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The Pedagogical Applications of Associating Color with Music in Entry Level Undergraduate Aural Skills

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by

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THE PEDAGOGICAL APPLICATIONS OF ASSOCIATING COLOR WITH MUSIC IN ENTRY LEVEL UNDERGRADUATE AURAL SKILLS

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This thesis explores the possible effects, pedagogical applications, and benefits of pairing color with certain musical elements in undergraduate aural skills courses. The aural skills exercises primarily used in this paper are melodic and harmonic dictations but the overall theory could be applied to any exercise used in aural skills courses. An extensive review of the history and uses of color in music, as well as the invention of the color organ and the resulting artistic movements that placed color and music into the same medium are presented along with their potential uses in aural skills. Our perceptions of and emotional reactions to color and music are intriguingly similar and by pairing those similarities along with a "natural synesthesia" we all have and use to explain and understand abstract topics such as color and music, it seems only logical to continue to explore any potential educational benefits this pairing may have. With the aforementioned topics and the recent studies that have looked at the use of color in both music education and the effects visual and auditory stimuli have on one another, I make the case for why color should be used when attempting to aid students in undergraduate aural skills. I conducted several studies to determine the possible role color could have in aural skills courses and I present those results as well as showing the possible ways in which color could be paired with certain drills. By creating a multi-sensory, enlivened learning experience in aural skills courses, struggling students and those who are more visual and kinesthetic learners may benefit. New software was developed to create a new, modern-era color organ which was used in my study that looked at the differences in the memory retention of visual and audio stimuli. The tests were analyzed through ANOVA which looked for any potential benefit color had with isolated solfège and chord qualities drills. Although the findings of the ANOVA analysis must be viewed with caution because one of the assumptions on which the ANOVA analysis is based was not met, results did show one group as approaching significance. The student feedback on the theory and study is discussed with several interesting and important trends seen in the testing, including the preference of visual stimuli. Finally, the future research needed and the pedagogical applications that could be utilized when pairing color to music in entry level undergraduate aural skills is examined.

To

Emily, Pat, Kellie, John, Mom, and Dad

Thank you for your love and support in all of my adventures

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CHAPTER I: INTRODUCTION

Aural skills, also known as "musicianship" or "ear training," are skills learned in music theory lab courses which are a requirement for all undergraduate music students wishing to obtain any degree in music. The exercises learned in aural skills include but are not limited to such things as interval identification, notating a given melody or chord progression, cadence identification, and knowledge of prolongations of tonic, predominant and dominant harmonies. An aural skills deficiency in incoming students is widely reported throughout academia. Gary Karpinski states in his *Aural Skills Acquisition: The Development of Listening, Reading, and Performing Skills in College-Level Musicians,* that "many universities, colleges, and conservatories report that entering students often suffer from deficiencies in aural skills."[1] It is also my impression, both as a teacher and student, that far too many students struggle in aural skills training, causing frustrations and delays in the completion of their degree or a loss of love and passion for music. While this is obviously not the goal of aural skills, it can be an unfortunate outcome for some. Other students may succeed just enough to move on, only to continue to struggle because their foundation and knowledge of the rudimentary elements are not as solid as they need to be.

The analogies we use show a link between color and sound that is undeniable. Listeners often use illustrative language to describe music as seen in the diagrams presented by Alf Gabrielsson and Erik Lindström from their article, "The Influence of

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[1] Gary Karpinski, *Aural Skills Acquisition: The Development of Listening, Reading, and Performing Skills in College-Level Musicians* (New York: Oxford University Press, 2000), 7.

Musical Structure on Emotional Expression," (see Appendix F) and words such as bright, warmth, love, and bold which were used to describe scale degrees, can easily be paired with appropriate colors.[2] Listeners feel the emotional impression of a piece or song, they visualize the imagery that they associate with certain sounds, they move to the shape and contour of the piece. Visual and kinesthetic analogies are deeply ingrained with our descriptions and understanding of music in and out of the classroom. Music and our responses to it are often a multi-sensory, multidimensional experience which is paired with our emotional responses, be it naturally or conditioned. Instructors of aural skills courses often tell their students to associate the sound of a minor triad with their other senses or in an analogy-based process. Words such as happy and sad or questions like "What does this sound remind you of?" are used to help the student link those sounds with prior knowledge in an associative manner. This process is then repeated with major triads. Instead of telling students to visualize a dark, sad or subdued color or image in their mind when they hear a minor chord, why not actually show them a cool, dark color that not only corresponds to the analogies used to describe that chord, but actually evokes bodily responses that also follow our conditioned descriptions of those sounds? Could this conditioning, a pairing of color and sound, a "learned synesthesia," help students build a better and stronger foundation of the basic principles of aural skills before having to build upon that base with the more complex tasks and chromatic sounds taught in later aural skills levels?

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[2] Alf Gabrielsson and Erik Lindström, "The Influence of Musical Structure on Emotional Expression," In *Music and Emotion: Theory and Research*, edits by Patrik Juslin and John Sloboda (New York: Oxford University Press, 2001), 235-239.

Synesthesia is a documented condition in which the brain allows a crossing of the senses. According to B.M. Galeyev, humans already use a “natural” type of synesthesia when learning and describing pitch-size, which is the association between musical pitch and actual physical size. “A low pitch looks big, thick, and opaque, while a high pitch is small, thin, and acute (children often describe pitches in this way).”[3] Another type of synesthesia, albeit natural and not as rare as once thought, is the pairing of sound with color. Many well-known composers appear to have had or stated themselves that they had this type of synesthesia, including Debussy, Ives, Rimsky-Korsakov, Scriabin and Schoenberg. Even before synesthesia was a documented condition, color and music have often been compared to or paired with one another, from Plato and Aristotle to the American psychedelic movement of the 1960s. Color and sound have always been closely related since their discoveries in many ways. The colors of the rainbow, often taught as R-O-Y-G-B-I-V to elementary students, is the byproduct of Isaac Newton adding the color indigo to his prism experiment results so there would be seven colors which would fit with the seven notes of the musical scale.[4] In fact, the color indigo is no more or no less prevalent than red-orange or yellow-green are. Another groundbreaking experiment which furthered the fascination between music and color was the discovery that light, like sound, was made up of waves. In Robert Crease’s *The Prism and Pendulum*, Thomas Young discovered that light was made up of waves and considered

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[3] B.M. Galeyev, “The Nature and Functions of Synesthesia in Music,” *Leonardo: Journal Of The International Society For The Arts, Sciences And Te*chnology, 40, No. 3 (2007): 285, accessed October 5, 2014, http://www.jstor.org/stable/20206419.

[4] Kerry Brougher et al., *Visual Music*: *Synesthesia in Art and Music Since 1900* (London: Thames & Hudson Ltd., 2005), 213.

light and sound as analogous phenomena.[5] The history of human interaction with and study of color, light and sound have many parallels and crossings of facts, analogies, and the human perception of them.

The use of color in music has also been used in commercial tools and educational aids, and seen throughout different art movements, from the eighteenth to the twentieth century, including the idea of synchromism which is the syncing of color to music in painting. The use of color organs is seen as far back as the early 1700s with many different attempts at pairing color and color wheels to Western musical scales. Rainbow Music Inc., Synthesia Piano, and other modern companies and publishers use color to teach such topics as ear training, note names, piano key identification, chord identification and basic sight reading skills.

While the uses and pairings of color and sound are extensive, few have been educationally based and even fewer have used these pairings and ideas in the modern, technologically advanced classrooms that we use to teach aural skills in today. The display of visual stimuli in conjunction with aural stimuli has never been simpler, and we should be trying to utilize these connections in a beneficial, educational way.

The problems and difficulties in aural skills courses will be different for each student but often involve the more complex tasks where multiple levels of thought and listening are needed to accurately hear and dictate the music. Melodic dictation and harmonic dictation are areas where these difficulties increase. While these activities typically only actively engage the sense of hearing (sight is used but passively), we use

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[5] Robert Crease, *The Prism and the Pendulum: The Ten Most Beautiful Experiments in Science* (New York: Random House, 2003), 108-109.

analogies and teaching methods that evoke the sense of sight and the sense of touch. Multiple senses are not actually engaged in the skill of accurately hearing a given exercise even though our analogies and methods lead us in that direction. The actual use of multiple senses in everyday life is something we all do constantly and naturally in order to decipher and learn the world around us. Richard Gregory notes that the most common, natural, and well-known mixing of the senses is flavor: "Flavor is usually defined as the overall sensation of taste and smell."[6] Without both senses working in conjunction, our sense of flavor and general ability to taste are greatly diminished. While many of us do not have a natural crossing of hearing and sight as documented in people with synesthesia, it does not mean that the benefits of a multi-sensory approach to aural skills cannot be learned. If color has been used commercially and is used naturally by those who have a color/sound based synesthesia, can those connections be utilized to help students in entry level aural skills?

Our hearing system is far too complex to dismiss students who might not understand or hear in the same way as someone who grew up learning and playing music that follows the Western/classical definition of tonality. By using color in conjunction with sound, a better foundation of the basic elements could be learned, helping students build stronger tonal relations in the music they hear rather than building upon weak foundations that were learned only for the sake of getting to the next level. In order to begin being able to pair color with music and test what effects may result, a small-scale study was developed to not only test the possible memory benefits of color pairing but

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[6] Richard Gregory, *The Oxford Companion to the Mind* (Oxford, New York: Oxford University Press), 903.

also to gather feedback from the students about what, if anything, was helpful about the study. The tests used in the study were designed to translate into possible melodic and harmonic dictation skills, mainly because these two elements are the core drills tested in aural skills courses and require more complex task management to complete them as mentioned previously.

In the following chapter I will review existing research and literature on topics related to color and sound. Synesthesia will be covered followed by a list of composers who appear to have had this condition and exploited it some way in their works. Several artistic movements, such as the visual/color music movement in which the term "colorist" appeared, and synchromism will be briefly discussed to show further linkage of color and music. The progression of the pairing of music and color will be explored through the history, evolution and fascination with it, from Plato and Aristotle to Newton, and from the development of the color organ in the early 1700s to our current views and research on the matter. The theories behind color and light and how they are used in design and in everyday occurrences in Western culture, such as advertisements and their targeted emotional responses, will also be examined.

Research into the effects that audio and visual stimuli have on one another will be reviewed and how auditory stimuli, can influence and improve the memory retention of visual information when both are presented simultaneously. Although limited research has been done studying the effect that visual stimuli have on the memory retention of audio stimuli, several experiments will be viewed for any benefit it may bring. The results from the aforementioned research will be used to further my exploration into the possible benefits to memory retention by engaging multiple senses. A dissertation that studied the effects and results of using color to teach 60-year-olds music theory rudiments, aural skills, and keyboard skills will also be examined and the results from it used to further the possibilities of using color in aural skills courses. The study involving 60-year-olds separated the subjects into three groups, each being taught identical material in the same fashion. One group used traditional black-and-white notation with a normal keyboard, a second group used color notation with a normal keyboard, and a third group used both color notation and a keyboard with color-coded keys. While this study used a different color pairing than those used in my studies, the results showed an interesting and overwhelmingly positive result in the students who were taught using color notation and the traditional keyboard when compared to the two other groups. Although not entirely conclusive on how and why the results came to be, this study will be used to show that in certain environments color does indeed seem to aid in the learning of many different musical topics, including aural skills.

By using several different ways in which tonic is possibly inferred and pairing those ways with different coloristic approaches that capitalize on the similar conditioned responses, analogies, and how color and music have progressed together through the passage of time, I wish to convey that not only is using color to aid in aural skills a feasible idea, but at times has been shown to actually help in certain musical activities and classroom environments. More active and focused students may be the result of a multi-sensory environment that engages not only their sense of hearing, but also their sense of sight.

Chapter III will explain my small-scale experiment in which a computer interface was developed that allowed the user to map colors onto a digital keyboard display. When this computer was linked to a separate MIDI keyboard, the selected color for each key was shown via a projector in conjunction with the audible pitch when those keys were pressed on the keyboard. The methodology of the test and structure of both the program and testing environment will also be covered in chapter III. Chapter IV will present the data and results of the testing conducted on undergraduate students of the Glenn Korff School of Music at the University of Nebraska-Lincoln.

Finally, by using color theories as well as the research on tonal inference and how we teach functional harmony in aural skills, reasons as to why and how certain colors could represent certain notes or chord qualities will be discussed. Further research will also be covered for what is needed before being able to conclude either way if the ideas behind assigning colors to notes and/or chord qualities could aid students in their aural skills curricula.

CHAPTER II: REVIEW OF LITERATURE

The research and literature that discuss the parallels between music and color are well documented. Some of the topics include the history of and fascination with the parallels observed between color and music, the similar scientific properties, perceptual workings, and meanings that color and music share. The early connections between music and color, the art movements that would arise from the fascination between them, the discovery of synesthesia to further that fascination, and the devices created to join color and music are all well documented. While the amount of research on audio and visual connections is rather large, its quantity diminishes when focusing on the effect, if any, that the visual has on the aural. Minimal research exists on the possible educational benefits of using color in aural skills courses.

Synesthesia

Synesthesia, a genuine crossing of the senses, is nearly seven times more common in artists, poets and novelists perhaps due to the fact that these types of people link unrelated concepts.[7] While musicians are not directly mentioned by Gregory, they often use the process of linking unrelated concepts when explaining and learning musical topics such as explaining the shape, or arch of a melody. It must be mentioned that the term synesthesia is used when describing any crossing between multiple senses, be it between smell and hearing or touch and taste. "Color hearing," or the literal seeing of a certain color when a note or chord is played is just one of many types of synesthesia.

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[7] Gregory, *The Oxford Companion to the Mind,* 900.

Gregory writes that "Recent experiments suggest strongly that synesthesia is a sensory phenomenon, not a high-level memory association."[8] Although many of us do not have synesthesia, this does not mean a "learned synesthesia" cannot be utilized to build memorable associations between two senses. As put by Charles Spence and Ophelia Deroy, "cross-modal correspondence refers to the general tendency for our brains and/or minds to match features or dimensions across sensory modalities."[9]

Many terms and associations are commonly used and show that although we may not have synesthesia, we have been conditioned to think in a manner consistent with synesthesia in music and aural skills courses. Besides the pitch-size association mentioned in chapter I, another common crossing widely encountered in non-synesthetic people is the correspondence of brightness and lightness with pitch.[10] It would be hard to find and even harder to explain someone saying that the highest register of the piano sounds dark or heavy; rather, the opposite is apparent. Certain words we use to describe music are synesthetic by nature. "Baritone" literally means heavy, as in the weight of an actual object, which is understood musically and when describing color. The term "light" is also used when referencing the weight of an actual object or its color, but is also understood when used to describe musical characteristics.[11] The analogies used in music have conditioned us to approach it in a similar fashion that someone with true synesthesia

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[8] Gregory, *The Oxford Companion to the Mind,* 899.

[9] Charles Spence and Ophelia Deroy, "On Why Music Changes What (We Think) We Taste." *i-Perception,* 4, no. 2 (2013): 137-140, accessed March 20, 2015, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3677333/.

[10] Galeyev, "The Nature and Functions," 285.

[11] Ibid.

would, meaning that although our senses are not actually crossing, we are associating topics in a “cross-modal correspondence” to better understand them. An example of this is how we say $\hat{7}$ pulls to $\hat{1}$, our kinesthetic understanding of the term pull helps us hear and understand the $\hat{7}$-$\hat{1}$ relationship. These show the example of association “by contiguity” and seem to be accepted in early childhood.[12] Associations “by similarity” are more complex but involve a spatial and temporal link, like the term “melody pattern.”[13] A study in 2012 looked at the the effect that music had on the taste of wine. Words like “heavy” and “mellow” were pre-selected to be options to describe the taste of wine while listening to musical selections that were considered similar to words like “heavy” or “mellow.” The results suggest that a stimulus may trigger a symbolic association to another stimulus if they are perceived at similar times.[14] While this study showed metaphorical associations, another study conducted the same year showed a “cross-modal correspondence” between bitter tastes with low pitches and sweeter tastes with higher pitches.[15] The question that is of most importance and remains is this: Can these conditions be learned and utilized to benefit student’s knowledge in aural skills?

The term *color* is used in music most often by an association with the musical term of timbre. This is reflected in the German language, at least; *Klangfarbe* literally means “tone color.” Even though “color hearing” is limited to those who have that particular type of synesthesia, there is still a consensus when describing certain elements

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[12] Galeyev, “The Nature and Functions,” 286.

[13] Ibid.

[14] Spence and Deroy, “On Why Music Changes,” 137-140.

[15] Ibid.

of music when using color. For example, although color and music are subjective, there still seems to be some type of agreement when using color to describe music. People may describe a flute sound as being light blue or bright yellow but we would be hard pressed to find someone describing it as being brown.[16] The reason is that listeners tend to associate a flute sound with words such as airy, light and quick and the color brown does not fit those descriptors as well as light blue or bright yellow. Dark colors, like brown, are perceived as being heavy and slow. These associations and metaphors are essential when having conversations about abstract topics and we use our "learned synesthesia," or "cross-modal correspondences," to help describe those elements, be it by color or some other type of description. Even our descriptions of tonality make use of this associative method by using terms like direction, weight, pull or gravity. Rimsky-Korsakov stressed the analogy between color/light and harmony/timbre, elements that were obvious in his view.[17] When discussing his thoughts on this association, he stated, "Harmony—light and dark. Major and minor. Joy and sorrow. Clearness. Vagueness, dusk."[18] These analogies, associations and descriptions are not only used naturally but are important in entry-level aural skills courses because they bring a sense of familiarity to music that is often lacking for students. "Synesthetic analysis not only fixes the link to reality, but also exposes the emptiness of extremely formal and narrow-minded positions in the study of

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[16] Galeyev, "The Nature and Functions," 285.

[17] Ibid., 287.

