 1993; MacKenzie, 1956).](image)

Irwin Cooper created the Cambiata Approach (Cooper & Kuersteiner, 1970) to boys’ changing voices and was one of John Cooksey’s college professors. Cooper’s approach included the creation of a voice part called cambiata, intended to accommodate what he described as the unique range and vocal quality of the adolescent male voice in transition (Figure 15). Like McKenzie, he believed that the voice changed in stages of gradual lowering vocal pitch and that the bass range is quite limited at first.
Frederick Swanson, a boychoir conductor, developed a range chart that appears more akin to traditional SATB voicings, albeit with a narrower range (Figure 16). This is due in part to his observation and belief that boys’ voices change rapidly. Still, his tenor part resembles the alto-tenor of MacKenzie, the cambiata of Cooper, and Stage 3 of Cooksey.

Cooksey asserted that his 1986 study (described in 2000a) affirmed his theory through the consideration of all the criteria of his vocal typology: range, register, vocal quality, physiology, speaking pitch, and tessitura. The role of each of these criteria in his indexing, however, was inconsistent. While Cooksey gave serious consideration to all his listed criteria, in the end, the voices were principally indexed according to range. The other criteria had measurement difficulties that limited their role in indexing. For
example, tessitura was not used in data analysis due to high variance (Cooksey, 2000a, p. 724).

MacKenzie, Cooper, Swanson, and Cooksey’s approaches are commonly mentioned in literature reviews (Collins, 1992; Cooksey, 1977a; Leck, 2009a). Of these four, Cooper’s Cambiata Approach and Cooksey’s CET are most visible. While differences in application between the two exist (Collins, 1993), the similarities in their treatment of range, tessitura and register warrant treating them as a single approach.

Both Leck (2009a) and Phillips (2014) expressed ranges by voice parts rather than stages. As shown earlier, Phillips separated the voice parts into junior high and senior high groupings for schools. Range classifications by grade are not uncommon (Davison, 2011), and have even been grouped by individual grade at the middle school level (Figure 17).

![Figure 17: Davison voice parts by grade (Davison, 2011).](image)

**Registration Fluency**

One of the principal differences between the two theories is their treatment of vocal registration. More specifically, CET favors single registration singing, while EVT is by definition a multiple registration theory (Leck, 2009a). Vocal registration is difficult
to operationally define (McCoy, 2012). For this reason, detailed attention was given to registration in this review.

Vocal register is a “series of consecutive, homogeneous tone qualities, the origin of which can be traced to a special kind of biomechanical (muscular) action” (Ware, p. 281). This biomechanical action is best understood as a laryngeal phenomenon rather than a phenomenon of the vocal tract (Baken & Orlikoff, 2000). In other words, in order to understand the mechanism of register, one must understand the mechanism of the larynx.

**Anatomy of vocal registration.** Rather than bone, the laryngeal structure is supported by cartilage. The larynx is comprised of four main cartilages: the cricoid cartilage, the thyroid cartilage, and a pair of arytenoid cartilages. The movement of these cartilages contribute to the pitch, intensity, and registration of a tone. Two vocal folds, whose vibrations make vocal sound, are anchored to the cricoid cartilage with their opposite ends attaching to each of the arytenoid cartilages.

The muscles connecting this cartilages are easily remembered as their names are derived from cartilages they connect. The cricothyroid (CT) muscle connects the cricoid and thyroid cartilages, while the thyroarytenoid (TA) muscles (Figure 18) connect the thyroid cartilage to the arytenoids. These muscles move in opposition; when the CT muscle is contracted, the TA are extended, and vice versa. The vocal folds, which fold around the TA, change in thickness depending on the activated muscle.
The relationship of these muscles determines registration. The contraction of the TA results in thicker vocal folds with higher vertical phase difference (McCoy, 2012, p. 144). In this way, the TA is a shortener of the vocal folds (Thurman, et al., 2000). This thickening lowers pitch and the resultant timbre is perceived as weightier and richer. In contrast, the contraction of the CT result in thinner and longer vocal folds, which raises pitch but lowers amplitude due in part to the increased longitudinal tension. The CT can be thought of as a lengthener of the vocal folds (Thurman, et al., 2000, p. 426). This action of the lengthening CT and shortening TA influence pitch, amplitude, and vocal quality provide a clear identification of registration through anatomical function.

Due to this muscular action, registers can be described by the vocal mechanism as cricothyroid and thyroarytenoid dominant production (Phillips, Williams, & Edwin, 2012,
p. 606), or thick and thin fold production (McCoy, 2012; Williams, 2012). Both physiological descriptions suggest a two-register approach, as does the widely used head voice/chest voice distinction (Ashley, 2013; Davison 2011; Kennedy, 2004; Collins, 2012).

Classifying register. Differences in register description, nomenclature, and operational definitions have made registration a particularly challenging topic for researchers and reviewers, and the debate on the location and number of vocal registers has been acrimonious (Baken & Orlikoff, 2000). Early voice pathologists prefer register classification that are expressions of laryngeal function, rather than as perceived timbral groupings (Baken & Orlikoff, 2000; Hollien, 1974). These pathologists identify three registers: modal, pulse, and loft. The modal register is the voice commonly heard in speech and most genres of singing, what this study refers to as chest voice and head voice. The pulse register consists of the lowest frequencies, which are heard as a rough pulsing due to the complete release of the CT. These pulse tones are often called “vocal fry” by voice pedagogues and are not relevant to this study. The loft voice is what is commonly called whistle, and is the least researched of the registers (Baken & Orlikioff, 2000).

William Vennard (1967) summarized three approaches to register that had developed over several centuries of voice pedagogy. The “Idealistic Approach” describes a single register throughout the range, unbroken by gaps and unified in timbre (p. 69). The “Realistic Approach” identifies three registers: chest voice, head voice, and falsetto. A “Hypothetical Approach” only has two registers: a heavy mechanism and light mechanism; these correspond to lower register and upper register respectively.
The use of three registers, (upper voice, mixed/passaggio voice and lower voice) as per the Italian school of singing has generally served as a starting point in the conversation (Miller, 1986, p. 313), and has been extended to discussion of the adolescent singer by proponents of EVT (Phillips, 1992, p. 16). Contemporary CET proponents, however, have endeavored to classify in a way that reflects specific anatomical functions. Table 1 is provided to clarify the differences in nomenclature between the two approaches.

Table 1

*Comparison of register nomenclature between CET and EVT*

<table>
<thead>
<tr>
<th>Anatomic Function</th>
<th>CET</th>
<th>EVT</th>
</tr>
</thead>
<tbody>
<tr>
<td>TA released</td>
<td>Falsetto</td>
<td>Upper register</td>
</tr>
<tr>
<td>Modal: CT dominant</td>
<td>Upper register</td>
<td>Passaggio (middle)</td>
</tr>
<tr>
<td>Modal: TA dominant</td>
<td>Lower register</td>
<td>Lower register</td>
</tr>
<tr>
<td>CT released</td>
<td>Vocal Fry</td>
<td>Vocal Fry</td>
</tr>
</tbody>
</table>

The *Bodymind* publications of The Voice Care Network (Cooksey, 2000a, Thurman et al., 2000) set forth five registers from lowest to highest pitch: (1) pulse register (described above), (2) lower register, (3) upper register, (4) falsetto register, and (5) whistle register. Cooksey’s treatment of register in his later writings is within this paradigm.

In *Bodymind*, **lower register** occurs when the TA and CT are both activated, but the TA are more contracted. This “tug-of-war” between the two stabilizes the vocal folds in “length, thickness, and tautness so that the $F_0$ also is stabilized for the perception of
sustained pitch” (Thurman et al., 2000, p. 437). The vocal folds are thick and create a rich, thick timbre. This corresponds with the terms chest and modal cited earlier. Definitions of each register are addressed in the text of the article as well as by spectral display.

The upper register, according to Bodymind researchers, occurs when TA and CT are both contracted, like in lower register, but the CT dominates (Thurman et al., 2000). While this register has the same stabilization as lower register, the change in muscular coordination thins the vocal folds. As a result, these tones are perceived as lighter and thinner.

Falsetto as described in Bodymind is achieved when the TA is completely released (Thurman, et al., 2000, p. 440). When this occurs, the arytenoids are apart which also keeps the vocal folds apart from each other. Without other muscular action, the falsetto voice can sound weak and airy. In order to achieve closure of the vocal folds, other muscles that bring the arytenoids together must be activated independently of the TA. This takes a particular and unique coordination that can be achieved from vocal experience: “As [the pitch] is increased in falsetto . . . register coordination, optimally strong action by the primary adductor muscles combined with the lengthening action of the CTs results in complete adduction and a fairly high intensity range (Thurman, 2000, p. 440).” A successful singer of falsetto, then has learned not only to coordinate the fine musculature of the larynx, but also has conditioned those muscles (Thurman, 2000, p. 440; Williams, 2013).

Voice pathologists and pedagogues agree on pulse and modal registers; however, there is less agreement on the demarcation and naming of the upper register. Some prefer the use of the term “falsetto,” which is often used “to avoid confusion (Baken & Orlikoff,
2000, p. 168), while others prefer the term “upper register” (McGlone, 1970). The authors of *Bodymind* prefer “the term upper register . . . to reflect the pitch-dependent nature of this register’s laryngeal coordination (Thurman, et al., 2000, p. 438).”

**Register and CET.** In applying these register definitions to the adolescent male voice, Cooksey uses term modal to indicate both upper and lower registers (2000a, p. 727). Falsetto is considered a separate register that does not appear until the Stage 3 High Mutation stage (2000b, p. 835). Cooksey does not specifically describe the laryngeal function of these registers, but refers readers to the registration chapter in *Bodymind* (Thurman et al., 2000). For this reason, his findings on registration can be difficult to interpret. In general, the term “upper register” in Cooksey’s writings should be understood as the modal upper pitches of the each stage’s range that are CT dominant and identified by a combination of perception and spectral analysis.

The description of register development in the Cooksey’s classification of stages is somewhat opaque. Registration development was not directly used in indexing the stages (Cooksey, 2000a). Cooksey operationally defined register development as the “degrees of tonal continuity and intensity level when producing lower, upper, and falsetto register pitches” (2000a, p. 724). Application of this definition to his California Longitudinal study’s data was confounded by the great variation in upper register throughout the first three stages (p. 722). While register development was not used in the indexing (p. 726), it did appear to influence decisions on participants’ voice stage assignments. Cooksey suggests that “the crossover frequencies between these two registers [upper register and falsetto] . . . can be used as an indication of changes in voice maturation and voice classification.” (Cooksey, 2000a, p. 726). For this reason,
registration appears to have informed certain judgments made by the researchers in
determining the veracity of sung pitches, particularly in decisions of what was in range
and what was not (p. 726).

Some have called the CET’s treatment of register as a single, lower register
approach (Phillips et al., 2012). Cooksey and members of the Voice Care network,
however, would disagree. For CET theorists, this modal grouping consists of two
registers that depend on the dominant muscle, TA and CT. Conclusions and
recommendations for repertoire, training, and classification in CET are intended for
contexts that generally omit falsetto singing.

Register and EVT. Twenty years ago, extended range (i.e., including falsetto)
singing for young men had little to no empirical research to inform its approach. While
boys’ extended range singing has been in existence for centuries, descriptive research on
such singing had been scant. Falsetto singing was not included in Cooksey’s analyses or
reports of findings (Cooksey, 1977b; 2000; 2000b), although it was taken into account in
Cooksey’s initial research design (Cooksey, 1977a).

In the last 5 years, research has begun to examine the treatment of head voice as a
component of boys’ singing. In the United Kingdom, research in EVT singing has been
applied to cathedral choirboy vocal health (Williams, 2010; 2012), secular trend (Ashley
& Mecke, 2013), cultural psychology (Welch, 2011), and qualitative research (Ashley,
2011). In the United States, current studies of boys’ singing in extended range tend to be
qualitative in nature (Freer, 2009b; Kennedy, 2004). The challenges of research in
registration for young men’s singing have led some to declare that: “A lack of conceptual
clarity, wide variations in choral practice and inconsistent attempts at measurement in the past demand both skepticism and further research.” (Ashley & Mecke, 2013, p. 1)

The challenge of research in changing voice registration is supported by recent studies. In a 2010 descriptive study of male adolescents’ vocal maturation, data were collected using “Cooksey procedures.” (Killian & Wayman, p. 5). In the study, voices were categorized using Cooksey’s stages and falsetto presence treated as a dichotomous variable (present/not present). No report of spectral measure or analysis was provided. The two researchers used their own judgment in categorizing voices and determining presence of falsetto. Reliability is explained in this way: “The two researchers discussed any disagreements and reviewed recordings as necessary until a consensus was reached. Thus, reliability was 100% for the purposes of this study” (p. 9). Additional statistical information on interjudge reliability was not provided. The operational definition of falsetto is not stated, and the data on range did “not analyze the presence/absence of falsetto so some high pitches may reflect the use of falsetto” (p. 11). The challenge of quantifying falsetto is further demonstrated in a speaking voice task where the researchers were “unable to reach a reliable consensus regarding whether these voices spoke in falsetto” (p. 13). The authors go on to express the complexity of aurally observed register discrimination. The study provided a table on the presence of falsetto in sung examples based on the judgment of the two researchers.

Another descriptive study (Emge, 1996) investigated the effects of multiple register singing on performance outcomes. A group of adolescent males (N = 61) of varying voice stages were trained in singing multiple registers over the course of a year. Singing was assessed three times over the school year on (a) total range, (b) register use
in varying tessituras, (c) judge’s perception of comfort, and (d) participant’s perception of comfort. Results found significant range expansion upward and downward, particularly in those labeled cambiata, and the study’s author suggests in his conclusion that school instruction should include multiple register singing. Both the Killian and the Emge studies used judgment as a measure.

Support for CET treatment of register. The primary vocal difference between the CET and EVT can be found in the treatment of vocal registration. In recent years, Cooper’s and Cooksey’s limiting of vocal registers in their classifications has been questioned (Ashley, 2013). Cooper’s Cambiata Concept emerged from his work in scholastic settings with public school boys and was intended for general music classes, not necessarily a choir setting (Freer, 2010, p. 30). His work suggests only modal singing for boys based on his range charts and the repertoire that emerged from the Cambiata Institute. This is further reinforced by Cambiata Concept proponent, Don Collins, who stated that falsetto singing is of limited value during and following voice change, although he permitted falsetto singing in extreme high passages (Freer, 2010a, p. 30-31). Because of this, Collins’, Cooksey’s and Cooper’s approaches have been called a limited range school of thought (Phillips, Williams & Edwin, 2012).

Cooksey’s treatment of register is partly explained by his intended population, which is “an oft-overlooked yet critically important aspect of his contribution to research.” (Freer, 2010, p. 31) Cooksey’s participants were boys in a school setting, many with limited vocal experience. For this reason, Cooksey emphasizes comfortable singing, which is often related to the speaking pitch, placing the voice in the lower register (Cooksey, 1999, p. 68). Such an approach eliminated the complex challenges of
negotiating the differentiation of registers that could discourage inexperienced singers (Hollien, 2012, pp. e38-39).

Another reason given for CET-based instruction of young men, and an argument against EVT, is the presence of the phonational gap: an inability to phonate pitches between the falsetto and modal registers. The gap typically presents in Cooksey stages 3 and 4. These “gaps between registers . . . (i.e., between the modal and falsetto registers)—may present a problem when the teacher attempts to increase the students’ singing range.” (Hollien, 2012, pp. e38-e39)

Researchers from Australia conducted an investigation into phonational gap as related to weight (Willis & Kenny, 2006). A sample of 18 adolescent males were measured five times over a one-year period. Of these young men, 11 expressed previous singing experience, although neither the quantity nor the quality of the experience is described. Phonational gaps were identified using ascending and descending vocal glides. Results indicated an association between the presence and location of phonational gaps to body mass and Cooksey stage, with an increase in the presence of gaps closest to the high mutational stages 3 and 4. Interpreters of the results from this study have asserted that “no voice education method could overcome phonational gaps” (Thurman, 2012, p. 19), which contradicted Leck’s and Swanson’s assertion that proper vocal training ameliorates register difficulties like phonational gap (Leck, 2009b; Willis & Kenny, p. 468). It is worth noting that while adjustments to the alpha level were made ($p < .10$) for significance testing to avoid Type II error, no report on effect size or confidence intervals was provided. Furthermore, the limited sample, even with statistical adjustment, weakens assertions that could arise from this study.
Criticism of CET treatment of register. Criticisms of CET tend to fall into two concerns. First, some choral method authors feel that the approach of CET is too limited, even in general music classes (Barham & Nelson, 1991). As boys’ singing can be situated in a variety of contexts, some authors have expressed a desire for a comprehensive approach to singing that can be extended to settings outside general music (Leck, 2009a). Secondly, objections have been raised to the emphasis on range and low register singing during vocal transition (Ashley, 2013, p. 5). Ashley has most recently observed a “tendency in much writing about adolescent voices to stress range only. Understanding of register . . . is crucial to the development of control and the avoidance of needlessly limiting ranges” (2013, p. 5).

