TRANSPLANTATION AND PERSONAL, PREFERRED MUSIC: A QUALITY OF LIFE STUDY

ROBERT MCKNIGHT

A THESIS SUBMITTED TO

THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF ARTS

GRADUATE PROGRAM IN INTERDISCIPLINARY STUDIES

YORK UNIVERSITY

TORONTO, ONTARIO

AUGUST 2018

Abstract

This project is a multiple methods, open-label, clinical experiment that provided iPods, headphones, and personal, preferred music to transplant patients to improve their quality of life. In total, the study enrolled 46 participants and collected 188 data points. Study participants were randomized to one of two study groups, either the control group or the iPod group, via electronic coin toss and data was collected using a modified version of the EQ-5D health survey to conduct in-person interviews every other day. Data was analyzed both quantitatively using linear regression, ANOVA, and Tukey's HSD test, and qualitatively by identifying common themes from the open-ended participant response. Overall, the study received a positive response from the participants, though the results from the quantitative analysis were ambiguous. There are some limitations to this study's analysis and some identified areas for improvement, which can be addressed in similar, future studies.

Acknowledgements

I would please like to my supervisory committee for their help in completing this thesis. The input I received from Profs. DeSouza, de Val, and Peisachovich was invaluable. They were instrumental in helping to conceive the methodology, research the literature, and revise this thesis.

Table of Contents

List of Tables

List of Figures

Glossary

Anxiety and Depression - A self-reported measurement of the amount of one's current anxiety and depression. One of the four aggregate factors of one's overall quality of life score.

EQ-5D Health Survey - A validated quality of life survey that measures quality of life across five indicator variables. The survey was modified for this project, and omits the "usual activities" variable.

iPod - A fourth generation iPod shuffle (Silver).

Mobility - A self-reported evaluation of one's current ability to ambulate either with assistance or independently. One of the four aggregate factors of one's overall quality of life score.

Over-Ear Noise-Cancelling Headphones - Sony MDRZX110NC Over-Ear Noise Cancelling Headphones (Black).

Pain and Discomfort - A self-reported evaluation of one's current physical pain and/or discomfort. One of the four aggregate factors of one's overall quality of life score.

Quality of Life (QOL) - A self-reported, aggregate score of one's state of health. This score includes, but is not limited to one's mobility, pain and discomfort, anxiety and depression, and ability to self-care.

Self-Care - A self-reported evaluation of current ability to care for oneself, including eating meals, washing, and dressing. One of the four aggregate factors of one's overall quality of life score.

Transplant - Multi-organ transplant specific to heart, lung, liver, and/or kidney.

Chapter One: Introduction and Overview

Introduction & Background

Receiving an organ transplant is a traumatic experience. Although the long-term benefits of a transplant are certainly a good incentive to undergo such a procedure, the immediate short-term consequences of this kind of invasive surgery can have a negative effect on an individual's quality of life (QOL). There are currently some strategies employed in-hospital to attempt to mitigate potential declines in a patient's QOL, but there is currently no entirely effective strategy in place to address the effect that hospital noise has on the inpatient experience. From the perspective of an inpatient, hospital noise can be omnipresent, cacophonous, and inescapable (Ugras & Öztekin, 2007; Konkani & Oakley, 2012), which can negatively affect a patient's QOL.

Some hospitals do recognize these challenges and have attempted to provide recourses to better inpatient experiences. For example, at an unnamed hospital situated in a large metropolis there are hour-long weekly programs freely available, but unfortunately these performances are often sparsely attended and most of the attendees are usually staff or non-inpatients, such as friends and family. As a result, generally the only relief patients experience from the hospital environment is either drug-induced, through television, or personal intervention. Incredibly, music offers the potential of being a powerful, safe, and inexpensive remedy to this problem, and although many healthcare programs, both nationally and internationally, are beginning to embrace music as an agent of care and wellbeing, there is still much that could be done to target the issues more successfully.