[18] Ibid.

art."[19] Can the enhancement of aural skills via synesthetic associations be improved by actually learning "color hearing?"

Many composers throughout history have either claimed to have or have been thought to have had synesthesia, most notably the "color hearing" type mentioned previously. Some of the significant names include Berlioz, Debussy, Gershwin, Ives, Liszt, Mahler, Messiaen, Rimsky-Korsakov, Schoenberg, Scriabin, and Wagner.[20] It must be pointed out that each composer mentioned above associated color with musical phenomena in different ways. For instance, Jonathan Bernard states that Messiaen used "color labels," of which there are three, to describe chords or groups of sonorities. His first label was monochromatic, the second was similar but was the result of mixing two colors, much like the edges of a rainbow, and the third was a combination of two or more colors.[21] Kenneth Peacock describes Rimsky-Korsakov's perceptions of color in that he perceived relationships between color and tonal keys as early as 1867, describing Rachmaninov's cellar scene of *The Miserly Knight* to be gold, the color of D major.[22] Despite the fact that these composers used different colors and processes to describe the same elements, the idea of music and color being linked in some way remains consistent.

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19 Galeyev, "The Nature and Functions," 288.

20 Brougher et al., *Visual Music*, 211.

21 Jonathan Bernard, "Messiaen's Synesthesia: The Correspondence between Color and Sound Structure in His Music." *Music Perception: An Interdisciplinary Journal,* 4, no. 1 (1986): 41-68, accessed March 22, 2015, http://www.jstor.org/stable/40285351?seq=4#page_scan_tab_contents.

22 Kenneth Peacock, "Synesthetic Perception: Alexander Scriabin's Color Hearing." *Music Perception: An Interdisciplinary Journal,* 2, no. 4 (1985): 483-505, accessed March 23, 2015, http://www.jstor.org/stable/40285315?seq=1#page_scan_tab_contents.

The connection between color and music is also often seen in the notation of pieces. Scriabin, Schoenberg, and Stravinsky are known to have used color in their scores for various reasons. Scriabin used color not only in score organization like Schoenberg but also used certain colors with certain notes or passages in which he saw them and wished for them to be displayed, as in his Prometheus. Charles Riley states that Stravinsky often used colors in his manuscripts to help him follow particular voices more easily and to show a true visual connection to the aural portion of his work.[23] Even Mozart used color in the autograph for his Horn Concerto No. 1, most likely as an organizational aid but possibly for other reasons. On the original manuscript of the second movement, Mozart notated the first horn line in the color red, and the second line in green.[24] Though complete speculation, it is possible that Mozart was trying to highlight the complementary relationship between the two musical lines by representing the first by the color red and its musical complement in green—visual relationships such as complementary colors are quickly and naturally noticed.

History of Music and Color

The intertwined histories of music and color are complex and ultimately beyond the scope of this paper, but they must be considered to highlight the important people, their ideas, and the connections that have been made between these two elements that have sparked such interest and enthrallment since their discoveries. Philosophers such as

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[23] Charles Riley, *Color Codes: Modern Theories of Color in Philosophy, Painting, Architecture, Literature, Music and Psychology* (Hanover, N.H.: University Press of New England, 1995) 277.

[24] Michael Poast, "Color Music: Visual Color Notation for Musical Expression," *Leonardo: Journal Of The International Society For The Arts, Sciences And Te*chnology*,* 33, No. 3 (2000): 217.

Pythagorus, Plato, and Aristotle all helped create and push the connections between music and color. Pythagorus is reputed to have discovered the mathematical divisions of the musical scale and Plato helped introduce the known planetary bodies at the time to those mathematical equations. As early as Aristotle's lifetime (384-322 BC), theories between the pairing of color and music existed. Aristotle presented his theories on the topic of color pairing in his *De Sensu.* He stated, "We may regard all colors as analogous to the sounds that enter into music."[25] The importance of color is also seen in Aristotle's work in which he represented the four elements (earth, air, fire, water) with color sent from the heavens. These early philosophers set the stage for countless different pairings of color to pitches, modes, and other musical elements.

As developments in the sciences unfolded, the basic way of representing color began to develop as well. Not only did the diagrams represent the colors and planets as it once did, but also their corresponding musical notes. The color wheel, or the cyclic view of color (red and purple at opposite ends that naturally bled into one another) was first introduced by Newton, as seen in perhaps the most famous rendition on the following page in figure 2.1.

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[25] Poast, "Color Music," 217.

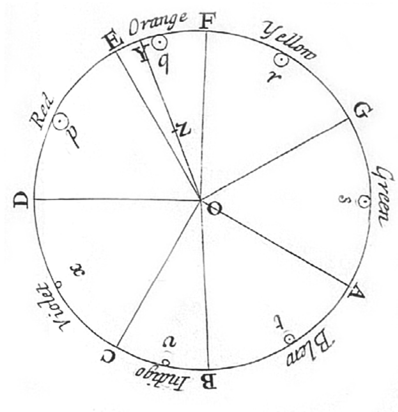

Figure 2.1: Isaac Newton's color wheel published in *Opticks,* 1704.[26]

This early mindset was also reflected in the birth of the music notational system, and from its inception, color was used to represent music.[27] This early music notational system and the descriptions of modes, as far back as the ninth and tenth centuries were represented with colors, as seen in elements of Gregorian Chant notation. Over time these colors did change and began to represent different aspects of notation before finally falling out of use in favor of the black and white notation used today. Jörg Jewanski traces the history of synesthesia and color pairing, showing that Athanasius Kircher developed a system around 1646 that paired colors with intervals as well as colors with different voice types.[28] Later, Newton's prism experiment—in which he discovered that white light was made up of the individual colors—not only turned the world against the Aristotelian tradition that color was an actual surface property, it also led to his color wheel because color was no longer viewed as a surface property and was instead made up

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26 Will South, *Color, Myth, and Music: Stanton Macdonald-Wright and Synchronism* (North Carolina Museum of Art, 2001), 30.

27 Brougher et al., *Visual Music,* 217.

28 Jörg, Jewanski, "What Is the Color of the Tone?" *Leonardo: Journal Of The International Society For The Arts, Sciences And Technology* 32, no. 3 (January 1, 1999): 227-228.

of white light, which itself consisted of the seven colors shown in figure 2.1.[29] One major opponent of Newton's findings that white light harnessed color was Jesuit priest Louis-Bertrand Castel, who argued that color and music came from the same mysterious physical source. While Newton paired color and the notes of the major scale together, Castel viewed them as being one and the same. Castel's views on color and music helped develop one of the first creations in which it would become possible to have actual representations of color accompanying music. The color organ would not only represent a pairing of color and music, it would usher in future art movements and allow synesthetic experiences of music and color to anyone.

The development of color organs, devices that were usually built from harpsichords, clavichords, or organs in which the performer pressed the keys to activate displays of color, usually by a color filter or glass that would be unveiled with the key press, allowed composers, artists and performers to have a visual representation of color to their music. Castel developed what he called an "ocular clavichord" in 1734 and it is regarded as the first color organ, or representation of such a device that displayed color and music in parallel.[30] Johann Gottlob Krüger developed his own ocular clavichord around 1743, and it became the last well-known such device until 1877, over a hundred years later. In 1877, Bainbridge Bishop, an American artist, patented a color organ that attracted the attention of P.T. Barnum and helped revitalize the ideas behind such devices.[31] The technological developments seen around the same time—the harnessing of

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29 South, *Color, Myth,* 30.

30 Brougher et al., *Visual Music*, 70.

31 Ibid.

electricity, inventions like the light bulb—provided a jolt to the designs and functionality of color organs.

Alexander Wallace Rimington, a British artist, successfully played a color organ to a large audience inside St. James Hall in London in 1895, pushing the device into the public view.[32] Although it was unable to produce sound, Rimington's color organ used a five-octave keyboard in which the color spectrum was mapped onto the musical chromatic scale, as seen in figure 2.2.

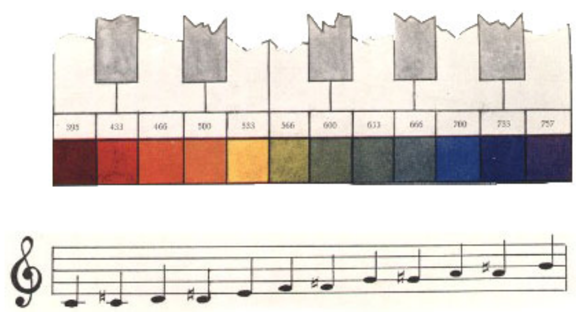

Figure 2.2: Rimington's color mapping on his color organ.[33]

Due to technological shortcomings and the lack of sound, it was his wish that his device either interpret music, that is to display the colors with the absence of music, or be accompanied by performing musicians during the display of color.[34] Other notable inventors, artists, and musicians such as Baranoff-Rossiné, Mary Hallock Grennewalt, Adrian Bernard Klein, Alexander László, and Zdeněk Pešánek all produced and used color-projection instruments. Rimington viewed his device not solely as a performing

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32 Brougher et al., *Visual Music*, 70.

33 Ibid., 71.

34 Ibid.

tool, but as an educational tool to study both color and sound. His contributions to the developments of color organs led to kinetic art performances and movements, but also helped to usher in the "color music" movement.[35]

Another important contributor to both "color music" and color organs was Alexander Hector, who was developing his own color organ and system in the late 1890s, around the same time as Rimington. According to James Wierzbicki, Hector believed that the Western culture's musical chromatic scale corresponded with the color scale, both of which used mathematical divisions between the distances of notes or colors.[36] He created several color organ-like instruments and influenced the growth of "color music," especially seen in 1910 with Scriabin's work *Prometheus: The Poem of Fire* and in 1913 with Schoenberg's opera *Die glückliche Hand.*

Scriabin's *Prometheus* is a pinnacle of the fusion of color with music. Although the colors used were personal choices of Scriabin, it was the first major piece by a well-known composer to display visualizations of colored light that were supposed representations of the music being played. It also garnished support from outside sources, with Edison Testing Laboratories creating a light machine called the Chromola specifically for the showing at Carnegie Hall in New York on March 20th, 1915.[37] While the piece received generally negative responses, it no doubt shaped the future of combining color and music as well as bringing the phenomena of synesthesia to a general audience. Color organs also became more widespread during this period, which is not

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[35] Brougher et al., *Visual Music*, 71.

[36] James Wierzbicki, "Shedding Light on the 'Colour Music' of Sydney's Alexander B. Hector," *Musicology Australia* 34, no. 1 (2012): 90.

[37] South, *Color, Myth*, 82.

surprising given that the impressionistic movements in both art and music were well underway, and it was a time rife with new discoveries, inventions, and ideas.

With color music, also known as visual music, becoming more popular, the term "colorist" was often used to describe composers and artists who participated in these movements. Although this term was yet to be coined during some of these composer's/artist's time periods, famous "colorists" include Berlioz, Wagner, Debussy, Messiaen, Čiurlionis, Kandinsky, Scriabin and Schoenberg. While the term color is usually used here to describe timbre in music, all of these composers and artists used it in different ways, sometimes within the definition of timbre but also literally, using actual color in compositions. Color had indeed awakened new possibilities in art and music. The contributions that helped lead color/visual music to mainstream audiences is full of both artists and musicians pushing the boundaries of art. Schoenberg, to some musicologists, is considered the composer who first made use of color as a true compositional element.[38] It is important to note that for Schoenberg, the term *color* in music meant something much different than actual color representations. But it is possible that his experience as a gifted painter influenced his use of color in an auditory manner in his music. Schoenberg viewed tone color, or *Klangfarbe,* as the element of pitch that was "much less cultivated, much less organized" than the other elements of pitch.[39] Schoenberg's third movement of his 1909 Chamber Symphony Op. 9, "*Akkordfarbungen"* ("Chord Colorings") is viewed by many as the closest realization of true color music.[40] The analogies and associations

[38] Riley, *Color Codes,* 279.

[39] Ibid., 280.

[40] Ibid., 281.

that exist between color and music mentioned previously have helped link the descriptions of timbre in an overwhelmingly visual and colorful manner. In Schoenberg's words, "In reality colors serve to make the train of thought more apparent, to make the main points stand out better, the secondary ones recede better."[41] Many of these composers, inventors, and artists contributed in some fashion to the birth and growth of visual/color music.

Wassily Kandinsky, a Russian artist and colorist who also is believed to have had a color based synesthesia, was not only in contact with Schoenberg, but was a firm believer in the marriage of color and music. "Finally, our hearing of colors is so precise that it would perhaps be impossible to find anyone who would try to represent his impression of bright yellow by means of the bottom register of the piano."[42] Kandinsky also saw the possibilities color had with the musical subject of counterpoint and created paintings based on the interactions of color. Swiss painter Paul Klee also used musical elements such as counterpoint, harmony and the idea of polyphony in his paintings and creative process. Klee's work *Ad* Parnassum, completed in 1932, featured a stippled "pointillist" technique with overlapping color planes that displayed the notion of "higher polyphony," and was a tribute to Johann Josef Fux's *Gradus ad Parnassum.* [43] Georgia O'Keefe and her teacher Arthur Wesley Dow viewed the use of listening to music and

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[41] Riley, *Color Codes,* 282.

[42] Brougher et al., *Visual Music,* 32.

[43] Ibid., 55.

musical analogies "as an essential ingredient of modern art," as seen in O'Keefe's series *Specials.*[44]

The worlds of art, music, and color began to mix more and more concepts, analogies and theories as the twentieth century wore on. After World War II the Whitney brothers used technologies that were developed for the war effort in their pursuit of creating fluid color music. John Whitney was a composer and abstract film maker who studied in Paris while his brother James helped create lighting systems that would be used in their compositions.[45] By combining Eastern metaphysics, scientific curiosity of atomic energy, and new technologies, the Whitney brothers revitalized visual music by developing systems that produced synthetic-sound, often by the motion of objects and pairing them with visuals.[46] By using items like anti-aircraft control devices, computer programs, and stencil systems that focused beams of light shot through them to produce the visuals, the brothers were able to create color music "movies" which allowed the viewing audience to become synesthetic.[47] The images and sounds in Whitney's visual music "movies" seem "inextricably linked," not one resulting from the other but rather sound is image and image is sound.[48] Brougher et al., states that "If Schoenberg's 1908 Second String Quartet in F♯m advanced modern music in one major step in Vienna, the Whitney's *Five Film Exercises* advanced visual music in one sudden shocking step during

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44 Brougher et al., *Visual Music*, 59.

45 Ibid., 125.

46 Ibid.

47 Ibid., 133.

48 Ibid. 125.

World War II."[49] These advancements in visual music and the psychedelic light shows of the Joshua Light Show in the 1960's and modern composers such as Daniel Nelson, all show a fascination with the possible links and similarities between music and color.

> In effect, the idea of synesthesia served to mediate between music and visual art in the early twentieth century and proved essential to the development of abstraction. Emphasizing the perceiving subject, the theory of synesthesia tended to break down sense perception into discrete units, whereby one sensation found its equivalent in another; music, with its notes and phrases, harmony and dissonance, compositional structures and abstract notational system, lent itself most readily to such analogy. For art that aspired to the condition of music, that sought synesthetically to call forth musical associations, the key pairing was with color.[50]

Although the scientific evidence points to a purely aesthetic, emotional, and analogy-based relationship between color and music, it seems logical to explore the benefits of this coupling in the classroom.

Synchromism, or color abstraction, paralleled the color/visual music movement, exploring the similarities between color and music and how color can be used in the same ways by an artist as notes are used by the composer. Morgan Russell, Stanton Macdonald-Wright, and Percyval Tudor-Hart were of great importance to synchromism. Russell and Macdonald-Wright were artists who viewed music as being able to "achieve expression directly yet abstractly" and Percyval Tudor-Hart was involved in the study of color-sound equivalents.[51] Tudor-Hart believed that color and sound were perceptually linked which is essential both to synchromism and to my question regarding the use of color to enhance and aid in the learning of aural skills. Tudor-Hart believed that color and sound are perceived in psychologically equivalent terms.[52] This is important in the

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[49] Brougher et al., *Visual Music*, 125.

[50] Ibid., 16.

[51] South, *Color, Myth,* 21.

[52] Brougher et al., *Visual Music*, 31.

classroom because if we perceive both color and music in a similar manner, then it seems that color should be the visual stimuli added to aid in aural skills courses. Tudor-Hart wrote that "luminosity octaves appear to the sense as equal intervals" and therefore developed his twelve-color wheel that corresponded to the twelve-tone Western musical scale.[53] His "luminosity octaves" represent the idea that the intervals between the colors in the visual color spectrum are perceived as being equal, much like the musical chromatic scale. This created his idea of a painter's color scale, a series of color intervals specifically aligned with the intervals of a major scale to be utilized when painting. His color scales worked as follows, seen on the following page in figure 2.3. Any color could serve as a tonic as long as the intervals between the colors stayed exactly constant with the intervals of the major scale.[54] Figure 2.3 shows Macdonald-Wright, Russell, and Tudor-Hart's twelve-color color wheel next to a color scale that dictates the color red as tonic. As the figure shows, the whole-step and half-step pattern of the major scale is overlaid onto the color wheel to select what colors will be used. This allows for any color to act as tonic so long as the pattern stays constant between both the order of color and order of the musical scale.

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[53] Brougher et al., *Visual Music*, 32.

[54] South, *Color, Myth,* 33.

