AN EXPLORATION OF AUDITORY IMAGERY ABILITY AMONGST CHORAL SINGERS AND CONDUCTORS

by

Evan C. Roberts

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Thesis Committee

Peter Miksza, Chair

Andrew Goldman

Brian Shaw

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Abstract

Auditory imagery is a fundamental skill for choral musicians, useful for imagining pitches in preparation for singing, as well as coordinating singing in tandem with others. Given the value that auditory imagery holds in the choral profession, I hypothesized that years of experience as singers or conductors would correlate with auditory imagery ability. Participants drawn from the choral profession completed a ten-minute questionnaire documenting their personal information, background in music, musical skill set, and self-reported ability to imagine both vivid and malleable auditory images. A previously designed questionnaire, the Bucknell Auditory Imagery Scale (BAIS, 2015), as well as additional choral music questions modeled after the BAIS were used to address auditory imagery ability. The BAIS and the supplementary choral music questions had two subscales, vividness (BAIS-V, the clarity of an image) and control (BAIS-C, the malleability of an image). Results indicated that years of conducting experience were associated with higher degrees of vividness and control of auditory images, while years of singing experience were also correlated with higher degrees of control. The purpose of this document was to better quantify the significance of auditory imagery ability in choral music-making environments, as well as to consolidate recommendations from research around cultivating auditory imagery ability in singers and conductors.

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Chapter I: Statement of the Problem

Rationale for Study

The universality of hearing music in one's head is often so colloquial that it does not have an operational definition, with its centrality in music pedagogy being somewhat assumed (Halpern & Overy, 2019). The fields of psychology and neuroscience most commonly refer to this process as 'auditory imagery', but it has many different names in music pedagogy, such as 'inner ear' (Kodály, 1976) or 'audiation' (Gordon, 1976). A music teacher or pedagogue is more likely to refer to the process of hearing music inside one's head as the using one's 'inner ear' (Kodály Method), engaging in 'mental rehearsal' (Seashore, 1919), or developing their 'audiation' skills (Gordon's Music Learning Theory).

Auditory imagery experiences are important to all musicians, but they are especially necessary for orchestral and choral conductors. Conductors cannot produce an orchestral or choral sound on their own, meaning that a large bulk of their practice is reliant on their ability to imagine and control internalized images (Hoffman, 2002). When tasked with creating an interpretation of a piece of music, conductors have several possible starting points: (1) reading the musical notation and imagining the music of the score, (2) playing the score on their respective instrument, and/or (3) studying with recordings (Brodsky et al., 2003; Crowe, 1996). While studying with pre-existing aural models can prove useful for improving error detection skills, particularly among beginning conductors (Crowe, 1996), using recordings can sometimes run contrary to a previously conceived interpretation of a piece, producing a negative effect on both expressive conducting and effective rehearsal verbalizations (Treviño, 2008; Montemayor & Moss, 2009). If conductors wish for their interpretations of pieces to truly be their own, they must either imagine music fresh from the score or manipulate imagery drawn from previously existing recordings to their liking. Both of these processes may require manipulation of auditory images. It is possible that a conductor could be making explicit decisions about tempo, balance, and a multitude of other musical responsibilities without the use of an internal model, so further research is needed to better understand the relationship between conducting and auditory imagery ability. Due to the impact that more vivid and controllable auditory imagery experiences may have on conductors' practice and performance habits, further research is also needed towards how conductors can develop and utilize these skills.

There is evidence that suggests musical experience is important for the development of auditory imagery. An fMRI study by Halpern and Zatorre (2004) showed that sounded and imagined musical experiences result in overlap in brain activation of areas associated with anticipatory hearing, e.g. the secondary auditory cortex (Halpern & Zatorre, 2004). It is also quite established that musicians experience more vivid auditory imagery, both voluntary and involuntary, than non-musicians (Aleman et al., 2000; Bishop et al., 2013a; Campos & Fuentes, 2016; Hubbard, 2010, Talamini & Vigl, 2022). Musical experience is also found to be correlated with stronger vividness of visual imagery (Talamini & Vigl, 2022), though the literature on this is mixed (Aleman et al., 2000). Researchers employing multiple types of auditory imagery questionnaires indicated significant correlations between high reports of vividness of auditory imagery and musical experience (Campos & Fuentes, 2016). When examining loudness of auditory imagery experiences by adjusting a slider in an imagined music task, Bishop et al. (2013a) also observed that imagined volume was the greatest for those deemed to be so-called expert musicians. Lima et al. (2015), through use of magnetoencephalographic imaging (MEG), found physical differences in brain size for participants with different self-assessed auditory imagery. Participants who reported higher scores on the vividness subscale of the Bucknell Auditory Imagery Scale (BAIS-V), regardless of age, working memory, and musical background, tended to have larger amounts of gray matter in the areas of the brain associated with preparation for movement (i.e., the supplementary motor cortex), the processing of sensory information (i.e., the parietal lobes), as well as relatively stronger cognitive functions such as memory, impulse control, problem solving, social interaction, and motor function which are associated with the frontal lobe. In addition to generalizations about cognitive skills, these findings also imply a strong relationship between one's past musical experiences and vivid auditory imagery.

The cognitive planning involved in auditory imagery is shown to differ dramatically across individuals, even among professional musicians with similar levels of expertise (Herholz et al., 2012).

Brodsky et al. (1999) found that wind players were faster at auditory imagery tasks from music notation than string players, despite near-identical self-assessments of their musical abilities and having fewer overall years of formal ear training. This process of silently reading sheet music is referred to as *notational audiation*, or the ability to imagine the sound of music in one's head from reading a score (Gordon, 1976; Wolf et al., 2008). Brodsky et al. indicates that auditory imagery ability may differ between musicians based on their choice of instrument.

Imagery skills are often trained in music theory and aural skills classes, such as when students are asked to imagine intervallic relationships in their mind before they sing or play them (Marvin, 2021). Though the term 'aural skills' is more often associated with sensory perception than imagery, strong aural skills may be an excellent predictor of high levels of self-reported auditory imagery (Highben & Palmer, 2004; Brodsky et al., 2003). A study by Highben and Palmer (2004) indicated that pianists with stronger aural skills were more successful in performing music memorization tasks without any auditory help from researchers. Maintaining a more accurate mental image of the music is useful for better retention of musical pieces. This is also found in studies of longitudinal mental practice. Iorio et al. (2021) found that engaging in a mixture of physical and mental practice, rather than physical practice alone, showed longer retention of musical notation and performance. Mental practice, combined with physical practice, may draw on valuable forms of long-term memory retention in addition to motor and auditory memory, such as narrative and linguistic memory.

Considering that choral and orchestral conductors may often rely on imagery for practice, it may be possible for them to show prodigious clarity and flexibility in auditory imagery tasks (Halpern, 2014). Even conductors that wish to use an instrument like piano for practice, rather than with purely imagined sounds, are still limited by the potential sounds of the instrument. It may benefit a conductor to hear the sounds of a piano, followed by imagining the actual instruments marked in the score, manipulating the pitches made clearer by the piano to be more sustained, more melodic, more connected to breath, and timbrally different. Even with an external instrument assisting their internal experience, these music-contextual examples could demand that a conductor's aural model be more malleable.

I have not been able to identify any studies that have examined whether conductors have better success in communicating their conducting gesture as a result of possessing relatively higher or lower auditory imagery abilities. There are many possible reasons for this gap in the literature, the first reason being that there is currently insufficient evidence of differences in auditory imagery between groups of musicians with similar levels of expertise. Researchers interested in individual differences most often organize groups by musician and non-musician, rather than focus on differences between high-achieving musicians on different types of instruments (Bishop et al., 2013; Gelding et al., 2015; Paquet et al., 2022; Talamini et al., 2022). Further research is needed to understand individual differences in auditory imagery between musicians. Though musical experience is shown to inspire more frequent and more vivid auditory imagery (Floridou et al., 2015), it can only account for part of the differences in auditory imagery between individuals. For example, Halpern (2015) reported weak, yet significant correlations between years of musical experience and self-reported auditory imagery using the most current, reliable, and valid auditory imagery questionnaire, the Bucknell Auditory Imagery Scale (BAIS).

A second reason for the lack of studies in conductors' auditory imagery may be because there is not yet a sufficient connection in the literature between how auditory imagery relates to expressive conducting, nor how expressive conducting becomes expressive performance (Morrison, 2009; Nápoles et al., 2021). While there is evidence that conductor expressivity has a bearing on how audience members perceive a performance (Morrison, 2009), this is not the same as the claim that gesture relates directly to the musical elements of a performance. Definitions of what constitutes an expressive gesture are multitudinous. Researchers have used the following elements of gesture in their operational definitions: facial expressions (Silvey, 2013; Nápoles et al, 2021), eye contact (Yarbrough, 1975), gestural height (Silvey & Fisher, 2015), or whether conductors utilize concave or convex gesture in their beat patterns (Platte, 2008). There are also studies that indicate that gender expression plays a large role in expressivity (VanWeelden, 2002). Since expressive gesture is a nebulous term that defies consistent quantification, it is hard to draw any conclusions about how it might relate to expressive performance.

Purpose Statement

In order to understand whether or not a conductor's auditory imagery has any impact on their musical performance, a useful step would be to understand if conductors have a proclivity towards higher self-reported vividness and/or control of auditory imagery. At the moment, there are no studies that account for how different musical experiences (i.e., comparable expertise on different instruments, vocalists vs instrumentalists, conductors vs non-conductors) contribute to changes in vividness and control of auditory imagery.

Therefore, the purpose of this study is to determine whether or not conductors of choral music present higher levels of self-assessed auditory imagery than choral vocalists of similar musical experience. I predict that conductors are not better at vividness of the BAIS scale, but they are better at control, which is commonly associated with rhythm, selective attention, and manipulation of already existing auditory images.

Research Questions

1. What is the relationship between choral conducting experience and vividness or control of auditory images?
2. What is the relationship between choral singing experience and vividness or control of auditory images?
3. What is the relationship between auditory imagery and a conductor's years of experience on the podium?
4. Are choral conductors' and choral vocalists' imagery abilities related to their perceived abilities to sight-read or memorize music?

Definition of Terms

Auditory imagery is "the introspective persistence of an auditory experience, including one constructed from components drawn from long-term memory, in the absence of direct sensory instigation of that experience" (Intons-Peterson, 1992, p. 46). In lay terms, it is the phenomenon of, either voluntarily or involuntarily, hearing things in one's head that are not perceptible to others. Though they are not the primary concern of this study, involuntary auditory imagery experiences, otherwise known as earworms (Beaman & Williams, 2010), may also provide additional, yet accidental artistic ideas for conductors. This study is predominantly concerned with voluntary auditory imagery.

Auditory imagery is often referred to in music pedagogy by other names, colloquially as the inner-ear, or by more formal terms, such as *audiation* (Gordon, 1976). Audiation is a term specifically coined by Edwin Gordon to be used in his pedagogical approach, Music Learning Theory. Gordon defined *audiation* as "hearing and comprehending in one's mind the sound of music that is not, or may never have been, physically present. It is not imitation or memorization." Gordon's methods of music audiation, such as the Primary, Intermediate, and Advanced Measures of Music Audiation (PMMA, IMMA, & AMMA, respectively), are still commonly used to measure the musical abilities of children, in both psychological (e.g., Grinspun et al., 2020; Yee, 2021) and brain imagery research (e.g. Paquet et al., 2022).

In the preface of his book *Learning Sequences in Music* (1980), Gordon states that "audiation is to music what thought is to language". Gordon was quite detailed about the function of his term, outlining six different stages and eight different processes of audiation in his writings, listed in Tables 1 and 2 below.

Table 1

Stages of Audiation

Stage 1	Momentary Retention (i.e. retaining a series of pitches and durations heard moments earlier in music)
Stage 2	Imitating and audiating tonal patterns and rhythm patterns and recognizing and identifying a tonal center and macrobeats (i.e. running through the mind what has just been heard, but not yet giving it musical meaning)
Stage 3	Establishing objective or subjective tonality and meter
Stage 4	Retaining in audiation tonal patterns and rhythm patterns that have been organized
Stage 5	Recalling tonal patterns and rhythm patterns organized and audiated in other pieces of music
Stage 6	Anticipation and prediction of patterns

Table 2

Types of Audiation

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

It is hypothesized that musicians coordinate their bodies within musical ensembles not just through auditory processing, but combined with anticipatory auditory imagery (Keller & Appel, 2010). This would imply that auditory imagery has strong ties to motor imagery as well. *Motor imagery* is "the mental execution of a movement without any overt movement or without any peripheral muscle activation" (Mulder, 2007, p. 1265). Similarly to how auditory imagery activates similar areas of the brain as auditory processing, motor imagery uses similar areas of the brain as actual movement. Many studies using motor imagery also discuss a *forwards* and *inverse model,* which may be interpreted as bottom-up (outside stimulus shapes decision making) and top-down (internal stimulus shapes decision making) cognitive processes respectively (Sobel et al., 2007). Both forwards and inverse models are hypothetical internal processes, conceptualized by Peter Keller in his studies focused on *sensorimotor synchronization* (Keller & Appel, 2010). Sensorimotor synchronization is the act of coordinating one's body, usually with others, through use of predictable auditory cues. Both a forwards and inverse are conceptualized as a pathway of various forms of sensory perception integrated into motor output for the purposes of sensorimotor synchronization, particularly in expressively timed (non-isochronous) music (Keller & Appel, 2010). In a *forward model*, motor commands are inspired by an outside stimulus to both the primary and nonprimary motor cortices, the first which affects movement, and the second which generates a prediction of what will happen (imagery). By sending to both, the brain is able to compare an intended outcome to what actually happens in the body, making error correction more efficient. In an *inverse model*, motor imagery is generated without the aid of an outside stimulus, an anticipatory action drawn from previous experience. An inverse model will generate an estimate of the motor commands needed to achieve something, ideally producing accurate motor signals that result in desired actions. When applied to expressively timed sensorimotor synchronization, these two models work together to accurately execute the timing of rhythmic actions.

Though conductors may present higher levels of self-assessed motor imagery as well, this study is not directly concerned with this relationship. The control subscale of the BAIS is found to be associated with inner rhythmic processing and sensorimotor synchronization tasks (Halpern, 2015). It would follow that conductors, who are largely responsible for regulating tempo of both isochronous and expressively timed music, might be more proficient at these skills than other types of musicians. Due to noticeable associations in the brain between the supplementary motor areas and supplementary auditory cortices during auditory imagery tasks (Herholz et al., 2012; Lima et al., 2015), it is likely that imagery for musicians not only contains auditory information, but also motor information. This is referred to as *multimodal imagery*. See Figure 1 in the appendix for a visual representation of forwards and inverse models of cognition.

The field of auditory imagery is underdeveloped compared to that of visual imagery. Because the two cognitive processes are somewhat related (Zvyagintsev et al., 2013), this interconnection gives many auditory imagery scholars a head start in designing their measurements. In order to design her own measure, Halpern used models from the visual imagery literature, the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973) and the Test of Visual Imagery Control (TVIC; Gordon, 1949), to design the *Bucknell Auditory Imagery Scale* (BAIS; Halpern, 2015). The BAIS consists of two subscales, vividness (BAIS-V) and control (BAIS-C). Through use of factor analysis, questions are divided in three subcategories: verbal, musical, and environmental auditory imagery experiences. The questions in both subscales are likely to be auditory experiences that participants previously encountered.

Halpern chose the VVIQ as a model due to its prevalence in hundreds of visual imagery studies that focused on a skill called 'object visualization', which predicts artistic creativity, as opposed to 'spatial visualization', which predicts scientific creativity. The BAIS is therefore modeled after methods thought to be more connected to creative processes, making it more specialized towards musicians. This first model Halpern chose, the VVIQ, had a test-retest reliability coefficient of .74, as well as a split-half reliability coefficient of .85 in a sample of psychology students. The other model, Gordon's TVIC (1949), is the first in a new kind of auditory imagery subscale, *control* over auditory images. This subscale is of particular interest to the present study.

The first subscale, the BAIS-V, measures vividness, a term synonymous with the clarity and precision of an auditory image. This subscale asks the participant to rate the vividness of various auditory imagery experiences on a seven-point Likert-type scale, with 1 being 'no image present at all' and 7 being 'as vivid as the actual sound'. The second subscale, the BAIS-C, is defined as the control and malleability of a given image. This subscale provides an initial example, followed by another example that is meant to change the existing image. This would imply, to some degree, that the subscale of vividness precedes control, that there must be some prerequisite level of clarity to an image for it to be manipulable (Zatorre, Halpern, & Bouffard, 2010). The Likert-type scales here ask how easy the image was to change, with 1 being ‘no image present at all’ and 7 being ‘extremely easy to change the image’.

Unlike previous measures in this summary, the BAIS has been used in conjunction with other types of auditory imagery measurement, both behavioral tasks (Gelding, Thompson, & Johnson, 2015; Zatorre, Halpern, & Bouffard, 2010) and physiological imaging (Lima et al, 2015). The BAIS-V is a strong predictor of the ability to sing in tune, referred to more officially as ‘vocal pitch imitation accuracy/deficit’ (Pfordresher & Halpern, 2013; Greenspon et al., 2017, Pruitt, Halpern, & Pfordresher, 2019), though it is not yet proven to correlate with pitch perception (Pfordresher & Halpern, 2013). Vividness scores of the BAIS also correlate with gray matter volume in both auditory and sensorimotor areas of the brain, such as the supplementary motor area (SMA), both the medial and middle frontal gyri, and the parietal cortex (Lima et al., 2015). The control subscale (BAIS-C) is correlated with performance of some musical imagery tasks (Gelding, Thompson, & Johnson., 2015), as well as sensorimotor synchronization of both expressively timed and isochronous music (Colley, Keller, & Halpern, 2018). The Bucknell Auditory Imagery Scale continues to be used as the most valid and reliable measures of self-reported auditory imagery (Halpern, 2015), and it is of great interest to my study.

Delimitations

While nearly everyone experiences auditory imagery, this study is specifically focused on musicians primarily focused on repertoire rooted in Western classical music structure. Participants will be considered only if they have choral experience, as vocalists and/or conductors. To aid in consistency, the collection of musicians for this project will be drawn from members with college-level music experience. Due to an anticipated participant imbalance in favor of vocalists over choral directors for this study, it will be necessary to reach out to additional institutions to find additional choral directors to complete the questionnaire.

Auditory imagery studies use a variety of methods, including self-report questionnaires, behavioral tasks, and physiological imaging. Though additional methods can be used, a questionnaire is the most applicable for this research study.

The components of the questionnaire will include personal information, musical background, musical skillset, vividness of auditory imagery (BAIS-V), control of auditory imagery (BAIS-C), and supplementary choral music questions modeled after the BAIS.

Chapter II: Review of Literature

This literature review highlights studies of auditory imagery that have implications for choral conducting pedagogy. As the purpose of this study is to determine whether or not conductors of choral music present higher levels of self-assessed auditory imagery than choral vocalists of similar musical experience, this review is focused on experiments that adequately measure the phenomenon, as well as account for its cross-relationships with motor and visual imagery. A secondary objective of this literature review is to provide studies on auditory imagery that inform a clearer understanding of gesture and rehearsal techniques for choral musicians.

Inclusion and Exclusion Criteria

Studies for this literature review were discovered through database search on Google Scholar, using combinations of the following words and phrases: *auditory imagery, music imagery, gesture, conductor, audiation, inner ear, embodiment, gestural imagery, pitch, creativity, sight-reading, notation,* and *movement*. Articles on auditory imagery are most frequently published in journals centered around music education, psychology, and cognitive neuroscience. Special attention was paid to the journals *Music Perception*, *Psychomusicology: Music, Mind, and Brain,* and *Music Scientiae*, as these three journals' emphases on both psychology and music education were congruent with the efforts of the present study. Upon an initial Google Scholar search, most of the literature in this review was discovered by exploring music education or psychological journals from the past twenty years. Studies were also found by 'treeing back' (retrieving studies from reference lists) from more recent articles.

Music research studies were drawn from the (1) *Journal for Research in Music Education*, (2) the *International Journal of Music Education*, (3) the *International Journal of Research in Choral Singing*, (4) the *Bulletin for the Council of Research in Music Education*, and (5) *Visions of Research in Music Education*. The most frequently referenced psychology journals included (1) *Neuropsychologia*, (2) the *British Journal of Psychology*, (3) the *Quarterly Journal of Experimental Psychology*, (4) the *Journal of*

Experimental Psychology: Human Perception and Performance, *Attention, Perception, and Psychophysics,* and (5) the *Journal of Experimental Psychology: Learning, Memory, and Cognition*, with some additional articles found in (6) *Psychonomic Bulletin & Review*, (7) *Psychophysiology*, and (8) *Frontiers in Psychology.* Less frequently referenced, but still important to the present study were neuroscience journals, including (1) *Brain and Cognition*, (2) *Imagination, Cognition, and Personality*, (3) *Cerebral Cortex*, (4) the *Journal of Cognitive Neuroscience*, (5) *European Journal of Neuroscience*, (6) *Trends in Neurosciences*, (7) *NeuroImage*, and (8) *The Journal of Neuroscience*. Auditory imagery studies were also frequently published in less cognition-specific or music-specific scientific journals, such as the *Annals of the New York Academy of Sciences.*

The date range of this literature review is approximately twenty-five years, spanning many types of auditory imagery measures and methodologies. The additional purpose of this review is to outline the reliability and validity of measures for potential consideration in the present study. As the field of auditory imagery has seen an exponential increase of interest (Hubbard, 2018), studies in this literature review are most commonly taken from the last decade.

The participants for the present study are exclusively musicians of relatively high expertise, though this is not a common trend in current auditory imagery literature. Many studies focus on differences between those with and without musical expertise (e.g., Aleman et al., 2000; Brochard et al., 2004; Herholz et al., 2008; Talamini & Vigl, 2022). Campos and Fuentes (2016) utilized two different auditory imagery scales to discover that musical experience correlated significantly with high self-reports of vividness in auditory imagery, while Bishop et al. (2013a) discovered that expert musicians displayed the largest imagined volume during auditory images in their study group. These and other studies consistently found that musical expertise positively influenced self-reported vividness and control of auditory imagery. However, few studies have explored how auditory imagery is related to varying types of musical expertise, such as between different instruments, or in the case of the present study, between conductors and vocalists of similar musical experience. Therefore, both this study and this literature review will focus as much as possible on literature emphasizing practice for aspiring professional musicians.

Embedded deeply and often implicitly in music education pedagogies is the importance of an ‘inner ear’ (Kodály, 1976), engaging in ‘mental rehearsal’ (Seashore, 1919), or learning ‘audiation’ skills (Gordon, 1976). Though the operational definitions of these terms often extend beyond the psychological/neuroscientific term of ‘auditory imagery’ to include additional cognitive processes like attention and reasoning, as well as musical context (Gordon, 1976), they have unquestionable overlap. These terms were therefore considered alongside auditory imagery for this review. Additional commentary on the historical and cultural context of ‘audiation’ is also considered below.

