

JOHNSON, MATTHEW S., M.M. Composing Music More Accessible to the Hearing-Impaired. (2009)

Directed by Dr. Alejandro Ruty. 42 pp.

A hearing-impaired individual's perception of the world is not devoid of music, he or she can experience and enjoy it as much as a hearing person can. Unable to hear sounds the way most people can, deaf persons often receive audio information through other means, including the tactile sensation of sound vibrations, residual hearing (the limited range of pitches that hearing-impaired persons may possess), and visual clues. Presenting existing music in a manner that takes these means of extended listening into account is not a new idea: visual representations of music through sign language or some form of mixed media have existed for many years, and in recent years technology has enhanced the experience of music through vibrotactile cues. However, there is little precedent for creating original music for the express purpose of appealing to those who are hearing-impaired. Taking the perceptions of hearing-impaired persons into account, a composer can create music that is meaningful to someone with a hearing impairment.

This document examines hearing-impaired individuals' perception of sound as it pertains to music, it evaluates the abilities and limitations that a hearing-impairment creates, and it suggests methods for creating original music for a deaf audience.

Application of these methods results in an original work with the express purpose of appealing to the hearing-impaired. I analyze this work, *Collapse*, through the criteria defined by the rest of the paper. I provide a score to *Collapse* (Appendix A) with a synthesized recording for reference (Appendix B) and a video that may be used in the performance of this work (Appendix C).

COMPOSING MUSIC MORE ACCESSIBLE TO THE HEARING-IMPAIRED

by

Matthew S. Johnson

A Thesis Submitted to
the Faculty of The Graduate School at
The University of North Carolina at Greensboro
in Partial Fulfilment
of the Requirements for the Degree
Master of Music

Greensboro
2009

Approved by

Committee Chair

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

Committee Chair _____
Dr. Alejandro Rutty

Committee Members _____
Dr. Elizabeth Keathley

Dr. Greg Carroll

Date of Acceptance by Committee

TABLE OF CONTENTS

	Page
LIST OF FIGURES.....	iv
CHAPTER	
I. INTRODUCTION.....	1
II. DEAFNESS AND MUSIC.....	3
III. HOW THE HEARING-IMPAIRED EXPERIENCE MUSIC.....	10
IV. MAKING MUSIC MORE ACCESSIBLE TO THE HEARING-IMPAIRED.....	21
V. <i>COLLAPSE</i> : A WORK OF MUSIC FOR THE HEARING-IMPAIRED.....	27
VI. CONCLUSIONS.....	35
BIBLIOGRAPHY.....	37
APPENDIX A. SCORE TO <i>COLLAPSE</i>	40
APPENDIX B. AUDIO FILE FOR <i>COLLAPSE</i>	41
APPENDIX C. VIDEO FOR PERFORMANCE OF <i>COLLAPSE</i>	42

LIST OF FIGURES

	Page
Figure 1. Levels of deafness.....	3
Figure 2. Range of hearing compared to range of tactile feeling.....	19
Figure 3. Expansion and contraction of dynamics, tempo, meter and pitch.....	28
Figure 4. Detailed expansion and contraction of pitch.....	29
Figure 5. Expansion and contraction in the underlying motif.....	30

CHAPTER I

INTRODUCTION

Hearing-impaired members of an audience are seldom adequately considered in the music world. According to the National Center for Health Statistics, more than thirty-seven million people in the United States have some form of hearing loss, approximately seventeen percent of the population.¹ While the largest percentage of persons with hearing loss are sixty-five or older, there are many individuals that go through their entire lives with an inability to hear most sounds. One child in every thousand is born deaf or becomes deaf by the age of three.² Approximately 0.5 percent of the United States population is diagnosed with severe or profound deafness, a quarter of which are from birth.³

The fairly common assumption that deaf persons cannot enjoy music is inaccurate, hearing-impaired people simply perceive music through different receptors. Many deaf persons can rely on a small amount of residual hearing. Deaf persons also use information gathered by their other senses to experience music, including their sense of sight and, perhaps most interestingly, touch.

¹ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf and Hard of Hearing: A Bridge to Accessibility*, (Elsevier Academic Press, 2004), 4.

² Nanci Scheetz, *Psychosocial Aspects of Deafness*, (Pearson Education Incorporated, 2004), 18.

³ Barbara R. Schirmer, *Psychological, Social, and Educational Dimensions of Deafness*, (Allyn and Bacon, 2001), 20.

Through considering the perceptions of a hearing-impaired audience, musicians can better serve their needs. Previous research on the subject has focused on creating a multimedia music experience through visualization and amplification. In the past few years technology has also improved the possibilities for a deaf person to experience somatic reception of music through vibrations. Most of this research has included the manipulation of pre-existing music, and while this is a noble and important venture, there is only so much one can do to present an existing work effectively to a deaf audience. The creation of original music that takes into account the perceptions of the hearing-impaired can result in music that will be more fully appreciated by deaf audience members. Researchers have applied this idea before, often through the use of controlled synthesizers, but it is largely uncharted territory in music for live performers. The purpose of this document is to provide one possible avenue of composition that will be more accessible to the hearing-impaired.

This study provides an overview of hearing loss and the role that music can play in the lives of deaf persons. I will evaluate the various ways through which the hearing-impaired may perceive music and apply these findings to the process of composition. I have written a work, *Collapse*, which is heavily influenced by this research, and I provide an analysis of the work in terms of the criteria defined in the preceding chapters. At the end of the document, I provide my conclusions and suggest avenues for further research.

CHAPTER II
DEAFNESS AND MUSIC

Not every person with a hearing impairment is completely deaf to the world around him or her. The term “deaf” (with a lowercase “d”) is used to identify persons with a variety of hearing problems that range in type and severity. When a person’s hearing is tested, the amount of hearing loss is measured as the lowest amplitude that he or she is able to perceive an event (FIGURE 1).

	Degree of Hearing Loss (HL)
NORMAL HEARING	-10 - 15 dB HL
SLIGHT	16 - 25 dB HL
MILD	26 - 40 dB HL
MODERATE	41 - 55 dB HL
MODERATE - SEVERE	56 - 70 dB HL
SEVERE	71 - 90 dB HL
PROFOUND	91 dB HL or more

Figure 1: Levels of deafness⁴

Total deafness is rare; most hearing-impaired individuals can hear to some degree. A person with a mild hearing impairment may be unable to hear events that are quieter than 25 dB (such as a whisper), while a person who is profoundly deaf would not be able

⁴ Nanci Scheetz, *Psychosocial Aspects of Deafness*, 17.

to hear events at 95 dB (such as a chainsaw). Many people with a profound hearing impairment are unable to perceive even the loudest noises, and are often more aware of vibrations than of actual sounds.⁵

Several factors may contribute to a hearing impairment. Heredity is responsible for one-third of childhood deafness, while the other two-thirds are caused by prematurity, ototoxic drugs (medicines that are known to have a negative effect on hearing), complications of the RH factor, or disease. Many diseases that contribute to childhood deafness are correlated with other disabilities or neurological damage, though more common ailments, such as meningitis and rubella, can also cause hearing loss in young children. The most common causes of adult hearing loss are presbycusis (the deterioration of hearing with age) and damage inflicted by noise. Every person who has ever been to a rock concert or visited a big city has experienced some degree of noise-induced hearing damage. Sounds above 100 dB can cause temporary hearing loss, often coinciding with a high-pitched ringing sound in the individual's ears, and repeated exposure to these sounds can cause a permanent hearing loss. Other causes of adult hearing loss include Ménière's disease (a disorder of the cochlea) and ototoxic drugs, such as those used to treat cancer and complications from HIV.⁶

The human hearing mechanism is a complex system of organs prone to damage and disease. The visible part of the ear, called the auricle, channels sound waves to the middle ear, which consists of the eardrum and three small bones: the malleus, incus, and

⁵ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 14.

