Soundscapes as therapy: An innovative approach to chronic pain and anxiety management

by

Mehdi Mark Nazemi

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Name: Mehdi Mark Nazemi
Degree: Doctor of Philosophy
Title: Soundscapes as therapy: An innovative approach to chronic pain and anxiety management

Examining Committee: Chair: Lynn Bartram
Associate Professor
Diane Gromala
Senior Supervisor
Professor
Barry Truax
Supervisor
Professor Emeritus
School of Communication
Steven J. Barnes
Supervisor
Instructor
Department of Psychology
University of British Columbia
Chris Shaw
Internal Examiner
Professor
Jillian Scott
External Examiner
Professor Emerita
Institute for Cultural Studies in the Arts
Zurich University of the Arts

Date Defended/Approved: April 11, 2017
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Abstract

Chronic pain, which can last months to years, is considered to be a progressive and multifactorial disease that has been the subject of study for centuries. Chronic pain emerges long after the process of tissue healing might have occurred, and results from complex interplay amongst several antecedents. Because the disease is incurable, the primary approach is that of “managing” chronic pain, which includes both short-term and long-term forms of neuroplasticity enabled by non-invasive therapeutic practices. It is not a surprise that the strong mind-body connection has inspired researchers and practitioners to use music and environmental sounds as a tool for healing. The approach for using music and environmental sounds in clinical settings has begun to grow, yet the focus of its use is limited when it comes to chronic pain management. Emphasis on the act of listening rather than simply hearing has been shown to have therapeutic effects in a number of contexts, such as traumatic brain injuries, and dementia. As part of this research, we are examining the potential effects act of listening has on patients suffering from chronic pain.

This research explores an approach of using soundscapes as therapy to help chronic pain patients manage their pain and anxiety. A review of literature in pain studies, auditory perception, music therapy, acoustic ecology, and immersion was conducted in developing a systematic approach for using soundscapes as a form of therapeutic intervention. In addition, three separate experiments were conducted with chronic pain patients to support the findings of this form of therapy, including future directions for improvement.

Keywords: Chronic Pain; Soundscapes; Therapy; Immersion; Biofeedback; Music Therapy; Auditory Perception
I am humbled and grateful to my family and friends who have supported me through this journey.
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<td>Background</td>
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<tr>
<td>CAM</td>
<td>Complementary and Alternative Medicine</td>
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<td>CFS</td>
<td>Chronic fatigue syndrome</td>
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<td>CIP</td>
<td>Congenital insensitivity to pain</td>
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<td>CP</td>
<td>Chronic Pain</td>
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<tr>
<td>dB</td>
<td>Decibel</td>
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<td>EEG</td>
<td>Electroencephalogram</td>
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<td>ITD</td>
<td>Interaural time difference</td>
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<td>SCL</td>
<td>Skin Conductance Level</td>
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Field recording at Minnekhada Park, British Columbia, Nazemi, 2015.
Chapter 1.

Introduction

Chronic pain, which can last months to years, is considered to be a mysterious, idiosyncratic, and progressive condition that is distinct from acute pain (IASP, 2011). Whereas acute pain is deemed to be an adaptive response that protects us from further damage and is expected to subside once healing begins, chronic pain is believed to be a malfunction in the pain response system, where it remains in a permanent immotile state of hypersensitivity. According to a research report, approximately 1.5 billion people worldwide suffer from chronic pain (Global Industry Analysts, 2011). The experience of chronic pain has a considerable psychosocial impact that over time can erode an individual’s identity, mental health, relationships amongst friends and family, and general quality of life. These consequences have led researchers from various disciplines including medicine, psychology, physiotherapy, health-based technology, and creative arts therapy to tackle the causes, mechanisms, management and course of chronic pain. As a result, new treatments are being developed in an attempt to reduce the personal burden on patients, including the considerable social and economic costs that are associated with this condition.

Since there is no cure for chronic pain, the focus is on managing the symptoms through varied forms of medical interventions, including complementary, and alternative (CAM) forms of therapy. These therapies include mindfulness meditation, sound-based therapies, relaxation practices, and art therapy. Music therapy is one type of therapeutic intervention that has been shown to decrease a person’s pain levels. For example, it is believed that listening to music may alter the neural pathways that are associated with the perception of pain (Holden, 2013). Investigations into the role of music as an analgesic vary considerably from the methods used to the type of music administered (Schneck and Berger, 2006). Although a body of research has been developed over the past several
decades on the therapeutic benefits of music therapy (see Koen, 2008), surprisingly, the research is sparse when understanding how recordings of environmental sounds, structured as compositions called soundscapes, can be used for stress and pain alleviation. Currently, the field of music and sound-based therapies in relation to chronic pain is in a nascent stage and remain largely unevaluated due to a lack of focus and rigorous research. Chronic pain patients are known to have highly increased sensitivity to sensory input (see Woolf, 2011). In consequence, any facilitators of such a therapy must be informed about how chronic pain works and how the patients are impacted by the administration of sound-based therapies. The focus of this dissertation is in part to fill this gap in knowledge by investigating the efficacy of soundscapes compositions in chronic pain therapy, and propose this as an alternative approach to pain and anxiety management.

Therefore, in my research, therapy\(^1\) is defined as a process for chronic pain sufferers to self-manage their anxiety using a combination of an immersive listening experience and biofeedback. This process of listening may help with thought redirection, provide relaxation and the sense that they may have some control over their pain (Alvarsson, 2010).

Theories and practices from the field of acoustic ecology are used to inform an arts-based model that, as I demonstrate, provides an effective therapy for chronic pain patients. In doing so, it enables patients to self-manage their pain simply through listening to soundscapes. In addition, I will attempt to clarify how men and women who suffer from chronic pain exhibit varied sensitivity responses to audio frequencies which influence their listening preferences to environmental sounds.

1.1. Rationale

The inspiration for this research came about from the extensive work conducted at Simon Fraser University by researchers from the World Soundscape Project (WSP), in

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\(^1\) The term “therapy” usually implies that a clinician is involved. This definition is consistent with traditional definitions that include: (1) of or relating to the treatment of disease or disorders by remedial agents or methods, (2) having a beneficial effect on the body or mind, (3) and producing a useful or favorable result or effect.
conjunction with the possibilities, I saw in new technological approaches such as biofeedback and virtual reality (VR). VR especially interested me because of the level, or depth, of immersion, one can experience through creating a perceptual change in environment. The goal was to produce a similar result – a dramatic change in perception – through the act of listening, and without the aid of visuals or a head mounted display (HMD).

The challenge with this research is that it is interdisciplinary. The position that I take to approaching pain and anxiety management are from the fields of acoustic ecology and music. Therefore, it is the combination of the study of chronic pain, the research and treatment of which tends to be medical in nature, and music/acoustic ecology, the impact of which is more experiential that I explore as part developing a non-invasive and easy approach to pain and anxiety management. An understanding of perception allows us to bridge the gap between these two disciplines thereby allowing for the creation of immersive soundscapes that have positive therapeutic effects for patients. In this dissertation, the term perception is drawn from cognitive psychology which is a branch of psychology that deals with perception as a process of recognizing and interpreting sensory stimuli. The experience of pain is more than just a physical response and involves a complex, multifactorial process that engages both mind and body. The perception of pain is individualized and influenced by our prior knowledge, cultural roots, gender, sensory stimulation and expectations. For example, cognitive psychologist Jerome Bruner’s definition of perception which involves a three-step analytical cycle can be applied to the connection between listening to soundscapes and pain reduction. Perception begins with an expectancy or preparation; that is, “we not only see, but we look for, not only hear, but listen to” (Bruner, 1951, 123-4). In this research attentive listening is required and this level of engagement causes an arousal of central cognitive and motivational processes. The act of listening allows the patient to be distracted from their current state of pain and anxiety similar to virtual reality-based interventions and mindfulness-based meditation techniques (Sanchez-Vives, 2005; Zeidan, 2010). The second step involved in the process of perception is the input stimuli derived from the environment. In this case, it is stimulating the somatic senses through the various sounds captured. On interpretation, these provide information about the environment which is in line with Barry Truax’s acoustic communication model (Truax, 2001). The model plays an integral role in the
development of the soundscape compositions used in this research. Lastly, a type of confirmation that is attained from the input modulates the experience – in this context, it allows the patient to feel less pain and stress. To verify this anticipated outcome, I use biofeedback to measure the physiological changes associated with pain and stress while the patients listen to soundscape compositions.

1.2. Method

To clarify how soundscapes can be used as a therapeutic intervention in chronic pain, I will cover the following major topics: (1) chronic pain and auditory perception; (2) the state of the literature on music therapy; (3) theoretical impetus for incorporating methods from acoustic ecology to develop specialized soundscape compositions for chronic pain management; (4) design guidelines for situating soundscape compositions as a therapeutic intervention as shown in Figure 1.1. The first two chapters are devoted to an understanding of chronic pain and its impact on hearing. The difference in hearing responses between chronic pain sufferers and healthy people will be a first step in designing a focused sound-based therapy.

This background knowledge leads us into the third chapter about music. Since music therapy is one of the oldest forms of art therapy, I examine the theories of how music is used to provide symptom relief. I adapt specific musical parameters such as pitch, tempo, rhythm, and cognitive processing to understand how we can structure environmental sounds as compositions for therapeutic use. Chapters 5 to 7 are dedicated to the theories and methods of the field of acoustic ecology. These include soundwalks, fixed and moving perspectives, multi-channel and binaural playback methods, field recording techniques, immersion, and presence. The chapters include two experiments that help us understand how different environments (natural vs. urban) affect patients. In addition, I examine how particular structural components of soundscapes and the perception of immersion can influence pain and stress levels.
Finally, the review of the various literature from pain studies, music therapy, and acoustic ecology, in conjunction with my studies with patients, will lead to a discussion of how soundscape compositions can be developed as a form of therapy for chronic pain sufferers. A breakdown of sonic properties and guidelines are provided suggesting ways to improve the recording process to enhance the immersive quality of soundscapes. In addition, I look towards how this research can be expanded upon by including real-time data acquisition from the body using sensors to generate soundscape compositions procedurally. An adaptation of the acoustic communication model will be presented that illustrates the possibility of a system that can produce soundscapes for self-management of pain and anxiety. Therefore, the theoretical contribution of this research is as follows:

1) When using sound as a form of therapy specifically for chronic pain patients, we must be mindful of the auditory content, especially the loudness level of mid to high frequencies as illustrated in user study 1. Hence, a general form of sonic therapy may not be appropriate for people with chronic pain.

2) I address the problem of anxiety and chronic pain management by providing an individualized therapeutic experience using a combination of active listening, soundscape composition, and analyzing the physiological changes in real-time using biofeedback technology.

3) (Figure 10-1) Finally, a procedural acoustic communication model is proposed that combines the theories of acoustic ecology, music, the technological aspects of sound creation, and the listener’s experience to auditory content in real-time.
Chapter 2. The experience of pain

The interdisciplinary approach of this research requires us to have an understanding of chronic pain. Therefore, to define chronic pain, the following topics will be reviewed in this chapter: (a) the challenge of pain (b) gender difference in pain perception (c) perception of pain and current definitions; (c) psychological fallout from chronic pain.

2.1. The Challenge of Pain

Pain is a personal and subjective experience: It is self-directed and reflects the internal state of our body that is modulated temporally; it is influenced by prior knowledge, our cultural roots, and expectations (both personal and social). It is also affected by previous injury and our evaluations of such injuries. Pain is considered to be subjective, and there are no known or regularly agreed-upon biomarkers that are usually found in other conditions (Borsook, 2011).

From a biomedical perspective, pain has been described as a problem, a puzzle, a challenge or a mystery (see Moscoso, 2012). In modern Western society, pain is thought of as a source of sorrow, suffering, hopelessness and frustration, and society wishes that this undesirable experience should be avoided at any cost (Honkasalo, 1998). The highest point of bodily pleasure as described by the ancient Greek philosopher Epicurus, is pain aponia, the absence of pain (Reale, 1985).

However, the sensation of pain cannot be ignored or permanently removed because pain is recognized as a defining feature of human existence. While the experience of pain is universally accepted, it is nevertheless a fundamentally subjective and individualized experience (Buylendijk 1962; Morris 1991). Although behavioural and/or pharmaceutical interventions are often necessary to treat or mitigate pain, the complete eradication of pain would ultimately lead to one’s demise. This is because pain functions as a warning system that protects us from threats that may impact our survival such as injury or infection. Therefore, from an objective standpoint, pain is necessary to
stay alive, providing a signal to help us avoid further injury or disease.

2.2. Perception of Pain and Current Definitions

Throughout history, differences in theories of how sensitivity to pain is understood have set unequal and often unjust social expectations. These ideas of differences in how pain is experienced are not only based on gender or sex, but include race, ethnicity, age, class, and weight. Examples of this include how women have been stereotyped as having a higher pain threshold and when given a sedative, while men receive stronger medication for their pain (Hoffmann, 2008; Butler & Moseley, 2008). Another example is found in a recent study that demonstrated that among African Americans there is a stronger link between emotions and pain experienced than is the case with Whites (see Riley, 2002). Furthermore, a literature review performed by experts in pain revealed that there is a growing racial and ethnic disparity in pain perception assessment and treatment across all types of pain in the United States (Green, 2003).

It is important to acknowledge that across all sensory modalities an individual respond to and experiences pain differently. Therefore, pain includes perceptions that can shift rapidly from one person to the next, and in some cases how it is evaluated may not align itself to the extent of an actual injury or noxious stimuli (see Bourke, 2012).

For some, pain becomes an intensely personal experience, and communicating with others may feel both dangerous and even impossible. Elaine Scarry delves further into this experience in her book *The Body in Pain* by suggesting that pain is an unshareable experience because it is a private, subjective event that “does not simply resist language but actively destroys it” (Scarry, 1985, 4). She explains that physical pain “has no referential content. It is not of or for anything” and therefore it “resists objectification in language” (Scarry, 1985, 4-5). Scarry focuses on the oppressive quality of pain and is “inexpressible” because unlike having feelings for somebody or something that “moves the individual beyond the boundaries of his or her body” (Csengel, 2012, 1-5), physical pain lacks referential content and therefore makes the experience difficult to represent in language.
2.2.1. Contemporary Approach to Understanding Pain

Over time, the Cartesian dualist approach was refined, and other theories evolved from Descartes’ model, such as the Specificity and Pattern theory. The fundamental tenet of the Specificity theory is that pain is an independent sensation with specific peripheral sensory receptors that respond to damage. These receptors send signals via nerve fibre pathways in the nervous system that lead to target centres in the brain. The amount of pain experienced is directly proportional to the amount of tissue damage incurred by the human body (Moayedi & Davis, 2012). The Pattern theory posits there are no specialized receptors in the skin. Instead there are “sense organs” that each respond differently to a dynamic range of stimulus intensities by encoding a unique profile using impulses generated by a spatiotemporal pattern (Moayedi & Davis, 2012).

The problem with these theories, including Descartes’, is that they do not account for the psychosocial aspects of the experience of pain. Many of the theories and methodologies were biased and left many questions unanswered when it came to understanding the mechanisms of pain (Melzack & Wall, 1965). A shift came about when Ronald Melzack and Patrick Wall developed the Gate Control theory. In the late 1960’s, Melzack and Wall explained that the spinal cord modulated pain sensations which comprised of a “gating system.” This “gating system” controlled ascending signals from the peripheral nervous system and descending signals from the brain, which took into account influences by cognitive processing and emotions. This theory fundamentally changed our understanding of pain because it included the phenomenological experience of pain as well as its modulation due to biopsychosocial factors that is unique to each (Melzack & Wall, 1965). Therefore, in 1975 the International Association for the Study of Pain revised and modernized the definition of pain to “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage.” By considering the psychology and social aspects, pain is no longer understood as a mere biological mechanism that is tied to the stimulus.
2.3. Chronic Pain

There are two major categories of pain: acute and chronic. Chronic pain has mystified mankind for centuries because it lacks the structural pathology that we see with acute pain or other forms of diseases and therefore appears to result from a complex interplay amongst several antecedents (Melzack, 1983). It is believed to be a malfunction in the pain response system, where it remains in a permanent immotile state of hypersensitivity (Gatchel, 2007). Whereas acute pain is considered an adaptive response that protects us from further damage following some injury or infection, and is expected to subside once healing begins, chronic pain emerges long after the process of tissue healing might have occurred. Because there is no cure, the approach to treating chronic pain tends to be a long-term process involving continual and varied forms of medical treatments, based on a biopsychosocial model (Gatchel, 2007). In this model, body (physiology), mind (psychology) and social context (sociology) are factors that need to be attended to over time to help reduce the effects of chronic pain. The biopsychosocial model has become widely accepted because it provides a comprehensive approach that covers a range of chronic pain symptoms (see Borrell-Carrio, 2004). According to Bruce Nicholson, chronic pain can be subdivided into two broad categories: neuropathic which is associated to damage or disease that affects the somatosensory nervous system and nociceptive pain is tissue damage that is described as sharp, throbbing, or aching pain (Nicholson, 2006).

I will outline three examples that illustrate the complex experience of pain without obvious tissue damage. These types of pain fall in the category of neuropathic pain, which is the result of damage caused to nerves that carry information about pain. This type of pain produces sensations that can be described as shooting, electric, stabbing, pounding, or burning.

**Example 1:**

A headache is a common painful experience that occurs in 12% of the population in North America, and about 14 million people experience chronic headaches daily (Migraine Research Foundation, 2016). Most of us may recognize the cause of a headache initiated from anxiety, alcohol consumption, or fatigue. However, severe forms of migraine or tension headaches are a collection of neurological symptoms. In such
cases, faint symptoms that may go unnoticed occur prior to a headache, such as mood change, excessive yawning, and craving for food. (Wang, 2013). This may be followed by an aura that tends to produce visual anomalies such as shimmering lights and or patterns which then advance to a headache on one side of the head. The experience of pain gradually grows to turn into pounding, throbbing, or tenderness with increased sensitivity to light, sounds, and smells (Burstein, 2011). Some sufferers experience nausea and vascular shutdown of gastrointestinal function due to the excessive pain or strong migraine medications. These severe types of headaches can last anywhere from 4 to 72 hours (Migraine Research Foundation, 2016). Diagnosing the root cause of a migraine is extremely challenging since the symptoms can vary widely amongst men and women. It is important to treat an acute migraine in order to prevent the development of a chronic migraine.

Example 2:

A condition that is rare yet causes severe pain to a specific area is Trigeminal Neuralgia. Because of its specificity, one may think that it is a localized pathology, yet the source remains elusive. One potential cause is believed to be blood vessels that are pressed on the trigeminal nerve as it exits the brain stem; the compression of this blood vessel over time damage the protective coating around the nerve, known as the myelin sheath, leads to the pain symptoms. It is thought that people who have Multiple Sclerosis are susceptible to this condition because the disease causes deterioration of the trigeminal nerve’s myelin sheath (Meaney, 1995). The condition elicits excruciating pain in the face with stabbing on one side that some have described as like an electric shock (Trigeminal Neuralgia Fact Sheet, 2013). The occurrence of the pain is sporadic, and even the gentlest stimulus around the trigger point, usually in the area around the mouth, may set off the pain. The condition occurs equally in both men and women. However, the chances of having trigeminal neuralgia increase with people over the age of 50. Treatment for this condition varies and includes medication, surgery such as microvascular decompression and complementary therapy like yoga.
Example 3:

Fibromyalgia syndrome (FMS) is a chronic condition that consists of an unexplained series of physical symptoms spread through many parts of the body, mostly in close proximity to the spine. Hypersensitivity occurs in response to palpitations that take place at what are referred to as “tender points” (Fred-Jiménez, 2016). FMS causes additional effects, which include functional impairment, fatigue, sleep disturbance, anxiety, and many more (Baumstark & Buckelew, 1992). Unfortunately, the cause of FMS remains unknown and it occurs predominantly in women. There are certain triggers that seem to expedite the process of FMS, such as bacterial infection, rheumatoid arthritis, lupus, and physical or psychological trauma (Yazmalar, 2015; Fitzcharles, 2016). Treatment for FMS may involve a team including a specialist, physical therapist, and or a rheumatologist. Exercise and rest are also important for managing symptoms of FMS.

These examples, illustrate how pain can be a complex experience that may not necessarily be due to tissue damage. Acute pain must be attended to in order to avoid developing chronic symptoms.

2.4. Gender and Pain Perception

A substantial body of research is revealing that women may experience greater pain-related distress and a heightened sensitivity to induced pain compared with men (Paller, 2009). This difference is of great importance when we want to develop an effective approach for chronic pain self-management. For the past 10 to 15 years, scientific and clinical research is beginning to uncover patterns that may enable tailoring of pain treatment to individual characteristics (Fillingim, 2009). Moreover, the consideration of gender differences amongst chronic pain sufferers has gained increased attention as an area of research that may lead to more focused treatments for both men and women (see Berkley, 1997). The gender difference is also apparent when it comes to listening preferences, sensitivity to sound frequencies, and side-effects from exposure to sound. As part of my research, I demonstrated that men and women have different sensitivity responses to audio frequencies and chronic pain further increases this sensation. Hence,
a more focused approach must be taken when administering a sonic based therapy to patients (see chapter 3 for more details).

A gender-based difference in pain response, and how the pathology is anticipated and interpreted makes the process of diagnosis and treatment much more complicated since reporting, coping, and responses to treatment differ (Berkley, 1997). One of the fallouts of treatment is the misuse, abuse, or addiction to opioid medications that has risen amongst women using these to combat pain (Ashburn, 1999).

Unfortunately, in many circumstances, research in understanding the correlation between gender differences in diagnosis and treatment is limited to a single condition at a time (Hassan, 2014). Evidence shows that women represent the majority of patients suffering from chronic non-cancer pain such as Chronic Headaches, Fibromyalgia, and Chronic Pelvic Pain (Greenspan, 2007). Because most often there is a co-occurrence of multiple pain conditions with overlapping symptoms, this single condition approach tends to be problematic; it leaves a gap in understanding the cycle of diagnosis and treatment (Vercellini, 2009).

2.5. Psychological fallout from pain

One of the primary goals of this research is to enable chronic pain sufferers to not just manage their own pain, but also anxiety, which is a symptom brought upon by chronic pain. In this section, I discuss stress that results from pain, environmental stressors and the transition from acute to chronic pain. The experience of pain as described involves internal factors such as an individual’s evaluation of their pain, but also external conditions like their milieu, relationships with friends and family, and economical status (Butler & Moseley, 2008). All these factors are in a constant state of change, one influencing the other, and making the process of coping with pain even more challenging. The fallout from the constant mediation of this situation can be a burden for chronic pain sufferers.
2.5.1. Anxiety and Stress

The biopsychosocial model is widely accepted as the most heuristic approach to chronic pain. Looking specifically at the behavioural dimensions, psychological and social factors can interact with brain processes that influence the wellbeing of chronic pain patients (Gatchel, 2007). Clinical reports suggest that chronic pain may induce anxiety, depression, and reduce the quality of life (Narita, 2005). High levels of anxiety can amplify sensitivity to pain and a number of fears and anxiety reactions (Asmundson, 1995). A common sequela of pain-related anxiety is of non-specific physical symptoms that are beyond the primary pain complaint. Furthermore, correlational analysis has shown that greater physical complaints are associated with reports of higher pain severity, symptoms of pain-related anxiety and anxiety, physical, and psychosocial disability (McCracken, 1993,1999). One way patients can shift to the adaptive coping category is by decreasing their anxiety and increasing acceptance of pain (McCracken, 1999).

2.5.2. Environmental Stressors

The environmental stressors that our early ancestors experienced have changed over time. There are new factors in our society, culture, and environment that have brought about new stressors which may lead to anxiety and stress. Individuals spend billions of dollars yearly to help reduce their symptoms of stress. Furthermore, the complexity of life that includes working longer hours and frequent change to lifestyle and habits leaves us more susceptible to stress. How people adapt to stress and anxiety can be described using two terms – Allostasis, and Allostatic load, or “overload”. Allostasis is the process of maintaining balance and stability (homeostasis) by actively suppressing stress hormones or other mediators. Allostatic load or overload refers to the damage caused by stress, or it can refer to it as the wear and tear on the body and brain that results from constantly having to maintain balance or allostasis (McEwen, 1998). The brain is not only involved in modulating the level of pain experienced, but it is also responsible for interpreting experiences as either threatening or non-threatening, followed by determining the appropriate course of action, which can be behavioural and or physiological. The hypothalamus responds to stressors while higher cognitive areas are responsible for anxiety, memory, and decision-making. Acute and chronic stress experiences influence
how these areas operate. In addition, our genetic makeup, social and cultural upbringing, any early life trauma, and aging can contribute to life-long emotional, behavioural, and pathophysiological problems (Felitti, 1998; Heim, 2001). Such an emotional burden over our lifetime can lead to anxiety that can, in turn, shape our personality. One example, termed a “trait,” refers to a disposition to consistently behave in an anxious manner over time or across situations. The most common way to measure this type of anxiety is using the State-Trait Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970).

The level of anxiety we experience, whether acute or chronic, can take a toll on the brain, the processes of allostasis and contribute to the allostatic load. When we sense sudden new pain, there is a general tendency to feel some level of fear. We all suffer from the natural fear of the “unknown” and its future consequences (Wall, 2000). The level of fear and anxiety we feel varies substantially depending on the context. For example, if we lose our job, we may experience fear and stress about the outlook of finding a new job and the amount of time it takes to resume a stable life again. But if we are faced with an incurable or chronic disease, that level of fear can increase exponentially. Chronic fatigue syndrome (CFS) and neuropathic pain such as fibromyalgia (FM), for instance, can cause an imbalance in allostasis (Diener, 1996). A cyclical process may then arise wherein both the level of pain experienced and psychological stress are increased. High emotions and anxiety can promote symptoms of idiopathic pain disorders such as irritable bowel syndrome (IBS), FM, and joint disorder (Diatchenko, 2006; Houdenhove, 2005; Ribeiro, 2005.) The frequency of brain activation in chronic pain sufferers, including the brain stem, amygdala, and hippocampus, among other regions is associated with central arousal, pain, and strong emotions (Baliki, 2006; Lawal, 2006; Wood, 2006). It is important for chronic pain patients to understand that the psychological fallout from stress and anxiety may lead to an increase in pain levels, cause allostatic overload and interfere with pain treatments.

2.5.3. Transitioning from acute to chronic pain

As mentioned earlier, fear generates anxiety, and the anxiety of pain generated by the unknown can become worse as the pain persists and short-term expectations of relief fail. For example, people suffering from chronic low back pain tend to experience fear of
movement known as kinesiophobia (Massé-Alarie, 2016). The experience of fear-based avoidance tends to be higher among older adults with chronic pain (see Larsson, 2016). The fear-avoidance model in Figure 2.1. shows how acute pain after an injury can become chronic due to pain “catastrophizing” (a term used in psychology which in this instance describes a persistent negative mental state about pain), fear of pain, and increased anxiety.

![Fear Avoidance Model](image)

**Figure 2-1 Fear Avoidance Model (LittleT889, 2014, licensed under CC BY SA 3.0).**

Therefore, one of the main goals of therapy for chronic pain should be to identify, understand and treat the anxiety that may follow diagnosis (McWilliams, 2003).

Depending on the nature of the pain, treatment may need to start immediately after an accident has occurred. Many sufferers of chronic pain, however, settle into a steady state of fear and anxiety that can progressively become harder to mitigate if not addressed from the onset (Krishnan, 1985). Without proper pain and anxiety management, the experience of persistent pain may lead to neural plastic change or sensitization, specifically in the medial pain system. Changes in morphology, neurochemistry, and gene expression are some results of such long-term exposure (Shyu, 2009). These changes can enhance pain responses causing hyperalgesia, a decrease in pain threshold to normally non-painful stimuli (also referred to as allodynia), and an overall increase in spontaneous pain (Cao, 2009).
Environmental factors may influence pain and anxiety for chronic pain patients. For example, healthcare facilities can indirectly create an atmosphere that is stressful and can undermine the psychological needs of patients (Ulrich, 2008). For patients, such environments can trigger anxiety, stress, uncertainty, and sometimes fear (Kroenke et al., 2013; Overhosler, 2009). Traditionally, healthcare facilities have been designed from a practical standpoint by providing efficient spaces for laboratories and increased numbers of rooms to accommodate more beds for patients. However, such an approach has often led to facilities that “function effectively” but are psychologically “hard” on patients (Ulrich, 1991). In addition to the design of the facilities, anxiety is further evoked by long wait times and noise in healthcare environments, which can lead to other adverse side effects for patients. One important element is that time perception can change depending on the level of anxiety experienced by patients. For example, those with higher levels of anxiety report longer estimates of wait times, and find intellectual tasks such as completion of diagnostic assessment forms seemingly more time consuming (Sarason, 1978). However, if anxiety levels are controlled, shorter estimations of time are perceived, and patients may have a higher level of confidence in their responses, such as answering questions or completing forms (Wudel, 1979). In a separate study, researchers found a similar result testing individuals with elevated levels of anxiety. They experienced time as moving more slowly, and attentional control and cognitive processes were also reduced (Bar-Haim, 2010). As the perception of time increases, quality of care tends to decrease (Katz, 2003). Due to the number of outpatient visits and capacity of hospitals and clinics, it may not be possible to reduce the wait times for patients; however, the subjective experience of time can be influenced if the anxiety level experienced by patients is reduced. Therefore, attempts at redesigning facilities to improve the atmosphere for patients have positively affected the perception of the quality of care received (Arneill, 2002).