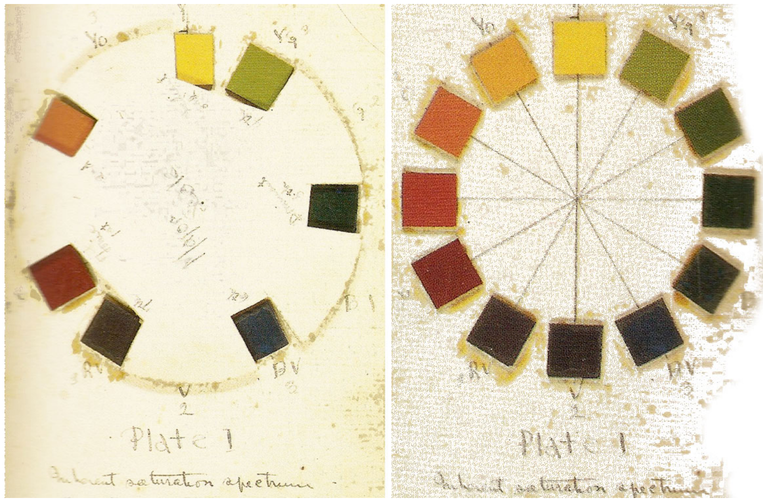

Figure 2.3: Macdonald-Wright's twelve-color color wheel and color scale.[55]

A painter, or musician, can adopt the same method to build musical chords to create color chords with which either to paint with or compose. This meant that all the colors, like the individual notes of a chord, had to be represented in order to hear or see the particular chord the colors were referencing within that scale. In figure 2.4, the same scale is used as in figure 2.3 but instead of showing the colors of the entire scale, the figure shows how triads are selected; in this case, the harmony shown would be tonic, or the I chord (C-E-G) because the colors of the triad represent the notes C-E-G in the color scale seen in figure 2.3. This process could then be used for any harmony within the scale. Although nothing was mentioned beyond the diatonic harmonies, a painter or musician could use this method for harmonies beyond the triad like seventh chords and extended/altered chords.

55 South, *Color, Myth*, 32.

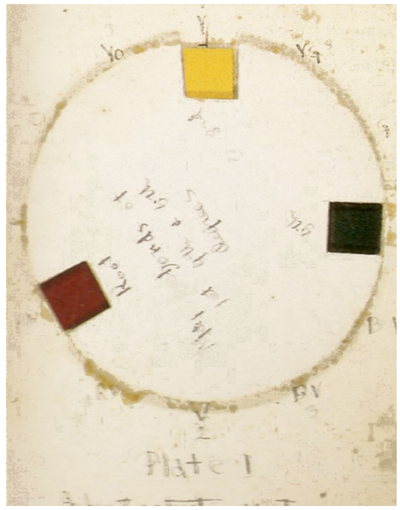

Figure 2.4: Triads/Chords used in color scale painting.[56]

This theory could also be used in all different styles of music a painter wishes to represent, from species counterpoint and modality to minimalism and serialism. Multiple color scales can even be juxtaposed much like combinatoriality in twelve-tone rows. Synchromism, along with the color/visual music movement, also gave an enormous push for developments in kinetic art which had an emphasis in the idea of light painting.

Alexander Hector's predictions about color music and color being paired to music came true not only with his own works and those of Scriabin's, but throughout the twentieth and twenty-first centuries.

> There is a definite co-relation between sound and color, and the discovery will so revolutionize music that in the concert of the future people will ask for color simultaneously with sound just as readily as they now ask for jelly on top of a piece of cake. It will be of great benefit, as it will give a new interest to music, a new beauty to it, and it will give a means to certain persons to enjoy music who have hitherto not enjoyed it. They will be able more or less to visualize it, and will see the rhythmic "movement" of it.[57]

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[56] South, *Color, Myth,* 32.

[57] Wierzbicki, "Shedding Light," 87.

The relationships between color and music forged throughout history are undeniable yet are lacking in the attempts to use this relationship in an educational way. If we perceive color and sound in a similar fashion and use shared analogies to describe and learn them both, could we create a new association by contiguity between them, much like that of our natural synesthetic process of describing pitch and size? The basics of color and color theory need to be discussed before applying it to music in an educational setting.

Color

Basics and Theories

Color, much like sound, are products of perception and electrical stimulation of certain nerves in our ears, eyes and brains. Adams Morioka and Terry Stone's *Color Design Workbook: A Real-World Guide to Using Color in Graphic Design* makes the provocative claim that "in a physical sense, there really is no such thing as color, just light waves of different wavelengths."[58] We perceive color through our eyes with three color receptors, one for red, one for green and one for blue (RGB). A small portion of the human population however, known as tetrachromats, carry a fourth receptor that perceives yellow wavelengths—theoretically allowing them to see millions more colors than the rest of the population. From these receptors we perceive our two types of primary colors, one being additive and the other subtractive. For additive, the primary colors are red, green and blue (RGB) and represent color in the form of actual light,

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58 Adams Morioka and Terry Stone, *Color Design Workbook: A Real-World Guide to Using Color in Graphic Design* (Beverly, Mass.: Rockport Publishers, Inc., 2006), 8.

coinciding with our eye receptors.[59] Subtractive color is further separated into two categories but both represent reflected light. The first is called the printer's primaries made up of cyan, magenta, and yellow (CMY) and the second, called the artist primaries, are the most familiar, having the primaries of red, yellow, and blue (RYB).[60] Figure 2.5 shows the visible color spectrum and figure 2.6 shows the additive and subtractive primaries and how the colors mix to create the colors within the visible spectrum.

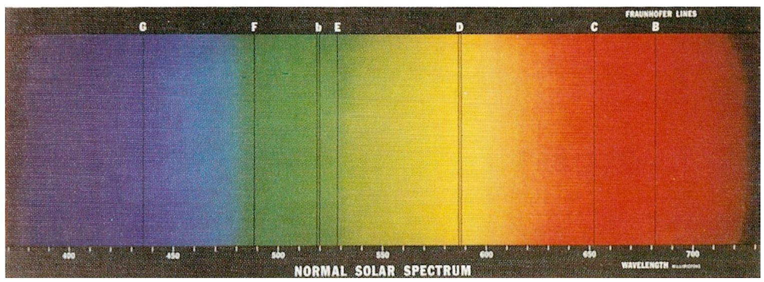

Figure 2.5: Visible color spectrum.[61]

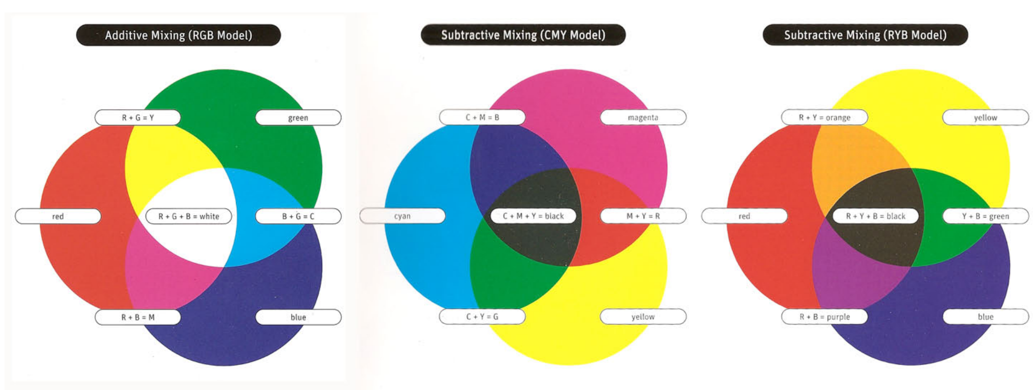

Figure 2.6: Additive and subtractive color primaries.[62]

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59 Morioka and Stone, *Color Design Workbook,* 10.

60 Ibid.

61 Paul Zelanski and Mary Pat Fisher, *Color* (Englewood Cliffs, New Jersey: Prentice Hall, 1989), 12.

62 Morioka and Stone, *Color Design Workbook,* 11.

Figure 2.1 displayed Newton's color wheel, which represented an important step in the color/music connection. By bending the straight visual spectrum he noted coming from the prism into a circle, he was able to represent color much like the circle of fifths or a musical scale, both of which eventually go back to their starting points. Purple circles back into red much like "ti" goes to "do" or the cyclic nature of the circle of fifths.[63] By starting on the note C and working around the circle of fifths, C will be reached again after 12 movements (C-G-D-A-E-B-F♯-D♭-A♭-E♭-B♭-F-C), much like what would happen on the modern color wheel (red-red/orange-orange-orange/yellow-yellow-yellow/green-green-green/blue-blue-blue/purple-purple-purple/red-red). In figure 2.6, you can visually see Newton's experiment in reverse in the additive colors diagram, with the white light in the middle occurring when all colors mix together. Hue, saturation, and brightness can all be changed in these colors to create an almost endless amount of colors, all from the primary and secondary colors.

The "trichromatic theory," which is based on the eye having three basic receptors, was advanced in 1801 by Thomas Young and further developed by Hermann von Helmholtz.[64] Advances in science and technology began to shed light on the complexities of color and the perception of it, much like those being made in sound perception. The "opponent theory" states that our perception occurs in either cells in our eyes or brain that register a color and its complement but will not carry both signals at once. This helps explain why we do not see reddish-green or bluish-yellow, and also sheds some light on

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[63] Zelanski and Fisher, *Color*, 12.

[64] Ibid., 20.

the phenomena of an "after-image."[65] The phenomena of an "after-image" cannot be explained simplistically, but after viewing a color for an extended amount of time, we perceive "after-images" of what we were viewing but often in the complementary color of the original image.

The theories of color perception are further complicated with E.H. Land's "retinex theory." Land proposed that color perception is based on a response between the long, medium and short wavelengths and his work showed that viewers correctly identified the colors of a landscape when showed a black and white photograph of that landscape through certain colored filters.[66] Neither the traditional wavelength theory nor the trichromatic theory can explain this phenomena seen in Land's experiments. Much like our perception of tonality, color perception is similarly complicated and rife with theories that both help explain yet seem to contradict one another. As seen in the study of music, the context, or what surrounds colors has an effect on our perceptions of them. An isolated G major chord is just a G major chord and only gets the dominant function when placed in the context of C major or C minor. Colors act in a similar manner and there are many variables shaping our perception of them. Our perception of the color of a shape may differ if that shape appears either as small or large. Different colors placed over a solid color will make the solid color appear to be made up of multiple colors—this phenomenon is often exploited in clothing and design. Figure 2.7 shows this perceptional anomaly in action: the background appears different, even though it is all the same color.

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[65] Zelanski and Fisher, *Color*, 20.

[66] Ibid., 21.

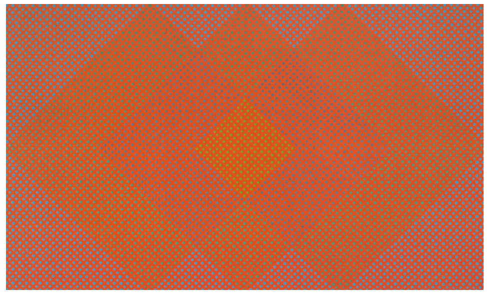

Figure 2.7: Richard Anuszkiewicz's *All Things Do Live in Three.*[67]

Color constancy is a product of visual memory. Our visual memory may override our actual perception of colors, meaning that we perceive colors as unchanging and this allows us to perceive a white piece of paper as white under any lighting scenario, or our house as the same color regardless of time of day or weather conditions.[68] Claude Monet is one of the more famous painters to apply the actual shifts in color due to a changing environment and lighting conditions. The similarities between sound and light outlined here help shape why this relationship should be studied further. With both being cyclic, meaning the starting point of each is repeated after a finite amount of movements, and the power of context and surroundings for both color and music having the power to change our perceptions allow for pairings that exploit these similarities. The complexity and competing theories about our perception of color and music also allow for more freedom when approaching different ways to pair color with music. The ability of our memory to override our perceptions may also prove useful if we are to attempt to harness the power of color for educational benefits in aural skills courses.

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67 Zelanski and Fisher, *Color*, 23.

68 Ibid., 21.

In Design and Culture

The use of color in design and culture is an area of color studies that must be explored because of the many parallels between music and color in analogies, metaphors, and physiological responses, all of which could be used in aural skills. The power of color has been utilized in many ways in varied domains; interior design, advertising, and even war propaganda. The power of color lies in its ability to convey messages, persuade opinion, provoke reaction, and evoke planned responses. Color clearly has power over the human brain. Morioka and Stone state that "Psychologists have suggested that color impression can account for as much as 60 percent of the acceptance or rejection of a product or service."[69] The Institute for Color Research found that "...all human beings make an unconscious judgment about a person, environment, or item within ninety seconds of initial viewing and that between 62 and 90 percent of that assessment is based on color alone."[70] By using color, a designer can influence a viewer's perception of a room and time. By association, specific colors can bring viewers back to simpler times or even transport them to a different location they once experienced. Strategic use of color is a highly powerful memory tool that can be both generalized or highly personal at the same time. With color being a familiar, constantly perceived stimulus that can instruct, evoke, effect, and provoke us, it may prove useful to exploit this by creating an association between sound and color, with color being the familiar, powerful memory tool to aid in the identification, and then memorization of the less familiar aural skills drills.

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69 Morioka and Stone, *Color Design Workbook,* 35.

70 Ibid., 36.

Color must also be carefully used when targeting either of the sexes. The use of blue for male and pink for female has become a tradition in Western culture, although research has yet to determine if this is due to physiology or socialization.[71] Regardless of the reason, this simple color association has become an almost uncontrolled, automatic response to the different sexes. Research has also found that more women have a favorite color and prefer soft colors while men prefer bright.[72]

The color of the environments in which we work, sleep, and learn, can unconsciously yet profoundly affect our mood and bodies. A study in 1976 found that people put in rooms that were sterile and gray caused the subjects to become stressed and bored, confirming the notion that color can lead to physical and emotional responses.[73] Though at times individually subjective, color still has the ability to express emotion and ideas by itself, being able to "...irritate or relax, encourage participation or alienate."[74] Harry Wohlfarth's study in 1983 showed that between four elementary schools, the schools that used improved lighting and color saw the largest improvements in both academics and IQ scores.[75] Another study, conducted by the U.S. Navy showed a 28% drop in accidents over three years after color was introduced into the work environment.[76] The power of color has also been used for thousands of years in medicine and healing, dating back to ancient Egypt and the Chinese dynasties.

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71 Morioka and Stone, *Color Design Workbook,* 34.

72 Ibid., 35.

73 Ibid.

74 Ibid., 46.

75 Faber, Birren, *The Power of Color* (Carol Publishing Group New Jersey, 1997).

76 Ibid.

As subjective as color is to the individual, a generalization can be made with regard to a cultural response to color, and that is that color symbolism seems to be a shared idea. Western culture's use of color is often tied with traditions, but more fundamentally with our associations and responses, whether they are conditioned or natural to those colors. The subtractive, "artist three" primary colors and resulting three secondary colors will be covered here (RYB-GPO) due to their use in my study, (outlined in chapter III).

The color red is associated with fire, blood, and sex but evokes emotional responses such as energy, excitement, power, aggression, and anger.[77] It is often used as an alert color to grab or direct a viewer's attention. This is why it is used on stop signs and stoplights, and emphasized in advertisements and marketing. It is also the most visually dominant color, suggesting action and producing bodily responses such as increased heart rate, breathing and appetite.[78] Yellow is usually associated with the sun and evokes optimism, radiance, joy, caution, and deceit.[79] Yellow is also used in construction and as a caution to direct attention to obstructions or workers. It is the first color the human eye notices but is also the most fatiguing, can speed metabolism, and is used on legal pads to enhance concentration.[80] The last primary, blue, is often associated with the sea or sky but evokes contemplation, coolness, coldness, depression, and

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77 Morioka and Stone, *Color Design Workbook,* 26.

78 Ibid., 27.

79 Ibid., 26.

80 Ibid., 27.

detachment.[81] Blue is heavily used in advertisements—the marketing of anti-depressants, for instance—but is also used in relaxing, subtle atmospheres where calmness is desired. The color blue suppresses hunger, causes the body to produce calming chemicals, and increases productivity in work settings.[82]

From the primary colors we get the secondary colors of green, purple and orange. Green is associated with the environment or natural products and evokes the emotional responses of harmony, nature, honesty, growth, poison, and inexperience.[83] Green is also used in stoplights and in advertisements as a "go" color or to create a moving along, no-stopping attitude. It is also the least fatiguing color on the eyes, has a calming and refreshing effect, and reportedly helps reduce stomachaches.[84] Purple is associated with spirituality and royalty and evokes imagination, mysticism, inspiration, exaggeration, and madness.[85] Purple is a color that is rare in nature so it seems artificial to humans, but is often used in children's bedrooms because it is thought to stir the imagination.[86] Lastly, the color orange is associated with autumn and citrus fruit, evoking creativity, energy, stimulation, crassness, and loudness.[87] Orange is also used as an alert color to draw attention or highlight obstructions or dangers. It is also an appetite stimulant and it has

[81] Morioka and Stone, *Color Design Workbook,* 26.

[82] Ibid., 27.

[83] Ibid., 26.

[84] Ibid., 27.

[85] Ibid., 26.

[86] Ibid., 27.

[87] Ibid., 26.

been found that when rooms are painted orange it promotes sociability and contemplation.[88]

With the three primary and three secondary colors discussed with regard to their usage culturally, socially, and the often noted emotional responses to them, we can begin to draw interesting and applicable links between color and music, ones that may benefit students in an educational setting. Our perceptions, emotional responses, uses, and analogies of color are similar to those of music and color seems to provide the most useful link between the visual and audible intelligences.

Audio/Visual Experiments

The effect that audio has on visual stimuli is a subject that has been well researched, but research working in the opposite direction is narrower and muddled. For this thesis, it is important to not only study the effects visual stimuli have on audio, but to remember that we often experience music in a visual domain, meaning that we are exposed to music when coupled with a visual stimulus, as in opera, live performances, movies and even video games. A recent study concluded, perhaps unsurprisingly, that "...musical soundtracks can influence the emotional impact, interpretation, and remembering of visual information."[89] This study showed a high degree of intersubjective agreement about which emotions were being triggered by a given musical selection.[90]

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[88] Morioka and Stone, *Color Design Workbook,* 27.