Some research supports these concerns, suggesting that a narrowed register approach does not use a young man’s full vocal potential (Phillips & Doneski, 2011, p. 208). A study by Ashley has found adolescent men “able and willing to phonate clearly and without break across a full three-octave range much in the way Leck describes. These boys added new notes more quickly to the bottom of their range than lost notes at the top and calls into question “the idea that boys tend lose upper pitches as they gain lower ones.” (Ashley, 2013, p. 8)

Perhaps the clearest difference between limited and multiple register pedagogy is noted by Kenneth Phillips (2011), who felt that single register approaches address “the adolescent voice ‘as is’ rather than what ‘could be’ with proper instruction. Cooksey has not researched the impact of vocal register development on the singing of adolescent males.” (p. 209) While he is speaking here of Cooksey’s descriptive research, the distinction could also be applied to the question posed by Martin Ashley’s 2009 book title
“How high should boys sing?” The answer depends on a teacher’s philosophy: shall voice be treated “as it is” or “as it could be?”

**Vocal Quality**

Teachers and researchers of boys’ voice often address vocal quality as part of their understanding of boys’ voices. Cooper used the term “wooly” to characterize the vocal quality of the cambiata voice (Collins, 1993, p. 150), describing the voices as rich and capable of beauty so long as they are not pushed. This understanding of the changing voice as possessing a unique quality became an important part of encouraging boys to sing through their voice change. It shifted the discourse away from boys being between voices, and sought to legitimize the value of boys’ voices in transition.

**Cooksey and vocal quality.** Cooksey included vocal quality descriptions of each of the stages as an additional guide in identification for the teacher. These are referred to as acoustics in his later writings (2000b), and are reported in terms of acoustic measurement by stages.

For the unchanged voices of the **Stage 1**, Cooksey noted that the full spectrum of harmonics are present. Intensities and noise are at levels comparable to the adult voice, indicating clear, efficient tone (2000b).

In **Stage 2** (Midvoice I), noise increases and amplitude decreases in the upper harmonics; however, lower harmonics are congruent with the healthy sound of the unchanged stage. In **Stage 3** (Midvoice II), also called the high mutation stage, fewer formant frequencies exist in the lower harmonic range, and intensities continue to decrease in the upper harmonics. Noise levels doubled from Stage 2. In the mutational
climax (Midvoice IIA), noise levels and intensities are at their weakest across all frequencies. There were also the fewest formants present of all the stages.

In **Stage 4** (Newvoice), a slight increase in formants can be observed, but with little change in intensities or noise presence in the lower register. In **Stage 5** (Emerging Adult Voice), lower harmonic noise increased in the lower register, but decreased in upper and falsetto registers. Harmonic intensities still do not approach adult norms, although upper harmonics have greater presence

We can see in these descriptions the “wooly” sound that Cooper described as the presence of noise. The unique brightness of the newly changed adolescent voice is explained by the stronger presence of upper harmonics in relation to lower ones.

Cooksey also confirmed the value of vocal quality as a criterion through a post-hoc discriminant function analysis (Cooksey, 2000a, p. 730). It showed four vocal/acoustic variables could accurately classify 41% of the cases: vital air capacity, the interaction of vital air capacity and perceived breathiness, the interaction of first and second formant, and low frequency noise. Three of these factors are related to vocal quality. Steven Demorest (personal conversation, 2013) has suggested that further application of discriminant function analysis on adolescent singing voice outcomes might contribute to a richer understanding of possible groupings of adolescent voices.

**Measurement of vocal quality.** In this study, voice quality is revealed in the perception of (a) roughness, (b) strain, and (c) breathiness is measured by the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V; ASHA, 2006), which are vocal qualities consistent with Cooksey’s and Cooper’s descriptions. Several acoustic factors have been shown to influence this perception: jitter, shimmer, and harmonic to noise ratio
(H/N). **Jitter**, also known as frequency perturbation, is the measure of involuntary pitch variation that can be caused by “diminished neuromotor and aerodynamic control” (Baken & Orlikoff, 2000, p. 190). **Shimmer** is a measure of involuntary loudness variation, also known as amplitude perturbation. Both shimmer and jitter can contribute to the perception of roughness, strain, and breathiness (Baken & Orlikoff, 2000). Recent acoustic measures that have been shown to predict vocal mutation in the speaking voice (Fuchs et. al., 2007) provide new interest in the value of these measures.

**Roughness** is to be understood as a frequency perturbation across a broad spectrum of harmonics (Baken & Orlikoff, 2000, p. 281). Perceived pitch fluctuation has been shown to correlate with spectral level measures of noise (Emanuel, 1991; Whitehead & Emanuel, 1974). Based on these studies, acoustic measures of jitter and perception measures of roughness should correlate. Another measure of roughness is the harmonic-to-noise ratio (H/N), which divides the mean amplitude of the average wave with the mean amplitude of the isolated noise components (Baken & Orlikoff, 2000, p. 282). Expressed in dB, this measure combines the harmonics and noise into a ratio. This makes sense as harmonics are often replaced by noise.

**Strain** is defined by Vennard (1967) as sound produced with too much effort for adjustment. Cooksey describes strain as a constriction of the voice (2000b, p. 834), and like Cooper, associates it with singing upper pitches (Cooksey, 1977a; Cooksey, 2000a). It is a regular concern of voice teachers, and often observed in the form of neck tension, misalignment, and rigid sound. All three of these observations imply a muscular activation that inhibits rather than enables normal vocal function. Observations of
irregularities in spectra could reveal strain in such a way as to confirm the perception of strain measured by the CAPE-V.

**Breathiness** is a common reported observation in boys’ changing voice. This is due in no small part in the irregularity in the shape and composition of the vocal folds (M. Denison, 2012). The source of breathiness in a sound can generally be attributed to air escaping through a non-vibratory gap in the vocal folds (see Figure 20-B). In high mutation (Cooksey Stage 3), the vocal folds become almost rectangular (Denison, 2012) reducing the ability of the glottis to fully close. Furthermore, the temporary appearance of a glottal chink can occur (M. Denison, 2012) also contributing to the perception of breathiness (Figure 19).

![Figure 19](image)

*Figure 19.* Posterior glottal chink. Normal glottal opening during abduction (A), glottis during adduction with PGC in evidence (B).

Another cause of breathiness happens on the external layer of the vocal folds. A coating of collagen bubbles, almost like water balloons, develop in a thick layer on the vocal folds. This layer offers a protection to the folds, but also can compromise glottal closure. The result is the breathiness often perceived by teachers (M. Denison, 2012).
As his research progressed, Cooksey began to consult *formant measures* of vocal quality to verify his measures of range and registration (2000a). Formant crossings in particular were cited as indications of shifts in registration (Figure 20) as well as indicators of vocal stage, confirmed by discriminant function analysis (2000a).

*Figure 20.* Formant crossing denoting register change.

**Speaking Voice**

Although Cooksey also consulted speaking voice data, its role in indexing the vocal stages was marginal (2000a). In the beginning of his research, Cooksey referred to mean spoken pitch as speaking voice (1977b). By 2000, Cooksey was referring to mean spoken pitch as the “average speaking fundamental frequencies (ASFF)”.

Regardless of the nomenclature, Cooksey used mean spoken pitch as well as the vocal quality of the speaking voice to describe each stage as well as confirm indexed stages throughout his research (2000a, 2000b). No statistical information on the relationship of these factors was provided, however.

Using the speaking voice as a point of information is common in teaching as well (Davison, 2011; Freer, 2009c). Typically, a teacher of a beginning adolescent singer will
determine the mean speaking pitch informally through conversation. From that pitch, they will begin their measurement of the vocal range. Teachers find the ease of physical execution and pitch matching found in the speaking pitch a useful entry point into understanding their students’ voices (Davison, 2011). With that information, they can determine developmental voice stage or voice part assignment.

Inclusion of speaking pitch in this study is a relevant measure for a similar reason. Regardless of pitch-matching ability, psychomotor limitation, or physical constraints, the mean speaking pitch provides information that is less likely to be variable due to these external constraints.

**Tessitura**

Tessitura in the case of boys’ singing is generally defined in terms of ease. Cooksey defined it as “most comfortable singing range (2000a, p. 722). Comfort can be difficult to systematically measure. As we saw with its antonym, strain, it is a challenge to quantify as an outside perceptual measure.

In a study by Baressi and Bless (1984), a group of 12-15 year olds ($N = 59$) were classified into Cooksey’s stages of voice change using conversation and scale singing. A panel of five experienced junior high teachers listened to scale samples of each participant. On a score sheet provided, the judges circled the pitches they perceived as tessitura pitches. Pitches that had agreement greater than or equal to 80% between judges were retained. Acoustic measures of onset, jitter, shimmer, and mean speaking pitch were collected. Results indicated little agreement between judges on tessitura pitches. The few pitches that showed agreement clustered in the midrange of each stage. The researchers
concluded that the teachers needed better training in identifying tessitura pitches, perhaps through the use of acoustic measurement.

Tessitura has been regularly reported along with range in Cooksey’s range figures (Cooksey, 1977b, 2000a), as well as Collins (1994). Phillips, a proponent of EVT, also provides tessitura in his most recent range figures (Phillips, 2014). Each of them, like Baressi, encourage teachers to find repertoire whose voice parts are predominantly in the tessitura range, rather than excessively at the extremes of the total range. Proponents of both theories ascribe importance to the consideration of tessitura; however, its value in research is dubious and as a result will not be a factor in this study.

Predictors of Vocal Outcomes

Motivation

Motivation research in music education can focus on several patterns: preference, intensity, persistence, and quality (Linnenbrink-Garcia, Maehr, & Pintrich, 2011). In the context of this study, the intensity and quality of motivation are of greatest interest. Intensity can be thought of as the degree of focus or degree of effortful action. Quality is reflected in the level of work on a task. For example, a hard-working, focused student who pushes his sound out of tune by oversinging is high in intensity but not in quality. There are many theories of motivation that could be seen as relevant to understanding the vocal outcomes of this study. This review considers two: attribution theory and self-determination theory.

Attribution theory. Attribution theory examines students’ beliefs about why events occur and how those beliefs affect future achievement (Asmus, 1986; Linnenbrink-Garcia, Maehr, & Pintrich, 2002; Peterson, 2002; West, 2013). According to
the theory, “there are four general causes to which people attribute their success or
failure: luck, effort, ability, and task difficulty” (Peterson, 2002, p. 33). Ability and task
difficulty are considered stable, while effort and luck are unstable, varying with each
attempt at a task. “Ability and effort were perceived as causes originating within the
individual while task difficulty and luck were perceived as causes outside the individual”
(Asmus, 1986, p. 265). Using these causes, an individual’s attributional condition can be
measured and potentially plotted on a figure with two poles of degree of stability and
cause.

The relationship between attribution and affective state are of interest in this study.
Weiner (1986a) proposed a model in which a motivational attribution acts upon an
affective state, which influences the results of a performance outcome. The outcome
affect in turn becomes a prime mover of subsequent action (Weiner, 1986b).

**Self-determination theory.** Self-Determination Theory suggests three elements
of intrinsic motivation that can engage adolescents: competence, autonomy, and
relatedness. **Competence** for boys does not simply mean the completion of a project.
Rather, boys feel competent when the completed project is done well. Anita Collins, in
presenting research findings at the Boys and Voices Conference in Melbourne, Australia
in 2005 found that the boys in her study supported a “high quality of singing performance,
whatever the genre of music” (Collins, 2012, p. 104). Boys are more aware of what is
happening musically than their performance ability may portray. In understanding boys’
motivation, then, we must first realize that their sense of competency is a function of
“both motivation and cognition . . . it makes little theoretical or practical sense to develop
models that only emphasize one or the other perspective” (Linnenbrin-Garcia et al., 2011).
The theoretical model proposed in this study supports the connection of vocal training to motivation.

In self-determination theory, a sense of both **autonomy** and **relatedness** is an important component in the construction of the emerging self. These conceptions are similar to the “possible selves” construct beginning to be explored within motivational research in music education (Freer, 2010b). Research in possible selves indicates that adolescent boys begin to “hypothesize about their future selves, including those they wish to become or fear becoming (Freer, 2012).” They judge each life experiences to establish what belongs to their identity and what they reject. Even the simplest vocal tasks, such as a passage in falsetto, can have identity implications that will be rejected or accepted by a young man, which in turn influences their singing. In other words, they are having conversations with themselves about their singing that declare “this is me” or “this is not me.” In so doing, boys approach singing tasks with a positive or negative affect that may act upon their motivation.

**Affective State**

Affective state, often thought of as emotional state, is often considered separately from motivation, but with an important role. The nature of that role however varies based on theoretical perspective (Linnenbrin-Garcia et al., 2011). Weiner asserts the influence of affective state both on motivation and by motivation (1986b): “the assignment of attributed causes, emotions, or affect is made, future striving is influenced. The model of attributional development begins with an action, which leads to an outcome, which results in attributions, which produces affect. This, then, influences the next attribution sequence.” (Asmus, 1994, p. 10)
Supporting this approach, as well as the theoretical structure of this study’s model, is research on student’s emotions in learning and achievement (Pekrun, Goetz, Titz, & Perry, 2002). The authors investigated the origins of affect within personality and environment, and the effect of those resultant emotions on academic outcomes. A self-reporting questionnaire on academic emotions was administered to university students (n = 230). Construction of the questionnaire included consideration of “affective, physiological, cognitive, and motivational processes” (Pekun et al., p. 95), followed by a scaling down of items into those applicable to an academic setting. Items were then divided into “class-related, learning-related, and test-related emotions” (p. 95). Results showed significant relationship between emotional affect, motivation, personality, self-regulation, and classroom environment.

A suitable measure that is consistent with Pekrun’s results is the Positive and Negative Affective Schedule (PANAS; Watson, Clark & Tellegen, 1988). Positive affect (PA) “reflects the extent to which a person feels enthusiastic, active, and alert (Watson et al., 1988, p. 1063).” Individuals with high PA are energetic, vital, and focused, while those with low PA are lethargic and gloomy. Negative affect (NA) “is a general dimension of subjective distress and unpleasurable engagement that subsumes a variety of aversive mood states, including anger, contempt, disgust, guilt, fear, and nervousness (Watson et al., 1988, p. 1063).” Those with low NA are in a calm and serene state. External validity of the PANAS was demonstrated with other mood measures: the Hopkins Symptom Checklist (HSCL), Beck Depression Inventory (BDI), and STAI State Anxiety Scale (A-State) (p. 1068).
Physiology

The relationship between physiology and vocal outcomes has been routinely studied as part of most quantitative research on male changing voice (Barressi & Bless, 1984; Cooksey, 1977b, Cooksey, 1982, Cooksey, 2000a, Welch, 2000, Williams, 2010). This study selected several markers for investigation based in part on Cooksey’s discriminant function analysis of his California Longitudinal Study (1985, reported in Cooksey, 2000a) and raw data (C. Denison, 2011).

As mentioned earlier, a discriminant function analysis (Cooksey, 2000, p. 730) showed four vocal/acoustic variables could accurately classify 41% of the cases: vital air capacity, the interaction of vital air capacity and perceived breathiness, the interaction of first and second formant, and low frequency noise. Two of these factors are related to physiology, specifically through vital air capacity.

Raw data from an earlier study (C. Denison, 2011) identified significant correlations between height, neck girth, waist, lung capacity, and weight with vocal outcomes. Height is the most reliable predictor of Cooksey stages (Cooksey, 2000a). Neck girth showed several correlations with vocal outcomes, while laryngeal prominence did not. The lack of correlation between laryngeal prominence and outcomes is consistent with the findings of Barresi and Bless (1984) who suggested further research in this relationship. It is possible that neck girth, which appears to have received minimal attention in the literature thus far, may be a predictor of vocal outcomes in adolescent men. Both waist and chest measurement were highly correlated with each other and both showed significant correlation with vocal outcomes. Waist was retained in this study due to prior experience and its slightly higher correlation with the outcomes. Lung capacity is
supported by Cooksey’s discriminant function analysis. Weight is supported by several studies that found a relationship between weight and vocal outcomes in adolescents, particularly phonational gap (Willis & Kenny, 2008, 2011).

**Personality**

**Musician personality.** Musical and musician personality have been extensively studied and reported by Anthony Kemp who used several measures to describe the personalities of musicians. In his book *The Musical Temperament* (1996), he explains the personality theories and measures of Catell (1956), Eysenck (1964), Myers-Briggs (1985), and the Five Factor Inventory (McCrae & Costa, 2008) among others. He examines the general personality of musicians by instrument (piano or string, for example) as well as profession (composer, conductor, or teacher). He summarizes and explains the extensive research personality and music preference and the interaction.

As this is a study of adolescent vocal outcomes, his chapter on musical development is particularly useful in addressing personality in the young emerging musician. Using L. A. Sosniak’s research and theories (1990), Kemp describes a transition from extroverted playful engagement at younger ages to a more introverted bearing, focused on musical growth. Kemp states: “The time is ripe for further research that might begin to disentangle these two effects” (p. 239). He goes on to argue that music study may indeed have an impact on personality development.

Kemp’s research (1995) on “developmental patterns from childhood to professional life” (p. 241) revealed a reversal of character traits between young performers and full time performers from expediency to conscientiousness. He further
asserted that young collegiate musicians are higher in desurgency than their peers, and are therefore more introverted.