This project attempts to address these challenges by providing a personal music device, over-ear, noise-cancelling headphones, and preferred music to transplant recipients. Indeed, providing such a personal music system to transplant recipients offers a safe, reliable, and inexpensive solution to these problems. Previous examples wherein personal music was administered to hospitalized individuals were shown to improve sociability, facilitate physical movement, improve cognition, alleviate pain, reduce anxiety, improve sociability, and assist with sleep, all of which positively affects a patient's QOL. Moreover, the benefits of personal music are not restricted to a particular demographic and the one-time costs associated with administering music are considerably lower than drug plans, which can cost hundreds of dollars per day (Danzon & Furukawa, 2008). The predicted outcome of this project was that music will positively affect an individual's QOL.

The study gathered data using a modified version of the EQ-5D survey. The EQ-5D survey was chosen as a basis for this study because of its breadth (five dimensions of assessment), its conciseness (five levels per dimension), and relevance to the inpatient experience. For example, many other QOL surveys attempt to assess the patient's life outside the hospital, which is excluded from this investigation (EuroQol Research Foundation, 2017). Also, the EQ-5D concludes with a visual representation of the patient's overall health state from a scale of 0 to 100. This concluding diagnostic is an opportunity for the patient to account for any variables that were not previously assessed by the first five responses by empirically stating their overall health state as an aggregate.

There are two modifications that have been made to the EQ-5D survey for the purpose of this study. First, the "usual activities" section was omitted. The EQ-5D survey defines usual activities as “work, study, housework, family or leisure activities,” however, the ability to do most these activities becomes compromised by a transplant procedure, except for perhaps socializing, which is at best an indirect link to “leisure activities.” Although observational experience suggests that visitation from family and friends is an important part of the healing process by helping to elevate a patient’s mood and thus by extension provide a higher QOL, ultimately measuring sociability was not undertaken due to the imprecise nature of such a measurement. Second, an additional section for comments or other notes was added to the end of the survey to more completely capture the entirety of the participant’s response. The addition of a comments sections allowed for more detailed capturing of qualitative data, which was critical to understanding each participant’s unique, subjective responses.

Overall, the aim of the study was to provide a higher QOL score than would otherwise be experienced without the use of an iPod with personal, preferred music. The purpose was to identify music as a valuable tool of healthcare through statistical analysis, which could then be extrapolated to a larger population, thereby perpetuating this kind of research. In the long term, one hopes that the accumulation of many studies with positive results could then be used as a mechanism to negotiate for the integration of music into the core protocols of healthcare. The rationale for this research is based in part on published literature, which identifies many instances of the benefits of music in the context of healthcare, as well as recent popular media, such as the documentary film, “Alive Inside,” which have contributed to a recent popular interest in music and health among the general public in special populations. As long as there is an interest in the relationship between music and health and there are potential benefits to the provision of music and health programs, as indicated by the forthcoming literature review, it would be fruitful to investigate this relationship more thoroughly in order to provide more effective music and health programs to the general public.

Literature Review

There is already some published research that examines a holistic measurement of QOL in the context of administering personal music via iPods to transplant patients. Perhaps the best-known publication that parallels this project would be the review of the Alzheimer's Society of Toronto's iPod project (Williams, Peckham, Rudoler, Tam, & Watkins, 2014). The project is ongoing, but overall the review found the project to be successful and recommended its expansion. In the same vein, there are other review publications that have examined the role of music interventions in other contexts. For instance, reviews by Kneafsey (1997), Wall & Duffy (2010), and Vink et al. (2013) also found mixed success of music interventions for patient populations who were afflicted with dementia. Nevertheless, it is important to note that none of the reviews found personal music administration to be entirely unsuccessful.

Moreover, there are also some studies that have evaluated the efficacy of music interventions after organ transplant. For example, Tong, Morton, Howard, & Craig (2009), Madson (2010), Ghetti (2011), and Crawford, Hogan, & Silverman (2013) all found qualitative improvements in the participants' QOL, which occurred in association with music, though there were also some limitations and challenges to the studies' methodologies. For example, these studies were limited by a small study population, a lack of control group, and an over-reliance on qualitative data, which could limit the potential for data to conclusively demonstrate results that could confidently be extrapolated to larger populations.