Since choral directors and vocalists have speech encoded in their music an overwhelming majority of the time, a special effort was made to include studies that involve the encoding of words in their methods. However, studies that pertained exclusively to speech and did not include music were excluded, as the relationship between neural processing of speech and music is not the target of the present study (for more information, see Tierney et al., 2013, Skoe & Kraus, 2010).

The literature on individual cognitive differences of auditory imagery is impossible to cover in a single literature review. While there is a large literature documenting involuntary auditory imagery experiences, otherwise known as ‘earworms’ (Beaman & Williams, 2010), the present study is primarily concerned with the voluntary aspects of auditory imagery. Additional psychopathological differences such as schizophrenia or other musical hallucinosis were not included in this review, nor were psychological phenomena such as synesthesia and amusia.

Following a historical overview of the term audiation, this literature review is organized into the following categories: (a) auditory imagery for simple musical structures, (b) auditory imagery in musicians and non-musicians, (c) auditory imagery and motor imagery, and (d) auditory imagery, score study, and expressive choral gesture.

Audiation: Historical and Cultural Context

Though the process of hearing music in one's head is commonly referred to as audiation in most music pedagogical contexts, I use the term auditory imagery, due to the historical and cultural context of the word audiation. Audiation differs from auditory imagery most obviously in its word choice. Gordon was not overly fond of the word *imagery*, as he felt the term would be easily conflated with vision, rather than hearing (Gordon, 1976). While auditory imagery and audiation are often used interchangeably in music literature, they are not the same. Gordon extended audiation to include not just auditory imagery processes, but also the scaffolding of musical concepts, that sounds must be comprehended in a specific framework.

Though much of the vocabulary around cognitive research is absent from Music Learning Theory, Gordon makes the claim that his method evolved from being more perception-based to being more cognition-based over time (Stokes, 1996). In his skill learning sequence (Tables 1 & 2), he is interested in how students perceive a musical stimulus, using learning-based words like *identify*, *associate*, *recognize*, and *translate*. While perceiving is one of the tenets of cognition, these prompts are potentially missing benchmarks guaranteeing that students had the mental experience his methods claimed.

Gordon argued that audiation is essential for listening to music intelligently, that audiation provides an "immediate readiness for the development of music literacy skills" (Gordon, 1976, p. 2). In the first chapter of Learning Sequences in Music, Gordon discussed the difference between musical aptitude, "a measure of students' potential to learn", and musical achievement, "a measure of what a student has learned" (Gordon, 2012, p. 45). From Gordon's observation, musical aptitude settled before a student reaches 9 years of age, after which their potential to learn is set. They are, from this point, only able to influence their achievement. Many of his critics push against these limitations, as well as arguing that thinking of audiation as a form of intelligence is problematic. Audiation should be considered a skill that can be applied to music, instead of being thought of as a measure of intelligence (Stokes, 1996).

A meta-analysis by Hanson (2019) determined that Gordon's Primary (Gordon, 1979), Intermediate (Gordon, 1986), and Advanced Measures of Music Audiation (Gordon, 1989) (PMMA, IMMA, AMMA, respectively) have a consistent, but not always strong correlation with music outcomes such as aural perception, creativity, affects, and musical engagement. The only strong correlation between these measures and any music outcomes was musical achievement of Western classical music. This meta-analysis provides contrary information to Gordon's original statements that his measurements would reliably impact musical outcomes other than performance achievement (Gordon, 1976). This calls into question whether or not these measurements should be used on any studies interested in music outcomes other than achievement in performance. To Gordon's credit, he eventually amended his statement and concluded similarly to Hanson (2019) that his music aptitude tests only correlate with achievement (Gordon, 1998).

Though Gordon did attempt to validate his tests among students that he defined as "culturally-disadvantaged" (Gordon, 1975) and "inner-city primary children" (Gordon, 1980), the musical contexts he tended to have in mind when designing his tests were much less multiculturally complex than that of today. Culture has an enormous influence on auditory perception and processing and must be accounted for in a twenty-first century musical ensemble. A recent study by Gouzouasis (2021) explored the relationship between Canadian Kindergarten children's ethnic heritage and their auditory music aptitude using Gordon's measurements. Results indicated a large difference between the mean tonal audiation scores of students in three different ethnic groups, Chinese, East Indian (Sikh), and Euro-Canadian. The mean for children of Chinese and Euro-Canadian ethnicity on the tonal section of the test were significantly higher than that of East Indian ethnicity. Conversely, rhythmic audiation scores were nearly uniform, with no statistical significance between the groups. Gouzouasis (2021) asserted that there were three possible, potentially overlapping reasons for the tonal discrepancy, either (a) developmental music aptitude is influenced by a child's environment, (b) there are more similarities between rhythmic frameworks than tonal frameworks in participants' cultural backgrounds, and/or (c) that the tonal content of the PMMA is biased towards a Western musical framework. Because 'audiation' is considered by

Gordon to be an innate human quality, as well as there being no research to support that entire ethnic groups or national groups are unable to audiate, Gouzouasis (2021) posited that the tonal patterns in the PMMA may cater unfairly to the Western diatonic system. Gordon's methods are not as universally applicable to audiation as they originally claimed.

Gordon's methods continue to be far-reaching and impactful to the field of music education, as evidenced by recent implementation of all three Measures of Music Audiation in both Greece (Verdis & Sotiriou, 2017) and Turkey (Esmergül & Önder, 2022). The research on the effectiveness of Gordon's measurements in non-Western cultures is mixed, making it important to view Gordon's concept of audiation within an appropriate historical context. Throughout this review, the term *audiation* is still used to describe findings from studies that utilize Gordon's tests, to remind the reader of the context from these findings. None of the studies utilizing Gordon's tests in this review were directly interested in musical achievement in Western classical music, and they must therefore be viewed with the appropriate limitations.

Auditory Imagery for Simple Musical Structures

In order to better understand the simplest cognitive scaffolding of auditory imagery, many researchers have focused on observing basic features of musical sound, such as pitch, timbre, and loudness. Simple auditory imagery is useful for musicians of almost all instrument types, who use imagined pitch for more accurate tuning in upcoming musical entrances (Trusheim, 1991). Imagery also presents remarkable timbral consistency to the physical sounds they are inspired by, from types of instruments to full-length songs (Halpern et al., 2004). Perceiving a pitch in one's mind does not merely involve imaging a simple sine-wave, i.e. a pitch devoid of overtonal qualities: it has association to the timbre and the loudness of the sound it is inspired by. Self-report auditory images can range in complexity from a single pitch to full-length, multi-instrument symphonic works, as evidenced by letters and autobiographies of famous composers such as Mozart, Schumann, and Berlioz discussing the robustness of their imagery (Agnew, 1922).

Pitch, timbre, and loudness all have gestural implications for choral conductors (Brinegar, 2020; Grady, 2014) and therefore, learning to communicate these musical features is a fundamental part of conducting pedagogy. Lack of unification of pitch, timbre, and loudness are among choral conductors' most common rehearsal challenges, and often require specific strategies of tuning and vowel unification (Gumm, 2018; Regier et al., 2022). Since conductors are tasked with these responsibilities, they may develop more robust skills in auditory imagery, potentially presenting higher results on self-report questionnaires. The following section explores these fundamental processes of (a) pitch, (b) timbre, and (c) loudness.

Auditory imagery and pitch

In the interests of discovering the most fundamental elements of pitch imagery, Yoo et al. (2001) organized a fairly simple imagery model, asking for participants to imagine a solitary and continuously-held note in their minds while they acquired an fMRI scan. This study was among the first to unpack the cognitive processes behind such a basic musical structure, finding activations in areas of the brain associated with language processing and speech production (Broca's area, inferior frontal gyri), mental imagery concerning the self (precuneus), auditory processing and social cognition (Brodmann's area, Wernicke's area, superior temporal gyri), impulse control and decision making (anterior cingulate gyri), and linguistic tasks such as response planning (middle frontal gyri). There was slightly higher activation on the left side for the inferior frontal gyri and higher activation on the right side for the precuneus and the superior temporal gyri. This study has measurement limitations, as they did not include any behavioral evidence that auditory imagery actually occurred in their participants during fMRI. Additional neurophysiological studies of auditory imagery confirm significant overlap in the neural areas found by Yoo et al. (2001), such as when imagining human vocal sounds of various emotions (Lima et al., 2015) or short samples of familiar songs (Herholz, Halpern, & Zatorre, 2012).

Of great importance to both choral directors and choral vocalists is how auditory imagery interacts with the ability to vocally match pitch. Pfordresher and Halpern (2013) explored the relationship between pitch imitation ability and auditory imagery by focusing on participants with vocal pitch imitation deficit (VPID). They found significant positive correlations between the vividness subscale of the Bucknell Auditory Imagery Scale (BAIS-V) and the percentage of pitch imitation trials sung in tune, supporting their underlying hypothesis that auditory imagery is crucial to the processing of pitch. Importantly, this correlation with vividness was found independent of musical experience, implying generalizability. The second subscale of the BAIS, which measures for control, was not significantly related to pitch production, suggesting that poor-pitch singing involves imagery deficiency at the most basic level, with no possibility of controlling an image if it cannot be adequately vivid.

A later study by similar researchers, Greenspon, Pfordresher, and Halpern (2017) applied these findings beyond individual pitches, to focus on melodies. They were interested in how mentally transformed melodies, such as via transpositions, reversals, and serial order shifts of notes, might affect the accuracy of vocal pitch. This task was modeled after Shepard and Metzler's (1971) design of mentally rotating visual images, designed to be the auditory equivalent of rotating geometric shapes. The final sample of participants was ten accurate singers and ten VPID singers, who did not differ significantly in their pitch discrimination abilities. Participants were given six trials with three- or four-note target sequences, asked to imitate the melody exactly, then to manipulate it according to the three transformations. After the production task, participants completed a series of surveys, including music and language background, as well as the BAIS. Vocal transformations were difficult for all participants, but VPID singers were exceptionally challenged by these activities, with results on these tasks approaching chance levels. VPID singers missed twice as many notes as those labeled accurate singers, indicating that imagery quality differentially affects production and recognition performance. The differences between these two groups suggests that VPID is related to a deficiency in multimodal imagery, and since auditory imagery is linked inextricably to motor performance amongst singers, this gives VPID singers a challenging time vocally matching. This study implies that functional pitch connectivity to the vocal mechanism is important for the successful manipulation of auditory imagery (see section on *subvocalization* below).

Like previously mentioned studies, Zatorre, Halpern, and Bouffard (2010) were interested in how pitch could be manipulated in the mind, but rather than working with a more general population, their study focused on professional musicians. Using fMRI imaging, they explored how musicians could use auditory imagery to evaluate or even generate unfamiliar musical melodies. Similar to the previously mentioned study, methods utilized retrograde melodies to assess the working memory and auditory imagery of participants. They designed a mental manipulation task where participants were presented with familiar tunes and were asked whether a second presented stimulus was an exact retrograde of the familiar tune or a false reversal, one that had misordered or incorrect pitches. Imaging data of participants during imagining of reversed melodies showed stronger activations in visual and spatial attentional areas of the brain (intraparietal sulcus, posterior parietal cortex) than initially anticipated. Activation was somewhat asymmetrical, primarily on the left, which is more associated with speech (Broca's Area) than with music (Brodmann's Area). There was no activation in the auditory cortex for either forward or retrograde melodies, which they concluded might have been because of the manipulative requirements of the task. Since the task was so cognitively demanding, they concluded it may have superseded the sound quality of mental imagery itself.

The connections between auditory imagery and pitch manipulation may have important implications for conducting. The idea of manipulating tones is a valuable skill for musicians with creative intent, such as composers, who are tasked with imagining new melodies, or conductors, who are tasked with reinterpreting and embodying them (Biasutti, 2012). Melodies are among the most commonly embodied musical elements for conductors, which is perceptible not only to the performers, but also to audiences (Kumar & Morrison, 2016). Listeners are quite sensitive to the way in which a conductor focuses on melodic lines (Kumar & Morrison, 2016). Since the bulk of conductors' practice time is spent without immediate access to an ensemble, it is useful for their imagined versions of the music to be vibrant, allowing them more dependable connections between motor skills and imagined elements of music.

Auditory imagery and timbre

Early studies in timbre and auditory imagery were offered by Crowder (1989), who played two tones with similar or contrasting timbres, and asked participants if the pairs of notes were the same pitch. The more mismatched the timbre, the slower participants were able to adequately judge pitch, indicating that timbre provides some interference with auditory perception of pitch. In the second half of the study, Crowder turned the same idea into an imagery task, asking participants to imagine the sound of a note of identical pitch on a separate instrument, a guitar, flute, or trumpet. Judgments of pitch were again slowed when the second tone played was on a different instrument than anticipated. Crowder concluded that participants' auditory images contain specific timbral information, and since the stimulus provided contrasted in timbre from participants' internal aural model, it required a cognitive transfer in order to perceive similarity of pitch.

A similar experiment was conducted by Pitt and Crowder (1992), who changed the timbre of a cello tone by alternating between bowed or plucked pitches. The purpose of this study was to examine whether or not harmonics and dynamics were also present in an auditory image. Participants were given different timbres to remember, and after being presented with a sine wave of a specific pitch, they were asked to assign the pitch to the timbre they remembered. After being given time to imagine the timbre prompted, participants were presented with a second tone, and they had to determine whether or not a pitch matched the pitch in their image. Decision making was slower when harmonics of the second sound were manipulated, but not when dynamics were manipulated. This led Pitt and Crowder to conclude that overtone frequency was present in auditory imagery, but not dynamics. Studies that utilize the timbral simulation of voices could be of more relevance to choral conductors, but both of these studies intentionally avoided vocal stimuli, as they were concerned that the sound of a voice might invite subvocalization or other motor processes, which would be a confounding variable in the experiment.

Halpern et al. (2004) conducted the first fMRI study to focus on timbral imagery. They scanned participants' brains during two tasks: the first involved auditory perception of pairs of eight different musical instruments, and the second task was to imagine those same instruments. Participants were asked to rate timbral perception according to two factors: brilliance and nasality. The ratings of timbre perception and timbre imagery were highly correlated. fMRI imaging confirmed activation in the areas of the brain associated with preparation for movement (supplementary motor cortex) in both perception and imagery tasks. The primary auditory cortex, tasked with auditory perception, was not activated during the timbral imagery task.

In a qualitative study by Reymore and Huron (2020), the researchers accounted for auditory imagery processes by asking participants to describe imagined sounds of Western classical musical instruments. Unlike the previously-mentioned studies of timbre, this study did not offer any pre-recorded auditory stimuli to help the participants, asking them instead to describe, in whatever detail they wished, various aspects of timbre in these instruments, drawing only from imagined sounds. The purpose of the study was to build a timbre *qualia* (experiential, intrinsic) model that might prove useful in music analysis. This study documented not only adjectives, but anecdotal stories, comparisons to other sounds, colorful metaphors, and onomatopoeia. After a series of preliminary analyses, they narrowed the findings to include nineteen components of timbre: rumbling/low, soft/singing, watery/fluid, direct/loud, nasal/reedy, shrill/noisy, percussive, pure/clear, brassy/metallic, raspy/grainy, ringing/long decay, sparkling/brilliant, airy/breathy, resonant/vibrant, hollow, woody, muted/veiled, sustained/even, open, and focused/compact. Results from this study indicate that discussions about timbre are predominantly metaphorical, with an enormous scope of possible language to describe music.

Documented evidence for the existence of timbre in one's auditory imagery has enormous implications for conductors. Among choral conductors' most common rehearsal challenges are lack of unification of pitch and timbre (Gumm, 2018). Conductors can solve these auditory discrepancies by embodying the sound they wish to hear in their gesture, but also by utilizing their words. Choral conductors, and indeed all music educators, often implement anecdotes to appeal more strongly and clearly to their singers, all with the purpose of retention and unification in ensemble sound (Durant, 2009; Fuelberth, 2003). Reymore and Huron (2020) have documented how drawing from a previously-heard auditory image from long-term memory into working memory can translate into meaningful creative wordplay that can unify musicians' attitudes towards a musical work.

There are different theories for how auditory imagery is conceptualized: *depictive*, with images and their physical representations being similar in form, or *descriptive*, with the mental representation of an image taking on a symbolic, language-like code (Hubbard, 2010). Depending on context and the person, it is likely that auditory imagery can be thought of both ways, with depictive images having a more subconscious value for conductors by informing their gesture, and descriptive images allowing for an easier translation of their musical ideals into words.

Auditory imagery and loudness

In a study by Wu et al. (2011), researchers explored how the brain perceives loudness of pitches in auditory imagery. Participants were primed for the experiment by developing an association of varying loudness with three visual stimuli, a circle (soft), a square (medium), and a triangle (loud). Once the auditory-visual associations were made, they measured the amplitude of the imagery with EEG during a simple task. Participants were asked to imagine the auditory stimuli that corresponded to the shape, as well as make a same/different comparison with the actual sound at the end of the task. EEG recordings revealed that mental images were greater in amplitude when participants attempted to imagine louder tones.

Bailes et al. (2012) was an experiment to investigate how disruptive effects would influence mental imagery for changes in loudness. Music-reading participants were asked to monitor aural models with various loudness change patterns of crescendi and decrescendi, all while either a distraction task simultaneously played. Participants were presented with a score and asked if it matched the aural model they had just heard. There were three different types of distractions: (1) letter sequences, which was a simple working memory task consisting of rhyming letters, (2) tone sequences, an 8-second-long, four-note aural stimulus in a different key than the actual task, and (3) movement sequences, a series of expressive conducting videos, with gestures ranging from slow to fast and small to large. Of the three distractors, the movement sequence was the most impairing to recalling changes in loudness in participants. The researchers posited that this conducting distraction was particularly potent because gesture is relevant for the communication of musical intensity. Observing a sequence of conflicting conductor gestures activated motor representations that were confounding to the aural model.

Another study by Bailes, this time with Bishop (2013a) focused on how mental imagery loudness was influenced by musical expertise. Participants were organized into three expertise groups: non-musician (M = 9 months of formal training, novice (M = 3.2 years of formal training), and expert (M = 11 years formal training). Auditory stimuli were excerpted from well-known classical music pieces (*Blue Danube Waltz* by Johann Strauß, *Habañera* from "Carmen" by Georges Bizet, *Jupiter* from "The Planets" by Gustav Holst), due to their absence of lyrics, dynamic contrast, and their tendency to be expressively-timed rather than isochronous. Participants were asked to listen to a CD containing these excerpts a minimum of twice a day for a week. In the second phase of the experiment, they were invited into a laboratory for a series of listening and imagery trials, where they were guided through a tapping task and a loudness task for each of the musical passages. This study showed that regardless of musical expertise, participants made consistent loudness judgments between listening and imagery trials, but musicians displayed greater overall accuracy between the two conditions. Not all novices or non-musicians perceived subtle loudness differences in the context of phrases. It is inconclusive from these findings whether judgments in loudness of imagery are a function of prior musical experience or of musical expertise, as many participants labeled novices or non-musicians outperformed many experts.

In addition to pitch and timbre, conductors are constantly attending to the volume of musical passages. Conducting textbooks frequently discuss gestural implications for dynamic control of an ensemble, usually larger gestures with more weight are indicative of louder dynamics (Brinegar, 2020). It is possible that auditory imagery, when tasked with keeping track of perceived volume, becomes intermingled with these kinds of iconic gestures over time. Due to the high generalizability of perceiving loudness in imagery amongst the general population, it is unclear whether or not conductors would be particularly adept at imaging degrees of loudness compared to other musicians. Studies that focus on distractions in auditory imagery loudness may be particularly relevant to novice conductors, who are often not yet proficient at conveying the same musical information with their bodies as they can with their words. This can lead to conflicting musical communication from the podium, producing all kinds of muddled interpretations throughout an ensemble.

In the present study, I am also interested in how loudness relates to auditory imagery, due to the use of the words vividness and clarity in many auditory imagery self-report questionnaires, words that likely have some components of loudness.

Auditory Imagery in Musicians vs Non-Musicians

It is well-documented that musicians experience more vivid and controllable voluntary auditory imagery than non-musicians (Aleman et al., 2000; Brochard et al., 2004; Herholz et al., 2008; Talamini & Vigl, 2022). The goal of the present study is similar to the goals of such studies, which were to further unpack differences between people based on musical experience. It is important to highlight these studies, not only due to their findings, but also due to them having similarities in research methodology to the present study.

In an early study on individual differences between musicians and non-musicians, Alemán et al. (2000) incorporated both musical and non-musical auditory imagery tasks, as well as a visual imagery task, to uncover which elements of imagery are associated with musical expertise. For the musical task participants were asked to compare the pitches of notes corresponding to familiar song lyrics, while the non-musical task explored acoustic characteristics of common sounds. For the visual task participants indicated which of three pictures was the outlier in terms of form. Each of these tasks had both a perception and an imagery condition. Results indicated that musical experience contributed positively to task success when subjected to auditory stimuli, but not visual stimuli.

Campos and Fuentes (2016) administered the Spanish versions of two different auditory imagery questionnaires, the Clarity of Auditory Imagery Scale (Willander & Baraldi, 2010) and the Betts' QMI (Sheehan, 1967) to 200 students, 100 from a secondary school and 100 from a music conservatory.

Conservatory students scored higher on all measures of auditory imagery, as well as in all imagery categories except for gustatory imagery on the Betts QMI. Based on these results, the authors concluded that engagement in musical activities provides benefits for general cognitive processing. However, this study failed to account for differences between the populations of students beyond their results on this questionnaire and their gender expression. Claiming that music study was the reason for musicians' success on the questionnaire is a simplistic and potentially error-prone evaluation.

In a similar study that utilized two different imagery questionnaires, researchers Talamini & Vigl (2022) compared the auditory imagery abilities of three groups: formally-trained musicians, self-taught musicians, and non-musicians. They administered a series of cognitive tests, an auditory questionnaire they designed, and a well-known test on visual imagery, the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). They chose not to use the Bucknell Auditory Imagery Scale due to many of its questions having musical content, which they felt would carry a bias towards musicians. Even without any questions relating to music, both formally-trained and self-taught musicians presented higher levels of self-assessed auditory imagery than non-musicians. The cognitive tests had no correlation with vividness of auditory imagery. Somewhat surprisingly, self-taught musicians presented higher levels of vividness than formally-trained musicians, which the researchers indicated may be due to self-taught musicians' reliance on their ears rather than the score.

Herholz et al. (2008) compared the imagery abilities of musicians and non-musicians with magnetoencephalography (MEG) using a familiar nursery rhyme musical task. Participants listened to the beginnings of these common melodies, which alternated between an aural model and silence. During these periods of silence, participants were asked to continue the nursery rhyme in their auditory imagery to maintain their place in the music, in order to determine whether the final auditory stimulus played at the end was either a correct or incorrect continuation of that melody. Results indicated that musicians were not only more discerning at identifying incorrect notes in the behavioral task, they also presented higher amplitude in their MEG scans when reacting to these misplaced pitches than non-musicians. Based on these findings, the researchers concluded that musical training modified the regions of the brain associated with violation of aural expectations to achieve superior auditory imagery ability.