⁶ Barbara R. Schirmer, *Psychological, Social, and Educational Dimensions*, 6-9.

stapes. These bones conduct vibrations and forward them through the oval window to the inner ear, containing the vestibular mechanism and the cochlea. The inner ear is filled with fluid and tiny hairs that convert the vibrations into electrical impulses that can be understood by the brain. Finally, these electrical impulses travel along the auditory nerve to the brain to be perceived as sound.⁷

Hearing impairments are often divided into four categories: sensorineural hearing loss, conductive hearing loss, a combination of sensorineural and conductive hearing loss, and central auditory processing dysfunction. Sensorineural hearing loss is a hearing impairment caused by a damaged auditory nerve or damaged hair cells in the inner ear. Conductive hearing loss is often caused by disease or an obstruction in the middle or outer ear and is generally less severe than sensorineural deafness. Although it is rare, some individuals suffer from a mixture of both sensorineural and conductive hearing loss. Central auditory processing dysfunction occurs in the auditory neural network in the brain and is often correlated with neurological disorder.⁸

While hearing impairments are measured and classified, each person's hearing loss is unique. Some people hear certain frequencies better than others, while others experience distortion at different amplitudes. Generally speaking, sensorineural hearing loss causes a greater loss of hearing in higher frequencies, a deterioration of pitch perception and temporal resolution, and some degree of recruitment (disproportionate increases and decreases in amplitude). Individuals with conductive hearing loss often

⁷ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 9.

⁸ Barbara R. Schirmer, *Psychological, Social, and Educational Dimensions*, 5.

experience loss of hearing spanning the entire frequency range, which can often be compensated effectively with surgery or amplification.⁹

While the National Center for Health Statistics and most medical organizations consider deafness a disability, many people with hearing impairments do not think of themselves as disabled. For hundreds of years, people with hearing impairments have gathered together to form distinct communities. The term “Deaf” (with a capital “D”) is now used to refer to members of a cultural and linguistic group defined by hearing loss. Deaf culture and Deaf communities do not normally exist as a separate group apart from society, but as a subculture within society. A defining attribute of Deaf communities in the United States is the use of American Sign Language (ASL) as a primary or secondary language. Deaf culture is a proud culture of people who do not allow a disability to prevent them from experiencing life to the fullest; there are schools for the deaf, theatres, churches, universities, and more.¹⁰

Most hearing-impaired people are not a part of this Deaf subculture, spending their entire lives without ever attending a deaf school or learning ASL. Approximately thirty percent of hearing-impaired children receive their education in a normal public school classroom setting. Another forty percent of deaf students attend regular schools but receive their education in self-contained classrooms or resource rooms. Only a quarter of students attend special schools for the deaf.¹¹

⁹ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 10.

¹⁰ *Ibid.*, 70.

¹¹ *Ibid.*, 7.

Music has been taught in deaf classrooms for over one-hundred and fifty years. Schools for the deaf often include music as part of their curriculum for a variety of reasons, from its ability to engage students in disciplined physical activity to the power of music to improve communications skills. Through listening to and participating in music, students can develop their ability to perceive other sonic events, such as speech.¹² Inflections in music mirror inflections in the voice, and music offers the wide range of dynamics that verbal conversation can include. In music classes, deaf students often sign familiar songs or play percussion instruments. The primacy of rhythm in the nature of percussion makes it the instrument family of choice in most deaf music classes, but it is not the only section represented in deaf music classes; many students learn piano, strings, and other instruments as well. Studies have shown that deaf students who are involved in some sort of musical activity are likely to have improved oral and aural skills.¹³

Deaf persons respond to music in a variety of different ways. Alice-Ann Darrow, a leading figure in the field of music education for the deaf, quotes one student's expressions of anger towards music:

Damn it, I can't hear. Why should I talk about music? Even music itself is a complete mystery to me! People seem to be intrigued by all kinds of music, so it must be something. Too bad I'm deaf.¹⁴

¹² Alice-Ann Darrow and Julie Novak, "The Effect of Vision and Hearing Loss on Listeners' Perception of Referential Meaning in Music," *Journal of Music Therapy*, (Spring 2007), 71.

¹³ Kate Gfeller, et al, "Musical Involvement and Enjoyment of Children Who Use Cochlear Implants." *Volta Review* (September 1998), 213.

¹⁴ Alice-Ann Darrow, "Sounds in the Silence: Research on Music and Deafness," *Applications of Research in Music Education* (Fall-Winter 2006), 6.

Another individual expressed her enjoyment of music:

Everyone has their own values, and some [deaf] people do love music, even if they can't hear much of it. What they get they appreciate. I personally do feel that way. And so they [hearing people] look at me and wonder how I can enjoy music. I don't know. How do you explain that? It's a very individual thing.¹⁵

Darrow points out that while some deaf individuals do not have an affinity towards music, and some may even resent it, many have a great interest in music.

An important factor that contributes to one's perception and enjoyment of music is the age that deafness occurred. Those who are born deaf or lose their hearing before the age of three (prelingual deafness) have little reference with which to listen to music: having lost their hearing so young they have little or no memory of how music sounds. Persons who lose their hearing later in life (postlingual deafness) may be able to listen to a piece of music with the memory of how it sounds. While their ears may not be able to convey all of the musical information accurately, their brains may be able to fill in the gaps. This phenomenon often has a significant influence on how a deaf person perceives music.

Music plays little or no part in the lives of some hearing-impaired individuals, while for others it is a large part of their daily lives. There are even people who make a career in music despite their disabilities, including many musicians, composers, and dancers. One of the most notable hearing-impaired musicians in recent years is Scottish percussionist Evelyn Glennie. Born in 1965, she took an early interest in music, learning the clarinet, among other instruments. She had a passion for all music, but had an affinity

¹⁵ Alice-Ann Darrow, "Sounds in the Silence," 6.

for percussion in particular. At the age of eight Glennie began to notice a difficulty hearing certain sounds. By twelve her hearing had severely deteriorated, and her teachers suggested that she attend a school for the deaf. After learning this she wrote, “I was looking at the prospect of being classified for life as disabled, and cut off from the music that was beginning to seem vital to my happiness.”¹⁶ She did not give up music, in fact she became more involved with percussion and is now a leading figure in both percussion music and music for the deaf.¹⁷

¹⁶ Harry G. Lang and Bonnie Meath-Lang, *Deaf Persons in the Arts and Sciences: A Biographical Dictionary*, (Greenwood Press, 1995), 146.

¹⁷ Ibid.

CHAPTER III
HOW THE HEARING-IMPAIRED EXPERIENCE MUSIC

Listening With One's Ears

There are many ways that a hearing-impaired person may experience music, both with his or her own hearing faculties and with other senses. Many deaf persons possess the ability to perceive certain frequencies despite profound hearing loss. Usually these are lower frequencies, though the exact frequencies are unique to each individual.¹⁸ Often pitch discrimination improves with lower pitches and increased intensity.¹⁹ Through this residual hearing deaf persons can perceive several aspects of music without personal amplification such as hearing aids, so long as they occur within their range of usable hearing.