Furthermore, it is also important to note that there have been several publications discussing the positive effect of personalized music within each area of this study's survey, namely mobility, pain and discomfort, and anxiety and depression.

To begin, music can facilitate mobility via aerobic exercise, as demonstrated by Dworkin's "Conductorcise" program (Sorrell & Sorrell, 2008). This program encourages older adults to use a baton to conduct recordings of high-energy classical music, such as the first movement of Beethoven's Fifth Symphony (Parker-Pope 2007). The purpose of the exercise is not precision; rather the goal is for the participants to feel the pulse of the music and translate that musical energy into kinaesthetic activity. Also, because this program concentrates on upper body exercise, even people confined to a wheelchair or who use a walker can participate.

The administration of personal music can also evoke spontaneous movement, as demonstrated in the documentary film, "Alive Inside" (Rossato-Bennett, 2014), mentioned above. In fact, music's ability to facilitate movement has even been successful in cases of Parkinson's disease (de Dreu, Van Der Wilk, Poppe, Kwakkel, & van Wegen, 2012). Of course, the kinds of movements elicited through music in the film are quite different from movements in the context of exercise. The spontaneous movements observed in, "Alive Inside," would not be considered aerobic, like Dworkin's conductorcise program.

The use of personal, preferred music has also been investigated in the context of mobility. For example, a 2015 study by Alter et al. used personal audio devices and sonically-enhanced music to study the adherence to physical activity among cardiovascular disease patients in cardiac rehabilitation. These researchers found that the patients who were randomized to the personal playlist group with tempo-pace synchrony achieved higher weekly volumes of physical activity than the control group and moreover, the sub-group of participants that received the enhanced audio playlist performed an even greater amount of exercise than both the non-enhanced and controls groups (Alter, et al., 2015).

In the context of transplantation, this study anticipated that mobility would be demonstrated through the patient's ability to ambulate either with assistance or independently and that personal music may perhaps encourage patients to be more receptive to in-hospital physical therapy exercises by facilitating a positive QOL.

Interestingly, a 2004 study by Van de Winckel, Feys, De Weerdt, & Dom demonstrated a connection between musically coordinated physical activity and cognitive preservation. This study utilized the Mini-Mental State Examination (MMSE), which is a short series of questions about time and place, word and language comprehension, arithmetic, and basic motor skills to measure cognitive impairment, and it was found that in the context of daily music-based dance sessions patients who participated in the program had significantly higher MMSE scores than those who did not. This is an interesting correlation, because it demonstrates that the effect of music on one area of an individual's QOL affects the others holistically. For example, the Conductorcise program also has incidental benefits like enhancing communication, as by design the program encourages multiple people to participate together, and it also preserves cognition, through the practice and memorization of choir ensemble passages (Sorrell & Sorrell, 2008).

Next, self-care may be demonstrated through behaviours such as eating meals, washing oneself, and getting dressed. In this context music has been demonstrated to facilitate these daily routines, like eating meals. The studies by Hicks-Moore (2005), Chang, Huang, Lin, & Lin, (2010), and the review by Johnson & Taylor (2011) each demonstrate a similar reduction in resistant or disruptive behaviour during meals. It is important to note that the music programs at meal times were applied to groups of people, as opposed to the individual morning routines, and although some resistant behaviour did persist (Hammar, Emami, Engström, & Götell, 2011a), the overall effect was beneficial to the entire group, including the staff, who reported that music made meal time easier (Chang, Huang, Lin, & Lin, 2010).

Similarly, a 1997 quasi-experiment by Thomas, Heitman, & Alexander demonstrated the potential for music to reduce agitated and aggressive behaviours among elderly individuals with dementia during bathing. The authors also noted that reducing physical aggressiveness via music had the dual effect of improving the patient's QOL and improving the staff's job satisfaction.