Kemp notes that there is little research specifically on the personality of singers. He mentions the general assumption that singers are extroverted due to the nature and requirements of their performances, and acknowledges the unique challenges of singers, who embody their instrument. In so observing, he notes the possibility of high introversion, since singers must internally sense their singing rather than hear it (p. 174). He concludes, “singers appear to be the most ‘integrated’ of all musicians in terms of personality development. . . (p. 177),” which might suggest a high variance in domains.

**Five Factor Theory of Personality.** The Five Factor Theory of Personality (FFT) receives mention from Kemp in his first chapter, but is not applied in subsequent ones; Cattell tends to dominate the discourse in Kemp’s writing. This is likely due to the FFT being relatively new at the time of Kemp’s writing (Coffman, 2007). Kemp was wary of FFT: "the development of what has become known as the 'big five' model of dimensions has done something to unite those working in the field, although in some quarters the debate continues" (Kemp, p. 18).

The five factors referenced in the theory are (a) Emotional Stability, (b) Agreeableness, (c) Openness to Experience, (d) Extroversion, and (e) Conscientiousness each of which is comprised of 3 to 6 subdomains called facets. The FFT arose in response to a perceived need for taxonomy in personality research (John, Naumann & Soto, 2008). The NEO-FFI (Neuroticism-Extroversion-Openness Five Factor Inventory) and NEO-PI-R (NEO-Personality Inventory Revised) were FFI-based tests that were intended to be of use to researchers who needed to theorize and measure within a taxonomic structure.
Since 1995, total studies influenced by FFT increased dramatically while Cattell and Eysenck related studies decreased (John et al., 2008, p. 116). Music research, like Kemp, has been slow to embrace FFT measures, but these tests are now increasingly used. (Camilli, 2010; Dunn, de Ruyter & Bouwhuis, 2012; Levy, Lounsbury & Kent, 2009; Payne, 2009)

Although the NEO tests were originally designed for adults, adapted forms of the test began to be applied to social science research in adolescence. Researchers had several approaches to the question of NEO test and adolescent personality: (a) use the NEO test to describe adolescent personality (McCrae et al., 2002), (b) use another test that measures Big Five for general population on this group like the Five Factor Inventory (Hendriks, Kuyper, Offringa & van der Werf, 2008), or (c) design a new test specifically based on Big Five.

The last approach informs the creation of the Adolescent Personal State Inventory (APSI; Lounsbury, et al., 2003), which mirrors the domains of the NEO-FFI but without the extensive subdomains. The APSI meets general reliability and validity standards, and has been used in several studies on adolescent behavior (Bade, 2010; Landers & Lounsbury, 2006; Lounsbury, Levy, Park, Gibson & Smith, 2009; Martin, 2012; Perry, 2003) with extroversion, conscientiousness, and emotional stability showing the higher levels of reliability. The domains of agreeableness and openness, however, had questionable applicability in their initial form (Lounsbury, 2003). Personality research that used FFI tests for adolescents administered on the facet level brought forth richer data sets, statistical models with greater explanatory power, and better factorial derivations (Dunn, de Ruyter & Bouwhuis, 2012; McCrae et al., 2010).
Recently, the APSI has been retitled to be a Transition to College test (TTC) (J. Lounsbury, personal correspondence, November 21, 2013). Although its content is identical, its new title, and apparent purpose, calls into question its validity. Although a promising measure, this change has made it difficult to include in research. Since a valid FFI measure for adolescents was not available, and Catell’s measures are time-intensive, motivation acted as a surrogate for trait personality.

**Singing Environment**

In this study, sampling controlled singing environment in that all participants had choral training and choir experience of some kind. Virtually all of changing voice theorists, pedagogues, and teachers discussed in this chapter have a training method that purport to yield positive vocal outcomes. Cooksey describes ways to facilitate full range and appealing vocal quality (1999). Leck (2009a, 2009b) addresses range, register facility, and vocal quality. *Teaching Kids to Sing* (Phillips, 2014) is a comprehensive EVT process that includes range, register, vocal quality, and tessitura. From the Cambiata school, Don Collins’ *Teaching choral music* (1993) presents the most comprehensive method of the CET group. Certainly focused time dedicated to improving singing through any of these methods will yield some degree of positive vocal outcomes.

**Social Psychology**

Both CET and EVT supporters agree that voice change is as much a psychosociological phenomenon as a physiological one (Leck, 2009b, p. 13; Shepherd, 1983; Harrison, 2010; Phillips, 2014; Welch, 2011; Williams, 2013). As shown earlier in this chapter, the divergence between the CET and EVT appears to be influenced to some
extent from where the singing is contextually situated. Several qualitative studies illustrate the influence of context on range and registration.

Scott Harrison’s study illustrates a school context, where “singing in a high voice was considered particularly un-masculine, even when the physiology prevented any alternate sound” (2010, p. 46). Ridicule of high voices in boys whose voices hadn’t yet changed was shown to stop singing. This is consistent with the common belief that high singing is gendered (Ashley, 2009, 2011; Green, 1997), and that gender identity is entwined with vocal mutation in boys. Harrison declared that “the idea that boys stop singing at this time is contrary to effective singing pedagogy that states boys should sing through the change . . . and provides proof that boys are on the outer in this particular activity” (p. 46). Such accounts are commonly encountered in practice and are supported by similar studies (Freer, 2009a; Freer, 2009b; Freer, 2009c). The reported experiences in these studies were seen as having a lifelong impact on the individual’s relationship to music, and merited serious consideration (Freer, 2006).

Several writers have expressed concern about the insistence on upper voice work without regard for socio-cultural context (Ashley, 2009; Freer, 2010a), deeming such insistence as neither desirable nor effective. In a similar way, repertoire could be pedagogically feasible for a group of young men, but lacking in consideration of the psychosocial implications of singing “certain lyrics and/or singing in a certain musical style.” (Harrison, 2010, p. 49) Instead of insistence, Patrick Freer and others suggest teachers cultivate honest dialogue with their students. Such conversation creates inclusive learning and better determines what should be sung and how it should be approached (Abrahams, 2012; Freer, 2009a, 2009b). Harrison reports that the result of
these conversations is a vocal repertoire that possesses “a rhythmic drive, a limited vocal range and an appealing message.” (2010, p. 49)

The impact of repertoire preference on young men’s singing outcomes does not always narrow range, however. At the American Boychoir School, where multiple range singing is the norm: “A surprising finding was the small degree of importance that the boys placed on range-appropriate repertoire. They handled the notes out of their ranges with apparent ease, devising inventive and practical coping strategies. Far more important to them was repertoire they liked” (Kennedy, 2002, p. 35). Here we see the strong influence context has on young men’s singing preference, and the diversity of those preferences depend on where the music is situated.

**Conclusion**

This review of the literature has shown clear justification for the consideration of several possible latent factors. Such factors may prove useful in statistical modeling.

- Range has proven to be the standard through which most changing voice classification has taken place.
- The treatment of registration, specifically the upper registration seems to be a major factor in the delineating the two theoretical approaches of CET and EVT.
- Vocal quality has shown to be an indicator of vocal development stages through acoustic and perceptual measurement.
- Speaking pitch is a commonly used indicator by both researchers and practitioners.
- Tessitura, while difficult to systematically classify, has been an important guide in repertoire selection for many the CET- and EVT- based authors and practitioners.
In addition to factors suggested by voice researchers, music education and psychology literature is rich with studies that verify the role of personality, developmental physiology, environment, motivation, and affective state on musical outcomes. Previous research of their direct effects on vocal outcomes has yielded mixed results. Causes of such results are vague operational definitions and small samples. Larger sample sizes that generate greater statistical power and clearer operational definitions of vocal outcomes could provide clearer results. The influence of psychosocial factors on musical outcomes is well supported in both quantitative and qualitative research. Most of these factors have not been systematically applied to classifications of boys’ development or voice part, even though both CET and EVT acknowledge their influence on vocal performance. This study’s purpose is to investigate the relationship of those factors to changing voice outcomes, and begin a systematic explanation of their possible connection.
CHAPTER THREE

METHOD

This study examines the effects of physiology, motivation, and affective state factors on the latent factors of range, registration facility, and vocal quality. Through structural equation modeling (SEM), the following questions can be addressed:

1. What interrelationships existed within and among the following latent variables: (a) Physiology, (b) Motivation, (c) Affective State, (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

2. What combination of variables and latent factors of (a) Motivation, (b) Physiology, and (c) Affective State best predicted the latent vocal factors of (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

3. What model of the variables best predicts vocal achievement outcomes in adolescent males?

This chapter describes the participants, measurement instruments, procedures, and data analysis in the study. Several decisions in research design were informed by raw data (Denison, 2011) collected from young men in a community boys’ choir, ages 10-15 ($n = 28$). This data was used to justify certain methodological decisions in this study.

**Participants**

The participants of the study were boys and young men ages 8 to 18 ($n = 196$), and current members of a community boys’ choir. The choirs selected to participate in the study were based on several criteria: (a) secure, well-established programs in existence for over 20 years, (b) multiple register singing, (c) volunteer or staff resources to sufficiently support data collection, and (d) ease of communication.
In selecting this particular population, several sources of variance were controlled. Gender difference in sight-reading ability has been shown in studies that concern locus of control (Kornicke, 1995) and parent involvement (Zdzinski, 2015). Charles Schmidt has also identified an interaction between gender and affective factors (Schmidt, 1995, 2011) in his description of a social-psychological model of musical ability. In this study, the male population eliminated such variance due to gender.

A community boychoir context provided several additional controls of variance. Since the participating boychoirs utilize multiple register singing, some variance due to training was controlled. This is especially true when this population is compared to the general adolescent male population and the wide variety of contexts for adolescent male singing. Also, family support of boys in these organizations includes arrangement of transportation, financial support, and volunteer work. While the results of family support on learning outcomes are mixed (Zdzinski, 2015), the unitary quality of this population’s support was desirable in reducing possible residual error in this study’s statistical modeling. By controlling for gender and environment through the sample, effects of the predictors were clearer.

All boys within each choral organization between the ages of 8 and 18 at the point of data collection were included in the study. This age range provided a rich sample of pre- and post-vocal mutation data. This richness was particularly important because age is an ambiguous predictor of voice range in adolescent male voices (Cooksey, 2000a, 2000b). A narrower age range may have excluded participants that would have been suitable for the study. Physiological changes as predictors of voice change have extensive literature support (Ashley, 2010, 2013; Barresi & Bless, 1984; Cooksey, Beckett &
Wiseman, 1985; Cooksey, 2000a, 2000b; Groom, 1984; Hollien, 2012; Killian & Wayman, 2010; Phillips, Williams & Edwin, 2012; Rutkowski, 1982; Thurman, 2012; Williams, 2012; Willis & Kenny, 2008). While age certainly correlates with voice and other physiological changes, it has been shown to be a weaker predictor of vocal outcomes than height and lung capacity. Participating choirs in the study included Florida’s Singing Sons Boychoir (FL), Texas Boys Choir (TX), the San Francisco Boys Choir (CA), and the Tucson Arizona Boys Chorus (AZ). Data for the Florida choir was collected in Fort Lauderdale, FL and the Texas choir’s data was collected in Fort Worth, TX. The San Francisco and Tucson choir’s data was collected at the International Boys’ and Men’s Choral Festival in Flagstaff, AZ on the campus of Northern Arizona University (NAU). Additional IRB permission was secured from NAU.

**Latent Variables**

In order to fully understand the initial specified model, an understanding of its structure is required. This is best accomplished through an examination of the latent variables and the theoretical paths that connect them. In the figures, latent variables are seen in ovals and measured observations are in rectangles (Figure 21).
This section provides an opportunity to examine each latent variable in isolation, and thereby understand the model’s underlying structure. This is analogous to understanding the human form through its skeleton. This section will also provide justification for the paths that connect them.

The three vocal outcomes of range, registration facility, and vocal quality examined in this study are derived from Cooksey’s typology (1977b, 2000a). In this section, they are not examined in isolation, but rather in the context of each variable that predicts them. They are acted upon either directly or indirectly by the latent variables of

- Physiology;
- Motivation; and
- Affective State.
The latent predictors and outcomes are shown in Figure 22 as part of the a priori theoretical structural model. This section will proceed from left to right in the diagram starting with Motivation, identifying and explaining the paths of the structural model.

**Figure 22.** Theoretical structural path model of vocal outcomes in adolescent males.

**Motivation and affective state**

Motivation and Affective State both function as latent variables in the model (Figure 23). They are treated together in this section in response to Linnenbrin et al. who state “there is a clear need to integrate affective processes into our cognitive models of motivation” (2011, p. 251). Charles Schmidt also integrates them in his Social-Psychological Model of Musical Ability (2011).

Known effects of Motivation and Affective State on performance outcomes justify the inclusion of them in this model (LeBlanc, 1994; Schmidt, 2011; Smith, 2011). Although direct effects of Motivation on performance outcomes have been shown in previous studies (Asmus, 1994; Austin & Vispoel, 1994; Linnenbrin-Garcia et al., 2011), indirect effects of Motivation on vocal outcomes as mediated by Affective State
(Linnenbrin-Garcia et al., 2011; Pekrun, Goetz, Titz & Perry, 2002) have also been found and are provided in the model (Figure 23).

Figure 23. Affective state as latent factor in isolation.

A single effect from Motivation to Affective State is shown in the figure; the effect is unidirectional. In SEM, since the relationship is unidirectional, it is said to be recursive. The recursive effect between Motivation and Affective State shown in the figure is supported by Weiner (1986b) as reported by Asmus (1996) who explains that through attribution “the assignment of attributed causes, emotions, or affect is made, future striving is influenced. The model of attributional development begins with an action, which leads to an outcome, which results in attributions, which produces affect. This, then, influences the next attribution sequence” (p. 10). For adolescents, motivation is still an emerging trait (Smith, 2011, p. 276), and not static. Affective state in this study is examined as a cross-sectional moment in time. As such, it influences outcomes as a mood state through which the emerging trait motivation is mediated (Watson, 1994). As this is a cross-sectional study, no significant effect of performance and Affective State on Motivation was expected.
**Physiology**

Physiology as a latent variable is shown in isolation in Figure 24. Its direct effect on the vocal outcomes of range, register facility, and vocal quality are shown.

![Diagram](image)

*Figure 24. Physiology latent variable in isolation.*

The direct effect of Physiology on overall singing is obvious, perhaps even more so in the adolescent male. Change in male vocal outcomes due to physiological changes is well established in the literature (Barresi, 1986; Cooksey, 1977a, 1977b, 1977c, 1978, 2000a, 2000b; Hollien, 2012; Thurman, 2013).

**Indicators**

Observed variables in this study are referred to as indicators so as to be consistent with the terminology of structural equation modeling (Keith, 2006; Kline, 2011) and are shown in rectangles in the figures. In this section, the indicators are grouped as endogenous and exogenous variables, roughly analogous to dependent and independent variables respectively. Endogenous latent variables are in two groups: (a) Affective State and (b) the vocal outcomes. The vocal outcomes are (a) Range, (b) Registration Fluency, and (c) Vocal Quality. In the theoretical model, Affective State functions both as a
mediator and a predictor. The predictive latent variables that are exogenous are (a) Physiology and (b) Motivation.

**Vocal Outcomes**

The vocal latent variables are derived from Cooksey’s initial vocal typology (Cooksey, 1977b, 2000b). In order to understand the vocal outcome measures of this study, a brief description of the sound samples and acoustic measuring instruments is in order. Each participant was asked to provide (a) 3 descending glides across all vocal registers on [ɑ], (b) 3 ascending glides in head voice only on [ɑ], (c) 3 descending glides in chest voice only on [ɑ], (d) 3 ascending glides in chest voice only on [ɑ], (e) 3 descending glides in head voice only on [ɑ], (f) 6 sentences, (g) 20 seconds of reading speech, (h) 20 seconds of conversational speech, and (i) 7 single pitches (D^3, G^3, C^4, F^4, Bb^4), each sung 3 times as a *messa di voce* on /ɑ/. *Messa di voce* is a crescendo-diminuendo effect on a single pitch. The use of glides and *messa di voce* are regularly used in current research on adolescent male voices (Ashley, 2009, 2013; Williams, Welch & Howard, 2005; Williams, 2010, 2012). This is also an approach that voice science supports and has been established in consultation with the voice science member of the dissertation committee.

A Zoom H6 portable audio recorder was used to record the samples. The Zoom H6 records in both .wav and .mp3 formats and can export via USB and SD cards. The Zoom H6 provides an acceptable level of bit resolution for research, 26 bits at 44.1 kHz (Svec, 2010) is portable and easy to use (ChoralNet, http://choralnet.org/230324). The microphone used will be the XY mic, which is included with the Zoom H6. The XY is unidirectional as recommended by Svec (2010), which will be ideal for this study in
which room noise is a possibility. Its maximum sound pressure input is 136 dB SPL, which is an acceptable level for this study (Baken & Orlikoff, 2000; Svec, 2010).

The acoustic properties of the samples were evaluated using spectral analysis via Praat (Boesma & Weenink, 2013). This software displays pitch and intensities as a lines, and individual formants as a grayscale whose density reflects amplitude of each formant. This facilitates evaluation of the relationship of individual formants in relationship to each other as well as the source pitch ($F_0$). Praat also provides maximum, minimum, and mean pitches and intensities of selected audio excerpts, which were used in the data analysis.