In this chapter, I explained pain as a subjective experience that is affected by emotion and meaning, and modulated according to our gender, age, cultural roots, expectations, injury and evaluation. Therefore, what we experience and identify as pain becomes unique to the individual. The theory of dualism was examined and critiqued for suggesting that mind and body operate as separate entities. Dualistic thinking is problematic since pain is a complex experience that cannot simply be a construct of the mind, but is rather a process that includes the body, subconscious and conscious
physiological responses, and combined sensory-emotional events. The Gate Control theory describes how mind and body work together to analyze, process, and modulate the pain experience. Furthermore, pain that is a composite of multiple systems that lasts longer than six months and is idiosyncratic is considered to be chronic pain. There is no cure for chronic pain. However, the biopsychosocial model is a holistic framework that allows us to understand the nature of pain. Combining this knowledge and the forthcoming chapters on music and sound enables the possibility of understanding how sound-based therapies designed for chronic pain patients may be used as an intervention to manage pain and anxiety.
Chapter 3. Pain and sound

The quest for understanding pain is not rooted only in medical science; this quest and exploration of pain extends to other disciplines including psychology, anthropology, sociology, ethnology, history, cultural studies, philosophy, musicology – and with the advent of technology, computer science, and digital art. It is important to note that here I am referring to an interdisciplinary approach as being important to understanding and expanding our knowledge of pain rather than positioning one discipline versus another. For example, the experience and visualization of pain can generate language and creative expression (Scarry, 1985). Evidence of this dates back thousands of years to ancient paintings, literature, myths, theatre, and performance (Morris, 1999) and pain has frequently appeared to signify torture, punishment, or martyrdom (Spivey, 2001; Moscoso, 2012). In addition, when there was no evidence of visible pathology, the pain was attributed to supernatural causes (see Loeser and et. al, 2001).

Art including music as a form of therapy and self-management dates to ancient times and anthropologists believed art served as a means to provide protection by engaging in healing rituals such as dance, music, rhythm, and visual imagery (Rubin, 1999; Malchiodi, 2007; Bourke, 2012). While there are many examples of artists depicting, or working with, pain – perhaps, as in Frida Kahlo’s case (see Figure 3.1), which she depicted disturbing and at times dark and bloody images on canvas allowing her to communicate her personal endeavour and painful experiences of chronic pain. In Frida’s case, painting was a form of self-healing, however, it is unfortunate that throughout history there have been so few accounts or depictions of pain produced by non-artist sufferers themselves (Spence, 1986; Scarry, 1985).

Perhaps it might be because of a misconceived idea that art as therapy has to be undertaken or directed by artists only. Additionally, there are debates as to who should
facilitate this form of therapy (Malchiodi, 2007; Rubin, 1999). However, one of the advantages of individuals using art therapy specifically for chronic pain is the importance of self-managing pain often from a mind-body perspective. Currently, the concept of teaching pain self-management is regarded to be the most important component of chronic pain treatment because it involves maintaining, changing, and creating new positive behaviours or life roles (Asmundson, 2004; Butler & Moseley, 2008). However, research has shown that there are frequent barriers to self-management because of unresolved psychological issues (Bullington, 2003; Müller-Busch, 1991) such as lack of motivation, fear of movement because of additional pain, and lack of confidence. This research builds on the idea that it is possible for patients to manage their pain and anxiety by improving their psychological state using self-administering sound-based therapy. In this thesis, I argue that patients can use soundscapes to reduce anxiety and thereby allow them to overcome their pain symptoms and positively affect their mood, sleep pattern, and other daily activities. In fact, this form of therapeutic intervention may help overcome some of the psychological issues caused by the onset of pain.
Before I discuss developing a sound-based therapeutic intervention, as an initial step, it is imperative to understand the fundamental processes involved in listening responses, and sensitivity to audio frequencies and environmental sounds music and soundscapes. Understanding some of these fundamental aspects are important for designing a focused therapy for chronic pain sufferers.

3.1. Our Senses

Any exploration regarding how the human body and mind function in specific contexts must acknowledge that the primary objective of our biological system is to continuously maintain itself for survival (Schneck, 2006). Through adaptation and physical accommodation, the body and mind develops a tolerance to various disturbances and avoids imbalances. Schneck’s notion of accommodation states that the responses of the human body are information-based, and therefore it is receptive in perceiving and adapting to new incoming information. The way the human body manages this involves exteroceptive senses, which are comprised of our five senses, in addition to interoceptive (internal) senses that continuously collect and respond to our ecological context before we can cognitively process information (Schneck, 2006). The collection of sensory impressions that accrue can invoke emotional or physical responses. In addition, such sensory impressions can enable access to knowledge about our surrounding environment (Pink, 2009). Although we typically do not attend consciously to these inner systems, it is possible to develop an awareness of at least some of them, such as our proprioceptive sense\(^2\) and other indicators of our internal states (Leder, 1990).

In order to understand how the body sustains equilibrium as it responds and attunes itself to its continuously changing environment it is important to examine two incoming sources of information, along with their interaction. The first source is from within

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\(^2\) **Proprioceptive Sense**: a process involving the muscles, joints, and tendons responding immediately caused by external forces. This allows us to sense the relative position and movement of our limbs and trunk.
our body. In this example, interoceptive pathways\(^3\) specifically function as internal sensing organs functioning pre-consciously, in the background of our awareness. Through training, however, some of these functions may be brought to the foreground of our awareness. Proprioceptive information often helps guide us through space or augment other exteroceptive senses, such as vision. Proprioceptors are located where tendons, joints, and muscles meet. The second source of incoming information is external: the world is apprehended through the exteroceptive senses, which gather information received from outside of our body. For our body to make sense of external information, a conversion from one type of energy to another occurs, usually referred to as transduction. Each form of transductive energy vibrates at a particular frequency, measured in cycles per second. Our body receives these vibrations and interprets these forms of energies. For example, at a specific range of frequency such as 400-750 terahertz, our eyes can perceive the spectrum of light that ranges from violet to red. Vibrations in the audible range are between 20 Hz to 20 kHz; as these vibrations come in contact with our body, transduction takes place, converting this physical form of energy into an electrochemical form, which we then perceive as sound. Within this range, our body can interpret the different tonal characteristics of sound.

3.2. Auditory Perception

The human auditory system provides rich information about the sounds that surround us. How sound is perceived is not just a reaction to a mechanical phenomenon of oscillating pressure changes, which are sounds travelling through space; our perception also involves the mediation and interpretation of sensory events. Our bodies mediate and we assign meaning, giving significance to our experience of sound (Purwins, 2008). Even though sound waves carry valuable information that provide clues about the physical properties of objects or events that create them, the goal is to be able to learn something about the sound sources – that is about the objects and events in our environment. The

\(^3\) Interoceptive Senses: The interoceptive system is associated with autonomic motor control and other indications of our internal state including temperature and blood pressure to name a few, can sense a variety of feelings including pain, itch, temperature, sensual touch, hunger, thirst, muscular and visceral sensations.
combination of our ears, the auditory brain\textsuperscript{4}, the mind, and our senses, enable us to easily
distinguish thousands of sounds from each other. The sounds that we hear around us are
immensely rich and complex and our auditory brain has the ability to extract extensive
information effortlessly from just a few surrounding pressure waves (Schnupp, 2011).

\textbf{Figure 3-2 An illustration of a sinusoidal wave pattern.}

When conducting sound-based laboratory studies on hearing we tend to use sine
waves, which are pure tones, for our sound source. A sine tone is considered pure
because it does not have any artifacts such as amplitude or frequency modulations. In
music, we would refer to this pitch modulation as “vibrato” which is commonly used in
compositions. A pure tone on its own sounds dull and unnatural compared to what we
normally hear. The reason we use sine tones has to do with the notion of simple harmonic
motion, which is like a mass-spring system. For example, consider a slingshot: the harder
we pull the mass in the slingshot against the elastic, the more the elastic will accelerate
the mass in the opposite direction. The mass would accelerate a lot if the slingshot has
been stretched a long way, if the slingshot is stiff, and the mass itself is small. The natural
behaviour for any mass-spring system is to vibrate in a sinusoidal fashion as shown in
Figure 3.1 (Schnupp, 2011). Some objects in the natural world have both mass and a
certain amount of springiness; these can therefore enter a state of simple harmonic
motion, which is to vibrate sinusoidally. Each object has a natural or a preferred frequency,
which will oscillate or vibrate, and this is known as the resonant (resonance) frequency.
This type of vibration, referred to as \textit{free vibration}, is dependent upon the object’s length,

\textsuperscript{4} Auditory Brain: The definition includes two types of pathways that are used to convey auditory
messages to the brain: the primary auditory pathway which exclusively carries messages from
the cochlea, and the non-primary pathway (also called the reticular sensory pathway) which
carries all types of sensory messages. Pujol, Rémy. "Journey into the World of Hearing."
tension, thickness, and materiality. The human body also has a *natural frequency* range between 4Hz to 14Hz. However, some bodily forms, such as organs, respond to different frequencies. The brain, for instance, vibrates between 0.5 Hz and 2 Hz, our chest cavity at 60 Hz, our heart beats at 1 to 4 Hz, our eyes vibrate between 1-100 Hz, and our abdomen at 4-8 Hz (Schneck, 2006).

Acoustic musical instruments, however, do not just produce a simple pure tone but emit a complex tone that is made of a number of frequency components. This complex tone is comprised of a fundamental frequency, which is the lowest frequency, and higher harmonics, which are the frequency components corresponding to the resonance above the fundamental (Moylan, 2007). These upper harmonics may not necessarily present themselves in equal amounts, and it depends on the initial condition of where and how the object was “excited”, and its geometry, or material structure (Schnupp, 2011). For example, a string would be considered one-dimensional, and the body of a guitar is three-dimensional; therefore, many modes of vibration can occur, and not all of them are necessarily harmonically related. In addition, the mass and materiality of an object determine how elastic the material is, and the amount of internal friction that may exist. These properties impact the duration of decay or amount of vibration. Therefore, a dense object compared to, for example, a bell, will have a different decay time. Thus, for instance, the sound of a bell ringing will last for a much longer period than will that of hitting a wooden castanet (Schnupp, 2011).

Amplitude is another aspect important to understanding how our bodies react to sound. Amplitude is the level of intensity that energy travels and dissipates over time. We perceive amplitude as volume. The energy level that our eardrums experience is a direct conversion of sound wave amplitude undulations, measured as sound pressure level (SPL) on a logarithmic scale, and is a function of the frequency of the sound waves. These cause our eardrums to vibrate, translating the frequency of vibration into what we consider to be pitch and amplitude as dynamic volume changes. The unit *decibel* (dB) is used to measure changes in amplitude and the minimum change in amplitude level that we can detect is one half decibel (Moylan, 2007). For example, a whisper falls between 10-20 dB, while a normal conversation is between 50-65 dB. The loudest decibel level we can hear is 120 dB, a level just prior to the level that initiates damage, which is referred to as the
threshold of pain. Table 3.1 illustrates instances of loudness levels of sounds.

<table>
<thead>
<tr>
<th>Decibel (dB) Level</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Lowest sound audible to human ear</td>
</tr>
<tr>
<td>10</td>
<td>Quiet library, soft whisper</td>
</tr>
<tr>
<td>30</td>
<td>Quiet office, living room, bedroom away from traffic</td>
</tr>
<tr>
<td>40</td>
<td>Light traffic at a distance, refrigerator, gentle breeze</td>
</tr>
<tr>
<td>50</td>
<td>Air conditioner at 20 feet, conversation, sewing machine</td>
</tr>
<tr>
<td>60</td>
<td>Busy traffic, office tabulator, noisy restaurant</td>
</tr>
<tr>
<td>80</td>
<td>Subway, heavy city traffic, alarm clock at 2 feet, factory noise</td>
</tr>
<tr>
<td>100</td>
<td>Truck traffic, noisy home appliances, shop tools, lawnmower</td>
</tr>
<tr>
<td>110</td>
<td>Chain saw, boiler shop, pneumatic drill</td>
</tr>
<tr>
<td>120</td>
<td>Rock concert in front of speakers, sandblasting, thunderclap</td>
</tr>
</tbody>
</table>

Table 3-1 Description of sounds at various dB levels.

The human ear is more sensitive to some frequencies than to others, and we tend to be most sensitive to sounds with frequencies between 1 and 4 kHz. Over millions of years of evolution, our hearing has become sensitized to this range, which is why significant components of the spectrum of speech and music are present in this range (Moylan, 2007). As we age, sensitivity to the upper frequency range tends to decrease; this loss is termed presbycusis.

For a detailed description of hearing, please refer to the appendix B of this dissertation.
3.3. **Study 1: Auditory response differences between chronic pain patients and healthy people**

Hyper-excitability of the central nervous system results in an increased sensitivity to pain in chronic pain patients (Banic, 2004; Curatolo, 2001). As part of my research, I wanted to understand the relationship between pain perception and sensitivity to sound. Since chronic pain is often conceived as being the result of a hypersensitive nervous system (Tomaino, 2000), does that hypersensitivity also extend to a patient's experience of particular sound stimuli? In addition, can gender influence our responses to audio frequencies and sensitivity to everyday sounds? And, if so, how can one compose music or design sounds that incorporate this knowledge for the dual benefit of practitioners – i.e. composers and sound designers – and patients in music therapy?

As an initial step towards answering these larger questions, I designed and conducted a study to help determine a set of optimal sound frequencies for use in music and sonic-based therapies for chronic pain sufferers. To determine if listening responses may be influenced by gender differences and chronic pain, my colleagues and I conducted a double-blind study measuring listening responses of chronic pain patients and healthy controls. We hypothesized that participants with chronic pain would show greater sensitivity to particular audio frequencies and certain everyday environmental sounds. A total of 24 chronic pain patients, 10 males and 14 females, were recruited from a complex chronic pain clinic located in Vancouver, Canada. Nineteen control participants, 10 males and 9 females, were recruited from the same clinic and from Simon Fraser University. From both groups, one participant was not able to complete the study in its entirety. Both groups completed a background questionnaire to determine their history with pain, their exposure to environmental sounds in addition to music, listening preferences (headphones or speakers), specific sensitivity to sound, and its perceived impact on their health. The average age for chronic pain patients in the study was 51 for males, and 49 for females. For typical participants, the average age was 41 for both males and females, as shown in Table 2.1. On average, the chronic pain patients reported experiencing chronic pain for about 10 years. The patients recruited had various types of chronic pain conditions which were broken into 4 categories: NP = neuropathic NO = nociceptive, NI = neurogenic inflammation APP = abnormal pain processing. It was important to understand
if hypersensitivity varied amongst the different chronic pain conditions reported by the patients.

<table>
<thead>
<tr>
<th>BG Questions</th>
<th>Number of Participants</th>
<th>Average age</th>
<th>Duration of chronic pain</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP (male)</td>
<td>10</td>
<td>51.1</td>
<td>10.3 Years</td>
</tr>
<tr>
<td>CP (female)</td>
<td>14</td>
<td>49.4</td>
<td>9.51 Years</td>
</tr>
<tr>
<td>HP (male)</td>
<td>10</td>
<td>40.9</td>
<td>N/A</td>
</tr>
<tr>
<td>HP (female)</td>
<td>9</td>
<td>41.78</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Table 3-2 The average age of participants and the duration of chronic pain suffering by patients.

Neuropathic pain as described earlier is a complex type of chronic pain that may be caused by damaged nerve fibers; these fibers may be dysfunctional or injured, sending incorrect signals to the pain centres. Nociceptive pain is caused by tissue damage, for example, inflammation from an infection, arthritic disorder or myofascial pain (a type of abnormal muscle pain). When the nociceptive nerves are damaged, pain signals are sent indicating irritation, and impending or actual injury where none no longer may exist. Neurogenic inflammation is a process by which inflammation is triggered by the nervous system through a physiological mechanism. Mediators are directly released from sensory C-nerve fibers that produce edema (an abnormal accumulation of fluid), and vasodilatation (widening of blood vessels), which together manifest as inflammation (Meggs, 1993). Finally, abnormal pain processing involves wide-spread pain, insomnia, and bodily fatigue with the potential of multiple tender points. Fibromyalgia and phantom limb are examples of abnormal pain processing (Staud, 2001). The incorrect signaling may be contributing factor in the hypersensitivity experienced by chronic pain sufferers. Therefore, it is an important consideration since in this study I am examining the sensitivity of patients to a range of auditory tones.
3.3.1. Background Phase of Study

In our study, fifty-four percent of the chronic pain patients had been exposed to loud sounds in their lifetime, compared to only thirty-seven percent of the typical participants. The patients had a higher rate of ear or sinus infection (63%), head injury (25%), and whiplash-cervical trauma (54%) compared to typical participants (42%, 19%, and 26%). One hundred percent of patients preferred listening to music using speakers; and comfort listening to music with headphones was much lower (21%). The majority of typical participants were comfortable listening to music either using headphones (68%) or speakers (100%) since they did not exhibit any sensitivity to the close proximity of sound by wearing headphones.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Long exposures to very loud noise</th>
<th>An ear/sinus infection</th>
<th>Head injury</th>
<th>Exposure to short loud noise</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>50%</td>
<td>63%</td>
<td>25%</td>
<td>54%</td>
</tr>
<tr>
<td>HP</td>
<td>31%</td>
<td>42%</td>
<td>19%</td>
<td>47%</td>
</tr>
</tbody>
</table>

Table 3-3 (Above and below) Exposure to sound and listening preferences between the groups.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Whiplash – cervical trauma</th>
<th>Exposure to loud noise</th>
<th>Listen to music Regularly</th>
<th>Listen to music rarely</th>
<th>Use Headphones</th>
<th>Use Speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>54%</td>
<td>54%</td>
<td>58%</td>
<td>33%</td>
<td>21%</td>
<td>100%</td>
</tr>
<tr>
<td>HP</td>
<td>26%</td>
<td>37%</td>
<td>79%</td>
<td>5%</td>
<td>68%</td>
<td>100%</td>
</tr>
</tbody>
</table>

See Appendix C for questionnaires.
General sensitivity to sounds experienced in the home by patients was reported to be higher than in typical participants. This include a range of short impact sounds, such as the sound of a phone ringing, to more continuous sonic textures such as ambient noise (e.g., a running refrigerator). Side effects arising from exposure to sounds were also found to be higher in patients than in typical participants. In addition, there was a tendency for patients to avoid direct sound sources because of a fear of potentially experiencing pain caused by auditory exposure.

<table>
<thead>
<tr>
<th>Participants</th>
<th>I am sensitive to household noise</th>
<th>I am sensitive to loud music</th>
<th>I am sensitive to the sound of a fan</th>
<th>I am sensitive to the sound of bells or phone rings</th>
<th>I am sensitive to the sound of the Ocean (static)</th>
<th>I am sensitive to noise at work</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>38%</td>
<td>46%</td>
<td>25%</td>
<td>17%</td>
<td>4%</td>
<td>29%</td>
</tr>
<tr>
<td>HP</td>
<td>21%</td>
<td>37%</td>
<td>26%</td>
<td>11%</td>
<td>0</td>
<td>21%</td>
</tr>
</tbody>
</table>

Table 3-4 A comparison of response and sensitivity to everyday sounds

<table>
<thead>
<tr>
<th>Participants</th>
<th>Anxiety</th>
<th>Irritability</th>
<th>Tension</th>
<th>Anger</th>
<th>Disorientation</th>
<th>Headache</th>
<th>I Move Away or Avoid the sound source</th>
<th>Ringing in the ear</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>35%</td>
<td>87%</td>
<td>83%</td>
<td>39%</td>
<td>4%</td>
<td>48%</td>
<td>70%</td>
<td>17%</td>
</tr>
<tr>
<td>HP</td>
<td>33%</td>
<td>100%</td>
<td>61%</td>
<td>28%</td>
<td>6%</td>
<td>28%</td>
<td>78%</td>
<td>50%</td>
</tr>
</tbody>
</table>

Table 3-5 CP patients experienced more health side-effects related to sound/noise factors compared to healthy typical participants.

In addition, chronic pain patients were more susceptible to experiencing pain and other psychological symptoms (see Table 3.5) after exposure to sound for longer than a few minutes, compared to typical participants as shown in Table 3.6. As mentioned earlier,
this is may be the result of lower pain thresholds and hypersensitive state of chronic pain sufferers in comparison to healthy participants.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Experience pain for a few minutes</th>
<th>Experience pain for more than 30 minutes</th>
<th>Experience pain for more than an hour</th>
<th>Experience pain for one day</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP</td>
<td>52%</td>
<td>9%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>HP</td>
<td>67%</td>
<td>5%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Table 3-6 Exposure time to pain is higher in CP participants than typical healthy participants.

### 3.3.2. Auditory Testing Phase

The testing phase comprised of an auditory stimulation test. Participants listened to a randomly ordered set of sine tones presented at different intensity levels. The frequency selection was based on standard acoustical testing (ISO 266: 1975) in which the reference frequency of 1000 Hz was used and extended above and below this frequency in octave and 1/3-octave intervals. During the presentation of each tone, the participants were asked to adjust the volume to their level of comfort on a sliding amplitude dB scale.

Several steps were taken during testing to ensure that participants never experienced a tone that would cause them pain. At the beginning of the testing phase, the tones presented were set to the lowest amplitude level (-70dB). If, for any sound frequency, the participant reported mild discomfort (on the sliding scale), subsequent presentations of that same tone would never increase beyond that intensity. Participants listened to the tones using headphones. The auditory stimulation test took no longer than 10 minutes to complete.

Statistical analyses were conducted in SPSS 20 using a three-way between-within ANOVA, with group (chronic pain vs. control) and gender as the between-
participants factors, and frequency as the within-participants factor. A three-way ANOVA is commonly used to determine if there is an interaction effect among three independent variables (chronic pain, control, and gender) on a continuous dependent variable (frequency).

![Graph showing P values for different frequencies](image)

**Figure 3-3 Frequencies that were rated at lower intensity by female chronic pain participants than typical participants.**

The sound intensity selected by the female participants with chronic pain was significantly lower than that selected by the female control participants for each of the following frequencies as shown in Figure 3.3. Although, the frequency range tested was from 20 Hz to 12,500 Hz, these particular frequencies in Figure 3.4 were reported as statistically significant. The range of these particular frequencies are in the range of human speech. There was a significant 2-way interaction (group vs. frequency) for the male participants, $F(28, 504) = 3.587, p < .00001$. The sound intensity selected by the male participants with chronic pain was significantly higher than the male control participants for each of the following frequencies as shown in Figure 3.5 and 3.6.
Figure 3-4 Difference in the hearing responses between female chronic pain (CP) and typical participants.

Figure 3-5 Frequencies that were rated at higher intensity by male CP participants than typical participants.
The result of this study based on the auditory test and qualitative responses show that chronic pain patients are more sensitive to specific audio mid to high frequencies. They also reported exhibiting sensitivity to complex everyday sounds, including music, than did healthy participants (88% and 69%).

These data also suggest that chronic pain patients should be informed about the potential ill effects of loud environmental sounds. The qualitative responses reinforce this problem; when participants were asked if they were exposed to loud sounds in their lifetime, fifty percent of the chronic patients had answered yes to this question. The majority of male chronic pain patients (70%) were less sensitive to higher frequency range compared to typical participants. This lack of sensitivity may be the result of age and damage to hearing caused by exposure to loud sounds in their lifetime. To be certain, an audiogram of each patient must be analyzed to understand any extent of hearing damage.

Only twenty-seven percent of the typical male participants had previously experienced prolonged exposure to loud sounds. Therefore, the typical male participants had healthier and more sensitive hearing responses than the male chronic pain participants. Another contributing factor to this finding could be the age since the male
chronic pain participants on average were 10 years older than the male typical participants.

3.4. From data to design

This study allowed us to identify two important factors: 1) chronic pain sufferers are more sensitive to mid and upper range audio frequencies 2) and specifically female participants exhibit greater sensitivity than male participants. Understanding these factors enables facilitators of music or sound for therapy to be mindful of the loudness levels of these frequencies in order to avoid triggering pain or anxiety in chronic pain patients – especially female participants. This intriguing finding can be used to compose original music or soundscape compositions by considering gender (perhaps offering two mixes of the same composition for each gender) and tailor them specifically for chronic pain patients. Further research is required to discover more about listening preferences amongst patients that may indicate other hypersensitivities to be studied in comparison to typical participants. In this study, both groups preferred speakers as opposed to headphones; however, no subject from both groups complained of discomfort from headphone used during the testing phase of the experiment. Therefore, discomfort may be associated with wearing headphones for long periods, which may bring about ear fatigue.

As demonstrated in this study, hypersensitivity caused by chronic pain may impact how patients situate themselves in their surrounding environment, and may influence the impact – both positive and negative – of stressors such as noise. In the study, we demonstrated that in the design of music or sound therapy that is administered to patients with chronic pain, frequency content of the audio must be taken into account and undergo further amplitude processing to avoid any trigger of pain or stress. In addition, the frequency response to sounds for female and male participants differs, and must be accounted for when developing focused music or sonic-based therapies.
Chapter 4.  Music perception & therapy

The previous chapter was devoted to understanding how we perceive acoustic information and how people with chronic pain exhibit differences in their sensitivity to sounds compared to healthy controls. We can now look at how music can be used as a powerful medium for expression, communication specifically for therapy, and to help with pain management. Emphasis on the act of listening rather than simply hearing has been shown to have therapeutic effects in a number of cases, such as traumatic brain injuries and dementia, to note two. For example, Oliver Sacks suggests that music can aid patients with parkinsonism, help orient, and anchor patients with advanced dementia because “musical perception, musical sensibility, and musical emotion and musical memory can survive long after other forms of memory have disappeared.” (Sacks, 2007, 337). A preliminary study examining the effect of “neurologic music therapy” in cognitive rehabilitation has demonstrated promising results in improving brain functions and improvements in emotional adjustment, decreasing depression, and anxiety (Hedge, 2014). It is in this context that we examine the potential effects of listening to music on patients suffering from chronic pain (Nazemi, 2012; Vidyarthi, 2012). According to the American Music Therapy Association, music therapy is the clinical and evidence-based use of music interventions to accomplish individualized goals within a therapeutic relationship. The practice of music as a form of therapy has been in use for thousands of years. Scientists predict that non-invasive approaches like music will routinely be prescribed as “medicine” to help with treating immune system disorders, improve brain function in neurologically disabled and aging patients, alter genetic makeup and manage pain (see Mannes, 2011). This chapter is by no means an exhaustive report on the field of music therapy. Instead, the focus is on new approaches and understandings of music as therapy, including considerations such as cultural influences, the efficacy of research, and technological approaches. A point that requires clarification is the difference between music as therapy vs. music in therapy. Psychologists may utilize a variety of techniques, one of them being music, in their sessions. In this case, the music is being used in therapy

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6 Neurologic music therapy (NMT) is based on stimulating music perception and production parts in the human brain. It is used as a therapeutic application for human neurologic diseases and cognitive, sensory, and motor dysfunctions.
because the focus of the sessions may not have been tailored towards strictly using music to get results, but rather to use music as a means of enabling rapport building to work further toward the therapeutic goals. When music is used as therapy, a registered music therapist takes all aspects of the music, including all musical elements such as rhythm, tempo, instrumentation, etc. into consideration in working towards a patient’s goals.

4.1. Music as Medicine

From ancient times dating back to the fifth century BCE, music has been documented as a stimulus for evoking emotional responses and as a method for promoting relaxation and healing (Grocke, 2007). The earliest record of the use of music as medicine points to ancient Persia, where al-Farabi (872-950) described the therapeutic effects of music on the body in his treatise *Meanings of the Intellect* (Haque, 2004). In Western culture, Richard Browne’s *Medicina Musica*, also known as a *Mechanical Essay on the Effects of Singing, Musick and Dancing*, 1729 (Gibbons, 1985) and Richard Brocklesby’ s *Reflections on Ancient and Modern Musick, with the Application to the Cure of Diseases* (1749) are some of the foundational studies that articulate and emphasize how properties of music can be quantified for the purpose of therapy. Humans have the ability to distinguish musical ideas from everyday sounds. For an obvious example, we can automatically process and differentiate between phonetic sounds, such as human speech, and musical tones (Tervaniemo, 2006). In most music therapy situations, certain genres of music, such as Classical or New Age, are preferred by therapists and patients for treatment sessions, particularly if the music is perceived to be relaxing. This preference is mainly based on the patient’s familiarity with the music and does not reflect its intrinsic effectiveness for pain management. Indeed, there has been very little research regarding the design of compositions that are specifically appropriate for reducing pain levels in patients. In a recent paper, researchers found that listening to music reduced acute and chronic pain (Bernatzky, 2012). Even more interesting is that both music and environmental sounds produced similar effects in reducing pain levels in participants (Villarreal, 2012). Further, both research conducted by Michael E. Geisser and my initial study demonstrated that patients diagnosed with chronic pain, specifically Fibromyalgia (FM), were more sensitive to everyday sounds compared to a healthy population (Geisser,
2008). Such research demonstrates the potential of music and sound for pain attenuation. As I discuss in this dissertation, the approach taken for designing sounds or musical compositions for therapeutic approaches may be considerably different from the standpoint of production, and the aesthetics of music albums or film soundtracks.

### 4.2. Cultural Influence in Music Therapy

As a sound designer looking into the potential therapeutic properties of sound and music, it is important to gain an understanding of how culture, exposure to music and rhythm, elements of music (i.e. melody and instrumentation), and biofeedback can have a positive or adverse impact on the human mind and body.

Music can be used as a transformational tool for promoting relaxation and a balanced, healthy state. However, we must not neglect specific cultural components in music as this may lead to an inaccurate generalization that music is a “universal language.” Personal interpretation, individual beliefs, and cultural context influence how music is perceived and mediated when used for therapy. Research into music therapy seems to be fundamentally biased towards Western music and classical traditions with few cases reported of using music from other cultures for experiments and clinical studies (Cross, 2003). The methodologies and compositional principles of Western classical music differ from non-Western music, which can be problematic if we are trying to administer a universal therapeutic intervention that works across multiple cultural boundaries. One example is mantra recitation, a common rhythmic prayer consisting of any string of words that are cyclically repeated, and intended to induce a meditative state or inspire a religious experience. Mantra recitations have been scientifically investigated, and have been shown to reduce anxiety, induce relaxation, and lower blood pressure (Lee, 1997; Janowiak, 1994; Seer, 1980). These findings suggest that this form of stimulation, aside from religious context or ornamental appeal, can be a powerful musical approach for therapy. Anthony Storr suggests that an examination of “exotic music” from different cultures, music with apparent dissimilarity to “Western” or closely culturally related music, is needed (see Storr, 2006). Although there are differences in musical systems across cultures, there are underlying components that resonate amongst all of us, no matter our cultural background. Rhythms and musical melodies can transcend cultural boundaries.
and therefore allow us to explore the relationship between such components, and their positive impact on our health. As Oliver Sacks suggests, rhythm can be a powerful tool in helping coordinate and energize basic locomotive movement, and may provide a reason why music can help push athletes to new levels, and support the ability of people with Parkinson’s to initiate motion (see Sacks, 2007). Bodily and autonomic elements responding to music are influenced by familiarity with the music as well as by musical training, cultural practices, and even belief systems (McAuley, 2006). For example, there is now a growing body of evidence that suggests drumming can positively affect a wide range of physical conditions, mental illnesses, and personality disorders (Goudreau, 2006; Friedman, 2001). We must consider culture as an important signifier for administering music therapy. In various cultures, the temporal structure of music can differ considerably, and the perceptual and cognitive temporal processes will be different for individuals based on their cultural exposure and experience. However, researchers Carolyn Drake and Daisy Bertrand hypothesized that although there are differences in musical compositions and rhythms in various cultures, there may be underlying approaches that can be deemed universal and applicable to all music structures.