[89] Marilyn Boltz, Brittany Ebendorf, and Benjamin Field, "Audiovisual Interactions: The Impact of Visual Information on Music Perception and Memory," *Music Perception: An Interdisciplinary Journal* 27, no. 1 (September 2009): 43.

[90] Ibid.

The results in the experiments also showed that visual information is better remembered by the presence of music: films were better recalled by subjects when music was used in an intentional manner.[91] It was also found that music videos influenced viewers' perception of the music. One explanation for this was that the visual impact of body movements seemed to help convey musical intentions that were not apparent when only the music was used.[92] These findings all point to some type of connection between audio and visual stimuli. In fact, it "provides further evidence that musical appreciation appears to be enhanced by visual information.[93]

In another study, the same authors explored what influence visual displays have on "perceived acoustical parameters that typically convey emotions within music."[94] In short, they paired visual scenes that had been pre-rated as either positive or negative and displayed them with "ambiguous" music.[95] Their results showed that visual displays did indeed influence music perception in multiple ways. The presence of visual information "enhanced certain musical dimensions such that melodies were heard as faster, more rhythmic, louder and more active than the same melodies heard by themselves."[96] These positive results help make the case for attempting to integrate a visual stimulus into aural skills pedagogy—such a visual stimulus would seem to enhance the perceptual impact of

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91 Marilyn Boltz et al., "Audiovisual Interactions," 44.

92 Ibid.

93 Ibid., 45.

94 Ibid.

95 Ibid.

96 Ibid., 51.

the audible stimulus.[97]

This research also suggests that visual stimuli affects the mood of the listener, spotlighting the inherent emotional characteristics we give to both color and music. A second experiment conducted by Boltz, Ebendorf, and Field was used to confirm their first experiment results since the perceptual ratings used are subjective by nature. This second experiment studied the behaviors of the first study but in a different context, one of "recognition memory that not only serves as a converging operation, but also enables one to assess whether visual displays influence other types of cognitive behavior beyond perceptual experience."[98] The results, much like those seen in their first experiment, showed that music cognition was influenced by visual information. More research needs to be conducted in the audiovisual field, however, their results do show that "it is possible that visual format may influence the remembering of other acoustical qualities, such as rhythm."[99] This would seem to support the need for discussion about possible pedagogical consequences.

Lastly, the idea of perceptual unification, or when multi-sensory stimuli are perceived as being related to one another, is extremely important in the audiovisual field as well as for my proposal of using color as an educational aid in aural skills. Perceptual unification is also consistent with Annabel Cohen's Congruence Associationist Model discussed in her work, "Music as a Source of Emotion in Film." This model states that in cinematic contexts, the brain processes musical and filmic materials separately, and then

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97 Marilyn Boltz et al., "Audiovisual Interactions," 51.

98 Ibid., 52.

99 Ibid., 55.

compares them for any cross-modal congruencies before reconciling the stimuli using either the visual or auditory modality.[100] The information enters short-term memory and is then compared to pre-stored knowledge of different situations.[101] As seen in the Boltz et al. experiments, when one modality (audio or visual) was ambiguous but was accompanied by a clear statement of the other modality (visual or audio), "the features of the latter appear to distort the perception and remembering of features within the former to achieve structural congruence and unity."[102] This shows that the relationship of music and visual stimuli is a reciprocal one which supports the idea of perceptual unification.[103] According to Tanya Krof, the concept of "cognition overload," or the inability to complete tasks due to the working memory becoming overloaded is a major problem seen in aural skills programs.[104] Although the results of the Boltz et al. experiments also show that distortions may occur in memory and perception, they "also can enhance the emotional impact of stimuli and, as argued by Welch (1999), serve to reduce cognitive processing effort."[105]

Color seems to be the perfect visual stimulus to use when attempting a pairing with music with perceptual unification in mind. With the analogies and emotional responses that seem to run parallel with both stimuli, color is a good starting point in

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[100] Annabel Cohen, "Music as a Source of Emotion in Film," In *Music and Emotion: Theory and Research*, edited by Patrik Juslin and John Sloboda (New York: Oxford University Press, 2001), 259.

[101] Marilyn Boltz et al., "Audiovisual Interactions," 56.

[102] Ibid.

[103] Ibid.

[104] Tanya Krof, "The Process of Musicking: An Alternative to Melodic Dictation and Other Activities Involved in the Undergraduate Music Program," (M.M thesis, University of Nebraska, 2014), 3.

[105] Marilyn Boltz et al., "Audiovisual Interactions," 56.

exploring the benefits that a visual stimuli might have on musical drills in aural skills courses. Faith Brynie summarizes recent memory research: if one really wants to remember a picture or scene, one needs to see it in color.[106] The familiarity of color, the similar analogies and emotional responses, and the power of color all point to the possibility that color has the capacity to help struggling students in aural skills when properly paired to certain musical elements.

Another important experiment by Kostas Giannakis and Matt Smith looked for cognitive associations between the auditory and visual senses. Their experiment examined the associations between pitch and loudness to the color elements of hue, saturation and intensity.[107] Their design sought to answer three specific questions: to what extent could a color model of hue (actual color), saturation (colorfulness) and intensity (brightness) be useful metaphorically to describe pitch and loudness; which of the color elements are associated with pitch and loudness; and whether sound frequencies influence color selections.[108] The experiment used twenty-four subjects with a range of musical and computer music backgrounds who were randomly assigned into three groups and were tasked to complete the Ishihara test to check for color blindness.[109] The test utilized a color picker, much like the one that will be discussed in chapter III, presented

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[106] Faith Brynie, *Brain Sense: The Science of the Senses and How We Process the World around Us* (New York: American Management Association, 2009): 117.

[107] Kostas Giannakis and Matt Smith, "Imaging Soundscapes: Identifying Cognitive Associations Between Auditory and Visual Dimensions," In *Music Imagery*, edits by Rolf Inge Godøy and Harald Jørgensen (The Netherlands: Swets & Zeitlinger B.V., 2001), 162.

[108] Ibid., 165.

[109] Ibid., 167.

to the subjects on a computer display. The subjects listened to different sound sequences in which the elements of pitch and frequency were tested.[110]

The sound sequences were divided into four complexity levels. The first level of complexity was comprised of sequences where tones either increased or decreased linearly in one of the two auditory dimensions (pitch or loudness) while the other stayed constant.[111] Level two was an extension of level one in which the constant auditory dimension became dynamic and the previously dynamic one stayed constant, and level three consisted of both loudness and pitch varying simultaneously in similar or opposite directions.[112] The final complexity level, four, extended level three and consisted of sequences that varied non-linearly.[113] The results of this experiment show several interesting associations between the auditory dimensions (pitch and loudness) and the visual dimensions (hue, saturation and intensity). As represented in figure 2.8 on the following page, an association between both auditory dimensions and two of the three visual dimensions (saturation and intensity) can be seen. The graphed results indicate that as the pitch became higher and quieter, the saturation of color became weaker, and the intensity of color became lighter. Although absent on the graph, a correlation was also observed in which low-pitched tones evoked dark colors (intensity) and saturation levels

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[110] Kostas Giannakis and Matt Smith, "Imaging Soundscapes," 166. It is important to note that this study used pure tones with a single sinusoidal frequency to eliminate the effect of timbral richness on the subjects. Timbral richness is an important factor in keeping aural skills training "musical" and should be considered in future research.

[111] Ibid.

[112] Ibid.

[113] Ibid.

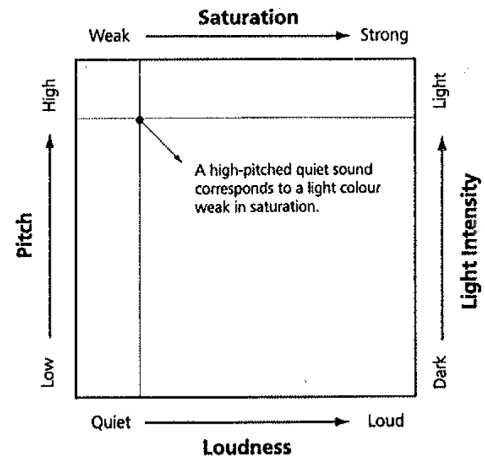

Figure 2.8: Giannakis and Smith's results showing visual/auditory associations.[114]

increased along with the loudness of the tone.[115] The third element of the visual dimension, hue, was affected in a different manner as seen in figure 2.9. Hue was found not to have any immediate connection with pitch or loudness, but did have a correlation with the general frequency ranges of low, mid, and high. Figure 2.9 shows that a higher number of subjects associated hue with the different frequency ranges in an ordered, cyclic color spectrum. Figure 2.10 on the following page represents this idea displayed onto the keys of the piano.

Hue Pairs	Low	Mid	High	Total
Red - Yellow	16	20	**28**	64
Green - Cyan	20	**28**	10	57
Blue - Magenta	**26**	19	8	51
Total	**62**	**67**	**46**	**175**

Figure 2.9: Giannakis and Smith's results of hue association.[116]

114 Kostas Giannakis and Matt Smith, "Imaging Soundscapes," 173.

115 Ibid., 172.

116 Ibid.

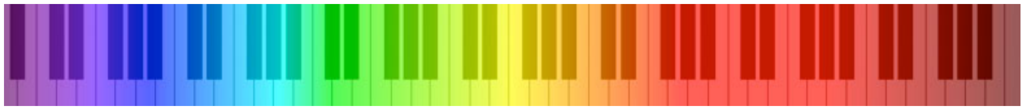

Figure 2.10: Representation of figure 2.9 on 88-key keyboard.

The findings of this experiment show that association is made naturally between color and music, which seems to correspond well with the analogies we use to explain certain musical elements. It also shows that people who are not synesthetic can and often do think about and relate to stimuli in a manner consistent to what is seen in synesthetic people.

The keyboard is the instrument of choice when explaining and learning written music theory and aural skills for several reasons. Perhaps one crucial reason is that it creates an easily understood visual representation of the material. James Baker calls the keyboard the perfect instrument for music theory because of the visual dimension it gives.[117] Many elements of the piano encompass the analogies or gestures we use to explain music. For instance, the movement of left to right and its correlations to the musical notation system of bottom to top all represent a visualization of our pitch registers of low to high.[118] Baker states that music learned at the keyboard not only maps auditory stimuli to the brain, it simultaneously maps the visual, tactile and motor stimuli associated to those sounds.[119] The visual representations of the sounds we hear help us understand music and the elements we hear in them—the visual can be as enlightening as

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[117] James Baker, "The Keyboard as Basis for Imagery of Pitch Relations," In *Music Imagery*, edits by Rolf Inge Godøy and Harald Jørgensen (The Netherlands: Swets & Zeitlinger B.V., 2001), 251.

[118] Ibid., 252.

[119] Ibid., 253.

the audible. Baker discusses Heinrich Schenker's idea of voice exchanges and how the pianist is at an advantage because this musical element is represented in multiple ways, evoking multiple senses. Not only do pianists *hear* the voice exchange, they also *see* and *feel* it, whereas a singer may be less aware of this musical feature.[120]

Could the illumination of aural elements using visual representations help beginning students who are struggling in aural skills? I argue that the power that visuals can have on any number of musical elements should be seen as a potential aid for aural skills fundamentals.

Color Experiments in Music Education

Data from actual experiments is minimal when discussing the effects that color may have in music education. However, one experiment shows promising results for learning music theory rudiments, aural skills, and keyboard skills with the help of color. In her dissertation, "The Effectiveness of Color-Coding for Learning Music Theory Rudiments, Aural Skills, and Keyboard Skills in Persons Aged 60 and Older," Vicki McVay explains the possible effectiveness of color pairing. By using the research and findings from kinesthetic intelligence, McVay argues that color-coding and the correlation between kinesthetic intelligence creates a basis for using color while teaching older adults and breaking the stereotypes linked to older adult music education.[121] McVay developed a curriculum with a focus on learning music theory rudiments in conjunction

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[120] Baker, "The Keyboard as Basis," 258.

[121] Vicki McVay, "The Effectiveness of Color-Coding for Learning Music Theory Rudiments, Aural Skills, and Keyboard Skills in Persons Aged 60 and Older" (PhD diss., University of Kentucky, 2004) 10.

with the color-coded music system of Rainbow Music, Inc.[122] In her study, three groups of subjects, all enrolled in the Donovan Scholars Program, received the same lessons and lesson content.[123] Group A was taught using traditional notation with a black and white keyboard, group B was taught with color-coded notation and a black and white keyboard, and group C was taught with color-coded notation and a keyboard with color-coded keys.[124]

The color pairing used in McVay's study was based upon Rainbow Music's pairing of seven colors to each note from C to B. Her study used the following colors: C=Red, D=Orange, E=Yellow, F=Green, G=Aqua, A=Purple, and B=Pink.[125] Groups B and C were not told that color was being used specifically as a teaching aid. At the end of their coursework, a post-assessment test was given to each subject and then compared to their pre-assessment test scores. Group B (used color-coded notation with a traditional black and white keyboard) scored significantly higher in the post-assessment and practiced the least amount of all the groups.[126] Not only did the findings show that color-coded notation helped in all the elements tested, but the students found it useful and enjoyed using it as well. Color-coded notation had a significant impact on learning music theory rudiments, keyboard skills and aural skills.[127] McVay therefore proposes that the

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[122] McVay. "The Effectiveness of Color-Coding," 114.

[123] Ibid., 91.

[124] Ibid., 114.

[125] Ibid., 115.

[126] Ibid., 149.

[127] Ibid., 154.

color-coding technique be elevated to "the foundation of a curriculum," at least for older adults who wish to begin learning the elements of music tested in this study.[128]

McVay's study shows that color can have an impact in the classroom when teaching aural skills. The visual impact of color is seen throughout our world and helps shape our experiences and memories, yet music education and aural skills classrooms function in isolation from color stimuli. Color is teeming with emotional meanings, analogies, knowledge, cultural significance, and organizational information that seem to run parallel to music. Introducing color into music classrooms could assist struggling students with their initial shortcomings in aural skills. In the next chapter I will explain how Jonathan Naylor and I developed a computer software program to create a modern day color organ to be used in my study that tested the possible benefits of using a visual stimuli in conjunction with aural skills drills.

[128] McVay. "The Effectiveness of Color-Coding," 162.

CHAPTER III: METHODOLOGY

In this chapter I will discuss my color pairings and the reasoning behind them as well as the testing software and the methodology of the testing. The purpose of this study was to investigate the effectiveness of using color to help in the memory retention of isolated solfège drills and the quality of chords. Color association, or a "learned synesthesia," is an area that should be examined in a future study that is structured in a way that the subjects are aware and exposed to the stimuli for longer periods of time.

Two groups of tests (A and B) were administered using three differing types of stimuli in an identical procedure for each test subject as seen in figure 3.1. Group A was administered first followed by group B.

TEST IA		TEST IIA		TEST IIIA
Color and solfège		Color only		Solfège only
TEST IB		**TEST IIB**		**TEST IIIB**
Color and chords		Color only		Chords only

Figure 3.1: Description of the stimuli for each test.

In group A, isolated solfège drills were used within the context of C major. Test IA paired seven colors to the seven diatonic notes of the C major scale and both the color and aural stimuli were presented simultaneously. Test IIA presented only the color stimuli, and test IIIA presented only the audible pitches of the C major scale. For the purposes of this study, scales were limited only to major and the key of C major was used exclusively in all tests for group A. Each test (See Appendices C and D) consisted of randomly generated patterns of notes to be used for the isolated solfège drills, with the first level presenting three pitches and/or colors and growing by an additional pitch and/or color for each subsequent level. Each stimulus was credited as an individual point to be awarded during testing, making the highest score of seventy-five possible. In group B, tests were presented in the same fashion but chord qualities were tested instead of isolated solfège (See Appendices C and E). Two of each of the four prominent types of harmonies used in tonal music were tested: major, minor, diminished and dominant seventh. In all tests, only the following chords were used, exclusively in root position and within the range of C3-C5: C and A major, G and D minor, E and C# diminished, and Bb and G dominant seventh. Test IB paired four colors with the prominent harmonies mentioned above, with the same type of harmonies using the same color. For example, both major chords used yellow, resulting in yellow being displayed whenever the C or A major chords were played. Identical to group A, test IIB presented the subjects with only color and test IIIB presented only the audible stimuli of the chords. As in group A, a total of seventy-five points were possible. Each stimulus within every level had to be correctly identified before moving on to the next level.

Prior to the testing, each subject read and signed the University of Nebraska's Institutional Review Board approved consent letter (See Appendix A). Each subject was asked their current level of study in music theory as well as what their main instrument was. The subjects then took their seat and read the instructions on their given test before a verbal explanation from the instructor was given. After asking if the subjects had any questions a copy of the consent letter was made available to them and the testing began.

Test Program, Equipment and Color Pairing

Test Program and Equipment

A customized computer software program was developed and implemented for these experiments. Software engineer Jonathan Naylor created an interface which is compatible with Mac operating systems. The interface (see Appendix B) lets the user assign any type of color to the individual keys of the computer displayed keyboard. As seen in appendix B, this was done in “manual mode.” A “spectrum mode,” which mathematically divides the visual color spectrum into equal parts along the eighty-eight notes of the piano keyboard, is also available. The software was installed on an Apple Macbook, which was then connected to both a Roland FP-80 stage piano/keyboard and a small portable projector. While a projector was used in these tests, displaying a single, omnidirectional image, hardware is being developed to replace it with RGB LED strips. These LEDs could be programed to display millions of different colors, shades, hues, and saturation levels, allowing for greater flexibility and complexity in associating the pitch and visual spectrum continuums.