The authors of these studies have consistently found that musical expertise positively influences self-reported vividness and control of auditory imagery. Differences between self-taught and formally-trained musicians showcase how different auditory imagery has enormous potential to vary even amongst a population of musicians. Few studies have explored how auditory imagery is related to varying types of musical expertise, such as between different instruments, or in the case of the present study, between conductors and vocalists of similar musical experience.

Auditory Imagery and Motor Imagery

A conductor is not merely tasked with imagining their ideal performance in their head: they must also embody it. Physiological fMRI studies of auditory imagery confirm that imagining music in one's head not only engages the supplementary auditory areas of the brain, but also the supplementary motor cortices as well (Lima et al., 2015; Lima et al., 2016; Herholz et al., 2012; Halpern et al., 2004). These studies imply that music, even when it is only imagined, creates anticipation for movement in the body. Similar to how auditory imagery primes the brain for hearing, so too does *motor imagery* prime the brain for movement. This potential for movement could be a reaction to sound, such as the case of fight or flight response, but could also include potential for movement along a musical instrument, and potentially expressively. Motor imagery is defined as "the mental execution of a movement without any overt movement or without any peripheral muscle activation" (Mulder, 2007, p. 1265). Auditory imagery is thought to help musicians stay in time by providing anticipatory auditory cues during expressively timed music (Colley, Keller, & Halpern, 2018). It is hypothesized that musicians coordinate their bodies within musical ensembles not just through auditory processing, but also with anticipatory auditory imagery (Keller & Appel, 2010). The two cognitive tasks of auditory perception and auditory anticipation allow musicians to accurately execute the timing of rhythmic actions.

Depending on the manner and style of music, conductors may be expected to maintain consistent rhythm, but are also responsible for expressively timed musical stimuli. Even when focusing on rigid tempo, a musical phrase can often contain subtle changes in tempo, referred to as microtiming (Frühauf et al, 2013, p. 247). These slight deviations from perfection are deemed more aesthetically valued than a piece with a strict metronomic rhythmic pattern (McGuiness, 2003). Conductors are often tasked to indicate subtle changes in time through their gesture, following markings in the score such as ritardando, rallentando, and rubato, among others. They act as a rhythmic conduit for this expression, through which all other musicians coordinate their movements. Studies focused on *sensorimotor synchronization* (SMS), or “the coordination of rhythmic movement with an external rhythm” (Repp & Su, 2013), explore how musicians organize their body movements differently depending on whether musical stimuli is perceived as isochronous or ‘expressively timed’ (Colley, Keller, & Halpern, 2018; Wöllner & Williamon, 2007). It is hypothesized that musicians use a combination of auditory and kinesthetic imagery to maintain rhythmic timing in their music (Pfordresher et al., 2015).

Subvocalization may be defined as subtle vocal muscle movements, sometimes called ‘covert singing’ (Pruitt, Pfordresher, & Halpern, 2019, p. 2). Frequent subvocalization is a common occurrence when musicians read music notation (Brodsky et al., 2008), but it is also correlated with poor writing skills, as well as reading words (Daneman & Newson, 1992). This phenomenon appears to be an outwards compensation for less vivid imagery. Due to the obvious relationship between choral music and the voice, the concept of subvocalization in auditory imagery studies is worth exploring. This section focuses explicitly on the cross-relationship between auditory and motor imagery, sometimes called *multimodal imagery* (Pfordresher et al., 2015, p. 242), with attention paid to potential interdependencies, (a) anticipatory auditory imagery and sensorimotor synchronization and (b) auditory imagery and subvocalization.

Anticipatory auditory imagery and sensorimotor synchronization

Pecenka and Keller (2009) explored the relationship between basic forms of auditory imagery and SMS in musicians. They hypothesized that musicians coordinate their actions based on anticipating the sounds about to be produced by their co-performers. If predicting in SMS is related to auditory imagery, then there should be a positive correlation between skills in auditory imagery and synchronization. Participants were asked to maintain a single pitch in their minds over a period of ten seconds, then adjust a different pitch stimulus at the end of the ten-second interval to the maintained pitch via a slider. SMS ability was measured using three different tapping tasks: tapping to a stable metronome, tapping to a metronome with subtle tempo changes, and off-beat tapping to a stable metronome. Individuals with more accurate pitch-imagery retention were more successful at all tapping tasks, with the highest correlations found in the tapping task that required subtle fluctuations of tempo. Though these findings are convincing that anticipatory auditory imagery leads to more successful sensorimotor synchronization, the methods used in this study are a bit simplistic. There is much more bodily coordination required for successful sensorimotor synchronization in ensemble performance than a simple tapping task could represent, nor is maintaining a single pitch in one's head over a ten-second interval a representation of auditory imagery that is ecologically valid with regard to music performance.

Keller and Appel (2010) focused on body sway in the anterior-posterior plane of pianists playing duets, and hypothesized that movement played a role in internally and externally coordinating synchronization. Secondary purposes of the study were to investigate how movements of ensemble members affected musical synchronization, as well as exploring the relationship between leading and following in a duet setting. Fourteen pianists with prior experience in mixed chamber groups were recorded using motion capture while they performed piano duets, alternating between primo and secondo parts. Visual contact was manipulated during the duets: half of the time, pianists could see each other, and the other half, they coordinated by sound alone. Variables included body sway in the anterior-posterior plane, asynchrony between keystrokes played by two pianists, and data from a small anticipatory auditory imagery tapping task. Findings indicated that duos of pianists with higher anticipatory auditory imagery were more coordinated in terms of keystroke and body sway, even when visual contact was absent. The strong correlation makes a case for the value of developing musicians' auditory imagery to perform more accurately in an ensemble setting.

Fascinatingly, body sway increased when visual contact was absent between the two pianists, showing that rhythm became more embodied when forced to rely on sound alone. Musicians performing the leader (primo) part of piano duets were found to have more asynchronous body sway with the timing of the played part, indicating how individual efforts to regulate one's internal time do not always communicate useful temporal information to others in the ensemble. Body sway may fulfill two functions in ensemble music-making: to communicate expressive intentions or to regulate an individual's internal tempo. This confusion led to synchronization challenges between groups of two musicians. Piano duets were much more synchronous when visual contact was absent than when it was present. This study showed how a musician's movements to regulate their own rhythm in their body runs the risk of being interpreted as a cue by their partner in expressively-timed musical moments.

Explicitly interested in expressively timed music, Colley, Keller, & Halpern (2018) explored how cognitive processes like working memory and auditory imagery impacted sensorimotor synchronization. They designed an experiment to see whether or not auditory imagery ability impacted synchronization to both expressively-timed and isochronous music. Forty-five participants who did not have regular exposure to classical music were administered a series of tests, starting with a musical background questionnaire and both subscales of the Bucknell Auditory Imagery Scale (BAIS; Halpern, 2015). Participants also completed two working memory tests: a digits backwards test, where they had to recite numbers in the opposite direction they were provided, and an operation span test, where they had to answer true or false to random assortments of semantically correct or nonsensical phrases. Afterwards, they completed two different auditory imagery tasks. The first, the Pitch Imagery Arrow Task (PIAT; Gelding, Thompson, and Johnson, 2015), asked participants to press arrows indicating whether notes in a scale were ascending or descending. Over time, the notes began to disappear, but the arrows remained, and participants were expected to keep track of the melodic line and confirm if a final stimulus note was possible after the given imagined sequence. The other auditory imagery task was the Temporal Imagery Task (TI), where participants had to keep track of gradually speeding up or slowing down progressions of beats. These beats, moving in accelerando or rallentando, eventually disappeared, requiring the participant to maintain the auditory image of a steadily increasing or decreasing beat pattern by tapping. Participants received a final audible stimulus at the end of the task, which asked whether it occurred too early or too late. Finally, participants completed a synchronization task, listening to a Mozart piano sonata (isochronous music) and a Chopin étude (asynchronous, expressively timed music), tapping along with the expected beat. They used three different Chopin recordings to monitor unique timing profiles between the recordings.

Findings of this study indicated that working memory was not significantly correlated with the ability to monitor asynchronous music, but researchers observed a significant correlation with both auditory imagery tasks. The control subscale of the BAIS was strongly correlated with synchronization tasks, while the vividness subscale had moderate correlation. The authors contended that the BAIS-V was less correlated because it is a measure primarily concerned with maintaining a static image. While people with accurate pitch imagery tended to synchronize better, they were not as successful at anticipating upcoming beat intervals. Sensorimotor synchronization is a dynamic and temporal process, and the BAIS-C is a measure of changing an established image.

In their recent magnetoencephalography study, Gelding, Thompson, and Johnson (2019) hypothesized that similar neural oscillations for auditory processing (beta-band, mu-band, and theta-band) might also trigger under conditions of auditory imagery. Nineteen participants were given the Pitch Imagery Arrow Task (Gelding, Thompson, & Johnson, 2015), as well as two non-imagery temporal tasks for control, while MEG monitored brain activity. They discovered that beta-band modulation was even more prominent in imagery tasks than in perception-based tasks, with the oscillation nearly uniformly distributed throughout both auditory and sensorimotor regions of the brain. This indicates that during auditory imagery processing, these areas are in tight communication with each other. While no mu-bands were statistically significant, theta-bands were connected in the left sensorimotor and auditory regions during the onset of auditory imagery, indicating more robust communication. These findings indicate the interdependence between sensorimotor and auditory regions in the brain, not only during actual auditory processing, but also in imagery.

Auditory and motor imagery interdependence is an important topic for conducting pedagogy. Conductors are often found preparing for pieces of music by waving their hands in tandem with their auditory imagery. These findings imply that these conductors are doing more than merely practicing their gesture, but also enhancing the quality of their imagery. It may in fact be desirable to have a clear auditory image before gesturing, as the introduction of any physical act may have an incidental effect on the image.

As far as I could determine, there are no known studies on how auditory imagery impacts conducting gesture, but studies featuring how other types of musicians more efficiently coordinate themselves rhythmically have implications for leadership on the podium. The findings from Keller and Appel (2010) may not be generalizable to conductors, since conductors operate under the assumption that their gestures are exclusively used to convey the music, rather than for their own internal regulation of tempo. Their internal reliance on tempo might present in their bodies differently, perhaps also due to the fact that they are not responsible for making sound themselves. Further research is needed to understand how conductors' inner regulation of tempo affects their gesture.

Based on the literature utilizing the Bucknell Auditory Imagery Scale, inner pitch and melody are more associated with the vividness subscale of the BAIS, while inner rhythm and sensorimotor synchronization are more associated with the control subscale (Halpern, 2015). Measurements for the control of an auditory image may have a strong correlation with conducting practice, since conductors are overwhelmingly responsible for expressively timed musical moments. Because the timing of motor commands of an ensemble is (ideally) entirely in conductors' control, assuming the most attentive musicians, it follows that they should have strong internal control over anticipatory auditory imagery. For this reason, it is possible that conductors would present higher levels of auditory imagery than other types of professional musicians.

Auditory imagery and subvocalization

In a study between auditory perception and the human voice, Brown and Martinez (2007) conducted a series of fMRI scans of musically-experienced participants, while they performed a series of melody and harmony discrimination tasks. Cortical activations in musicians during melody and harmony tasks heavily overlapped with a previous PET study focused on vocal production tasks for music and language (Brown, Martinez, & Parsons, 2006), leading the researchers to conclude that there is strong connection between discrimination of pitch and vocal production. Both studies demonstrated an overlap of activation in the frontal operculum, which is responsible for stimuli in the mouth. They also found activation in other areas involved in vocal planning and production, such as Broca's area (motor-speech), the supplementary motor area (SMA, anticipation for movement), and the anterior insula (focus of attention, emotions). Interestingly, Brown and Martinez did not incorporate rigorous controls for vocal experience in their methods, noting only the experience levels the musicians had on the instrument of their choice. This lack of information about background in vocal music limits the generalizability of the findings, as it is difficult to say that non-musicians would default to using vocal musculature when presented with melody and harmony discrimination tasks. This study did not focus on imagery in particular, but laid a useful foundation for future studies interested in the relationship between auditory perception/imagery and subvocalization.

Pfordresher and Halpern (2013) sought to understand the relationship between pitch imitation ability and auditory imagery. They posited that inaccurate vocal imitation of pitch relies on poorly functioning bottom-up processing via a process they called an *inverse model* (Keller & Appel, 2010). This is an implicit, not necessarily conscious model of perception that guides motor planning. This is different from the bottom-up *forwards model*, in which outside stimuli such as noise enters the cognitive sphere and dictates action (e.g., auditory processing). In this study, 138 participants with minimal musical experience were guided through a series of vocal imitations and pitch discrimination exercises. They were also asked to complete both subscales of the previously-described Bucknell Auditory Imagery Scale (BAIS). Analysis focused on whether individual differences in vocal imitation are related to self-report measures of auditory imagery, as measured by the BAIS. Significant positive correlations were found between the BAIS subscale of vividness and the percentage of trials sung in tune, as well as total years of musical experience. This supported their underlying hypothesis of the relationship between auditory imagery and the pitch processing, regardless of musical experience and the range of the pitches in the activities in this test, both of which they controlled for. Since only the vividness scale yielded significant results, Pfordresher and Halpern (2013) suggested that poor-pitch singing involves imagery deficiency at the most basic level, which meant that the control subscale of the BAIS could barely be considered.

In a more recent study by Pruitt, Halpern, and Pfordresher (2019), the researchers had a particular interest in how auditory perception leads to vocal action in singing. Previous research on singers with poor pitch led the authors of this study to propose that singing requires a priming of a multimodal image containing both auditory and motor imagery. Operating under these assumptions, they designed a study to observe subvocalization in auditory imagery activities. Forty-six participants were given alternating auditory and visual imagery tasks while attached to an sEMG machine that measured muscle activity at various vocal sites: the R/L sternohyoid, the upper lip, the mastoid process above the left ear, and, for control, the non-dominant bicep muscle. Participants were also given the BAIS, as well as the Vividness of Visual Imagery Questionnaire (VVIQ; Marks, 1973). Findings indicated that sternohyoid activity was significantly greater during auditory imagery than visual imagery, and the relationship between sternohyoid activation and frequency of singing errors was also statistically significant. The upper lip was not significantly activated or associated with errors, which was hypothesized to be a non-factor due to all auditory stimuli being manipulations of a single sound, [du]. Inaccurate singers were therefore more likely to engage in subvocalization than accurate singers.

Choral conductors commonly admonish their ensembles for humming starting pitches before singing, and while this may partially be due to the desire to regulate the sound of the room, findings from studies on vocal pitch imitation deficit indicate that it may be beneficial for singers not to vocalize or subvocalize in order to improve the vividness of their imagery skills. While physicalizing an entrance point for singers with a hum is often common practice, it is possible that externalizing an auditory image before an entrance may interfere with the efficiency of internal auditory processing.

Auditory Imagery, Score Study, and Expressive Choral Gesture

To my knowledge, there are currently no known studies that explicitly connect auditory imagery and *expressive choral gesture*, but the literature on how score study leads to better conducting preparation may have implications for this relationship. Halpern (2014) notes that conductors in particular might place enormous value in hearing sounds of instruments in their heads simply by looking at the score, and it would follow that conductors should have flexibility on auditory imagery tasks by virtue of their profession (p. 16). The following section focuses on the relationship between score study and auditory imagery.

Auditory imagery and score study

The main purpose of Hoffman's (2002) study was to discover whether or not electroencephalography (EEG) could be used to measure auditory imagery, but the researcher also addressed whether or not conductors' familiarity with a music score led to a difference in auditory imagery output. Six participants were given three musical scores, one that was thoroughly studied enough for a vivid and detailed auditory image to occur, another that was not studied at all, and another that was only studied for an hour. Different pieces were alternated amongst the participants so the music itself was less of a factor. It is difficult to account for diverse strategies participants may have used on their own to thoroughly study the score, so they were asked not to listen to a recording of the piece, nor use any instruments other than a tuning fork or pitch pipe for pitch references. When arriving in the laboratory, participants were fitted with an EEG electrode cap and measured for baseline brain activity. Then, they were asked to imagine the sounds of the three differently-prepared musical scores, from start to finish.

After completing the scan, they were presented with a small questionnaire, asking them (via Likert-type scales) about their degree of attention towards musical concepts like timbre, dynamics, harmony, rhythm, melody, texture, and tempo. Results indicated significant differences between the levels of preparedness on the score in conductors' cognition, with readings from prepared scores showing greater alpha band connectivity in occipital and parietal lobes assumed to represent visual processing. Beta bands were more focused in the left temporal lobe on the prepared score condition, which Hoffman concluded corresponded with acoustical processing. The right temporal lobe remained relatively consistent throughout all conditions, which was interpreted as spatial musical processing and auditory decoding.

The specific conclusions drawn from the EEG are difficult to interpret. Because there was no behavioral task associated with this measurement, it is difficult to say that auditory imagery was actually being performed at all times throughout the study. Furthermore, participants were tasked with hearing an entire piece, which is an incredibly broad and multivariable image. A small questionnaire at the conclusion of the study is not adequate to account for what specific elements of music (timbre, dynamics, harmony, etc.) conductors focused on while being scanned. EEG is also fairly limited at detecting pitch- and melody-driven elements of music, as spikes in alpha- and beta-band activity are much more obvious when rhythm is involved (Schaefer, Desain, & Suppes, 2009). This study is emblematic of a criticism made by Zatorre and Halpern (2005) regarding early physiological studies of auditory imagery, stating that "merely placing subjects in a scanner and asking them to imagine some music, for instance, simply will not do, because one will have no evidence if the desired mental activity is taking place" (p. 9).

Score study and expressive gesture

Among a conductor's many challenges is figuring out how to turn knowledge of a musical score into physical embodiment, to take their score study and turn it into something interpretable by a musical ensemble. In Treviño's (2008) dissertation, he examined how the conducting gesture of thirty undergraduate conductors might be influenced by different score studying practices. Treviño used two different conditions: conductors in the experimental group were given a score study procedure that involved listening to an aural model, while the control group was given a score without an aural model. After a brief two-minute period, conductors were asked to demonstrate their gesture under two conditions: silently (using only their auditory imagery) and along with the aural model provided for the experimental group. Results revealed a similar level of expressiveness in the no-music condition, but significantly more expressive performance for those with prior experience in the recording. Treviño (2008) contends that the familiarity with the recording prompted a "personalized and experiential internal aural image" (p. 79), which allowed them to have constant reinforcement while exposed to the external model. The significant negative effect of the recording on the conductors in the control condition may imply that whatever imagery these conductors individually developed ran contrary to the musical information provided by the aural model. The initial image in the control condition may have been weaker or more unstable than those reinforced by an aural model, but it is also possible that their imagined interpretations of the piece were simply different enough from the aural model to cause confusion. A study expanding on this, but utilizing a live choir instead of a consistent aural model, would better shed light on this confound.

In a study by Bodnar (2016), novice conductors were organized into two groups, with the experimental group receiving individual score study coachings. Participants in the experimental group were offered advice on planning their gestures in relation to markings in the score, as well as the opportunity to talk through their artistic ideas. A panel of experts indicated no statistically significant difference between gestures of the experimental and control group. Bodnar gave a few reasons for this discrepancy, that studying gestures may have monopolized the time participants in the experimental group spent towards learning the piece, or potentially that *intention-based* gestures (endogenous and determined purely by the conductor) are less effective than *sensory-based* gestures (exogenous, determined by the environment). It is unclear from the methods which gestures were developed by self-discovery from the novice conductors, or if they were prescribed by those assisting the novice conductors. Cross-modal verbalization has a strong impact on procedural memory, and may have complicated conductors' gestures in the experimental group (Flegal & Anderson, 2008). Follow-up interviews in the Bodnar study indicated that some participants were so focused on the gesture they were about to produce, that they tuned out other elements of the piece. They also expressed frustrations for the parts of the pieces they had prepared explicit gestures for, but missed. Both of these symptoms may indicate that these self-reported missed gestures did not have a robust enough connection to their memory of the piece, a thoroughly developed musical image.

Silvey (2011) explored how score study could prepare novice conductors for more successful rehearsals. While this study was not exclusively focused on the relationship between auditory imagery and gesture, some elements of Silvey's score study session included auditory imagery strategies, and a few of Silvey's intended performance outcomes corresponded with expressive gesture (eye contact, facial expression, conducting gesture). Novice conductors with two semesters of experience were asked to participate in two conducting sessions, a week apart. Before conducting in the second session, the experimental group met with Silvey for score study for a period of thirty minutes. Participants were rated for both performances by members of the brass section they conducted, as well as three wind conducting experts with Likert-type scales from 1-5. Variables included "eye contact, facial expression, conducting gesture, ability to lead a musically accurate performance, and knowledge of the score" (Silvey, 2011, p. 36). Silvey's score study session for the experimental group was filled with numerous strategies, including listening to a diverse range of recordings, a piano-accompanied sing-through of all the parts in the excerpt, performing the parts on the participants' respective instruments, and, most notably, the development and strict adherence to "an internal sound image" (Silvey, 2011, p. 38) throughout the session. No gestures were used throughout the entirety of the score study session. Ranking for the score study group and the control group differed significantly in the second conducting session, particularly in score familiarity and eye contact. However, no significant differences were found between the two groups for facial expression, effective gesture, or ability to lead the ensemble toward a musically accurate performance.

Follow-up interviews were conducted with the participants in each study session, with those in the experimental group expressing numerous positive attributes about their growth over the course of two sessions. Many of these observations from participants, such as "meaningful instrument-specific eye contact", "clear pre-determined musical goals", and "feelings of increased comfort and confidence" have considerable overlap with a list by Connolly and Williamon (2004) that highlights potential functions for why imagery might be beneficial to musicians: (a) improving learning and memory, (b) making practice more efficient, (c) overcoming technical difficulties and developing skills, (d) heightened sensory awareness, (e) gaining more interest in the music itself, (f) refocusing attention during performance, (g) enhancing general confidence and resilience onstage, (h) achieving greater control over negative emotions, (i) achieving a greater connection and presence with the audience, and (j) achieving peak experience. It is not possible to say that more informed musical imagery is the sole reason these participants were stronger on the podium, nor are the above functions exclusive to auditory imagery. Perhaps spending additional time on the piece with a mentor elicited more confidence in the participants. Additionally, it is difficult to parse out which elements of Silvey's score study session produced the most transformational results. A second control group that implemented self-directed score study strategies might allow for more insight into which elements of score study best inform success on the podium. Nevertheless, Silvey's insistence that participants maintain a comprehensive mental image of the piece, both in totality and in individual parts, does suggest that a vivid mental image of the music inspires confidence on the podium.