### 4.3. Design Considerations

The following are their key findings from Drake and Bertrand’s work:

**Segmentation and Grouping:** To overcome processing limitations, we can arrange events into small perceptual groups. Perceptual groups are incoming events that are either similar or dissimilar in terms of their acoustical and/or temporal characteristics. Listeners tend to segment sequences as a function of “surface characteristics” such as timbre, pitch, event duration, and intensity. Therefore, any sudden deviation from the grouping can cause a ‘break’ in the sequence. Since this way of structuring is non-culture-specific and does not require any specific learned skill, it can be applied to various types of musical genres and sound based therapies. In addition, segmentation and grouping can be useful when we are trying to develop a meditative or immersive experience for patients. The goal would be to structure the sonic events in such a way as to promote immersion (see chapter 8 for details), and to have consistency in the sounds, so we can allow the listener to focus rather than overload them with processing new auditory events.
**Predisposition towards regularity:** Our perceptual system has the ability to compare each newly arriving event with preceding ones. If, for example, the event is similar in duration to what preceded within an acceptable timeframe, then we perceive it as being the ‘same’ or similar. If the event is much shorter or longer than the preceding event (beyond the timeframe) then it is categorized as ‘different’. Our perceptual system may include sub-categories of ‘longer’ or ‘shorter’ such as same/different or same/longer/shorter. Another way to understand this approach is by looking at the temporal microstructure of performed music that consists of local lengthenings and shortenings of no more than 10 per cent (Penel, 1998). These are common occurrences and are not necessarily picked out by listeners as irregularities (Repp, 1992).

Adapting regular and irregular sequences while being mindful of tempo discrimination can be easily integrated in the context of therapy and used with people from various cultural backgrounds. An understanding of such structuring is even more important when we are controlling tempo fluctuations based on physiological responses, such as using heart rate or other sensor data. Too much deviation in tempo may cause cognitive processing overload since the listener cannot perceive the composition as a set of consistent events.

**Active search for regularity:** So far, we have recognized that categorizing events concerning temporal regularity can be a cognitively economical way to process auditory information. If we sequence musical or sonic events in such a fashion, then the need for cognitive processing is reduced. This makes it easier for the listener to experience the affective and emotional qualities produced. One component that can improve temporal regularity is allowing the listener to identify the ‘pulse’ of the composition. This identification can manifest as listeners beginning to tap their foot or nod their head. Therefore, synchronization may play an important part in helping bind the sequences of events together to promote regularity and reduce cognitive processing. To allow for cross-cultural compatibility, particular musical or sonic excerpts familiar to the participant (their own musical idiom) must be selected. This can be challenging if the goal is to achieve universal adaptability, since in some rhythmic structures it may be difficult for some individuals to recognize the underlying pulse. Therefore, in a therapeutic setting, we must
begin with simple structures to train listeners, and once they are familiarized, we can introduce more complex sequences.

**Temporal zone of optimal processing:** Typically, people spontaneously listen for important events occurring at equally spaced moments in time. The rate at which this search is conducted is specific to each individual (Jones, 1976; Jones, 1989). This means that understanding the rate of temporal sequencing is important. Sensitivity to change is at its highest if events occur about every 600 ms, and with an acceptable range between 300 and 800 ms interonset interval (IOI) (Drake, 1993). An interonset interval is the interval between the perceived beginning of, for example, one musical note, and that of the next note. This model can be adapted across cultures but more importantly, when considering patients as the listener, we may be able to use this optimal interval zone as a means of communicating important events during therapy. For chronic patients who are in a hypersensitive state, it may be possible that this particular rate of temporal sequence would have to be adjusted for them to recognize and acknowledge important auditory cues.

### 4.4. Neuroplasticity and Music

New approaches and applications are allowing for music therapy and the study of ethnomusicology to shift from a humanistic-phenomenological perspective and include a scientific framework that can incorporate facets of neuroscience and cognitive psychology. Doing so allows us to better understand key musical components that may be of great importance for providing alternative therapies. In the context of chronic pain, my interests are in the long-term physiological and psychological changes effected by music, which I hypothesize may be explained with respect to the processes of neuroplasticity (Davidson, 2004). Prior to the 1980’s, it was thought that network connections between neurons are built primarily during cerebral maturation processes in childhood, with the exception of only the structures that are directly involved with cognitive tasks, such as memory, and that these connections would not change later in life. However, since the 1980’s, new research has shown that substantial modification to the brain can be made through sensory experiences during adulthood (Pantev, 2003). The prominent Canadian neuropsychologist Donald Hebb suggests that effective connections between neurons are
formed depending on synchronous activation and that therefore, “cells that fire together, wire together” (Shatz, 1992, 64). In music, there is a close relationship between the interplay of sound and silence that is fundamental to our overall perception and response to music; in neuroplasticity, it is the connectivity and non-connectivity of neurons, networks, and regions that are the determining factors for perception and response when encountering stimuli in the world around us (Stegemöller, 2014). Recently, neuroimaging studies have revealed that listening to music stimulates dopaminergic regions in the brain (Menon and Levitin, 2005; Salimpoor and et. Al, 2011). Dopamine is a neurotransmitter in the brain that has been shown to be involved in motivation and reward-seeking behavior (Dayan and Balleine, 2002; Salamone and Correa, 2002). The excitation of this region by listening to music suggests that this form of intervention may stimulate the same neural network as that involved in reinforcement learning and reward (Chanda and Levitin, 2013). Although the use of music listening, specifically pleasurable music is in its nascent stages, nevertheless it illustrates the potential of music when applied therapeutically to facilitate neuroplasticity.

In the case regarding chronic pain, research has shown that people with chronic pain have a common “brain signature” in areas known to be involved in pain regulation (May, 2008). This particular alteration of the brain may be the consequence of frequent nociceptive input. Therefore, it may be possible to halt and or reverse this alteration of the brain through the process of neuroplasticity by managing the pain over the long term.

4.5. Therapy through Entrainment

It is important to consider music as therapy as achieving long-term goals for specific anatomical and physiological changes, and for healing or managing human conditions such as chronic pain. In this process, using compositional elements such as rhythm and melody, music can be used to enhance and facilitate entrainment. Entrainment is a concept that originated from the complex system theory that posits that two or more independent, autonomous oscillatory processes, if and when they interact, can influence (entrain) each other mutually and the degree of influence is dependent on the coupling forces (Berger, 2011). Coupling forces can be defined as psychological and cultural factors that can act as regulators of coupling strength. Music psychologists have begun
applying an entrainment model in which rhythmic processes endogenous to the listener entrain to cues in the musical sound (Large and Kolen, 1994). The tendency for rhythmic processes or oscillations to adjust to match other rhythms is prevalent and observable in various biological systems. For example, fireflies illuminate in synchrony and human individuals can adjust their speech rhythms to match each other in conversations. Endogenous or naturally occurring rhythms are found within the human body and include the heartbeat, blood circulation, respiration, locomotion, eyes blinking, female menstrual cycles, and many more. This process of entrainment through learning and practice can help synchronize and reset internal organs and other functions (see Clayton, 2004). It should be no surprise that musical entrainment can be a powerful therapeutic method since the body has a natural predisposition to connect with and respond to feedback from internal and external environments. Ultimately, the goal of music as therapy is to initiate neuroplastic change that may alleviate specific diagnosed chronic conditions.

Current research has demonstrated that exposure to music over time can produce consistent emotional responses (Krumhansl, 1997; Koelsch, 2005) – responses that have a neurochemical substrate. Such a system that adapts through musical entrainment may impact internal psychophysiological behaviour influenced by neurotransmitter activities, including the flow of cytokines, a cell structure that regulates intercellular communication in the immune and nervous systems, along with other biological supporting systems (Schneck, 2006; Saito, 2001). Physiological entrainment can initiate and help optimize homeostatic control through training and physiological adaptation. The study of entrainment is still far from being complete and much of the detail, and operational definitions of selective neural inhibitions and excitations, remain unknown. There are however several types and mechanisms of physiological entrainment that have been studied which use music as the input source. For example, entrainment can be applied to the nervous system to gain access to the body through central, peripheral, and autonomic

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7 An example of physiological entrainment includes circadian rhythms which act as a “master clock” with an oscillation period of 24 hours. To maintain synchrony with the environment, the circadian rhythms need to be entrained daily by inducing light-dark cycles. When this is interrupted as in the case of jet lag, our rhythm is no longer in synchrony and therefore we experience improper sleep, dizziness, hunger, etc. Golombek, D. A., and R. E. Rosenstein. "Physiology of Circadian Entrainment." *Physiological Reviews* 90.3 (2010): 1063-102. Web.
nerve pathways. A sensory input can be entrained by the body and activate physiological mechanisms that are in charge of determining firing patterns of nerves. This is achieved by selectively inhibiting or exciting neural pathways which can help improve memory of sensation and build new nerves (by way of plasticity) through repeated stimulation (Doelling, 2015; Mainka, 2015).

4.5.1. Entrainment & Rhythm

One of the most natural responses of the human body to music is the synchronization of anatomical movements and other physiological/psychological functions with musical rhythms. Our body — through pre-conscious processes — is quick to recognize and “feel” vibrations, the foundation of what makes the rhythmic pulse. Our body senses the vibrational events, and we begin to interpret this sonic resonance as rhythmic events (Massumi, 2002). We regularly recognize regular vibrations as rhythmic events, such as the ticking of a clock or the beat of a drum, as well as irregular events such as speech or street noise (Sonnenschein, 2001). This also reflects on how our body detects these pulses through our auditory, exteroceptive sense, and our proprioceptive system. The human body has its own set of what we may term biological rhythms. The “thud” of our heart pumping and the rhythm of our breathing and blinking are some of the physiological rhythms that are familiar and discernable. However, other conscious processes often override our awareness of the intricacies of our internal rhythms and psycho-physiological responses to music, which then function in the background of our attention. For example, our heartbeat consists of a polyrhythmic structure. This structure results from variability and fluctuations of concurrent beating, and of the flow of blood in the arteries. Our body is constantly adjusting the tempo of these rhythms to accommodate for changes in the nervous system and our physiological and psychological states (Schneck, 1999). For example, studies of the electrical activity of the cerebral cortex of the brain monitored via electroencephalography (EEG) show that auditory cues can capture one’s attention, and this form of attentiveness results in brain waves becoming synchronized with the binaural auditory beat frequency (Fries, 2001). The binaural auditory beat is a perceptual phenomenon that occurs when auditory signals of similar frequency are presented separately to the left and right ear as listened to via headphones. Although each ear hears only one of the frequencies, the listener perceives the middle
frequency and the amplitude modulation – even though the auditory beating that is heard does not exist in physical space. For the past 25 years, there have been anecdotal reports of the efficacy of using binaural beats for therapy. Additionally, some published studies show that this form of brain synchronization can positively affect psychomotor performance and mood (Lane, 1998; Padmanabhan, 2005). In a recent study, the use of binaural beats has shown to reduce the perceived severity of pain experienced by chronic pain patients (Zampi, 2016). The National Institute of Mental Health also conducted a study to try to understand the underlying mechanism of the binaural beat phenomenon and its connection to cerebral resonance. They discovered that through sensory entrainment, synchronous firing of neurons occurs in the brain when a subject makes a deliberate attempt to focus or pay attention to a sensory stimulus while ignoring all other distractions. The researchers suggested that the resonance phenomenon that occurs after entrainment may be the brain’s way of amplifying the volume of brain signals. The threshold of amplification would be above the level of surrounding “noise,” boosting the intensity of the stimuli (Fries, 2001). Therefore, this type of signal workflow, which is entrainment leading to brain-wave synchronization, leading in turn to resonance and amplification, might be the brain focusing its attention on a particular stimulus while ignoring the surrounding distractions. The behaviour of our biological rhythms has similarities to how we compose rhythm in music. For example, music has a pacing and resting like our breathing, as well as dynamic tempo changes that can rise or fall like our heart beat. We can take advantage of these musical behaviours by modulating the patient’s response to music; we can adapt the rhythm of the music to coincide with specific pain therapies, such as meditation. In one study, participants listening to music preferred tempi (musical pace) which were directly proportional to an individual’s normal heart rate ranging between 60-100 cycles per minute (Iwanaga, 1995). Additional minor rhythmic pattern variations can be added to create a sense of communication or attunement with our central nervous system and brain functioning. According to the Gestalt Law of Perception (Arnheim, 1943), and later verified by perceptual studies, it is the relationship between the musical notes and the interplay of rhythms that is important, not so much the individual notes that make up the music. Therefore, in the context of music therapy, the rhythm must be kept simple for the brain to process the information and for the patient to acknowledge the musical and rhythmic relationship occurring over time.
4.6. Structuring musical parameters for therapy

4.6.1. Use of Melody for Therapy

To compose a melody that has an impact in a therapeutic context for chronic pain management, we must design it so that it can be sensed as a stream of continuous pitch changes and sequenced in a manner that has specific relationships to each other as noted above in Carolyn Drake and Daisy Bertrand’s work. There are four characteristics to a melody. They include pitch, phrase (a musical sentence that can repeat), prosody (the content having a rhythmic pattern, pace, or linked pitches), and profile, which is the shape of the melodic flow typically referred to as the melodic contour. These four characteristics of melody can be superimposed onto a rhythmic “bed track” that helps create a pace. This also helps define a flow across time and space in which the melody can affect and help modulate mood and emotions as it progresses and evolves. Careful attention must be placed in selecting appropriate instrumentation or timbre quality for the melodic lines that contribute to creating a receptive therapeutic response for patients. For example, chimes or bells used for composing a melodic line that resembles a lullaby can shift the focus from the pain to the music, a technique referred to as thought redirection (Grocke, 2007). In another study, a 30-minute lullaby-like, rhythmically dominated music was administered to patients with chronic cancer and the results showed an increase in synchronization and coordination of heart rate and musical beat. Furthermore, trained patients reported feeling relaxed, and an analgesic effect was induced during the synchronization phase (Reinhardt, 1999).

The brain can also remain attentive if the phrasing, timbres, and tonalities of the melody can conjure up memories for the patients. Clinical studies have shown that using specific melodies can help with memory loss amongst patients diagnosed with Alzheimer’s (Darnley-Smith, 2001). In music, for example, the Phrygian mode conveys a sense of peace or compliance, while the Dorian mode enhances a sense of stability. Furthermore, calming music such as ambient or classical music, sometimes referred to as sedative music in therapy, can help reduce anxiety and pain levels when administered post-surgery (Voss, 2004).
Melody can, however, have a negative impact if the content is made up of dissonant sounds and has a wide dynamic range of tonality and volume. A rise in adrenaline may result, producing an increase in patients’ stress levels (Nazemi, 2013). Keeping the musical composition simple, with few rhythmic and melodic changes, can help create a sense of calm that can lead to anxiety reduction for patients (Elliot, 2011; Wolfe, 2002).

There are also drawbacks in using melodies in music therapy, which are in part due to the patient’s health condition and biological functioning. For instance, some patients might experience spectral attenuation\(^8\) due to a disorder in the basilar membrane, which is located in the cochlea of the inner ear. What is perceived through the outer ear is entirely modulated by these cancellations, changing the response a listener has to the music. Some listeners might perceive the melody as harsh or brittle because of the high sensitivity they experience in the upper harmonic range of the instruments. Patients who experience chronic pain, or migraines as proven are prone to this effect. Others might hear dissonant harmonies arising from a disorder in the basilar membrane, which causes the music to feel as if it is out of tune. Loudness can also change the musical content for a patient who is sensitive to high-intensity music. To explain, a timbre may be subjectively experienced even though there was none in the music presented; the phenomenon of the “ear creating” particular aural harmonics occurs when sound waves pass beyond the subject's threshold of loudness and cause the person to hear multi-frequency sounds (Buser, 1992). This non-linearity depends on the intensity level so it may be possible to avoid such an effect using softer music.

### 4.6.2. Affective Quality of Scales and Harmony

Harmonic tension and resolution can have a great impact in a therapy session for controlling muscle movements, attention, breath control, and tension. Pitch suspensions\(^9\) that require resolving can be used as a form of entrainment for the body and are able to

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\(^8\) Spectral attenuation is a gradual loss in intensity of auditory frequencies such as in hearing loss.

\(^9\) Suspension in music is a popular technique for creating tension and release in music. It occurs when there is a pitch that initially fits a chord, then doesn’t fit, and finally resolves down to a pitch that does belong in the chord.
modulate the psychological states of the patients. In one study, the valence of music (pleasant vs. unpleasant) helped reduce pain levels experienced by participants suggesting that positive valence in music can have a hypoalgesic effect to painful stimuli (Zhao, 2009). The research conducted by Elizabeth C. Prophet and Patricia R. Spadaro demonstrated that emotional responses were elicited from patients who were exposed to various musical scales and key signatures. In their research patients who suffer from highly dynamic behaviours such as aggression or shyness can benefit from tonic modes such as the key of C major because they are perceived to be the most stable and therefore produce a sense of grounding. In their research, they recognized that the heart responds to tonic\textsuperscript{10} modes and may be beneficial for the development of immunological functions (Prophet, 2000). Mediant modes such as E major may be useful for reducing stress levels in patients since the nervous system, and cerebral cortex tends to be susceptible to these modes for entrainment. Dominant modes such as G major and sub-dominant modes like F major may create a sense of balance and comfort. Certain portions of the brain and the musculoskeletal system that deals with proprioception and equilibrium appear to be affected by these modes (Prophet, 2000). Sub-mediant modes like A major are effective for patients who need to manage sleeping and waking activities. The sub-mediant modes tend to produce a tranquil and peaceful feeling. The leading-tone modes such as B major complement the tonic modes, and because they are meant to be resolved, they create a sense of closure and satisfaction. The brain, the adrenal glands, and the autonomic nervous system are best candidates for exposure to leading-tone modes, especially if pitched-percussive instruments are used in the rhythm section. Although melodic structures or scales and modes elicit a positive emotional response, we must also account for the temporal processing involved in music perception and performance. For example, musical events should be grouped together or situated in time in relation to surrounding events to overcome any memory constraints (Drake, 2003). These experimental accounts are providing more insight into the potential healing power of music. However, more scientific studies need to be developed to test the efficacy of using musical scales as a way of providing healing for various illnesses or pain management for chronic pain patients.

\textsuperscript{10} Tonic is the principal tone; sometimes also synonymous with key
4.7. Biofeedback

Recent technologies have led us to a reconsideration of foundational aspects of music and sound design including composition techniques that may impact people who experience pain. Real-time and adaptive capabilities for processing sounds and audio effects, in addition to systems that adapt to our embodied reactions through biofeedback, allow for a deeper sense of immersion and approaches to how one may investigate pain therapy and management. Although the validity of biofeedback has waxed and waned from decade to decade, it is currently used as a treatment modality that has gained increasing acceptance in the medical domain. The applications for biofeedback have expanded rapidly since 1990’s as computer processing and acquisition of psycho-physiological data has become more advanced, quantified-self has become an extensive research and design topic, and consumers are adopting wearable devices. Users can learn to gain conscious control over their physiological and psychological states based on data communicated by sensors attached to their body. Biofeedback technology allows researchers to understand how patients can bring conscious awareness to involuntary bodily responses, and modulate them in real-time. Research has shown that voluntary control of the autonomic nervous system can be achieved to lower blood pressure, relax muscles not previously under conscious control, alter brainwave patterns, change heart rate, and increase temperature in peripheral extremities (Yucha, 2004). Using biofeedback, patients have been found to respond to pain in unique ways (Schwartz, 1995).

One of the projects designed by our research team called *The Meditation Chamber* demonstrated that combining biofeedback with virtual reality (VR) helps to accelerate the process of meditation. Meditation in this instance refers to the process by which the body can act as a natural mediator (for music as an example). The practice of meditation can be extended with (artificial) meditation technology (like biofeedback or VR) so that the mental activity may cross “traditional boundaries into environments both natural or virtual that otherwise cannot be accessed [solely] by the natural mediator” (Leman, 2008, xiv). *The Meditation Chamber* project demonstrated that using the system improved the participants’ ability to enter a meditative state because biofeedback enabled them to experience the cause and effect of their intentional efforts (Shaw, 2007). Different types
of biofeedback sensors are designed to respond to various autonomic processes. For example, Galvanic Skin Response (GSR) sensors can detect arousal based on skin conductivity. In our Virtual Meditative Walk project, shown in Figure 3.4, GSR data captured from the participant controls the amount of fog in the virtual environment; when patients learn how to reduce arousal, which is correlated with stress, the fog dissipated.

Other sensors measure physiological aspects that are correlated to stress, such as temperature and heart rate variability (HRV). Electromyography (EMG) sensors measure muscle activity, providing data that has been used in certain rehabilitation treatments, such as treating Raynaud’s disease, which causes numbness in fingers and toes (Yucha, 2004). The electroencephalograph (EEG) detects brain activity, and data has been used to assist in recovery from addiction. Recovering patients engaged in drumming experienced feeling relaxation and an increase in EEG brainwave amplitudes in the Theta range (Winkelman, 2003). We can use the continuously changing biofeedback data to control audio parameters in order improve the quality of treating chronic pain patients in ways that they themselves can sustain outside of the therapeutic context.

4.8. Accompanying Therapy using Biofeedback

Biofeedback technology enables us to gain insight into how music or sound cues can change the status of a patient’s responses in real-time. For example, we can use a GSR sensor to monitor the arousal level and detect if a patient is nervous or anxious; if so, we can modify the tempo, volume or melodic content of the music to adjust the patient’s state. A scenario can be created in which the patients can learn to calm themselves by using biofeedback to match their heart rate to the tempo of the music.
The consensus amongst neurotherapists is that using sound with biofeedback tends to be an important form of neurotherapy over other types, especially for modulating brain activity (Demos, 2005). In addition, it can allow for detection of subconscious activities that may be difficult to detect. For example, in one study, EEG activation of right frontal indicated decreased levels of cortisol in depressed test participants upon presentation of music. However, there was no significant difference reported in subjective perception of change in mood (Field, 1998). Music can be used in conjunction with biofeedback in two ways; it can be either an input to the psychophysiological system or an output of that system. As an input, music can be pre-recorded and may include environmental sounds. Input can also be by way of the playing of spontaneous improvisational music, administered by a music therapist or by the participants themselves. As an output, it usually involves the playing of an instrument, or the triggering of sounds/music digitally via a computer by the subject, and the music therapist will then record and interpret emotional content and physiological state based on this. The sensors used to measure physiological parameters are sensitive to noise. Therefore, to obtain useful data, usually a combination of sensors is used, such as GSR, Temperature, and BVP (blood volume pulse) then analyzed for correlation that would indicate changes in physiological state. In addition, medical grade biofeedback devices allow users to capture raw sensor data with the ability to filter noise within the dedicated software environment. The advantage of using biofeedback in conjunction with music as a therapeutic intervention is that the results obtained can be compared to patient verbal reporting. Furthermore, the comparison between the qualitative reporting and quantitative data from the physiological tests can be used to measure the efficacy of the procedure. Knowledge and training are required to understand physiological data capturing and sensor
placement, and to understand proper music selection that will provide consistent bio-guided therapy for patients. Therefore, when devising bio-guided music therapy, we must account for the following:

- Choice of music: this includes, instrumentation, keys, scales, tempo, and genre.
- Pre-recorded or live performance of music.
- Duration of the music played back to the subject(s).
- Sensor selection. This is dependent on the goal of the session; for example, to reduce stress, monitoring breathing, heart rate, and GSR is appropriate.
- Verbal or non-verbal direction. Sometimes, instructions are necessary, but these must be incorporated in such a way that the patient is not interrupted by interjection (Miller, 2011).

In Table 4.1, which is adapted from Eric B. Miller’s work, is a breakdown of bio-guided approaches for music therapy.

With my focus being on pain and stress management, it is important to discuss how music or sound therapy in this context can be enhanced using biofeedback. There is new research that suggests specific brain structures such as the amygdala and the hippocampus are associated with stress and anxiety (Romeo, 2016; Johnson, 2016). The amygdala functions like a communication or relay centre for incoming sensory information and perceived threats of danger. In addition, the amygdala seems to respond to music (Levitin, 2006), and when stimulated it can moderate the production of stress hormones that affect heart rate and blood pressure (Taylor, 2009). Furthermore, clinicians can detect changes in stress level by monitoring heart rate and galvanic skin response (GSR) in real time while the subject is listening to music.

4.8.1. Biofeedback loop models

One of the challenging tasks of using biofeedback as part of an analysis of physiological changes while also training a subject to manage their stress level is that of determining the initial feedback loop model.
<table>
<thead>
<tr>
<th>Music Therapy Intervention</th>
<th>Symptoms and Disorders</th>
<th>Biofeedback measuring type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drumming</td>
<td>Addictions, depression, stress, cancer, fibromyalgia</td>
<td>HRV, HEG</td>
</tr>
<tr>
<td>Toning / Chanting</td>
<td>Stress, anxiety, high blood pressure (HBP), pain</td>
<td>EDA, HRV, TEMP, HEG</td>
</tr>
<tr>
<td>Imagery</td>
<td>Anxiety, attachment disorder, chronic illness, HBP</td>
<td>EDA, EEG, TEMP</td>
</tr>
<tr>
<td>Music Listening</td>
<td>Anxiety, headache, HBP, pain management, Raynaud’s</td>
<td>EMG, EDA, EEG</td>
</tr>
<tr>
<td>Musical Meditation</td>
<td>Anxiety, headache, HBP, pain management, Raynaud’s</td>
<td>EMG, EDA, EEG</td>
</tr>
<tr>
<td>Drumming, improvisation</td>
<td>Addictions</td>
<td>EDA, Alpha/Theta, HRV</td>
</tr>
<tr>
<td>group</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melodic improvisation,</td>
<td>ADHD</td>
<td>SMR, Theta/Beta</td>
</tr>
<tr>
<td>drumming</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4-1 A summary of bio-guided approaches for music therapy.
There are two ways a feedback loop can be set up as shown in Figure 4.2:

1. The first model is to have the music therapist obtain the biofeedback data from the subject without allowing the patient to see the real-time data during the session. Instead, the music therapist may adjust the musical parameters (volume level, genre, instrumentation, etc.) based on biofeedback data and how the patient’s physiology is responding to the music. The subject then receives an interpretation of the result from the therapist, which includes a breakdown of the outcome that was achieved during the listening session. This model is useful for new participants who are not familiar with biofeedback and are experiencing high stress or pain levels. If the subject is shown the real-time biofeedback data, then a paradoxical response could occur, in that an increase in stress may take place, or perhaps even worse, a vicious cycle can occur where the fear of a panic attack could potentially increase galvanic skin response (Gilbert, 1986).

2. The second model involves the subject viewing their physiological response on a computer screen in real-time during a listening session. The type of feedback that is provided could be analytical, such as a graph representing changes in GSR or heart rate. Or it could be a visual ambient feedback that is subtler, yet which can communicate the results through representing raw data in real-time. Both of these methods can work if the subject has developed skill in physiological relaxation. There may be a preference for ambient or abstract visual feedback.
that represents biofeedback data over a technical graphical approach (Karamnejad, 2014).

Based on these two models, it is recommended that patients suffering from severe cases of anxiety or pain should start with the first model to avoid the possibility of inducing more stress. Patients who have difficulty adapting can also practice mindfulness meditation to help ease the learning process of controlling physiological responses (Williams, 2007). Once a patient has become comfortable with this model, they can then transition to the second model, since the latter can be more beneficial to their learning how to improve control over their stress levels so they eventually rely less on medicine or other interventions.

4.9. Vibroacoustic Therapy

Vibroacoustic therapy is still in its infancy, but recent research suggests that it may be a compelling component of interactive systems designed for therapeutic use. As stated earlier, since our body can detect vibrations from its surrounding environment, we can take advantage of using subtle vibrations for therapy. Vibroacoustic therapy involves pre-recorded music or pre-recorded music combined with sinusoidal low-frequency sound (30 Hz to 120 Hz) administered through loudspeakers built into a chair or bed unit. The body is then exposed to this music for a short period of time during a therapy session (Hooper, 2001). Some aspects of vibroacoustics, such as audible low frequency sound vibrations, can be designed and integrated with Virtual Reality (VR) to help patients reduce their pain levels, achieve a sense of relaxation, and lower stress levels (Boyd-Brewer, 2004). The music is designed to incorporate specific frequencies that not only are emotionally effective, but also can create the necessary physical and tactile sensations that help enable pain relief.

It has been documented that low-frequencies produced between 30 Hz and 120 Hz are ideal for therapeutic use (Skille, 1989). A study conducted by Kris Chesky, Director of Education and Research for the Texas Centre for Music and Medicine at the University of North Texas, found that low to low-mid frequencies – 60 Hz to 600 Hz – provided optimal pain relief in patients at these specific frequency ranges. In another study, 272 adults with
various diagnoses such as cancer, heart and lung disease, mood disorder, and infectious disease, reported symptom relief after exposure to vibroacoustic therapy (Patrick, 1999). There is evidence that shows long-term exposure to vibroacoustic therapy when compared to music therapy, may be effective in providing an increase in the subjective level of relaxation, as well as improved cognitive processing (Brodsky, 2000).

Understanding the benefits of using Vibroacoustic therapy is still in its nascent stage, and additional research is needed to identify specific criteria needed for selecting patient groups who may benefit and to describe protocols for treatment. Additionally, the risk of adverse effects such as exposure to extremely low frequencies below 20Hz — referred to as infrasound — may exist when using vibroacoustic therapy.