**Range.** The proposed indicators of the latent variable of Range were mean measure of highest terminal pitch in head voice (R-HTP) and lowest terminal pitch in chest voice (R-LTP). The mean R-HTP and LTP were measured and reported by Praat software, expressed in hertz (Hz). As Praat is a digital acoustic measure, high reliability was expected.

*Figure 25. Range indicators.*

**Registration Fluency.** The proposed indicators of Fegistration Fluency were Passaggio, Overlap, and Intensity (Figure 26). These were be measured and reported by digital software. As such, they were expected to have high reliability.
Spectral analysis was used to determine upper register LTP (U-LTP), lower register HTP (L-HTP), and lower register LTP (L-LTP) by observing formant activity. This is shown in Figure 27 where the center of the disruption of lower formants determines the U-LTP.

Passaggio is expressed as an absolute range in hertz (Hz) calculated from mean HTP and LTP passaggio pitches (P-HTP and P-LTP) derived from the vocal glides across all registers. In the descending glide shown in Figure 28, a disruption of the lower formants (shown in red) denotes the beginning of the passaggio. The point of greatest disruption was the P-HTP. The beginning of the phonational gap denotes the P-LTP in this case. In other cases, the P-LTP may be observed in a disruption of formants similar those at the P-HTP. The difference in Hz between P-HTP and P-LTP were the absolute
range (AR) of the passaggio. A high value in passaggio could indicate high registration fluency with greater midrange AR indicating finer motor control of intrinsic laryngeal musculature (Thurman, Welch, Theimer, Grefsheim & Feir, 2000; Titze, 1994).

Figure 28. Spectral display demonstrating passaggio AR determination.

*Register Overlap* was the total range in hertz of the pitches shared by the head voice and chest voice registers. This was calculated by subtracting the mean falsetto LTP from the mean modal HTP. A high value in register overlap could indicate high registration fluency since greater midrange indicates finer motor control of intrinsic laryngeal musculature (Thurman, Welch, Theimer, Grefsheim & Feir, 2000; Titze, 1994). Figure 29 shows this overlap in red. The term *register* was substituted for Lecks’ word *range* for consistency.
Figure 29. Register overlap as seen in Leck (2009a) denoted in red.

Intensity was an additional indication of registration fluency (Titze, 1994), using *messa di voce* on 146 Hz, 196 Hz, 261 Hz, 349 Hz, and 466 Hz. The maximum and minimum intensity and range for each of the pitches were then extracted using Praat. The resultant values are expressed in dB, and higher values for range indicate greater Registration Fluency (Titze, 1994).

**Vocal Quality.** The proposed indicators of Vocal Quality were measures within the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V), which were used to analyze the reading passage. A two-judge panel of experts on male changing voice completed the CAPE-V.

Figure 30. Vocal Quality latent indicators.

The CAPE-V (Consensus Auditory Perceptual Evaluation of Voice) assessment is a perceptual measure used by voice pathologists on a reading of six sentences. Although its assessment purpose is to describe vocal deviance, it standardizes verbal description of vocal qualities in a way that can be applied to adolescent male voice. The
vocal qualities measured by the CAPE-V are (a) overall quality, (b) roughness, (c) breathiness, (d) strain, (e) pitch, and (f) loudness. Evaluation of each quality is expressed by an x mark on a 100-millimeter continuum line ranging from “mildly deviant” to “severely deviant,” indicating the numeric value of the quality. It has an acceptable level of reliability and validity, and is regularly used in vocal pathology analysis (ASHA, 2006; Bursac et al, 2011).

For this study, the CAPE-V measures of overall quality, roughness, breathiness, and strain were applied to the readings. Pitch and loudness were excluded as they were measured acoustically elsewhere in this study. Also, to adapt the scale to a more suitable form, the “mildly deviant” pole of the continuum was changed to “healthy.” The continuum markings were expressed in millimeters, and the four values were summed together to yield a composite score to limit the number of parameters. (Appendix A) Since higher values in the CAPE-V indicate poorer vocal quality, the composite score was subtracted from 100 to reverse code the measure.

Definitions provided in the CAPE-V booklet were applied in judgments and are as follows:

**Overall quality:** Global, integrated impression of voice deviance.
**Roughness:** Perceived irregularity in the voicing source.
**Breathiness:** Audible air escape in the voice.
**Strain:** Perception of excessive vocal effort (hyperfunction). (ASHA, 2006)

**Predictors**

**Motivation.** Motivation was measured by the Asmus Measure of Motivation: Magnitude of Motivation (AMM:MM; Asmus, 1989). This assessment of 23-items is comprised of four factors: (1) Ability Self-concept, (2) Personal Commitment, (3) Choir Compared to Other Activities, and (4) Affect for Ensemble. Items about class and
classroom were changed to choir and rehearsal room to accommodate the different context of the participants (Appendix B). Each item was rated on a 4-point Likert scale ranging from strongly agree to strongly disagree. The test has a reliability of Cronbach’s $\alpha = .932$. (Asmus, 1989). Evidence of external validity in regards to FFI personality measures (Lounsbury et al., 2003) has been suggested by other data (Denison, 2011), which found significant correlation between openness and magnitude of motivation ($r = .595, p < .01$) and extroversion and magnitude of motivation ($r = .764, p < .01$).

Figure 31. Motivation indicators.

**Affective State.** The Positive and Negative Affect Schedule-Short Form (PANAS) provided two indicators of Affective State: Positive and Negative (Watson, Clark & Telegen, 1988; Watson & Clark, 1999). This study measured how participants felt at “this moment,” as opposed to “today,” “past few days,” or “this week,” which were alternative time frames offered by the PANAS. Responses to the 20 single-word items were on a 5-point Likert scale ranging from “very slightly/not at all” to “extremely.” Both positive and negative affect scales have acceptable levels of reliability (Cronbach’s $\alpha = .89, .85$ respectively). They also have “excellent convergent and discriminant correlations with lengthier measures of . . . underlying mood factors:” the Hopkins
Symptom Checklist (HSCL), Beck Depression Inventory (BDI), and STAI State Anxiety Scale (A-State) (Watson, Clark & Tellegen, 1988, p. 1068).

*Figure 32. Affective State indicators.*

**Physiology.** In the proposed model, physiology is expressed in the measures of Height (inches), Weight (lbs.), and Lung Capacity (ml). All three have been regularly included in studies on adolescent male voice (Ashley, 2010, 2013; Barresi & Bless, 1984; Cooksey, Beckett & Wiseman, 1985; Cooksey, 2000a, 2000b; Groom, 1984; Hollien, 2012; Killian & Wayman, 2010; Phillips, Williams & Edwin, 2012; Rutkowski, 1982; Thurman, 2012; Williams, 2012; Willis & Kenny, 2008).

*Figure 33. Physiology indicators.*
Height has been shown to be a strong predictor of voice stage (Cooksey, 2000a) justifying its inclusion in the model. The use of Weight as an indicator has dubious support from the literature in the past (Barresi & Bless, 1984), but recent research has suggested a relationship between weight, phonational gap, speaking pitch, and register (Cooksey, 2000a; Willis & Kenny, 2008) that supports its inclusion in the study. The inclusion of Lung Capacity in this study is supported by a discriminant function analysis by Cooksey (2000a), which showed lung capacity as the “most potent predictor of voice change” and “correlated significantly with certain acoustic variables” (2000a, p. 731).

Procedure

Once approval was secured from IRB, data collection began at the rehearsal sites of each choir as agreed by the investigator and the gatekeeper of each choral organization. Before collection, gatekeepers received information detailing the procedure: (a) permissions, (b) scheduling, (c) registration nomenclature, (d) survey administration site, (e) audio recording site, (f) physiological measurement procedure, and (g) unanticipated issues related to the study.

Permission forms were distributed to the participants to take home. Upon distribution, the investigator and gatekeeper described the study to, and fielded questions from the participants and family members. Parents were encouraged to discuss the study with their sons (Ashley, 2013). Once permissions were secured, participants were coded by assigning a letter denoting their choir, and a number denoting participant. For example, Johnny Doe from Florida’s Singing Sons is fifth in the choir’s roster; his code would be F5. A key with each participant’s name and identification tag was provided to the
participant’s choir director for their reference. Once coding was complete and directors confirmed receipt of the codes, the investigator’s copy of the key was destroyed.

There were five types of data collected from each singer: (a) singer survey (AMMM:MM), (b) physiological measurement (P-MAV), (c) director survey (D-MAV), (d) Positive and Negative Affective Schedule (PANAS), and (e) audio recording. Data collection within each choral organization occurred in two sessions: one with the full group of participants, the other with individuals. Group testing was comprised of singer survey and director survey. Each director was encouraged to take the director survey concurrently with the singers. The individual portion began with physiological measurement, followed by the PANAS survey, and then the audio recording.

The singer survey (Appendix G) was the Asmus Magnitude of Motivation test (AMMM:MM) The survey averaged 10 minutes and was administered separately from the physiological measurement and sound recording testing. The PANAS test (Appendix H), however, was administered immediately before each participant’s audio recording. Test administration and measurement followed the written instructions of the measurement procedures (Appendix I). The sound recording of participants followed a script of the audio recording procedures (Appendix K). Each participant’s sound recording was saved as a separate file. Follow up questions to the instructions for each sound item were permitted to aid in clarity for the participant.

Audio data was recorded in a room with as little reverberation as possible, colloquially called a “dry acoustic.” In most cases, ambient noise from neighboring rooms was present. Particular attention was paid to consistency in the audio recording, specifically the participants’ and recorder’s placement, which was 20 cm apart on a
horizontal plane. A Zoom H6 recorder (http://www.zoom.co.jp/products/h6/spec/) was used for audio data collection.

The physiological measurement lasted about 3-5 minutes for each participant. The PANAS lasted about 2-3 minutes per participant, the AMMM:MM 10 minutes, and the sound recording 7-12 minutes. Director surveys were turned in separately at varying times. Total data collection time per singer was about 20-25 minutes. This time was divided into a group session (AMMM:MM, director survey) and individual session (physiological measurement, PANAS, and sound recording). The use of a research assistant accelerated the overall rate of data collection by collecting PANAS and physiological data of participants during their wait for sound recording.

**Data Analysis**

Data collected were analyzed by SPSS and MPlus. Data were initially analyzed with descriptive statistics for normality, homogeneity, sphericity, and missing values. The descriptive statistics were evaluated to establish suitability for inferential analysis.

1. What interrelationships existed within and among the following latent variables:
   (a) Physiology, (b) Motivation, (c) Affective State, (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

   Bivariate correlations were examined and significant correlations reported. The resultant correlation matrix was retained for further analysis.

2. What combination of variables and latent factors of (a) Motivation, (b) Physiology, and (c) Affective State best predicted the latent vocal factors of (d) Range, (e) Registration Fluency, and (f) Vocal Quality?
Combinations of indicators on latent vocal outcomes were examined through Exploratory Factor Analysis (EFA) of the correlation matrix to examine combinations could best indicate the latent variables. The resultant factors were then used in part to respecify the model.

3. *Could a tentative model predicting vocal achievement in adolescent males be created and statistically tested?*

To answer the third question, a two-step hybrid structural equation model was applied. The first step was a confirmatory factor analysis (CFA) of the measurement model (Figure 34). The CFA was intended to yield beta weight results of the indicators regressed on the latent factors. CFA also measured covariance between the latent variables. The resultant latent covariances were used to address the first and second research question.

*Figure 34. Measurement model of vocal outcomes in adolescent males.*

Step two of the hybrid model determined path coefficients, standard error, confidence intervals, and *p*-values of the a priori model between the latent variables (Figure 35) through structural regression. The structural regression model with acceptable
fit indices and parsimony supported by logic, literature, and experience was retained as the tentative model.

**Figure 35.** Path model of vocal outcomes in adolescent males.

**Summary**

In statistical modeling, as in most statistical techniques, the control of unexplained variance is desirable. This chapter has sought to control unaccounted variance first through its sample. The boychoir context provides control of variance that occurs due to gender, vocal experience, and family support in general populations. This is important in structural equation modeling since additional factors create paths, which add undesired complexity to the model. Also, although SEM has a high tolerance of homogeneity under .90 in large samples (Kline, 2011), indicators that are expected to have high homogeneity with other factors were eliminated increasing the parsimony of the model and accommodate the smaller sample size.

High reliability of measures was expected due to the written tests used (AMMM:MM, PANAS) and the digital acoustic measures. The CAPE-V, while a perception measure, has been shown to be superior in validity and reliability to other measures (Bursac et al, 2011). Also, the use of a single recorder provided the desired consistency of audio sampling.
In providing external control of variance through the sample and by using indicators with suitable reliability and validity, a clearer understanding of the relationships between indicators and factors can be observed. A magnitude of the effect of psychosocial predictors on vocal outcomes can be identified and their relationships clarified in an emergent structural model.
CHAPTER FOUR
RESULTS AND DISCUSSION

A thorough evaluation of the theoretical model required a preliminary analysis of the data at the micro level through descriptive and correlational procedures. Descriptive analysis examined the suitability of the data for later analysis. Subsequent analyses were conducted to answer the three questions of the study:

1. What interrelationships existed within and among the following latent variables: (a) Physiology, (b) Motivation, (c) Affective State, (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

Pearson r correlations were used to answer this question. The first set of analyses of observed variables considered correlations within proposed latent factors. This was followed by correlational analyses of observed variables between latent factors.

2. What combination of variables and latent factors of (a) Motivation, (b) Physiology, and (c) Affective State best predicted the latent vocal factors of (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

Combination of observed variables for prediction are best served by regression, which is a core statistical process of SEM (Kline, 2011). The difference between a multiple regression and a structural regression model is that a structural regression model allows variables (indicators) and structural variables (latents) to be estimated simultaneously within a single model (Kline, 2011). Before the model was tested, an exploratory factor analysis was conducted to determine the appropriate observed variables that would best group to create latent variables for a structural regression.
3. What model of the variables best predicts vocal achievement outcomes in adolescent males?

The model that should best fit to the data was retained. Several fit indices were used to determine goodness of fit.

**Preliminary Data Analysis**

A preliminary descriptive data analysis was conducted to determine the suitability of the data set and to establish the suitability of variable definitions to be used in subsequent analyses. The preliminary results of descriptive and correlative results are grouped within the latent factors proposed in the proposed model (Figure 22, p. 74) with several noteworthy changes. Ranges and passaggio were considered together due to the nature of the measures. Variables of interest raised by the literature review were also included. Mean substitution by age was used to fill missing data (Tabachnick & Fidell, 2013).

**Descriptive Analysis Results**

**Physiology.** Descriptive results in this section were grouped by literature, theory, and method as described in the previous chapters. Table 2 displays the physical characteristics of the participants. The standard deviation of Height (18.73 $SD$) and high kurtosis reflects the wide age range of participants. Normality is verified by the low standard deviation in relation to the mean ($M = 12.93; SD = 2.47$) a very low positive skewness (.08) and a slight negative kurtosis (-.59). The high negative skew and positive kurtosis indicate a greater number of taller participants close to the same height, indicating a stabilization of height as boys grew older. This is to be expected of growing boys.
Because Weight was outside normal distribution, a Height-weight ratio was added to the data, which resulted in a normal distribution. This is consistent with Cooksey’s inclusion of such a ratio in his analyses (2000a).

Fewer data points for Pitch (conversation) exist because after some initial factor analysis it was found to have low loading on factors, and was not further analyzed. This choice is also supported by the fact that conversation is not performative in nature compared to reading.

Table 2

*Physical Characteristics*

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Skew</th>
<th>Kurt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>192</td>
<td>12.80</td>
<td>2.48</td>
<td>.20</td>
<td>-.79</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>192</td>
<td>159.30</td>
<td>15.56</td>
<td>-.06</td>
<td>-.95</td>
</tr>
<tr>
<td>Weight (lb.)</td>
<td>192</td>
<td>122.82</td>
<td>46.68</td>
<td>1.21</td>
<td>2.23</td>
</tr>
<tr>
<td>Height/Weight</td>
<td>192</td>
<td>1.43</td>
<td>.39</td>
<td>.33</td>
<td>-.30</td>
</tr>
<tr>
<td>Lung Capacity (ml)</td>
<td>192</td>
<td>2744.52</td>
<td>962.40</td>
<td>.17</td>
<td>-.96</td>
</tr>
<tr>
<td>Pitch (reading)</td>
<td>192</td>
<td>216.53</td>
<td>62.10</td>
<td>.12</td>
<td>-.86</td>
</tr>
<tr>
<td>Pitch (conversation)</td>
<td>145</td>
<td>201.66</td>
<td>67.5</td>
<td>.40</td>
<td>-.71</td>
</tr>
</tbody>
</table>

*Note.* Speaking pitches are in hertz.

**Motivation and Affective State.** Table 3 shows descriptive results for motivational and affective variables. Motivation variables were normally distributed. The participants appeared to have a strong self-concept of their vocal competence as would be expected of boys in high-level community chorus programs. They were less certain when compared to others. Self-concept, a variable only measured by two items, was discarded in future analyses for reasons of high kurtosis compared with the other psychological variables.
Affect, as measured by the PANAS, indicated a high Positive Affect with normal distribution. Negative Affect’s high skewness and kurtosis indicate a low presence of negativity during the data collection process. This would be expected from a group of participants whose participation in singing is voluntary and extensive.