At the moment, no researchers who have focused on expressivity in novice conductors have designed an experimental condition about gesture that reaches statistical significance. Some conducting manuals discuss how notational audiation can inform gestures on the podium (Brinegar, 2020), but these connections are not yet backed up by empirical studies. The relationship between auditory imagery and gesture is made even more distant by a lack of consistent evidence that expressive conducting actually translates to more expressive performance (Morrison, 2009; Nápoles et al., 2020), particularly amongst novice conductors. Both Grechesky (1985) and Sidoti (1990) did discover statistical significance in this relationship, but these studies focused exclusively on expert conductors, who have considerably more experience in developing their nonverbal and score study skills than novice conductors. There is a need in the field for research to understand how conducting gestures are informed by auditory imagery.

Conclusion

The purpose of the present literature review was twofold: (1) to contextualize the present study within the currently existing auditory imagery literature and (2) to provide rationale for further study into individual differences in self-reported auditory imagery. Most researchers interested in individual differences in auditory imagery focus on musical expertise, which is most commonly defined in these studies by years of experience on an instrument. The present study accounts for these differences in years studied, as well as moving into an unexplored area: the potential impact that domains of musical expertise can have on auditory imagery, such as conducting and singing. There is quite an absence of experimental investigation directly related to how auditory imagery can assist conductors, despite allusions to its value from conducting manuals (Brinegar, 2020), interviews with conductors (McClung, 1996), and pedagogical approaches to undergraduate conducting classes (Silvey et al., 2016). Without this information, it is difficult to ascertain a clear path in developing the skills of novice conductors. Further research is needed into how auditory imagery furthers the musicianship of both conductors and vocalists.

Chapter III: Methods

Studies accounting for differences in auditory imagery amongst musicians and non-musicians traditionally define expertise by a number of years on a particular instrument. Because the purpose of this study accounts for specific types of musicians rather than amongst musicians in general, additional factors of musical experience must be accounted for, beyond the traditional expectations of the common musician/non-musician paradigm.

The purpose of this study is to investigate the associations between self-reported auditory imagery ability and choral conducting experience. To accomplish this, I generated a 10- to 15-minute cross-sectional survey with multiple parts, asking participants for their age, self-identified gender, and their years of experience in various musical contexts (choral singing, choral conducting, composition and arranging, years playing the piano, years playing other instruments). In order to address my research question about the relationship between auditory imagery and sight-reading ability, I also asked participants of their self-perceptions around their musicianship, which included a rating scale from one to seven of how confident they were in sight-reading and memorizing musical passages. Finally, I administered both subscales of the Bucknell Auditory Imagery Scale (Halpern, 2015), as well as several musical imagery items that I designed to be ecologically valid to the choral profession.

Participants

The survey generated ninety-seven usable responses (N = 97, 40 female, 4 non-binary, age range 18–75) sampled from two different musical professions: choral conducting and choral singing. Participants who did not report choral experience of any kind were excluded from the data. Participants were solicited at convenience from a large Midwestern university, but due to an insufficient number of choral conductors present at one institution, participants were also drawn via professional connections from an additional Midwestern and Western university, via personal choral music contacts of the researcher, and via posting to choral music social media groups on Facebook. Since participants were drawn from a variety of sources, the range of years of experience in various musical contexts was quite large.

Table 3

Music Experience

	M	*SD*	*Med*	*Min*	*Max*
Age (years)	35.37	14.82	30.00	18	75
Years singing in choir	20.40	15.65	15.00	0	60
Years conducting choir	7.19	9.70	3.00	0	54
Years composing arranging	5.00	6.94	2.00	0	34
Years playing piano	18.00	16.13	14.00	0	66

Participants were also asked to recount their academic experience, so as to document the breadth of their choral music study and their formal experience in aural skills classes. Given that academic institutions vet students based on previous aural skills ability, measuring academic experience provided some information regarding the participants' likely aural skills proficiency. The percentage of participants currently in school was 54.6% (n = 53), and the percentage out of school was 45.4% (n = 44). Those in school were asked to report their current degree track, displaying a wide range of academic degrees in progress: BM 11.8% (n = 7), BME 6.7% (n = 4), BA 6.7% (n = 4), MM 37.3% (n = 22), MME 1.7% (n = 1), MA 8.4% (n = 5), DMA 10.1% (n = 6), PhD 8.5% (n = 5), and other 8.5% (n = 5). For those out of school, they were asked to relay the highest degree they were conferred: HS 4.5% (n = 2), BM 9.1% (n = 4), BA 27.3% (n = 12), MM 22.7% (n = 10), MA 13.6% (n = 6), DMA 13.6% (n = 6), PhD 6.8% (n = 3), and other 9.1% (n = 4). Given the relationship between success in aural skills classes and the presence of absolute pitch, participants were also asked whether they believed they had it: 18.6% (18) reported yes, 72.2% (70) reported no, and 9.3% (9) reported unsure.

Measures

The Bucknell Auditory Imagery Scale (BAIS-V & BAIS-C)

The Bucknell Auditory Imagery Scale is among the most valid and reliable measures of self-reported auditory imagery (Halpern, 2015). A copy of the BAIS, including both subscales, can be found in appendix A**.** The questionnaire consists of two subscales, vividness (BAIS-V) and control (BAIS-C). Vividness is synonymous with the clarity and precision of an auditory image. The items on the vividness subscale require the participant to rate the vividness of various auditory imagery experiences on a seven-point Likert-type scale, with 1 being “no image present at all” and 7 being “as vivid as the actual sound.” The second subscale, control, is defined as the malleability of a given image. This subscales includes pairs of items, one of which is an example of a sound, and the next is another example that is indicates a change to the initial sound. The Likert-type scales paired with the control items ask participants to rate how easy the image was to change, with 1 being “no image present at all” and 7 being “extremely easy to change the image.” Factor analysis revealed that the vividness and control items loaded on three factors the researchers labeled: vocal sounds, musical sounds, and environmental sounds (Halpern, 2015). Examples of items that loaded strongly on the vocal sounds, musical sounds, and environmental sounds factors include “the slow-paced voice of your English teacher,” “the sound of an all-children’s chorus singing the first verse of a song,” or “the sound of waves crashing against the rocks,” respectively.

The vividness subscale (BAIS-V) is a strong predictor of the ability to sing in tune, referred to more officially as vocal pitch imitation accuracy/deficit (Greenspon et al., 2017; Pfordresher & Halpern, 2013; Pruitt, Halpern, & Pfordresher, 2019). It is not yet proven to correlate with pitch perception (Pfordresher & Halpern, 2013). The BAIS-V has fourteen questions; three items are environmental, one is vocal, two are musical, three are environmental/vocal, three are musical/vocal, one is environmental/musical, and one is environmental/musical/vocal. In this study, the BAIS-V demonstrated excellent internal consistency (alpha = .94).

The control subscale (BAIS-C) is correlated with performance of some musical imagery tasks (Gelding et al., 2015), as well as sensorimotor synchronization of both expressively timed and isochronous music (Colley, Keller, & Halpern, 2018). Since conductors hold a large responsibility over the regulation of ensemble tempo, they may be likely to perform particularly successfully in this subscale. Like the BAIS-V, the BAIS-C also has fourteen questions; two are environmental, three are vocal, two are musical, two are environmental vocal, four are musical/vocal, and one is environmental/musical. In this study, the BAIS-C also demonstrated excellent internal consistency (alpha = .92).

Supplemental Choral Imagery Items

It is important to note that no questions in either subscale of the Bucknell Auditory Imagery Scale are hypothetical scenarios: they are likely auditory experiences that participants have previously experienced. Auditory imagery ability is domain specific, in that previous experiences with sounds will produce a more vivid image than that of a sound infrequently or never before experienced. Because the nature of this study is specific to the field of choral music, it follows that there should be a number of items modeled after the BAIS that apply specifically to choral music scenarios. I created an additional seven items for each subscale, modeled after the vividness and control dimensions of the BAIS, to address this. The instructions for responding to these items are included in the BAIS (see appendix A).

In order to design more domain specific items for the questionnaire, I thought of what might be the fundamental aural responsibilities of a choral musician, both a conductor and a vocalist, and looked for overlapping themes between the two professions. In Timothy Hubbard's literature review of auditory imagery (2010), he organized studies first according to basic musical structures of "pitch, timbre, and loudness," moving to complex musical and non-verbal stimuli such as "musical contour, melody, harmony, tempo, notational audiation, and environmental sounds," and finally discussed verbal stimuli such as "speech, text, in dreams, and internal monologue" (p. 302). In order to preserve the reliability and validity of the original questionnaire, I sought to explore what currently existing BAIS items might fall into Hubbard's basic and complex musical categories. After this, I considered what additional musical structures might not be accounted for, and I created additional items to fill in these gaps.

Choral musicians are tasked with controlling dynamics (item 1), unifying timbre (item 2), aligning rhythmic patterns (item 3), recognizing pitches (item 4), identifying harmony (item 5), artistically phrasing (item 6), and honoring agogic text stress (item 7). They are capable of creating an auditory image at sight from written music, likely without the aid of a piano or other instrument, depending on how robust their aural skills are. When at their best, a choral musician has a robust aural and kinesthetic model of the piece of music they are about to perform, which they recall before and during musical passages. They are also capable of relating an internalized aural model to the currently existing sound, noting the differences between the two, and making the necessary changes in their physicality to have the outside music more closely resemble the ideal.

The main difference between conductors and singers is how this shared aural model converts into kinesthetic motion. For a conductor, an auditory image of a piece of music should translate to clear and expressive conducting gestures. For a singer, they must maintain a model of their own part, likely with additional elements such as accompaniment and adjacent voice lines, but they are not necessarily tasked with imaging the entire piece.

Conductors and singers are also responsible for each other. A conductor must attend to the difference between their internal image and the external sound, offering their musical guidance through gesture, verbal communication, musical modeling, or other rehearsal techniques. A singer is responsible for interpreting this, either consciously or unconsciously, aligning their voice with the expectations of the conductor and their fellow performers.

Upon initially creating my own items, I presented them to a few of my choral conducting colleagues, who were enrolled as masters or doctoral students at a major Midwest university. The reviewers reported that the items read clearly and that they were able to generate an image and assign a number to their internal experience. As expected, the reviewers also reported having more ease with domain-specific questions than those of the Bucknell Auditory Imagery Scale, mostly presenting with five, six, or seven in both vividness and change for my items. Due to a small sample size, I am unable to determine whether or not all of these conductors have robust auditory imagery ability, or if these preliminary trials portend an inevitable ceiling effect.

After presenting my items to a panel of experts, consisting of my academic advisors, it was pointed out that these questions might cater more specifically to conductors than singers. Although many of these items indicate mutual choral experiences regardless of the conductor-singer power dynamic, conductors are potentially more likely to attend to these moments due to the responsibility they have over them. Singers might not maintain as robust of an aural image of these experiences, by virtue of the different nature of their required attention in a rehearsal space. It is also possible that singers, due to where they sit in the rehearsal room, are less equipped to get a full aural picture of the ensemble. Conductors, who are situated in front of the choir, are able to hear all of the voices in their entirety, whereas a singer might only be able to hear the tuning mistakes or timbral shifts in their immediate surroundings. This lack of full context could lead to an incomplete aural model as outlined in the above items, though there is no evidence that whatever image singers created would be any less vivid or practical.

I also considered the length of my questionnaire, which would receive fewer responses if not carefully streamlined. The original intention was to create an additional subscale for the BAIS, something akin to musical or choral sounds. As one would expect of supplemental questions about choral music, my items primarily include the imagining of vocal sounds, which are most similar to the items on the BAIS's subscales for vocal and musical sounds. By including my questions, I oversaturated these subscales, leading me to consider whether or not I should focus specifically on the vocal and musical subscales, removing any items that are considered exclusively environmental, or to potentially replace some of the vocal or musical items in the original subscale with my more domain-specific items. I ultimately decided to include the BAIS-V and BAIS-C in full, so as not to affect the initial reliability of the subscales. In this study, Cronbach's alpha internal consistency estimates for my supplementary vividness items and control items indicated excellent reliability, alpha =.90 for both. Internal consistency for composite control and vividness scores—including both the BAIS items and the items I created— was also excellent, alpha = .95 for vividness and .94 for control.

Procedures

A questionnaire designed in the Qualtrics platform was sent out to conductors and vocalists via email. In order to disseminate the survey, I contacted the music education and conducting departments of two large Midwestern universities, as well as a West coast university. I also posted my survey several times on the social media site Facebook throughout a period of a week, asking various choral colleagues to fill it out if they expressed interest in the project. Participants were also asked at the end of the survey if they wished to include their email address to be entered into a drawing for a $50 Amazon gift card. The survey took participants an average of twelve minutes to complete.

Chapter IV: Results

Preliminary Analyses

The Pearson correlation between the scores of the BAIS-V and the supplementary music vividness items was strong (r = .81, p < .001) (Figure 2), as was the correlation between the BAIS-C and the supplementary music control items (r = .72, p < .001) (Figure 3). This discrepancy of reliability is potentially due to control being a more complex auditory imagery phenomenon than vividness. The correlations indicate that choral conductors' and choral vocalists' general auditory imagery abilities were positively related to their choral music imagery abilities.

In the pilot testing for the BAIS, Halpern (2015) described the BAIS-V and the BAIS-C as "parallel subscales" (p. 38). Studies utilizing the BAIS previously documented a high correlation between these two subscales, such as Pfordresher & Halpern (2013) (r = 0.50, p < .01), as well as Halpern's original study (2015) (r = 0.74, p < .01). Commensurate with previous studies documenting sizable correlation in the BAIS in their participants, the Pearson correlation between the BAIS-V and BAIS-C amongst participants was moderately positive and statistically significant (r = .59, p < .001) (Figure 4). The music vividness and music control scores based on items constructed for the purpose of this study, also demonstrated a moderately positive and statistically significant correlation (r = .50, p < .001) (Figure 5). Accordingly, the composite imagery vividness and composite imagery control scores were similarly correlated (r = .58, p < .001) (Figure 6).

Given previous research outlining the auditory imagery abilities of musicians vs. non-musicians, it was predicted that those with choral experience would be likely to present higher-than-average scores compared to scores reported by those in the general population in the original analysis of the BAIS-V (M = 5.10, SD = 0.90) and BAIS-C (M = 5.10, SD = 0.90) (Halpern, 2015). The original survey was done with a generalized population of college students, regardless of age (M = 22.6 years, SD = 8.1), years of formal education (M = 14.0 years, SD = 1.8), or musical background (Halpern, 2015). The average scores for participants in the present study were noticeably higher and more varied than those from Halpern's

(2015) participants' scores, for both vividness (*M* = 5.5, *SD* = 1.15) (Figure 7) and control (*M* = 5.8, *SD* = 0.99) (Figure 8), as well as having a larger standard deviation (*SD* = 1.15, *SD* = 0.99). This is to be expected, as the participants in the present study demonstrated a both larger age disparity (*M* = 35.4 years, *SD* = 14.8) and more specialized musical range of experience (years singing in choir, *M* = 20.4 years, *SD* = 15.6), as well as being specifically chosen due to their musical backgrounds. Correlations between age and the imagery measures were calculated, and only two very weak statistically significant coefficients were found for music control (*r* = .27) and composite control (*r* = .22). Participants' average scores showed a moderate to strong auditory imagery ability, falling between the definitions of "fairly vivid" (marked as 4 out of 7 on the Likert-type Scale) and "as vivid as the actual sound" (marked as 7 out of 7 on the Likert-type Scale). Because the domain-specific questions were modeled after the subscales of the Bucknell Auditory Imagery Scale, two composite scores (BAIS-V with music vividness, BAIS-C with music control) were also created (Table 2, Figures 7-12).

Table 4

Descriptive Statistics for Imagery Measures

	M	*Med*	*SD*	*Skew*	*Kurt*	*Range*
General Vividness (BAIS-V)	5.40	5.64	1.17	–0.92	1.16	5.93
Music Vividness	5.68	5.85	1.29	–1.51	2.41	6.00
Composite Vividness	5.50	5.76	1.15	–1.26	2.15	5.95
General Control (BAIS-C)	5.78	6.00	1.01	–1.38	3.76	6.00
Music Control	5.82	6.14	1.15	–1.32	2.21	6.00
Composite Control	5.80	6.00	0.99	–1.51	4.39	6.00

There is strong evidence to suggest that auditory imagery ability is highly correlated with aural skills ability (Marvin, 2021). Therefore, participants were asked to communicate both their self-assessed sight-reading ability and their ability to memorize music, using Likert-type rating scales ranging from 1-Very Poor to 7-Excellent (Table 3, Figure 13-14). The ratings were not particularly varied, with 86% of participants reporting 5 or higher confidence in their sight-reading abilities. This demonstrates a great deal of overall confidence in musicianship amongst participants in the present study. 83.5% of participants also reported 5 or higher confidence in memorization ability, which is also substantially higher than the average. This is not surprising, since the majority of participants were drawn through connections in music conservatory education.

Table 5

Descriptive Statistics for Self-Assessed Sight-Reading and Memorization

	1	2	3	4	5	6	7
Sight-reading	0	1	2	8	27	30	29
%	0	1.0	2.1	8.2	27.8	30.9	29.9
Memorize	1	1	5	9	33	22	26
%	1.0	1.0	5.2	9.3	34.0	22.7	26.8

Musical Experience and Auditory Imagery Subscales

Singing Experience

Though not all participants in the present study were conductors, they all held the mutual experience of being a choral singer, ranging from 2-60 years. Years of choral singing experience was correlated with music control (*rho* = .21, p = .037), but no other subscales.

Composition/Arranging Experience

In this experiment, it was hypothesized that choral musicians with composition and arranging experience might present stronger auditory imagery ability than those without, based on their interest in imagining new sounds. Though 60% of participants had at least one year of composition and arranging experience, no participant in this study denoted more years of composition experience than choral experience. Years of experience in composition or arranging was not correlated with any auditory imagery subscales.

Instrumental Experience

The piano is a staple of choral music-making, being the main source of musical accompaniment for choral selections, as well as the most common and useful instrument for choral conductors to hold experience in. Therefore, it was important to assess whether piano experience held any connection to auditory imagery ability. Somewhat surprisingly, there was no significant correlation between years of piano experience and any of the auditory imagery subscales. It is possible that, since the tuning of keyboard instruments are usually unchangeable during practice and performance, it may be less necessary for pianists to imagine the sounds of the keys before they are played. This is not the case for other instruments, such as the voice, strings, woodwinds, and brass, where a musician is responsible for tuning.

While conducting the analyses to address the research questions, I also became curious as to whether the degree of instrumental experience the participants reported would be related to their self-reported auditory imagery abilities. There was a correlation between years of instrumental music experience and music control (r = .25, p = .015), but no other subscales.

Conducting Experience and Auditory Imagery Subscales

Choral conductors often have many years of choral singing experience, but choral singers are not always afforded the reciprocal experience of conducting. If a participant had any years of experience, they were placed into a choral conductors group, while participants without were placed into the choral singers group. In order to assess whether imagery vividness or control varied as a function of conducting experience, an independent samples *t*-test was conducted according to these two groups. Statistically significant differences were found for music vividness, $t(95) = 3.60$, $p < .001$, $d = .69$ and composite vividness, $t(95) = 2.61$, $p = .009$, $d = .49$. No statistically significant differences were found for any of the other imagery variables.

Once it was clear that there were statistical differences to be found between conductors and vocalists, it was sensible to delineate years of choral conducting experience further, to better understand how it played a factor in auditory imagery ability. In order to better address these research questions, participants were divided into three groups instead of two. Participants with ten or more years were labeled *experienced* conductors, participants with one to nine years were labeled *novice* conductors, and those with no years of experience were labeled *non-conductors*. Ten years of experience was chosen as the benchmark for the highest group because it can be a sufficient amount of time to develop expertise in a given domain. A Kruskal-Wallis H-test revealed a significant difference in music vividness (15.57, $p < .001$), composite vividness (9.01, $p < .009$), and music control (9.01, $p < .011$) as a function of conducting experience. Regarding music vividness, the H-test showed a large difference between non-conductors and novice conductors (2.66, $p = .008$), as well as non-conductors and experienced conductors (3.92, $p < .001$), but not between novice and experienced conductors, which is consistent with the two-group finding previously mentioned. For composite vividness, the H-test showed differences between non-conductors and experienced conductors (3.07, $p = .002$), but no other pairs. Finally, for music control, the H-test revealed significant differences between non- and experienced (2.35, $p = .019$) and novice and experienced (2.81, $p = .005$). See Figures 15-20 for relationships between these tests.

Table 6

Years of Choral Conducting and Auditory Imagery Subscales

	Spearman Correlation
General vividness	.23, p = .024
Music vividness	.43, p < .001
Composite vividness	.31, p = .002
General control	.15, p > .05
Music control	.30, p = .003
Composite control	.20, p = .047

Music Skills and Auditory Imagery Subscales

Due to leadership on the podium often requiring a particular music skillset, it follows that better auditory imagery ability might be beneficial for musicians' sight-reading and their ability to memorize music. Participants' reports of confidence sight-reading were significantly and positively related to their music vividness (*rho* = .21, p = .037) and music control (*rho* = .24, p = .018) imagery scores, but no other variables. However, it is important to note that these correlation coefficients are extremely weak. In addition, no statistically significant correlations were found between confidence for memorization and any of the imagery variables.

Table 7

Spearman Correlations for Music Skills Ratings and Auditory Imagery Subscales

	Sight-reading	Memorization
General vividness	.10	.08
Music vividness	.21, p = .037	.005
Composite vividness	.01	.05
General control	.13	–.001
Music control	.24, p = .018	–.033
Composite control	.17	–.015

Chapter V: Discussion

The present study is among the first to document differences in auditory imagery ability between those with varying musical specializations. Differences between choral conductors and choral vocalists were found in both music vividness and composite vividness, with the conductor group demonstrating higher vividness scores. Interestingly, the stronger vividness abilities were more pronounced between non-conductors (no experience) and novice conductors (1-9 years experience) than between novice conductors and experienced conductors (over 10 years experience). Based on this data, it is not possible to determine whether or not musicians pursued music leadership as conductors due to their enhanced auditory imagery ability or whether or not their experience in the domain of conducting led to increased auditory imagery vividness scores.

Somewhat in opposition to my hypothesis, choral singing experience was correlated with music control, while choral conducting experience was not. Though it was hypothesized that differences in auditory imagery ability might also show up in the control subscale between conductors and vocalists, these differences did not reach statistical significance. To be a successful choral singer is to figure out how to function within the whole, constantly contextualizing one's instrument with the surrounding noise. Conductors are not necessarily responsible for fitting themselves into this collective experience. Though they are undoubtedly tasked with the quality of the sound-making, conductors do not produce noise themselves. Because conductors occupy more of a leading role than a following one, they are not necessarily required to fit themselves into this collective experience. Singers, on the other hand, are absolutely mandated to physically line up their bodies with others, simultaneously breathing, producing words, regulating dynamic contrast, and performing countless other musical responsibilities that require both inwards and outwards listening. The findings from the present study linking music control with singing experience line up with previous connections by Keller and Appel (2010), who found a connection between sensorimotor synchronization in ensembles and anticipatory auditory imagery, as well as that of Colley, Keller, & Halpern (2018), who found a strong correlation between the BAIS-C and various synchronization tasks. Auditory imagery control, based on previous findings, is much more associated with coordinating with others in the moment of music-making. It would seem like both conductors and singers would need to be in the moment, but there is something about the physical simultaneity of choral singing that conductors do not get to experience. Lining up one's body to others in relationship to others appears to be inadequate: it may need to be the exact same task to more profoundly involve auditory imagery control.