4.10. Conclusion

In this chapter, I argued that the concept of music as universal may be difficult to accept because of differences in culture, gender, and musical knowledge amongst people. However, several processes for compositions and rhythms developed by Drake and Bertrand were outlined which can be applied to overcome some of these barriers. Furthermore, a shift towards quantitative analysis is now possible using biofeedback to measure physiological changes in the body. That data can then be correlated with patient reporting. New insight into using brain imaging has shown that neuroplastic changes are possible through long-term exposure to music, and these may have significant health benefits. One form of long-term therapy that shows promise is using rhythmic entrainment, which can promote synchronization of anatomical movements and other physiological/psychological functions. New studies into the affective qualities of using musical scales and melodies as an intervention are revealing potential health benefits, but more research is needed to verify these findings. Included is vibroacoustic therapy, which could offer additional health benefits, but might also have adverse effects on the body when low-frequency sounds are used in combination with music in therapy. Overall, the field of music therapy has gained traction and is recognized as a legitimate field with positive health benefits covering a wide range of illnesses. One potential direction for music therapy is the combining of several approaches to develop a comprehensive therapy that allows patients to learn to self-manage their pain. For example, VR and
biofeedback can be used together to construct music in real-time in a way that enables users to become aware of their autonomic or inner processes. Through this new understanding, users learn to reduce their on-going pain levels with music that is generated based on their physiological responses. Once biofeedback and mindfulness meditation skills are learned, users are then able to draw upon this skill beyond technological systems, whenever they require it. Further research is necessary to demonstrate the long-term links between using music in conjunction with other media technologies for pain therapy.
Chapter 5. Soundscapes Theory

To facilitate a therapeutic intervention using environmental sounds constructed as soundscapes; first, a theoretical understanding of soundscapes is necessary, followed by a consideration of practical approaches for creating compositions. This chapter focuses on the theories of soundscapes and includes a background on acoustic ecology, acoustic communication, listening modes, noise, and silence.

5.1. Acoustic Ecology

In 1971, a team of researchers in the Communication department at Simon Fraser University organized the World Soundscape Project (WSP). Led by R. Murray Schafer, the objective of the project was to understand the acoustic environment and how human activity has affected the level of sound present in our surroundings. This work resulted in the publishing of several booklets, including The New Soundscape, and The Book of Noise. Furthermore, this body of work helped introduce new Canadian noise bylaws. Through this longitudinal research project, the researchers established the field of Acoustic Ecology. Schafer’s intention was to capture, record, and document the idealized soundscape of the natural environment and preserve it from the negative aspects of modernization. In his book, The Tuning of the World, Schafer formulated the term soundscape during his field studies with the WSP (Schafer, 1977). As part of his documentation process, he defined background sounds as “keynotes,” which is similar to how a keynote is used to identify the central tonality or key of a musical composition. Sounds that attract attention, which typically occur in the foreground, are defined as “sound signals,” and iconic sounds that are memorable and culturally significant are called, “soundmarks,” analogous to landmarks. These sound markers could be natural sounds such as a waterfall, particular types of birds, or man-made, such as the sound of a bell or a fog-horn. The combination of keynotes, sound signals, and soundmarks creates a soundscape that can identify an environment or community.
Over time, our surrounding environment has gone through changes resulting from industrialization and technology. Schafer expresses these changes by categorizing soundscapes as “hi-fi” and “lo-fi” as summarized in Table 5.1.

<table>
<thead>
<tr>
<th>Hi-Fi (high-fidelity) Sounds</th>
<th>Lo-Fi (low-fidelity) Sounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oceans, Rivers, Rain</td>
<td>Ships, Cars, Airplanes</td>
</tr>
<tr>
<td>Wind, Breezes, Thunder</td>
<td>Drills, Saws, Tractors</td>
</tr>
<tr>
<td>Birds, Cattle, Candles, Breathing</td>
<td>Traffic, Trains, Machine noise</td>
</tr>
</tbody>
</table>

Table 5-1 Examples of Hi-Fi and Lo-Fi sounds.

The hi-fi (high-fidelity) soundscape of the pre-industrialized environment had an “acoustic horizon” that could extend for miles. On this horizon, sounds from nearby homes could be heard at considerable distances, producing a locative quality that gave a sense of place and space that identified the communities in close proximity to each other. Prior to the industrial revolution, sound played a significant role in European daily life. Sound functioned as a semiotic system that coordinated politics, economics, civic, and social life (Smith, 2007). Similarly, sound had a communicative role (as it does to this day) in non-Western countries such as Africa with their “drum languages,” and in Middle Eastern nations, with the call to prayer propagating from mosques carrying over vast distances. In a hi-fi environment, there is a sense of acoustic balance due to the dynamic range and clarity in the spectra. Schafer also suggests that in a hi-fi soundscape, there is no masking in the overlapping of sounds; therefore, a hi-fi environment offers a clear separation between foreground and background sounds (Schafer, 1993). The lack of masking in the overlapping frequencies of two sounds that are in close proximity to each other allows the listener to discern individual sounds as being distinct. In addition, the reflections of these sounds from surrounding environmental surfaces, and fluctuations in weather such as temperature, humidity or wind eliminates any “anonymous sound” (Westerkamp, 1995). In this context, the listener becomes informed about the sound source, its size, and surrounding space in relation to their physical position.
In contrast to the lush and clear soundscape of hi-fi environments, the lo-fi soundscape is characterized by an acoustic colouration caused by a cacophony of noise that results from industrialization and machines. The aural space of an individual in a lo-fi environment is reduced, and detail associated with reflected or distant sounds is minimized to a small area surrounding the individual. At times, this reduction can be so pronounced that aural space becomes “less than that of human proportions” (Truax, 1984, 20). In this instance, sounds of movement, speech, and any acoustic information become masked, and in turn becomes a texture that we consider to be noise. This noise creates a “Sound Wall” which tends to isolate the listener from the environment (Schafer, 1977). The industrial revolution caused a change in our living patterns. Factories, for instance, began operating around the clock, and identifiable daily routines of communities, people, and nature significantly eroded over time. Furthermore, as the shift to electric power occurred, banal sounds were generated as a by-product of machines and electrical processes; we refer to these as drones. These noise-like textures serve no function and can be heard in industrial areas twenty-four hours a day.

5.2. Acoustic Communication

Through his field research and writings, Schafer focused on the importance of maintaining a hi-fi sonic balance in our environment by minimizing noise generated as a by-product of modernization. Barry Truax, on the other hand, set out to look at the communicative aspects of sound. Thus, he developed the acoustic communication model, first published in the 1984 edition of his book, Acoustic Communication. In Truax’s model, rather than focusing on the energy transfer of sound, he emphasized the importance of the exchange of information between the listeners and their environment through sound. According to Truax, through cognitive processing, we are able to examine the sonic information and to discern the level of importance, or what is deemed to be useful, of the information sound provides. The central tenet of this communication model then is the human act of listening. Unlike hearing, listening requires the active participation of an individual to experience the sonic environment that surrounds us. Paul Carter refers to this as intentional listening, and this receptive method of actively listening is part of a “dynamic system of information exchange” (Erlmann, 2004; Truax, 1984). That is, the usability of
the information is driven by context and interactions, and it is through these that we are able to derive meaning from the sonic information. The context helps the listener understand the functionality of sound, and helps build the relationship between listener and environment. From a cultural standpoint, active listening can bring about social, historical and cultural references and inferences (Erlmann, 2004). Figure 5.1. depicts the relationship of listener and environment created through sound. Although sound appears to be in the centre of this figure, this does not reflect the lack of centrality of listening. Instead, it illustrates the listening process as relational and as a matter of information exchange within a specific context.

![Figure 5-1 Exchange of sound information between listener and environment (modified from Wrightson and Truax, 2001).](image)

Truax’s communication model also takes into account the role of the listener as “sound-maker.” Therefore, the system is comprised of the listener and the environment, which together establish the “soundscape”. According to Truax, an auditory channel is formed when a connection between the sonic event and the listener is established. A shared channel amongst multiple listeners produces social cohesion (Truax, 1984; Blesser, 2007). When the relationship of listener and environment is at equilibrium, the exchange of sonic information is at the highest degree. However, if an imbalance exists in the system, then the richness of information is degraded. In an acoustic environment, noise tends to be the main culprit that causes this imbalance in the system. Figure 5.2 illustrates the encoding and decoding process of sound.
The amount of sonic activity in the environment can cause the soundscape to deteriorate, affecting our awareness of the subtleties normally audible in our environment. This deterioration reduces the meaning of sounds to simply a positive or negative valence such as bad (loud) or good (quiet). In today’s developed society, the ratio of signal to noise has shifted dramatically towards noise. One type of noise that has been well-documented to have an adverse effect on mind and body is “ambient stressors.” Environmental conditions such as residential crowding, traffic congestion, and constant human activity are all ambient stressors. The term ambient refers to sounds occurring in the background that affects us at all levels, including our physiology, motivation, behaviour, and cognitive processing (Campbell, 1983). As Jean-Paul Thibaud suggests, “when we listen to an ambiance, we hear the unfolding of social life itself. Ambiances cannot be reduced to a subjective domain, but rather a public expression of a specific form of life, a way of living together (Thibaud, 2011, 6). For example, the Kaluli environment studied extensively by Steven Feld showed that the sight-lines and visual scope limited by the tropical rainforests made the community depend heavily on sounds to not only communicate, but to overcome visual restrictions by bridging the visible and invisible (Feld, 1996; Smith, 2007). Janis B. Nuckolls describes this framework of interaction as sound alignment which not only refers to human to human interaction, but includes human and non-human (environment and animals) interaction (Erlmann, 2004). Cultural norms influence our interpretation or the type of meaning that is derived. As an example, in 1975 the World Soundscape Project undertook a study analyzing the soundscapes of five European villages. In the village of Cembra, Italy, the researchers noticed the prominence of dialogue in the community. The extensive overlap of dialogue and the frequency of two or more people speaking at once was much greater than that found in any of the other villages they had visited. This
abundance of dialogue was contextually not noise, but was part of the Italian culture, creating a human soundscape (Schafer, 1978).

The importance of implementing the communication model is that it shifts our focus from prioritizing the physical properties of sound towards the manner in which sound mediates the relationship between the individual and environment. Further, the human experience within the context of an environment can be extended to include attitudes, memories, and a visceral sense of awareness (Smith, 1993). For example, what we might consider being delightful sounds, such as the sound of birds, is not only based on the physical properties of the sound, such as sound intensity or frequency levels; rather, it depends on the type of receptive information that is derived from listening to sounds: what makes a difference to the listener are the memories that we might associate with or its novelty (Southworth, 1969). This is similar to how listening to music can evoke memories as described in chapter 4. Therefore, by taking into account these human experiences, we can gain insight into the functionality of sound, and this, in turn, provides design opportunities.

5.3. Modes of Listening

5.3.1. Listening

Don Ihde explains listening and hearing from a phenomenological\textsuperscript{11} perspective and suggests that “any one object of experience may appear in different ways – perceived through the senses, imagined, remembered, hypothesized, etc” (Ihde, 1977, 18). Relating this back to sound and music, Ihde states that “I do not merely hear with my ears, I hear with my whole body. My ears are at best the focal organs of hearing” (Ihde, 2007, 44). Therefore, an exercise in hearing not only involves our auditory system but also, as Truax explains, “includes all modes of sensory and bodily experience” (Truax, 2013, 2). There is an additional component to listening that transforms our experience of listening, and that

\textsuperscript{11} Phenomenology is the study of components and structures that produce a subjective experience and consciousness normally from a first-person perspective as suggested by Edmund Husserl. It is the way humans construct an experience based on his or her own reality rather than a commonly shared objective reality.
is the influences of a ‘technological culture’. We have now adapted ourselves to “listen farther” in terms of distance through technological means, such as the telephone. Murray Schafer also shares this perspective and adds that transportation systems starting with the steam trains allowed sound to travel at greater distances, and later, through the introduction of air travel, we expanded our sonic milieu not just horizontally but vertically as well (Schafer, 1993). According to Ihde, sound is “continuously present to experience” (Ihde, 2007, 81). It penetrates our awareness and invades our presence. It can be pleasant at times, like the sounds of birds, or painful, like traffic and machine noise. Ihde considers the importance of hearing and its ability to allow us to hear voices of objects and shapes of sound. For example, the blind man tapping his cane provides an embodied experience of feeling and hearing the world. It provides the ability for the person to discern a concrete sidewalk from a boardwalk. That is, an object is made audible through the interaction of tapping but the sound is not limited to the object itself; it reveals the space one is situated in (Blesser and Salter, 2007). The proximity of an object is also made possible by sensing such an echo. Moreover, the distance of an object can either be experienced as synchronized or syncopated. For example, the sound from an object that is at close proximity, such as tapping on a glass window, is considered synchronized; we hear the glass and see the glass almost synchronously. But an airplane flying over can seem syncopated, meaning we hear the airplane in the distance, and after moments of looking up at the sky we may see it. We experience a delay between hearing and identifying the object. The opposite can occur as well, when we see an object first, and later we hear the sound. For example, with lightning we typically see the flashing of light, which is later followed by a burst of roaring explosive sound. Ihde also explains that hearing sounds can morph based on spatial changes that may occur. For example, a sound can have a very specific sonic quality in a small room, but the sound can morph (sometimes dramatically) if shifted to a larger space. This shape aspect of the sound changed by a shift in space can cause a misrepresentation of the size of the object involved in producing the sound. Nevertheless, it gives us the ability to detect the depth and size of the space itself.

Training ourselves to listen critically can dramatically increase our ability to hear subtleties never experienced before. Acknowledgement of the existence of sound, and its conceptualization only becomes true for us when we critically perceive, attend, and listen
to sonic information (Fluegge, 2011). Ihde provides several examples of discriminatory listening; one is that of an auto mechanic who can detect engine problems by listening to the nuances of the engine revs without having to dismantle the entire assembly. Some critically-trained musicians can hear the subtle microtonal timbral changes in Indian music. However, our ability to focus on the act of listening could potentially be disrupted by the domination of “visualism” (Ihde, 2007). Visualism is defined as a bias in favour of the dominating role of vision or that which can be seen. Ihde explains “visualism can be called into question by pointing up consequences that lead to the inattention to important dimensions of experience in other areas, here, in particular in an inattention to listening” (Ihde, 2007, 13). Historically and for perceptual reasons, we have developed a focus on visualism and it may be argued that sound habitually is of secondary importance (Gagnon, 2007). This comparative inattention to sound has gradually led to desensitization to the entire spectrum of sensory phenomena. Ihde, however, points out that there are limitations to how critically we can focus ourselves on the act of listening. We cannot isolate sound from its context and therefore engage in a “pure auditory experience” specifically from a phenomenological perspective.

Paul Rodaway, a researcher in the field of phenomenology, suggests that in North American and European culture we rely too much on visual information for providing context, and this therefore makes us susceptible to labeling sound events based on the object making the sound, rather the phenomenon (Rodaway, 1994). The scholar Walter Ong also distinguishes between sound and sight by suggesting that the world of sound is an event-world, while the world of sight is an object-world (Ong, 1971). Figure 5.3 is the sensuous matrix developed by Rodaway. It clearly illustrates the physical and mental processes at play and their relation to auditory sensation and meaning.

Rodaway expands our understanding of perception by breaking it down into two dimensions. First, perception can be a form of sensation. Sensation indicates a relationship between a person and the world that is both kinetic and biochemical by way of environmental stimuli mediated by our senses. Secondly, perception can be a form of cognition, a mental process that gives us the ability to culturally mediate, remember, associate, and recognize (Rodaway, 1994).
Figure 5-3 Sensuous Matrix created by Nazemi, 2016.

In these models, the auditory experience therefore becomes interactive, involving our body and our senses in the process of comprehending and deriving information from various sounds, both consciously and pre-consciously. Ihde provides an example of a context in which we might listen to rock music: the low frequency bass notes may be detected through resonance in our lower body, including the feet, while high frequency tones from the vocals and guitars are felt in our chest and head. It is also easy to separate sight and sound, and explain each dimension on its own. However, if we combine and overlap the two together, there may remain “the excess of sight over sound in the realm of the mute object” (Ihde, 2007, 51). That is, sound may become less significant when we encounter inaudible objects. On the other hand, there are situations where sound can dominate the visual senses. Ihde provides an example of walking along a dark country path. Our awareness of sound increases dramatically when our vision is limited due to the low light conditions. “Listening make the invisible present in a way similar to the presence of the mute in vision” (Ihde, 2007, 51). Sound which is event-based and can temporarily “fill” the space between us, like the wind we feel and hear, is an example of experiencing the invisible. Technological interventions such as using headphones and microphones can also heighten our sense of listening to sonic detail. Headphones also occlude the external space, creating an empty container of silence that is later filled with sounds.

Ihde provides two types of focusing that we may use during the active listening process. Narrow focusing involves a high level of concentration at the onset of the sound, usually at the source-point (from where the sound originally emanates) or the tail end of
the sound, the point at which we may hear only the trailing of reverberation. This narrow listening may be used to decipher what the sound source is and what its characteristics are, such as texture and shape. We may be put in a position of narrow listening when it is a matter of survival. For example, when we are in a forest and we hear a sound that could indicate that a large predator is nearby, we automatically switch to narrow listening to localize the sound source and detect the position of the animal. Another type of focus is broad or open, where we may listen to the richness of the sounds in a temporal domain, and perhaps consciously experience the affective quality, as would be the case with music. Analysis of the sounds in a temporal domain may involve a comparison of musical notes that preceded, just occurred, and are expected, which dictates the depth of listening we are engaged in with the music. Figure 5.4, is a simple visual illustration of the modes of focusing during the listening process.

![Diagram showing comparison of narrow and broad listening in an auditory field.](image)

**Figure 5-4 Comparison of narrow and broad listening in an auditory field.**

Critical listening can also become polyphonic. That is, we not only listen to a single sound but a multitude of sounds, which also includes hearing ourselves in the process. In addition, polyphonic listening includes subjective listening by involving “perceptual and imaginative modes” (Ihde, 2007). Polyphonic listening commonly occurs when we listen to music especially when the music engages us in a bodily listening mode by attuning our body to move with the music.
5.3.2. **Background and Foreground Listening**

The categorizations of hi-fi and lo-fi environments as defined by Schafer (see page 58) are linked to how attentive we are to the sounds in our environment, and how we relate to modes of listening as described by Barry Truax’s Acoustic Communication model. According to Truax, there are two modes of listening that we must recognize as designers: background and foreground. Usually, the background has repetitive and banal sounds while the more salient sounds are in the foreground. Distinguishing between background and foreground sounds is significant because when we compose soundscapes or are designing multi-layered immersive environmental audio compositions, the hierarchical levels in which sound cues are embedded will either be set to be in the background or foreground. Therefore, these two modes are useful in comprehending the level of attention that is required from the listener. In film sound, sound designer Walter Murch categorizes the listening process in a similar manner: foreground sounds are meant to be listened to, while middle-background sounds are to be heard on a subconscious level (Paine, 1985).

In a virtual environment (VE), this is an important factor because the user’s state continually changes according to interactivity; therefore, the system has to be designed to prioritize sound cues.

Background listening relates to our level of attentiveness. If a sound such as a running fan has no real significance sonically, we tend to ascribe that sound to the background even though we are aware of it. Our awareness of the sound is at a conscious level; however, no significant meaning is derived from that sonic information. Technological sounds such as electrical hums, fans, and motors, which are repetitive in nature and have consistent volume level, would be considered to promote a background listening mode since they do not communicate valuable information. The consistency of background sounds can cause a smearing or masking effect, which can have an impact on the perceived depth of a space. Therefore, in a soundscape composition, repetitive sounds, which are automatically identified as background sounds by the listener, could impact the perceived spatiality of the environment, such as reducing the sense of scale. Or it could lead to ear fatigue, and therefore negatively affect the degree of immersion.

When sound begins to have some level of significance, then our focus shifts from background to foreground listening. In a foreground listening mode, when there is enough
meaningful sonic information, we become more aware of the sound. Of course, the amount of significant information might become degraded if it is being masked by background sounds. For example, on a busy street, the noise level might be loud enough to cover the foreground sound, thereby reducing its importance from a communicational perspective. Therefore, when considering volume levels for sound cues, we have to realize the balance between background and foreground sounds and create clear pockets in which information can be mediated. Furthermore, if redundancy of a sound such as footsteps is constantly heard in the composition, then eventually that sound will switch to background listening, which may impact the level of immersion experienced by the participant. Hence, we must consider the phenomenological experience of listening elicited by environmental sounds. As interaction designer William Gaver suggests, we hear events in our surrounding milieu rather than hearing sounds (Gaver, 1993). Another concern with the act of listening is the influence of visual perception and how our meaning of the sound can potentially change. Music philosopher Marcel Cobussen describes the simultaneous bodily and mental activity of listening and hearing as ‘registering,’ that is we can consciously and unconsciously register many sounds (Cobussen, 2012).

5.3.3. Everyday Listening

When developing soundscape compositions for chronic pain patients, it important to understand how the compositions affect the way the listener comprehends the sonic material. In addition, the designers new to the field of soundscapes must train themselves to the different ways we can listen to sounds. For example, the kind of meaning that is communicated from each layer of sounds (background and foreground sounds), and how the meaning and affective quality of sound can change when we apply digital processing (reverberation, time manipulation, sampling, and synthesis).

Cobussen offers five categories of everyday listening based on Ruth Herbert’s work.

1. Our experience of listening fluctuates; at times we may focus our attention purely on the act of listening to music, while other times the sound may barely be received.
2. Listeners may experience multi-sensory coupling or a heightened state of awareness. Specifically, everyday listening typically involves other activities and therefore may become an amalgamation of aural, visual, kinaesthetic, and other bodily senses.

3. Listening can turn into a form of ‘visual listening,’ which may produce a filmic quality, turning the music into a soundtrack and changing our experience of our surrounding environment. This listening experience is consistent with the findings of sound researcher Michael Bull that many people who listen to music using portable music players have the ability to create their own ‘soundtrack’ as they move through space and time (Bull, 2006). This form of visual listening is also a by-product of shutting out the noisy world around us by submerging ourselves into music as we move about in our environment. The music, in this case, becomes a virtual soundscape that overpowers the sounds of the environment, controlling it rather than allowing it to express naturally.

4. Listening can be a form of distraction or act as a mental block by causing ‘changes of thought’ or ‘reduced thought experiences’ – either positively, such as in meditation, or negatively, as a defence against certain thought processes or concerns. Such a phenomenon is called ‘imagery,’ which through music can aid in concentration or create dreamlike states. This phenomenon of music listening has been used in therapeutic settings. For example, often assisting patients with Alzheimer’s or Dementia to regain cognitive focus (at least while exposed to music), evoke memories of earlier events, or place patients in a state of mind that cannot be conjured in any other way (Sacks, 2007).

5. Finally, one practical reason for the everyday use of music is to just ‘pass the time,’ such as when waiting in a doctor’s office (Herbert, 2011).

Although these categories are meant for music, they are applicable to listening to everyday environmental sounds.
5.3.4. Multi-modal Listening

Composer and musicologist Pierre Schaeffer also explored our mental or cognitive process of multi-modal listening by stating that there are four modes, or ways of listening, and divided them into two sets of oppositions as shown in Table 5.1. He described a form of a reduced mode of listening, which is defined as attending to the sound without any focus on its source.

<table>
<thead>
<tr>
<th></th>
<th>Abstract</th>
<th>Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Comprendre (Understand)</td>
<td>Écouter (Listen)</td>
</tr>
<tr>
<td>Subjective</td>
<td>Entendre (Hear)</td>
<td>Ouïr (Listen)</td>
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Table 5-2 Schaeffer’s four ways of listening.

The objective modes are related to the object of perception, that is, the meaning derived from sound is directly dependent on its context and therefore the perceptual objects or events it points to become the focus of the listening experience. The subjective modes are listener-centred and place focus on the sound without attending to the referent object. The concrete modes involve listening to sound without extracting any meaning from it (beyond its deictic function) and conversely, the abstract modes deal with situations in which we do derive meaning from the sound (Kane, 2007; Vickers, 2012).

Schaeffer’s work has received criticism since his model undermines the importance of the surrounding environment and how it can shape the listening experience. It is important to note that Schaeffer’s theoretical model does imply that sounds from our everyday world can be used and listened to musically. Gaver’s musical listening also shares some similarities to Schaeffer’s and suggests that it is possible to listen to everyday auditory environments as music and to break down musical performances in terms of their causality and sound sources (Gaver, 1989). One example of how environmental sounds can be produced, packaged and listened to like music is the extensive work that was released by American field recordist Irv Teibel from 1970 to 1990. His Environments series became very popular releases and ignited an interest in field recordings to such an extent that his recordings were published by a major record label (Cummings, 2016). Composer
Michael Chion adapted the theory of reduced mode of listening to sound design and essentially converted it into an analytical tool for understanding the role of sound from a communication standpoint for film applications. Similar to Schaeffer, Chion was interested in *acousmatic* situations whereby the causality of sound is not always visible to the listener. This approach allowed the freedom to experiment more with the sound itself by combining or synthesizing artificial sounds from both natural and non-natural sources (Chion, 1994).

### 5.3.5. Causal, Semantic, and Reduced Listening

Furthermore, Chion expanded the modes of listening by categorizing them into *causal, semantic*, and *reduced* modes as shown in Table 5.2. Causal listening is the most common since it involves listening to a sound to understand its cause or source. If the cause is visible, for example, a dog barking, then the sound itself can provide us with additional information about the nature of the bark. One caveat with causal listening is that it may not always be accurate and could potentially be deceptive, or influenced by other factors including the surrounding environment, cultural attachment, and memory recall. Therefore, causal listening may take place at various levels and is dependent on the recognizability of the sound source, proximity (in addition to visibility), and how informed we are about the variances of the sound. Semantic listening refers to language or sonic code like Morse or Sonar. The way semantic listening functions is very complex, and it involves our recognizability of phonemes and acoustical properties that relate to affect, in addition to comprehension based on pronunciation. In the movie *Avatar*, a significant effort was put into constructing a new language (Na’vi), used by the characters playing the people of “Pandora,” thereby adding plausibility and realism for the audience. Reduced listening, which derives from Pierre Schaeffer’s work, focuses on the traits of the sound itself without any emphasis on its cause or meaning. In order for the reduced listening to take place, the sound must be fixed because it requires repeated listening to grasp the complexity of the sound itself. This makes the process very challenging since the sound must be regenerated in exactly the same way. Recordings and electronic instruments such as synthesizers make this a possibility, but it is very difficult to do this with live performing musicians.
Causal Listening | Semantic Listening | Reduced Listening
---|---|---
Source based | Culture specific | Abstract
Ecological | Context driven | Subjective or qualitative oriented
Involves “everyday listening” | Communicative listening | Listening to sound itself

Table 5-3 Chion’s modes of listening.

Reduced listening involves critical listening, and practice to hear the nuances of a sound, such as identifying the pitch of a tone or distinguishing between two musical tones. Murray Schafer attempted to understand the properties of environmental sounds by referring to them as *sound objects*. In this way, we can analyze the spectral quality of the sound including its transients, body, and decay. However, in today’s world of technology, reduced listening has become more convenient since we are tempted to use very detailed visual spectrum analyzers to understand the properties of sounds. Reduced listening can help improve our creativity when engaging in sound design work. By familiarizing ourselves with sound objects, we can create new interesting sounds, which can be advantageous when developing unique sounds for film and game projects. Ben Burt’s sound design work is a great example of using reduced listening to create iconic sounds, like the sound of Wall-E, or the sounds of the light sabre in *Star Wars*.

5.3.6. **Connotative Listening**

The connotative mode of listening involves focusing on sounds that evoke early associations to pre-conscious experiences in the listener. This form of listening is essential for this research into self-administered sound therapy for chronic pain sufferers because it allows for patients to reference past experiences that hopefully produce a positive valence. It provides an opportunity to escape momentarily to another place by having sounds trigger instances of memory that are important to the listener. The sounds essentially become a building material that helps augment those past experiences. A
connotative listening mode is a subjective form of critical listening that at a fundamental level allows the listener to infer various physical properties of sound. This listening mode includes perceptual information related to the sound source and environment (Tuuri, 2007). Connotations can also be evoked through structural rhythms of sounds like the intensity of rainfall or patterns of walking. This form of listening can be useful when we want to augment the immersive quality of a soundscape composition for patients and support the creation of a perceptual change of environment while listening.

5.3.7. Reflexive Listening

Finally, the reflexive listening mode is considered to be an emotional reaction to listening rather than the act itself, and it is brought about by snippets of audio samples and abrupt volume changes. Music cognition researcher David Huron discusses various forms of reflexes that are evoked by sounds, expectations, habituation, attention, and sensory dissonance. These include defense reflex, startle response, and orientating response (Huron, 2002; Tuuri, 2007). These reflexes are difficult to control since they are the result of involuntary responses by the listener and usually resist conscious mediation and interpretation. For this research, this mode is very crucial since patients may already be in a high stress or painful state, and any sound that may bring about a negative reflex can cause additional pain or stress. It is, therefore, important to study sounds that are considered to evoke a negative reflex and remove those from compositions.

5.4. Noise & Silence

5.4.1. Silence

According to the Webster dictionary, silence is a lack of sound or noise. Silence has often been associated with “slow-time,” and the highly sensory events that tend to be experienced by most people in this elongated time frame (Bruneau, 1973). From an acoustic ecological perspective, the positive cultural outlook on silence in rural landscapes can have a calming effect and provide a sense of peace (Miller, 1993). The sonic environment, experience, and aesthetics can provoke our senses and change the way we experience objects, people, and our surrounding environment (Steel, 2004). In this
instance, I am suggesting that silence has a communicative quality. As artist and writer Salomé Voegelin states, “silence is not the absence of sound, but the beginning of listening” (Voegelin, 2010, 83). Focusing on sounds in silence elicits a subjective form of amplification by which all audible objects feel as if they are in close proximity to a microphone, picking up every nuance and modulation.

In addition, silence can be considered as a concept, and an “actual process of the mind” (Bruneau, 1973). Silence provides the opportunity for the mind to focus inwards – that is, shifting the focus from the environment to our body and inside our body. A form of intersubjective listening can take place allowing us to become more attuned to our breathing, the pulse of our heart, and the growl of our stomach when hungry. This experience is that of listening to the soundscape of our own body. Intersubjective listening can be disrupted if we experience extreme suffering like chronic headaches, tension, and anxiety (Southworth, 1969). The absence of sound due to hearing damage can be deafening and the phenomenon cannot be tolerated by both our mind and body (White, 1975).