Despite the positive bias of the participants, the distribution of Positive Affect showed normal distribution. This is consistent with the reports of the test’s validity in both its creation (Watson, Clark, & Tellegen, 1988) and its application (Thompson, 2007).

Table 3

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motivational and Affective Characteristics</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Self-concept</strong></td>
</tr>
<tr>
<td><strong>Commitment</strong></td>
</tr>
<tr>
<td><strong>Compared to Others</strong></td>
</tr>
<tr>
<td><strong>Choir Motivation</strong></td>
</tr>
<tr>
<td><strong>Positive Affect</strong></td>
</tr>
<tr>
<td><strong>Negative Affect</strong></td>
</tr>
</tbody>
</table>

*Note.* High scores indicate greater motivation or affect.

**Ranges and passaggio.** Table 4 shows the various range measure results. They show a group of experienced singers with wide ranges across registers. Their similar experiences in training and performance are the likely cause of the high positive skew of the Highest Terminal, Highest Chest, Lowest Head Pitches, as well as Head, Passaggio, and Total Range. All of these would be expected of experienced boy singers who started training before their voice change and continued performing into their late teens.

With a large sub-group of experienced participants, it is not surprising to see high positive skew and kurtosis on the Highest Terminal Pitch, and greater normality on the
lowest. This also explains the high skewness and kurtosis values in Highest Chest, Lowest Head, and Passaggio Range.

The high kurtosis values are likely the result of a group of participants that have shared similar training and performance experiences, which would explain such a dense grouping around the mean, especially in regards to range. Group warm-ups that do not account for individual differences could be seen as creating a ceiling effect on range by only allowing range extremes and tessituras that are accessible to the majority of the singers.

Table 4

Vocal Ranges

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>M</th>
<th>SD</th>
<th>Skew</th>
<th>Kurt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head Voice Range</td>
<td>191</td>
<td>428.72</td>
<td>286.62</td>
<td>.87</td>
<td>1.14</td>
</tr>
<tr>
<td>Chest Voice Range</td>
<td>191</td>
<td>170.65</td>
<td>87.08</td>
<td>.68</td>
<td>1.97</td>
</tr>
<tr>
<td>Total Range</td>
<td>192</td>
<td>566.50</td>
<td>253.78</td>
<td>1.55</td>
<td>3.85</td>
</tr>
<tr>
<td>Highest Terminal Pitch</td>
<td>192</td>
<td>718.28</td>
<td>254.30</td>
<td>1.17</td>
<td>2.31</td>
</tr>
<tr>
<td>Lowest Terminal Pitch</td>
<td>192</td>
<td>151.78</td>
<td>59.76</td>
<td>.76</td>
<td>.40</td>
</tr>
<tr>
<td>Highest Passaggio Pitch</td>
<td>140</td>
<td>349.13</td>
<td>83.67</td>
<td>.52</td>
<td>.73</td>
</tr>
<tr>
<td>Lowest Passaggio Pitch</td>
<td>139</td>
<td>271.62</td>
<td>86.61</td>
<td>.22</td>
<td>-.38</td>
</tr>
<tr>
<td>Passaggio Range</td>
<td>154</td>
<td>72.22</td>
<td>60.34</td>
<td>1.56</td>
<td>3.94</td>
</tr>
<tr>
<td>Highest Chest Pitch</td>
<td>140</td>
<td>319.92</td>
<td>102.29</td>
<td>1.13</td>
<td>1.90</td>
</tr>
<tr>
<td>Lowest Head Pitch</td>
<td>130</td>
<td>297.85</td>
<td>94.33</td>
<td>.45</td>
<td>1.09</td>
</tr>
</tbody>
</table>

Note. All pitches are in hertz.

Intensities. Table 5 shows maximum, minimum, and range intensities for five pitches across the commonly accepted vocal registers. 261 and 349 Hz were found within normal parameters. 466 Hz had the highest mean intensity (62.20 dB) and the highest kurtosis (9.12). Despite that, mean decibel values are in close proximity across the
pitches. Consideration of 146 Hz in the data analysis was abandoned partway through the analysis due to the high number of boys unable to access the pitch.

Table 5

*Maximum, Minimum, and Range Intensities for pitches at 146, 196, 261, 349, & 466 Hz*

<table>
<thead>
<tr>
<th></th>
<th>146Hz</th>
<th>196Hz</th>
<th>261Hz</th>
<th>349Hz</th>
<th>466Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maximum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>60.92</td>
<td>57.75</td>
<td>59.59</td>
<td>59.93</td>
<td>62.20</td>
</tr>
<tr>
<td>( SD )</td>
<td>8.79</td>
<td>12.18</td>
<td>10.11</td>
<td>9.36</td>
<td>9.70</td>
</tr>
<tr>
<td>Skew</td>
<td>.35</td>
<td>-1.74</td>
<td>-.45</td>
<td>-.84</td>
<td>-2.02</td>
</tr>
<tr>
<td>Kurt</td>
<td>2.42</td>
<td>5.27</td>
<td>.14</td>
<td>1.26</td>
<td>9.12</td>
</tr>
<tr>
<td><strong>Minimum</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>34.06</td>
<td>32.41</td>
<td>33.96</td>
<td>35.07</td>
<td>38.01</td>
</tr>
<tr>
<td>( SD )</td>
<td>7.55</td>
<td>8.90</td>
<td>8.40</td>
<td>8.65</td>
<td>9.59</td>
</tr>
<tr>
<td>Skew</td>
<td>.93</td>
<td>-.53</td>
<td>-.18</td>
<td>-.34</td>
<td>-.42</td>
</tr>
<tr>
<td>Kurt</td>
<td>4.06</td>
<td>1.14</td>
<td>-.06</td>
<td>.97</td>
<td>1.19</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( M )</td>
<td>25.51</td>
<td>21.77</td>
<td>24.81</td>
<td>24.18</td>
<td>23.25</td>
</tr>
<tr>
<td>( SD )</td>
<td>10.63</td>
<td>11.54</td>
<td>8.29</td>
<td>7.31</td>
<td>7.96</td>
</tr>
<tr>
<td>Skew</td>
<td>-1.20</td>
<td>-1.02</td>
<td>-.54</td>
<td>-.64</td>
<td>-1.25</td>
</tr>
<tr>
<td>Kurt</td>
<td>5.02</td>
<td>1.17</td>
<td>2.91</td>
<td>3.03</td>
<td>3.07</td>
</tr>
<tr>
<td>( n )</td>
<td>83</td>
<td>162</td>
<td>185</td>
<td>185</td>
<td>182</td>
</tr>
</tbody>
</table>

*Note.* All intensities are in decibels.

**Vocal quality.** Table 6 shows the voice quality of the reading passage. One would expect that breathiness would also be present since such irregularities in the mucosal layer of the vocal folds cause weaker glottal closure, but that is less the case with this group as seen in the high positive skew of the breathiness variable.
Table 6

*Voice Quality of Reading*

<table>
<thead>
<tr>
<th></th>
<th>$M$</th>
<th>$SD$</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness</td>
<td>22.20</td>
<td>10.19</td>
<td>.65</td>
<td>.22</td>
</tr>
<tr>
<td>Breathiness</td>
<td>13.19</td>
<td>9.06</td>
<td>1.80</td>
<td>4.04</td>
</tr>
<tr>
<td>Strain</td>
<td>11.39</td>
<td>9.06</td>
<td>1.83</td>
<td>3.36</td>
</tr>
<tr>
<td>Overall</td>
<td>15.95</td>
<td>9.29</td>
<td>1.40</td>
<td>2.06</td>
</tr>
</tbody>
</table>

*Note.* Higher values indicate greater vocal irregularity. $N = 192$.

**Correlational Analysis Results**

**Physiology.** Table 7 shows the strong relationship between the physical indicators. Age accounts for over half the variance in speaking pitch encountered in this data. As a result, speaking pitch was reclassified as a physiological indicator rather than a vocal one. The next best correlation with speaking pitch was height. Because of the high correlations among the variables, dimension reduction by factor analysis is indicated for greater parsimony in the model.

Table 7

*Pearson Bivariate Correlations of Physical Traits*

<table>
<thead>
<tr>
<th></th>
<th>Height</th>
<th>Weight</th>
<th>Height/Weight</th>
<th>Lung Capacity</th>
<th>Reading</th>
<th>Conversation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.82</td>
<td>.69</td>
<td>-.66</td>
<td>.72</td>
<td>-.76</td>
<td>-.75</td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td>.79</td>
<td>-.75</td>
<td>.77</td>
<td>-.74</td>
<td>-.72</td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
<td>-.92</td>
<td>.63</td>
<td>-.57</td>
<td>-.56</td>
</tr>
<tr>
<td>Height/Weight</td>
<td></td>
<td></td>
<td>-.62</td>
<td>.55</td>
<td>.53</td>
<td></td>
</tr>
<tr>
<td>Lung capacity</td>
<td></td>
<td></td>
<td>-.63</td>
<td>.81</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* All correlations are significant ($p < .01$).
**Motivation.** Table 8 shows the relationship among the domains of motivation as measured by the Asmus Measures of Motivation in Music (1989). While a significant relationship between domains is clear, their $r$ values are such that they can be considered unique parts of a single construct; that is, a latent variable of motivation is indicated by a singer’s commitment, how they compare themselves to others, and their feelings about being in the choir. The higher correlation between Commitment and Compared to Others ($r = .70$) is likely due to the structure of the community choruses and the experience of the singers. While more highly correlated, the distributions were not similar; Commitment show greater normality than Compared to Others. Due to this difference, Commitment and Compared to Others were retained for further analysis.

Table 8

*Pearson Bivariate Correlations of Motivation Domains*

<table>
<thead>
<tr>
<th></th>
<th>Commitment</th>
<th>Compared to others</th>
<th>Choir motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-concept</td>
<td>.36**</td>
<td>.29**</td>
<td>.22**</td>
</tr>
<tr>
<td>Commitment</td>
<td></td>
<td>.70**</td>
<td>.51**</td>
</tr>
<tr>
<td>Compared to Others</td>
<td></td>
<td></td>
<td>.55**</td>
</tr>
</tbody>
</table>

*Note.* All correlation are significant ($p < .01$).

**Affective state.** Positive and Negative Affect were correlated ($r = .45$, $p < .01$). One may expect a negative correlation, but since they were measured on the same scale, high positive affect and high negative would be positively correlated. Hypothetically, if a boy was highly interested (positive affect = 5) and highly disgusted (negative affect = 5) the two items of seeming opposite affect that would be perfectly and positively correlated due to how the test was scaled. In actuality, the two affect PANAS test measures are continuums that can be thought of as axes in a circumflex model.
Ranges and passaggio. Table 9 shows the bivariate correlations between the pitch and range variables. Strong relationships are seen in those indicators that measure Head, Chest, and Total Range. Passaggio and mid-voice ranges (HPP, LPP, PR, LHP, HCP) were either not significant or showed moderate to weak relationships.

Table 9

Pearson Bivariate Correlations of Ranges

<table>
<thead>
<tr>
<th></th>
<th>CVR</th>
<th>TR</th>
<th>HTP</th>
<th>LTP</th>
<th>HPP</th>
<th>LPP</th>
<th>PR</th>
<th>HCP</th>
<th>LHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVR</td>
<td>.29**</td>
<td>.87**</td>
<td>.88**</td>
<td>.05</td>
<td>.08</td>
<td>.01</td>
<td>.1</td>
<td>.31**</td>
<td>-.14</td>
</tr>
<tr>
<td>CVR</td>
<td>.37**</td>
<td>.31**</td>
<td>-.25**</td>
<td>.07</td>
<td>.02</td>
<td>.07</td>
<td>.79**</td>
<td>-.08</td>
<td></td>
</tr>
<tr>
<td>TR</td>
<td>.97**</td>
<td>-.13</td>
<td>.06</td>
<td>-.08</td>
<td>.19**</td>
<td>.27**</td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTP</td>
<td>.11</td>
<td>.17**</td>
<td>.06</td>
<td>.14</td>
<td>.36**</td>
<td>.21*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LTP</td>
<td>.45**</td>
<td>.60**</td>
<td>-.21*</td>
<td>.4**</td>
<td>.42**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HPP</td>
<td>.8**</td>
<td>.24**</td>
<td>.35**</td>
<td>.40**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LPP</td>
<td>-.36**</td>
<td>.40**</td>
<td>.39**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR</td>
<td>-.07</td>
<td>-.06</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HCP</td>
<td>.18*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: HVR = head voice range; CVR = chest voice range; TR = total range; HTP = highest terminal pitch; LTP = lowest terminal pitch; HPP = highest passaggio pitch; LPP = lowest passaggio pitch; PR = passaggio range; HCP = highest chest pitch; LHP = lowest head pitch

* p < .05, ** p < .01

Correlations across variables groups. In understanding the decisions in dimension reduction made later in the analysis, recognition of other correlations at this point across a priori factors is valuable. Some correlations indicate a relationship unique to the social context of the study, but others address conclusions made in prior literature.

Physiology. Height correlated directly with several pitch outcomes: Highest Pitch of Passaggio (-.46, p < .01), Lowest Pitch of Passaggio (-.56, p < .01), Lowest Terminal Pitch (-.76, p < .01), and Highest Terminal Pitch (-.21, p < .01). The negative correlation
of height to highest pitch is certainly to be expected: taller boys cannot sing as high. The lower correlation value, however, especially when compared to lowest terminal pitch, is worth noting. This is likely attributed to the multiple register singing context of the participants.

Age had a weaker correlation of pitch outcomes. Highest Terminal Pitch (-.16, \( p < .05 \)), Lowest Terminal Pitch (-.721, \( p < .01 \)), and Highest Chest Pitch (-.411, \( p < .01 \)) all scored lower than correlations with Height.

As one would expect, there was a high correlation of Height to the Intensity Range of 146 Hz (.79, \( p < .01 \)). Age, however, was also shown to be a comparable predictor to Height in intensity measures of higher pitches. Both Height and Age correlated with reading pitch at the exact same value (-.71, \( p < .01 \)).

As seen in Table 10, Age and Height have similar, and occasionally identical correlations with vocal intensity outcomes. The sole exception is the Intensity Range of 466 Hz, which has low correlation to Age and no significant correlation to Height. In fact, none of the physiological measurements (Height, Weight, and Lung Capacity) correlated significantly with the intensity range of 466 Hz.

Table 10

<table>
<thead>
<tr>
<th></th>
<th>196 Hz</th>
<th>261 Hz</th>
<th>349 Hz</th>
<th>466 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age</td>
<td>Height</td>
<td>Age</td>
<td>Height</td>
</tr>
<tr>
<td>Maximum</td>
<td>.58</td>
<td>.60</td>
<td>.58</td>
<td>.58</td>
</tr>
<tr>
<td>Minimum</td>
<td>.39</td>
<td>.43</td>
<td>.42</td>
<td>.43</td>
</tr>
<tr>
<td>Range</td>
<td>.58</td>
<td>.56</td>
<td>.39</td>
<td>.35</td>
</tr>
</tbody>
</table>

Note. All correlations significant \( (p < .01) \) except Range x Height at 466 Hz.
Such a close set of correlation values merit closer scrutiny whether Age or Height is a better predictor of elements of voice change. For this study, height was given preference as a predictor as reported by Cooksey (2000a).

**Motivation and Affective State.** The correlation output showed several significant correlations \( p < .05 \) between motivation and affective state: positive affect to self image -.16, negative affect to self image .15, negative affect to commitment .194, positive affect to commitment -.17, positive affect to compared to others .19. None of these were so highly correlated as to be a concern to homogeneity. Affective state variables and vocal outcome variables had no correlation.

**Exploratory Factor Analysis**

In order to verify the variables selected a priori for later analysis, an exploratory factor analysis using a principal factors extraction technique with varimax rotation was performed. The analysis was conducted on (1) the four motivation components, (2) the two affective states, (3) the terminal pitch values and ranges of chest voice, head voice, and passaggio, (4) the terminal decibel values and ranges of the 5 *messa di voce* samples, (5) the four measures of voice quality, and (6) the physiological measurements. Several variables appeared with strong loadings, but the resulting matrix was not positive definite, which meant that further analysis could not be conducted. The resultant scree plot also displayed several points of inflexion, indicating several possible numbers of factors.

In order to determine the source of error, an additional principal factor extraction with varimax rotation was performed with factor constraints to ascertain highly-correlated groupings, low loadings, and cross loadings. Variables with low standardized loadings below .40 were removed (Tabachnick & Fidell, 2013).
Variables removed by this procedure included Lung Capacity, which showed promise in Cooksey’s research as a predictor of voice outcomes (2000a). In the present study, a ceiling effect was observed during data collection when older participants regularly exceed the maximum measure (5000 ml) of the spirometer. Its elimination removed several cross-loadings in the analysis.