For centuries, strides have been made to allow deaf persons to function normally in a hearing society. From the primitive “ear trumpet” of long ago to modern hearing aids, the vast majority of advancements have improved hearing through process of amplification. Today, deaf persons have a variety of options available to them; including a variety of “hearing aids,” cochlear implants, and assistive listening devices. These devices do not improve hearing like a pair of glasses with corrective lens can improve vision; they simply makes certain sounds louder (and sometimes, softer).

¹⁸ Stephen Gulliver and George Ghinea, *How level and type of deafness affect user perception of multimedia video clips*, (Brunel University, 2003), 3.

¹⁹ William B. Davis, *An Introduction to Music Therapy*, 215.

The majority of “hearing aids” are small personal devices that manipulate sounds as they reach a person’s ear and amplify them to levels that are perceptible to the wearer. They come in a variety of shapes and sizes, fitting inside the ear, around the ear, or as an external module connected to a headset. Each device has a microphone that receives sound and a processor that converts the sound into an electrical signal, amplifies the sound, then converts it into acoustic energy once more. Some hearing aids are relatively simple, while others contain a digital programming feature, allowing the person to change the way the hearing aid amplifies sound for different listening situations.²⁰

Most hearing aids do much more than simply amplify sounds; they are calibrated to match the hearing of the individual. Usually they amplify specific frequencies between 100Hz to about 8000Hz in order to counter high-frequency hearing loss and improve speech perception. Some of the more complicated digital hearing aids have what is called automatic gain control (AGC), which levels out the dynamic range perceived by the wearer, combating recruitment. These digital devices can also include algorithms for feedback reduction. Despite a plethora of advancements in hearing aids, they are optimized for speech, not music.²¹

One of the most recent developments in medical technology for the hearing impaired is the modern cochlear implant, a device which in many ways surpasses the effectiveness of all previous hearing aids. This device, too, is designed with the purpose of assisting in speech perception. A processor on the surface of the device encodes

²⁰ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 90.

²¹ Rosalie Rebollo Pratt, ed., *Music Therapy and Music Education for the Handicapped: Developments and Limitations in Practice and Research*, ed., (MMB Music Incorporated, 1993), 133.

aspects of sound waves considered pertinent to speech perception and transmits an electrical signal to electrodes implanted in the cochlea. As of 2002, more than 21,000 hearing-impaired persons in the United States had received cochlear implants, and that number is growing exponentially.²²

Cochlear implant-related research has consistently emphasized speech perception. This is understandable, considering the design of the device; however, it ignores the impact it may have for musical listening. Several music therapists have addressed this issue, including Gfeller, Lansing, and Woodworth. They have concluded that the coding strategies of cochlear implants are inefficient for transmitting many properties of music, including pitch.²³ Their research discovered that, while adult recipients of implants have the ability to perceive simple rhythms as successfully as an individual with normal hearing, they have considerably less success in distinguishing melodic patterns and instrumental timbres. In fact, hearing-impaired persons who receive cochlear implants later in life often find the timbral qualities of some instruments to be less pleasant than before their implants, especially persons with post-lingual deafness.²⁴ Louder sounds, even those in the lower frequencies, can distort pitch discrimination for a person with a hearing aid or cochlear implant.²⁵

²² John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 91.

²³ Kate Gfeller, "Musical Involvement and Enjoyment," 214.

²⁴ Ibid.

²⁵ Rosalie Rebollo Pratt, ed., *Music Therapy and Music Education*, 133.

Despite the great advancements in hearing aids, it is estimated that only twenty percent of those who need hearing devices use them. A range of reasons may account for these numbers, from the cost of hearing aids to the preference of Deaf individual to communicate with ASL.²⁶ Similarly, while cochlear implants have grown in popularity, relatively few people use them. These devices are primarily found in wealthier countries, costing between \$60,000 to \$100,000. Another reason that some people do not choose to receive cochlear implants is the permanent nature of implants and research that suggests that implants actually destroy the person's residual hearing.²⁷

A third type of hearing device may prove more effective in listening to music for most hearing-impaired persons. Assistive listening devices, available at many entertainment venues, use simple amplification to enhance a musical listening experience. Often these are portable devices utilizing FM radio frequencies and microphones to eliminate amplification of unwanted sounds. Wireless microphones pick up a signal at its source and send it directly to the assistive listening device. These devices do not have the same quality as most hearing aids, but can be useful in noisy environments (such as music halls). Many theatres and public performance areas are required by law (Title III of the Americans with Disabilities Act of 1990) to provide audience members with an assistive listening device at no charge if one is requested.²⁸

²⁶ John W. Adams and Pamela S. Rohring, *Handbook to Service the Deaf*, 90.

²⁷ Christopher W. Turner and Lina A.J. Reiss and Bruce J. Gantz, "Combined Acoustic and Electric Hearing: Preserving Residual Acoustic Hearing," *Hearing Research* (2008), 170.

²⁸ *American Disability Act of 1990*, Public Law 101-336, *U.S. Statutes at Large* 104 (1990): 327, codified at *U.S. Code* 42, § 12181-12189.

Listening With One's Eyes

Many people believe there is a correlation between a sensory disability and enhanced perception in the other senses. While there is no definitive evidence to support this, research suggests a direct connection between deaf persons who communicate with ASL and increased visuospatial abilities.²⁹ Forms of mixed media incorporating both sight and sound can enhance a deaf person's enjoyment of music, help provide context, and enhance meaning. William Wolcott Turner and David Ely Bartlett write:

In estimating the pleasure that can be derived from music, it must not be forgotten that the sensation or perception of sound is not the whole of pleasure produced by music. A considerable part of this pleasure results from the rhythmical character of the movement, which can be perceived by the sense of sight alone to a considerable extent, and yet more perfectly with sight and feeling together.³⁰

Darrow examines the role of referential meaning in music and its influence on the ability for deaf children to develop communications skills, noting that “visual representations of music allow children to define or to clarify what they hear.”³¹

The advent of video technology has created many new avenues for musical expression. From the early live accompaniment of silent movies to the modern popular music videos, the combination of music and video creates a mixed media experience that provides a wide range of expression. Regardless of whether music supports the visual

²⁹ Marc Marschark and Patricia Elizabeth Spencer, eds. *Oxford Handbook of Deaf Studies, Language, and Education*, (Oxford University Press, 2003), 467.

³⁰ Turner & Bartlett (1848), quoted in Alice-Ann Darrow, “Sounds in the Silence,” 6.

³¹ Alice-Ann Darrow and Julie Novak, “The Effect of Vision and Hearing Loss on Listeners' Perception of Referential Meaning in Music,” *Journal of Music Therapy*, (Spring 2007), 71.

aspect of a film or whether it is the visuals that support its music, vision can help a hearing-impaired individual extract meaning (or assign meaning) to musical events. Sometimes video reveals a great deal about its music, particularly when the meaning of both are consistent or complementary. Visuals that “mickey-mouse” the music can transmit a great deal of musical information to the deaf viewer, allowing the individual to rely heavily on his or her sense of sight. However, music that is contradictory to the visuals (perhaps through irony) requires the individual to rely on his or her sense of hearing to understand the meaning fully.