5.5. Noise

Although tranquil hi-fi environments may allow us to experience momentary mental and physical relaxation, in reality, the difficulty is having access to such environments, since we are mostly involved with a busy and constantly aroused city life. If silence is associated with tranquility and calmness, then noise fits on the other end of the spectrum and can be associated with lo-fi sounds. For example, we describe the liveliness or excitement of a city as having a “buzz,” referring to the continuous noise and activity that is situated in the environment. Sound essentially becomes one of the “characteristics that makes a city a city” (Kelman, 2010, 217). This experience is in contrast to how many of us have come to view the countryside or the wilderness as remote, “off the grid” (disconnected from technology/electricity), and boredom.

The physical and psychological toll that arises from direct exposure to living in noisy environments is important to consider. The ambient noise that surrounds us can increase our experience of stress and anxiety without realizing the culprit (Edsell, 1976;
Lercher, 1996; Nivison, Endresen, 1993). We try masking the noise, the sounds of our surrounding environment, with music or noise generating home appliances such as fans acting as an “audioanalgesic,” which Schafer refers to as a sound-wall that blocks our inner dialogue or emotional stresses (Schafer, 1977). In addition, Schafer had developed a representation to show how competition between sonic awareness and control was leading to an increase in environmental noise levels by 0.5 decibels per year. This increase in noise levels makes it difficult to discern what is information and what is not. As the writer and sound artist Elen Fluegge suggests, we are now living in a society where privacy over personal sound space has become a commodity, whether we prefer noise or silence. The noise itself does not need to be in the foreground or be loud to destroy sonic signifiers. In fact, any sound including music can turn into noise. Therefore, a boundary exists between pleasure and annoyance in sounds. If music is played loud enough or the genre is not suited to our liking, then it becomes noise to us. Sounds in the environment that are repetitive or loud tend to be perceived as “formless” yet have a spatial quality that targets the “listening body” (Voegelin, 2010). The affective quality of noise is especially disconcerting for chronic pain sufferers whose sonic territory is threatened due to increased noise, and since they have an elevated level of sensitivity to sound, it can lead them to experience longer periods of pain and anxiety.

Figure 5-5 Schafer’s Noise Generator Model (Wrightson, 2000).

Schafer’s goal was to promote hi-fi soundscapes and eradicate noise. Whereas soundscape researcher Heikki Uimonen, on the other hand, suggests that we should
concentrate on the importance of everyday sounds “as a source of wellbeing for individuals and community, instead of concentrating on sound only as a disturbance and unwanted noise” (Uimonen, 2011, 256).

Noise is not always a by-product of our environment. I refer to this as inter-subjective noise, and it is different from the mental dialogue we may experience in our head. The hypersensitivity experienced transforms the sounds to an unpleasant noise like quality. This form of noise can affect our mood, sleep, the perception of time, and interaction with people. The experience of inter-subjective noise can be further amplified by stressors and sensitivity to our surrounding environment. Recently, studies have shown that noise can impede the process of neuroplasticity. Exposure to noise can interfere with limbic system, the area of the brain that controls emotion (Amemiya et. Al, 2010; Kraus and Canlon, 2012). This intersubjective noise may blur our cognitive ability to think clearly and keep us locked in an agitated state. I have observed this first-hand by speaking to chronic pain patients who have said that the pain becomes a nagging noise and can be debilitating, acting as a wall that doesn’t allow for any escape.

In this chapter, a theoretical framework for composing soundscapes was provided that help defines the relationship between human beings and their environment mediated through sound. From a design standpoint, the communicative qualities of sound, the different listening modes, and the affective qualities of noise and silence were discussed that can be used as a guideline for composing soundscapes for therapeutic purposes. Using this theoretical framework in addition to the upcoming chapters on soundscape compositions and its impact on patients may give us insight into how we can allow chronic pain patients to reduce their exposure to inter-subjective noise caused by pain and anxiety. In turn, this approach may help them regain control over their mind and body through listening to therapy-focused soundscape compositions.
Chapter 6. Soundscape composition

In the previous chapter, I examined the theories associated with acoustic ecology and soundscapes, beginning with acoustic ecology, a discipline that uses sound to analyze the ecology of landscapes, the influences humankind has had on the sonic environment and its impact on us. The acoustic communication model, modes of listening, noise, and silence were also discussed; these are foundational to composing soundscapes. As a designer, a shift in focus is required in order to move from the theoretical framework of soundscapes to practical methods of composing soundscapes to administer to chronic pain patients for anxiety and pain management. Therefore, a better understanding of soundscape composition, the immersive quality of these compositions, and the listener experience, is key to this research. In this chapter, I discuss the practical approaches and process of creating soundscape compositions, including soundwalks, field recording techniques, listening perspectives, and spatialization through audio playback methods.

6.1. Soundwalks

As a designer, especially if new to the field of acoustic ecology, we can be more attuned to the environment and become better at listening critically by participating in a soundwalk. A soundwalk is an important practical method that involves the active participation of listening to the sounds of an environment one is in. A soundwalk can take place anywhere: in a park, a restaurant, or a city block. Even the backyard may sometimes serve as an interesting place for sound discovery. The practice of soundwalks was developed by the World Soundscape Project (WSP) as a means to deeply understand a particular acoustic environment through specific listening exercises. The goal of a soundwalk is to prioritize the act of listening to become more receptive to and aware of the sounds of the environment. Through this practice, we become akin to a human field recorder, attentively listening to the nuances around us. Soundwalks consist of 3 diverging parameters: time, space, and event. These become the parameters for deriving meaning from the sonic environment. During a soundwalk, the environment can be experienced from a performative perspective, wherein the listener becomes an active participant,
listening and attentively moving through the space. The sounds are not limited to the environment; however — they include the sounds produced by the participant, such as footsteps, or breathing. This practice, in turn, generates a real-time soundscape composition that is unique to the individual participating in the soundwalk. Jean-François Augoyard created a research method called *Qualitative listening in motion* in which recordings of the environment were captured while interviewing participants. An interviewer and interviewee would select a route and while walking, the interviewee would record sounds with a microphone and comment about what he or she was listening to (Uimonen, 2002) thereby making it useful for documenting sound-related memories and experiences.

There are several ways in which a soundwalk can be organized. A soundwalk can have a predetermined route, and be hosted by a leader who monitors the pace of participants and provides relevant information about the location. A soundwalk may also incorporate additional sonic elements that participants may actively introduce into the environment — for example, through a loudspeaker or contact microphones, or by hitting objects using mallets and re-amplifying it back into the environment. Changes in the sound environment also depend on the size of the space and the time of day. Therefore, repeating the soundwalk at different times of the day may reveal new soundscapes that could vary dramatically. The organizers of a soundwalk can compose the walk in a way that reveals or masks certain sonic qualities. They may also base the walk on themes, such as the sounds of a parking lot or those of a local Chinese restaurant. Regardless of the amount of organization that occurs during the scoring phase of a soundwalk, the unpredictability of nature, such as changes of weather, or the interjection of human activity, can cause variations in the experience of it. As Westerkamp explains, “one can attempt to find a route that keeps the ears alert, i.e. that offers changes and contrasts, opportunities to rest overburdened ears, etc. But what occurs during the planning of a soundwalk route may not happen at all during the final group walk” (Westerkamp, 2008).

The importance of the soundwalk is that it creates a strong connection between the listener and the environment. Therefore, as a sound designer working with creating compositions specific for pain and anxiety management, I find it important to understand the environment in terms of its spatial and locative qualities, in addition to the types of
sounds heard that might have a therapeutic effect. By using soundwalks as a preparatory phase of design, we may heighten the experience of the participant in the virtual auditory landscape and improve its immersive quality by creating a stronger connection between participant and environment.

6.2. Field Recording

An important practical method to capturing the sounds of an environment is by becoming familiar with field recording techniques. As a designer, field recording plays an integral role in my research, utilized for documenting my soundwalks and capturing the sounds of the environments as source material for developing soundscape compositions. According to Paul Virostek, field recording can be used for storytelling, sampling, sound libraries, creating interaction, and treating the edited sounds as a collection of tools that can be utilized for various sound design projects (Virostek, 2013).

6.2.1. Story Telling

For telling stories, the field recordist, similar to a photographer, takes sonic snapshots of sounds that may elicit emotion, memory, or describe certain events such as celebrations. This role may require the field recordist to capture an extensive collection of sounds over time to produce the right story. It may also involve the recordist providing a running commentary during the walk (Rennie, 2014).

6.2.2. Sampling and Contributing

A field recording artist may use specialized equipment to capture a large series of sounds that may later be edited and sold as sound effects libraries. For example, world-renowned field recording artist Chris Watson is known for his wonderful ability to capture sounds of wildlife. Over the years, he has developed his own recording methodologies for capturing sounds, such as positioning microphones on branches, in the ground, or other locations to capture both the sound of animals but also of the surrounding environment. Watson Wu is another field recording artist who specializes in recording sounds of cars and guns for action-based video games. He uses an assortment of
microphones placed at various distances to capture both close and distant sound of objects. These artists usually spend time editing the recordings by optimizing volume levels and cutting unwanted sounds from the recordings.

6.2.3. Creating an Interaction

Field recording can be very challenging, and it requires practice to learn how to use professional equipment for recording accurately, and understand environmental constraints such as wind noise, rain, and the sound of the field recordist - e.g., breathing – interjecting in the recording process. A field recording artist needs to grasp the relationship between the role of equipment and that of the recordist, and how both influence the outcome of the recording process (Drever, 2017). Therefore, soundwalks can be very useful in practice because you can take the same route multiple times at different times of the day to capture all the nuances of the environment. In addition, playing back the recording will allow the recordist to get a sense of how his or her role (body, clothing, pace, breathing, etc.) impacted the recording.

6.2.4. Collecting Tools

The final purpose of field recording is to treat the recorded audio samples as your tools. I consider them to be the raw material used as building blocks for soundscape compositions. When setting out to record a session, especially in the context of research, the recordist must understand the goal and audience. It is the why, and for whom that allows the recordist to select the appropriate location, equipment, and recording approach. For my research, I am trying capture sounds that can be used to create auditory journeys that have positive therapeutic effects when played back for patients.

Paul Virostek provides four categories field recording: controlled, investigative, stealth and guerrilla.
6.2.5. **Controlled**

In a controlled situation, the role of the sound recordist is to be present a particular set location and follow the recommendations provided by a client to capture sounds. The sound recordist has complete control of the situation and can direct the role of people (perhaps actors) and equipment (e.g. cars) in order to capture the best results. Normally these field recordists have access to elaborate microphone arrangements and multiple recorders. Detailed pre-production planning goes into preparing such a session since there may be time and budget constraints that must be adhered to by the recordist and client.

6.2.6. **Investigative Field Recording**

This type of recording requires research when determining the best sound(s) needed, and a session is arranged in a way that fits the requirements. A client may have an idea for custom sounds that are required, and it is up to the field recordist to determine how to capture and create them. Several takes of the same sound may be recorded and layered later to produce the desired result. The environment used may not necessarily be controlled, and again a soundwalk may be useful to determine the appropriateness of the location. The challenge is that there is the possibility of capturing a fair amount of unwanted sounds, which may increase the editing time in post-production.

6.2.7. **Stealth Field Recording**

This type of field recording may break ethical boundaries if there are people or locations that have not been confirmed or informed ahead of time. The environment could be considered to be ‘hostile’ since the presence of the recordist must not be known; otherwise it could compromise the recording session. The equipment must be concealed and protected, or it could raise suspicion. Sometimes, the field recordist may have to wait for a long time to capture the right moment for a sound event to take place. Although this method may produce some unusual and evocative sounds, for the purpose of conducting research, this approach is typically frowned upon due to privacy concerns.
6.2.8. Guerrilla Field Recording

This last category requires the field recordist to be constantly on the move to capture that perfect moment. Similar to stealth recording, the field recordist is working in an uncontrolled environment with moments of unpredictability, including unstable weather conditions. This type of recording requires a lot of experience, and the recordist must be able to quickly analyze the situation and accommodate for any changes. Imagine trying to capture the sounds of a riot or a war zone for a documentary. Both the field recordist and his or her equipment may be at risk in this situation.

For my research, a combination of controlled and investigative field recording methods is used to capture the appropriate materials for creating the soundscape compositions.

6.3. Composing Soundscapes

In the fall of 2007, the editors of Soundscape: The Journal of Acoustic Ecology issued a call for action to challenge the acoustic ecology community to dig deeper into the role of soundscapes and consider ways that the works produced can contribute in a more practical and influential way to the work of scientists and activists. “Where is the sound art that communicates and helps ground scientists, or that speaks directly to the crises that call for widespread changes in our society’s relationships with the natural world?” (Cummings and Miller, 2007). This comment from the editors resonates with me as I believe the way I am using soundscapes is diversifying the role of this artistic practice to contribute to the field of health sciences.

The concept for composing soundscapes was developed as part of the research conducted by the WSP group. The premise was to re-contextualize or re-embbody the environmental sounds through soundscape compositions. These compositions would then be played back in a performance space such as a concert hall. Generally, the use of post-processing was kept to a minimum during the editing phase to enable listeners to re-experience the sonic environment. However, editing and processing were also used to enhance the soundscape by creating an imagined or ‘abstracted’ environment. In this
instance, the use of post-processing such as granular synthesis\textsuperscript{12}, algorithmic\textsuperscript{13} or convolution reverb may be used to create an imagined space. Pioneers such as Barry Truax and Hildegard Westerkamp conceived of experimenting with re-contextualization and re-presenting the subjective experience of soundscapes through post-editing and post-processing of environmental sounds.

The goal of creating a soundscape composition is to focus on producing an imaginative space that the listener can associate with, and one that can evoke memories. According to Truax, there are four important principles/characteristics for composing a soundscape that can be used as guidelines:

- Listener recognizability of the source material is maintained.
- Listener’s knowledge of the environmental and psychological context is invoked.
- Composer’s knowledge of the environmental and psychological context influences the shape of the composition at every level.
- The work enhances our understanding of the world, and its influence carries over into everyday perceptual habits (Truax, 2002).

Sound designers may easily integrate these four principles as a means of developing an effective soundscape. The types of sounds that can be used when composing a soundscape range from found sounds recorded with field recorders to Foley, which is the creation or re-creation of sounds in the studio using an array of objects that have different tonal qualities. Moreover, the sounds can be combined and processed using effects to create abstracted and texturized sounds. Abstracted sounds are sounds that are synthetically produced through the use of effects processing, sampling, and synthesis. The original source for an abstracted sound may be a found sound but it eventually morphs

\textsuperscript{12} Granular Synthesis: a method by which short sound samples (30-50ms) called grains are used and reorganised to produce other complex types of sounds.

\textsuperscript{13} Algorithmic and Convolution Reverb: algorithmic reverb produces a room’s characteristics by using algorithms that can generate a set number of reflections, subject them to high-frequency damping, pre-delay, simulate room size, etc. While convolution reverb achieves this using “impulses” which are short sampled recordings of a room’s decay characteristics.
into an abstracted form based on synthetic processing techniques like granular synthesis and convolution.

6.4. Perspectives

As a composer of soundscapes, it is important to understand how the choice of sonic material, arrangement, and audio processing can influence the listener. Therefore, an understanding of perspectives is necessary to properly create an immersive and engaging listening experience. Since this research relies on creating an individualized experience, we must understand the role of personal sound space. The auditory interaction we experience in a physical or virtual space is subjective and complex. The personal sound space refers to an “individual’s auditory experience, which entails not only what a person may be hearing or where they are hearing it, but also the social conditions influencing their apprehension. It makes allowance for the way interactive situations and overlapping of sound spaces can change the conceptualization of one’s own aural circumstance” (Fluegge, 2011, 1-2). Perspective plays an important role in determining the relationship between place and listener in an environment. Barry Truax focuses on the structural approaches to composing soundscapes by providing three types of aural perspectives: fixed, moving, and variable (Schafer, 1997 and Truax, 2002).

6.4.1. Fixed Perspective

Emphasis is placed on the relationships of the sounds and their interplay as time flows. The composition is derived from recorded material from one location, and only the time parameter may be adjusted. Therefore, the emphasis of the composition is placed on the flow of sound events in time. The fixed perspective provides an opportunity for the listener to experience the sound events without movement or changing listening positions. Such experience of time not only can occur by way of sound events that are unedited or processed during the composition phase, but the experience can be enhanced and ‘densified’ by layering and changing the duration of each sound object. For example, granular synthesis can be used to time-stretch the original sound, creating a new textural sound. Further, the illusion of time itself can be compressed or remain unedited depending on the length of the composition. The layering of the sounds can create an enhanced or
rich environment when the composition is played back using a multi-channel sound system. In Truax’s composition *Pendlerdrøm (1997)*, four separate stereo recordings of the Copenhagen train station were recorded in close temporal proximity to each other and then layered together in an octophonic audio configuration. In an octophonic configuration, eight discrete speakers are placed in a circular position at an approximately 45° angle. A cubic speaker formation can also be used if space is limited. By using such layering techniques, the resolution or complexity of the sound is enhanced, evoking a sense of a busy train station. The approach for transitioning from one sound to another is made relatively smooth through long crossfades. However, to indicate the passage of time or shifting from one perspective to another, abrupt sounds that have a fast attack and short decay — such as a door slam — may be used to emphasize this shift. Poems, narration, and spoken words are additional types of sonic media that can be incorporated to enhance the listening experience. The fixed perspective can also include additional perspectives in successive series that are too fast to acknowledge the “sense of travel.” Truax provides the film cut as a reference to how such an abrupt transition could be included as part of the composition. Hildegard Westerkamp’s *Talking Rain (1997)* is a good example of how such a transition can be embedded in the composition. In this composition, the passing of a car on a wet pavement and its stereo shift from one speaker to another depicts the transition between the opening rain forest scenes (Westerkamp, 1998).

The fixed perspective provides an opportunity to encourage a narrowly focused listening experience as defined by Ihde because, in this manner, attention is placed on the sound events that emanate from the speakers. The nature of the space in which the speakers are placed can cause distortion in locating the original source of each sound event. Reflective surfaces and resonant frequencies of the sounds can mask the original location of the sonic event. However, such displacement may add an additional layer, specifically the element of surprise, to the performance. The movement that is caused in the space by the sounds can produce an affective quality that could be symbolic, hypnotic or mood changing. Truax suggests that the high level of concentration on sound events and their movements in the space may be similar to the experience of meditation, “where one releases all intentionality and the mind remains open to whatever may occur” (Truax, 2002, 9).
6.4.2. Moving Perspective

The changing of spatial location over time can help enhance the sense of immersion when listening to soundscape or music compositions. In addition, the use of surround-sound or binaural recording can add dynamism to the placement of sounds and can enable the listener to feel more engaged in a shifting environment. Our auditory system is equipped to sense a change of space and perspective quickly. This type of composition is termed a moving perspective. According to Truax, the journey can be “literal in the sense of an adventure, psychological in the sense of the developmental stages of life, or symbolic in the sense of conflict and resolution. Soundscape compositions that propose the illusion of a moving perspective may function at any or all of these levels” (Truax, 2002, 10). The moving perspective can involve the broad or open listening proposed by Ihde, in which a change in perspective can occur over a longer period, such as the entire length of a musical composition. The idea of movement is a parameter that is part of the definition of a sound, a vibration or a wave pattern. However, when viewed from a macro level, movement can also be event-based; it can have a distinct pattern or evolve over time into something new. For example, the composer can shift from one environment to another using crossfade and panning techniques. This dynamism associated with sound is a function that we are accustomed to therefore, we can easily understand and sense such changes. The depiction of dynamic movement is a powerful sound design technique used to enhance the soundscape both spatially and semantically.

There are several other techniques that can be used to create this type of perspective. For example, editing the length of each sound by compressing or stretching with changes to reverberation can convey a sense of change in perspective. Truax provides an example of a ferry trip in the WSP’s Vancouver Soundscapes document (1973) that simulates this type of perspective by creating distant sounds and sounds near the ferry using reverberation and audio editing. Although there are flaws in the recording, like the overlapping of ambiances and sounds of waves, it seems possible that the audience is willing to forgive such errors and listen broadly to the journey itself. Such an editing style is similar to how movies are edited to depict passing of time; the audience overlooks the temporal inconsistencies and the compression or expansion of the linear flow of time. The creation of a moving perspective is not limited to just editing and
adjustment in reverberation. It can involve the morphing of one sound event into another by ‘doubling’ audio tracks, layering, pitching one from another, and real-time processing of effects. In addition, the use of surround-sound can be used to take advantage of such perspective changes by discretely assigning sound events to move from one location to another. The use of multi-channel speakers immerses the listener in an experience that shifts the soundscape composition from “the highly plausible to the highly abstracted, with the possibility of smooth transitions between them” (Truax, 2002, 11).

6.4.3. Variable Perspective

A rapid change can produce another perspective, which is referred to as a variable perspective. Such a sudden shift may not necessarily convey movement but a sense of disembodiment from the environment, which creates a “schizophrenic” listening experience (Truax, 2002). Although this type of listening may seem to produce a certain feeling of nervousness, as suggested by Murray Schafer (see Schafer, 1993), we are culturally accustomed to the multiplicity and overlapping of natural and reproduced sounds with various spatial characteristics. This polyphonic way of listening seems natural since listeners are used to experiencing music via headphones and multi-channel systems. The challenge for the composer is to know how to maintain the focus of the listener and actively engage them in the complexity of sound events occurring in soundscape or music compositions. A composition that involves a variable perspective will generate an experience that combines both attentive and distractive listening (Thibaud, 2011). Such active engagement in listening requires work and proactive participation by the listener. In addition, the listener may need to have knowledge of the technical processing, or familiarity with the compositional style to interpret or discern auditory sensation; otherwise passive listening, “a letting of sounds wash over the ear” (Stefan, 2007, 625), could be encouraged. Truax explains how in his piece, The Blind Man, the bells of Salzburg Cathedral that were recorded by the World Soundscape Project, were transformed by removing specific frequencies, altering, morphing, and assigning the sound to a particular speaker position.
6.4.4. Mediated Spaces

Mediated spaces can be conceived of as exploratory spaces that use the principles of soundwalks and soundscapes to create a simulated environment through the means of audio playback. The audio may consist of environmental sounds recorded using binaural microphones, narration, or music. It is a technique in which the listener is also an active participant; this transforms the environment into more of a performance space. In such a mediated space, the participant physically moves through a real environment but is simultaneously immersed in a virtual space created using binaural recordings that are played back through headphones. The use of binaural recordings helps to recreate a convincing sensation of three-dimensional sound. Using a combination of binaural recording and blending or crossfading, the virtual and physical environments together can create a sense of mediation. Janet Cardiff and Christina Kubisch are sound installation artists known for their seminal soundwalks that focus on mediated spaces. Since the late 1970’s, Kubisch has used electromagnetic induction to explore the sonic responses of magnetic fields in the environment. Electromagnetic pickups were embedded in headphones that picked up these synthetic sounds. Her sound-related works were meant to enhance aural and visual explorations of spaces such as gardens, castles, cellars, parks, buildings, and galleries. In The Walk Book, Miriam Schaub describes Cardiff’s interactive audio performance titled Her Long Black Hair (2005), as “the overwhelming physical immersion in an apparently boundless soundtrack that begins to dominate our shared experience” (Cardiff and Schaub, 2005, 14). In creating this walk, Cardiff placed miniature microphones in the ears of a dummy head to capture binaural recordings of the sounds in Central Park in New York City. The sounds that were captured were then layered with Cardiff’s voice, which guides the participant through an immersive soundwalk in Central Park. As a result, the boundaries are blurred between a participant’s physical presence and a mimetic journey. The participants are encouraged to synchronize their movement by breathing and walking according to Cardiff’s pace. Directive instructions are given to guide a participant’s walk in the park. Schaub discusses how the walks created by Cardiff heighten the senses and draw the attention of the participants from their own body image, drawing and integrating them into the environment imagined and experienced through Cardiff’s own subjective experience. Schaub explains that
you can smell what she is describing and you can taste the salt from the sea air. Cardiff expands our sense of self-awareness by drawing our attention to the process of perceiving the immediate environment and talking candidly about our bodies as instruments of perception and their reactions to the world around us” (Cardiff and Schaub, 2005, 132).

The soundwalks produce a distinct quality which helps focus the attention of the participant on three intertwined levels: a micro narrated experience, which elevates visceral sensation as the participant engages with the voice of the narrator; the soundscape composed from the binaural recording; and the immediate, real-time physical presence of the participant in the environment.

Cardiff explains that when she first discovered the binaural recording technique, she quickly became attracted “to the closeness of the sound and the audio bridge between the visual, physical work and [her] body” (Egoyan, 2002, 66). In such a performance, one of the key components is that the participant is mobile. That is, they have the freedom to explore and move around the environment through the guided narration. This parallels the role of the participant in a virtual environment. The distinction is that the focus in a typical virtual environment is on exploring the environment visually rather than aurally. Like film production, the audio in a virtual environment tends to take a secondary role, supporting the visual information rendered for the viewer. This approach masks or reduces the communicative capacity of sound within the virtual environment.

6.5. Spatialization

Spatialization in the context of this research refers to the techniques used to record and playback sounds that can produce the most immersive personal listening experience for patients. Sound may be spatialized using headphones or multi-channel speakers. There are three important parameters to consider when spatializing sound. Azimuth, which is the angle to the left or right of straight ahead, and elevation determine the angular perception of the sound source from the perspective of the listener. Distance represents the depth perception of space which is affected by loudness levels and spectral quality of a sound source, and the reverberant nature of the space. The last parameter is the size, which is the width or the perceived spaciousness of the environment (Hendrix and
Woodrow, 1996). These parameters must be taken into account in order to properly evoke the sense of a three-dimensional space. I will briefly explain multi-channel sound and stereo, however, the focus will be on binaural, since this research solely relies on this method for recording and playback.

In the 1970’s, one popular method that attempted to improve the immersive quality of sound in a space was a quadraphonic sound configuration. This configuration involved placing four speakers in a square room. Two speakers are placed in the front and two in the back of the room as shown in Figure 6.1. However, there are challenges with using quadraphonic sound due to compatibility issues with stereo playback systems and poor frontal imaging, often leaving a “hole” in the desired immersive audio experience. However, recent advances in multi-channel technology provide inexpensive commercially produced hardware that allows for increased possibilities in developing sound based works in multichannel formats.

![Figure 6-1 An illustration of a quadraphonic speaker configuration.](image)

In a surround-sound configuration, the advantage is that a three-dimensional space can be created for more than one listener simultaneously. Although the typical configuration of a home-theatre system is 5.1 channels, it is more appropriate to use 8 or more channels to localize sounds because sounds are heard not only from the front and back but also from the sides. An eight-channel configuration would resolve some

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14 A 5.1 configuration involves 5 speakers and a subwoofer. Two speakers represent the front left and right, one for the centre, and two for the rear left and right.
localization issues by improving the sounds placed on either side of the listener. No matter the configuration, the sound designer must take into account the appropriate placement of sounds based on the speaker configuration to enhance the immersive experience. One method of surround sound that has proven to overcome some of the challenges with encoding, decoding, correct spatial imaging and space configuration, is that of using ambisonic sound. Ambisonics can encode sounds from all directions in great detail and decode these signals to a number of speaker channels with psychoacoustically enhanced filtering to correct any shadowing effects by the human head (Rumsey, 2001). Another advantage is that this approach allows for a flexible number of speakers and arrangements no matter the acoustic space that is used for playback. For this reason, it has been an attractive choice for network applications, such as real-time musical collaboration between distant locations (Gurevich, 2011).

Stereo sound is the most common system used at home and is comprised of two speakers placed in the front to create a left and right image. Due to a number of limitations, stereo sound can be a poor choice for audio playback if we are trying to enhance the immersive experience: it is limited to frontal positioning only, and the sound image is positioned in the centre with a separation of no more than 60 degrees between a pair of speakers. This configuration limits phantom imaging\(^{15}\) to a narrow ‘sweet spot,’ especially if the participant is positioned farther away from the speakers. The localization of sounds is disrupted once the listener moves off-axis, and this effect may be depreciated further with head rotation (Malham, 1998).

In the context of this research, whether a patient is waiting in a clinic or at home, the goal is to create a personalized, immersive listening experience for anxiety and pain relief. As discussed in chapter nine, the use of headphones is a convenient and affordable method of doing this, and using a binaural approach would produce a convincing three-dimensional sound. It is an effective way of reproducing and replicating what the ear would hear in a natural situation. This type of playback may promote active listening for two reasons: while wearing headphones, distracting noise bleeding from the physical

\(^{15}\) A phantom image can sometimes be created by doubling the sound between any two (or more) of the loudspeakers, creating the illusion of an additional speaker or (more importantly) adding to the overall spatial realism.

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environment is reduced, and the binaural playback creates a sense of depth and spatiality that would be challenging to reproduce using multichannel speakers in a home or clinical setting. Such use of binaural recordings may improve the communicative aspects of sound and reinforce immersion. Several key concepts must be introduced to understand how binaural processing produces this level of spatiality.

6.5.1. Localization

As discussed earlier, the way humans perceive the directionality of a sound source is through two key components: direction and distance. The way we localize sound is through time differences that occur as sound arrives in both ears. This method of localization is referred to as the interaural time difference (ITD). Furthermore, we may localize sound based on the differences in sound volume levels in both ears and on the frequency content of the signal (Rumsey, 2001). For example, sounds that contain frequencies above approximately 1500 Hz have half wavelengths smaller than an average human head. Therefore, phase information is no longer a reliable source for localization, and we revert to relying on volume differences caused by head shadowing or sound attenuation resulting from our head obstructing the far ear as shown in Figure 6.2 (Balkany, 2013).

![Head Shadowing](source: http://www.developer.oculus.com)

**Figure 6-2 The head shadowing effect (source: http://www.developer.oculus.com).**

One of the challenges we face is with frontal and back localization since we cannot rely on time differences because ITD or volume level differences may be zero for a sound
in front of or behind the listener. Therefore, we rely heavily on frequency changes through filtering, and reflections caused by the shape and size of our head, body, and outer ears. For example, a sound that is emitted from the front produce high-frequency spectral colouration created by the interior of our ear (pinnae), while sounds emitted from behind are shadowed by our ear. These reflective and shadowing effects create a direction selective filter, giving us the ability to recognize front and back localization (Dietz, 2011).