A difference in music control did show up amongst two subgroups of conductors, between novice and experienced. The subscale of music control aimed to sample seven real-life situations that conductors typically encounter, and it follows that more time spent in front of a choir would lead to greater confidence in these scenarios. Since the present study denoted composers by years of experience rather than by musical level, it is difficult to assess through these findings whether or not the music that experienced conductors frequently facilitate is more sophisticated than that of novice or inexperienced conductors. However, it follows that the longer a conductor advances in their career, the more likely they are to pursue music that requires more intense score study, more nuanced gesture, and a stronger aural model in order to perform effectively. This finding mirrors that of the disparity in the literature related to expressive conductor performance. It is only in two studies, Grechesky (1985) and Sidoti (1990), where there were any conclusive findings that a conductor is able to noticeably influence sound with gesture alone, and these were each case studies with conductors labeled as experts. As of time of the present study, there are no known studies that have ever been able to link expressive choral conducting with expressive performance amongst novice conductors. This significant difference in music control between novice and expert conductors aligns with the conductor's skill set. Experts would have considerably more experience communicating non-verbally, as well as having more consistent score study skills, than novice conductors would. Gesturing effectively in accordance with the music takes a conductor an extraordinarily long amount of time to learn, and it involves a strong connection to one's inner model of the music. A common observation when working with expert conductors is that their gesture maps directly onto the music, as if their musical ideal is simply flowing through them. This bears striking resemblance to multi-modal imagery, as conducting music would utilize both auditory and kinesthetic imagery processes. If successful choral gesture does come from a conductor's internal aural model, it follows that control of auditory imagery would also develop as a conductor matures. Further research with a larger sample of choral conductors is needed to understand how choral conducting experience leads to more robust auditory imagery control.

Correlations between participants' self-perceptions of sight-reading ability reached statistical significance for both the music vividness and music control imagery variables, but no others. This is to be expected, given that many of the questions provided in the musical subscales were theoretical in nature, such as asking musicians to imagine a I - IV - V - I progression, as well as simple rhythms. Since those with higher levels of musicianship can often adopt leadership positions in choirs, it is not surprising that perceived sight-reading ability correlated with choral conducting experience, but was not significantly correlated with singing experience. Interestingly, self-perception of memorization ability was not correlated with any auditory imagery subscales. One might imagine that the ability to perceive sounds in one's head would be related to remembering them, but these cognitive processes appear to be more distinct than previously hypothesized. It is possible that, for the participants targeted in this study, that they are not often expected to memorize choral pieces. In college-level choral study, due to both limited rehearsal time and challenge of repertoire, memorization is not as common of a practice than in earlier stages of choral development.

Limitations

It was difficult to accurately encapsulate the choral experience in the span of seven questions when designing the supplementary music items. While conducting and singing are two distinctive roles in a choral environment, there is invariable overlap between the two skill sets involved for each. Although conductors and singers were labeled differently in this study, it is important to note that the conductors generally held more singing experience on average than the singers. Though not all conductors begin as members of a choral ensemble, many become choral leaders due to their love of communal singing, which makes these two groups difficult to independently distinguish. It is possible that the supplementary music imagery items, for both vividness and control, were more likely to be questions that choral conductors would address than choral singers. However, it is also possible that the versatility afforded by choral singing itself is adequate to develop musicians' auditory imagery ability, since years of singing experience was correlated with music control imagery, but no other subscales. Further research is needed to determine which aspects of a choral environment might lead to enhanced auditory imagery abilities.

As the aim of this study was to focus on the domain of choral music, the questionnaire I designed was almost exclusively promoted to choral musicians. Participants were therefore drawn primarily from the choral profession. In order to account for covariates in the study, I asked participants to provide the range of their musical experiences, including composition experience, which I imagined would relate very strongly to auditory imagery ability. This study did not draw statistical significance between composition experience and any of the auditory imagery subscales. It is important to acknowledge that since I did not specifically draw musicians from the composition profession, the statistical findings around auditory imagery and composition/arranging experience cannot be generalized to composers and arrangers. Since this study organized participants into groups based on years of experience, rather than by self-identification, it also cannot be inferred that music composition was not the concentrated musical focus of several participants in this study. Further study is needed to understand the connection between auditory imagery and composers/arrangers.

In this study, I chose to measure choral conducting and singing experience by their number of years participating in choir. This form of measurement is relatively blunt, as it discounts the massive array of choral experiences that participants likely encountered. Measuring choral experience without also finding a way to address its quality is quite reductionist, and providing participants to mention whether they self-identified as a choral singer, choral conductor, or choral composer/arranger would have presented a different avenue to explore the data. Future studies wishing to address auditory imagery in different domains of music would benefit from asking participants how they are using their musical skills, rather than simply asking them their range of experiences.

Though some steps were taken to account for musical skill set, in the form of documenting self-perception of musical sight-reading and memorization, this measurement was also taken regardless of choral musicians' musical abilities. This makes it incredibly challenging to measure how their skill sets developed, or even where they were used throughout the years of experience documented. Furthermore, self-assessment of aural skills is not the same as accurately measuring musicians' musical abilities. A study that accounts for choral conducting ability or quality is an important next step to better understand how auditory imagery connects to the choral domain. Future research could ask musicians to document their musical development in a more detailed fashion than the present study, perhaps grouping musicians by the number of ensembles they participated in and having them rank the perceived prestigiousness of these opportunities.

Implications for music education

Hearing a sound in one's head, well before the pitch is actually in the air, is a required skill of both conductors and singers, but especially for those who lead ensembles. For conductors, the necessity to attend to or imagine future events is different than that of a choral singer, as they are responsible for physicalizing cues in preparation for musical moments. Cues come in many forms, depending on rhythmic, dynamic, and pitch content, and they most often happen on the beat preceding the exact moment. As conductors develop their anticipatory skills over time, this is likely to be accompanied by a more vivid auditory imagery experience. Conductors must also embody the music they want to create. In an ideal circumstance, conductors are not gesturing at what they are hearing from an orchestra or choral ensemble, but rather are gesturing at what they *want* to hear, in order to produce a musical ideal that other musicians can follow. This is especially pronounced amongst orchestral conductors, who often receive musical feedback from the orchestra at the top of their ictus rather than at the bottom.

For many beginning choral singers who have not trained their auditory imagery ability, it can be easier at first to wait and hear a pitch sung by others first before singing it themselves, listening first to those around them. While listening to fellow choristers to address issues of timing and timbre is a necessary skill, to sing while waiting for a neighbor to sing first will typically result in being late to the beat. Choral directors often remind singers in their ensembles that every member must be a leader, that they must all sing at precisely the moment where the music asks them to. A choral musician who wishes to provide meaningfully to the collective must therefore be *predictive* of an entrance, rather than *reactive* to the musical moment they just missed. Auditory imagery ability is a skill necessary for leadership in a choral space, in that it creates an ideal image of the music the moment before it is brought into real time.

The present study indicated that the largest difference in auditory imagery vividness ability was between those with no conducting experience and those with 1–3 years experience. Though it is not possible to conclude from these findings that more robust auditory imagery comes directly from conducting experience, it is interesting to consider how these initial years of exposure to conducting may have a disproportionately higher impact on musicians' inner hearing. It is possible that conductors develop auditory imagery skills that lead them to this initial experience on the podium, but it is also possible that the experience itself changes the way that a chorister fundamentally thinks about music. If operating under the assumption that more robust auditory imagery comes from choral conducting experience, music educators may consider offering space on the podium to their students for unique choral leadership opportunities. Even the act of periodically bringing singers to the front of the classroom may help create a more holistic understanding of ensemble sound amongst students, having a potentially valuable effect on their internal models of the music.

Participants in this study documented a myriad of outside musical experiences that may have confounded the findings. There was a correlation between experience on woodwind, brass, and string instruments and the subscale of music control. Because the control subscale accounts for transforming one sound to another, it follows that musicians with two domains of musical competence would be constantly looking for the connections between them, relating their prior experience to further their musicianship in the other domain. It is common in instrumental pedagogy to be encouraged to learn to sing, as the voice provides a personal accessibility, as well as a fundamental understanding of breath, that allows for a more meaningful melodic line. Interestingly, there was no significant correlation between auditory imagery and piano experience. Perhaps it has to do with the lack of breath in the instrument, the fact that a pianist is responsible for much more than a vocalist's single note, or perhaps it has to do with less need to imagine sounds when a keyboard instrument comes pre-tuned. For winds and strings, just like in the singing voice, there needs to be an internal understanding of pitch in order to be in tune. The present data suggests that musicians with additional experience on instruments responsible for tuning might relate that information more effectively to their singing voice than that of pianists. Further research is needed to understand the collective musical benefits of simultaneous study of instrument and voice.

Conclusion

Auditory imagery is a cognitive phenomenon implicit to music education, yet it is simultaneously intangible and difficult to monitor. If auditory imagery underpins both choral conducting and singing, choral educators should consider ways in which auditory imagery ability could be more directly cultivated. Based on previous findings from studies in auditory imagery, encouraging singers to hear pitches in choir first before subvocalizing (Pruitt, Halpern, and Pfordresher, 2019), as well as encouraging them to learn music by ear (Talamini and Vigl, 2022) has demonstrated effectiveness at strengthening the vividness of auditory imagery. The simple act of asking students to imagine sounds during warm-ups can help reframe student attention more inwardly throughout the rehearsal process. Educators could also consider incorporating compare-and-contrast tasks, first by asking students to sing or conduct a passage, then imagining the same passage silently in their inner ear, and finally, singing or conducting the same passage, taking note of differences between the two performances. This task could demonstrate remarkable and more individual differences in student interpretation of a piece of music, while also engaging their auditory imagery processing.

For educators tasked with assisting novice conductors, focus-of-attention tasks, such as asking conductors to attend only to bass or soprano parts during a homophonic texture, could inspire more foundationally or melodically expressive gestures that can better support either harmonic or melodic elements of the music. Recommending that conductors first develop an auditory image in their head before beginning the act of gesturing will better align their physicality with their aural ideal, rather than gesturing to find what they wish to hear (Brinegar, 2020; Colley, Keller, & Halpern, 2018; Keller & Appel, 2010). It may be also useful to remind conductors that sensory-based gestures coming from within may have a deeper connection to their aural model than an intention-based pre-prescribed gesture (Bodnar, 2016), and that engaging with music as a conductor is about exploring how to convey their own ideal rather than someone else's. Auditory imagery is, after all, one's own personal experience with music, and it can only be developed by spending more time with what it is that you wish to say.

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Appendices

Appendix A: Bucknell Auditory Imagery Scale: Vividness Subscale (Halpern, 2015)

Vividness Rating Scale

1	2	3	4	5	6	7
No Image Present at All			Fairly Vivid			As Vivid As The Actual Sound

Vividness Rating

1. For the first item, consider the beginning of the song "Happy Birthday." The sound of a trumpet beginning the piece._____
2. For the next item, consider ordering something over the phone. The voice of an elderly clerk assisting you._____
3. For the next item, consider being at the beach. The sound of the waves crashing against nearby rocks. _____
4. For the next item, consider going to a dentist appointment. The loud sound of the dentist's drill.______
5. For the next item, consider being present at a jazz club. The sound of a saxophone solo.______
6. For the next item, consider being at a live baseball game. The cheer of the crowd as a player hits the ball._____
7. For the next item, consider attending a choir rehearsal. The sound of an all-children's choir singing the first verse of a song. ______
8. For the next item, consider attending an orchestral performance of Beethoven's Fifth. The sound of the ensemble playing. ______
9. For the next item, consider listening to a rain storm. The sound of gentle rain. ______
10. For the next item, consider attending classes. The slow-paced voice of your English teacher.______
11. For the next item, consider seeing a live opera performance. The voice of an opera singer in the middle of a verse.______
12. For the next item, consider attending a new tap-dance performance. The sound of tap-shoes on the stage.______
13. For the next item, consider a kindergarten class. The voice of the teacher reading a story to the children.______
14. For the next item, consider driving in a car. The sound of an upbeat rock song on the radio.______

Appendix B: Bucknell Auditory Imagery Scale: Control Subscale (Halpern, 2015)

Ease of Change Rating Scale

1	2	3	4	5	6	7
No Image Present at All			Could Change the Image but With Effort			Extremely Easy to Change the Image

Change Rating

1. For the first pair, consider attending a choir rehearsal.
   a. The sound of an all-children's choir singing the first verse of a song.
   b. An all-adults' choir now sings the second verse of the song. ______

2. For the next pair, consider being present at a jazz club.
   a. The sound of a saxophone solo.
   b. The saxophone is now accompanied by a piano.______

3. For the next pair, consider listening to a rain storm.
   a. The sound of gentle rain.
   b. The gentle rain turns into a violent thunderstorm.______

4. For the next pair, consider driving in a car.
   a. The sound of an upbeat rock song on the radio.
   b. The song is now masked by the sound of the car coming to a screeching halt. ______

5. For the next pair, consider ordering something over the phone.
   a. The voice of an elderly clerk assisting you.
   b. The elderly clerk leaves and the voice of a younger clerk is now on the line.______

6. For the next pair, consider seeing a live opera performance.
   a. The voice of an opera singer in the middle of a verse.
   b. The opera singer now reaches the end of the piece and holds the final note. ______

7. For the next pair, consider going to a dentist appointment.
   a. The loud sound of the dentist's drill.
   b. The drill stops and you can now hear the soothing voice of the receptionist.______

8. For the next pair, consider the beginning of the song "Happy Birthday."
   a. The sound of a trumpet beginning the piece.
   b. The trumpet stops and a violin continues the piece.______

9. For the next pair, consider attending an orchestral performance of Beethoven's Fifth.
   a. The sound of the ensemble playing.
   b. The ensemble stops but the sound of a piano solo is present.______

10. For the next pair, consider attending a new tap-dance performance.
    a. The sound of tap-shoes on the stage.
    b. The sound of the shoes speeds up and gets louder.______

11. For the next pair, consider being at a live baseball game.
    a. The cheer of the crowd as a player hits the ball.

b. Now the crowd boos as the fielder catches the ball._____

12. For the next pair, consider a kindergarten class.
    a. The voice of the teacher reading a story to the children.
    b. The teacher stops reading for a minute to talk to another teacher. ______

13. For the next pair, consider attending classes.
    a. The slow-paced voice of your English teacher.
    b. The pace of the teacher's voice gets faster at the end of class. ______

14. For the next pair, consider being at the beach.
    a. The sound of the waves crashing against nearby rocks.
    b. The waves are now drowned out by the loud sound of a boat's horn out at sea. __

Appendix C: Supplementary Choral Imagery Questionnaire: Vividness Subscale

Vividness Rating Scale

1	2	3	4	5	6	7

No image present | Fairly Vivid | As Vivid as the Actual Sound

1. For the first item, consider the volume of a particularly loud cadence at the end of a choral piece.______
2. For the next item, consider the sound of a soprano section, with one particularly eager vocalist sticking out of the texture.______
3. For the next item, consider the volume of this rhythm (♫ ♫♩ ♩), either clapped or played on a pair of claves.
4. For the next item, consider the sound of a tenor soloist performing the melody of a popular folk song, such as Danny Boy.______
5. For the next item, consider the sound of a I - IV - V - I progression, played on the piano in any key of your choosing.______
6. For the next item, consider an expressive phrasing of the first choral entrance of Mozart's Ave Verum Corpus.______

7. Consider a waltz of your choice, the stress of the first beat of every measure in 3/4 time.

Appendix D : Supplementary Choral Imagery Questionnaire: Control Subscale

Ease of Change Rating Scale

1	2	3	4	5	6	7
No image present		Could Change the Image, but with Effort			Extremely Easy to Change the Image	

1. For the first pair, consider the dynamics of a choral passage of your choosing.
    a. The choral sound is a healthy mezzo forte dynamic.
    b. The choral sound slowly decrescendos to a piano dynamic.
2. For the next pair, consider warming up a choir.
    a. The sound of the ensemble singing an [u] vowel slightly out of tune.
    b. The sound of the ensemble becomes uniform and pure.______
3. For the next pair consider a challenging rhythmic passage.
    a. The sound of the ensemble is slightly out of phase with itself.
    b. The sound of the ensemble begins to align.______
4. For the next pair, consider assisting the tenor section by playing their pitches on the piano.
    a. The sound of the melody line played by the piano.
    b. The sound of the piano melody line now includes members of the tenor section.______
5. For the next pair, consider studying a Bach chorale at the piano.
    a. The sound of playing through all four parts of a Bach chorale.
    b. The Bach chorale is now sung by four parts of an ensemble.
6. For the next pair, consider the same Mozart example above.
    a. The sound of the opening choral line, expressively phrased.
    b. The choir begins to sing robotically, devoid of expression.
7. For the next pair, consider a carefully balanced final chord of a piece.
    a. The sound of the choir being too soprano-heavy.
    b. The chord becomes more balanced.

Additional items for Supplementary Choral Imagery Questionnaire, excluded

1. Change: For the next pair, consider a choir singing in four parts. (spacial location)
    a. The sound of the choir singing in four distinct sections on the risers.
    b. The choir sings the same passage in mixed formation.______
2. Change: For the next pair, imagine a string quartet.
    a. The sound of all four instruments playing in homophony.
    b. The sound of all four instruments changes into an SATB ensemble.______
3. Vividness: For the next pair, consider the clarity of pitch in the provided melodic passage.______

Appendix E: Figures

Figure 1

Forwards and inverse models of cognition

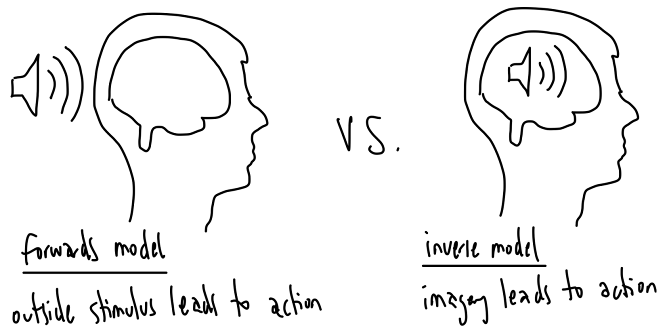
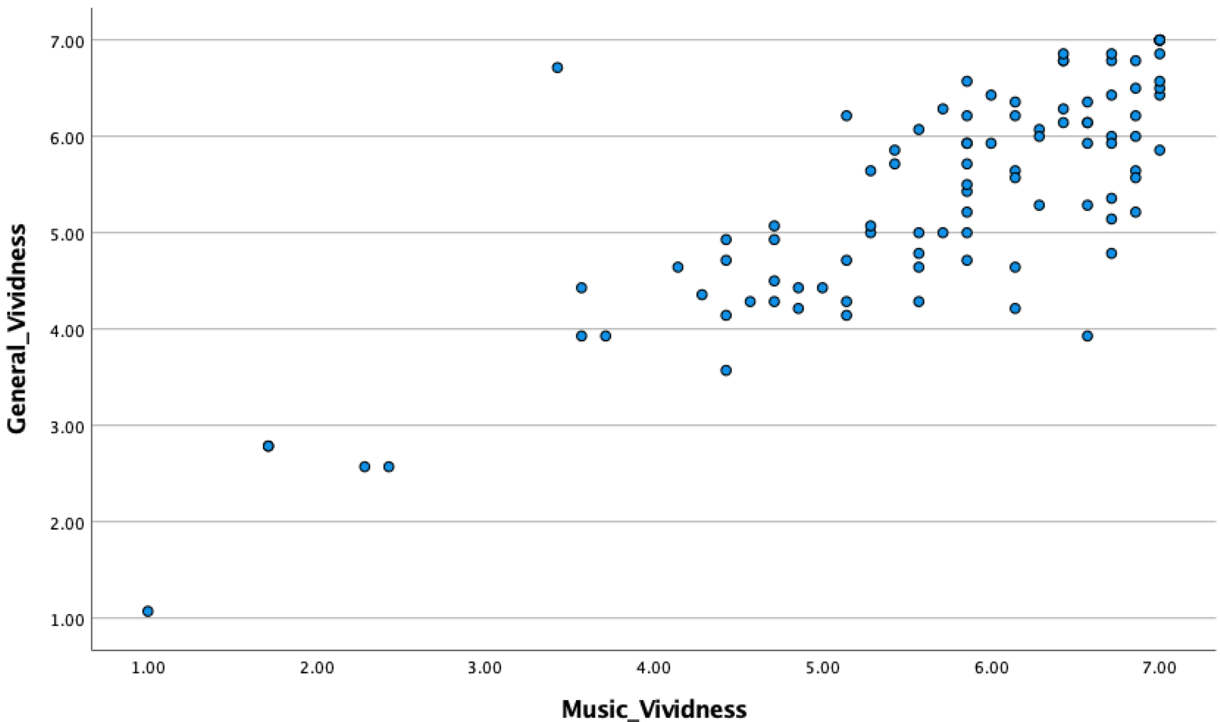