Technology to represent music visually has existed for several years. One of the most familiar examples is the visualization software in the Microsoft Windows Media Player, which presents music in a variety of different image options. The software does not give a true representation of a piece of music, but it responds visually to various aspects of music such as amplitude, rhythm, and tempo. Color-auditory synaesthesia-influenced software developed by Xuelong Li analyzes properties of music (such as amplitude, rhythm, tempo, tonality, and timbre) and assigns corresponding still images.³²

Since its inception in the early 1970s, the closed captioning system enables viewers to see the dialogue of speakers in film and television as text on the screen. Since 1993, every television built has been designed to make film and television more accessible to hearing-impaired people. Not only is the spoken word projected as printed text, but so is other audio information. Often cues like “ominous music,” the name of the

³² Xuelong Li, Dacheng Tao, and Stephen J. Maybank, “Visual Music and Musical Vision,” *Neurocomputing*, (2008).

song, or even the text to vocal music are provided for the hearing-impaired. While subtitles are helpful to those who are used to them as part of the viewing and listening experience they can be distracting to people not used to them.³³

The idea behind closed captions can also be found in the theatre in the form of opera supertitles. Though the primary purpose of opera supertitles has little to do with the hearing-impaired, this system has made both theatre and music more accessible to deaf individuals. Supertitles may be used to extract and apply meaning to what a hearing-impaired person sees and hears, but they are not always effective visual cues. Supertitles are usually translations of the text that the singers are performing to the vernacular and therefore do not accurately reflect what is heard. In order to be an effective visual cue, supertitles need to be displayed in the same language that is being sung.

Opera supertitles are not the only example of theatre that is more accessible to the hearing-impaired. Several theatre companies and organizations are actively involved in making provisions for the deaf in live productions. One of the most influential companies for the hearing-impaired has been the National Theatre of the Deaf, a performing group that focuses on presenting both pre-existing and original works in ways that are accessible to the hearing-impaired. Productions often incorporate signing and choreography with speech in performance modes ranging from Kabuki to opera.³⁴

³³ Stephen Gulliver and George Ghinea, "How level and type of deafness affect user perception of multimedia video clips," *Universal Access in the Information Society*, (2003), 12.

³⁴ Kanta Kochhar-Lindgren, "Hearing Difference Across Theatres: Experimental, Disability, and Deaf Performance." *Theater Journal* (2006), 421.

Dance is another medium that can enhance a deaf person's experience of a piece of music. From ballet to tap dancing, performers and choreographers create movements that not only convey the rhythmic nature of music but express its meaning. Ballets often tell a story without words, using music to drive the dancers' physical narrative. This unique genre of storytelling is appropriate for those without the ability to hear because it conveys both meaning and rhythm through visual information. Other types of dance, such as tap or interpretive dance can provide a similar function on a smaller scale.

Even without video, theatre, or dance, a live musical performance is seldom just an audible experience. The movements of the conductor, the sight of bows sweeping across strings, and the rise and fall of drum sticks can convey a lot of information to someone who cannot hear. Just as a hearing-impaired person may infer text and mood from the expressions on an actor's face, the mood of a piece of music is often visible in the movements of the performers. In a vocal performance, lip-reading and facial expression can provide many context clues to a deaf audience member. Also, the use of sign language in vocal performance can be an extremely useful tool to those who cannot hear. Signing in concerts has been a practice for over a hundred years, though it seldom implemented outside of deaf communities or special occasions (graduations, etc.).

Use of coordinated video or lights in a performance is another method of conveying music to the hearing impaired in concert. Large screens may be used in concerts to project imagery, such as the practice of showing clips from movies in pop concerts that feature movie themes. Lighting can also be used in innovative ways, as demonstrated in the well-known scene from *Mr. Holland's Opus*. For those unfamiliar

with the movie, the title character is a composer and music educator who experiences a disconnect from his deaf son. In one of the more touching moments of the movie, Mr. Holland puts on a concert for the school for the deaf that his son attends, performing a symphonic work while a panel of lights blink in rhythm with the music. Festivals of light and music occur frequently throughout the world (and not just as Christmas lights to the music of the *Trans-Siberian Orchestra*), with both live and recorded music.

Listening Through Vibrotactile Sensation

Vision is not the only other sense that hearing-impaired persons utilize when listening to music. Researcher Russ Palmer describes how he experiences sounds: “I know that when I switch off my hearing aids there appears to be a 'switching over' of senses to my 'tactile' senses.”³⁵ As people who can hear, we often think only about how sound vibrations reach our ears as music, while these vibrations are also sensed by the rest of the human body. Research has shown a correlation between how a person with normal hearing hears sounds and how a hearing-impaired person experiences vibrations. Recent studies on the brain reveal that deaf people sense vibrations in the same part of the brain that other people use for hearing. According to Dr. Dean Shibata, “the perception of the musical vibrations by the deaf is likely every bit as real as the equivalent sounds, since they are ultimately processed in the same part of the brain.”³⁶

³⁵ Russ Palmer, *Feeling the Music Philosophy*, (Finland, 1997), 3.

³⁶ University of Washington, “Brains of Deaf People Rewire to ‘Hear’ Music,” *ScienceDaily*, November 28, 2001, <http://www.sciencedaily.com/releases/2001/11/011128035455.htm> .

Russ Palmer makes observations about the way that music can create sympathetic vibrations in the body. He notes that lower tones can be felt in the feet, legs, and hips; mid-range tones can be felt in the stomach, chest, and arms; and higher tones can be felt in the fingers, head, and hair.³⁷ In terms of pitch, our range of hearing is much wider than our range of feeling. Similarly, certain parts of our bodies resonate in certain ways as the result of specific frequencies. Most of these frequencies are in lower range of our hearing, with some lying below our range of hearing (FIGURE 2). This idea of sympathetic resonances explains why sometimes we feel string vibrations from music in our lungs or in our eyes.

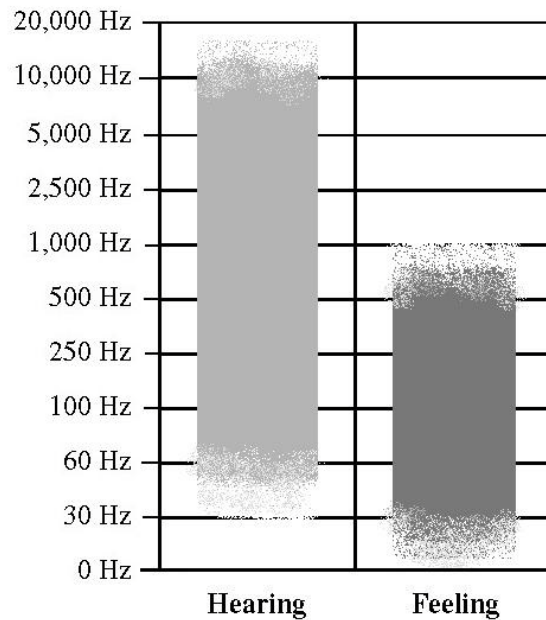


Figure 2: Range of hearing compared to range of tactile feeling.³⁸

³⁷ Russ Palmer, *Feeling the Music Philosophy*, 1.