6.5.2. HRTF

In a binaural system, filtering for proper localization can be encoded as a head-related transfer function (HRTF). Binaural microphones, which are usually made of two omnidirectional microphones placed in a dummy head, help capture the HRTF by taking into account the head geometry. Using HRTF allows for three-dimensional spatialization no matter the type of headphones used for playback. One limitation to binaural sound which should be noted is a need to account for individual HRTFs. The mismatch between these subtle angular changes of the ear can limit the receptive response to frontal and rear sound cues (Chan, 2005). This in turn can cause the participant to make a judgment error in recognizing the location of a sound. It must be noted that calculating the HRTF for every individual in real-time can be computationally taxing. With VR technology, we can accommodate for this by relying on head motion that occurs when using a Head Mounted Display (HMD). Turning our heads, for example, can overcome the front/back localization errors that may arise by positioning it laterally.

6.5.3. Distance Cues

Distance cues are usually registered by the human ear as we detect the loudness level of each sound. In addition, we can get a sense of distance based on time delay. This provides an estimation of the size of the environment (space). Through reverberation techniques, we can adjust the size of such auditory spaces by modifying initial time delays and the number of reflections. Another factor that allows us to identify the proximate distance of an object is by the apparent movement of a sound source. For example, in one binaural recording, I captured the sound of a bee traversing very quickly from right to left. When listening back, we can easily perceive the bee as being very close to our face,
due to how quickly it moves from one direction to another. However, if we capture the sound of an airplane in binaural, the time it takes for the airplane to move from left to right might be very slow, which indicates that the plane is at a far distance from us.

In this chapter, I built upon the theoretical framework of acoustic ecology and soundscapes by discussing the practical methods used to create soundscape compositions. The immersive quality of the compositions can be further enhanced if we use binaural microphones to capture the sounds we deem appropriate. In addition, using binaural recordings is a cost effective and efficient method to produce a personalized three-dimensional listening experience. In the following chapters, soundwalks, field recording, binaural recording techniques, and soundscape compositions will be put to the test with patients to create a focused therapeutic intervention.
Chapter 7. Study 2: Testing soundscapes with patients

In 2001, the Institute of Medicine included patient-centred care as 1 of 6 specific aims at improving and bridging the quality, effectiveness, and efficiency of care required for patients. Specifically, to this date, no non-invasive technological intervention has been developed that addresses the negative impacts endured by chronic pain patients. The majority of these patients suffer from increased anxiety and pain caused by stressors such as wait times in clinics & hospitals, environmental factors such as noise, and mobility issues. Currently, treating chronic pain costs $32,000\(^{16}\) per patient per year. A widely accepted approach to pain management is to use a biopsychosocial approach\(^{17}\). The biopsychosocial approach addresses the psychological and sociocultural fallout in addition to the biomedical and physiological aspects. This research (and in particular the following study and the final study in chapter 9) uses an interdisciplinary approach that fits in the context of the biopsychosocial model. By combining the theoretical framework of soundscapes and practical methods of designing soundscape compositions we may be able to develop a therapeutic intervention to administer to chronic pain patients to manage their anxiety and pain.

Murray Schafer’s seminal work in soundscapes informed us about the harmonious sounds of nature (hi-fi environments) and the potentially disruptive cacophony of modern life (lo-fi environments). In addition, Schafer, along with Truax developed listening methods through aural investigations and field research that serve as a means to develop soundscape compositions. Although Schafer’s preference is a hi-fi environment, as part of my user study I wanted to understand how recordings of soundwalks could be captured and adapted to create a perceptual change of environment for chronic pain patients based on their preference for either hi-fi or lo-fi environments.

\(^{17}\) http://www.paineurope.com/articles/the-biopsychosocial-model-and-chronic-pain-an-overview
Considering the aforementioned, several research questions are needed to be investigated in this regard, such as the following:

1. Can a perceptual change in the environment help minimize the level of discomfort for patients experiencing chronic pain?
2. Using Barry Truax's acoustic communication model, can the artistic practice of recorded soundwalks provide positive distraction, and create an immersive experience for patients that may help with stress and anxiety control?
3. Which environment do patients prefer? (lo-fi vs hi-fi)
4. In addition, what specific sounds can help improve the structure of the soundscape compositions?

Based on previous reporting by chronic pain patients from the past studies conducted at the Pain Studies lab, the hypothesis was that patients would prefer hi-fi environment to help ease anxiety or stress.

In seeking to answer these questions, my colleagues Maryam Mobini, Tyler Kinnear, and I set out to investigate potential sites we could use for recording our soundwalks. We selected several locations we deemed to be hi-fi including Stanley Park, Kitsilano Park, and Lighthouse Park. I also selected two sites that were lo-fi, downtown Vancouver and Granville Island market area.

As part of our investigation, we experimented with various microphone techniques, as shown in Figure 7.1, to capture both stereo and binaural sounds.
We conducted several soundwalks and recorded 3 types of environment for this experiment.

Location A

The first, a hi-fi location consisted of a natural environment and its composition was based on soundwalk recordings from Kitsilano Park, Stanley Park, and Lighthouse Park. Figure 7.2 shows a snapshot of the latter location and indicates the duration of the walk, sounds that are of potential interest indicated by the pink triangles, the pace, and the blue line representing the dynamic range.
Figure 7-2 Photograph documenting a site of field recording, Lighthouse Park, British Columbia, 2014.

Location B

The second location, which we considered to be lo-fi, is of Vancouver downtown streets, as shown in Figure 7.3. The pace was moderate since at the time of the recording, a fair amount of foot traffic meant that a slow pace was not possible.
Location C

As backup, a third lo-fi environment was recorded inside the main shopping market at the Granville Island Public Market with the tail end of the recording exiting outside to the pier. In this location, the pace was much slower than was the first lo-fi environment, as shown in Figure 7.4. In addition, the recording transitions from lo-fi to hi-fi since the pier area consists of human and natural sounds. Therefore, we used location C recording for our user study instead of location B to make sure that stress was not induced while listening to the recording.
A control group recording was composed based on sounds edited from recordings of clinics and hospitals. For privacy and ethical reasons, the recording of sounds from the location of the study was prohibited.

Using Sound Professional’s in-ear binaural microphones produced the best result in terms of capturing a 3-dimensional recording of each environment. During the recording process some challenges were encountered that we had to resolve. The first was maintaining a walking speed that did not induce anxiety during playback. We also did not want the walking to sound “rushed”, hence the decision to choose location C. In addition,
head movement during recording using the binaural microphones had to be kept to a minimum to reduce the feeling of nausea when listening to the recordings. The goal was to focus on creating a sensorial journey that promoted relaxation.

7.1. Participants

Participants selected for this study were adults (over the age of 19 years) with some form of chronic pain diagnosed by their doctor. Patients for this study were recruited from the Vancouver Arthritis Research Centre by a research assistant approaching the patients while waiting to see their doctor. Ethics approval for this study was obtained through Simon Fraser University’s Research Ethics Board.

7.2. Patient Processing

Our focus was to administer the soundscape compositions for patients to listen to during the pre-processing phase, since patients have to wait on average 30 to 40 minutes before completing their examination. Typically, the outpatients processing by hospitals and clinics include 3 phases of waiting: pre-process, in-process, and post-process. Pre-process is the time it takes for patients to go from arrival to the examination area. In-process begins when patients enter and complete their examination. Post-process involves completion of necessary paperwork, and exiting of the facility. All three phases on average can take up to one to four hours. Patients going through these phases have been shown to experience annoyance, irritability, and stress (Taylor, 1994).

7.3. Experiment Procedure

The experiment at the Vancouver Arthritis Research Centre consisted of three phases of testing: (1) a background anxiety screening questionnaire phase\textsuperscript{18}, (2) a testing phase, and (3) a feedback phase.

\textsuperscript{18} See Appendix C. Digital audio files of recordings available.
Phase 1

In the first phase, anxiety was measured using the Hamilton Anxiety Rating Scale. This scale assesses the patient’s level of anxiety based on a 14-item interviewer questionnaire. The total score ranges from 0 to 56 points. In addition, questions were asked regarding frequency of visits to the clinic, and if participants were currently taking prescribed medication for anxiety relief.

Phase 2

For the testing phase, the recordings were randomly assigned to patients who volunteered to participate in the experiment. Based on our observation, the average wait time for each patient at the clinic was 30 minutes. This was sufficient time for patients to complete the background questionnaire (5 min to complete), listen to a randomly selected soundscape recording (5 min), and complete the post-soundscape-questionnaire (7 min).

Phase 3

During the feedback phase, patients were asked questions specific to their experience of listening to the soundscape recordings (location A, C, and control), and they reported any physiological and psychological changes that occurred during the listening phase.

7.4. Results

Data was collected from 30 patients who participated in the study. These were predominantly female (25) with 5 male participants. The mean age was 55.72 years (SD 12.66). Statistical analyses were conducted in SPSS 20. The results, as indicated in Table 7.1, were analyzed using a 2-way between-participants ANOVA for each of the measures. Gender was used as a secondary factor for the analysis. In the pre-listening phase, there were no significant differences between the three soundscape (hi-fi, lo-fi, control) listening groups from the Hamilton Anxiety Rating Scale, p = 0.990.
The responses from the post questionnaire reporting provided further insight about the affective qualities experienced by the patients listening to the soundscape recordings. Interestingly, 85% of the patients experienced moments that brought particular images to mind. The patients also experienced emotions (43%) and physical sensations (30%). Patients found the duration of the compositions to be optimal at 5 minutes per recording. This was an important factor because one of our concerns was ear fatigue caused by wearing headphones and the hypersensitivity experienced by the chronic pain patients.

Qualitative responses from the recordings varied drastically as shown in Table 7.2. It was evident from the patients reporting that the soundscape recording of the hi-fi location had the most positive psychological impact on the patients, while the recording of the Market (lo-fi) and the control group recording agitated the patients.

<table>
<thead>
<tr>
<th>Location A: hi-fi environment (trails, parks, ocean)</th>
<th>Location C: lo-fi environment (the market)</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Calm, waves always are relaxing to me’&quot;</td>
<td>&quot;People sounds, I do not like being around places where people congregate. All I want to do is go home. I live in the country&quot;</td>
<td>&quot;Baby crying, loud noises’&quot;</td>
</tr>
<tr>
<td>&quot;Like I am out for a walk”</td>
<td>&quot;It seemed to be difficult to comprehend&quot;</td>
<td>&quot;Agitated’&quot;</td>
</tr>
<tr>
<td>&quot;Foot-steps walking behind me, like someone was coming up on me’&quot;</td>
<td>&quot;Mad. Noise made me mad’&quot;</td>
<td>&quot;The sound of a loud ventilation system was annoying. Also conversations I couldn’t quite hear were uncomfortable’&quot;</td>
</tr>
<tr>
<td>&quot;Pleasant, relaxation being close to nature’&quot;</td>
<td>&quot;Heart beat faster’&quot;</td>
<td>Most sounds I heard were busy sounds. There were just a few pleasant sounds</td>
</tr>
<tr>
<td>“Walking along a beach with the water slapping at the shore wild birds calling”</td>
<td>“It seemed to be useless sounds that urges to shut it off may have been more or better use of my time!”</td>
<td>Imagined being in a hospital</td>
</tr>
<tr>
<td>“Walking on the stones, a little annoying”</td>
<td>“Tension in the neck and shoulders”</td>
<td>Busy office</td>
</tr>
<tr>
<td>“Felt like I was down by the beach enjoying it”</td>
<td>Kids noise, people speaking Cantonese (live restaurant). Girl texting on phone</td>
<td></td>
</tr>
<tr>
<td>“Relaxation of muscle,sleepy”</td>
<td>Simply people moving around at great loss and need of help.</td>
<td></td>
</tr>
</tbody>
</table>

Table 7-1 Comments from patients after listening to the soundscape recordings.

7.5. Discussion

Despite our effort to be mindful while composing the soundscapes, we discovered some factors that can help improve the experience for patients. The most surprising element was that the sound of walking itself brought about fear and anxiety in some patients. Although the binaural recordings were meant to situate the listener in the environment, the misalignment of footsteps in relation to the rest of the sounds made the listener feel as if they were being followed rather than they themselves walking.

This limitation is understood to be due to the generic HRTF encoding that occurs using binaural microphones, and when the human body type is also not encoded. In addition, some of the high frequency content from particular sounds, such as walking on the rocks by the beach, need further attenuation. This anxiety may also be attributed to the hypersensitivity chronic pain patients experience when listening to high frequency content, as noted in our first experiment.

Editing more dynamic changes by introducing sound-markers that are of interest for each location might also serve to keep the listeners more attentive to the composition. Although we encountered challenges during the development of this study, the experiment
shows there is potential for using soundscapes as a distraction mechanism to help patients manage anxiety during their visit at clinics.

Ideally, we would have liked a larger group of 15-20 participants for each listening group. The larger group size may also help balance out the female to male ratio, which was significantly skewed towards female participants. Our low recruitment was due both to the availability of the doctor, and accessibility to patients during our phase of the study. Although 23% of all the patients reported taking medication for anxiety, their responses led to a low baseline anxiety level, which might have produced a floor-effect, that is the participants scored near the bottom. Furthermore, due to time constraints with the patients, we were not able to administer the Hamilton Anxiety Scale post-listening phase. In addition, I also believe that biofeedback could provide a more accurate reading of physiological changes in addition to the qualitative reporting.

7.6. Conclusion

This study provided insight into how chronic pain patients perceive soundscape compositions of hi-fi and lo-fi environments based on the theoretical and practical methodologies from the field of acoustic ecology. The findings from this study help refine the approach to recording environmental sounds and composing soundscapes that improve the therapeutic quality for chronic pain patients. In regard to the choice of environment, the results from the qualitative responses were consistent with our hypothesis that hi-fi environments are the optimal choice for creating a positive perceptual change of environment for patients. Patients reported that the natural (park) environmental sounds like water, birds, and open space had the most calming effect, while the city sounds and clinics confused or in some cases irritated, patients; as one patient succinctly stated, they felt “agitated”. In all three recordings, patients were distracted, and the hi-fi environment proved to be the most effective in communicating meaning to the patients based on their reporting. Using Schafer’s terminology, memorable soundmarkers in the recordings administered in this study did distract the patients. In addition, the high level of memory recall and descriptions of ‘being in the environment’ provided by the patients in the post-listening phase is reflective of an immersive listening experience. Minimizing the sound of footsteps is important to maintain the quality of presence in the environment. As
noted in the reporting, the sound of footsteps caused two problems: 1) patients felt they were being followed rather than having the sensation of them walking in the environment. Further experimentation is required with binaural recordings in order to reduce the perception of “being followed”, and to improve alignment of placing the listener in a virtual auditory environment.

2) the surface (i.e. gravel, grass, or concrete) is important to consider because the sound of walking on surfaces may have too much high-frequency content. This may induce further stress on the chronic pain patient since they may be more sensitive to the mid to upper level frequency range.

The method for measuring anxiety has to be refined since it was unclear if patients experienced anxiety because of the clinical environment, or because of events prior to their arrival that might contribute to their psychological state. A better option for future studies would be to use the State-Trait Anxiety scale which is commonly used in clinical settings to diagnose anxiety by measuring trait and state anxiety. Obtaining significant information from doctors is challenging since they are focused on their consultation with patients and do not have enough time to provide detailed reporting of their experience.

The next step is to focus the compositions on hi-fi environments and improve the immersive quality of the soundscapes for anxiety and pain management. In addition to the qualitative reporting, biofeedback will be required to measure physiological changes that may reinforce the therapeutic effect on chronic pain patients.
Chapter 8. Immersion

So far, I have discussed the potential therapeutic effects of environmental sounds structured as soundscape composition for pain and anxiety relief. To maximize this analgesic effect, I propose composing soundscapes by being mindful of the immersive quality one can generate from carefully choosing the appropriate sound material, spatialization format (e.g. binaural), and composition techniques. First, I will define different facets of experiencing immersion specifically for the context of this research. Currently, theories of immersion and presence prevalent in the VR and gaming domain have been adapted from the fields of psychology and ethnography, with most of the discussion dominated by a focus on visual, rather than aural experience. However, we can still apply many of these theories and techniques to audio and understand the role of perception, immersion, presence, flow, and psychological absorption.

8.1. Perception

It is often difficult to separate the link between our awareness of our internal experience and the physical environment (external space) because the experience of the physical space exists in the listener’s consciousness. Cognitive psychologist Jerome Bruner believed that the mind does not just respond to environmental stimulus but rather we interpret that environment in a way that is personal and subjective. Therefore, perception begins with an expectancy or readiness; that is something, “we not only see, but we look for, not only hear, but listen to.” (Bruner, 1951, 123-4).

In other words, stimuli by themselves do not cause responses but alter existing cognitive states. The interpretation by the mind is therefore not just based on some input stimuli but is also dependent on the pre-existing state of the mind (Olson, 2007). We can also understand perception to be multisensory and culturally defined (see Pink, 2009). That is, our experience is not necessarily dominated by a single sensory modality, but rather, the experience is “understood, evaluated, and maintained through all the senses” (Pink, 2009, 13) in any one culture.
My stance on this in relation to this research is that pain can dampen or filter certain sensorial experiences like vision (migraine sufferers tend to avoid light since it can cause further pain) while heightening others, such as the sense of hearing at specific frequencies, as demonstrated in my first user study. This breakdown of synergy amongst our senses can skew our perception of the world and our experiences. John Levack Drever suggests that the practice of creating soundscape compositions share a focus on “fieldwork through sensuous experience and the creation of an outward response to that experience from the inside” (Drever, 2002, 24).

Rodaway considers our senses to be inter-relational and perceptual systems that integrate into bodily and mental processes (Rodway, 1994, 19-20). Furthermore, the environment itself has a role in structuring our sensory stimulation (optical, auditory, tactile, etc.) and becomes a source of information rather than just raw data (Rodaway, 1994, 20). Through situating chronic pain patients in a virtual auditory environment that eliminates some of these sensorial barriers, one can argue that over time patients may be able to become more perceptive of their surroundings, regaining some of these diminished sensory modalities and improving their responsiveness to their environment. In addition, the calming effect that is produced via listening to soundscapes can help reduce some of the hypersensitivity experienced since the mind and body do not have to be in a constant defensive mode, and pain may no longer be a dominant instigator. Bruner theorized that behaviour is purposive and learning results in a change in knowledge, creating a cognitive map that links actions and goals. Hence, assisting patients in learning about the therapeutic effects of soundscapes, and allowing them access to such recordings can potentially improve their mood, psychological wellbeing, and pain state over time.

8.2. Immersion

Perception can help immerse a person in an auditory world. Tim Ingold connects the idea of perception and immersion by suggesting that “perception...is not the achievement of a mind and body, but of the organism as a whole in its environment, and is tantamount to the organism’s own exploratory movement through the world.” This
makes “mind immanent in the network of sensory pathways that are set up by virtue of the perceiver’s immersion in his or her environment” (Ingold, 2000, 3). However, in order to maintain a high level of engagement with an auditory world, the experience has to be continuously immersive. In this context, immersion can be seen as the individual’s perception and reaction to a virtual auditory environment. Barry Blesser suggests that “a simulated spatial reality can be understood as a surrogate implementation: real spaces use sound waves, whereas virtual spaces use signal-processing algorithms. If the virtual space closely mimics a real space, a listener will, in effect, perceive the real space” (Blesser and Salter, 2007, 132).

In the world of gaming and virtual reality, there is a commonality amongst all successful platforms, and that is the ability to engage and draw people in by distracting them from everyday concerns. It offers players the ability to lose themselves in the VR world, in some cases so deeply that they tend to not notice the amount of time passed, nor anything around them, including other people. The player’s attention is focused on the game or the experience in a VR environment to such an extent that people describe themselves as literally feeling being lost in the game (Jennett, 2008). It is the amalgamation of these elements that we refer to as immersion.

8.2.1. Levels of immersion

An immersive experience is considered to be a positive and enjoyable experience, but the term can get lost in translation, and it may be difficult to pinpoint its actual meaning and or what makes it immersive. In a study that was conducted by Brown and Cairns, three distinct levels of immersion were identified; these include engagement, engrossment, and total immersion. Engagement is related to how easily the player can overcome barriers related to gaming preferences such as the amount of time, effort, and attention necessary to learn the game and a sense of the controls. Engrossment is tied to the game construction; the game is set up in such a way that the controls become “invisible” to the player, and the emotions are directly affected by the content of the game. This experience leads to the gamer becoming less and less aware of their physical surrounding. This experience is consistent with other findings that suggest a game has the ability to induce the feeling of actually being present in the virtual environment (Wirth,
It is also at this point that the player is now entering total immersion through which a sense of presence and attention in the virtual environment is greatly increased, and any barriers concerned with empathy and atmosphere are overcome. The sensation is one no longer considers oneself a ‘player’ rather someone that is participating in the computer world (Brown and Cairns, 2004). The first two levels are more commonly experienced, whereas “total” immersion may only occur sporadically throughout a game or VR world.

In a non-gaming environment such as a museum exhibit, researchers have realized that the level of immersion is increased when a progressive structure is applied to the construction of the environment, allowing users to relate their own ideas and cognitively connect to the understanding of the immersive environment. In this context, technological features such as visual displays that are extensive, inclusive, surrounding, and vivid may contribute to the level of immersion experienced (Blesser and Salter, 2007).

In game studies, three broad features of immersion have been identified:

- Lack of awareness of time passing by.
- Loss of the sense of being in the real world.
- High level of involvement in the virtual environment.

There are other contributing factors that are related to immersion that allow for an engaging experience, and these include flow, cognitive absorption, and presence.

### 8.3. Flow

According to Csikszentmihalyi, focus and concentration hold the key to achieving flow. It is a term used to describe feelings of enjoyment that occur when there is a balance between skill and challenge, typically achieved when we are involved in a highly rewarding activity (Csikszentmihalyi, 1997, 1998). It is a process of having an optimal experience; the state in which individuals are so involved in an activity that nothing else seems to matter (Csikszentmihalyi, 1990). Being in flow does not necessarily mean we are happy; rather, it suggests that the feeling is only relevant to the activity. Happiness may be the end result of being in flow followed by a sense of satisfaction and a rush of well-being once the task is completed. Csikszentmihalyi suggests that the more flow we experience
in our daily life, the more likely we are to feel happy overall (Csikszentmihalyi, 1997). Flow has eight components in total, and Csikszentmihalyi (1990) defines them as:

- Having a high degree of concentration
- The loss of feeling self-consciousness
- Having clear goals
- The sense of time does not feel linear and is distorted
- There is direct and immediate feedback
- A balance is obtained between the level of ability and challenge
- There is a sense of personal control
- The task is highly rewarding

These components reveal the overlapping relationship between immersion and flow, specifically the notion of time distortion, and the ability to engage a person based on the level of challenge provided. Flow is more in line with total immersion since it is an extreme experience we have, and therefore it may not always be present. For example, we may be engaged in playing a game, but we have an awareness of knowing when we need to meet a friend or let the cat in by opening the door. Therefore, immersion can be a progressive experience by which a person may be immersed but not to the point of losing themselves completely in the task, hence never reaching the flow state (Brown and Cairn, 2004). The altered state of flow is not necessary to have a highly immersive experience. As a teenager, I remember being engrossed in games such as Myst, although there were no clear goals to the game. The puzzles and clues provided through the journey in the game did not always provide direct feedback, yet I was completely engaged in the experience.

8.4. Presence

The exact definition for presence is still in its nascent stage but so far, we can understand the term as being in a normal state of consciousness (Mania & Chalmers, 2001) and as the sense of being immersed in a simulation or virtual environment (Hale and Kay, 2015). In a virtual environment, presence becomes an important factor in our experience of immersion in that artificial space. How natural the interactions feel within a
virtual environment and its close replication of real-world experiences affects to what extent presence is sensed (Witmer and Singer, 1998). Although presence can be a subjective concept, difficult to quantify, it can be enhanced through the use of auditory, visual, and tactile cues (Slater and Wilbur, 1997). It is suggested that the level of coupling between perception and action can be used as a way to measure presence in a VR environment in comparison to the real world (Zahorik and Jension, 1998). The difference between presence and immersion is that presence may be considered a state of mind, while immersion is an experience in time. Therefore, one can feel presence in a VR environment but not necessarily experience immersion.

Auditory spatial awareness can be considered as our internal experience of an external virtual or physical environment (Blesser and Salter, 2007). Therefore, using the proper spatialization of sound in conjunction with using environmental sound recordings within a virtual environment may help reinforce the feeling of presence. As participants become more aware of their presence in the virtual environment it may lead to further engagement through discovery and interaction, and contribute to experiencing immersion. Jean-François Augoyard describes immersion in the context of sound as the “dominance of a sonic micro-milieu that takes precedence over a distant or secondary perceptive field” (Augoyard, 2006). The use of audio does not necessarily help with increasing the sense of realism but it has been shown to improve the level of presence within a virtual or simulated environment (Witmer and Singer, 1998). Therefore, if great consideration is taken with the creative and design process of sound, it can lead to a production of ‘audiation’, which allows the participant to ascribe meaning to an environment based on the sound and visual cues provided. This in turn provides a greater sense of presence within the virtual environment (Fencott, 1999). Other factors affect the sense of presence, including sensory engagement, task, distraction, quality of the interface, and the involvement of the participant (Jerome and Witmer, 2002; Schuemie, 2001).

8.5. Psychological Absorption

Unlike immersion and presence, psychological absorption induces an altered state of consciousness that involves total engagement in the present experience (Irwin, 1999). Tellegen and Atkinson (1974) theorized that absorption is a form of experiential readiness
with deep involvement and heightened sense that makes the person impervious to normally distracting events. This type of openness to experience is what allows us to daydream, have artistic sensitivity, and awareness and appreciation of emotional responses (McCrae and Costa, 1983). How many times have you driven and thought about something else aside from driving? Yet your mind is still in total control of your driving! This experience is what happens when we are psychologically absorbed; and absorption in which a momentary cognitive restructuring takes place, and may include a dissociative response that separates our thoughts, feelings, and individual experiences, making them less accessible to consciousness (i.e. separating thought from the acquired skill of driving) (Glicksohn and Avnon, 1997).

When we are deeply involved in software such as a video game or VR world, we define this experience as cognitive absorption (Agarwal and Karahana, 2000). There are several dimensions to cognitive absorption that have similarities to flow. These include: temporal dissociation, heightened enjoyment, control, curiosity, and attentive focus. Cognitive absorption differs from immersion because it is considered to be an attitude towards information technology, whereas immersion is the actual experience at a particular instance while playing a game or traversing a VR world. Although cognitive absorption is mainly used in research to better understand user reactions to information technology, we can use some of its traits to understand people’s attitude and perception towards engaging with a purely auditory experience via soundscapes and binaural recordings.

The goal now is to adapt these theories to soundscape compositions to test and understand how immersion can be enhanced through various compositional structuring of sounds, and the use of binaural as a means of creating a 3-dimensional auditory environment. Similar to mindfulness meditation, if we are able to increase the perception of immersion significantly, it may allow patients to feel less anxious and experience less pain simply by listening to soundscapes.
Chapter 9.  Study 3: Soundscapes and anxiety management

In the previous chapter I hypothesized that composing immersive soundscapes may help patients with stress and pain reduction. To test this hypothesis, we designed a user study to expose fifty-five patients experiencing chronic pain and/or high levels of stress to five different soundscape compositions. Physiological measurements of skin conductance level (SCL), heart rate (HR), and heart rate variability in the low frequency and high frequency range (HF HRV and LF HRV) were captured to understand how soundscapes can impact the activation of sympathetic and parasympathetic systems.

9.1. Introduction

For over a hundred years, sound therapy devices have been used for the purpose of distraction and healing. Some people feel that using sound enrichment can bring about physiological changes in sensitivity in the hearing parts of the brain, while others believe it acts as a psychological distraction, or an aid to relaxation (see Hobson et al., 2010). In clinical environments, research has shown that patients recover faster when looking at natural settings through a window (Ulrich, 1984). Much of the research on sensory experience and healing has focused on the impact of visual stimuli, such as videos, photographs, and virtual reality, rather than investigating a purely a sonic approach (Ulrich, 1984; Parsons, 1998; Hoffman, 2000). Furthermore, while some have reported greater restorative experiences when exposed to natural environments, research exposing chronic pain patients to environmental sounds via soundscapes is limited.

A factor that may be a burden for many patients is noise that seems to lead to anxiety or pain flare-ups (Dijkstra and et al., 2006). One of the goals for promoting wellness includes the creation of a “psychologically supportive” environment (Ruga, 1989). While the effects of incorporating such supportive design may fast-track the healing process, the scientific research on psychologically supportive health design remains limited. We therefore must look to other disciplines and theories that may help address this limitation.
Noise levels in hospitals and busy clinics can act as ambient stressors, and are hypothesized to lead to subjective and/or physiological ambient stress (Topf, 2000). The ambient stress experienced is volatile and can modulate based on the degrees of intensity, duration, and controllability (Veitch, 1995). Even though hospitals are aware of these detrimental effects of noise, patients continue to endure the unpleasant sounds inherent in major hospitals across North America (Falk, 1973; Carbrera, 2000; Millman, 1997).

9.2. Ethics Consideration

Harmonized ethics approval for conducting this study was granted by the University of British Columbia and Simon Fraser University.

9.3. Methods

9.3.1. Participants

Participants were recruited from three different locations: Fraser Health Chronic Pain Clinic, St. Paul’s Hospital Gastroenterology (GI) Clinic, and a private complex pain clinic located in Vancouver.

Fifty-five patients participated in this experiment (34 women and 21 men, mean age = 49.8 years). Out of the fifty-five patients, seven reported having being diagnosed with a hearing condition. The conditions ranged from tinnitus (buzzing in the ears when no sound is present), minor hearing loss in one ear, and sudden sensorial loss (total hearing loss in one ear). These patients confirmed that they wanted to continue participating in the study. None of the patients had any surgical implant such as a pacemaker. This was an important factor that would have disqualified participation since it may have caused interference with the recording of physiological data.
9.3.2.  Experimental Design

The experiment was composed of three different phases: (1) A pre-listening background questionnaire\(^{19}\) which included a State Trait Anxiety questionnaire and a Visual Analog Pain Scale, (2) a 5-minute soundscape composition listening session, and (3) a follow-up post-questionnaire phase bringing the total time for the experiment to approximately 20 minutes.