Also, two studies by Hammer et al. (2011a and 2011b) both found positive results of a musical intervention in the daily routine procedure of getting dressed. Researchers found that by using music, either in the background or foreground, such as the caregiver humming or singing a song, there was a decline in resistant or disruptive behaviour (Hammer et al. 2011b) and there seemed to be an increase in positive emotional response from the patient and engagement in the task (Gerdner & Schoenfelder, 2010). Positive emotional response and engagement was demonstrated by eye-contact, smiling, and sometimes reciprocated musical expression (Gerdner & Schoenfelder, 2010). Akin to the results of Thomas, Heitman, & Alexander's 1997 quasi-experiment, the caregivers found music to positively impact their job experience (Götell, 2000).

Music has been demonstrated as having the ability to alleviate symptoms of pain and discomfort (Cadigan et al., 2001; Good et al., 2001; Nilsson, 2008; Bernatzky, Presch, Anderson, & Panksepp, 2011). This phenomenon is demonstrable whether the musical intervention was applied either intra-, or post-operatively (Nilsson, Rawal, & Unosson, 2003). As an intra-operative procedural intervention, music has been demonstrated to reduce the need for painkilling medications. For example, in instances where music was administered with an analgesic the amount of the drug required to achieve the same effect was found to be less than if music had been absent (Good et al., 1999). Similarly, in instances where music was present during invasive surgical procedures it was found that patients reported experiencing less pain and discomfort postoperatively. For instance, during the postoperative treatment phase of the procedure, Voss et al. (2004) demonstrated that music positively reduces pain and discomfort among inpatients, relative to those who did not receive music.

Finally, music is also an effective agent in the reduction of anxiety. For example, a 2010 review by Sung, Chang, & Lee suggested that listening to preferred music was so effective in reducing anxiety that it is a viable alternative to chemical or physical restraints, and the conclusions of the review have been since affirmed by other investigations. For example, a 2010 study by Gerdner & Schoenfelder observed decreases in combativeness, use of psychotropic drugs, and elopement among patients exposed to music. Moreover, music listening as a means to reduce anxiety is beneficial because it need not necessarily be done in a clinical setting. A 2009 study by Park & Specht found that mean agitation levels were significantly lower while and immediately after listening to music, compared to before. Similarly, the physiological effects of music in non-dementia patient populations have also been well-documented. In addition to reducing pain, musical interventions of surgical procedures were also demonstrated to have reduced anxiety, affirmed through results of pulse, rate of respiration, muscle tension, and self-report (Leardi et al., 2007; Bringman, Giesecke, Thörne, & Bringman, 2009; Nilsson, 2008; Eitner, Sokol, Wichmann, Bauer, & Engels, 2011).

Preferred music is also a crucial and foundational component of this experiment. Although the use of preferred music in clinical research studies, as opposed to the application of purportedly objective labels, such as, “relaxing,” or, “sedative,” is overall a relatively recent innovation, the use of music is this fashion has seen some compelling results. For instance, a 2006 study by Mitchell and MacDonald compared the effect of listening to preferred music against both white noise and specially designed relaxation music in the context of pain and found that both male and female participants had longer thresholds for pain tolerance with preferred music, and the researchers concluded that is an influential factor when considering music’s analgesic effects. Next, a similar study by Clark et al. (2006) studied the use of preferred music to reduce emotional distress and treatment-related disorders from radiation therapy. On the whole the results of this study suggest that higher doses of preferred music produce greater declines in stress, though the authors note that further research is needed to clarify the differentiation between the control group and the study group. These methodological concerns were echoed in a 2005 review by Sung and Chang on the use of preferred music in the context of reducing agitation in an aged population with dementia. Their review examined eight studies and although the results of the studies the authors reviewed were positive, they noted that the small sample sizes and variances in application suggest that further research is needed to make more definite conclusions.

Significance & Implications

The significance of this work cannot be overestimated. In the short term, the successful introduction of music-based wellness techniques in healthcare could reduce the high cost of pharmaceuticals in the Canadian healthcare system. To that end, not only does music have the potential to work in conjunction with pharmaceutical programs, but it can also provide novel treatment regimens not currently being broached by current healthcare institutions. For example, in the context of dementia, music can simultaneously stimulate motor and verbal responses while also elevating mood, which is a combination not available through any other treatment regimen.