³⁸ Bruel & Kjaer, *Human Vibration*, (Denmark, 1988), 7.

The use of vibrotactile cues to experience music has been applied in several ways over the past few years. Several simple methods, such as providing balloons to hold or having hearing impaired individuals sit close to sources of vibrations, have been applied in live concerts in the past, but in the last decade many advanced technologies have emerged that are designed to enhance the experience of music vibrations like never before. The Vibrato System, designed by Shane Kerwin, is a small device that enables a hearing-impaired person to feel music through their fingertips. The Tac-Tile Sound System is a portable floor designed by Russ Palmer that amplifies music vibrations through the feet.³⁹ Similarly, a company called Strike-A-Chord produces the Good Vibrations chair that amplifies music and routes its vibrations to sections of the chair.

The Baxter School for the Deaf in Maine has a specific room for listening to music where several 100-watt amplifiers are positioned face-down, sending vibrations through the floor and exciting the nerves of listeners. In addition to these amplifiers, there is an audio-spectrum analysis device that displays properties of the music as visual information (colors, swirls, lines, etc.). A recent concert in Toronto, billed as the “first rock concert for the deaf,” featured “emoti-chairs,” new devices that translate music into vibrations and blasts of air. In addition to these chairs, several visualizations were also provided to enhance the hearing-impaired audience’s experience, including visualizations, open captioning, and signing interpreters.⁴⁰

³⁹ Russ Palmer, *Feeling the Music Philosophy*, 5.

⁴⁰ Debra Black, “Concert Will Give Deaf Chance to Rock,” *Toronto Star* (February 6, 2009).

CHAPTER IV

MAKING MUSIC MORE ACCESSIBLE TO THE HEARING-IMPAIRED

As I have discussed in the previous chapter, the idea of making music more accessible to the hearing-impaired is not a new one. From signed vocal recitals to rock concerts with visualizations and “emoti-chairs,” a movement to enable the deaf to experience music has begun. Most (if not all) of this movement has involved an innovative presentation of existing music. While the use of pre-existing works is ultimately necessary to achieve the goal of making any and all music accessible to the deaf, at the present time it may be construed as ineffectual. The construction of original music can accommodate the unique listening perspective of a hearing-impairment more effectively.

In order to create a work of music geared toward the hearing-impaired, I have determined that three criteria should be met: the work must be accessible to a deaf person’s usable hearing, the work must contain some sort of visual element that reflects or enhances the music, and the work must employ some sort of vibrotactile stimulation that is reflective of the music. While meeting one or two of these criteria may provide enough information for many deaf individuals to enjoy a work of music, meeting all three would further ensure reaching all persons who experience hearing loss.

In describing an approach to music education for the deaf that she labels the “total perception approach,” Lau Chiu Kay writes that “the idea here is to educate the deaf child to perceive music naturally through multisensory channels, such as auditory, visual,

tactile, and kinaesthetic; the auditory mode, however, remains the main input channel.”⁴¹

In order to create music that can be audibly perceived by a hearing-impaired person several factors must be considered. The use of hearing devices and one’s unique residual hearing have a significant influence on how a deaf person might hear a piece of music.

It would be rather easy to write a piece of music and simply hope that people’s hearing aids and cochlear implants modify the sound so that it can be heard more accurately by the listener, but this is not likely to be the case because these hearing devices are optimized for speech, not music. While they may be helpful in amplifying certain frequencies, these devices cannot be trusted to transmit the music accurately; in fact, in some cases these devices may do more harm than good in a normal listening experience. Ultimately, the most helpful devices for listening to a live musical work are the simpler assistive listening devices and regular amplification. While residual hearing varies from person to person, it is in many ways more reliable than hearing aids.

Research in music education for the deaf suggests a clear hierarchy in the reception of different aspects of music. The easiest property of music for hearing-impaired persons to perceive is rhythm. While a deaf person may have difficulty recognizing the pitch of a sound, the metric pulse of a piece of music and the rhythms therein are often the first thing that hearing-impaired children grasp in early music education. Slower tempos and detached rhythms are more conducive for accurate listening, particularly when there is a sufficient release rate for each sound.⁴²

⁴¹ Rosalie Rebollo Pratt, ed., *Music Therapy and Music Education*, 147.

⁴² *Ibid.*, 133.

Another property of music that is relatively easy for a deaf person to perceive is the intensity and changes in amplitude of a musical work. When composing a work for the deaf, it would be easy to make the mistake of assuming that louder is better. Dalgarno suggests that “it is wise to assume that loud sounds will be uncomfortable or painful until proved otherwise. Care is needed with sound volumes to avoid putting off the very people we can help, and one should start by getting the volume right.”⁴³ While making the dynamics of a work too loud can be detrimental to its reception, a softer dynamic can decrease pitch discrimination.

If music is presented in a register that falls within a listener’s residual hearing, and its volume is conducive to listening, pitch can be understood more clearly. Most hearing-impaired persons retain residual hearing in the bass and tenor range of their hearing. Within this range, leaps of a minor third or larger are more easily perceived than stepwise motion of a minor or major second.⁴⁴ In order to insure that pitches are clearly heard by hearing-impaired audience members, a melody should consist of leaps of a third or larger.

The most difficult property of music for most deaf individuals to perceive is musical timbre. Distinguishing the sound of an oboe from that of a flute can be difficult even for someone with normal hearing, but it is especially difficult for someone with a hearing impairment. In order to increase the likelihood of a hearing-impaired audience to differentiate between instrumental timbres, a musical work should either contain

⁴³ Rosalie Rebollo Pratt, ed., *Music Therapy and Music Education*, 133.

⁴⁴ William B. Davis, *An Introduction to Music Therapy*, 215.

instruments with similar timbres or instruments with drastically different timbres (such as brass and strings).⁴⁵ Gfeller recommends using instruments with large vibrating surfaces, stating:

Poor auditory acuity can be accommodated by selecting rhythmic musical instruments with large vibrating surfaces, such as drums, pianos, bass tone bars, and xylophones. The piano (lower octaves) and bass or tenor instruments also meet the criteria for low frequency range and tactile access. In fact, some of these low frequency and percussive instruments are more easily heard than human speech (which is comprised of many high frequencies). Therefore careful selection of musical instruments is crucial to the success of listening activities.⁴⁶

Another factor to consider when selecting the instruments for such a composition is the visual performance of the instrument. The performance of most percussion instruments contains a great deal of revealing visual information, as does the performance of many stringed instruments through bowing or strumming motions. However, in order for visual cues to be useful in a listening experience, clear visibility of the instruments is essential.

Several genres of music may lend themselves to the hearing-impaired more than others. Vocal and choral music, for example, has several qualities that deaf persons may perceive over others. The text of a vocal work can provide a narrative and often reveals other qualities of the music to the deaf listener. Many hearing-impaired individuals have a talent for lip-reading, which in vocal music (if in a language understood by the listener) can convey the words more effectively than signing. If texts are provided, the words may

⁴⁵ William B. Davis, *An Introduction to Music Therapy*, 216.

⁴⁶ Kate Gfeller, "Musical Involvement and Enjoyment," 214.

act as a “road map” of sorts that a hearing-impaired individual may follow. Similarly, programmatic works in general may be more accessible to deaf audience members.