Conversation Pitch ($M = 201.66$) was removed and Reading Pitch ($M = 215.36$) was retained. Reading seemed a logical choice as a more formal representation of a speaking pitch variable, similar in design construct to the vocal outcomes. Height and Weight were at first subsumed into a Height/Weight Ratio, a variable supported by Cooksey (2000a). Maximum and minimum intensities were not retained as they often grouped with physiology at lower loadings. Intensity Range of 146 Hz was also eliminated due to incomplete data. Pitch range measures of Passaggio, Highest Chest, and Lowest Head were regularly grouped with physiologic maturity measures at lower loadings and were thus removed. These removals yielded a suitable matrix for further analysis.

The most valuable information gleaned from the analysis was the consistent grouping of the intensity ranges of 261 Hz, 349 Hz, and 466 Hz across several different levels of factor constraints. This grouping supports the understanding of registration fluency as a function of intensity control rather than as range that is beginning to be addressed in the literature (Ashley, 2013; Williams, 2012, 2013). Variables of range that had highest factor loadings with no cross-loadings were Chest Range, Head Range and Total Range.
In sum, six factors were extracted from the correlation matrix supported by a priori theory, literature and logic: Vocal Quality, Motivation, Range, Registration Fluency, Physical Maturity, and Affective State. The loadings of variables on each factor ranged from “good” to “excellent” (Tabachnick & Fidell, 2013). There were no crossloadings above .40. Table 11 displays the retained factors, variables, and loadings.

Table 11

*Exploratory Factor Analysis with Varimax Rotation*

<table>
<thead>
<tr>
<th>Variable/Factor</th>
<th>Vocal Quality</th>
<th>Motivation</th>
<th>Range</th>
<th>Registration Fluency</th>
<th>Physical Maturity</th>
<th>Affective State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughness</td>
<td>.925</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strain</td>
<td>.915</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Breathiness</td>
<td>.902</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compared to others</td>
<td></td>
<td>.873</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commitment</td>
<td></td>
<td>.858</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Affect for choir</td>
<td></td>
<td>.761</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total range</td>
<td></td>
<td></td>
<td>.939</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Head range</td>
<td></td>
<td></td>
<td>.931</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest range</td>
<td></td>
<td></td>
<td>.520</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity range at 349 Hz</td>
<td></td>
<td></td>
<td></td>
<td>.873</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity range at 466 Hz</td>
<td></td>
<td></td>
<td></td>
<td>.816</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intensity range at 261 Hz</td>
<td></td>
<td></td>
<td></td>
<td>.693</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.898</td>
<td></td>
</tr>
<tr>
<td>Reading Pitch</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-.898</td>
<td></td>
</tr>
<tr>
<td>Positive Affect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.801</td>
<td></td>
</tr>
<tr>
<td>Negative Affect</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.566</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Factor loadings lower than .40 are not reported.
Figure 36 shows the respecified model based in part on a priori theory, literature, descriptive analysis of the data, EFA, and logic. Variables with high loadings that contributed to a positive definite correlation matrix were retained while those with lower loadings that confounded a positive definite matrix were eliminated. A positive definite matrix ensures that no division by zero will take place during the estimation of the model’s parameters. Although Affective State showed no significant correlation to vocal outcomes, it was part of the initial model. It was retained to investigate the loadings under SEM, which uses the unstandardized covariance matrix rather than the correlation matrix. Spoken vocal quality was moved to a predictor position which is consistent with practice (Davison, 2011) and supported by correlation data.

Figure 36. Respecified model.

**Structural Equation Model**

The respecified model derived in part from the EFA was examined for fit to the data through structural equation modeling (SEM). For the SEM, two-step estimation was
used. The first step was a measurement model using Confirmatory Factor Analysis (CFA) to uncover any measurement issues and confirm the choices made in the EFA. The results of the CFA were used to respecify the model. The revised measurement model was examined for identification; that is, whether a unique set of parameter estimates are theoretically possible (Klein, 2011).

The second step was a structural test of the respecified model structural model using just the latent factors derived from theory, literature, and the measurement model. While slightly more complex than one-step modeling, the two-step approach is better because it allows for separation of measurement issues from structural issues (Kline, 2011). Unless noted otherwise, coefficients are reported using StdYX standardization, which is used for continuous data, unless otherwise noted.

**Measurement Model**

The data was analyzed on Mplus 7.11 using maximum likelihood (ML) estimation. This estimation method is the default of most SEM software, and most SEM models in the literature are estimated using this method (Kline, 2011). Syntax can be found in Appendix J. The full positive definite covariance matrix was used for analysis, which can be found in Appendix K. A covariance matrix was used rather than correlation matrix because in maximum likelihood estimation, better fit results are likely (Kline, 2011). The model had 196 observations corresponding with the 196 participants in the study. The model has 63 free parameters; these parameters can be understood as hypothetical direct and indirect effects based on the data. Error, disruptions, and covariances were also estimated as free parameters. The model did not converge at 1000 iterations, so 20000 iterations were specified at which point the model converged.
Most fit indices supported the measurement model fit. The comparative fit index (CFI = .9) represented an adequate fit of the model to the data; although the Tucker-Lewis index (TLI = .87) was slightly below the threshold of acceptable fit (Keith, 2006). The root mean square error of approximation test (RMSEA = .08, \(p = 0\)) represented reasonable fit. The standardized root mean square residual (SRMR = .07) indicated good fit. The one statistic that did not confirm model fit was the chi-square measure (\(\chi^2 = 223.371 (89), p = 0\)).

These various indices demonstrate several important characteristics of the data and the model. The SRMR confirms the strength of data correlation to predicted model correlations. Furthermore, the RMSEA supports that it is not a poor model; as the hypothesis test of RMSEA is one of poorness of fit (Keith, 2006).

While the model terminated normally, the latent variable of Affective State prevented the latent covariance matrix from being positive definite. This would have made ML estimation of the structural model impossible. The \(R^2\) estimate for both the Positive (.02, \(p = .77\)) and Negative (.03, \(p = .76\)) indicators of affective state demonstrate that their indication of the latent Affective State was negligible. Furthermore, the parameter estimates for the indicators of affective state were not significant with Positive Affect at .12 (\(p = .56\)) and negative affect at -.18 (.54). For these reasons, Affective State was removed from the structural model.

The residual variance of Height (.07, \(p = .78\)) and Total Range (.02, \(p = .78\)) also show possible causes of model weakness calling their reliability into question. They will be retained in the model, however, due to strong literature support (Cooksey, 2000a;
Thurman, 2012) and significant path coefficients from their latent variables: Height from Maturity (.97, \( p = 0 \)) and Total Range from Range (.99, \( p = 0 \)).

The respecified theoretical measurement model displaying standardized parameter estimates is shown in Figure 37. Curve lines indicate covariance. Their low values confirm that each latent is a unique factor, minimizing shared variance between the latent variables. Center lines indicate standardized estimates showing the predictive power of the latent to its indicators, all of which are strong. The values to the right indicate the standardized error; that is, variance not explained by the latent variable.

\[ \begin{align*}
\text{Vocal Quality} & \quad .85^{**} \quad \text{Roughness} \quad .27^{**} \\
\text{Motivation} & \quad .92^{**} \quad \text{Strain} \quad .16^{**} \\
\text{Range} & \quad .86^{**} \quad \text{Breathiness} \quad .26^{**} \\
\text{Registration Fluency} & \quad .85^{**} \quad \text{Compared} \quad .26^{**} \\
\text{Physical Maturity} & \quad .82^{**} \quad \text{Commitment} \quad .35^{**} \\
& \quad .89^{**} \quad \text{Affect for choir} \quad .59^{**} \\
& \quad .99^{**} \quad \text{Head Range} \quad .20^{**} \\
& \quad .92^{**} \quad \text{Total Range} \quad .02 \\
\text{Vocal Quality} & \quad .86^{**} \quad \text{Chest Range} \quad .36^{**} \\
\text{Motivation} & \quad .80^{**} \quad \text{Intensity Range 349Hz} \quad .36^{**} \\
\text{Range} & \quad .69^{**} \quad \text{Intensity Range 466Hz} \quad .53^{**} \\
\text{Registration Fluency} & \quad .67^{**} \quad \text{Intensity Range 261Hz} \quad .57^{**} \\
\text{Physical Maturity} & \quad .97^{**} \quad \text{Height} \quad .07 \\
& \quad -.73^{**} \quad \text{Reading Pitch} \quad .46^{**}
\end{align*} \]

**Figure 37.** Measurement model using confirmatory factor analysis showing standardized maximum likelihood parameter estimates.

\( **p < .01 \)
**Structural Model**

The final theoretical structural model was based in part on the measurement model outcome. Figure 38 shows the theoretical structural model that was respecified following the measurement model along with the standardized estimates.

![Figure 38. Structural model with standardized path estimates.](image)

The data was again analyzed on M-Plus 7.11 using maximum likelihood estimation from the same covariance matrix as was used for the measurement model. Syntax can be found in Appendix L. The model had 14 indicator variables and the 5 continuous latent variables. The structural model also did not converge at 1000 iterations, so 20000 iterations were specified at which point the model converged at the criterion of .00005.

Fit indices indicated mixed results. The standardized root mean square residual (SRMR = .07) indicated good fit of the model to the data. The root mean square error of approximation test (RMSEA = .1, $p = 0$) was slightly below acceptable fit (Keith, 2006) as was the comparative fit index (CFI = .89) and the Tucker-Lewis index (TLI = .87). Based on the mixed indices, the parameter results should be regarded with caution.
The effect of Physical Maturity on Registration Fluency ($\beta = .27$) is strong (Keith, 2006). Physical Maturity also has a small but meaningful effect on Range ($\beta = -.08$). Spoken Vocal Quality has a moderate direct effect on Range ($\beta = -.22$) but no meaningful effect on Registration Fluency ($\beta = .03$). Most importantly, is the moderate direct effect of the psychological latent factor of Motivation on Range ($\beta = .13$) when Physical Maturity and spoken vocal quality are held steady. This is the first model where physical characteristics and psychological traits have been used to predict vocal outcomes in this population.

Discussion

Several statistical analyses were conducted to understand the data at micro and macro levels with the goal of testing an a priori theory and answer the study’s research questions:

1. What interrelationships exist within and among the following latent variables: (a) Physiology, (b) Motivation, (c) Affective State, (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

2. What combination of variables and latent factors of (a) Motivation, (b) Physiology, and (c) Affective State best predicts the latent vocal factors of (d) Range, (e) Registration Fluency, and (f) Vocal Quality?

3. Can a tentative model to predict vocal achievement in adolescent males be created and statistically tested?

Interrelationships

To answer questions one, descriptive analyses, correlational analyses, and exploratory factor analyses were conducted to understand the relationship between
variables and how they grouped. Correlational analysis confirmed a common sense understanding about boys’ voices; that the older boys get, the lower their voices get. This is not a perfect relationship, however, because boys develop at different rates.

This study confirmed Cooksey’s research identifying Height as a good predictor for pitch, but call into question his assertions that Age is an inferior predictor compared to Height; both Reading and Conversation Pitches were best correlated with Age rather than Height ($r^2_{\text{read}} = .58$, $r^2_{\text{conv}} = .57$). Height and Age tended to have similar relationships with other variables. Older and taller boys showed a stronger affinity for the choir and stronger dynamic range on individual pitches, including head voice. Older and taller boys also had a slight tendency to have a breathier sound ($r = -.16$, $p = .03$).

Cooksey (2000a) asserted the value of Lung Capacity as a predictor of vocal outcomes. For that reason, Lung Capacity was included in the study as an observed variable. While it was not retained in the model due to ceiling effect, its correlation with Intensity Range is of interest. The higher the pitch, the less correlated Lung Capacity was with Intensity Range (Figure 39). One inference that can be drawn is that higher pitches in these boys’ voices have a greater intensity range due to other factors outside of lung capacity. At 196 Hz (Middle C), however, Lung Capacity has a stronger association.
As a community choir whose members participate on a voluntary basis, it is to be expected that they would have a high sense of commitment. Still, there was enough variety in their answers to show some significant relationships with other variables. Boys with more commitment tended to compare themselves well with others ($r = .7, p < .001$), sing higher ($r = .16, p = .03$), and have a wider range ($r = .15, p = .04$). The mood of a boy at the time of testing appears to have no significant effect on any of the vocal outcomes.

The results from this study provide some evidence in support of expanding voice theory (Leck, 2009; Phillips, Williams, & Edwin, 2012). A strong relationship exists between a boy’s highest pitch and his Total Range ($r = .97, r^2 = .94, p < .001$) and his chest voice range ($r = .30, p < .001$). Also, the wider a boy’s chest range the wider his head voice range ($r = .29, p < .001$) tends to be.
This study suggests that in addition to an expansion in pitch range, there is also an expansion in intensity or dynamic range. As a boys voice lowers in both registers, his ability to sing louder and softer increases. In other words, the lower the pitch a boy can sing in chest voice, the louder and softer he is able to sing on all pitches that he can access, including higher pitches. Although chest voice has a stronger relationship to dynamics, lowest head voice notes in both changed and unchanged voices correlates with dynamic range across registers across registers.

Changes in vocal quality, as suggested by Collins (1993), were also suggested by the data. Boys who were younger with greater head voice range, tended to have a less breathy sound. As the age increased, the breathier the sound became ($r = -.16, p = .03$). Breathier speaking voices were also associated with narrow head voice range ($r = -.15, p < .04$) and total range ($r = -.19, p < .01$).

Roughness was the sole indicator of Vocal Quality that was normally distributed. This is to be expected as the participants range across several developmental levels. The term roughness in many ways seems to match Collins (1993) description of the unique wooly sound of the adolescent voice. This is confirmed by voice science, which describes irregularly distribution of collagen on the superficial layer of the vocal folds as well as glottal chink as sources of roughness in the sound (Denison, 2012). The high values in skewness and kurtosis in Breathiness, Strain and Overall Vocal Quality are likely due to the vocal experience of the boys participating.

Caution is suggested in interpreting these results. These relationships do not show causation, nor can they be used to predict. Correlations merely show that when one
variable changes, the correlate variable will also change. What causes the change cannot be ascertained from these correlations.

Consider Age and Height, for example. Both often have the same strength and direction of relationship on vocal outcomes, like pitch and dynamic range. But which is a better predictor? And which one combines best with other physical variables to create an overall sense of Physical Maturity? This is why deeper analysis is required.

**Combinations**

The measurement model showed what combination of the variables could be used for prediction of vocal outcomes, answering the second question of this study. At this stage, Affective State variables failed to combine in a way that could be modeled.

Factor analysis was used to identify groups of variables. In this study, indicator variables that were derived from tests with high validity (Motivation, Affective State, and Vocal Quality) were highly correlated and grouped together with high loadings. Vocal outcomes tended to group as either Range variables or Intensity variables. Because of recent literature support, the intensity variables were taken as indicators of Registration Fluency (Titze, 1994). Spoken pitch and height grouped to indicate Maturity, based on literature support. These “super-variables” (Tabachnick & Fidell, 2013) formed by combining other variables are called latent variables.

Individual variables that had the strongest relationships to a latent variable were retained as its indicators. Variables that confounded the strength of the overall correlation matrix were removed. The result of these combinations is shown in Table 11 (p. 99), with higher numbers showing greater presence in the latent variable. The top row denotes the
latent variable names while the left column shows the loadings of each variable on the latent.

Models

From the latent variables and their indicator variables, a theoretical model was derived based on literature, a priori theory, and logic. A great deal of evidence exists to support the effect of Motivation on musical performance, and Physical Maturity on sung outcomes. Logic tells us that if Spoken Vocal Quality has deviance, the sung voice will as well. All three of these were used as predictors of vocal outcomes. While there is evidence that Affective State effects vocal outcomes, its indicators were much weaker than the others and so it was eliminated from the model.

A structural regression model informed by the measurement model was tested to answer the third research question. The structural model showed moderate predictive power among the latent variables with most paths at meaningful levels (Figure 46, p. 104). Physical Maturity had a large prediction effect on Registration Fluency, and Spoken Vocal Quality had a moderate effect on Range (Keith, 2008).

The fit indices of this data to the model were mixed. The results should be regarded with some caution. Still, the path results are compelling, especially as this is a first attempt at understanding voice change through modeling of psychological and physiological factors.

Physical and psychological factors

In addition to the physical and spoken predictors, which were well-supported by previous literature, the psychological predictor of Motivation predicted a vocal outcome. This result is important for several reasons. First of all, this model is the first that
includes physical and psychological factors on sung vocal outcomes. Secondly, other factors were held steady when a path was estimated. This means that any psychological effects on vocal outcomes are not present in the calculated effects of physical factors, and vice versa. For example, neither Physical Maturity nor Vocal Quality affects the estimated effect of Motivation on Range.

Finally, this study demonstrates that a model that includes both physical and psychological factors can be generated. A model like the one generated in this study provides information to researchers and practitioners on the magnitude and direction of effects taken in isolation on sung outcomes.

**Context of Participants and its Effect on Results**

The results from this study are derived from a specific context of participants, namely, members of community boychoirs. The strength of using this group of participants for this study is that gender is controlled by design, and the choirs share similar social constructs for music making. Rehearsal and performance is at the core of their musical activity. Training and education are also an important part of each choir’s activity. To a certain extent, choral pedagogy variance is also controlled by the research design. This is best heard in the multiple register singing of each choir in their respective recordings.