In the long term, this research has the potential to change how healthcare functions in Canada. Music could be a catalyst for the introduction of a wider range of arts-based therapy and wellness techniques. To accommodate the introduction of these innovations both the nature and infrastructure of the healthcare system would have to be reformed in order to continue to be self-sustaining. Not only would this mean financial support for music-based endeavours, but also logistical and technical support for the personnel and equipment.

The transition between the long-term and short-term is challenging. In his book, *The Structure of Scientific Revolutions* (2012) Thomas Kuhn theorized that the nature of revolution is cyclical and transitions between periods of complacency and upheaval ad infinitum. However, the nature of the Canadian healthcare system precludes the rapid introduction of music-based wellness programs. That is to say, these types of programs cannot simply be introduced overnight, because proper deployment requires careful research and planning. The success of pilot projects can create momentum, which could then be further developed into more widely implemented, music-based wellness programs in the national health system.

Overview of Chapters

1) Introduction - An overview of the work as a whole and an organic synthesis of the subsequent

chapters.

2) Historical and Contemporary Developments in Music and Health - A historical account of music related healthcare practices from prehistory though antiquity to the present day.

3) Music and the Psycho-Physical Body - The relationship between music and the psycho-physical body. Both performing music and listening to music affect the body, including the mind, in unique ways. How are the body and mind affected within these different contexts? What is the benefit for healthcare to be aware of these differences?

4) Music and the Brain - Sound, and therefore music, is a phenomenon that occurs in the brain, and thus it is crucial to understand how music affects the brain. Interestingly, music appears to affect all areas of the brain and depending on how people engage with music, their neural responses can be very different.

5) Project Overview - A discussion of the project, including the methodology, a multiple methods analysis, and anonymized results.

6) Study Conclusions, Limitations, and Next Steps - What can be concluded from this project, what were the projects limitations, and what could be improved in similar, future studies.

Chapter Two: Historical and Contemporary Developments in Music and Health

When one considers the relationship between music and healthcare one's thoughts are perhaps immediately drawn to the already established discipline of music therapy. However, the connection between music and healing long predates the modern era. In fact, the earliest associations between music and healing can be traced back to prehistorical times in a number of cultures. Interestingly, despite being separated by vast distances across time and space one may observe a number of similarities among the following examples regarding the music and healthcare relationship in pre-modern cultures. A timeline may be observed in Appendix A.

To begin, given music's ephemeral nature it is extremely difficult, if not entirely impossible, to pinpoint exactly when music became associated with health, but there is some anthropological evidence that early hominids used music in conjunction with healing practices. For example, cave paintings dated circa 26,000 years old are the first known to suggest healing uses for music practices (Hanser, 2009) and there is even evidence that shamans were using music for healing as early as 30,000 years ago (Moreno, 1991). These examples roughly coincide with the advent of the earliest known sound tools, bone and ivory pipes, which are dated circa 35,000 years old (Blake and Cross, 2008). The sophisticated construction of these instruments suggests that these artifacts are likely not the first instruments ever (Blake and Cross, 2008), and in fact, the precise construction would rather suggest that creating instruments was a skill that was developed, honed, and passed on to subsequent generations.

In addition to music's ephemeral nature, there is also no agreed, cross-cultural definition of early hominid music. That is to say, if a contemporary audience were to hear early hominid music it may not be recognizably music to modern sensibilities. There are multiple theories about early sources of sonic manipulation, which may have constituted music circa 30,000 years ago. For instance, knapping is a process that requires expert precision to create and shape stone tools that involves striking one stone with another. Multiple hominids engaged in knapping in close proximity to one another could have resulted in a number of interesting sonic rhythms and could even be a precursor to group cohesion.