In addition to composing music that is geared to the hearing-impaired, it is important to provide some sort of visual aid that can enhance the perception of the music to someone with limited hearing. These visual cues can take several different forms, and may provide information about almost any aspect of the music: rhythm, volume, melody, mood, and timbre to name a few. Since it is often easier for a deaf person to perceive rhythm and amplitude than mood or timbre, it would be wise to provide visual clues that enhance these properties of music. A composer needs to keep in mind the visual aspect of a music performance itself: the patterns of a conductor or the rise and fall of drumsticks may provide a great deal of musical information to the hearing-impaired.

External visualizations may also reflect an underlying narrative of a musical work, providing a sense of direction and meaning to the music. There are many forms that a visual aid may take, from dance to video. The visual medium may be a pre-existing video or could be video controlled by a software that responds to music (such as Microsoft Windows Media Player). The visual cues could also come from a live element, such as dance or staging instructions for the performers. Whatever form the visualization may take, the result should be a carefully planned aid which reflects and enhances the experience of a piece of music.

The final component to consider is vibrotactile stimulation. A work for the hearing-impaired needs to be composed with consideration of how the work will be physically felt. At the basic level, the composer can assume that events that fall within

the range that people can usually feel vibrations will be understood better by many deaf persons than by a hearing composer. Other factors need to be considered, however. If the composer wants to avoid use of amplification and subwoofers, the instrumentation and performance space is going to play a large role in the somatic reception of the work. Ideally, the most evident vibrotactile properties of a work should play an important role in the musical narrative, conveying a sense of the music and enhancing the music where appropriate. The composer should also consider non-traditional means of perceiving these vibrations in performance, such as the use of technology or objects conducive to somatic stimulation.

CHAPTER V

COLLAPSE: A WORK OF MUSIC FOR THE HEARING-IMPAIRED

The purpose of this research is to provide new avenues of musical composition that may appeal to the hearing-impaired population. As a result of this research, a preliminary work has been composed that applies the criteria outlined in the previous chapters. This piece, entitled *Collapse* (see Appendix A), is designed to appeal to a hearing-impaired person's own unaided hearing, as well as his or her visual and somatic senses. While written with the express purpose of appealing to a deaf audience, the work is not lost on hearing ears.

Collapse utilizes an ensemble of seven performers: three cellists, two basses, and two percussionists, on timpani and bass drum. The underlying idea in the piece is a gradual motion of expansion and contraction that occurs on multiple levels. The work is programmatic, evoking the imagery of a star at the end of its life. The star, which has burned consistently for billions of years, begins to expand as it exhausts the supply of hydrogen at its core. As it expands it cools and forms a "red giant." After it reaches a certain point, it begins to shed its outer atmospheres and shrinks to form a "white dwarf" that cannot support its own mass. Eventually the star reaches the Chandrasekhar limit and explodes in a massive "supernova" that collapses to become a "black hole," which slowly envelops everything in the surrounding space. This process, which would normally take millions of years, is conveyed musically in a matter of minutes.

This expansion and collapse occurs on multiple levels simultaneously: rhythm, dynamics, and pitch (FIGURE 3). One of the defining properties of *Collapse* is a constant underlying pulse that undergoes gradual expansion and contraction over the course of the work. At points of stability (mm. 1, 72, and 131), this pulsing motion occurs in all voices; while in periods of expansion or collapse the pulse occurs primarily in the percussion. The piece begins with all of the instruments marking this pulse in 3/4. As expansion begins to occur, the meter moves from 3/4 to 4/4, augmenting the distance between downbeats by simply adding a beat (as opposed to a gradual *rallentando*). As this first expansion reaches its greatest diameter and temporary stability (the Red Giant phase), 4/4 becomes 5/4 and the tempo slows down for the first time. As this expansion reaches its greatest diameter and temporary stability (the Red Giant phase), 4/4 becomes 5/4 and the tempo slows down for the first time.

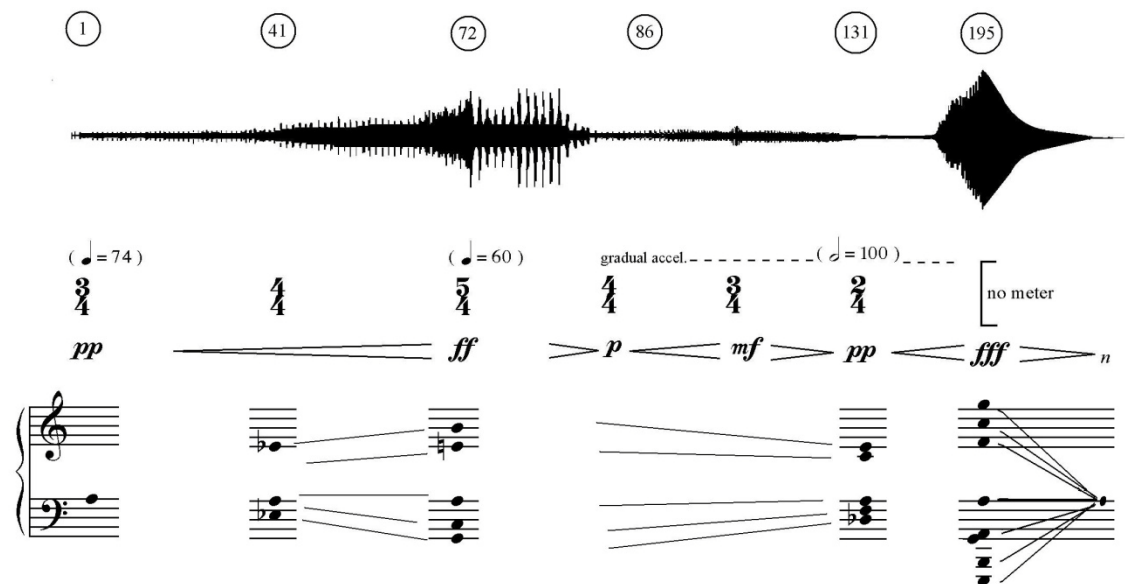


Figure 3: Expansion and contraction of dynamics, tempo, meter, and pitch.

At m. 86, the meter returns to 4/4 and the tempo begins a very gradual *accelerando* led by a constant quarter note pattern in the first timpani part. As the tempo continues accelerating, the meter changes to 3/4. At m. 120, the strings begin to play obfuscating the pulse by introducing a 2/4 against the 3/4 in the bass drum. This motion anticipates the resolution of this contracting motion to a final instance of stability: a fast 2/4 section (the White Dwarf phase). Unable to maintain an equilibrium, the tempo and amplitude begin to increase as the ensemble rushes headlong towards the climax of the work: a sudden and intense intervallic expansion (the Supernova phase). For the final two minutes of music, all sense of meter is lost as the independent voices move slowly towards the tonal center of the work and fade into silence (the Black Hole phase).