Figure 2

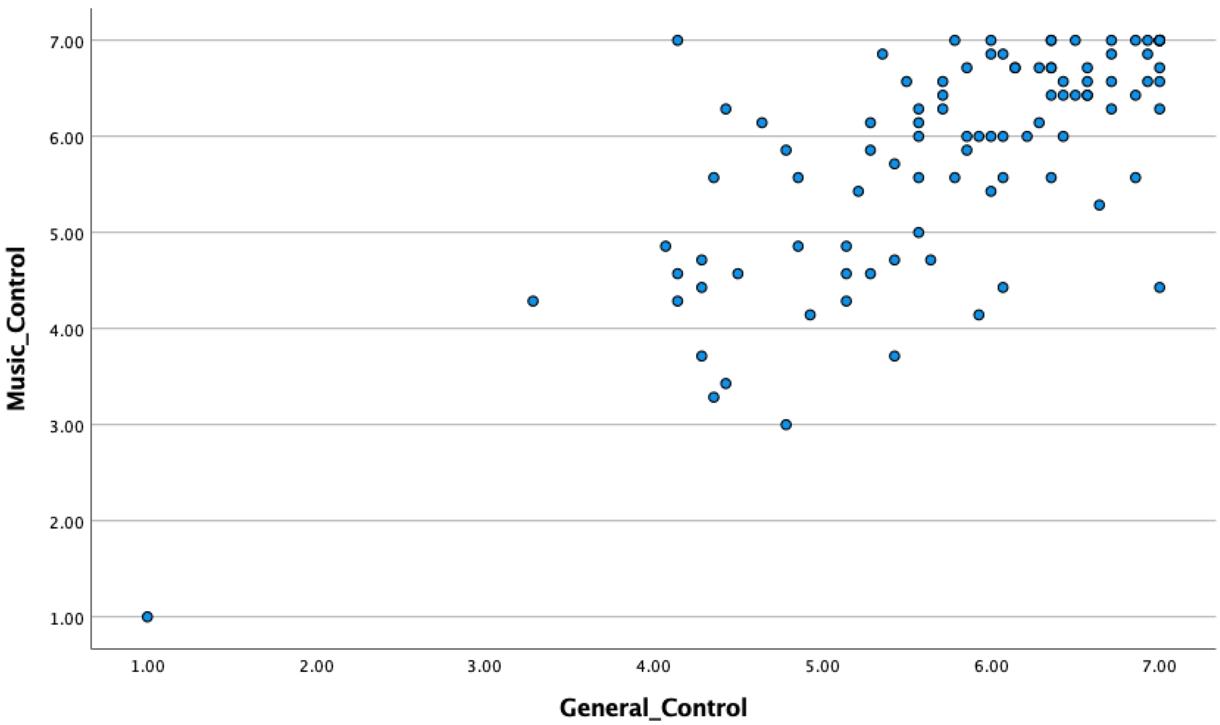
Establishing composite vividness



Note: General_Vividness is BAIS-V

Figure 3

Establishing composite control



Note: General_Control is BAIS-C

Figure 4

Correlation between BAIS-V and BAIS-C

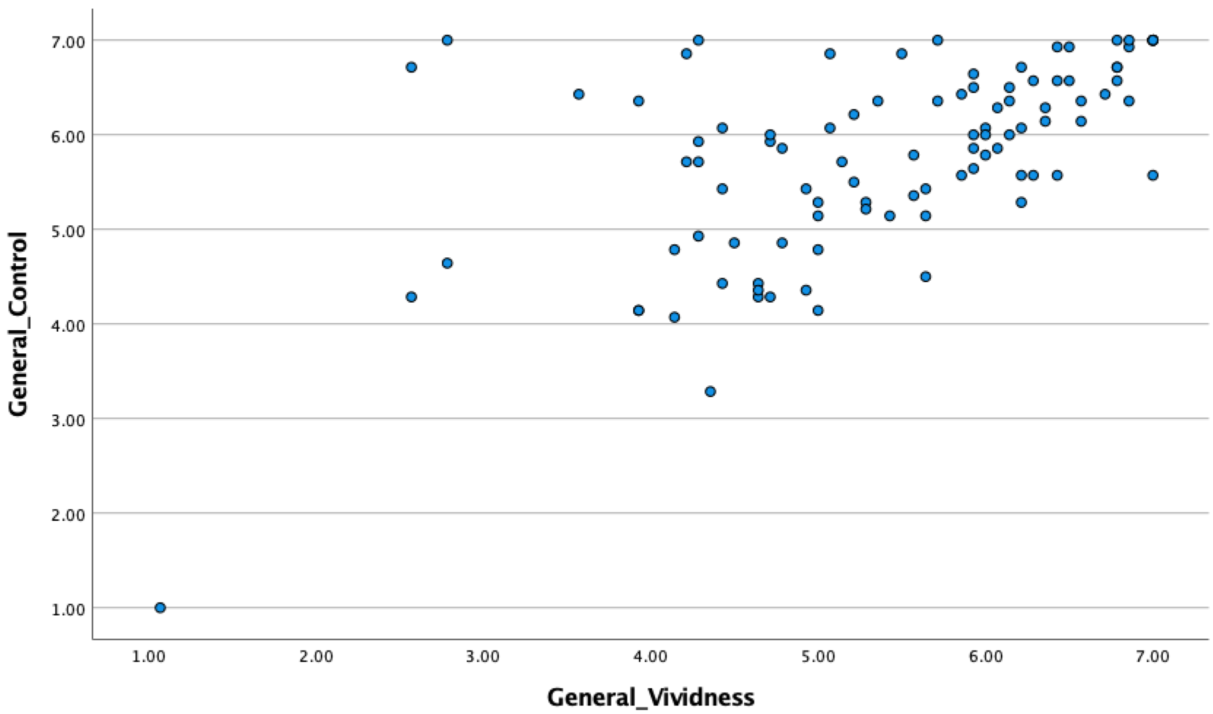


Figure 5

Correlation between Supplementary Vividness and Supplementary Control

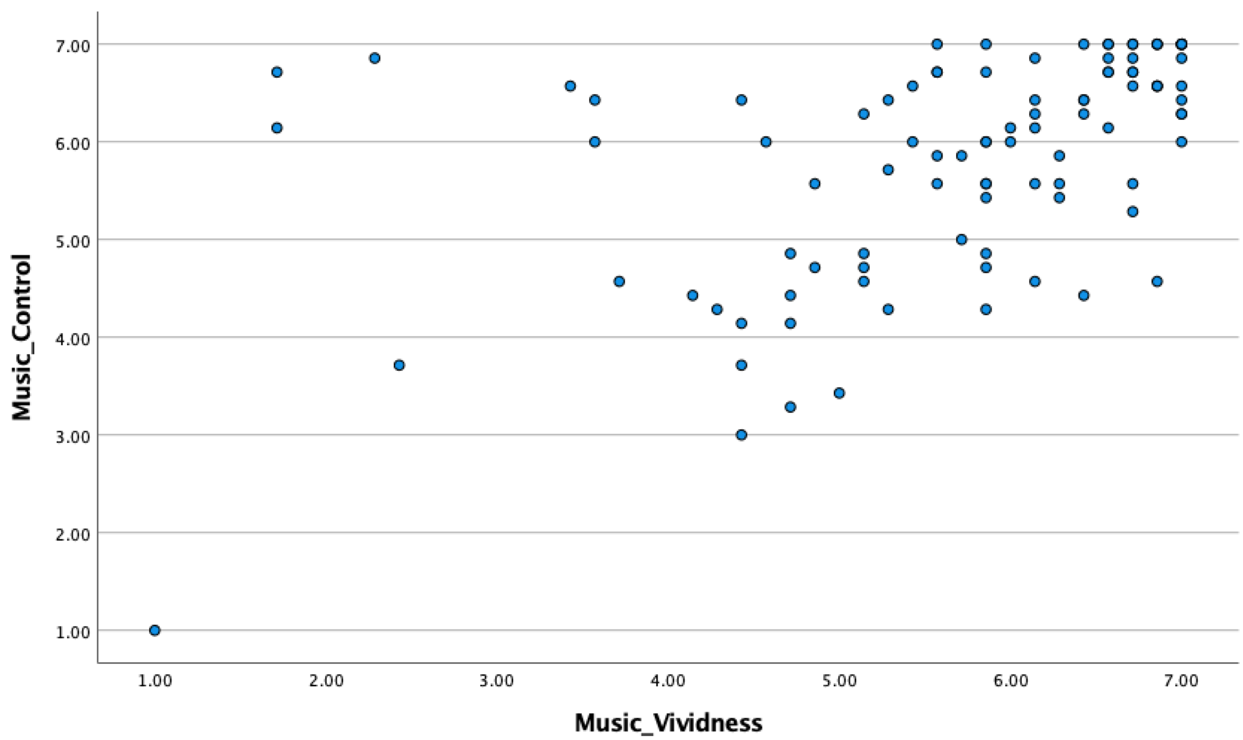
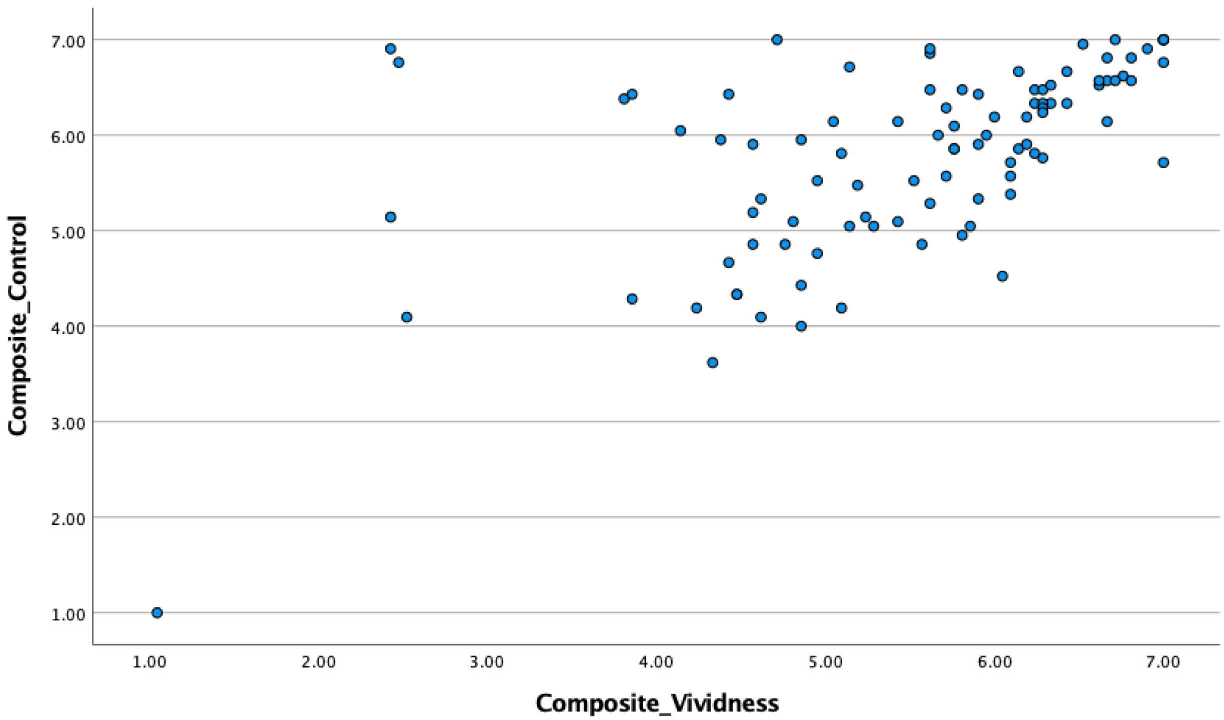


Figure 6

Correlation between Composite Vividness and Composite Control



Note: Composite vividness is the combination of General_Vividness and Music_Vividness findings. Composite control is the combination of General_Control and Music_Control.