It is also theorized that knapping could have exposed early hominids to lithophones, or rock-gongs that emit a discrete pitch when struck (Blake and Cross, 2008). There are many contemporary examples of lithophone instruments from around the world, often with the rocks arranged similarly to a xylophone or piano, like a row of keys, wherein each rock represents a discrete pitch, but there are also other arrangements such as chimes or gongs, and it is not anachronistic to theorize that early hominids may have been intrigued by a lithophone's unique sonic properties, because possible examples of rock gongs appear in tandem with other art, cave and open-air rock images (Blake and Cross, 2008). It is also notable that natural lithophonic formations, such as stalagmites and stalactites, were present in caves where bone and ivory pipe instruments were found. Furthermore, Blake and Cross also theorize that the caves themselves may have been a source of heightened acoustic awareness (Blake and Cross, 2008). For instance, unique reverberations inside caves can produce seemingly otherworldly sonic artifacts, which may have fascinated early hominids, and in conjunction with the presence of natural lithophones, these caves may have been significant sites for early cultures.

On a related note, there are some intriguing examples from Mayan culture, which highlight similarly extraordinary sonic phenomena. Mayan architecture is known to produce unique sonic phenomena. For example, the Kukulkan Temple at Chichen Itza attracts thousands of tourists every year who stand in front of the temple, clap their hands, and listen to the unique reverberations of the echo. The facade of the temple is constructed in such a way that the initial signal from the clap rebounds on the listener multiple times in succession, creating the illusion that either the sound rebounds multiple times to the one source or that the echo is unnaturally extended beyond the expected duration.

Analogously, just as the phenomenon of early cultures being fascinated with sonic artifacts was not limited to the Western world, so too was the construction of bone flutes not limited only to Europe. For example, 23 bone flutes were found at an anthropological dig site in China dating to approximately 7000-5800 BC (Mair, 2006). The manufacturing techniques for these flutes bears a remarkable similarity to bird bone flutes found in France that are dated circa 25,000 years old. The oldest bone flute ever found came from a 35,000-year-old mammoth tusk, which was found amongst other flutes made from swan bones in the Geissenklösterle cave in Germany (Mair, 2006). A modern replica made from elder wood suggests that the instruments would have produced pitches that roughly correspond to the contemporary pentatonic scale and thus, the instruments would have likely been capable of producing expressive melodies (Mair, 2006). Additionally, the site also yielded a number of small ivory figures (Mair, 2006), which affirms the contemporaneous production of art. Furthermore, the difference in years between the Chinese and European artifacts and the development in sophistication of European manufacturing suggests a dissemination and migration of sonic technology among early hominid cultures.

However, that is not to say that Asia was lacking in musical practices before the introduction of European technologies. Indeed, the importance of sonic phenomena was already well-known to the ancient Asian world and many of their ideas are paralleled in contemporary Western practices. For example, the holistic model of health as presented in ancient Chinese and Ayurvedic treatises directly parallels holistic models of contemporary music therapy practices.

To begin, traditional Chinese medicine relies on the idea of Chi and balancing the five elements, namely wood, fire, earth, air, and water. In this paradigm balance is associated with harmony (Hanser, 2009), and similarly, Ayurvedic medicine also focuses on the notion of harmony and balance and concedes that sound could be a useful medium to maintain harmony. Indeed, ancient Indians believed in primordial vibrations of universal ether and that total immersion in worldly music, 'struck sound,' could allow one to transcend and hear 'unstruck sound' (McClellan, 1991)

On that note, a foundation of Ayurvedic medicine is the idea of chakras, which are meta-physical energy centres within the body that vibrate in response to both internal and external sounds. For example, toning and chanting are two techniques to maintain harmony in one's chakras (Montello, 2002) and the use of singing bowls has also been shown to affect the acupuncture meridians that correspond to some of the body's chakras (Hanser, 2009; Allen and Shealy, 2005). In total, there are three main elements of the classical Indian musical experience, which are the following:

1) the ritual importance and power of music to preserve order and avert disaster

2) the aesthetic model of drama extended to other forms of art, including the loss of individuality and the sense of the universal

3) that music is a bodily representation of spiritual necessity (Katz, 2014).