To complete the design process for the interface, Mr. Naylor combined Node (used to create real-time, data-intensive communication between devices), web based application technologies, and third-party Javascript modules. From this, Mr. Naylor was able to create a responsive, realtime color mapping application called HummingBird. To communicate with the Roland keyboard, jQuery (a Javascript library used to simplify HTML scripting) and a node library called node-midi were used. These allowed for connection and communication between the software and Roland keyboard. Major changes in elements of color such as hue, saturation, value and tint/shade will be made adjustable within the HummingBird interface in a future release of the software. These main elements of color will also be able to be programmed to work in conjunction with the dynamics, key sensitivity, and decay of the sound signals from the keyboard, allowing for a completely customizable, user-friendly program that displays visual signals in conjunction with sound signals. Appendix B shows the various modes of the HummingBird interface. By pressing on each key displayed on the computer screen, a pre-determined color selector appears allowing the user to select what color should be assigned to that particular key. A color picker, much like the one available at colorizer.org and seen in figure 3.2, will be incorporated to replace the color selector in later versions of the software, allowing for countless possibilities.

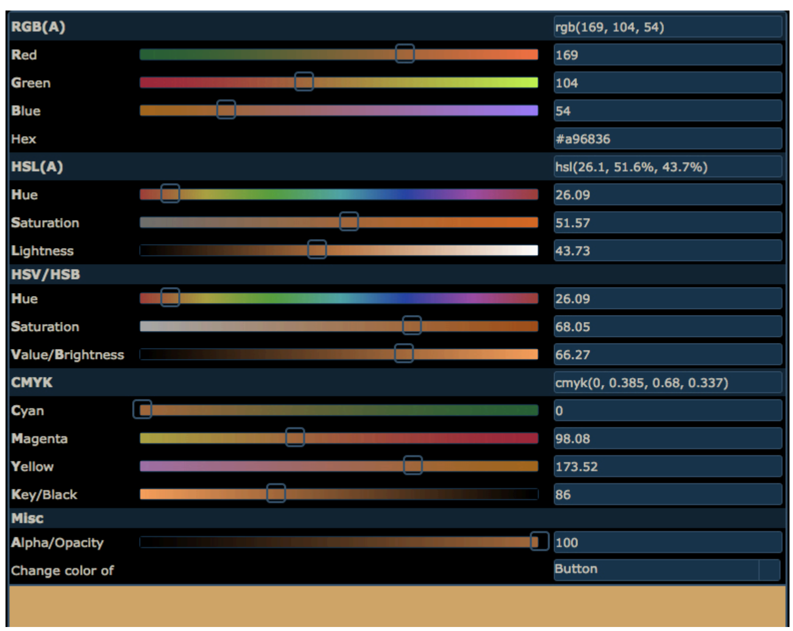

Figure 3.2: Color picker from colorizer.org.[129]

[129] Color Picker, accessed February 15, 2015, http://www.colorizer.org.

Once assigned a color, when that key is pressed on the Roland keyboard, the software senses the touch and then instantly translates it into a signal to show that specific color on both the HummingBird interface and through the projector or LED technology.

Color Pairing

The subjective manner of both musical emotion and color perception was covered in chapter II. Instead of using an existing pairing, I chose to create my own based on the emotional similarities seen in the Western culture's use of color and the analogies used in music. The human physiological responses noted in research on the effects of color was also used in helping pair color to sound. These bodily responses to color fit well with our responses to certain characteristics found in tonal music as well as the analogies we use to describe those characteristics. For instance, the color red has been seen to increase viewer's heart rates and has been used throughout the Western world as a color to provoke alertness, draw attention to advertisements, highlight possible dangers, and to pop, or extend towards a viewer.[130] Teachers often explain ways to identify the dominant (V7) chord in tonal harmony in a similar manner as to how we perceive the color red, as an attention provoking sound signaling our ears to be alert for something expected to happen. Inspired by these similarities, the color red was assigned to both dominant harmony as well as $\hat{5}$. The color blue, or any "cool" color, is said to recede from viewers and evoke a sad, or calm atmosphere. In *The Physics and Chemistry of Color: The Fifteen Causes of Color* by Kurt Nassau, a room painted blue has even been found to

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130 Zelanski and Fisher, *Color*, 30.

make people feel colder and cause them to adjust the thermostat settings of the room.[131] These responses align with our analogies that often have become our conditioned responses to minor harmonies in the tonal system, and therefore cool colors were assigned to them.

Though extremely subjective, color should be seen as a possible teaching aid rather than a perfectly aligned stimulus to another highly subjective topic, music. The following pairing uses reasons that may or may not be agreed with due to the subjective nature of both topics, but the idea of color being used individually as an educational tool is the ultimate goal of the study.

Group A needed a pairing that used different colors for each note of the C major scale. Figure 3.3 shows the colors assigned to each note of the scale.

Figure 3.3: Color mapping of the C major scale used in group A.

For group B, the four types of chords were paired with four colors, with major being yellow, minor blue, diminished orange, and dominant seventh red. The reasoning behind the tests using slightly different color schemes has to do with two different topics taught in aural skills, melodic and harmonic dictation. By using the two tests, the possible

131 Kurt Nassau, *The Physics and Chemistry of Color: The Fifteen causes of Color.* (New York: Wiley, 1983), 15.

memory retention benefits could be concatenated more simply to their equivalent area of study in aural skills courses, group A being used as justification for melodic dictation and group B towards harmonic dictation.

The color pairing for group A was nevertheless similar to group B because it was created with the resulting harmony from each scale degree. Tonic, or $\hat{1}$, was the exception and used the color white. Although the reasons for this are mostly metaphysical and extremely simplified, it also makes use of how light acts in nature and how it is explained in physics. White light is made up of all the colors of the spectrum (red, orange, yellow, green, blue and purple) interacting (simultaneously) with each other, much like the collection of notes D-E-F-G-A-B (not simultaneously) do to create the sense of C major. The perception of light in the human eye was briefly covered in chapter II and does highlight the simplicity of this idea. Cool colors were paired to $\hat{2}$, $\hat{3}$, and $\hat{6}$ (blue, green, and purple) because the resulting harmonies built from those scale degrees in the major scale are all minor. These cool colors can evoke calm and sad responses and align with our analogies of minor chords. Yellow was paired with $\hat{4}$ and is considered a warm, bright color, often implying the sun, nature or happiness.[132] This also aligns well with how major chords are often taught, to sound happy and bright, especially when compared to the sound of minor chords. Red was paired with $\hat{5}$ because of the dominant pull it has in tonality and the alert, warning response that the color red evokes. Though also major, $\hat{5}$ was given a different color than $\hat{4}$ because of the aforementioned function. The harmony built on $\hat{7}$ is used as a weaker dominant replacement in our tonal system, and orange is

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[132] Morioka and Stone. *Color Design Workbook,* 26.

seen as a weaker but similar color to red, both in wavelength, perception and response. Not only did this pairing help link the two different tests and their possible applications (melodic and harmonic dictation) in aural skills, it also highlights the rare interval theory (discussed in chapter V) by using aggressive, alert colors for “ti” and “fa” as well as highlighting the ascending fourth, descending fifth theory by using the boldest color red for “sol.” While we use elements from melodic dictation in harmonic dictation and vice versa, a single color scheme as seen here may not work because of the importance of tonal functions and scale degrees belonging to multiple harmonies.

Test Setting and Test Subjects

Test Setting

Every test was administered in the same setting and location to minimize possible variables affecting the test results. All testing took place at the University of Nebraska-Lincoln in a single classroom of Westbrook Music Building. The room was arranged the same way for each test, with the subjects sitting approximately three feet from the white board on which colors were projected. Behind the subject’s chair and slightly to the left was the projector, which was connected to an Apple Macbook running the HummingBird software synchronizing via MIDI to a Roland FP-80 stage piano. The lights were switched off for each test with enough illumination from both the projector and piano light for subjects to see, read and write without issue. The doors were closed to prevent outside light from creating difficulties in seeing the colors as well as to prevent any outside noise from becoming a distraction to the test subjects. Test subjects were asked if they could see and hear clearly before the testing began.

Test Subjects

The thirty-five test subjects were all volunteers and students of the Glenn Korff School of Music at the University of Nebraska-Lincoln. Test subjects were all undergraduates and ranged in their music theory levels from first-semester freshmen to seniors who had passed all their theory courses. Gender and age were not considered in the selection of subjects. The only criteria for dismissal from the test were colorblindness, perfect pitch, and epilepsy that could result in seizures. Starting with group A, the tests were given in order, with the first subject receiving IA, the second IIA, the third IIIA, the fourth IA, etc. until all the subjects who had signed up completed their given test. This same setup was used for group B. This ensured an evenly distributed number of each test and that the tests and subjects were paired randomly.

Procedure

The proper forms and training were completed to meet the requirements and obtain permission from the University of Nebraska's Institutional Review Board. Individual consent forms (see Appendix A) were given to each subject prior to the test which required them to read and sign before any testing began. The subjects then took their seat in front of the white board and were given one of the six tests and read the instructions (see Appendix C). A brief explanation was given to the subjects about what was expected of them as well as the structure of their particular test. It was explained to the subjects taking test IA that they would see a series of colors at the same time as hearing a series of notes. The same explanation was given for test IB except instead of a series of notes they would hear a series of chords. For test IIA and IIB, the subjects were told they would only see color. For test IIIA the subjects would hear isolated solfège and IIIB, chords. They were then told not to write anything down during the test, but once the last stimulus was given, they were given a set amount of time (See Appendix C) to write down the pattern they remembered. Subjects' responses used color, solfège/chord symbols, or a combination of both, depending upon which test they had when identifying the pattern they recalled. For test IA, before the test began, the subjects were played a harmonic progression in C major (I-IV-I-V7-I) and given the note C, or "do" before hearing the first note of the level. For example, if the first level consisted of the notes E-G-A, the subjects would hear the harmonic progression, followed by C, then E. This would center their ear around which solfège/scale degree was the starting note as long as they heard the interval properly. Then the possible colors were shown with a verbal representation identifying each color. This was done to avoid any confusion between orange and yellow and between blue and purple. Following this, the lights were turned off and the testing began. Each key press displayed the proper color and the keyboard supplied the audible pitch. All levels in every test were played at a tempo of 55 stimuli per minute. After the last stimulus was given the color faded to black along with the decay of the audible pitch before the time that was given to the subject for writing began. If the students properly identified each stimuli that was given (see Appendix D and E), they moved on to the next level. If they incorrectly identified any pitch or color, they received an alternative pattern of the same length before being able to move up to the next level. If this alternative pattern was also remembered incorrectly, the testing stopped and the subject finished at their current level. Each subject was given one alternative pattern for the entirety of the test and once the subjects misidentified that alternative pattern, the testing stopped.

Each test followed the same procedure with several exceptions not discussed above. In test IIA, the volume was turned off on the keyboard which resulted in the same color progressions as IA but without the audible pitch. The students were told they would only be seeing color and did not require being put into a key. In test IIIA, the projector was turned off and pitch was only tested. This test, however, did require being put into a key and given the first interval as described in test IA above and used the same progressions as IA and IIA.

The second group of tests (IB, IIB, IIIB) followed the same procedure of the first group except that group B was tested on chord quality rather than short melodic patterns (see Appendix E). The subjects in this group were not oriented to a key. They did, however, receive an audible representation of each of the four possible harmonies and/or four possible colors before testing began. The levels were the same length as group A as was the time that was allowed for the subjects to write down the pattern they remembered. Test IB tested color and chord quality in the same manner as test IA operated. Test IIB, like IIA used only color and test IIIB tested only audible chords. The chord qualities used were restricted to the four main types of harmonies heard in tonality and were randomly generated in the same process as the tests in group A. The tests in group B were also played at a metronomic speed of 55 stimuli per minute and when applicable the screen faded to black after the last stimuli of each level.

It is important to note that the test subjects were not told that the colors were always assigned to the same solfège or chord quality. This ensured that the test compared the possible memory retention benefits of a visual stimulant, rather than an association exercise. (Of course, a learned association between the color and corresponding pitch to help aid in the learning process is worthy of future study). Interestingly, only a small number of subjects reported, after completing several levels of test IA or IB, that they recognized the colors as being paired with certain scale degrees or chords and began to utilize that association between the color and sound to help remember the subsequent levels. While this has to be considered as a variable in the testing, it is promising that some subjects began using the visual stimulant in an associative manner. Student feedback will be examined as well as the data, treatment, and results from groups A and B in the following chapter.

CHAPTER IV: TEST RESULTS, DATA AND STUDENT FEEDBACK

This chapter discusses the instructional strategies (treatments) used for teaching, the analysis, the variables, the results from the statistical ANOVA analysis, and the student feedback given by the IA and IB testing subjects. Each main group (A and B) were analyzed separately using two different ANOVA treatments.

Data Treatment

Variables and Analysis

A total of thirty-five tests were conducted on volunteer test subjects in the Westbrook Music Building at the Glenn Korff School of Music at the University of Nebraska-Lincoln. The subjects were tested in a random fashion and the only criteria for participation was that they had to be undergraduate music students and not suffer from epilepsy, colorblindness, or have perfect pitch. The subjects signed up for a single available time slot and the test sheets used were organized by the main and sub-groups which kept the test results confidential and anonymous. After the conclusion of each evening's testing, the results were moved and kept in a secure location by the proctor. No pre-assessment was needed or given for this study.

Although no pre-assessment test was given, the possible pool of subjects to draw from for testing was delimited to only undergraduate students, ranging from freshmen to seniors. By chance, all but two test subjects in group IIA were enrolled in the same level of music theory aural skills (sophomore level). One of the two participants was enrolled in freshman aural skills, and the other had already completed the required aural skills courses. It is worth noting that group IIA was tested only on color, so the varying skill levels should not have impacted the results for that given test. The subject matter used for testing was below what a sophomore level aural skills course covers, so students should have been familiar with isolated solfège drills and the differences between major, minor, diminished, and dominant seventh chord qualities.

During testing, one incorrect response per testing subject was allowed. When an incorrect response was given, a new pattern of the same length was provided to the subjects and had to be correctly answered in order to move on. A scoring system was implemented in which each stimulus was scored as a single point. For all of the tests, level one consisted of three stimuli which would then be counted as three points. Level two consisted of four stimuli which counted as four points. The point system was cumulative, meaning level one success paired with level two success would total seven points. Each subsequent level grew by a factor of one stimulus. The highest level possible was level ten, which totaled a maximum of seventy-five points. Every test was given in the same manner, used the same materials and organization, and took place in the same classroom. Each test within their main group used the same stimulus patterns regardless of which test was being given (see Appendices D and E).

There were a few possible variables that, while minimal in impact, must be considered. One variable in testing was the difference in the amount of stimuli types between groups A and B. In group A, solfège was used within the C major scale resulting in a total of seven possible notes and seven possible colors. In group B, chord quality was used which resulted in only four types of harmonies and four types of colors. No student feedback was given in regard to this difference and although separate ANOVA treatments were run for both groups, it is worth mentioning as a possible variable within the study. Perhaps the greatest source of variance is seen in both groups A and B within tests IA and IB. Although the subjects were not told to favor one stimulus over the other, an assumption has to be made that it is impossible to conclusively say what, if any, benefit resulted since the subjects could have favored the use of visual stimuli over the auditory or vice-versa. Lastly, no two students can be considered equally knowledgable in aural skills even if both are in the same class or level of training. Student feedback, particularly in tests IA and IB, is both important and enlightening and will be covered later in this chapter.

After the students had completed their specific tests, the results were taken and with the exception of those who took test IA and IB, the students were free to leave. Subjects who took test IA or IB were asked several questions after their results were collected. The subjects were asked what their positive and negative thoughts about the study were and what their approach was to the specific test they took. The student feedback was informal and recorded by the proctor before the next test began. Many students who did not receive tests IA or IB still asked about the study and several provided feedback after a description of the study and its purpose was given to them.

Descriptive Statistics

The final scores from each test were recorded and can be seen in figure 4.1. The scores indicate the amount of correct pitches, chords, or colors each subject identified. The scores are compiled for all thirty-five subjects by their main groups (A and B) and by the tests of IA, IIA, IIIA, IB, IIB, or IIIB. Each participant's total score was used as the basis for the ANOVA analysis and those conclusions are presented next.

GROUP A		IA		IIA		IIIA
	SUBJECT	SCORE	SUBJECT	SCORE	SUBJECT	SCORE
	1	14	7	12	13	27
	2	16	8	15	14	24
	3	16	9	30	15	15
	4	23	10	22	16	21
	5	16	11	52	17	2
	6	15	12	42	18	5
GROUP B		IB		IIB		IIIB
	SUBJECT	SCORE	SUBJECT	SCORE	SUBJECT	SCORE
	19	28	25	46	31	17
	20	21	26	30	32	15
	21	36	27	21	33	3
	22	42	28	16	34	5
	23	19	29	13	35	14
	24	5	30	28		

Figure 4.1: Individual scores of each subject respective of grouping.

The highest score possible for all tests was seventy-five. The resulting means of groups A and B are as follows: IA = 16.6667, IIA = 28.8333, IIIA = 15.6667, IB = 25.1667, IIB = 25.6667, and IIIB = 10.8000.

These results were processed separately for groups A and B through an

ANOVA (analysis of variance) to compare the mean scores to show any possible significance within each individual group (A and B). The ANOVA computes this by analyzing variance and utilizing the following assumptions: 1) Data is distributed normally in each group; 2) The presence of homogeneity of variance between each group; and 3) Observations in each group are independent of one another.

An important flaw must be discussed before viewing the results. Assumption number three of the ANOVA was not met in this study because all three tests in group A and the three in group B did not operate independently from one another. Test IA utilized the same observations (color/sound) used in tests IIA and IIIA and test IB used the same observations as test IIB and IIIB. Although the failure to meet the third assumption and the overall number of participants was too small to be scientifically conclusive, the results of the ANOVA are still relevant and should be discussed. The results of the ANOVA are shown in figure 4.2 on the following page. A summary of figure 4.2's results as well as a brief outline of how the ANOVA operates is needed to further our understanding of the data shown in the ANOVA analysis graph.