9.3.3.  Patient Recruitment

*Fraser Health*

Patients were recruited ahead of time by the clinic via phone call. Each participant who had consented would participate in the experiment prior to their regular appointment with their doctor. Each participant was taken to a diagnostic room located near the general waiting area to complete the experiment.

*Private Complex Pain Clinic*

This was a busy pain clinic and therefore, patients were asked to participate while they arrived for their doctor’s appointment. Since the wait time on average was 30 minutes, it provided us with the appropriate timeframe to have patients participate in the experiment. A small room near the waiting area was used to conduct the experiment.

*St. Paul’s Hospital GI Clinic*

Patients were contacted by a resident research assistant at the hospital who obtained consent for the study. This is a busy hospital so our team had to work efficiently to have participants complete the experiment. The various phases of the study took place in a specific room used for prepping multiple patients right before they went into surgery. We had approximately 25 minutes per participant.

\(^{19}\) See Appendix C. Digital audio files of recordings available.
9.3.4. Pre-Listening Phase

In the pre-listening phase, participants were asked to complete a background questionnaire that consisted of the following items:

Participants were asked to report if they have ever experienced chronic pain, and if so the duration of it in terms of months or years. In addition, they were asked to complete a pain Visual Analog Scale (VAS) to determine their current pain level during this experiment. The pain VAS has been widely used in diverse adult population and is a unidimensional method of measuring pain intensity (McCormack, 1988). The pain VAS consists of a horizontal line with two verbal descriptors, one for each extreme symptom “no pain” score of 0 and “worst imaginable pain” score of 10. In addition, a visual descriptor comprised of faces depicting pain emotions are included to make it easier for participants to indicate their pain level as shown in Figure 9.1.

![Figure 9-1 (VAS) administered to patients](see McCormack et al., 1988).

This particular pain scale was used because it is easy, efficient, and fit the time frame we had with each patient. In addition to the pain VAS, patients were asked to indicate any hearing condition and surgically embedded implants such as a pacer. Finally, they were asked to complete the State-Trait Anxiety Inventory (STAI), commonly used in clinical setting to measure and diagnose trait and state anxiety (Spielberger, 1983). The scale has 20 items that assesses trait anxiety which is a general long-term quality of experiencing stress and 20 for state anxiety which is a temporary condition of feeling stress. The completion of the pre-listening phase was estimated to take 10 minutes per participant.
9.3.5. Listening Phase: Soundscape Compositions

Five different soundscape compositions were created for the listening phase of the experiment. The main object of this study was to find out if the structure of soundscape compositions could impact the physiological responses and the experience of immersion. In the previous study (User Study 2), based on the results from the control group, there was no observable interaction effect from using headphones that may have influenced stress and anxiety. Therefore, in this study we did not include a similar group (headphones only) and focussed on how sonic elements (natural environmental sounds) and compositional parameters derived from the field of acoustic ecology and the acoustic communication model may improve the experience of immersion and anxiety reduction. Each soundscape was treated as a five minute “journey” that included soundmarkers, which are iconic or recognizable sounds. The sounds were recorded using a 702 Sound Devices field recorder, a Korg M2 handheld field recorder, Sound Professional in-ear binaural microphones and a 3-DIO binaural handheld microphone. Additional post-processing and editing of the compositions was done using a series of software binaural processing plugins to enhance the HRTF quality, ear and head size. Soundwalks (see chapter 6.1 for details) were conducted ahead of time to identify appropriate locations that would fit the context of each journey. The following locations were used to capture the sounds: Mount Seymour Provincial Park, West Vancouver Sea Wall, Lighthouse Park, Minnekhada Park, Whytecliff Park and several short trails in North Vancouver. A combination of controlled and investigative field recording methods (see chapter 6 for definition details) was used for capturing sonic material for creating the soundscape.
compositions. Frequencies between 1500 Hz to 3500 Hz were attenuated to compensate for the hypersensitivity chronic pain patients experience.

**Journey One**

The first soundscape was designed to have a calm feeling with subtle shifts in perspective, such as walking through a trail, hearing the birds sing as we reach the ocean, and then returning back to the trail. This format is based on Carolyn Drake and Daisy Bertrand’s concept of segmentation and grouping (see chapter 4). The goal was to have this composition end in repose; that is, to have a soft tranquil ending to the soundscape. Figure 9.3 illustrates the journey and the transitional changes occurring during the composition. In total, 10 participants listened to Journey 1.

![Diagram of Journey One soundscape]

**Figure 9-3 Depicting the soundscape for Journey 1.**

**Journey Two**

The second composition begins in a similar fashion to journey one, with the sound of birds in a trail; however, the goal was to end with active sounds that have a higher dynamic range.
Therefore, in this case as we pass through the trail it begins to rain, at times fairly heavily, with the occasional sound of thunder. Twelve participants listened to this recording.

**Journey Three**

The goal with journey three was to create a completely dynamic and active composition by including sounds of human activity (people jogging and talking), birds, waves hitting the shore, and the distant sound of a seaplane flying by. In this recording, the sound of the footsteps walking by the sea wall was also audible at times. Eleven participants listened to this recording.
**Journey 4**

This journey was designed to remain primarily in a single location with very little change in perspective. The soft sound of the ocean waves and footsteps on the beach are the main sounds heard throughout the composition. There is a brief moment at the beginning where we hear a conversation, and that was used on purpose to avoid making the listener feel as if they were on an isolated island. Towards the end, there is a subtle shift in perspective as we move away from the beach towards the trail. Eleven participants listened to this journey.

![Diagram](image)

**Figure 9-6 Depicting the soundscape for Journey 4.**

**Journey 5**

This soundscape is the most distinct from all the others since it includes a layer of musical drone with heavy processing of reverb on some of the sounds. This particular composition is closer to a movie soundtrack with a cinematic feel. Soft transitions are made from one perspective (location) to another as we move through this journey. It is meant to have a surreal feel rather than replicating any existing environment. Eleven participants listened to this journey.
9.3.6. **Sound Pressure Level (SPL) monitoring**

At the beginning of each listening session, the equivalent continuous sound level (Leq) was recorded over a period of one minute, providing us with the average and maximum dB (A) SPL. Leq is the most ideal method for measuring sound levels that fluctuate over time, yielding a single decibel value that takes into account the total sound energy over the measured period. The ‘A’ symbol denotes the A-weighting setting used; weighted SPL is referred to as Sound Level (SL). This setting filters low frequencies of the signal during the measurement by a factor similar to the human ear’s filtering of low frequencies at lower intensity levels. The intention of using the measurements was to find out if environmental noise could potentially be an added stressor for these patients during wait times.

9.3.7. **Physiological measurement**

The goal for measuring physiological changes is to understand how the Autonomic Nervous System (ANS) responds to stimuli (soundscape composition, pain, and anxiety). The ANS is responsible for maintaining many important bodily functions, such as body temperature, blood pressure, digestion, and some aspects of emotional behaviour. These particular activities are known to be automatic and occur without conscious control, although research into certain practices, such as mindfulness meditation has shown that one may be able to gain various degrees of control over such activities (see Peressutti, 2012). The goal of ANS is to maintain homeostasis, self-regulation of the body when
faced with internal and external changes that may cause a breakdown in bodily balance. The sympathetic nervous system (SNS) is a division of ANS and its goal is to mobilize the body’s fight or flight response. The sympathetic response is adaptive, and is meant to enhance our survival, while the parasympathetic nervous system (PNS) controls homeostasis and the body’s rest and digestive response. Although SNS and PNS have inverse functions, the activities are integrated, and the systems act in a complementary fashion to maintain overall body health (Andreassi, 2007). In this experiment, skin conductance level (SCL) and the skin conductance response (SCR) can be used to measure sympathetic activity. Heart Rate (HR) and Heart Rate Variability of a high frequency (HRV HF) can detect parasympathetic changes. Lastly, the low frequency of HRV is sometimes used to measure both sympathetic and parasympathetic activities (Khazan, 2013).

To measure SCL two electrodes were fitted by the research assistant to the index and ring finger of the patient. The SCL was measured via the conductance between the two electrodes. Heart rate and HRV were obtained by connecting a pulse sensor to the middle finger. Thought Technology medical grade biofeedback equipment was used to capture and record the physiological data at 1000 Hz. Statistical analyses were conducted in SPSS 20.

9.3.8. Measuring Immersion

In this experiment, we measured the subjective experience of participants in the post-listening phase by creating an immersion questionnaire that includes questions specific to immersion, flow, presence, and cognitive absorption. To recap the terminologies, immersion involves losing yourself in an engaging and engrossing experience. Flow is defined as an absorbing optimal experience in an activity whereby nothing else matters to the individual (Csikszentmihalyi, 1990). Cognitive absorption is being in a deep state of involvement with a particular software or task (Agarwal and Karahana, 2000). Finally, presence is having a normal sense of consciousness while in the psychological state of being in a virtual environment (Slater, 1994). The questions are adapted from previous studies (Agarwal and Karahanna, 2000; Brown and Cairn, 2004; Slater, 1999) related to these areas and modified to fit the context of this experiment.
Specifically, questions related to user interface, playing in the game world, and game content were removed. The word game was replaced by auditory world. The results from this questionnaire assisted us in understanding how soundscapes can be structured to improve their immersive quality, and potentially help with stress and pain reduction.

9.3.9. Listening equipment

Patients were provided with a high-quality headphone set with comfortable ellipsoid ear pads. Recordings were placed on a portable mp3 player that was given to each patient to adjust volume level. The recordings were selected by the research assistant. After each listening session, the headphones were sanitized for repeated use.

9.4. Results

9.4.1. Patient profile

During the screening phase, forty-eight of the patients reported having experienced chronic pain. The average length of time that they had experienced chronic pain was 10 years, with various chronic pain types including fibromyalgia, migraine, chronic back pain, myofascial pain, complex regional pain syndrome (CRPS), arthritis, stomach pain, dystonia, Central Sensitization Disorder, nerve damage, and enteritis.

9.4.2. VAS Result

Scores from the VAS revealed patients experiencing moderate pain levels prior to the listening phase.
Table 9-1 Results of the VAS score amongst the five listening groups. Moderate pain ranges between (45-74).

There were no significant difference amongst the groups in terms of VAS scores F(1,4) = .614, p = .655. Table 9.1 shows the means for the groups.

9.4.3. State Trait Anxiety Scores

The range of scores for each subtest (state and trait) is 20-80. A higher score indicates a greater level of anxiety. The cut-off point of 39-40 is an indicator for detecting significant symptoms for the anxiety scale (Knight, 1983). Specifically, for healthy adults ages 40-49, the cut-off point is 35.88 SD 10.52 for males and 36.03 SD 11.07 for females (Spielberger, 1984). In this experiment, the results from the questionnaire revealed using tests of between-participants effect no significant difference for both state F(1,4) = .260, p = .902 and trait F(1,4) = .751, p = .562 amongst the groups, which was to be expected.

The overall mean for female and male groups for state and anxiety were:
Table 9-2 Results of the State Trait score for female and male participants.

Based on the means, both female and male participants were experiencing a moderately high level of anxiety prior to the listening phase.

9.4.4. Physiological Measures

The goal for the physiological data was to a) understand if listening to soundscapes can in general affect sympathetic and parasympathetic activity, and b) to compare how different compositional approaches can vary activity levels in the ANS to maximize anxiety relief. The physiological data used for analysis was checked for outliers and none were detected. Since there was heterogeneity of variances in our data, a two-tailed paired-samples t-test was used for analysis.

Skin conductance level (SCL): We analyzed the time difference by computing the mean of the first minute (seconds 0-60 of the baseline period) and the mean of the last minute (240-300 seconds of the x period). The results revealed a significant reduction in the SCR based on the first minute (m=1.55, SD=1.49) and last minute (m=1.10, SD=1.25), t(54)=-4.922, p=.000.
Next, we used a one-way between-subjects ANOVA, to look for significant differences in SCR amongst the 5 listening groups. The results revealed no statistically significant differences, \(F(1,4) = .068, p = .991\).

*Heart Rate and Heart Rate Variability (HRV)*: Results from both a two-tailed paired samples *t*-test and a one-way ANOVA revealed no statistically significant reduction in heart rate (all \(p>0.05\)) in general, and interaction amongst groups for heart rate, HRV HF, and HRV LF as shown in Table 9.3 and 9.4.

<table>
<thead>
<tr>
<th>Physiological Measure</th>
<th>Paired samples <em>t</em> test</th>
<th>(p) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>(t(54) = -1.965)</td>
<td>.055</td>
</tr>
<tr>
<td>HRV High Frequency (HF)</td>
<td>(t(54) = -1.785)</td>
<td>.436</td>
</tr>
<tr>
<td>HRV Low Frequency (LF)</td>
<td>(t(54) = -1.920)</td>
<td>.060</td>
</tr>
</tbody>
</table>

Table 9-3 Results of the paired samples *t* tests for HR and HRV.

<table>
<thead>
<tr>
<th>Physiological Measure</th>
<th>One-way ANOVA</th>
<th>(p) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>(F(1,4) = .959)</td>
<td>.438</td>
</tr>
<tr>
<td>HRV High Frequency (HF)</td>
<td>(F(1,4) = .904)</td>
<td>.469</td>
</tr>
<tr>
<td>HRV Low Frequency (LF)</td>
<td>(F(1,4) = 1.592)</td>
<td>.191</td>
</tr>
</tbody>
</table>

Table 9-4 Results of the one-way ANOVA for HR and HRV.

**9.4.5. Qualitative Assessment of Immersion and Anxiety**

In tandem with the physiological data, we wanted to find out if a) the participants in general felt immersed when listening to soundscapes, and to what extent they felt relaxed after the listening phase was completed; b) we also wanted to look for any significant interaction among the listening groups to understand how the structure of the
compositions may have impacted the perception of immersion. Comparison of qualitative responses using a between-subjects ANOVA showed no statistical significance interaction amongst the listening groups $F = 2.356$. Therefore, we resorted to combining all the groups into one and looked for any significant findings.

*Relaxation response:*

Using a Likert-scale, participants rated their level of relaxation from 0–10 (0 = not at all, 10 = very relaxed). The combined mean results show that the participants felt moderately relaxed ($m = 6.78$, $SD = 2.29$) in the post-listening phase. However, using a one-way ANOVA, we did not find any statistically significant difference $[F (1,4) = .500, p = 0.736]$ amongst the listening groups.

*Testing for immersion:*

Nineteen perceptual questions were created based on previous studies on immersion and related areas such as flow, cognitive absorption (CA), and presence to test the participant’s subjective experience of immersion. Included was a single question to measure for immersion (e.g. rate how immersed you felt from 0–10) and a mixture of questions combining aspects of flow, cognitive absorption, and presence.

The mean results from the single immersion question show that overall the participants felt immersed listening to the various recordings ($m = 7.16$, $SD = 2.15$). However, no significant differences were found among the different listening groups ($F (1,4) = .855, p = .498$). Figure 9.8 shows the mean values for each group.
Three additional questions were also asked that were related to the experience. A mostly neutral response was provided by the participants regarding “feeling as if they were travelling through the environment”.

Q1. To what extent did you feel emotionally attached to the sounds you were hearing? (0 Not At All– 5 Very Much So): m= 3.44 (SD = 1.34)

Q2. I did not find myself feeling any pleasure from what I was hearing (0 Strongly Disagree–4 Strongly Agree): m= 3.21 (SD = 0.85)

Q3. I felt I could interact with the environment I was hearing as if I was in the real world (0 Strongly Disagree–4 Strongly Agree): m= 2.65 (SD = 1.22)

Testing for presence:

Four questions related to testing for significant level of presence in the virtual auditory journey were asked in the post-listening phase. Overall, all participants listening to the recordings agreed feeling a sense of “presence” in the auditory journey based on the following questions:

Q1. I sometimes found myself feeling as if I was there in the environment (0 Strongly Disagree–4 Strongly Agree): m= 3.13 (SD = 1.04).
Q2. I felt myself to be directly travelling through the audio recordings (0 Strongly Disagree–4 Strongly Agree): $m = 2.68$ (SD = 1.19).

Q3. To what extent did you feel that the audio you listened to was something you were experiencing, rather than something you were just participating in? (0 Not at all–5 A Lot): $m = 3.50$ (SD = 1.33).

Q4. To what extent was the experience of listening stronger than your sense of being in the real world? (0 Not at all–5 A Lot): $m = 3.38$ (SD = 1.21).

Testing for flow:

We asked four questions that were related to only the time distortion property of experiencing flow, since the task of listening was not considered challenging. Based on the results shown below, we can conclude that participants at times did experience the state of flow and were not aware of their surroundings or everyday concerns.

Q.1 To me it felt like a short amount of time had passed (0 Strongly Disagree–4 Strongly Agree): $m = 2.8$ (SD = 1.07)

Q2. When I was listening, it felt like time was going by very slowly (0 Strongly Disagree–4 Strongly Agree): $m = 1.76$ (SD = 1.14).

Q3. To what extent did you forget about your everyday concerns? (0 Not At All–5 Very Much So): $m = 3.51$ (SD = 1.32)

Q4. Did you feel the urge at any point to stop listening and see what was happening around you? (0 Not At All–5 Very Much So): $m = 1.65$ (SD = 1.16)

Testing for cognitive absorption (CA):

We asked participants three questions related to CA by observing if there were significant levels of enjoyment experienced while listening to the recordings. Based on the results, the participants agreed that they enjoyed the experience of listening to the soundscape compositions.

Q1. I was interested in listening to the different sounds in the recordings (0 Strongly Disagree–4 Strongly Agree): $m = 3.22$ (SD = 0.85)
Q2. It did not interest me to know what sounds I would hear (0 Strongly Disagree–4 Strongly Agree): m= 1.22 (SD = 1.12)

Q3. I enjoyed the sounds of the recording (0 Strongly Disagree–4 Strongly Agree): m= 3.2 (SD = 0.80)

9.4.6. Noise level comparisons

The results from measuring the SPL response of each location revealed a statistically significant difference between the average noise levels (F (1,2) = 75.124, p = 000) and maximum dB levels (F (1,2) = 23.491, p = 000) at the clinics versus the hospital.

![Average dB Levels](chart.png)

**Figure 9-9 Average dB levels.**

The mean level for both data sets was higher for the hospital compared to the clinics, as shown in Figures 9.9 and 9.10.

Since the maximum mean level for the hospital is 61 dBA, we do not believe this level of noise is considered an added ambient stressor as it falls within the normal conversation range.
9.5. Discussion

In our previous two studies, the results indicated that chronic pain patients might experience hypersensitivity towards upper mid to high frequencies when listening to audio. In addition, based on qualitative reporting, chronic pain patients preferred listening to hi-fi (natural environmental sounds) soundscape compositions. In this study, the primary objective was to understand the level immersion experienced by chronic pain patients listening to soundscape compositions and measure physiological changes related to anxiety and pain in addition to the qualitative reporting. As part of the research, it was important to investigate whether patients can reduce their stress and allow for an easy way to self-manage pain by listening to soundscapes.

Based on the data captured, a statistically significant change of SCL was identified suggesting that patients can experience anxiety reduction via activation of the sympathetic nervous system no matter the pain type. The qualitative response supports the physiological data of participants feeling more relaxed after listening.

Figure 9-10 Maximum dB levels.
The results also showed heart rate and heart rate variability were unaffected, and therefore parasympathetic activation may not be affected by soundscapes during stress recovery. Since parasympathetic responses are meant to control homeostasis and control the body’s response while at rest, it may be useful to test the relationship between parasympathetic activation and listening to soundscapes in a post-surgery scenario.

We also identified that there was no statistically significant difference among the soundscapes compositions as shown in Table 9.5.

<table>
<thead>
<tr>
<th>Physiological Measure</th>
<th>P Value from t-test</th>
<th>P Value from ANOVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>0.055</td>
<td>0.438</td>
</tr>
<tr>
<td>HRV High Frequency (HF)</td>
<td>0.436</td>
<td>0.469</td>
</tr>
<tr>
<td>HRV Low Frequency (LF)</td>
<td>0.06</td>
<td>0.191</td>
</tr>
</tbody>
</table>

Table 9-5 Group comparison of Journey types.

One reason may be that a larger group size is required for each journey type to show a clearer distinction in the physiological data and the qualitative reporting.

In addition to measuring physiological changes, we wanted to investigate the role of immersion and other similar perceptual experiences such as flow, presence, and cognitive absorption. Through our questionnaire, we were able to obtain a result that showed the experience of immersion does occur while listening to soundscapes. Personality traits and cultural attachment to sounds may also impact the level of immersion. We were able to capture anecdotal responses that support this claim. Some found the sound of people “annoying” while others welcomed the sounds of children playing as it reminded them of family time and social gatherings. One participant also reported enjoying hearing the sound of crows. When asked the reason, she explained that she raised crows as a younger adult and so the sounds reminded her of the time she spent with the birds. Participants who had an openness to experience listening to soundscapes reported being able to visualize themselves walking in the forest and hearing the sounds of the birds and water. However, most participants felt neutral towards feeling as if they
were walking in the virtual environment. The reason for this could be that the binaural recordings are not accurate enough to produce a first person perspective since HRTF encoding is generalized and does not account for individual head and body type. One way to perhaps enhance this effect is by including a visual reference and movement control via a head-mounted display (HMD). However, using such technologies may lead to other problems such as difficulty of use and side-effects such as nausea. Some participants were critical of some of the sounds. For example, one participant stated that “the sound of the ocean seems too fast” even though no time alteration was conducted on any of the sounds. Similar to the previous study, sounds of footsteps were also found to be “annoying” or “distracting.” Therefore, Journey 3 was deemed to be the least favourite of all the compositions since it included sounds of people, machine noise (airplane), and the sound of walking. There were mixed feelings about Journey 5, which included a musical layer. While some reported “feeling being at the spa”, perhaps the artificial creation of space via reverb made it seem less immersive for participants.

9.6. Conclusion

The results of this experiment revealed that the experience of listening to soundscapes can be immersive, and it may be possible that through sympathetic activation, patients can experience anxiety reduction which may also reduce the intersubjective noise (see chapter 5) and therefore the burden impact of pain. A more comprehensive study that includes additional groups (headphones only and headphones with music) to evaluate the physiological responses experienced by patients. In this study, due to time constraints and limited exposure to patients, we did not have the opportunity to balance the number of male and female participants. In the future, adjusting the study to include sex differences may provide new insights into listening responses and the experience of immersion.
Chapter 10. Conclusion

According to the American Chronic Pain Association, there are more than a 100 million people in North America that struggle with chronic pain with an estimate annual cost of as much as $635 billion in treatment and lost productivity. Fueling the problem is the misuse of potent opioid painkillers, increasing the risk of addiction and abuse that can confuse the conversation around appropriate ways of addressing the management of chronic pain. The focus is on managing the symptoms of chronic pain through varied forms of medical interventions that include complementary and alternative forms of therapy. However, the investigation of using non-invasive methods of managing chronic pain is in its nascent stages. This promising research directly addresses this gap by attempting to provide a tool for chronic pain patients to self-manage their pain and anxiety using a non-invasive technological approach. Through active listening and the customization of composing soundscapes we may be able to create a perceptual change of environment that is calming for chronic pain patients.

10.1. Developing a systematic approach

A multi-disciplinary approach was taken to examine the efficacy of using soundscapes compositions and providing them as a form of therapeutic intervention for chronic pain patients. As part of the research, an attempt was made to define chronic pain and the psychological fallout from its sequelae, and to propose possible avenues for developing soundscapes specifically for pain and anxiety management. Based on the background literature provided, we understand chronic pain to be a multi-factorial, personal, and subjective experience. Since its case and cure are not known, self-management of chronic pain becomes the primary approach beyond the use of pharmaceuticals. The notion of self-managing pain provide an advantageous method because the goal is not to develop a cure, but to enable chronic pain sufferers to potentially rely less on medication and opioids through an alternative, and cost-effective method of treatment.
Three experiments were designed and administered, as shown in Table 10.1, in order to develop a focused methodology that can be used for creating immersive soundscapes that can maximize stress and anxiety reduction.

<table>
<thead>
<tr>
<th>Study 1: testing auditory sensitivity amongst CP patients vs. health participants</th>
<th>Study 2: comparing soundscape compositions of hi-fi to lo-fi environments</th>
<th>Study 3: testing for immersion, physiological measures, anxiety reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensitivity difference to audio frequencies in the mid to upper ranges in CP patients vs. healthy participants</td>
<td>CP patients preferred the natural hi-fi soundscapes</td>
<td>CP patients were more relaxed after listening to soundscape compositions based on physiological measures and qualitative reporting</td>
</tr>
<tr>
<td>Sensitivity was higher in female participants vs. male</td>
<td>A significant amount of memory recall and the sensation of being present in the virtual auditory environment</td>
<td>Listening to soundscapes was an immersive experience based on qualitative reporting</td>
</tr>
<tr>
<td>Environmental and machine noise (including at home) may induce further pain and anxiety in CP patients</td>
<td>Based on qualitative reporting, CP patients felt relaxed after listening to hi-fi soundscapes</td>
<td>Did not find noise in the clinics and hospital to be a concerning factor</td>
</tr>
</tbody>
</table>

Table 10-1 Summary of results from three user studies conducted in this research.

The acoustic communication model and the research conducted by the World Soundscape Project has enabled sound designers, musicians, and acousticians to more deeply understand the communicative quality of sounds within an environment. This mediation of information can be built upon to develop techniques that take advantage of using environmental sounds to have a greater role in therapeutic settings.
10.2. Auditory sensitivity

The initial step required for developing soundscapes for self-management is to understand differences in the hearing perception of chronic pain sufferers versus healthy participants. Based on our experiment verified that there are aural sensitivity differences experienced by chronic pain patients compared to healthy participants, including that of gender and specifically sensitivity to frequencies in the upper mid–to–high range. This study highlights the importance of developing customized music or sound-based therapies for chronic pain sufferers. As a designer, it is important to be mindful of choosing appropriate sound material and control high frequencies that may cause further pain and anxiety during listening sessions. In addition, everyday sounds deemed to be disturbing or stressful to chronic pain patients such as household noise (e.g. vacuum cleaner, phone ringing or a fan) should be evaluated. This finding can be used as part of a design guideline for designers and therapists to advise patients about the health side-effects caused by environmental noise.

10.3. Music

A non-exhaustive section on music therapy was provided in chapter four to assist in understanding how sound, rhythm, and compositional structure can be used in potentially therapeutic contexts adapted for developing soundscapes. Based on the literature, it is understood that there are challenges with using music because of differences in culture, gender, and musical knowledge amongst people. However, the use of biofeedback technology may help quantify how music and sound in general affects the mind and body.

We concluded that long-term exposure to music and environmental sounds designed for therapy is necessary in order to have significant health benefits because of potential neuroplastic changes that may take place. Longitudinal studies in music, and specially soundscape therapy, are needed to better understand the mechanisms at work, and how both can be applied to treat chronic pain. New research into music that provides evidence of its positive health effects is promising, and was outlined in chapter four.
10.4. A framework for composing soundscapes for therapy

Next, the acoustic communication model posited by Barry Truax was built upon by examining two aspects: the central tenet of this communication model is the human act of listening. Unlike hearing, listening requires the active participation of an individual in order to experience the sonic environment. Using this model and investigating the qualitative aspects of soundwalks, field recording, and soundscape composition, we began to develop our process for testing soundscapes as a form of therapy.

Second, an experiment was designed to understand the qualitative and subjective perception of listening to hi-fi (high-fidelity sounds of natural environments) and lo-fi (low-fidelity sounds of urban environments) soundscapes on patients. In addition, since I was inspired by the growing interest in the field of virtual reality, one of the initiatives was to explore the immersive quality of creating soundscape compositions by using binaural recordings. The results revealed that patients preferred the hi-fi soundscapes over the lo-fi recordings. In addition, chronic pain patients reported experiencing vivid memory recall of past events and having physical and emotional reactions to the sounds in the recordings. We also discovered some limitations with our compositions, such as a need to minimize head movement while recording sounds using binaural microphones, and suppress the sounds of footsteps, since patients found them to provoke anxiety, and in some instances painful to hear.

Lastly, theories of listening were used to facilitate both the design process of the compositions and to engage the participants of the user studies (Study 2 & 3) in an active listening mode. Careful attention was placed on creating a soundscape that included both background and foreground sounds to help maintain the attention of the listener. Meditative musical sounds were used (Study 3) to elicit a form of personal soundtrack listening. Soundmarks, which are memorable sounds, were captured during the recording process to produce a connotative listening experience for the participants.
10.5. Immersive Journeys

The idea of soundscapes as journeys was introduced in the final study by exploring varied soundscape structures based on fixed, moving, and variable perspectives as described in chapter six. In addition, we applied theories from sensorial ethnography and game theory to better understand concepts of immersion, presence, flow, and psychological absorption in enhancing the immersive quality of the compositions. Since the study of immersion is very limited in the context of soundscapes, theories from previous studies and methods were adapted for this research area. A questionnaire with a focus solely on audio was adapted based on the theories of immersion for this research and was used during the final study to measure immersion, presence, flow, and psychological absorption.

10.6. Testing for immersion, noise, and anxiety reduction

The final and extensive experiment incorporated biofeedback, a State-Trait Anxiety questionnaire, an adapted immersion questionnaire (see chapter nine), and noise measurements of clinics and hospitals. Based on the findings, a patient profile was obtained based on background questions administered. In general, chronic pain sufferers on average had experienced 10 years of chronic pain, and a moderately higher level of trait and state anxiety compared to a healthy population. The data from the study revealed that listening to soundscapes developed for therapy using binaural processing and careful sound selection of natural sounds framed as journeys can be an immersive experience. Most importantly, the biofeedback data of skin conductance level revealed sympathetic activation of the autonomic nervous system during the listening phase, which meant patients experienced recovery from stress and anxiety while listening to the five-minute soundscape recordings. Based on the data, we also concluded that the parasympathetic system is not significantly affected by listening to soundscapes.
10.7. Conclusion and future work

In closing, listening to soundscapes is a subjective experience but an effective adjunct to chronic pain treatment for patients. A focussed form of sonic therapy for chronic pain patients was investigated by using theories from music therapy and composition, acoustic ecology, biofeedback, and the acoustic communication model. The method of recording and administering immersive soundscapes to patients was challenging and need to be overcome when designing soundscapes as summarized in Table 10.2.