Next, ancient Greek culture also placed great importance on using music to preserve cosmological harmony (West, 2014). Unlike today, the ancient Greeks believed that the agency of music healing practices did not act directly on the patient, but rather appealed to the supernatural (West, 2014). Nevertheless, the Greeks rationalized music in a logical way that is still in use today in contemporary music practices, even beyond health. Indeed, Pythagoras, the father of acoustics, discovered the ratios for the octave, fourth, and fifth intervals, Damon associated modes, rhythms, and tempos with ethical qualities, and Plato explained why these modes have certain particular ethical qualities (West, 2014).

More practically, Pythagoras advocated music for calming the mind, and for waking and falling asleep (West, 2014), Aristoxenus prescribed music for "purifying the soul," and Xenocrates used non-vocal music to cure hysteria (West, 2014). However, despite the saturation of music within ancient Greek society, the use of music was largely ignored in the Hippocratic corpus, being dismissed as "fringe medicine" (West, 2014).

Subsequent dissemination of knowledge after the fall of ancient Greece did little to change the healing practices of music among healthcare professionals. Notably, musical performances were sanctioned at the Mansuri hospital in the Ottoman Empire (Shiloah, 2014), though the paradigms of agency in regard to the efficacy of applying music to healthcare were largely similar to the aforementioned Greek, Indian, and Chinese cultures. For example, Jewish and Muslim traditions also viewed music as a means of maintaining balance and it was believed that there was a natural and indivisible harmony between the body and soul (Shiloah, 2014), which could be influenced by the cosmos, and that health was an equilibrium of the fundamental elements (Shiloah, 2014). Indeed, so much so that natural harmony could not be described without subordinating to the natural ideal laws of music (Shiloah, 2014).

It was not until the eighteenth century that a major turning point occurred in the relationship between music and medicine (Rorke, 2001). The Age of Enlightenment saw the development of the scientific method, which enabled physicians to rely on the tenets of experiment, observation, and analysis to form a basis for conclusions. The physician Richard Brocklesby (1722-1797) was one of the first to write a treatise on music and the effect that listening to music can have on one's health. In his treatise he discusses how ailments of the passions and emotions, such as delirium, frenzy, melancholia, and mania, are affected by music and the positive qualitative effect that can be observed by exposing individuals with these afflictions to music. His analysis favours consonant music and even alludes to the efficacy of preferred music (Rorke, 2001), which is quite forward thinking for the time of publication.

Although it would be anachronistic to apply the scientific method in retrospect to these practices of the ancient world, nevertheless the effect of these peoples' musics must have still had some effect on both the individuals and the collective, and indeed, given how commonplace music is in human societies, it seems logical this relationship is more than superficial (Will and Turow, 2011). Recent studies support the idea that music affects both the mind and body in unique ways, which will be further discussed in upcoming chapters.

Subsequent European traditions in the nineteenth century built on these foundational ideas and expanded the prescription of music to other areas of healthcare. One of the most notable developments in the European tradition at this time is the inception of live music performances in healthcare institutions and indeed, the most famous example of this was undoubtedly the Illenau asylum in what is now modern-day Germany. Similar to previous music and health traditions, health at Illenau was based on *Gemüth*, a unifying, inherently rhythmic element between the body and soul. *Gemüth* was believed to be mediated by sensations connecting states of the body with states of the mind and was thought to exist as a continuum between the individual and the collective, like the asylum's entire patient, staff, and visitor population, for instance (Kramer, 2000a). Illnesses were thought to be representative of arrhythmia, either individual or collective, and musical prescriptions included both individual and group listening, composition, and even performance (Kramer, 2000a; Kramer, 2000b). Moreover, there was a wide variety of music prescribed for the individuals admitted to the asylum to cater to the unique tastes of each patient. Interestingly, the music of Felix Mendelssohn (1809-1847) was reportedly a popular choice (Kramer, 2000a).