Analysis of Variance (One-Way) - Group A						
Summary						
Groups	*Sample size*	*Sum*	*Mean*	*Variance*		
I	6	100.0000	16.6667	10.2667		
II	6	173.0000	28.8333	246.5667		
III	6	94.0000	15.6667	105.4667		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	644.7778	2	322.3889	2.6695	0.1019	3.6823
Within Groups	1,811.5000	15	120.7667			
Total	2,456.2778	17				

Analysis of Variance (One-Way) - Group B						
Summary						
Groups	*Sample size*	*Sum*	*Mean*	*Variance*		
I	6	151.0000	25.1667	174.1667		
II	6	154.0000	25.6667	142.6667		
III	5	54.0000	10.8000	40.2000		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*p-level*	*F crit*
Between Groups	754.7980	2	377.3990	3.0279	0.0808	3.7389
Within Groups	1,744.9667	14	124.6405			
Total	2,499.7647	16				

Figure 4.2: Analysis of variance for groups A and B.

Each main group (A and B) used a separate ANOVA as shown in figure 4.2. The DF (degrees of freedom) column is one less than the total number of sub-groups in each main grouping which results in two while the SS (sum of squares) is divided by the number in the DF column which gives the result seen in the MS (mean square) column.[133] The more the test subject's scores differ, the higher the SS score will be. The level of confidence, which controls chance, is represented by the p-level column and must be at or below .05 in this study in order to report any significant difference in the means. The level of confidence, or the p-level column,

133 DF represents the number of independent observations minus the parameters while SS measures any variation from the mean.

represents the most important data for this study.

In group A, no significant difference resulted which can be seen when viewing the p-level of .1019. With a p-level well above .05 along with the low number of participants and the variables previously discussed, the results of group A show no important change and further discussion is not warranted. Group B however does have an interesting result. As shown in figure 4.3, the p-level is .0808 which can be read as approaching significance. Although the assumption that was discussed earlier stating that in test IB there was no way to record which stimulus (auditory or visual) the students were using, test IIIB and its resulting mean score is significantly lower than IB and IIB. Several possibilities exist which may explain the results. The addition of color in test IB may have helped the subjects retain more of the progressions heard when compared to test IIIB which was considerably lower. This data can also be viewed to show the important role that function may play in our understanding of music and harmonic progressions. Test IB's stimulus is arguably one of the easier elements drilled in aural skills courses when the chords are played in isolation, however the results seen in figure 4.3 show that this was the most difficult (lowest mean score) of all the tests because the chords were played in succession like a harmonic progression but in a non-functioning, random order. A conclusion could be drawn that not only are the function of chords in harmonic progressions more musically significant, they are perhaps more important to our mapping and remembering of them, even subconsciously, than the mapping and remembering of the isolated qualities. Further discussion follows in the student feedback section and in the possible pedagogical applications discussed in the following chapter.

Student Feedback

With the limited scope of the study and the variables which had to be accounted for in the results, student feedback became an important part of the study for several reasons. As mentioned previously, student feedback was only gathered from subjects who had completed tests IA or IB but several subjects from outside tests IA and IB did provide comments after an explanation of the study and the reasons behind it. The first and most important question gauged their reactions to the basic concept being tested and asked if they would have deemed it useful in their previous studies in aural skills. While this question is not scientific or supported as such, it is important because the engagement of a student and the possibility of a placebo effect could be quite powerful and useful in a teaching environment. Placebo effects have been studied and reported on extensively in the medical field but would warrant further research into the possible effect it may have in the classroom. One thing that can be said for certain is the power a placebo effect has on our minds and bodies which would be of interest to explore in the classroom. Students were also asked about their technique and their approach to individual tests and what some of the positive and negative aspects were. Student feedback was not completed with a formal questionnaire but instead done through informal discussions with each test subject upon completion of their test, many of which were initiated by the students' curiosity.

Most subjects' initial reaction to the test was one of guarded interest. The students were asked if they found any correlation between the sounds and color. Out of the twelve total tests for IA and IB, only three subjects noticed the correlation between the pitches or chords and the colors being displayed during the test. Out of those three, only two knowingly utilized the association between the auditory and visual stimuli to help them during the testing. Although no hints were given about the relationship of color and sound, it is interesting to note because as mentioned previously, association is a primary way of learning and a critical step toward a "learned synesthesia." The remainder of test subjects either did not notice any correlation or were hesitant to use or focus on it. Other initial reactions were usually directed questions as to what the test was attempting to do and the reasoning behind it.

After discussing the tests, my thesis, and the reasoning behind the use of color, they were asked if something similar would have been useful to them in their early studies in aural skills. An overwhelming number of the test subjects said they would have enjoyed a similar method used in their entry level aural skills courses. Many thought that the color association would have been helpful to them personally, especially with the foundation aural skills builds on.

The techniques and approaches to the tests stayed relatively consistent between each subject in tests IA and IB with some notable differences. As previously discussed, a major limitation of the study was the inability to measure which of the stimuli was having the resulting effect upon the data. Through reviewing the tests and asking the subjects, some important techniques and approaches began to become more apparent. More than half of the participants of test IA and IB switched to focusing only on the visual stimulus after two or three levels. The feedback regarding this shift in attention was that it was too hard to try to focus on two separate things happening at the same time, or that it was easier to retain the colors than to retain the pitches or chords. Although not surprising, this does show that when given a choice, subjects tended to choose the visual stimulus because of familiarity even though the auditory components should have been equally familiar to them. In future research, subjects' preferred learning styles should be tested prior to the study which may help illuminate certain trends like the one mentioned above.

The other main trend was that certain subjects would rely mainly on the visual stimulus but would then begin to use the auditory stimulus in certain areas, often at the start and end of each level. This allowed for a "breaking" of the amount of individual stimuli they had to remember. For instance, if the level tested a pattern of seven stimuli, instead of memorizing seven colors, they would only remember five colors and then remember how the auditory pattern started and ended. This trend was mainly seen in test IB when chords were used but also occasionally in test IA when tonal relationships like $\hat{7}$-$\hat{1}$ or $\hat{5}$-$\hat{1}$ were heard at the start or ending of the progression. In tests IB and IIIB, the chords used were in non-functional progressions which many students said proved to be much more difficult than first thought after their initial reaction to the explanation of the test.

One other important component to the student's feedback was that the majority of the subjects thought they could have done much better than they did if they knew that the colors and pitches or chords were in an associative relationship, meaning that blue was always "re" in test IA or always a minor chord in test IB. For the aforementioned three participants who did notice this, the two that utilized it attempted to use it to aid in their memory retention of the patterns. Lastly, the majority of the subjects reported that they would have enjoyed participating in or seeing something similar in a semester-long, classroom setting. This would not only eliminate the initial novelty of seeing colors being displayed with music, but also expose the subjects long enough to the study so that visual and auditory associations could be made and used as teaching aids as discussed in chapters two and three. This would also lower the Hawthorne Effect, which is the changing of behavior due to the knowledge of participating in a test.

Further testing with the HummingBird software will incorporate the use of LEDs which may or may not have a different effect upon each student but the feedback to such an idea was extremely positive. A consensus of opinion was given by the subjects about future testing being more attractive and immersive than the projected image. The use of LEDs could enhance the perception of the color by changing the entire environment into a pool of colored light instead of a single, projected two-dimensional image.

Summary

Student feedback was an important element and it illuminated several flaws with this particular test but it also showed that most test subjects were interested and open to the concept of using color in aural skills courses. Also reported in high numbers among the test subjects was the agreement about the usefulness of such a concept. Most said they believed they would have benefited from the use of color in their early aural skills training if they were aware of the associations between the audio and visual. An agreement between the test subjects was also seen in the potential future use of LEDs instead of the projected color that was used in testing which would have resulted in a more immersive and engaging colored environment. The techniques and trends seen from subjects preferring the visual stimulus as well as the “chunking” of groups of color while remembering audible stimuli that had tonal cues is interesting and should be examined in future studies.

The results seen in group B showing a p-level that approaches significance and the general consensus seen in the student feedback review all point to a possible benefit that color may have in aural skills courses, be it by association, placebo effect, visual engagement, or merely a more attentive student. Any of these possible outcomes of using color would result in a student who is better prepared for their next level of aural skills training.

CHAPTER V: PEDAGOGICAL APPLICATIONS, FUTURE RESEARCH, AND CONCLUSION

The use of color in conjunction with music spans several centuries and disciplinary fields. New theories about how we infer tonic and the possibility of training our eyes and brains to perceive more colors in the world and the advancements in technology that study the operations and interplay of our senses point to a future full of interesting interdisciplinary pedagogical possibilities. Although the study of audio-visual connections is an active area of research, there has yet been only minimal adoption of that research's findings into classroom settings. We need to examine the role color, or any visual stimulus, may have on auditory stimuli and how it may benefit students in aural skills courses. Perception and emotion, along with tonal induction, are important elements to study when attempting to create pedagogical applications that use color in aural skills courses. These elements will be linked to color in ways that may prove pedagogically useful even though future research is still needed. It must be mentioned that assigning color based on one parameter in a multi-contextual setting becomes problematic. While I explore many different options below, it is important to remember that color may be most useful in isolated, smaller elements of aural skills instead of an extensive, unified theory between color and music.

Perception and Emotion

Our perceptions of and emotional reactions to music function similarly to our perceptions of and reactions to color. This is not surprising given the connections we build in our brains and the crossing of our senses that we use to explain abstract subjects. As Brougher et al., states:

> Organized according to a relative scale that bears direct comparison to that of music, color is a core element of sensory perception. Immediately apprehended without much effort from the subject, color requires no interpretation or deciding, yet can act directly upon the emotions, like a musical note.[134]

James Beament's *How We Hear Music: The Relationship Between Music and the Hearing Mechanism* describes our perception of music in a simple way: the listener remembers a pitch and then compares it to the next pitch heard.[135] Our perceptions and judgments of musical notes are directly affected by their surroundings, just as our perceptions of color are. Leonard Meyer states that Gestalt psychologists show that we tend to group stimuli into patterns and relate those to one another.[136] If we group musical notes into patterns that are familiar and similar to aid in memory retention, could using colors to visually aid those similarities and patterns help students better learn the materials given in early aural skills training? Emotional and physiological responses to music exist, of course, but are highly subjective. If exploring these responses helps students identify elements of music, however, then this theory can function as a successful learning aid. Upon hearing music and seeing color, our bodies respond physiologically similar, with music and color having an affect on pulse, respiration and blood pressure.[137] The emotional and physiological responses to music could be closely

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[134] Brougher et al., *Visual Music,* 18.

[135] James Beament, *How We Hear Music: The Relationship Between Music and the Hearing Mechanism* (Rochester, New York: Boydell Press, 2001), 5.

[136] Leonard, Meyer, "Emotion and Meaning in Music," In *Musical Perceptions,* edited by Rita Aiello and John Sloboda (New York: Oxford University Press, 1994), 9.

[137] Ibid., 13.

paired with those similar reactions that certain colors can produce, either through a prescribed pairing, or a more individualized color pairing for each student.

Our memories use tendency and expectation as tools to aid in our perceiving of music.[138] We learn schema and begin to create short-term memories (STM) and long-term memories (LTM) of what usually happens, or what we expect to happen, in music. This builds our expectations which then allow for surprises to be heard in the music when those expectations are not fulfilled. Steven Kaup states in his “Cognitive Processes for Inferring Tonic” that the dominant-tonic relation occurs so frequently in Western music that it has become a learned schema.[139] If the basis of tonality is a learned schema, then one can argue that by using a color association with the V-I schema, it could benefit students by allowing them to use a known stimulus, color, and apply it to an unknown stimulus, the chord progression. We learn by association and teach aural skills in the same manner. By actually showing students a visual stimulant that matches the emotional, physical, and physiological analogies we tell students to use in the classroom, we may see better and more lasting results.

The kinesthetic thought processes required for musical learning serve as potential learning tools in the classroom as well as help justify the use of color. McVay’s color-coding engages the visual intelligence but it may also emphasize the fact that music is a spatio-temporal process and “color is conceived as a direct link to a kinesthetic learning style,” thus supporting the idea that color-coding could enhance learning in music theory,

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138 Meyer, “Emotion and Meaning,” 23.

139 Steven Kaup, “Cognitive Processes for Inferring Tonic” (M.M. thesis, University of Nebraska, 2011), 16.

keyboard, and aural skills.[140] McVay uses the term "kinesthetic intelligence" which is a term developed by Howard Gardner to describe someone who best learns through physical activity rather then traditional classroom techniques.[141]

Gardner posits that the different types of intelligences (visual, kinesthetic, tactile, auditory) work together and may be able to enhance one another. The near-transfer theory postulates that multiple intelligences can be enhanced via mappings onto one another.[142] By pairing color in some fashion with aural skills drills, the visual and auditory intelligences may benefit from each other. This associative relationship could benefit students by acting as a "learned synesthesia" to aid them in their aural skills studies. This may prove especially useful to students who are visually based, or "visual learners" who struggle with verbal instructions but understand that same information when it is viewed in an instructional video or diagram. By replacing the example of verbal instructions with aural drills, color could serve as the visual stimulant they need to begin to understand and learn the material. Although the learning process is much different, the mapping of particular colors onto aural materials will still result in a schema that a student can recognize and begin to commit to memory.

This approach is already used in aural skills by both instructors and students, by extracting new information from previously known material. For instance, the sound of an ascending minor third is learned by many from comparison with the opening of *Greensleeves*, *Smoke on the Water,* or Brahms's *Lullaby.* If associations with already

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140 McVay, "The Effectiveness of Color-Coding," 9.

141 Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences* (New York: Basic Books, 1983): 208.

142 McVay, "The Effectiveness of Color-Coding," 68.

known melodies can facilitate the absorption of intervals, such as the ascending minor third in the above mentioned pieces/songs, then perhaps a color association with particular intervals could result in similar connections. In a similar vein, protonotation—the quick, vague sketching of a melodic contour during performance of a melody—has been shown to increase perception over those who only listened intently.[143] This practice not only engages the kinesthetic intelligence, but also the visual one and allows those intelligences to aid the student's auditory intelligence. Adding color to this practice could help in identifying other elements besides contour, such as chordal outlines, tendency tones and harmonic motion. These practices could also help change the undergraduate mentality of "I must only use my ears in aural skills" which is too often seen in students enrolled in these classes. The student's understanding of theory as well as visualization of shapes, colors and tendencies can be expanded through other means besides the auditory. "Utilizing color-coding in music, or in any field requiring organization of thinking, will greatly enhance learning and streamline the process of playing."[144] The organization of thoughts and activities is often done in color, from the entries of a simple personal calendar to the magnificent musical lines in the scores of many great composers, such as Mozart, Wagner, Scriabin, Stravinsky, Schoenberg, and Berg.

Our emotive reactions to music and color are associative, not intrinsic. A minor chord and the color blue are not inherently sad, but are associated through acculturation with sadness. Both musical elements and color have been linked to emotional associations. Alf Gabrielsson and Erik Lindström's diagram (see Appendix F) shows

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143 McVay, "The Effectiveness of Color-Coding," 77.

144 Ibid., 79.

numerous emotional responses that were recorded during testing of many types of musical elements, from tempo and form to harmony and intervals. The responses to harmony and intervals was of greater importance to the present study, but the idea of color as a teaching aid could be used to highlight any of those musical elements that seem to connect with a listener emotionally.[145] By pairing dissonant intervals with colors that trigger similar responses, for instance red or orange, the student would receive a visual stimulus to reinforce what their ears are perceiving and their brains are interpreting.

Tonal Induction and Color

How do we as listeners know where tonic or the tonal center is in music? This is the question of tonal induction and it has been looked at by both theorists and psychologists, most notably in the last several decades. While the ideas presented below represent only a few of the leading theories on the subject, there is still much to learn about this topic. A combination of these theories seems to be more appropriate instead of a single theory explaining the vast complexity of tonal induction.

Richmond Browne's "Tonal Implications of the Diatonic Set" explores the notion that listeners gather tonal information, put simply, by using the location of "rare intervals" and their surroundings within the diatonic set.[146] The rare intervals found in the diatonic set, the m2 and more importantly the tritone, are what guide our ears in a hierarchical process to inferring what and where tonic is. The interval vector of the diatonic set, <254361>, or two m2/M7, five M2/m7, four m3/M6, three M3/m6, six P4/

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145 Gabrielsson and Erik Lindström, "The Influence of Musical Structure," 235-239.

146 Richmond Browne, "Tonal Implications of the Diatonic Set," *In Theory Only* 5, nos. 6-7 (1981): 8.

P5 and one TT, is a representation of how many of each type of intervals occur in that particular collection of notes. The importance of this set is that it is the only one that contains every interval, and represents them in different amounts. Since the m2 occurs twice and the tritone only once, these rare intervals guide us in conjunction with the more common intervals to where tonic or our tonal center is.

Another theory of importance for my study was introduced in Piet G. Vos's article "Key Implications of Ascending Fourth and Descending Fifth Openings" which shows with overwhelming results that listeners inferred tonic by the 4/5 opening rule.[147] This rule means that when a piece of music opened with either an ascending fourth or descending fifth interval, the second tone was regarded as tonic. This theory may elide with Browne's mentioned above because it supports the idea of tonality being established by "special intervallic relations between pitch classes."[148]

The role of cultural influences and the abundance of different music throughout the world are important factors when studying tonal perception. However, the ideas put forth in this paper and study have been, for good reason, geared towards basic Western tonal music that is used in aural skills courses in the United States. Thus, despite its importance in a broader study, the role of how culture shapes tonal perception will not be covered in further detail.

If the rare interval theory is used to shape our pairing with color, then the two minor seconds and single tritone in the major scale would need to be highlighted in some

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[147] Piet Vos, "Tonality Induction: Theoretical Problems and Dilemmas," *Music Perception* 17, no. 4 (2000): 410.