The tonal material of *Collapse* also reflects this idea of expansion and contraction. At the largest formal level, the intervals between parts expand and contract over the course of the entire work (FIGURE 4). On the smallest level, the underlying motif that

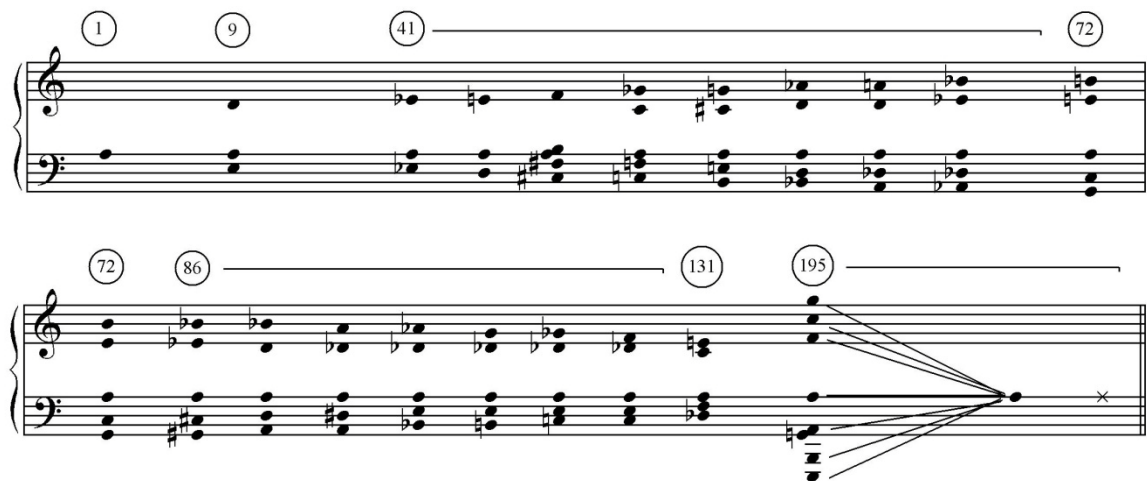


Figure 4: Detailed expansion and contraction of pitch.

pervades the work exhibits the same expansion and collapse, both in interval and rhythm (FIGURE 5).



Figure 5: Expansion and contraction in the underlying motif.

The work begins with each instrument playing the steady pulsing figure at unison, each voice bringing a different timbre to the sound (pizzicato, harmonics, tremolo, etc.). The motif is introduced in m. 9, signifying the circumference of this star that will soon begin expanding. The motif is traded between the first and second cellos, gradually overlapping each other. In measure 42 the intervals between pitches begin to expand. At m. 72, stability is achieved as all of the instruments resume their initial role within a pulsing motion reminiscent of the beginning of the work. The idea is expanded to a more complex sound as the individual timbres have grown to larger figures, but the motion is the same. In m. 76, the second cello recalls the initial motif, the last time that it is heard through a single voice.

The distance between the outer pitches begins to contract in measure 86. The motif is suggested through the cellos playing sustained tones, bowing in rhythms that slowly become defined. As the tempo begins to accelerate out of control and the meter begins to contract, the intervals grow closer together until achieving stability at m. 131

with a chord consisting of stacked thirds. At m. 195, the work climaxes with a chord of stacked fifths spanning more than four octaves. The final collapse occurs as a gradual glissando in all voices, moving towards the tonal center of the work. While this contraction to the pitch center that began the work could be mistaken as a return to the original idea, the destination is a completely new entity: no longer a star producing light, but a singularity that consumes all light. The final sound that the listener perceives is a bass drum roll slowly fading into silence, as though the gravity of the black hole has distorted all sense of pitch.

Many aspects of the music lend themselves to the limited hearing of a deaf person. The frequencies fall primarily in the tenor and bass register, making the music more accessible to one's residual hearing. The initial slow tempo allows time to establish the underlying pulse, while the use of silence after each unison statement is intended to leave appropriate time for a hearing impaired person to perceive the release of each sound. The pulsing figure at m. 72 achieves a similar sensation. This pulsing figure throughout the work also provides a guide for perceiving the rhythms or the other instruments, which can be both complimentary and contradictory at times. The patient unfolding of the melodic material (mm. 9 through 41) is designed to provide sufficient time for someone with limited hearing to absorb the motif that serves as the basis of the work. The gradual changes in dynamics are intended to diminish the undesirable distortions caused by recruitment.

The use of leaps and larger intervals in the motif and throughout the work is intended to improve the accuracy of a hearing-impaired individuals' pitch discrimination;

while the gradual motions of expansion and contraction should be conceived not as individual pitches, but more as a larger motion outward or inward. As the work progresses, these motions become smoother and individual pitches become more obscured. In the first expansion (mm. 41 through 71), the music undergoes stepwise motion over time through leaps. In the first contraction (mm. 86 through 131), the music undergoes gradual stepwise motion, though the leaps of the motif are hidden in the harmonies of the cellos. At the final collapse (m. 195 to the end), stepwise motion has become a slow glissando, the ultimate manifestation of the obscured pitch.

The instrumentation of the work was chosen carefully to cater to someone with a hearing impairment. All of the voices fall in two instrument families (strings and membranophones), creating a rather unified timbre. All of the instruments fall in a range that is most likely to be perceptible to a deaf audience, but they can also convey a sense of the music visually in a performance. Through the bowing and plucking of strings or the rise and fall of timpani mallets an audience member can infer rhythm, intensity, and even pitch.

The visual aspect of the work is an essential part of the performance. In addition to the sight of the performers playing their instruments, the work calls for a visual element that enhances the meaning of the work and supports the narrative of the music. The choice of visual medium is left up to the performers; suggestions include choreographed dance, creative staging, or video. A video presentation is provided with the work (Appendix C) that depicts the collapse of a star. When choosing a visual element, performers should not feel limited to the portrayal of a star collapsing, but

should feel free to express the idea of “collapse” as they see fit. Whatever visual element is incorporated, it is important that the instruments still be visible and in a performance space conducive to vibrations from the instruments.

The experience of vibrations is also an important factor in the performance of this work. These instruments lend themselves to vibrotactile sensation, particularly the timpani and bass drum, whose vibrations are highly perceptible to even the most inexperienced listener. Although certain intended to be heard, the percussion section’s primary role in this work is to convey somatic sensations. The pulse kept by the bass drum becomes a sort of a heartbeat of the work, and the use of rolls in the timpani and bass drum are intended to be felt just as much as they are heard. The bass drum performer is instructed to experiment with the placement and angle of the bass drum in the performance space. For example, in a smaller space it might be advantageous to angle the bass drum horizontal to the floor, while in a larger performance hall it might be more effective to point the head towards the audience.

While the percussion instruments act as the primary vehicle for vibrations, especially to the hearing members of an audience, the vibrations created by the strings are equally important in the reception of this work to the hearing-impaired. In some performance spaces, it may be necessary to amplify the instruments (particularly the strings) to achieve a better balance and to utilize vibrations more effectively. In the performance notes, the composer encourages experimenting with exterior sources to enhance the experience of vibrations. Any of the methods mentioned in chapter 3 can be utilized, but the most efficient solution is probably the use of an inflated balloon.

Balloons can be provided to each audience member before the performance, and everyone can be instructed to listen to the music with their ears, eyes, and fingertips while holding the balloon. Whenever and wherever this piece may be programmed, care should be taken to consider the acoustics of the room in order to insure a complete listening experience.

CHAPTER VI

CONCLUSIONS

A person who is hearing-impaired can experience music as completely as someone with normal hearing. Even people with profound hearing disabilities usually possess some degree of residual hearing and an ability to perceive sounds at high volumes. Through utilizing tendencies of residual hearing, music can be composed that is more perceptible to persons with hearing impairments. Recent research in the field of neuroscience suggests that the brains of individuals with pre-lingual hearing impairments are “rewired” to perceive vibrations in the same areas of the brain that most people perceive music, supporting the notion that many deaf people hear music more through vibrations than auditory hearing. In addition to “feeling the music,” studies show that deaf persons often rely on sight to inform them of certain aspects of music.