Figure 7

BAIS-V Distribution

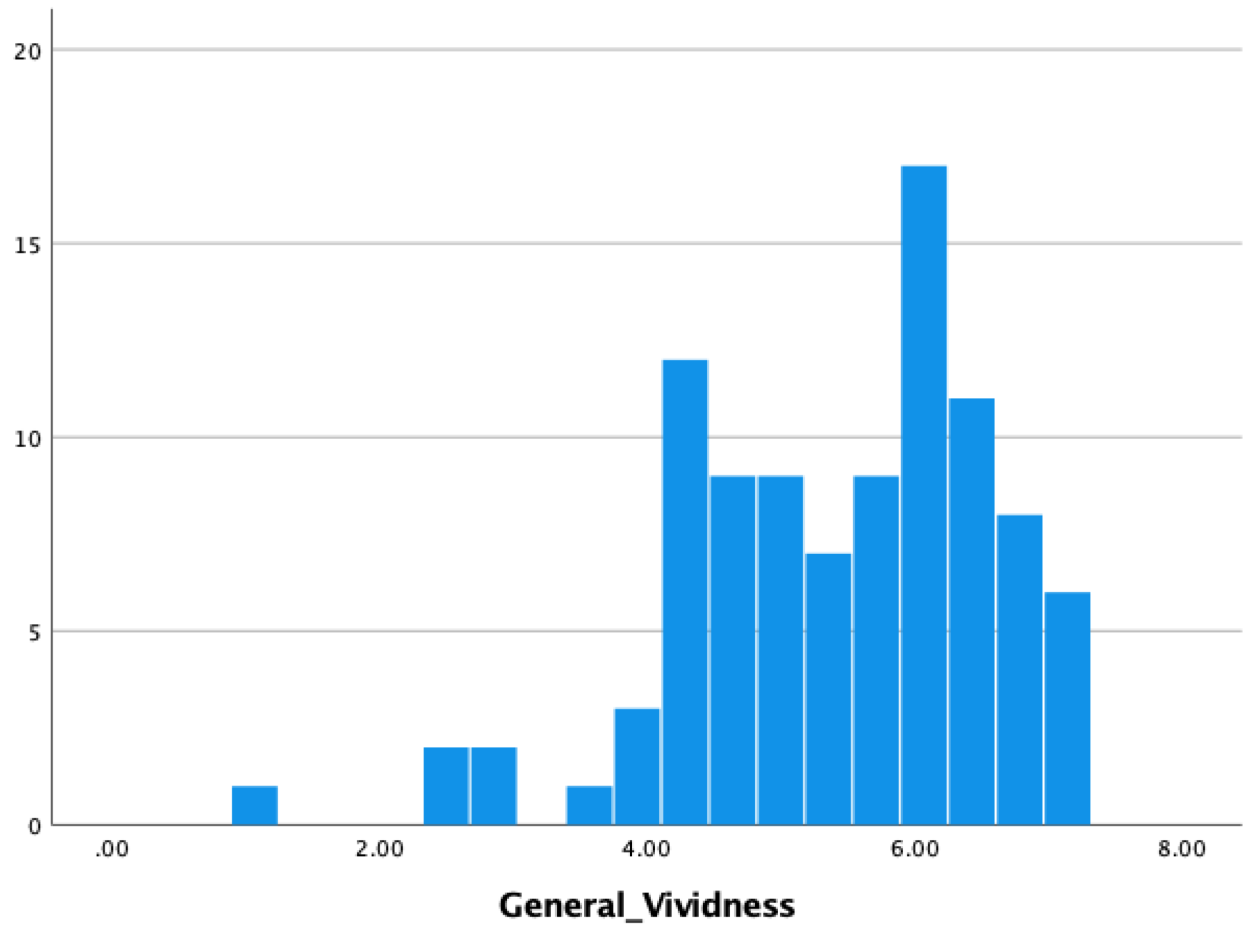


Figure 8

Supplementary-V Distribution

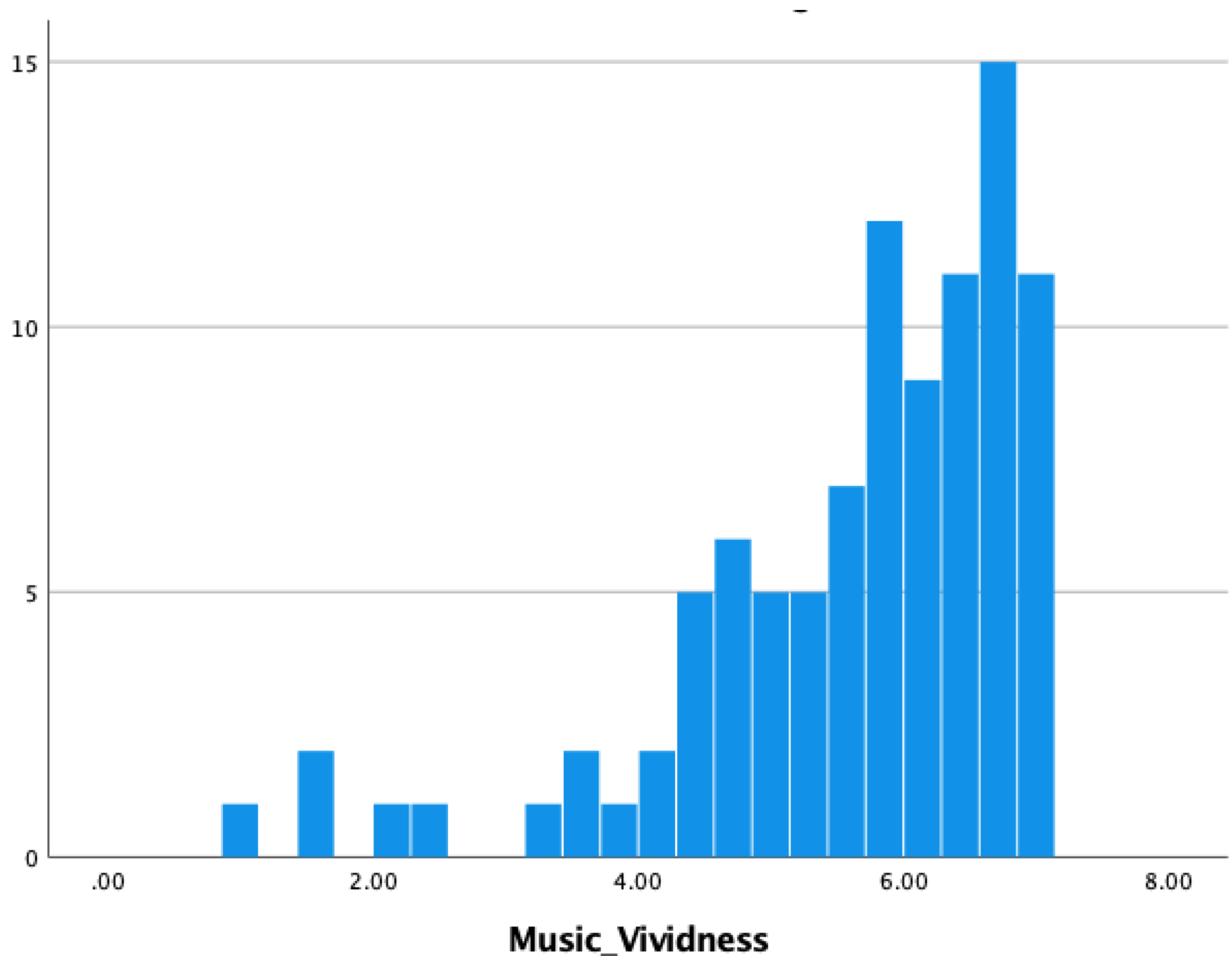


Figure 9

Composite-V Distribution

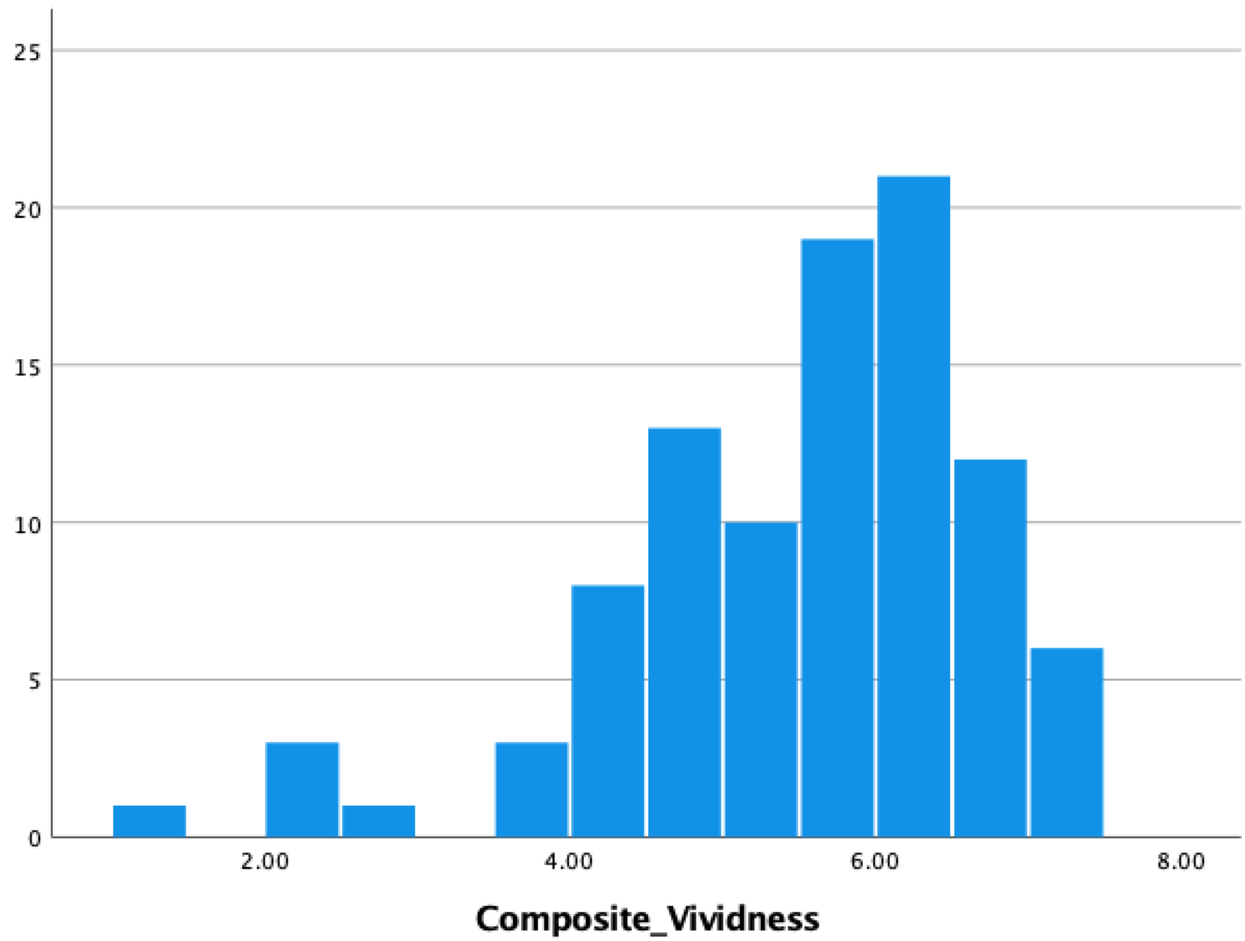


Figure 10

BAIS-C Distribution

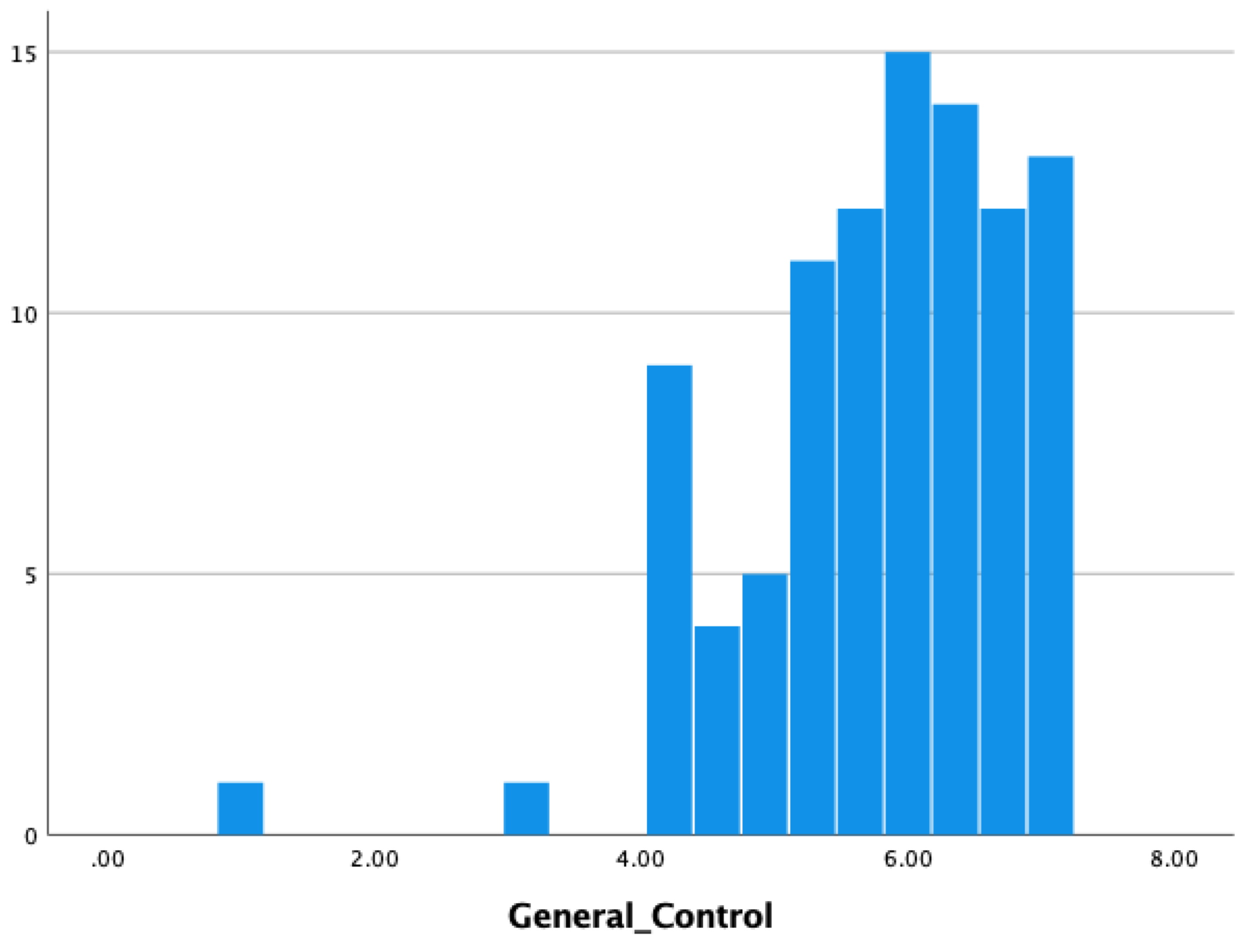


Figure 11

Supplementary-C Distribution

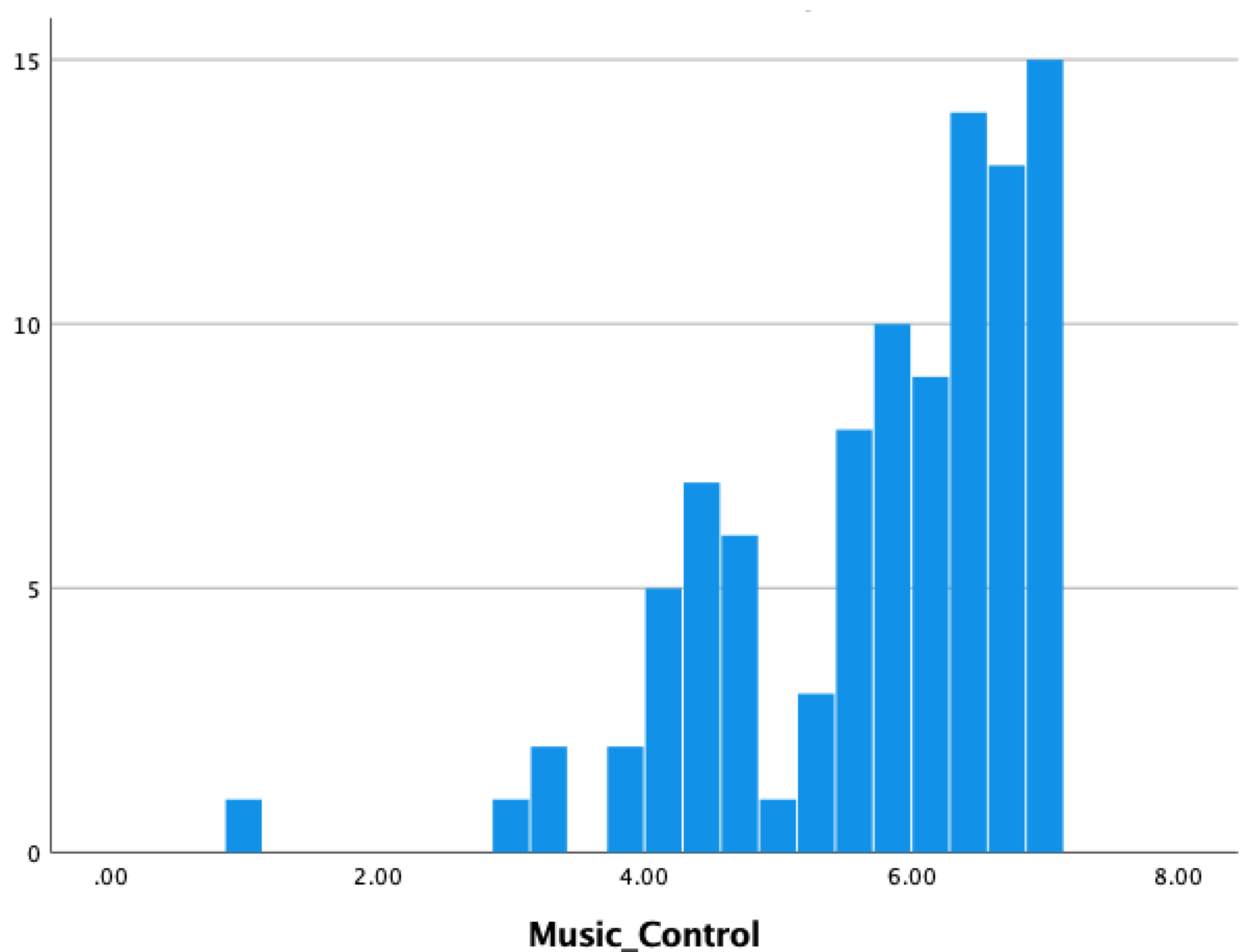


Figure 12

Composite-C Distribution

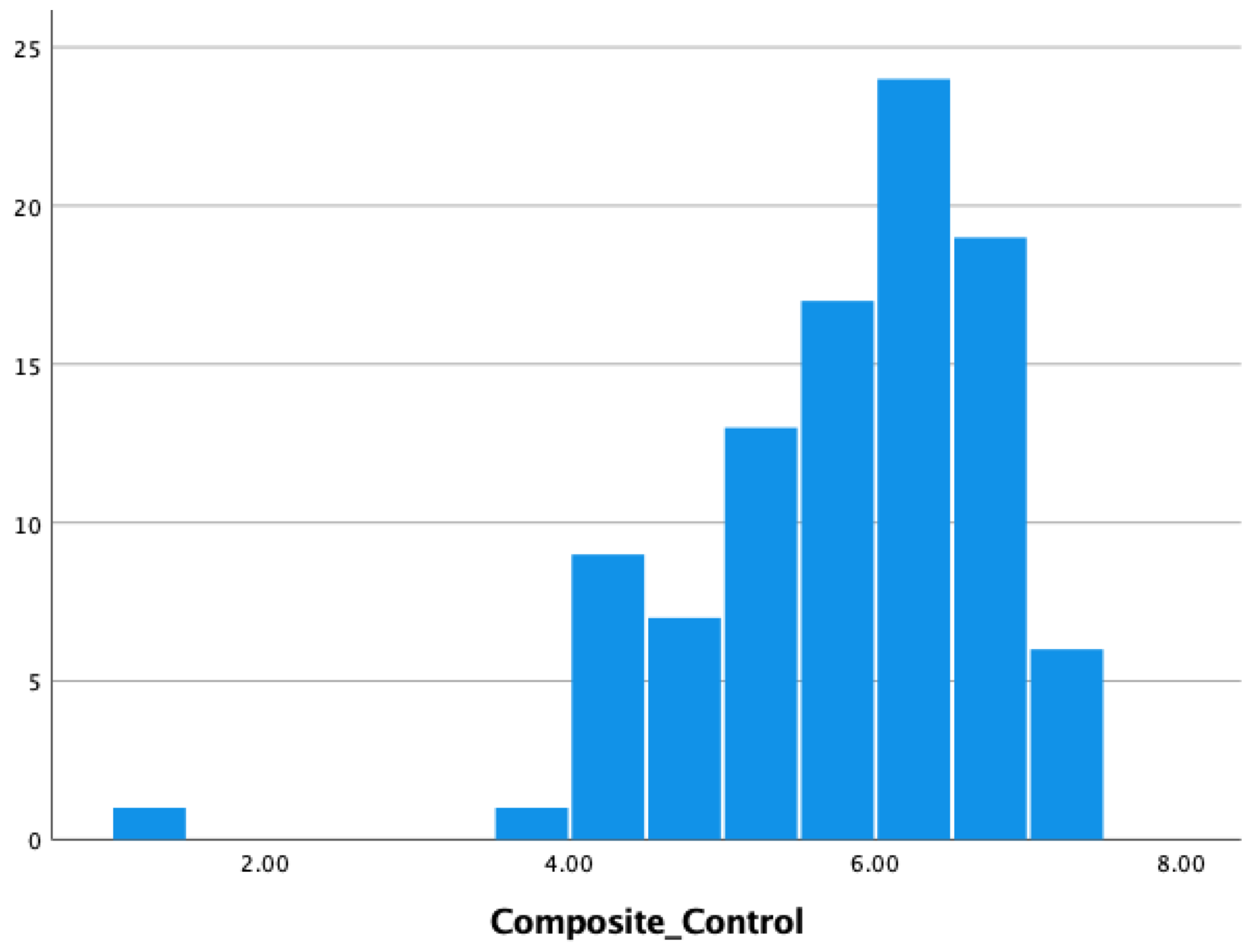


Figure 13

Self-Assessed Music Sight-Reading

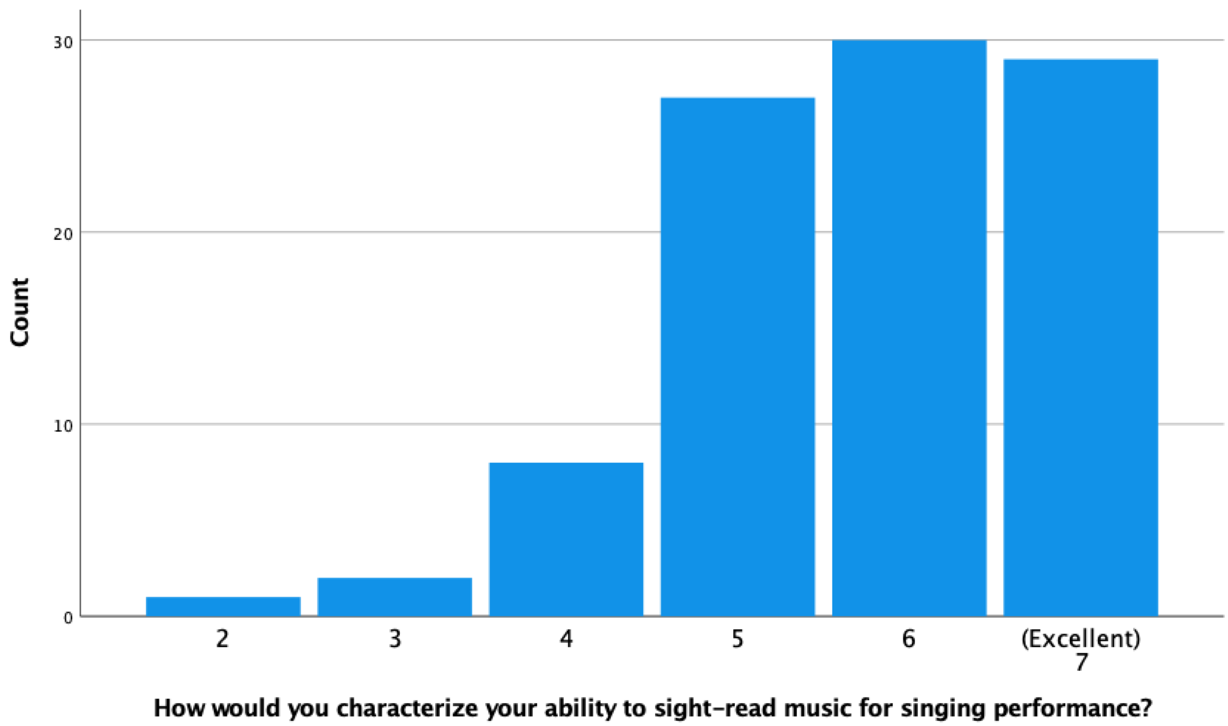


Figure 14

Self-Assessed Music Memorization

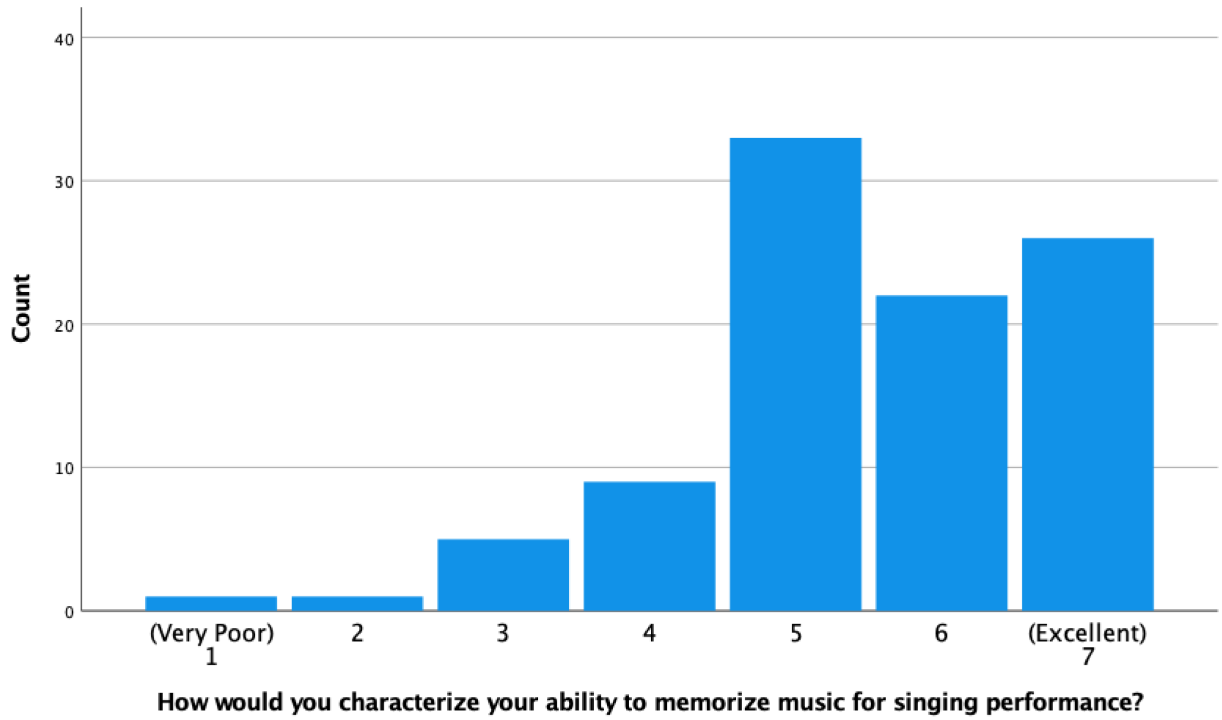


Figure 15

BAIS-V and Conducting Experience

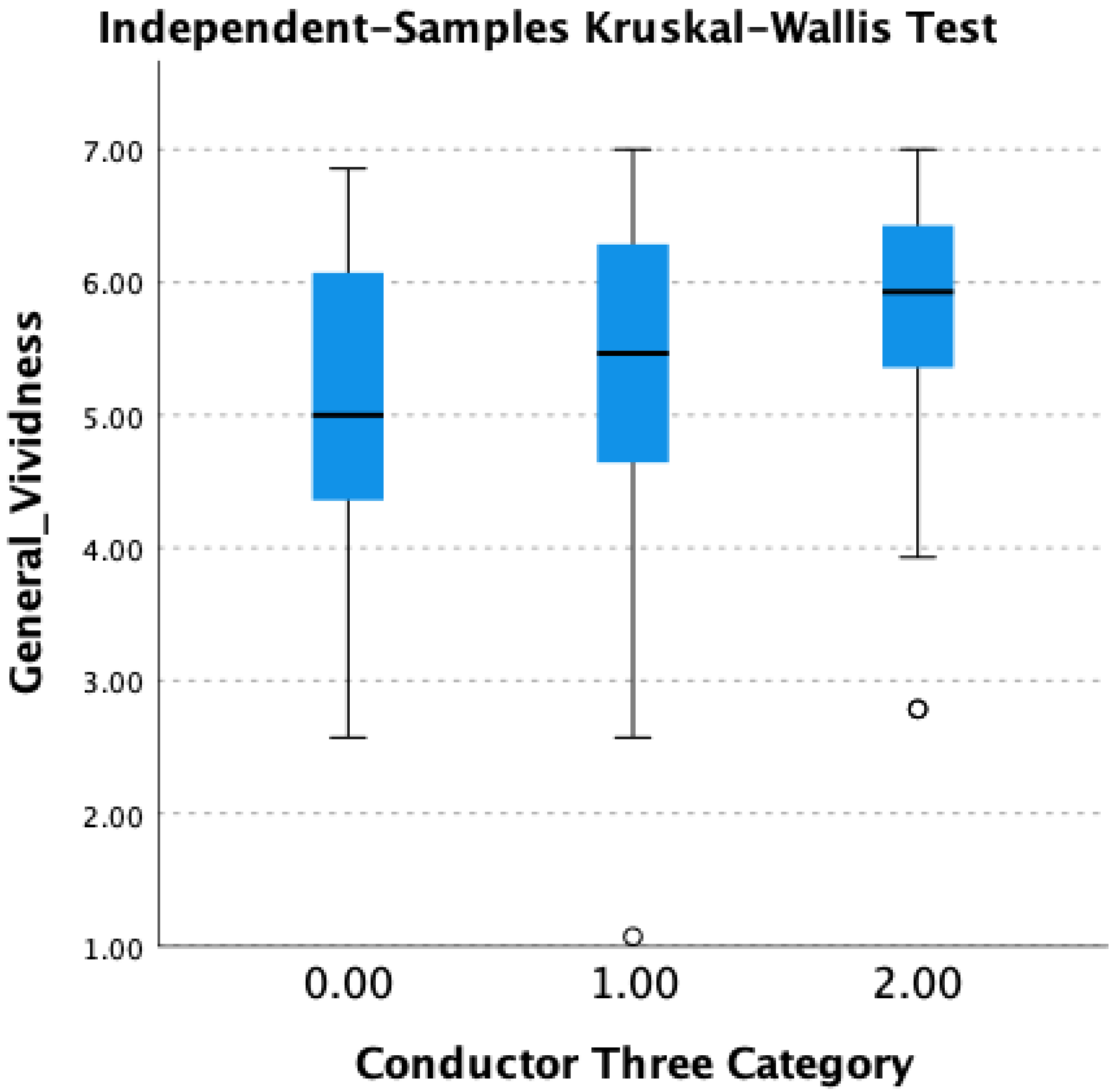


Figure 16

Supplementary-V and Conducting Experience

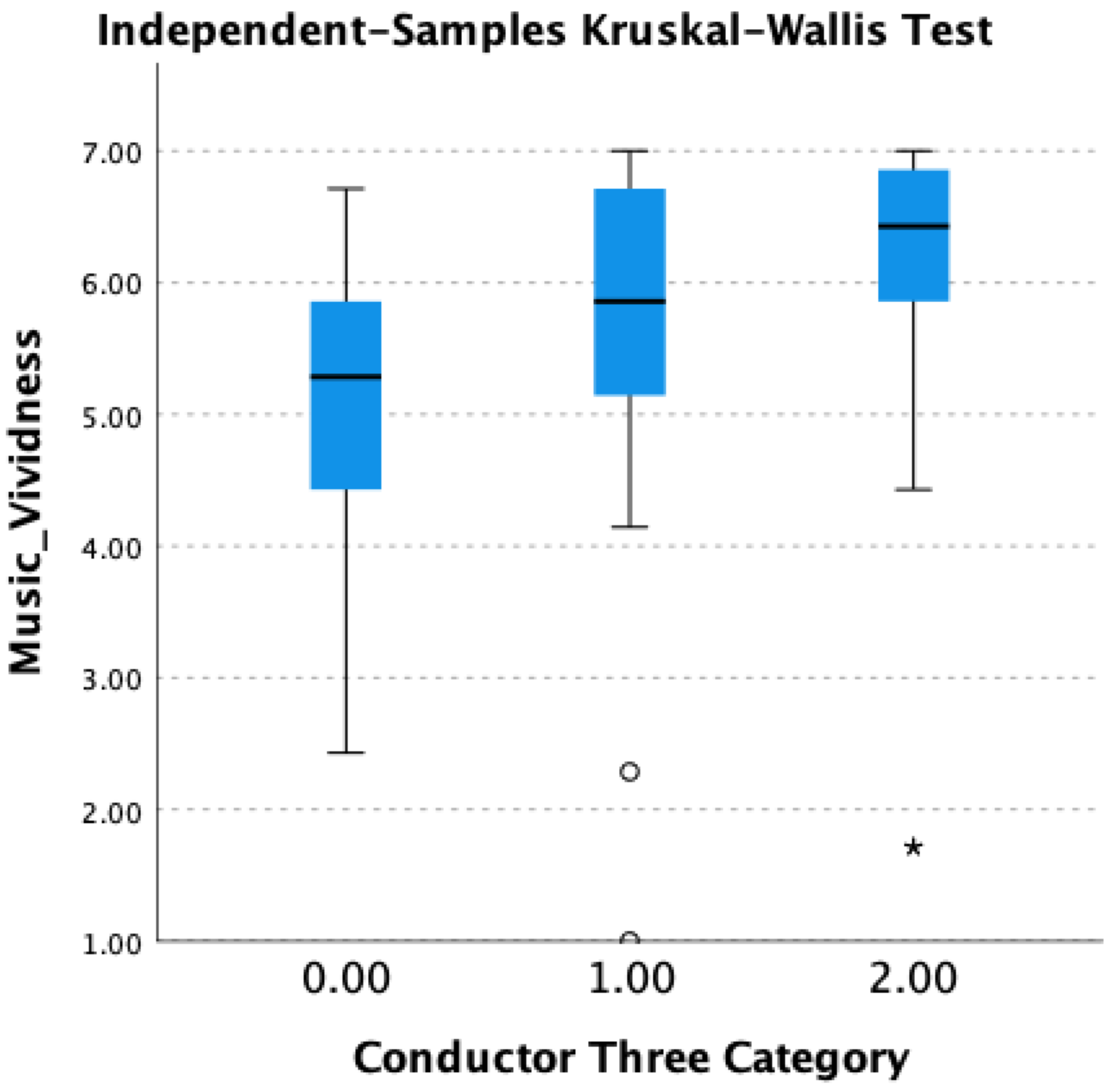


Figure 17

Composite-V and Conducting Experience

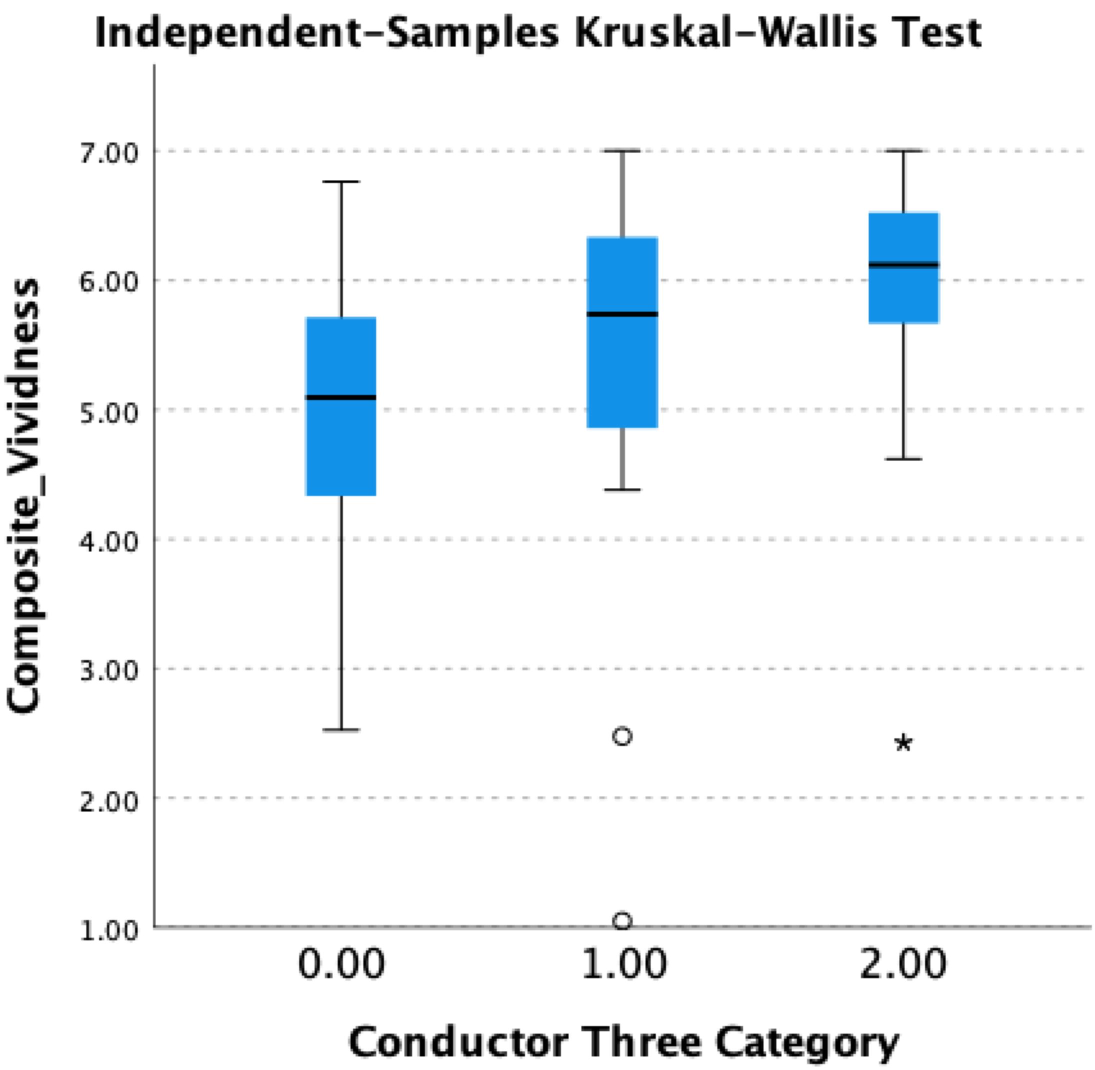


Figure 18

BAIS-C and Conducting Experience

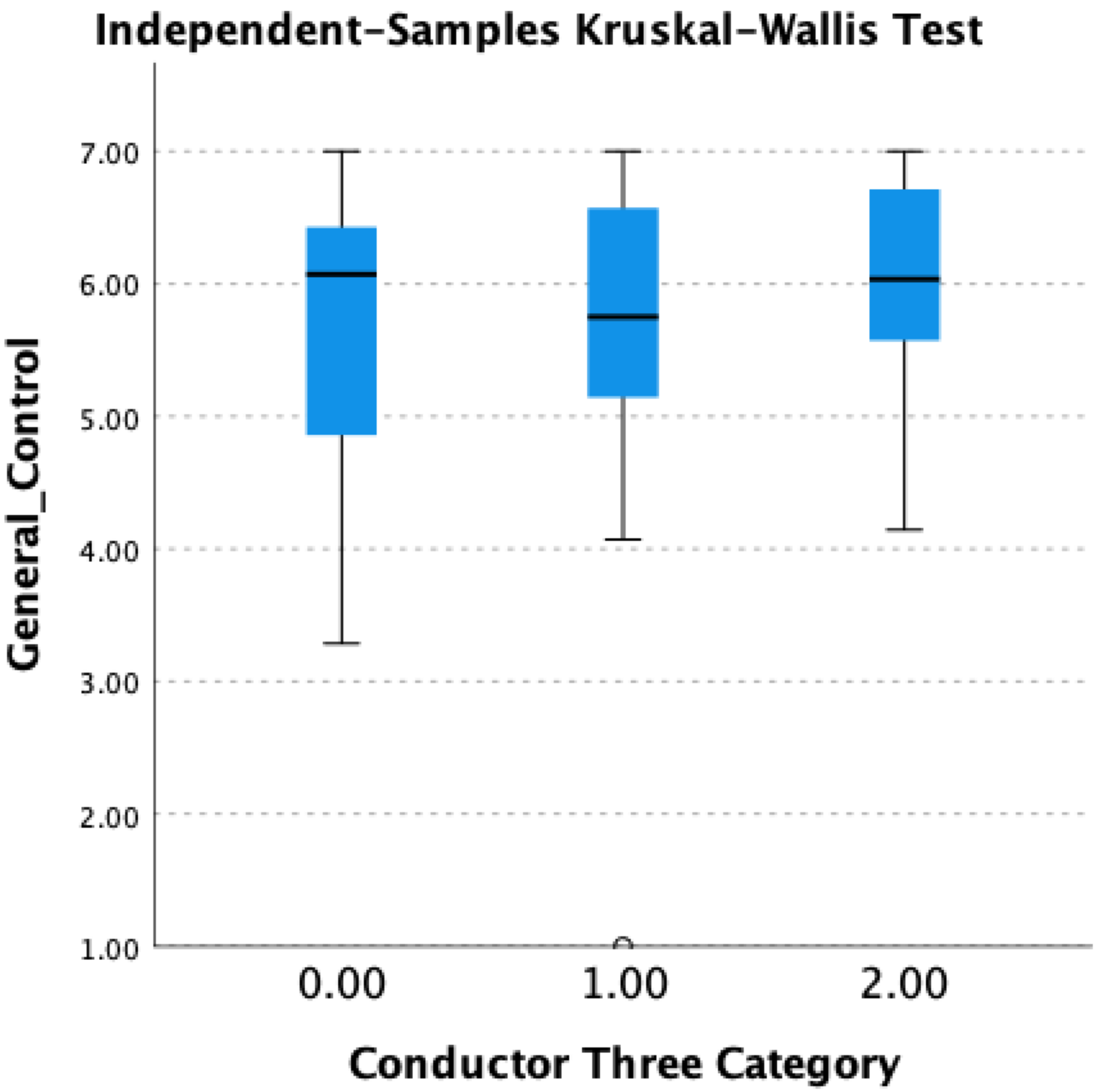


Figure 19

Supplementary-C and Conducting Experience

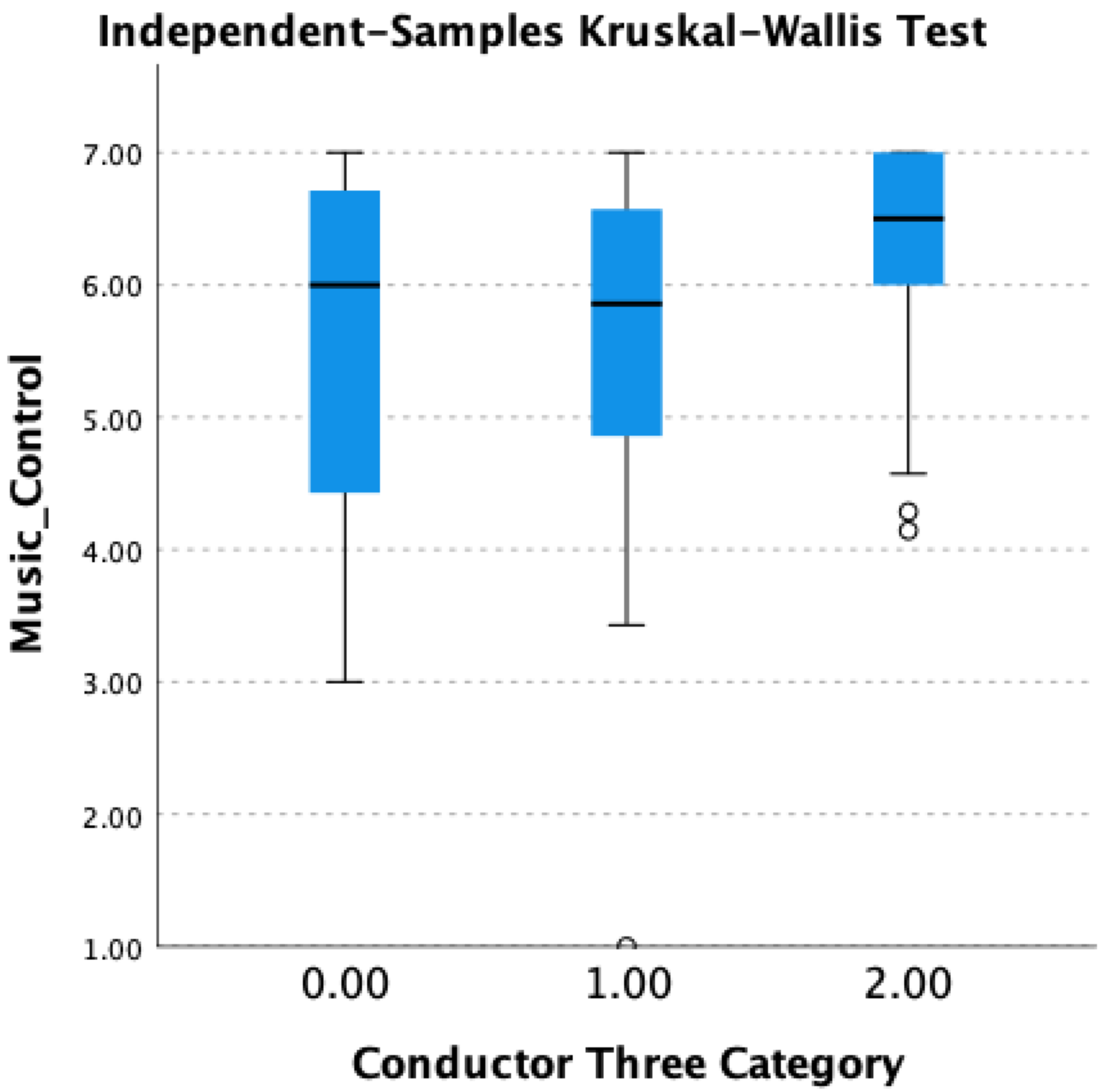


Figure 20

Composite-C and Conducting Experience

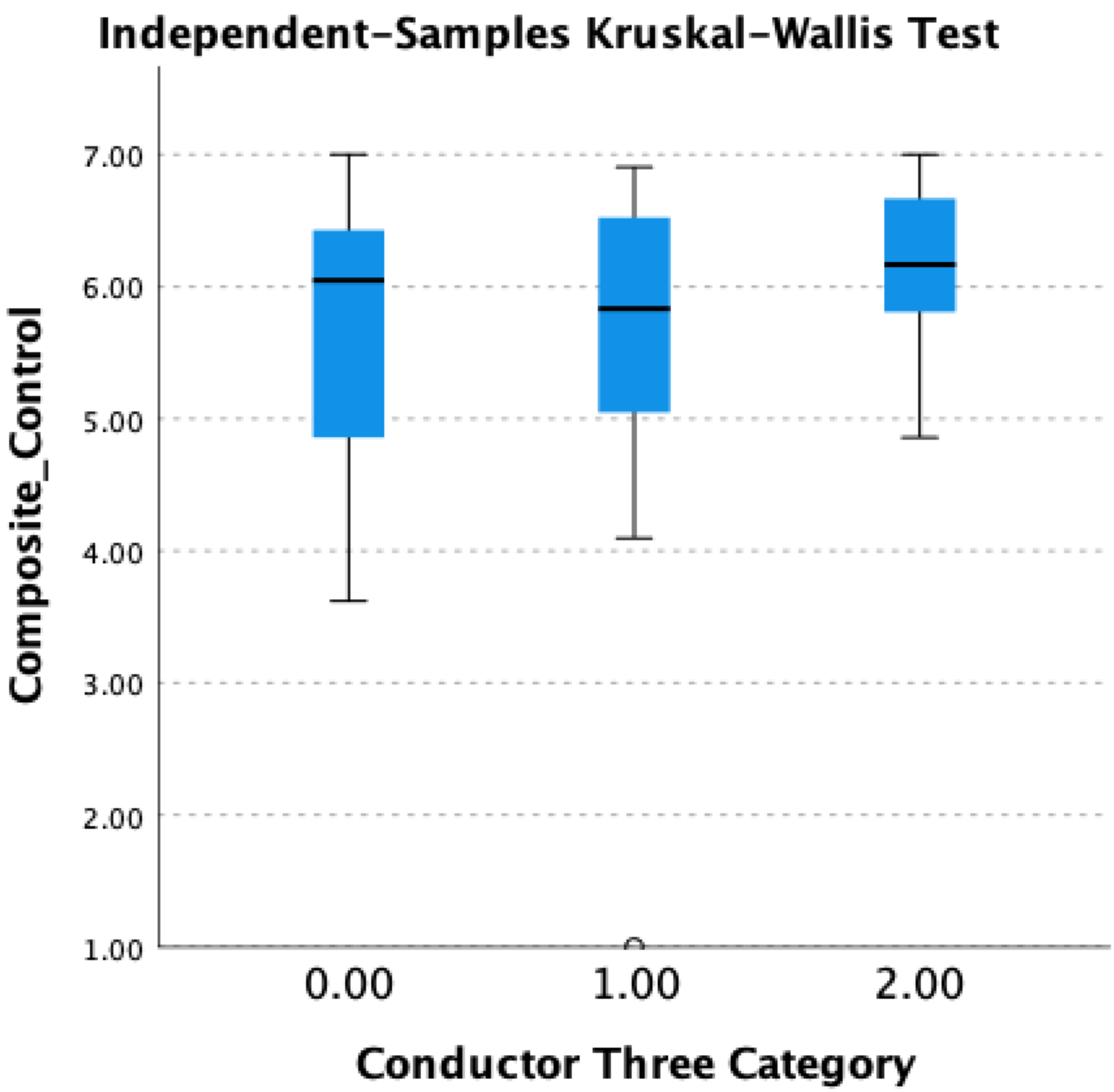
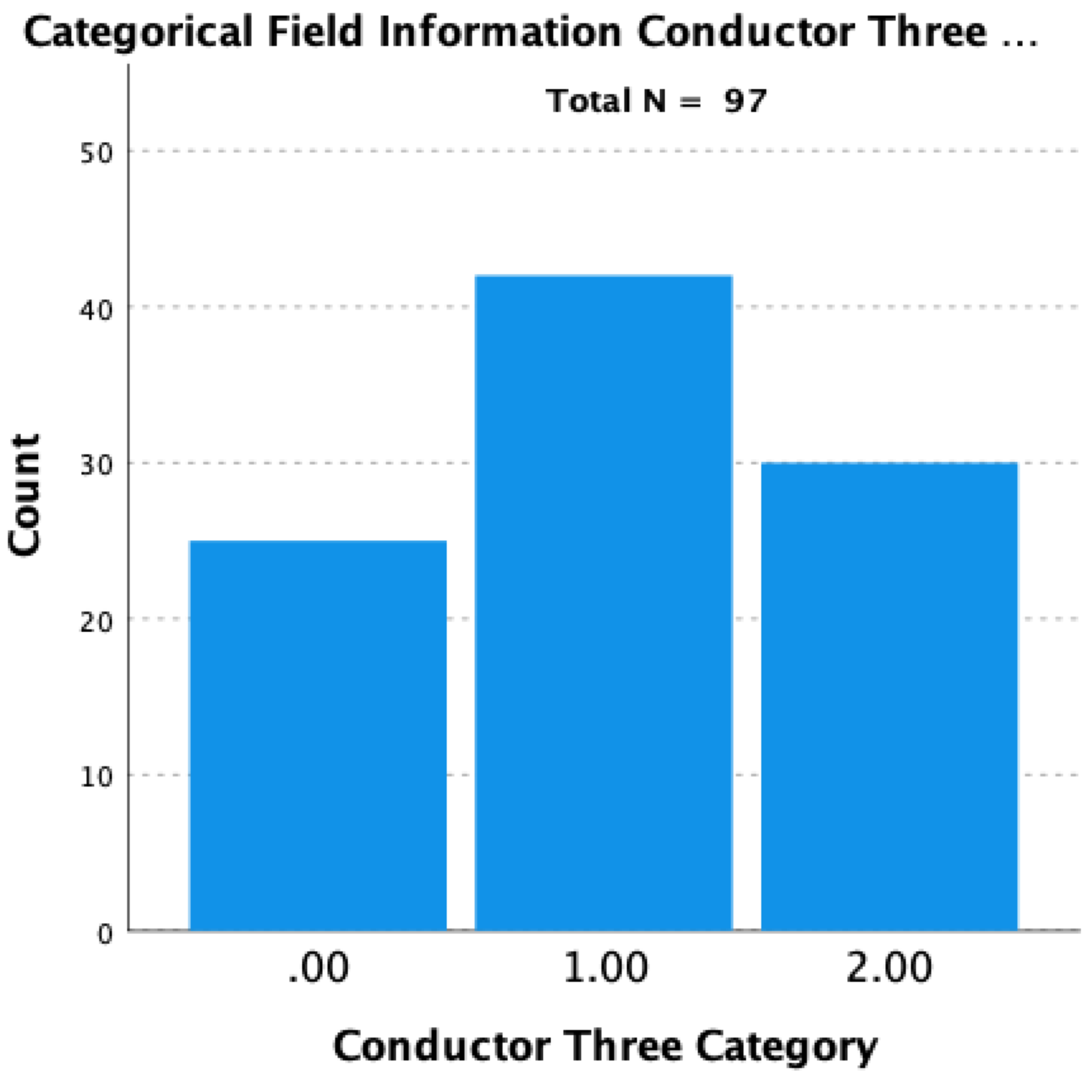


Figure 21

Participants in Three Conductor Group



Appendix F: Recruitment Script

Dear [Name],

My name is Evan Roberts, and I am a Masters' student in Music Education at the Jacobs School of Music at Indiana University Bloomington. I am conducting a research study examining individuals in the choral profession, both singers and conductors, in how they respond to questions related to auditory imagery. Auditory imagery is nearly synonymous with the term audiation, and it is defined as the act of voluntarily hearing sounds in your head when sound is not actually present. Since you are a choral professional, I would love it if you would participate in the study. The study consists of a fifteen-minute survey asking you to imagine the vividness of various imagined sounds. Participation in the study is voluntary. If you wish to leave your email address at the conclusion of the survey, you will be eligible to win a $50 Amazon gift card. Your identity will otherwise remain anonymous. If you have any questions, please contact me via email at evanrobe@iu.edu.

Thank you for your consideration,
Evan Roberts, M.M.E
Indiana University Bloomington

Appendix G: Study Information Sheet

Auditory Imagery Experiences Among Choral Singers and Choral Conductors

You are being asked to participate in a research study. Scientists do research to answer important questions that might help change or improve the way we do things in the future. This document will give you information about the study to help you decide whether you want to participate. Please read this form, and ask any questions you have, before agreeing to be in the study.

All research is voluntary. You can choose not to take part in this study. If you decide to participate, you can change your mind later and leave the study at any time. You will not be penalized or lose any benefits if you decide not to participate or choose to leave the study later.