[148] Ibid., 411.

fashion when compared to the other intervals present. By pairing with particular colors the half steps between $\hat{3}$ and $\hat{4}$ and $\hat{7}$ and $\hat{8}$, and also the tritone between $\hat{4}$ and $\hat{7}$, students would be visually reminded of the importance and function of those intervals within a major key. In a melodic dictation, the tendency tones mentioned above could be colored with warm colors. By using reds and oranges, both of which visually evoke the same perceptual and emotional responses and analogies we use to teach those tones, a student may benefit from the extra stimuli to help reinforce what they are hearing. In a harmonic dictation setting, the same ideas could be used, by using reds and oranges to highlight chords in which these active scale degrees are present, for instance the V7 chord or the viiº7 chord. By using red for the dominant and orange for the diminished, (red is a stronger/more-provocative color than orange, just like V7 is compared to viiº7) a student would be visually reminded of the subtle aural difference between the two chords.

The ascending fourth/descending fifth theory is another way that we may perceive tonic. According to Vos's work, these intervals play a critical role in tonal induction at the openings of works. By highlighting these intervals with a single warm color, it may help students understand the differences of the $\hat{5}/\hat{1}$ relationship when approached from below or above in comparison to the $\hat{4}/\hat{1}$ relationship, especially in a melodic or harmonic dictation.

Another possible pairing in a melodic sense would be to use a method like the famous color scale painters used (see chapter II, figure 2.3). By using the twelve-color wheel, a scale could be laid over it and the interval patterns between the colors and notes would stay consistent. This would highlight half-steps within the musical scale by color movements of shorter distances when compared to the whole-step sections. This mapping takes advantage of the cyclic nature of a musical scale and color. While not as emotionally charged as mappings of color to function or harmony, some students may find an objective (if arbitrary) association of particular colors and intervallic distances useful.

In a harmonic dictation setting, a color pairing based upon function and the similar emotional analogies would utilize many associative elements color may have to offer. In the major scale/key, the quality of the chords and their functions can be made to match fittingly with particular colors. The ii, iii, and vi chords might be assigned cool colors (blue-green-purple) to reinforce the sad, or calm state that both minor chords and cool colors are said to evoke. The major IV chord could be assigned a warm, bright color such as yellow, reserving the other warm but more active colors, red and orange, for V and vii°. The tonic chord could be paired with white in this type of pairing but an important question arises when using this approach in a melodic dictation —do color mappings need to be consistent in melodic and harmonic dictations? Harmonic dictations could use the above outlined color mapping rooted in function whereas a melodic dictation could use a completely different, contradictory color mapping. If the mappings do stay consistent from harmonic and melodic dictation, then the importance of what to display becomes an issue, function or scale degree. If the ii chord is blue in a harmonic dictation, should a melodic dictation's outline of the ii chord be all blue or should the colors change note to note, meaning (in C major) D-F-A would produce blue-yellow-purple because of the harmonies built on each note? Limiting the color mappings to only the primary, secondary, and ternary colors rather than allowing complex mixes and shades may be important because the eye naturally recognizes the colors of the rainbow whereas different shades require an intellectual shift to occur, possibly causing unnecessary cognitive effort.[149] Color pairings from past composers and artists are presented in appendix G.

If chord function and quality are the main tools a student uses to take down a harmonic progression, but in a melodic dictation he/she instead focuses primarily on contour shape and interval size, then the question arises about how to pair the color properly to the varied stimuli. One possibility would be to use function and contour and apply those to color. As discussed earlier, dominant functions could be represented with bold reds and oranges and then paired with Giannkis and Smith's results by making adjustments to the saturation and intensity levels depending upon the direction of the pitches. An ascending $\hat{7}$-$\hat{2}$-$\hat{5}$ line could be modeled as red, moving from a more saturated, intense shade to a muted, lighter one.

Function is crucial to the way we listen to music, and is far too important for it to not be discussed further. As mentioned in the student feedback section of chapter III, function seems to play an important role not only in our understanding of music, but our perception of it. Although subjects in group B were limited to only four harmonies which were all played in root position, many said it was much more difficult than they imagined it would be. The identification of the quality of triads is a method used often in aural skills courses which tends to be an easier topic for many students, however, when played

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[149] Morioka and Stone, *Color Design Workbook,* 24.

in succession, this once easy task proved to be more difficult for most. Ian Quinn presented a paper titled "Harmonic Function without Primary Triads" at the Society of Music Theory in 2005 where he outlined a change in his aural skills courses at Yale, doing away with the traditional roman numeral labeling system in favor of the Riemannian functions of tonic, subdominant (predominant), and dominant.[150] Several elements from Quinn's aural skills courses could be utilized in conjunction with color which could prove even more useful to students. Instead of having his students label roman numerals, Quinn requires them to focus on the function of each chord, resulting in such labels as T1, D2, T3, or S4, etc. A common mistake made by many undergraduates is to confuse the following harmonic progressions seen in figure 5.1 because of their similar bass lines and similar functioning harmonies.

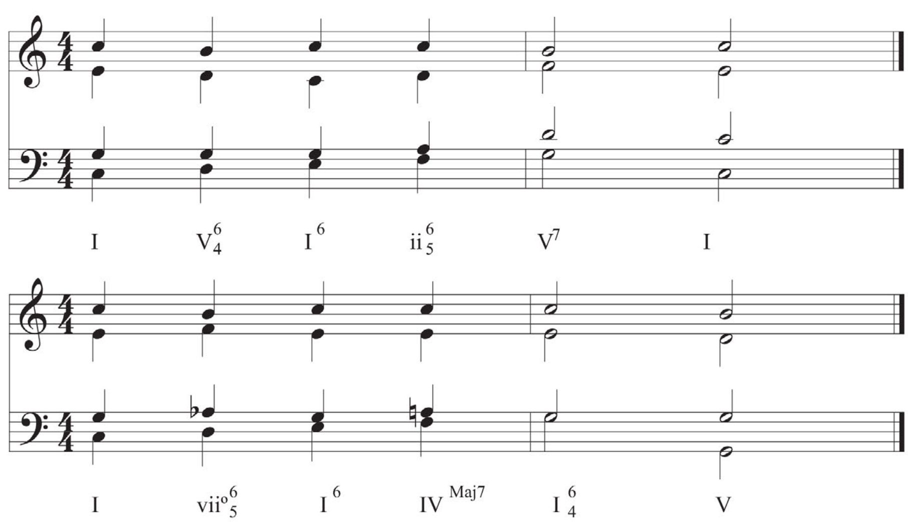

Figure 5.1: Harmonic progressions often confused with one another.

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150 Ian Quinn, "Harmonic Function without Primary Triads" (paper presented at the annual meeting of the Society of Music Theory, Boston, November, 2005).

Instead of requiring the students to hear the differences between these progressions, they instead focus on the function of the line and bass note, which would result in the labeling shown in figure 5.2.

Figure 5.2: Quinn's labeling of figure 5.1.

A variation of this could be used with color to highlight an issue some instructors may have with the labeling of a V6/4 chord as a dominant function when in the above mentioned progression a tonic prolongation is actually occurring. Color could be paired to the three aforementioned functions, with tonic function being any cool color such as blue, green or purple. A T1 function, or the strongest tonic function, could be represented by the most intense and saturated of the color choices, while weaker tonic functioning chords, such as a T3 (first inversion tonic triad or iii) or T6 (vi) could be represented by the same color but weaker in intensity and saturation levels. Subdominant (predominant) could be shown with a warm color like yellow while the dominant function could be shown as red or orange. A D2 could still be red but a much less saturated and intense red than a D5 in order to represent it being a dominant type chord, and, like the previously mentioned progression, how its overall function is subservient to the surrounding chords and tonic prolongation. In the above mentioned progression, T1-D2-T3 could be seen with a saturated green moving to a muted red (green's complement), then back to a less saturated green. This would highlight both the functions and also the prolongations that occur within that progression.

Another possible way of pairing color with drills in aural skills would be to approach both harmonic and melodic dictations in a prolongational way only. While maintaining the traditional approaches of dictating pitch and rhythm or chord type and outside voices in the class, a new, additional drill could be used to only highlight prolongations within each example by using color. If tonic, predominant, and dominant prolongations were focused on within a harmonic dictation and highlighted by color, then perhaps students would begin to learn to listen this way in the traditional drills, rather than simply linking outside voices to possible chords that theoretically make sense. Tonic prolongations could be marked with a soft, cool color such as purple or blue, which does not evoke activity and alertness. The predominant could be highlighted with yellows to provide some type of activity and movement but the strong colors, such as reds and oranges, could be used to show dominant prolongations. Again, Giannakis and Smith's findings on saturation and intensity levels could also be adjusted to follow the contour.

Many mappings and methods are possible when joining color to musical elements, and while many have promising parallels to music, they are not without flaws. Alexander Hector, one of the men responsible for the advancement of color organs and color music, seems to have taken a multifaceted approach instead of settling on one particular method of pairing. His color pairings were all centered on his theory that used logarithmic spirals for light and sound, yet his pairings often started on different colors that spanned the entire keyboard or just a single octave, and pairings that followed the phenomena of rainbows.[151] The seemingly infinite number of possibilities may be beneficial in an educational setting, however, allowing a student to choose what color pairing and what mapping method works for them may be the best course of action.

However, before these connections can be made and applied across multiple areas in aural skills, a semester-long study should be done that specifically looks for any enhancement color may have on the isolated drills themselves. This could be accomplished by taking two class sections of the same level of aural skills and having the same instructor teach both with the same lesson plans. The only difference would be one section would be taught either harmonic or melodic dictation with color and the other section would not use color, creating an experimental group and control group. Instead of using the final grades at the end of the semester as an assessment, a pre-assessment test could be given at the start of the course followed by a post-assessment test at the conclusion and then results of both tests would be compared to show the differences between the scores across both sections. This type of testing could show what effect, if any, color had on that specific type of drill.

Pedagogically, the main goal of using color would be to aid students in learning the fundamentals of aural skills. This color aid could be used in a way that creates a more secure foundation for students before they move on to the more advanced, chromatic

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151 Wierzbicki, "Shedding Light," 97.

drills seen in later levels of aural skills courses. The concepts learned later on will be easier for instructors to teach and much simpler for students to comprehend if their understanding of the foundation of tonality is strong and unquestionable. If a student is still unsure if a harmonic progression is either I-vi-ii^6-V7-I or I-IV^6-IV-V-I, then secondary function chords, chromatic predominant chords and altered dominants will become even harder to listen for and focus on because they are still struggling to hear the differences between a vi chord and a IV^6 chord or a ii^6 and IV chord.

Conclusion

Attaining aural skills mastery at an appropriate level is one of the largest hurdles many undergraduate students face while pursuing a degree in music. The reasons for this are numerous and complex, but it should be our responsibility as educators to explore different teaching methods and help guide students through the learning process. This process is as individual as the students themselves and our teaching methods should attempt to lessen the disconnect that occasionally occurs. Without an engaging atmosphere in the aural skills classroom or the flexibility of an instructor to adapt his or her teaching methods to the variety of learning styles, students might fail to recognize the relevance of aural skills, fail to identify strategies for success, and even become too frustrated to continue their studies in music. Offering students a variety of approaches and techniques to learn material in beginning level courses should only help to solidify the foundations of their music education, even if those approaches seem avant-garde.

The insular approaches that many aural skills classrooms and curricula take stand in stark contrast to the multi-dimensional, metaphorical ways in which music is often described and analyzed outside of academia. We should capitalize on the illustrative language in which we discuss Debussy's harmonies, or Mozart's drive towards cadence. We use the term *Fortspinnung* to explain how a baroque fugue grows organically from its subject, yet the illustrative and kinesthetic potential of associations like this are often forgotten in aural skills, and this can lead to mindless drills in which students find no relevance. The analogies that exist within the words we use to describe music, both casually and in academia, are often visual or kinesthetic by nature. Embracing these analogies could serve as a starting point to help awaken the student's other senses. "Learned synesthesia" is within the grasp of most people, and perhaps is already used by many, but by showing an actual visual representation of the words we use to describe Debussy's harmonies, Mozart's cadences or Bach's fugues would create an entirely new space in which to experience, talk about, teach, and learn music. With all the modern technology available today, creating this space has never been easier.

Our emotional responses to auditory and visual stimuli are already constantly crossing paths and working together, creating cross-modal correspondences to help us identify and discuss certain topics. Color not only shares many analogies with music, but our emotional responses as well. Our perception of music and color are overflowing with shared complexities, and the leading theories on perception in both fields can enlighten the possible relationships between the two. Music and color are heavily dependent on context, and we often respond in similar ways physiologically when exposed to either of them. Color is a familiar stimulus that requires no new knowledge base and is something that we are already constantly perceiving and interpreting. Additionally, how we use color and react to it in our daily lives aligns with the ways we teach certain elements of aural skills.

The connections between color and music throughout history have been filled with mysticism, but also with logic and scientific reasoning. These pairings are often done with an aesthetic focus, but they never lack some type of logical, emotional, scientific, or perceptual reasoning behind the pairings. Inventions like color organs and color scales point to the innate potential for color being a useful visual stimulus when describing music.

Positive results have been seen in audiovisual research fields when studying the effects that these stimuli have on one another. These results, along with the fact that color, above many other visuals like shape, is what the eye perceives best and speeds the recognition and memory retention of objects, point to many types of connections between color and music that could be utilized in aural skills courses. These connections could help our brains wire the visual stimulus of color with the audible stimulus of music, creating a learned synesthesia that may aid in the learning of basic drills used in aural skills courses. The neuroscience quip, “the neurons that fire together, wire together,” is often used when discussing memory and association, and is an important concept to remember when exploring the possibilities of a “learned synesthesia.” Although simplified, this link or association could be made between the visual and auditory stimuli, connecting an individual color with a specific musical element, training students in a quasi-Pavlovian manner. By combining findings from the audiovisual fields and the musical imagery field along with the effects that saturation and intensity had on musical criteria, justification can be made to further explore any benefits that may be present if color was used in aural skills courses as a teaching aid for struggling students.

The results from Vicki McVay's study that used color notation in the teaching of music theory rudiments, aural skills and keyboard skills, represents proof of the connection and potential benefit of using color to aid in music education, at least for older adults who are learning music late in their life. Although the reasoning behind how and why this worked was not conclusive, the results do show that color seems to play some type of beneficial role when learning all of the aforementioned elements, including music theory aural skills.

My set of tests did have their weaknesses: the third assumption of ANOVA was not met, variables occurred that fell outside of the controls, and the tests would have benefited from a larger number of subjects. Nevertheless, some of the results were worthy of being mentioned. These results could also be used as a starting point to direct further research in the field, and help create a study that fixes the major issues mentioned above.

My study also called for a completely new piece of software to be written and developed and when used in conjunction with an electronic keyboard, could be considered a new-generation color organ, open to any and all types of color pairings the users wish to create. Although the HummingBird software used was still in an alpha version, the updated, or beta version of the software will include a hardware element that will make possible the incorporation of LEDs into the software application. The beta version will also further user friendliness by allowing the user and not the software engineer to make major and minor changes to all the options available as well as increase the amount of those options in both the elements of color (saturation, value, intensity, etc) and how they are applied to the elements of music (dynamics, staccato/legato, key sensitivity, decay, etc). This will allow for a range of different applications using single note and octave pairings to entire keyboard spectrums. Educators and students will be able to shape the pairings to their personal choices or needs (it also opens up the possibilities of a musician controlling lights/visuals during live performances).

Ultimately, my experiments are not statistically conclusive. Even so, the results showed an interesting trend in group B in which the p-level began to approach significance. The reasons for this are unclear but are important when looking ahead to future research, particularly in color/music applications and in the role and importance of function in our perception of music. The customized software platform which was created can be used for many applications including in the future research of color/music education, as well as being considered a new, variation of the original color organs that have fascinated many composers and artists throughout history.

Above all, any research, new discovery, or possible adaptation should be pursued in the attempt to expand our students' understanding and liven the teaching atmosphere. The understanding of music can and should be attainable by all, regardless of age or experience. Often the concepts that seem natural or come easy are the most difficult to teach. There is far too much untapped potential in the world of music to not explore abstract and avant-garde ideas and methods, especially as we begin to understand the complexities of different learning styles. The next musical genius could easily never be discovered if we do not attempt different approaches and embrace varying methods of teaching that maximize our students' chances for success.

APPENDIX A
INFORMED CONSENT FORM

UNIVERSITY OF Nebraska Lincoln

IRB# 20141114767EP
Date Approved: 11/13/2014
Valid Until: 11/12/2015

GLENN KORFF SCHOOL OF MUSIC

Participant Informed Consent Form

IRB# 14767

Title: Using color in music education.

Purpose:
This research project will aim to study the possible effects of paring color with elements from music theory aural skill classes. You are invited to participate in this study because you are a UNL student and this study is looking for ways to improve the teaching options available for you during your theory course.

Procedures:
You will be asked to take a test in which you are asked to recite back a pattern of colors and/or tones which build up in length after each successful pattern retention. The procedures will last anywhere from a minute to ten minutes depending upon your advancement, and will be conducted at/in the Westbrook music building at UNL. You will be asked to supply your musical background, stating your main instrument type as well as your current level of music theory.

Benefits:
There are no direct benefits to you as a research participant however by looking at ways to improve the teaching technique the benefits could include feedback from the students point of view about what works and what does not.

Risks and/or Discomforts:
If you suffer from or have suffered from epilepsy you will not be able to participate in this study in an abundance of caution.

Confidentiality:
Any information obtained during this study which could identify you will be kept strictly confidential. The data will be stored in a locked cabinet in the investigator's office and will only be seen by the investigator during the study and for two years after the study is complete. The information obtained in this study may be published in scientific journals or presented at scientific meetings but the data will be reported as aggregated data and no personal information will be used.