The idea of making music more accessible to the hearing-impaired is not new, in recent years many strides have been made to enhance the listening experiences of hearing-impaired persons through innovative methods. From vibrating chairs and floors to light shows and spectral visualizations, technology has opened up a world of possibilities for representing music faithfully through other mediums. Most of the attempts to make music more accessible to the hearing-impaired have involved some sort of enhancement or modification of an existing work, often the addition of another medium (such as video or sign language). The idea of creating music that caters to the hearing tendencies of a deaf audience is a vastly unexplored concept, one with the

potential of opening a whole new world of sound to people with hearing loss.

Collapse is a work written with the intention of being accessible to the hearing-impaired. The composition is a multisensory experience, where visual and vibrotactile events are designed to correspond to and enhance the music, expressing the musical narrative on multiple levels at the same time. The work satisfies many of the criteria defined in this document as perceptible to most deaf persons.

This document is only a small step forward in a field that could be beneficial to many hearing-impaired people. In order to fully explore this idea, further research needs to be done that includes surveys of deaf individuals and their perception of such music. The tendency for previous researchers to focus on using controlled synthesized sounds could be a practical first step, but the end result should feature live acoustic music in a variety of genres.

BIBLIOGRAPHY

- Adams, John W., and Pamela S. Rohring. *Handbook to Service the Deaf and Hard of Hearing: A Bridge to Accessibility*. London: Elsevier Academic Press, 2004.
- Black, Debra. "Concert Will Give Deaf Chance to Rock." *Toronto Star* (February 6, 2009).
- Bunt, Leslie, and Sarah Hoskyns, eds. *The Handbook of Music Therapy*. New York, New York: Brunner-Routledge, 2002.
- Darrow, Alice-Ann, and Julie Novak. "The Effect of Vision and Hearing Loss on Listeners' Perception of Referential Meaning in Music." *Journal of Music Therapy*, vol. 44, no. 1 (Spring 2007): 57.
- Darrow, Alice-Ann. "Music for the Deaf." *Music Educators Journal*, vol. 71, no. 6. (February 1985): 33-35.
- Darrow, Alice-Ann. "Sounds in the Silence: Research on Music and Deafness." *Applications of Research in Music Education*. vol. 25, no. 1 (Fall-Winter 2006): 5-14.
- Darrow, Alice Ann. "The Role of Music in Deaf Culture: Deaf Students' Perception of Emotion in Music." *Journal of Music Therapy*, vol. 43, no. 1 (Spring 2006): 2-15.
- Davis, William B., and Kate E. Gfeller and Michael H. Thaut. *An Introduction to Music Therapy: Theory and Practice*. Dubuque, Iowa: William C. Brown Publishers, 1992.
- Edwards, Eleanor M. *Music Education for the Deaf*. South Waterford, Maine: The Merriam-Eddy Company, 1974.
- Gfeller, K. et al. "Musical Involvement and Enjoyment of Children Who Use Cochlear Implants." *Volta Review*, vol. 100, no. 4 (September 1998): 213-233.
- Gulliver, S.R., and G. Ghinea. "How level and type of deafness affect user perception of multimedia video clips." *Universal Access in the Information Society*, vol. 2, no. 4 (November 2003): 374.

- International Conference on Deaf Culture. *The Deaf Way: Perspectives from the International Conference on Deaf Culture*. Edited by Carol J. Erting, et al. Washington, DC: Gallaudet University Press, 1996.
- Kochhar-Lindgren, Kanta. "Hearing Difference Across Theatres: Experimental, Disability, and Deaf Performance." *Theater Journal*, vol. 58 (2006): 417-436.
- Lang, Harry G., and Bonnie Meath-Lang. *Deaf Persons in the Arts and Sciences: a Biographical Dictionary*. Westport, Connecticut: Greenwood Press, 1995.
- Lerner, Neil, and Joseph N. Straus, ed. *Sounding Off: Theorizing Disability in Music*. New York, New York: Taylor & Francis Group, 2006.
- Li, Xuelong, Dacheng Tao, and Stephen J. Maybank. "Visual Music and Musical Vision." *Neurocomputing*, vol. 71 (2008): 2023-2028.
- Marschark, Marc, and Patricia Elizabeth Spencer, eds. *Oxford Handbook of Deaf Studies, Language, and Education*. New York, New York: Oxford University Press, 2003.
- Moore, Brian C.J., and Geoffrey A. Moore. "Discrimination of the Fundamental Frequency of Complex Tones With Fixed and Shifting Spectral Envelopes by Normally Hearing and Hearing-Impaired Subjects." *Hearing Research*, vol. 182. (2003): 153-163.
- Pijl, Sipke, and Dietrich W.F. Schwarz. "Intonation of Musical Intervals by Musical Intervals by Deaf Subjects Stimulated With Single Bipolar Cochlear Implant Electrodes." *Hearing Research*, vol. 89 (1995): 205-211.
- Pratt, Rosalie Rebollo, ed. *Music Therapy and Music Education for the Handicapped: Developments and Limitations in Practice and Research*. St. Louis, Missouri: MMB Music Incorporated, 1993.
- Scheetz, Nanci A. *Psychosocial Aspects of Deafness*. Boston, Massachusetts: Pearson Education Incorporated, 2004.
- Schirmer, Barbara R. *Psychological, Social, and Educational Dimensions of Deafness*. Needham Heights, Massachusetts: Allyn and Bacon, 2001.
- Soto-Faraco, Salvador, and Gustavo Deco. "Multisensory Contributions to the Perception of Vibrotactile Events." *Behavioural Brain Research*, vol. 106 (2009): 145-154.
- Sucher, Catherine M., and Hugh J. McDermott. "Pitch Ranking of Complex Tones by Normally Hearing Subjects and Cochlear Implant Users." *Hearing Research*, vol. 230 (2007): 80-87.

- Thai-Van, Hung, Christophe Micheyl, Arnaud Norena, Evelyne Veillet, Damien Gabriel, and Lionel Collet. "Enhanced Frequency Discrimination in Hearing-Impaired Individuals: A Review of Perceptual Correlates of Central Neural Plasticity Induced by Cochlear Damage." *Hearing Research*, vol. 233 (2007): 14-22.
- Turner, Christopher W., Lina A.J. Reiss, and Bruce J. Gantz. "Combined Acoustic and Electric Hearing: Preserving Residual Acoustic Hearing." *Hearing Research*, vol. 242 (2008): 164-171.
- Xu, Li, and Bryan E. Pfingst. "Spectral and Temporal Cues for Speech Recognition: Implications for Auditory Prostheses." *Hearing Research*, vol. 242 (2008): 132-140.

APPENDIX A. SCORE TO *COLLAPSE*

Due to formatting limitations of this document, the score is included as a separate pdf document.

APPENDIX B. AUDIO FILE FOR *COLLAPSE*

An audio recording of *Collapse* has been included as a supplemental file. The recording was made using synthesized instruments.

APPENDIX C. VIDEO FOR PERFORMANCE OF *COLLAPSE*

A video has been included as a supplemental file. This video is intended to be used in the performance of *Collapse* and is discussed in the body of this document.