This research is intended for individuals 18 years of age or older. If you are under age 18, do not complete the survey. The purpose of this study is to investigate the auditory imagery abilities of choral vocalists and choral conductors of similar musical experience.

We are asking you if you want to be in this study because you are a collegiate choral singer and/or conductor at a college or university in the US. The study is being conducted by Evan Roberts and Dr. Peter Miksza from the music education department at Indiana University Jacobs School of Music.

If you agree to be in the study, you will do the following things. You will complete an anonymous online questionnaire about your auditory imagery abilities. It will take approximately 15 minutes to complete the questionnaire. Before agreeing to participate, please consider the risks and potential benefits of taking part in this study.

You will answer some survey questions about your auditory imagery abilities. If you feel uncomfortable answering any of the questions, you can skip the ones you do not want to answer.

There is a risk that someone outside the study team could get access to your research information from this study. In order to ensure confidentiality, you will not be asked to provide your name in the questionnaire. However, you will be asked to enter your email address if you wish to be considered eligible for a drawing for a $50 Amazon gift card. We don’t think you will have any personal benefits from taking part in this study, but we hope to learn things that will help researchers in the future.

You will have the opportunity to make yourself eligible for a $50 Amazon gift card for participating in this study. There is no cost to participate in the study. The probability of being selected will be about .025 or 1 out of 40 likely participants. There is no cost to participate in the study.

We will protect your information and make every effort to keep your personal information confidential, but we cannot guarantee absolute confidentiality. No information which could identify you will be shared in publications about this study.

Your personal information may be shared outside the research study if required by law. We also may need to share your research records with other groups for quality assurance or data analysis. These groups include the Indiana University Institutional Review Board or its designees, and state or federal agencies who may need to access the research records (as allowed by law).
If you have questions about the study or encounter a problem with the research, contact the researcher Evan Roberts at 626-755-4447 or evanrobe@iu.edu; or Dr. Peter Miksza at 812-855-7253 or pmiksza@iu.edu.

For questions about your rights as a research participant, to discuss problems, complaints, or concerns about a research study, or to obtain information or to offer input, please contact the IU Human Research Protection Program office at 800-696-2949 or at irb@iu.edu.