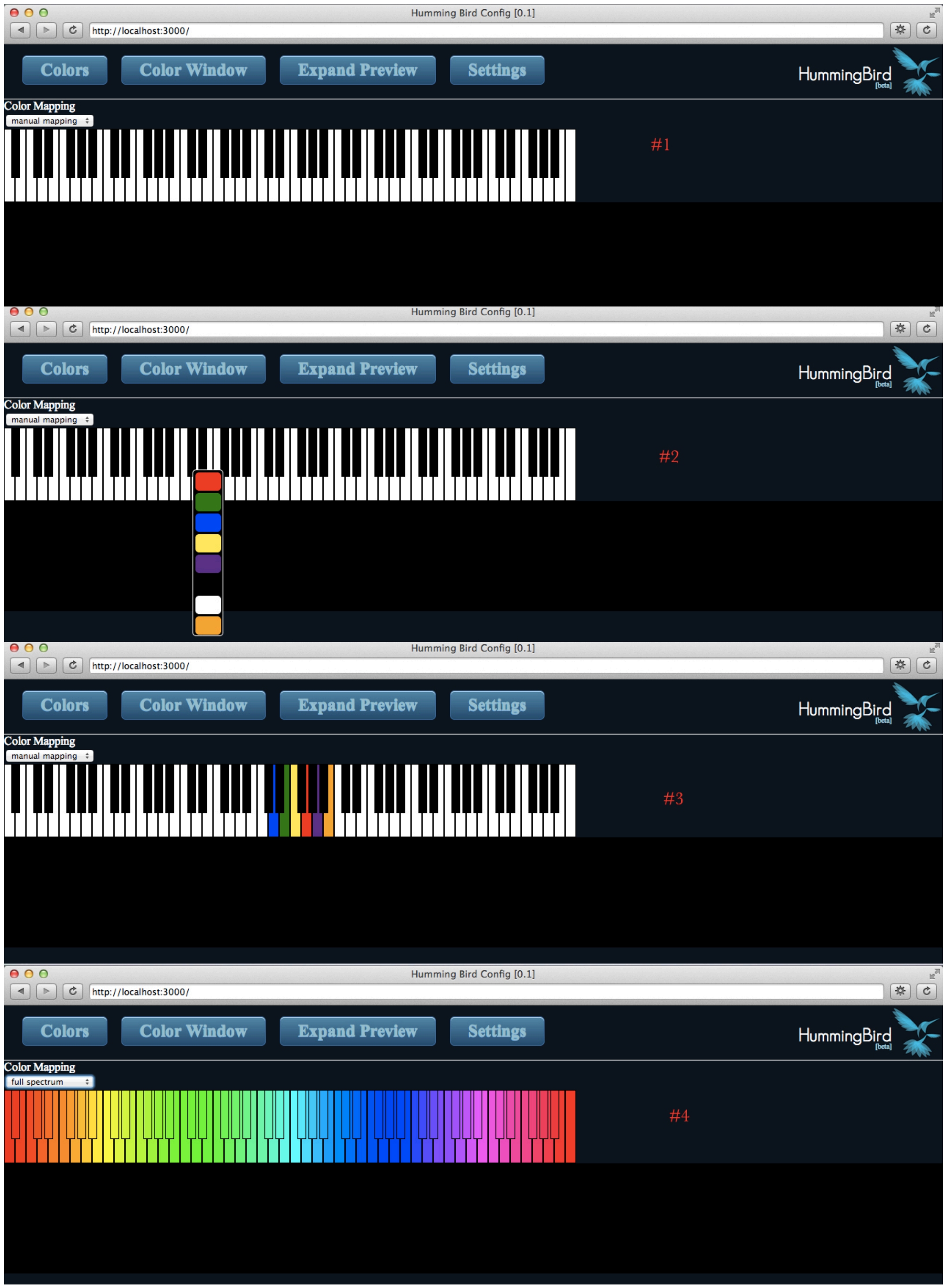
Compensation:
There is no compensation for participation in this study.

Opportunity to Ask Questions:
You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study. Or you may contact the investigator(s) at the phone numbers below. Please contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965 to voice concerns about the research or if you have any questions about your rights as a research participant.

Freedom to Withdraw:
Participation in this study is voluntary. You can refuse to participate or withdraw at any time without harming your relationship with the researchers or the University of Nebraska-Lincoln, or in any other way receive a penalty or loss of benefits to which you are otherwise entitled.

113 Westbrook Music Building / P.O. Box 880100 / Lincoln, NE 68588-0100
(402) 472-2503 / FAX (402) 472-8962 / music.unl.edu

APPENDIX B
HUMMINGBIRD SOFTWARE INTERFACE



HummingBird software produced by Jonathan Naylor, Cryptonic26@gmail.com

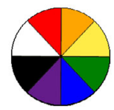
Photo 1 shows the interface at start up and in "manual mode." Photo 2 shows how the manual mapping of colors to keys is accomplished. Photo 3 is the result of the manual mapping and photo 4 is the spectrum divided equally.

APPENDIX C
TEST SHEET PROVIDED TO EACH TEST SUBJECT

You may use a combination of color and/or chord qualities or solfège to fill out each level after they are played. You will have a set amount of time per level to fill in the blanks with your pen after each hearing before being asked to recite back your ordering.

Below are representations of the possible colors, solfège and chord qualities you may or may not see and/or hear during each level of testing:

Do-Re-Mi-Fa-Sol-La-Ti-Do



Major, Minor, Diminished, Dominant

EXAMPLES: blue, red, minor, green, diminished. **OR**: Do, Fa, Mi, blue, red, Do.

5 seconds Level 1: ____ ____ ____

10 seconds Level 2: ____ ____ ____ ____

10 seconds Level 3: ____ ____ ____ ____ ____

15 seconds Level 4: ____ ____ ____ ____ ____ ____

15 seconds Level 5: ____ ____ ____ ____ ____ ____ ____

20 seconds Level 6: ____ ____ ____ ____ ____ ____ ____ ____

20 seconds Level 7: ____ ____ ____ ____ ____ ____ ____ ____ ____

25 seconds Level 8: ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

25 seconds Level 9: ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

30 seconds Level 10: ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ __

<u>To be filled out by primary investigator only:</u>

TEST IA: ____ TEST IIA: ____ TEST IIIA: ____

TEST IB: ____ TEST IIB: ____ TEST IIIB: ____

Subjects current level of music theory aural skills: ____
Main instrument type: ____

APPENDIX D
INSTRUCTOR'S KEY FOR TESTS IA,IIA, AND IIIA

C D E F G A B C

Level 1: E C A **Alt:** A D A
Mi Do La — La Re La

Level 2: C B G F **Alt:** D C D C
Do Ti Sol Fa — Re Do Re Do

Level 3: G C D C G **Alt:** A E C D A
Sol Do Re Do Sol — La Mi Do Re La

Level 4: D C E G F C **Alt:** C B C F B E
Re Do Mi Sol Fa Do — Do Ti Do Fa Ti Mi

Level 5: F A C D G A B **Alt:** A G F C A B D
Fa La Do Re Sol La Ti — La Sol Fa Do La Ti Re

Level 6: B F C B C E G F **Alt:** C A D C E A G D
Ti Fa Do Ti Do Mi Sol Fa — Do La Re Do Mi La Sol Re

Level 7: B A F E A D G F B **Alt:** C G A E F G D G C
Ti La Fa Mi La Re Sol Fa Ti — Do Sol La Mi Fa Sol Re Sol Do

Level 8: E A E C G A C F B C **Alt:** A B G C E D C A G D
Mi La Mi Do Sol La Do Fa Ti D — La Ti Sol Do Mi Re Do La Sol Re

Level 9: F C A D E F D G D C B
Fa Do La Re Mi Fa Re Sol Re Do Ti

Alt: B C D E G D A F E C A
Ti Do Re Mi Sol Re La Fa Mi Do La

Level 10: A B C B F G B C D G A B
La Ti Do Ti Fa Sol Ti Do Re Sol La Ti

Alt: D A F D F G C D A C B E
Re La Fa Re Fa Sol Do Re La Do Ti Mi

APPENDIX E
INSTRUCTOR'S KEY FOR TESTS IB,IIB, AND IIIB

MAJOR	MINOR	DOMINANT	DIMINISHED
C A	Dm Gm	Bb7 G7	Eo C#o

Level 1: C#o G7 Gm Alt: A Dm Bb7

Level 2: Bb7 C Eo Gm Alt: G7 C Dm A

Level 3: G7 Dm A Dm Eo Alt: C Dm A C#o C

Level 4: Gm C Eo Gm C G7 Alt: C C#o C Gm C#o Bb7

Level 5: Gm A G7 Eo Gm A C#o

Alt: Gm A G7 A Bb7 Gm Eo

Level 6: G7 Dm A Dm Eo Bb7 C Dm

Alt: A Dm Bb7 Gm C G7 Eo Bb7

Level 7: G7 C#o Dm C C#o C Bb7 D Eo Gm

Alt: C G7 Gm C Bb7 Eo Gm C Bb7

Level 8: A Eo Gm Bb7 C Dm A G7 A G7

Alt: G7 Eo Gm G7 C Bb7 A C#o A Dm

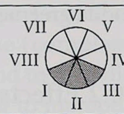
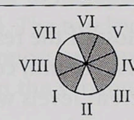
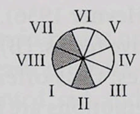
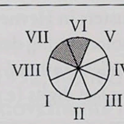
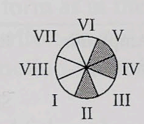
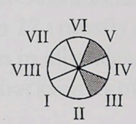
Level 9: Eo G7 Dm Eo Bb7 Gm Bb7 A Dm Bb7 Eo

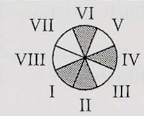
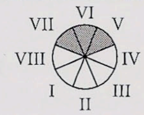
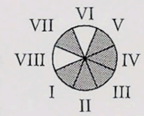
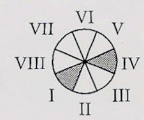
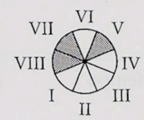
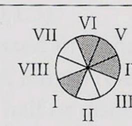
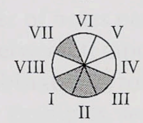
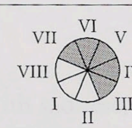
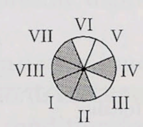
Alt: A Bb7 C Eo C Gm A Dm Eo Bb7 Dm

Level 10: Eo Bb7 Dm A Bb7 Dm Eo G7 Gm Eo Bb7 A

Alt: Gm Bb7 Dm Bb7 Eo Gm C#o A C#o G7 C Dm

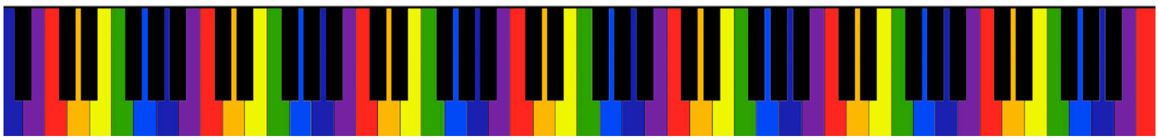
APPENDIX F
GABRIELSSON AND LINDSTRÖM'S SUMMARY OF RESULTS ON EMOTION IN MUSIC

Factor	Levels	Emotional expression	Adjective circle (Hevner)
	Legato	(A) I: solemn; II: melancholy, lamentation; III: longing (Ri39) (B) Softness (We72c) (C) Tenderness, sadness (Ju97)	
Harmony	Simple/ consonant	(A) VI: happy (He36, Wa42), joy (Ri39; V: graceful; IV: serene; III: dreamy (He36); I: dignified (He36, Wa42), serious (Wa42), solemn (Ri39); VIII: majestic (Wa42) (B) Gaiety, pleasantness (We72c), attraction (Ni82) (C) Relaxation, tenderness (Li97)	
	Complex/ dissonant	(A) VII: exciting (He36, Wa42), agitation (Ri39); VIII: vigorous (He36); II: sad (He36, Wa42) (B) Gloom, unpleasantness (We72c), tension (Ni82, Kr96) (C) Tension (Ni83, Kr96, Li97), fear (Kr97), anger (Li97)	
Intervals	Harmonic:		
	Consonant	(C) Pleasant, 'non-active' (Co00)	
	Dissonant	(C) Displeasing (Ma80), unpleasant, 'active', strong (Co00)	
	High-pitched	(C) Happy, powerful (Ma80), 'activity', potency (Co00)	
	Low-pitched	(C) Sad, less powerful (Ma80, Co00)	
	Melodic:		
	Large	(C) Powerful (Ma82)	
	Minor 2nd	(C) Melancholy (Ma82)	
	Perfect 4th, perfect 5th, major 6th, minor 7th, octave	(C) Carefree (Ma82)	
	Perfect 5th	(C) Activity (Sm99)	
	Octave	(C) Positive/strong (Sm99)	
Loudness	Loud	(A) VII: excitement (Wa42), triumphant (Gu35); VI: joy (Ri39) (B) Gaiety (Ni82), intensity (We72c), strength/power (Kl68), solemnity (We72c), tension (Ni83, Kr96) (C) Anger (Ju97)	
	Soft	(A) II: melancholy (Gu35); V: delicate (Gu35); IV: peaceful (Wa42) (B) Softness (Kl68, We72c), tenderness (Kl68) (C) Fear, tenderness, sadness (Ju97)	
Loudness variation	Large	(C) Fear (Sc77)	
	Small	(C) Happiness, pleasantness, activity (Sc77)	
	Rapid changes	(A) V: playful, amusing; III: pleading (Wa42) (C) Fear (Kr97)	

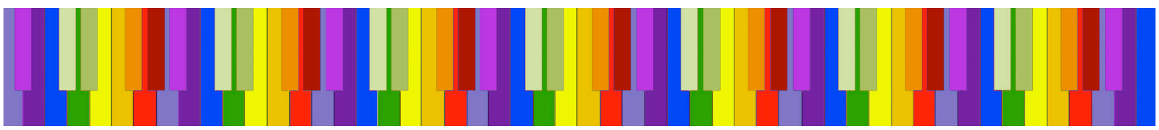
Factor	Levels	Emotional expression	Adjective circle (Hevner)
	Few/no changes	(A) II: sad; IV: peaceful; I: dignified, serious; VI: happy (Wa42)	
Melodic (pitch) range	Wide	(A) V: whimsical; VI: glad; VII: uneasy (Gu35) (C) Fear (Kr97), joy (Ba99)	
	Narrow	(A) I: dignified; II: melancholy; III: sentimental; IV: tranquil; V: delicate; VII: trimphant (Gu35) (C) Sadness (Ba99)	
Melodic direction	Ascending	(A) I: dignified; IV: serene (He36) (C) Tension (Ni83, Kr96), happiness (Ge95)	
	Descending	(A) VII: exciting; V: graceful; VIII: vigorous (He36) (C) Sadness (Ge95)	
Pitch contour	Up	(C) Fear, surprise, anger, potency (Sc77)	
	Down	(C) Sadness, boredom, pleasantness (Sc77)	
Melodic motion	Stepwise motion	(C) Dull melodies (Th92)	
	Intervallic leaps	(C) Excitement (Th92)	
	Stepwise + leaps	(C) Peacefulness (Th92)	
Mode	Major	(A) VI: happy (He36), joy (Ri39); V: graceful (He36); IV: serene (He36); I: solemn (Ri39) (B) Happiness (Kl68, We72c), attraction (Ni82) (C) Happiness (Sc77, Cr85, Kr97, Pe98)	
	Minor	(A) II: sad (He36); lamentation (Ri39); III: dreamy; I: dignified (He36); VII: agitation (Ri39) (B) Sadness (Kl68, We72c), tension (Ni82) (C) Sadness (Cr85, Kr97, Pe98), disgust, anger (Sc77)	
Pitch level	High	(A) V: graceful; IV: serene; VI: happy (He37), joy (Ri40a); III: dreamy (He37), sentimental (Gu35), pleading (Wa42); VII: triumph (Ri39), exciting (Wa42) (B) Gaiety (Kl68, We72c) (C) Surprise, potency, anger, fear, activity (Sc77)	
	Low	(A) II: sad (He37, Wa42), melancholy (Gu35), lamentation (Ri40a); VIII: vigorous (He37); I: dignified (He37), serious (Wa42), solemn (Ri40a); VII: exciting (He37), agitation (Ri40a); IV: tranquil (Gu35) (B) Serious (Kl68), sadness, solemnity (We72c) (C) Boredom, pleasantness, sadness (Sc77)	

APPENDIX G
NOTABLE COLOR AND PITCH PAIRINGS

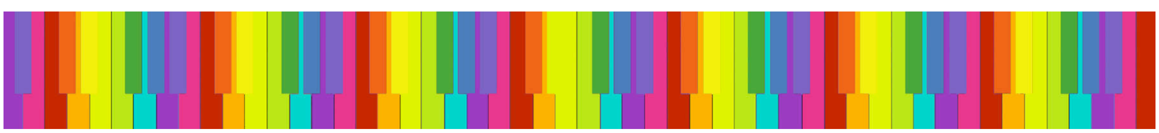
Lorenz Christoph Mizler (1739)



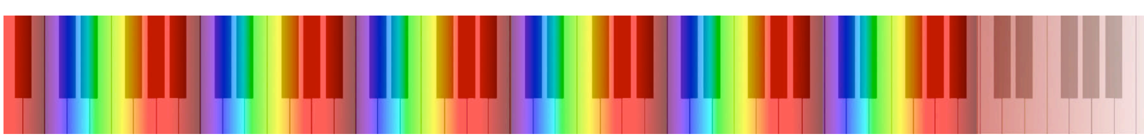
Louis-Bertrand Castel (1742)



Bainbridge Bishop (1893)



Alexander Hector (1917)



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