<table>
<thead>
<tr>
<th>Challenges with composing soundscapes for therapy</th>
<th>Solutions addressing these challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choosing appropriate locations</td>
<td>Hi-fi locations are preferred, minimize presence of machine noise</td>
</tr>
<tr>
<td>Recording</td>
<td>Minimize footstep sounds (mindful of walking surface, i.e. gravel, grass, pavement)</td>
</tr>
<tr>
<td>Playback type</td>
<td>Ideally headphones with binaural processing minimizing head movement during recording</td>
</tr>
<tr>
<td>Composing</td>
<td>Experiment with perspectives, control high-frequency content by applying EQ to dampen frequencies. May need to apply further spatialization techniques to improve the immersive quality.</td>
</tr>
</tbody>
</table>

Table 10-2 Summary of challenges and solutions of using soundscapes for therapy.

Based on the results of the experiments, one potential direction that could overcome some of the barriers experienced is to use technology to enhance the experience for patients. I propose a hybrid theoretical model (see Figure 10.1), which addresses the use of procedural sound design techniques to enhance the communicative and pragmatic role of sound in virtual auditory environments. The end result, promises to produce a sonic environment that is customized according to the listener’s preference, and thereby may heighten the experience by cognitively engaging patients with sounds within a particular time and space.
For example, if we apply a procedural processing technique, the sound can dynamically change in real-time based on the participant's physiological measures and interaction. Further, patients can choose to filter sounds they find disturbing, and customize their journeys to their liking. In addition, similar to the Virtual Meditative Walk (see chapter four), biofeedback data can help drive some of the parameters controlling sounds, such as volume level, frequency, reverberation, etc. This approach is similar to the theory of the acoustic communication model in which equilibrium may be maintained between the listener and the environment. Table 10.3 is an example of how theories of the communication model can be parameterized. In the procedural model, sonic information is mediated and controlled by parameters in real-time. These parameters may also be influenced by the actions of the listener. For example, the listener may choose the type of sounds they would like to hear such as birds, rainfall, or people.

<table>
<thead>
<tr>
<th>Communication</th>
<th>Listener</th>
<th>Sound Types</th>
<th>Dynamic Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background/Foreground</td>
<td>Listener Preference</td>
<td>Static</td>
<td>Pan</td>
</tr>
<tr>
<td>Dynamic Perspective</td>
<td>Active / Passive</td>
<td>Gestural</td>
<td>Volume</td>
</tr>
<tr>
<td>Functional Equilibrium</td>
<td>Maximize pleasing, informative sounds</td>
<td>Live Input</td>
<td>Filter</td>
</tr>
<tr>
<td>Micro &amp; Macro levels</td>
<td>Minimize unwanted, uninformative sounds</td>
<td>Music</td>
<td>Reverberation</td>
</tr>
<tr>
<td>Mediation</td>
<td>Enhanced Listening</td>
<td>Voice</td>
<td>Biofeedback</td>
</tr>
</tbody>
</table>

Table 10-3 Parameterizing the acoustic communication model.

The compositions may then adapt to such filtering by structuring soundscapes based on user preference. This may also help reduce the subjectivity of composing soundscapes since the listener can participate in choosing the appropriate sonic material that they may like to hear.
This real-time mixing of sounds may help focus the attention of the patient and improve the level of immersion and presence experienced listening to the soundscape composition. Improving the immersive quality and engaging the patient in actively listening to the soundscape may act as a mechanism of distraction to help with pain and anxiety management. The system itself may automate and balance the dynamic controls in real-time to maintain equilibrium between the dynamic exchange of information between the listener and the virtual auditory environment.

Figure 10-1 Procedural acoustic communication model proposed by Mark Nazemi.

Finally, sound from a physical space can be integrated with the virtual auditory world, which in turn may help further improve the immersive quality of the simulated world. For instance, rather than having to use audio samples to generate breath sounds, microphones embedded in a head mounted display (HMD) may capture the sound of the user’s breath and re-amplify it in the virtual world. In a sense, using a live input microphone to capture sounds from the physical environment may allow for real-time soundscape composition similar to Janet Cardiff’s mediated sound installation Taking Pictures\textsuperscript{20}. As

\textsuperscript{20} One notable work to view is Cardiff’s piece Taking Pictures from 2001. More information: http://www.cardiffmiller.com/artworks/walks/takingpictures.html
Cardiff suggests, “The walks are really about play,” says Cardiff, “like the kids’ game, a letting-someone-guide-you, covering your eyes, wondering what they’ll do with you” (2001). The success of the work is based on the listener acting as the vehicle which the virtual auditory world is revealed but just as importantly, it is the sounds themselves that generate new ways of listening that draws the listener into an immersive experience.

Currently, my colleagues and I are developing a prototype using this model to investigate the relationship between sound, environment, and the listener. Future testing of this system is planned for 2017 with patients at regional health institutions.
References


Brocklesby, R. (1749). *Reflections on ancient and modern musick, with the application to the cure of diseases To which is subjoined, an essay to solve the question, wherein consisted the difference of ancient musick, from that of modern times*. London: Printed for M. Cooper, at the Globe in Pater-Noster Row.


Appendix A.

Supplementary material for chapter 2

A delayed response to pain

There are countless reports of people who have suffered injuries wherein they feel no pain at the moment of injury, but the pain experience emerges later (Wall, 2000). Harry K. Beecher, who was a medical officer during World War II, studied soldiers who were injured during battle. Beecher asked soldiers right after the injury had occurred two simple questions: “Are you in pain? Do you want something for it?” Surprisingly, 70% of the men who were severely wounded answered no to both questions (Beecher, 1956). Another incident was reported by a 43-year-old reserve major who fell into a crevasse with ice walls after a snow bridge had collapsed. After falling, he found himself wedged firmly in an ice crack. His arm was jammed, and he could not move his legs but interestingly, aside from being wounded, did not feel any pain. It was only after he was airlifted to the hospital that he started feeling tremendous pain (Wall, 2000). These case scenarios amongst many others reveal that the gravity of an injury does not necessarily align itself well to the amount of pain experienced. In these cases, there is a delayed response to experiencing pain but not necessarily absent in relation to injury.

For others, however, the onset of injury can bring about unimaginable pain. In 1812, Frances Burney, a renowned French novelist, wrote a letter to her sister describing the painful experience she had while undergoing a mastectomy. She was not given any anesthetic during the procedure and described it as ‘the most torturing pain’ and ‘so excruciating was the agony.’ Burney was able to account the details of the operation in her letter and explains how ‘the dreadful steel was plunged into the breast — cutting through veins, arteries, flesh, and nerves’ and at that moment could not restrain her cries anymore and began screaming until the procedure ended (Helle, 2007).

Congenital Insensitivity to Pain (CIP)

Some people have a congenital insensitivity to pain (CIP); they feel no pain and are consequently at constant risk of causing harm to their bodies without realizing it. People
diagnosed with CIP can feel the difference between sharp and dull or hot and cold, but cannot sense that a hot stove is burning their hand. This lack of pain can lead to many undetected injuries. For instance, some children suffer from oral cavity damage or bone fractures while others suffer from infections, corneal damage, or burns by coming in contact with dangerous foreign objects. Many who suffer from CIP also tend to experience anosmia (a complete loss of the sense of smell), which can lead to even more injuries (Peddareddygari, 2014).

**Pain due to tissue damage**

When we succumb to injury, there are sensory nerve endings all around our body that initiate the sensation of pain. These particular cells are called nociceptors. The brain and spinal cord are important pain registration areas that manage how the body reacts to tissue damage. There are cell clusters known as ganglions in which sensory nerve fibers originate. These lie close to the spine, and each vertebra has one ganglion. The spinal cord can be thought of like a relay station that can send vital information such as changes in temperature, pressure, or pain from the periphery – which includes the skin, joints, and muscle – to the brain. Figure A1, shows the structure of the spinal cord (Gianino, 1996).

![Spinal Cord Diagram](image.png)

**Figure-A1 Details of the spinal cord structure (image created by Nazemi, 2016).**

The white matter contains the axons of the nerve cells while the grey matter contains nerve cell bodies. The brain also consists of white and grey matter, but their positions are inverted; that is, the white matter is in the centre, and the grey matter is around it. A canal
lies in the centre of the spine carrying cerebrospinal fluid that nourishes the central nervous system, which includes the spinal cord, and the brain. Motor nerve fibers extend outwards from the front of the spinal cord, and these particular fibers carry information out of the spinal cord (Gutman, 2001). There are nerve fibers connected to the back or dorsal of the spinal cord and these particular fibers are known as the sensory fibers. These transmit information to the spinal cord and can also be transmitted to the brain. If we prick our finger with a nail, the nociceptors – the pain-sensing nerve cells in our skin – become stimulated. The skin has three types of sensory fibers as shown in Figure A2., including A-beta fibers that are wrapped in a fatty protein called myelin and can sense even the slightest amount of pressure. The second type is called the A-delta fibers, which are slightly thinner and sensitive to heavy pressure and temperature. Usually, the sharp pain we experience is when A-delta fibers have been damaged, such as in the case of a pin pricking our skin. Finally, C-fibers are thin with no myelin and respond to pressure, chemicals, and temperature stimulation.

Figure-A2 Noxious stimulus applied to various nerve fibers and the signaling to the spinal cord (image created by Nazemi, 2016).
The speed at which pain information is relayed back to the spinal cord and brain depends on the type of injury that occurs (Loeser and Melzack, 1999). There are various lengths of sensory nerve fibers in our body. Some are very short, only a few centimeters long, running from the teeth to the hindbrain while others can be more than a meter long, running from our toes to the middle of the back. Detection of events such as a nail penetrating the skin occurs at the ends of the sensory nerve fibers. The signaling of the event can happen in two ways: first, short nerve impulses that last only one thousandth of a second and depending on the thickness of the fibre can travel between 1 and 100 meters per second through the fibre to the spinal cord. The second method of sensory transmission is much slower. The nerve endings of C-fibers that absorb chemicals from the tissue slowly transport these chemicals all the way to the cell bodies in the ganglia and to the dorsal horn (the back of the spine). The transportation time of these signals depends on the location of the injury. For example, if the injury occurs in the foot it may take several days for the injury to become apparent, or conversely only a few hours if the injury is closer to the face. The burning or throbbing pain that occurs is a signal that C-fibers have been damaged. Figure A3., illustrates the different types of sensation experienced based on the type of fibers that are damaged.

![Figure-A3 Pain signaling difference between A-delta and C-fibers](image created by Nazemi, 2016)

Nociceptors release chemicals called pain neurotransmitters that are received by a neuron called the second ordered neuron that sends this information to the brain. At the location
of the injury, we may see some dramatic changes to the skin such as a discoloration caused by hemoglobin, the protein molecule in red blood cells that has leaked into the damaged tissue. We may sometimes see a rainbow effect caused by the breakdown of hemoglobin. Pain is produced when an influx of pain-producing chemicals is poured into the damaged area, and we may even feel tenderness – pain experienced when gentle pressure is applied to the area. The tenderness is due to nerve endings having become sensitized due to the damage and pain modulation triggered by the central nervous system. After the onset of damage, white blood cells pour in to remove all dead cells and the reparative process beings. The lateral spinothalamic tract carries the signal to the thalamus in the brain. The outer part of the brain, which is associated with sensation, consists of the somatosensory cortex and receives all sensory input from our body. The level of sensitivity from one part of the body to another is disproportionate; that is, one area such as the face can be much more sensitive than, for example, our shoulder as is illustrated in Figure A4., Somatosensory cortex is both on the left and right side of the brain.

![Homunculus sensory model](image.png)

**Figure-A4 Homunculus sensory model,** a physical illustration of the somatosensory cortex (image adapted from OpenStax College, 2013, licensed under CC BY 3.0).
If an injury occurs on the right side of the body, the left side of the somatosensory cortex processes this information. If injury occurs on the left, then the right side of the brain processes this information. For example, if we pricked our right finger then the nociceptors (from our right finger) would send this information to the second-order neuron in our spinal cord. This neuron relays this information by crossing over to the left side and sends this information to the brain, specifically to the third order neuron in the thalamus, where it is then processed by the sensory cortex. Other areas of the brain are also involved in receiving input signals generated by tissue damage, and the brain is actively involved in sending descending control systems that shape the received messages. A negotiation occurs between the spinal cord and the brain regarding how much sensitivity or pain should be experienced. The spinal cord cells will exaggerate sensitivity if a lot of damage has occurred. Chemical messages from severe damage such as cut nerves further increase the sensitivity, and many parts of the brain then feedback to the spinal cord cells and amplify or reduce their output messages. The gate control theory proposed by Ronald Melzack and Patrick Wall suggest that the experience of pain is modified by other incoming stimuli before reaching the brain. A “gate mechanism” in the dorsal horn of the spinal cord modulates the pain signal as shown in figure A5. This gate opens and closes depending on feedback from other nerve fibers in the body. Patients with chronic pain have noticed that pain seems to increase or decrease from time to time without any change to the amount of tissue damage (Melzack, 1996).

The experience of pain is complex by nature, and even though it may be hard for some to believe, pain can occur without any pathology. The pain system can malfunction in many ways, causing intense pain that may not be the result of any tissue damage. This form of pain can be difficult for doctors to diagnose and assign treatment, but patients themselves also feel frustration because detecting the initial trigger of pain can be very challenging. Furthermore, doctors may find an inability to help patients in these cases, and even claim that the pain is self-inflicted or imaginary.
We know that the brain has the ability to control the sensitivity of nerves, specifically requesting additional information from the peripheral nerves, ordering them to produce more signals even though the stimuli may be fairly minute. Evidence shows that the peripheral nerves can change chemically or physically in response to requests from the brain, tissue conditions, or both (Wall, 1986). Therefore, the experience of pain is modulated through mediation among our brain, central nervous system, and potential or actual tissue damage (Wall, 1979).
Appendix B.

Supplementary material for chapter 3

Hearing

The point at which hearing begins is at the ear canal as sound waves enter and push against the eardrum. The ear drum separates the outer (external) ear from the middle ear as shown in Figure B1. The middle ear acts as a bridge between the air-filled spaces of the external and middle ear and the fluid-filled spaces of the cochlea. The fluid inside the cochlea is saline water, and the acoustic impedance of water is much higher than air. Therefore, the water must be pushed much harder than air if the water particles are to oscillate with the same velocity.

![Illustration of the human ear, outer, eardrum, middle, and inner ear sections](image-url)

*Figure-B1 Illustration of the human ear, outer, eardrum, middle, and inner ear sections (courtesy of OpenStax, 2016, licensed under CC-PD Mark).*

Furthermore, an air bound sound wave arriving at a water surface is too weak and cannot travel easily across the air-water boundary (Schnupp, 2011). Hence, the purpose of the middle ear is to concentrate the pressure of the sound wave onto a small spot by collecting
the sound pressure over a relatively large area of the eardrum and focusing it on the much smaller surface area of the stapes footplate.

The middle ear has other duties aside from the transference of sound pressure waves. It also helps protect the delicate inner ear structures from damage due to very loud sounds. The stapedius muscle which controls this function is controlled unconsciously and because its reflex is slow in comparison to the speed of sound, sudden loud noise such as a gunshot can penetrate our ear and cause ear damage. The stapedius muscle works when vocalization is involved, and therefore speaking while surrounded by sudden loud noises may help protect our hearing (Pang, 2007), although we should not solely rely on this method for protection!

As mentioned earlier, the audible range of hearing is between 20 Hz to 20 kHz and most sensitive between 1 kHz to approximately 4 kHz. This is because the middle ear cannot transmit these frequencies to the cochlea with equal efficiency. The middle ear which consists of ossicles are small and light but have some inertia that limits the transmission of very high frequencies.

A structure known as the basilar membrane runs across the entire length of the cochlea as shown in Figure B2.
The cochlea operates as a kind of mechanical frequency analyzer since it is equipped with two sources of mechanical resistance: the stiffness of the basilar membrane and the other by the inertia of the cochlear fluids. There are 24,000 closely packed and tightly stretched fibers that are very short near the entrance to the cochlea and gradually increase in length as one progresses up the cochlea to its apex similar. The basilar membrane, therefore, behaves similarly to a miniature harp, with the shorter fibers being associated with high-pitched sounds and longer fibers corresponding to low-pitched sounds (Buser, 1992).

When a vibration travels through the cochlea, it will search for the most efficient path. Since the inertial resistance is frequency dependent, the optimal solution is for the path of overall lowest resistance. Therefore, it is a long path for low frequencies, which are less affected by inertia, and increasingly shorter for higher frequencies. Figure B2. also shows the relationship of frequency, and the distance along the basilar membrane. If a pure tone is perceived, then the place of maximal vibration in the basilar membrane will provide a good indication of the frequency and if a complex tone is perceived, then, multiple areas are excited corresponding to each of the frequency components within a resolution limit known as the critical bandwidth.
The transduction process which in this case is the conversion of mechanical vibration of the basilar membrane into a pattern of electrical excitation occurs by the organ of Corti. This organ runs along the entire length of the basilar membrane as shown in Figure B3.

The organ of Corti often referred to as the organ of hearing, is stimulated by moving up and down when the basilar membrane begins to vibrate in response to acoustic stimulation. Sensory hair receptors sit at the top of the structure directly on the basilar membrane, and there are two types of such hair cells: inner hair cells and outer hair cells which respond to higher and lower sound levels respectively. The outer hair cells receive information from the brain in addition to messages from inside the cochlea which can either elongate or shrink. Interestingly these outer hairs respond to musical stimulation by stretching and contracting rhythmically.

Figure-B3 A cross-section of the cochlea (Ropshkow, 2008, licensed under CC BY SA 3.0).
The outer hair cells play an important role in the reception of soft sounds. The outer hairs usually become damaged first when exposed to loud sounds and without these hairs, we would experience approximately forty to sixty decibels of sensorineural hearing loss (Venema, 1998). Therefore, with proper protection, the outer hair cells can amplify soft sounds that are below forty to sixty decibels and can "fine-tune" the frequency resolution of the basilar membrane. There are approximately 3000-3500 inner hair cells. Their task is to send afferent information to the brain and is essentially responsible for signal transduction. The inner hair cells connect to type I auditory nerve fibers (outer hairs connect to type II) and represent the acoustic information collected by the inner hair cells as a pattern of nerve impulses. These inner hair cells are connected to as many as twenty types I fibers and the reason for so many connections is to allow for a more precise representation of the sound (Bregman, 1990).
Appendix C.

Questionnaires from user study 1-3

Background Questionnaire User Study 1

Age: ____________

Gender: ____________

1. Have you ever experienced chronic pain?
   Yes     No (if no, please proceed to question 4)

2. Are you currently experiencing symptoms of chronic pain?
   Yes     No

   If Yes, for how long you have experienced these symptoms?

3. What type of chronic pain are you currently diagnosed with? (if you don’t know or haven’t been provided with a formal diagnosis, please write ‘don’t know’)

4. Circle any of the following that you have experienced.

   Long exposures to very loud noise

   An ear/sinus infection

   Head injury

   Exposure to short loud noise

   Whiplash – cervical trauma
5. Have you ever had consistent exposure to loud noise (e.g., construction site)?

Yes  No

If Yes, please indicate the duration of that exposure (in days, months, or years):

6. Have you ever worn a hearing aid(s)?

Yes  No

If Yes, in which ear (choose one)?

Left Ear  Right Ear  Both Ears

7. How often do you listen to music (please circle only one)?

Whenever I can

Regularly

Once in a while

Rarely

8. How loud do you listen to music (you can circle more than one)?

Constantly loud, wearing headphones

Constantly loud, listening to speakers

Speech level, wearing headphones

Speech level, listening to speakers

9. Please indicate if you have ever experienced one or more of the following symptoms
(you can circle more than one)?

I occasionally ask people to repeat what they say
I can't hear whispering very well

I tend to increase the volume on my television

I encounter difficulties communicating with others in restaurants or during meetings

I am sensitive to household noise

I am sensitive to loud music

I am sensitive to the sound of a fan

I am sensitive to the sound of bells or phone rings

I am sensitive to the sound of the Ocean (static)

I am sensitive to noise at work

**Post Questionnaire User Study 1**

1. What type(s) of music do you prefer to listen to?

2. Can you remember ever feeling bodily sensations (i.e., change in breathing) when you were listening to music?
   Yes  No
   If Yes, please describe those sensations to the best of your ability.

3. Have you ever experienced moments when the music you were listening to brought particular images or pictures to mind?
   Yes  No
   If Yes, briefly describe your most vivid example.

4. When you listen to music, at what sound level do you generally like to listen to it at?
   Loud  Speech level  Quiet

5. What type of everyday sound(s) do you find pleasant to listen to?

6. Please rate your comfort with the following sounds using this rating scale:
   1-comfortable, 2-tolerable, 3-uncomfortable, 4-highly uncomfortable

   Loud Music ___________________ Phone ringing ___________________
   People speaking loudly ______________ A blender ________________
   Traffic ______________________ Plastic bag ___________________
Police siren __________ Car Horn __________
Rain __________ Dog barking __________
Door slamming __________ Construction site __________

7. Please indicate any of the following reactions you experience when listening to uncomfortable sounds (you can circle more than one).

- Anxiety
- Disorientation
- Irritability
- Headache
- Tension
- I Move Away or Avoid the Sound Source
- Anger
- Ringing in the ear

Other(s):

8. With respect to your answers in question 7, approximately how long does your symptom(s) last for?

- A few minutes
- More than 30 minutes
- One hour
- More than an hour
- One day
- If none of the above, please indicate the duration below:
Background Questionnaire User Study 2

Screening Questionnaire

Researcher's Initials
Participation Number
Date

Please state your Age

Please state your Gender

Please answer the following questions as honestly as possible by ticking the box that best fits with your opinion.

<table>
<thead>
<tr>
<th></th>
<th>Not Present</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANXIOUS MOOD (worries, irritability)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TENSION (startle, cry easily, restless, trembling)</td>
<td></td>
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</tr>
<tr>
<td>FEARS (fear of the dark, fear of strangers, fear of being alone, fear of animal)</td>
<td></td>
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<tr>
<td>INSOMNIA (difficulty falling asleep or staying asleep, difficulty with nightmares)</td>
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<tr>
<td>INTELLECTUAL (poor concentration, memory impairment)</td>
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<tr>
<td>DEPRESSED MOOD (loss of interest, lack of pleasure in hobbies)</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Page 1 of 3
Please answer the following questions as honestly as possible by ticking the box that best fits with your opinion.

<table>
<thead>
<tr>
<th></th>
<th>Not Present</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Very Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SOMATIC</strong> (muscular pains and aches, twitching, stiffness)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SOMATIC</strong> (sensory, blurry vision, Tinnitus, hot &amp; cold flashes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CARDIOVASCULAR SYMPTOMS</strong> (palpitations, pain in chest, tainting feeling)</td>
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<tr>
<td><strong>RESPIRATORY SYMPTOMS</strong> (pressure or constriction in chest, choking feelings, sighing)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>GASTROINTESTINAL SYMPTOMS</strong> (difficulty in swallowing, wind abdominal pain, burning sensation, nausea)</td>
<td></td>
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<tr>
<td><strong>GENITOURINARY SYMPTOMS</strong> (urinary frequency or urgency)</td>
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<td></td>
</tr>
<tr>
<td><strong>AUTONOMIC SYMPTOMS</strong> (dry mouth, flushing, tendency to sweat, tension)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>BEHAVIOR AT INTERVIEW</strong> (fidgeting, restlessness, tremor of hands, strained face, signing)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Will you see your usual or regular doctor today?

Yes
No
Not sure
Thinking about the doctor you are about to see, please answer the following questions as honestly as possible by ticking the box that best fits with your opinion.

<table>
<thead>
<tr>
<th>Disagree</th>
<th>Neither agree or disagree</th>
<th>Slightly Agree</th>
<th>Mostly Agree</th>
<th>Totally Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I know this doctor very well</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This doctor really knows how I feel about things</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This doctor takes me seriously</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>This doctor accepts me the way I am</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel totally relaxed with this doctor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In a few words, how would you describe the atmosphere of the waiting room at the clinic?

Is this your first time visiting this clinic?
- Yes
- No

If no, please indicate how often you visit this clinic.
- Once a month
- Every 2 weeks
- Once a week

Do you take medication for anxiety? If so, please indicate the type of medication.
- Yes
- No

Please provide any additional feedback.
## Post Questionnaire User Study 2

### Participant Number

<table>
<thead>
<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
</table>

### Are you presently experiencing any feelings of anxiety?

- Yes
- No

If Yes, please indicate the level of anxiety using the scale below

- Anxiety Level (0 being none, 2 mild, 5 moderate, 8 severe, 10 worst)

### Were there any sounds on the recording that caused you to feel discomfort?

(Example: heard discomfort, caused anxiety, felt dizzy, etc.)

- Yes
- No

If Yes, please indicate which sounds.

### What sounds during the listening session did you find pleasing?

### Did you notice changes in your breathing while listening?

- Yes
- No
Did you experience any emotional sensation as you listened to the recording?
   Yes
   No
If Yes, please indicate the emotion experienced

Did you experience any physical sensation as you listened to the recording?
   Yes
   No
If Yes, please indicate the physical sensation experienced

While listening, did you experience moments that brought particular images or pictures to mind?
   Yes
   No
If Yes, briefly describe your most vivid example.

What type of environmental sound(s) do you find pleasing?
Did you find the duration of the recording to be:
  - Short
  - Just right
  - Too Long

Do you listen to music for calming effects? If so, please briefly describe the type of music you listen to and the setting (example: headphones while sitting, speakers in my bedroom, etc.)
Background Questionnaire User Study 3

Age: ________  Gender (Circle)  M   F

Have you ever experienced chronic pain (Circle)?  Y   N

Are you currently experiencing symptoms of chronic pain (Circle)?  Y   N

If yes, for how long have you experienced these symptoms?

What type of chronic pain are you diagnosed with?
(Skip this question if you answered No to question 2)

Do you currently have any surgically implanted electronic device such as a pacer?  Y   N

Are you diagnosed with any hearing condition (Circle)?  Y   N
If so, please explain

On the following page, a number of statements which people have used to describe themselves are given provided. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.
<table>
<thead>
<tr>
<th>Feeling</th>
<th>NOT AT</th>
<th>SOMETHAT</th>
<th>MODERATE</th>
<th>VERY</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel calm</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel secure</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am tense</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel strained</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel at ease</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel upset</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am presently worrying over possible misfortunes</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel satisfied</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel frightened</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel comfortable</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel self-confident</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel nervous</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am jittery</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel indecisive</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am relaxed</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel content</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I am worried</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel confused</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel steady</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>I feel pleasant</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>
On the following page, a number of statements which people have used to describe themselves are given provided. Read each statement and then circle the appropriate number to the right of the statement to indicate how you generally feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

I feel pleasant ................................................................. 1
I feel nervous and restless ................................................................. 1 2 3 4
I feel satisfied with myself ................................................................. 1 2 3 4
I wish I could be as happy as others seem to be ..................... 1 2 3 4
I feel like a failure ........................................................................... 1 2 3 4
I feel rested .................................................................................... 1 2 3 4
I am “calm, cool, and collected” ....................................................... 1 2 3 4
I feel that difficulties are piling up so that I cannot overcome them 1 2 3 4
I worry too much over something that really doesn’t matter......... 1 2 3 4
I feel am happy .............................................................................. 1 2 3 4
I have disturbing thoughts ............................................................... 1 2 3 4
I lack self-confidence ...................................................................... 1 2 3 4
I feel secure ................................................................................... 1 2 3 4
I make decisions easily ................................................................. 1 2 3 4
I feel inadequate ............................................................................ 1 2 3 4
I am content .................................................................................. 1 2 3 4
Some unimportant thought runs through my mind and bothers me 1 2 3 4
I take disappointments so keenly that I can’t put them out of my mind ............................. 1 2 3 4

I am a steady person .......................... 1 2 3 4

I get in a state of tension or turmoil as I think over my recent concerns & interests .......................... 1 2 3 4

**Post Questionnaire User Study 3**

Please rate your personal experience of listening to the recordings by circling one of the options for each question. 0 = Strongly Disagree  1 = Disagree  2 = Neutral  3 = Agree  4 = Strongly Agree

1. I did not feel any emotional attachment to the audio recordings.  
   0 1 2 3 4

2. I was interested in listening to the different sounds in the recordings.  
   0 1 2 3 4

3. It did not interest me to know what sounds I would hear.  
   0 1 2 3 4

4. I sometimes found myself feeling as if I was there in the environment.  
   0 1 2 3 4

5. I did not find myself feeling any pleasure to what I was hearing.  
   0 1 2 3 4

6. I enjoyed the sounds of the recording.  
   0 1 2 3 4
7. I felt myself to be directly travelling through the audio recordings. 0 1 2 3 4

8. I did not feel as if I was moving through the audio recordings. 0 1 2 3 4

9. I felt I could interact with the environment I was hearing as if I was in the real world. 0 1 2 3 4

10. I was unaware of what was happening around me. 0 1 2 3 4

11. I was aware of my surroundings. 0 1 2 3 4

12. To me it felt like a short amount of time had passed. 0 1 2 3 4

13. When I was listening, it felt like time was going by very slowly. 0 1 2 3 4

14. How immersed did you feel? (10 = very immersed; 0 = not at all immersed)

0 1 2 3 4 5 6 7 8 9 10

15. To what extend did you forget about your everyday concerns?

Not at all 1 2 3 4 5 Very Aware

16. Did you feel the urge at any point to stop listening and see what was happening around you?

Not at all 1 2 3 4 5 Very Much So

17. To what extend did you feel that the audio recording was something you were experiencing, rather than something you were just doing?

Not at all 1 2 3 4 5 A Lot
18. To what extent was your sense of listening to the audio recordings stronger than your sense of being in the real world?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Very Much So</th>
</tr>
</thead>
</table>

19. How relaxed did you feel after listening to the recordings? (10 = very relaxed; 0 = not at all relaxed)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

20. To what extent did you feel emotionally attached to the sounds you were hearing?

<table>
<thead>
<tr>
<th>Not at all</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Very Much so</th>
</tr>
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</table>