While there are benefits to having these controls, the community boychoir context had an effect on the outcomes of this study. Each choir was a group of boys and young men who participated voluntarily in their choir, and often at the expense of other activities. This is can be understood in part by the high positive grouping at the mean of
self image and commitment. Their musical experience was also demonstrated in the high positive skew of the vocal outcomes Total Range and Highest Terminal Pitch.

These young men have been trained in a group setting. Due to the unitary setting of instruction, often for hours at a time, the vocal outcomes would likely be strongly grouped. In a choral warm up, range exercises extend to the same pitch extremes for every singer; they are not as individualized as in studio instruction. Therefore, high kurtosis, or grouping at the mean, for vocal outcomes was expected. Such grouping could be seen in highest terminal pitch (2.31), highest chest voice pitch (2.17), head voice range (1.14), chest voice range (1.97), total range (2.90). High kurtosis also occurred in intensity range outcomes for G (196Hz) and F (349Hz) and Bb (466Hz). What is striking about this effect is that the age range of 8-18 crossed all vocal developmental stages delineated by Cooksey, and yet several kurtosis values were high. This could indicate that the threshold for dynamic range is consistent across developmental levels.
CHAPTER FIVE

SUMMARY, CONCLUSIONS, IMPLICATIONS, AND RECOMMENDATIONS

After decades of research on adolescent male voices, questions still remain as to the causes of the variety of singing heard in boys’ voices. This study began as a search for a clearer understanding of young men’s voices both across ages and within ages that would include both physical and psychological factors. The purpose of the study was to develop and test a statistical model of these factors.

A literature review revealed conflicting accounts of how boys’ voices change. One school of thought supported a single register concept of singing. Some referred to this as the limited range school, and it included the work of Cooksey, the Contemporary, Eclectic Theory (CET) and Collins (the Cambiata approach). Quantitative research conducted in schools provided evidence supporting these approaches, and the pedagogy derived from that research is widely accepted and used, especially in schools. Indeed, the vast majority of quantitative research has supported single register singing, and has becomes a valuable resource for teachers. Research in CET explained and systematized boys’ voice changes into either developmental stages (Cooksey, 1977a, 1977b, 1977c, 1978, 1984, 1993, 2000a, 2000b; Cooksey & Welch, 1998) or pedagogical groupings (Barham, Cooksey, 1999, Collins 1993).

Another school of thought explained the boy’s changing voice as expanding in range. Proponents of this approach tended to work in community choir contexts. By including upper register singing, the range of a boy’s voice was thought to extend rather than simply lower in tessitura. This second school of thought resembled my previous experience in Boychoir work, but no quantitative research existed to explain, support, or
even criticize my experience. The Expanded Voice Theory (EVT) was, until more recently, untested by quantitative research.

Jenevora Williams and Martin Ashley began looking at multiple register singing in cathedral and church contexts. Williams was interested in vocal health during maturation, and part of Ashley’s sociological research examined the context of church singing. Both of researchers expressed a desire for an understanding of boys’ voices that could encompass both single register and multiple register singing contexts.

Structural equation modeling provided an opportunity to bring together the seemingly disparate theories, practices, and contexts into a single model. As it was the first study of its kind, its scope had to be limited to ascertain if such a model was possible. Using observed variables derived from experience, literature, logic, and theory, a theoretical model was created. The research questions focused on examining the correlation, combination, and modeling of variables within larger latent factors. The proposed model included all variables that seemed relevant to the study.

One of the most challenging of the vocal outcomes to define and measure was vocal registration. Since one of the principal differences in approach to boys’ voices is the treatment of vocal registration, clear operational definitions and reliable measurements of register had to be developed. Both the definitions and the measurements proved elusive in several ways. First of all, no commonly agreed number of vocal registers exists among vocal pedagogues, and voice scientists. Secondly, the nomenclature for various registers is highly varied and idiomatic. Two registers, the traditionally understood chest voice and head voice, were selected to maintain clarity, even though their meaning is ambiguous.
This study measured registration in two ways derived from literature on boys’ voices. First, timbral and pitch difference were identified as boundaries of the passaggio using descending glides across all registers; such measurement was used previously in phonational gap research. Second, the overlap of head voice range and chest voice range were measured. Both the passaggio measure and the overlap of registers were intended to serve as indicators of vocal registration fluency.

Observed variables in the initial model included measures of personality, environment, motivation. The initial model also included acoustic measures of jitter and shimmer. All were supported by the literature as predictors of vocal outcomes. The vocal outcome variables indicated range, Registration Fluency, vocal quality, and speaking pitch. Each of these factors has 4 indicators on average.

Following the proposal defense, at the recommendation of the committee, the model was scaled down to a more parsimonious model. Motivation was retained as a trait surrogate for personality. Affective State was added as a mediator between motivation and the vocal outcomes. A modified voice-range profile measure was added to provide maximum and minimum intensities at 146, 196, 241, 361, and 466 Hz. Since the participants in the study were in extra-curricular community boychoirs, they received similar training, performance experiences, and family support. For this reason, environment was eliminated from the model, since sampling controlled its variance.

Acoustic variables for vocal quality such as jitter, shimmer, and harmonic to noise ratio were eliminated in favor of a perception measure. Submission to IRB further reduced the scale of the study, particularly in the numbers of participants, by prohibiting
the directors of the choirs to collect the data. I was required to collect all data alone and in person.

The participants of the study were boys and young men ages 8 to 18, and current members of a community boychoir. Data collection took place in three geographic areas: Flagstaff, AZ; Fort Worth TX and Fort Lauderdale FL, spanning three months. Separate IRB permission had to be secured in Flagstaff because data collection took place at Northern Arizona University. Boys and their families received letters explaining the study, and a presentation was made to each choir concerning the purpose and procedures of the study. Signed parental consent and participant assent were secured before collecting the data. In the end, 196 participants were secured from four choirs.

Data collection consisted of three components: a motivation survey (S-MAV), physical measurements, and audio recording. A written mood survey (PANAS) preceded audio recording. Directors of each choir were surveyed on their pedagogy and structure of their choral organization (D-MAV). Participants took the S-MAV by choir grouping. Physiological measurements, the PANAS, and audio recording were taken individually in that order.

Physiological measurements were of height, weight, and lung capacity. Instruments of measurement were a tape measure for height, bath scale for weight, and spirometer for lung capacity.

A Zoom H6 portable audio recorder recorded the audio samples. Consistency in the audio recording was ensured by placing participants and recorder 20 cm apart on a horizontal plane.
Sound sample collection followed a script that was read to the participants. The first sample was of conversation, answering the question, “What did you do today?” The second sample was a series of three glides from high to low across registers. The next set of samples consisted of glides to terminal pitches of both registers: highest head voice pitch, lowest chest voice pitch, highest chest voice pitch, and lowest head voice pitch. Each participant was instructed to hold the pitch for 3 to 5 seconds. Each glide was recorded three times. Following the glides, participants were instructed to read six sentences from the CAPE-V. The final samples were a series of *messa di voces* on six pitches (146 Hz, 196 Hz, 261 Hz, 349 Hz, and 466 Hz), each sung three times.

Data was analyzed using SPSS for descriptive, correlational, and factor analysis. M-Plus was used for modeling. The acoustic properties of the samples were evaluated using spectral analysis via Praat (Boesma & Weenink, 2013). Data screening and preliminary statistical analyses took place concurrent with acoustical analyses. Information from the preliminary statistical analyses revealed that lung capacity measures contained a ceiling effect error. It was eliminated during factor analysis.

Exploratory Factor Analysis followed the descriptive and correlational analyses. Final decision on extracted factors was based on variables with high loadings that contributed to a positive definite matrix. When the matrix was not positive definite, variables that were highly correlated with other variables were eliminated.

Results of the Exploratory Factor Analysis indicated high loadings on six factors with no cross loadings: Vocal Quality, Range, Physical Maturity, Motivation, Registration Fluency, and Affective State. This result showed the exceptional strength of the latent variables as indicated by these variables. The intensity measures were labeled
as measures of Registration Fluency, based in part on literature, and in part on experience. The six latent variables extracted were Physical Maturity, Motivation, Affective State, Range, Spoken Vocal Quality, and Registration Fluency.

A two-step structural regression model was conducted using maximum likelihood estimation. The first step was a measurement model that used Confirmatory Factor Analysis to identify the relationships between the observed and latent variables, and to examine the covariance between the latent variables. The measurement model showed low standardized covariance values between the latent variables, which provided evidence that the latent variables were unique domains within the model. Affective State had low path coefficients and no significant correlation with vocal outcomes, and was removed from the model.

The respecified structural regression model tested the direct effects of the three exogenous factors Motivation, Spoken Vocal Quality and Physical Maturity on the two endogenous factors Range and Registration Fluency. Results showed a strong direct effect of Physical Maturity on Registration Fluency, a moderate effect of Motivation on Range, and a moderate effect of Vocal Quality on Range. A small but meaningful effect was noted of Physical Maturity on Range. Direct effects of Motivation on Registration Fluency, and Spoken Vocal Quality on Registration Fluency were too small to be meaningful.
Conclusions

Based on the results of the data analysis, the following conclusions can be reached:

• Height, weight, lung capacity, speaking pitch, and age are all highly and significantly related, as would be expected as boys grow.

• Self-image, commitment to choir, how a boy compares himself to other singers, and his affect for choir are significantly related to each other. The significant relationship between positive and negative affect reflects the complexity of mood, and discourages a good mood/bad mood dichotomy. Motivation and Affective State variables share several significant relationships, but neither positive nor negative affect relate to vocal outcomes.

• Relationships between ranges and terminal pitches of registers are consistently significant with the exception of passaggio measures whose relationships are mixed.

• A relationship between Height and Age to intensity ranges is significant across registers.

• The best combinations of specific observed variables reveal the underlying latent factors as follows:
  o Motivation is indicated by levels of commitment to choir, how a boy compares himself to others, and how he feels about choir.
  o Spoken Vocal Quality is shown through deviance in roughness, breathiness, and strain.
  o Physical Maturity is indicated by height and spoken pitch.
- Affective State is indicated by positive and negative affect.
- Range is indicated by head voice range, chest voice range and total composite range.
- Registration Fluency is indicated by intensity ranges on 261 Hz, 349 Hz and 466 Hz.

- A predictive model of boys’ singing can be created and tested. This model includes different physical development stages and psychological traits. It also provides information on the strength of the relationship.

- Physical Maturity has a strong effect on Registration Fluency and Spoken Voice Quality has a strong effect on Range. Motivation has a moderate effect on Range, and Physical Maturity had a small but meaningful effect on Range.

- The smaller magnitude of Physical Maturity on Range calls into question systems of classification that purport a strong relationship between the two. Inclusion of upper register outcomes appears to change the magnitude of Physical Maturity’s effect on Range.

This study provided evidence in supporting both approaches to boys’ voices.

Correlations between observed variables height, age, and speaking pitch with ranges in upper and lower registers, intensity ranges and breathiness validated Cooksey’s previous findings (2000a), although he focused on the lower register findings. Physical Maturity outcomes also predicted composite range across registers, supporting small but meaningful support of the Expanding Voice Theory of voice change (Leck, 2009; Phillips, Williams, & Edwin, 2012; Williams, 2013).
**Recommendations for future study**

The data collected from this survey raises more questions. Most importantly is whether the lack of normal distribution for some variables weakened their relevance to the factor analysis and the model. This is especially true for variables with high kurtosis, which affects chi-square measures, and is difficult to transform. Also not known is what effect increased statistical power would have on the results. Passaggio measures based on descending glides, while showing a few significant correlational relationships were too weak to be of value for modeling.

While descending glides have been used in previous research of boys’ voices (Ashley, 2013; Thurman, 2012; Willis & Kenney, 2008) future research may benefit from utilizing a descending chromatic scale rather than a glide, especially with this population. Glides encouraged collapse of support that likely exaggerate the precipitous drops in pitch at the passaggio. Several experienced boy singers in this study asked to sing scales as a means to avoid phonational gap. Because of this collapse of support it became impossible to evaluate the relationship of passaggio to overlap of chest range and head range. Future modeling of Registration Fluency should include a pitched variable.

Formant values were not analyzed in this study nor included in the model. The effect of psychological and physiological latent variables on a latent formant variable could prove valuable information in evaluating its role in clarifying vocal development (Howard, Williams, & Herbst, 2013).

While speaking pitch is a useful tool in analyzing voice quality, sung pitches can reveal additional deviances can then be analyzed as vocal outcomes. The CAPE-V test
used in this study for speaking quality proved to have strong validity. It may be an efficient and effective measure for sung pitches as well.

More studies on boys’ voice change exist than on girl’s voice change. This gap widens when only quantitative research is considered. While great strides have been made in adolescent vocal research thanks in large part to Lynn Gackle (2011), there is much still to learn. The process used in creating this model should be replicated for girls.

While Motivation provided a moderate effect on Range, it is possible that a stronger effect might be appreciated through a different theoretical lens. The Motivation indicators were derived from a test based on Attribution Theory of Motivation. Measuring motivation with instruments based on Self-Determination Theory may be more suitable (Freer, 2012b). Furthermore, Motivation may not be as powerful a trait measure for this population as measures based on Personality Theory.

The removal of Affective State from the as a state indicator should be closely examined. The PANAS test is an efficient measure whose validity is well-supported. By using hierarchal modeling, its inclusion may still be possible.

If more data is collected, equivalent models and modifications based on modifications indices could be considered. A model with adequate sample size will have sufficient statistical power. Normality measures and fit indices may respond to such power to add more support to the model, or provide an alternate model with better fit. Furthermore, if data were collected across several time points, a latent growth model would be especially illuminating. A large group of younger boys of the same age could measured by this model a several time points across their developmental stages into
young adulthood. The resultant latent growth model could show how path direction and magnitude of those paths change as a boy grows.

Latent growth model techniques can be applied to other populations as well. What magnitude of effect does aging physiology have on vocal outcomes? What psychological changes come with aging? And what effect does each have on singing when the other is controlled?

Even more fascinating would be the comparison of effects between populations. How does rural compare with urban? Boys with girls? Older singers with younger singers? The presence of both physiology and psychology in the model creates rich possibilities for an integrated understanding of the voice.

**Limitations**

Several external factors limit the results of this study. Principally, although a plan was in place to collect a sufficient sample size for sufficiently powerful SEM ($N = 600$), post-design IRB restrictions made such data collection impossible. This seriously weakens statistical power. Still, that moderate fit occurred at the measurement level provides and mixed fit at the structural level provided evidence that the latent constructs are unique and strong enough to be used in future research.

The participants were from a community boy choir setting. This likely controlled variance due to environment and experience, since the contexts were consistent. Any generalization of these results can be applied to that context, but may not be appropriate in other contexts.

Another limitation was the instrument used for measuring lung capacity. Because of a ceiling effect, lung capacity was not considered in the study. Even with the ceiling
effect, strong correlation between lung capacity and age, lowest terminal pitch and intensities support Cooksey’s high view of lung capacity as a predictor (2000a).

**Implication for practice**

The term context has been used frequently in the reporting of this study and has certainly been an important component of boys voice research in the past. In order to apply the findings of this study, it is important to be ever mindful of the context in which a particular boy is taught. Context is determined by several factors: (1) gender, (2) time, (3) performance, (4) repertoire, (5) class size, (6) experience, and (7) home environment.

In this study, limiting the participants to members of community boy choirs controlled all of these factors. These choirs are comprised of boys and young men who begin vocal technique training 2-5 years before vocal mutation. Their membership can span many years, and the oldest participants have likely been in their choir for a decade. They regularly perform at a high level for diverse audiences. The family support includes transportation and financial support. For this study, the choirs’ similarities controlled for environment and training.

Even though the context of these participants is narrow, this study provides important information on the direction and magnitude of the effects seen in the model. Most important for the teacher is the role of Motivation on Vocal Range. In this study the extent of a boy’s motivation affects his vocal range. While repertoire with narrow range is appropriate for all boys in every stage of development, this study implies that those with higher motivation can achieve more. An effective teacher of boys’ voices considers motivation and other psychological factors in choosing part assignment, repertoire, and ensemble placement. This is supported by the moderate effect of Motivation on Range.
When predicting the vocal range of a student, a teacher should first examine the speaking voice quality. This study showed a strong effect of vocal quality on range. Physical Maturity, although having a meaningful effect on Range, had only a small effect. A boy with a rough or breathy voice can be expected to have a limited range compared to a tall boy with a healthy, low speaking voice. A partnership with a voice pathologist is valuable in improving speaking voice quality, which in turn can be expected to improve vocal range.

Of course, head voice singing for young men is not generally accepted in wider culture, and it is only in unique contexts that such singing may be possible. Still, it is of value to know that it is possible if a boy is motivated have a wide vocal range. A model that places Motivation as a mediator between Speaking Voice Quality and Range may provide information that could better generalize outside the boychoir context.

While Physical Maturity had a small effect on Range, it had a large effect on Registration Fluency as indicated by intensity ranges in passaggio and head voice. This means that physical changes in the body predicted greater dynamic range. As the body grows, it gains greater expressive potential through dynamics. While dynamics are a valuable tool of expression for all levels and ages of singing, pre-mutational singers have a narrower range of intensities in which to work. More importantly, these results call into question practices that encourage “manly singing” that is defined by simply singing loud. Maturing voices should experience music with greater dynamic contrast not less. In doing so, they will experience opportunities to choose and blend registers, allowing for greater flexibility in group singing.
In order to promote a better understanding of registration in their own voices, maturing boys can be encouraged to sing *messa di voce* on the pitches used in this study: D3, G3, middle C4, F4, and Bb4. To attempt these, the class environment must be one of play, where boys can be comfortable taking risks in front of each other. Cracking and phonational gaps are likely to occur, but as they grow, they will begin to understand how to connect registers on single pitches, a skill that is as valuable as smoothing register changes in descending glides. To facilitate this, it is critical for teachers to have complete understanding of vocal register, especially when connected to practice.

The latent variable of Range was indicated by upper and lower registers as well as the total register. The presence of upper register head voice singing across the full age range of 8 to 18 clearly demonstrated the ability of mature and maturing voices to access these pitches. A complete teacher education would address this fact and give prospective teachers the full understanding needed to make informed decisions on materials, curriculum, repertoire, and experiences for learning.

Should we treat a boy’s voice as it is, or as it could be? The results of this study leave no question as to what boys’ voices can be. A teacher education that does not make this knowledge available to potential educators is incomplete. Aims, goals, and objectives for teachers need a complete trajectory, one that recognizes the full potential available to the student. When it is recognized, the range of vocal choices for a lifelong enjoyment of music is richer. Single register pedagogy is a narrow understanding of a complex and rich instrument. Still, the question of what they should sing is very important. The ever-present concern of context returns when we ask what boys should sing. To answer this question, teachers need to carefully and wisely be aware of where they are and the boys
with whom they are working. A single register curriculum may be the most appropriate choice for their context. Beginning schoolteachers are recommended to assume single register singing is suitable for their new school until they are better acquainted with their community.

The model in this study shows that factors other than age and physiology can predict vocal outcomes in young men; psychosocial factors also affect their singing. This is the first model that includes both physiology and psychology as predictors of singing. The prediction of direction and magnitude provide important information on these effects. The results of this study also provide support for two seemingly contrary pedagogical approaches to boys’ singing: single register singing, and multiple register singing. In fact this model affirms the suspicion of several researchers that both approaches are right. This synergistic model of singing that uses social psychology and physiological elements shows that is possible, and allows for future model building that can provide a holistic view of singing.
References


Ashley, M., & Mecke, A. (2013). “Boys are apt to change their voice at about fourteeene yeere of age”: An historical background to the debate about longevity in boy treble singers. Reviews of Research in Human Learning and Music, 1(1) 1-19.


Martin, A. J. (2012). The role of personal best (pb) goals in the achievement and behavioral engagement of students with ADHD and students without ADHD. Contemporary Educational Psychology, 37(2), 91-105.


Swanson, F. (1977) *The male singing voice ages eight to eighteen*. Cedar Rapids, IA: Ingram.


Appendix A

Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V)

ID #: ____________________________

The following parameters of voice quality will be rated on reading sentences provided by the CAPE-V Continuum runs from healthy (H) to moderately deviant (MD) to strongly deviant (SD).

<table>
<thead>
<tr>
<th>Overall quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Breathiness</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
</tr>
</tbody>
</table>
Appendix B

Asmus’ Magnitude of Motivation in Music (AMMM) test items

Subscale codes
MSC: Motivation Self-concept
MPC: Motivation Personal Commitment
MIE: Motivation in Ensemble
MCO: Motivation Compared to Others

Items
MSC  I am a good singer.
MPC  Music is a very important part of my life.
MIE  I work hard to do well in choir.
MCO  I like myself best when I am singing.
MPC  Listening to music is more important to me than watching television.
MIE  I enjoy choir more than classes at school.
MCO  I want to be involved in musical activities more than in other activities.
MPC  I would rather sing than read a book.
MIE  Rehearsal is my favorite class of the day.
MCO  Attending a musical activity is more important to me than attending a sports activity.
MPC  If I could, I would spend more time listening to music.
MIE  I find rehearsal to be more exciting than some other classes I take.
MCO  I am willing to put more time into my music than any other of my interests.
MPC  If I can, I will be involved with music all my life.
MIE  Rehearsal is never a waste of time.
MCO  I can do without other things, but I have to have music.
MPC  I think about music frequently.
MIE  I find rehearsal to be very stimulating.
MCO  I am willing to work harder on my music than on anything else.
MPC  Music is one of my favorite activities.
MIE  If I had my way, I would spend more time in rehearsal.
MCO  I would like to pursue a career in music.
MSC  I am an excellent musician.
Appendix C

Director-Measure of Adolescent Voice (D-MAV)

Please fill out a sheet for each choir in your organization.

1. Organization name

2. Choir level name (example: Training Choir)

3. How many days per week does this choir level rehearse?

4. How many hours per week does this choir level rehearse?

5. On average, how many minutes per rehearsal is devoted to warm-up and or vocal technique instruction?

6. Do you discuss registers in this level of choir?

7. If so, what are these registers called in rehearsal? In other words, what terms for register would the boys of this choir level understand? For example:
   a) upper-middle-lower
   b) head-passaggio-chest
   c) high-low

Please add any additional helpful information on how you teach register below:

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________

_______________________________________________________________________
Appendix D

Singer: Measure of Adolescent Voice (S-MAV) survey

Name ________________________________

ID number (filled out by director only)__________________

**Singer Survey**

**General Information**

1. Age _________________
2. Birthday _________________
3. How many years have you been in the choir? _________________

**You and music**

**Directions:** The items in this section ask your opinion about various aspects of music and musical activities. Each item consists of a statement to which you are to respond by circling

1 if you strongly agree with the statement,
2 if you agree with the statement,
3 if you disagree with the statement, and
4 if you strongly disagree with the statement.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I am a good musician.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2. Music is a very important part of my life.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3. I work hard to do well in rehearsal.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>4. I like myself best when I am making music.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>5. Listening to music is more important to me than watching television.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6. I enjoy rehearsal more than classes at school.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SA</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>----</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7. I want to be involved in musical activities more than in other activities.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>8. I would rather sing than read a book.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>9. Rehearsal is my favorite class of the day.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. Attending a musical activity is more important to me than attending a sports activity.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>11. If I could, I would spend more time listening to music.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12. I find rehearsal to be more exciting than some other classes I take.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>13. I am willing to put more time into my music than any other of my interests.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>14. If I can, I will be involved with music all my life.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>15. Rehearsal is never a waste of time.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>16. I can do without other things, but I have to have music.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>17. I think about music frequently.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>18. I find rehearsal to be very stimulating.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>19. I am willing to work harder on my music than on anything else.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20. Music is one of my favorite activities.</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Item</td>
<td>SA</td>
<td>A</td>
<td>D</td>
<td>SD</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>----</td>
<td>---</td>
<td>---</td>
<td>----</td>
</tr>
<tr>
<td>21. If I had my way, I would spend more time in rehearsal.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>22. I would like to pursue a career in music.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>23. I am an excellent musician.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix E

Positive and Negative Affect Schedule items and scale

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Not really</th>
<th>Moderately</th>
<th>Mostly</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upset</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Hostile</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Alert</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Ashamed</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Inspired</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Nervous</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Determined</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Attentive</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Afraid</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Active</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Uninterested</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
Appendix F

Instructions for measuring lung capacity

1. Instruct the choirboy to blow out all the air he can.

2. Once the lungs are empty of air, have him inhale through the mouthpiece of the meter, like sucking a giant soda straw.

3. The plunger will rise. Once it has reached its highest, read the measurement at the TOP of the plunger.

4. Note the value on the form.

5. Clean the mouthpiece of the spirometer with the alcohol swap.
Appendix G

Physiological measure sheet (P-MAV)

Name _____________
Code _____________
Date _____________

Physiological measures

1. **Height** in inches, shoes off ________________

2. **Weight** in pounds, shoes off ________________

3. **Lung capacity** ________________
Appendix H

Instructions and script for sound collection

Do NOT use boys’ names during recording.

For this sound collection you will need:
  a) the Zoom H6 recorder provided
  b) enough PANAS forms for all boys to be tested
  c) the reading sheet with the five sentences
  d) a way to provide pitch efficiently

1. Before the sound check, have him fill out the PANAS and note the ID on his paper.
2. Collect the PANAS form and place in an envelope for later mailing.
3. Position the choirboy in a comfortable position 20 cm from the microphone.
4. State the ID number of the singer. Do NOT use his name at any point.
5. Say: “I’m going to ask you to sing several different exercises. Some of them will be easy for you to sing, others might be difficult. Do the best you can, and don’t worry if it doesn’t come out the way you like. Just do what you can. First of all, tell me a little about your voice, what it’s like, what part you sing, things like that.” Let them talk for about 20 seconds.
6. Say: “Number 1: On ah, slide from your highest note to your lowest note as smoothly as you can.” (Boy sings)
7. “Again” (Boy sings)
8. “One more time” (Boy sings)
9. “Number 2: In head voice only, slide to the highest note you can hold for four seconds on ah.” (Boy sings)
10. “Again” (Boys sings)
11. “One more time” (Boy sings)
12. “Number 3: In chest voice, slide to the lowest note you can hold for four seconds on ah.” (Boy sings)
13. “Again” (Boys sings)
14. “One more time” (Boy sings)
15. “Number 4: In chest voice only, slide to the highest note you can hold for four seconds on ah.” (Boy sings)
16. “Again” (Boys sings)
17. “One more time” (Boy sings)
18. “Number 5: In head voice only, slide to the lowest note you can hold for four seconds on ah.” (Boy sings)
19. “Again” (Boys sings)
20. “One more time” (Boy sings)
21. Have the choirboy look at the reading sheet. “Number 6: Read these six sentences.” (Boy reads)
22. “I am going to play 5 pitches. After each one, sing that pitch from soft to loud and back to soft (messa di voce) on /a/ for about 5 to 7 seconds. Don’t worry about how it sounds, just do what you can.”
23. “Number 7” Play D³, which is the D below middle C (Boy sings)
24. “Again” (Boys sings)
25. “One more time” (Boy sings)
26. “Number 8” Play G\(^3\). (Boy sings)
27. “Again” (Boys sing)
28. “One more time” (Boy sings)
29. “Number 9” Play C\(^4\), which is middle C (Boy sings)
30. “Again” (Boys sing)
31. “One more time” (Boy sings)
32. “Number 10” Play F\(^4\), which is the F above middle C (Boy sings)
33. “Again” (Boys sing)
34. “One more time” (Boy sings)
35. “Number 11” Play Bb\(^4\), (Boy sings)
36. “Again” (Boys sing)
37. “One more time” (Boy sings)
38. Press stop on the recorder and thank the boy.
Appendix I

Sentences for Sound Collection

This is stated as number six, and follows the glides.

1. The blue spot is on the key again.

2. We eat eggs every Easter.

3. How hard did he hit him?

4. My mama makes lemon muffins.

5. We were away a year ago.

6. Peter will keep at the peak.
Appendix J

Syntax for Confirmatory Factor Analysis

TITLE: CFA_4_9

DATA: FILE IS MEANFULLCOV.csv;
    TYPE IS MEANS FULLCOV;
    NOBSERVATIONS ARE 196;

VARIABLE: NAMES ARE ROUGH STRAIN BREATH TCOMP TCOMM TENSM TRNG HRNG CRNG RNG349 RNG466 RNG261 HT READ POSIT NEGAT;

ANALYSIS: ESTIMATOR= ML;
    ITERATIONS= 20000;

MODEL: Motivation BY TCOMP TCOMM TENSM;
    Affect BY POSIT NEGAT;
    Maturity BY HT READ;
    Fluency BY Rng261 Rng349 RNG466;
    Quality BY STRAIN ROUGH BREATH;
    Range BY HRNG TRNG CRNG;

OUTPUT: SAMPSTAT CINTERVAL MODINDICES (10) STAND RESIDUAL;
Appendix K

Lower triangle covariance matrix

<table>
<thead>
<tr>
<th>Covariances/Correlations/Residual Correlations</th>
<th>ROUGH</th>
<th>STRAIN</th>
<th>BREATH</th>
<th>TCOMP</th>
<th>TCOMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUGH</td>
<td>103.850</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRAIN</td>
<td>65.490</td>
<td>67.264</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BREATH</td>
<td>68.209</td>
<td>57.972</td>
<td>82.099</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TCOMP</td>
<td>0.463</td>
<td>-2.127</td>
<td>-3.293</td>
<td>19.432</td>
<td></td>
</tr>
<tr>
<td>TCOMM</td>
<td>-0.274</td>
<td>-2.411</td>
<td>-2.078</td>
<td>11.343</td>
<td>13.685</td>
</tr>
<tr>
<td>TENSM</td>
<td>4.572</td>
<td>-1.648</td>
<td>-0.120</td>
<td>8.838</td>
<td>6.897</td>
</tr>
<tr>
<td>TRNG</td>
<td>-288.119</td>
<td>-466.767</td>
<td>-438.609</td>
<td>94.575</td>
<td>142.576</td>
</tr>
<tr>
<td>HRNG</td>
<td>-364.185</td>
<td>-420.843</td>
<td>-368.872</td>
<td>102.828</td>
<td>129.784</td>
</tr>
<tr>
<td>CRNG</td>
<td>-108.924</td>
<td>-80.406</td>
<td>-93.808</td>
<td>-2.907</td>
<td>-10.902</td>
</tr>
<tr>
<td>RNG349</td>
<td>11.589</td>
<td>4.637</td>
<td>-0.742</td>
<td>-0.859</td>
<td>0.851</td>
</tr>
<tr>
<td>RNG466</td>
<td>-4.711</td>
<td>-4.828</td>
<td>-10.755</td>
<td>-1.050</td>
<td>-0.784</td>
</tr>
<tr>
<td>RNG261</td>
<td>5.369</td>
<td>-4.293</td>
<td>-9.355</td>
<td>-0.444</td>
<td>-1.510</td>
</tr>
<tr>
<td>HT</td>
<td>11.404</td>
<td>-17.207</td>
<td>-31.285</td>
<td>1.485</td>
<td>-1.966</td>
</tr>
<tr>
<td>READ</td>
<td>-89.125</td>
<td>45.625</td>
<td>79.307</td>
<td>6.842</td>
<td>9.529</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Covariances/Correlations/Residual Correlations</th>
<th>TENSM</th>
<th>TRNG</th>
<th>HRNG</th>
<th>CRNG</th>
<th>RNG349</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENSM</td>
<td>13.182</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRNG</td>
<td>94.432</td>
<td>64405.550</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HRNG</td>
<td>86.814</td>
<td>60118.061</td>
<td>72155.801</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRNG</td>
<td>45.649</td>
<td>7854.574</td>
<td>7047.129</td>
<td>7145.018</td>
<td></td>
</tr>
<tr>
<td>RNG349</td>
<td>-0.918</td>
<td>-79.440</td>
<td>-219.101</td>
<td>92.954</td>
<td>53.366</td>
</tr>
<tr>
<td>RNG466</td>
<td>-1.428</td>
<td>288.814</td>
<td>178.889</td>
<td>175.264</td>
<td>31.724</td>
</tr>
<tr>
<td>RNG261</td>
<td>4.050</td>
<td>242.042</td>
<td>117.203</td>
<td>190.695</td>
<td>30.768</td>
</tr>
<tr>
<td>HT</td>
<td>8.974</td>
<td>-116.783</td>
<td>-703.519</td>
<td>52.875</td>
<td>17.786</td>
</tr>
<tr>
<td>READ</td>
<td>-23.814</td>
<td>489.608</td>
<td>2501.605</td>
<td>287.241</td>
<td>-48.661</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Covariances/Correlations/Residual Correlations</th>
<th>RNG466</th>
<th>RNG261</th>
<th>HT</th>
<th>READ</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNG466</td>
<td>57.684</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNG261</td>
<td>25.811</td>
<td>66.461</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HT</td>
<td>11.731</td>
<td>44.576</td>
<td>242.057</td>
<td></td>
</tr>
<tr>
<td>READ</td>
<td>-63.626</td>
<td>-151.089</td>
<td>-686.006</td>
<td>3856.905</td>
</tr>
</tbody>
</table>
Appendix L

Syntax for Structural Model Analysis

INPUT INSTRUCTIONS

TITLE: Structural Model Proposed No Affect 4_7

DATA: FILE IS MEANFULLCOV.csv;
    TYPE IS MEANS FULLCOV;
    NOBSERVATIONS ARE 196;

VARIABLE: NAMES ARE ROUGH STRAIN BREATH TCOMP TCOMM TENSM TRNG
         HRNG CRNG RNG349 RNG466 RNG261 HT READ POSIT NEGAT;
USEVARIABLES ARE ROUGH STRAIN BREATH TCOMP TCOMM TENSM TRNG
         HRNG CRNG RNG349 RNG466 RNG261 HT READ;

ANALYSIS: ESTIMATOR= ML;
          ITERATIONS= 20000;

MODEL:
    Motivation BY TCOMP TCOMM TENSM;
    Maturity BY HT READ;
    Fluency BY RNG261 RNG349 RNG466;
    Quality BY STRAIN ROUGH BREATH;
    Range BY TRNG HRNG CRNG;

    Range ON Maturity Quality Motivation;
    Fluency ON Maturity Quality Motivation;

OUTPUT: SAMPSTAT CINTERVAL STAND RESIDUAL MODINDICES(10);