Illenau became a model for other hospitals across Europe as nineteenth-century psychologists began to recognize and appreciate the value of salutary musical experiences (Kramer, 2000b). Indeed, it was thought that music could adjust or calibrate certain psychological states and that the reception of music was dependent on the patient's frame of mind (Kramer, 2000b). To that end, an 1835 treatise by Peter Joseph Schneider titled *System einer medizinischen Musik (*A System of Medical Music) is often cited as one of the first examples of imagining a specialist medical discipline devoted entirely to music and health, a forerunner that is not entirely dissimilar to modern music therapy (Kramer, 2000b). The increased popularity in applying music to healthcare contexts even attracted celebrity attention, as the Hungarian composer and pianist Franz Liszt (1811-1886) himself attended hospitals to play music for the patients (Kramer, 2000b).

Another famous example is the Guild of St. Cecilia, which was founded in 1891 by Frederick K. Harford (1865-1935), a musician, composer, and cleric who advocated the use of sedative music to relieve anxiety among patients in hospital (Harford, 667). His practice was set apart from other similar contemporaneous examples, because he published his findings and appealed to others to replicate his results (Tyler, 2000). Harford later updated his protocol to include stimulative music as well with mixed results and reactions (Tyler, 2000). Harford identified five foundational qualities in his paradigm, which are as follows:

1) music can affect patients in physical and emotional distress
2) music is an effective treatment alongside medical intervention
3) cooperation between musical and medical professionals
4) training is essential
5) efficacy of work is determined through systematic evaluation and publication (Tyler, 2000)

Interestingly, sometimes the patients did not see the musicians perform (Tyler, 2000) and the invention of the phonograph in 1877 allowed for new possibilities in the administration of prescribed music. Indeed, listening to music was now no longer dependent on the presence of live musicians; instead, lifelike music could be mechanically reproduced ad infinitum (Tyler, 2000). On that note, the physician Evan O'Neil Kane (1861-1932) noticed the ability of music to enhance anaesthetics. He believed that music had the ability to neutralize other sensory stimuli and influence mood (Tyler, 2000). Nevertheless, at this time music and health programs were subordinate to psychology and would remain so until after the Second World War (Tyler, 2000).

Developments in music and health in the early twentieth century worked towards an established discipline or body of music therapy, which was initially splintered. There were two distinct models of music therapy operating at this time, namely British and American, which were called recreational and medical, respectively (Tyler, 2000). The first national organization to appear was the National Association of Music Therapy, which was founded in New York in 1950, followed shortly after by the genesis of the British Society of Music Therapy, which was founded in 1958 (Tyler, 2000). At this time the terms 'music' and 'music therapy' were being used interchangeably (Tyler, 2000).

From these national organizations came the birth of the first music therapy disciplines. Mary Priestley (1925-2017), along with Paul Nordoff (1909-1977) and Clive Robbins (1927-2011), are often hailed as the first generation of foundational musical therapy pioneers (Pavlicevic, 2000), Priestley for the development of improvisational music therapy, and Nordoff and Robbins for the development of Nordoff-Robbins music therapy.

Priestley was influenced by free association techniques and what set improvisational music therapy apart from contemporary practices was the relationship between the therapist and the patient (Tyler, 2000). That the therapist performs with the patient represents a synthesis of recreational, educational, psychological, and musical influences, an idea which flourished to maturity in the late 1960s to early 1970s (Tyler, 2000).

Simultaneously, Nordoff-Robbins music therapy developed as a collaboration between the composer, Nordoff, and the special needs educator, Robbins, and was founded on the philosophical principles of Rudolf Steiner (1861-1925), who espoused the importance of music and arts in all lives (Tyler, 2000). The discipline was originally conceived to exclusively target children with special needs, such as those with psychological, physical, or developmental disorders, but was eventually expanded in the 1970s to include adults as well (Tyler, 2000).

Nordoff and Robbins' techniques distinguished themselves from their contemporaries by using audio and video recording technology and by developing the idea of 'The Music Child,' which is the notion that there is an innate musical ability inside everyone (Tyler, 2000). Nordoff-Robbin's consideration of music therapy as a discipline led to the discipline's gaining legitimacy in the eyes of the public and government. Indeed, by 1976 Britain offered a post-graduate diploma for two professional training courses and in 1982 the Department of Health and Social Security stopped subsuming music therapists under the National Health Service, the Department of Education, and Social Services, and instead recognized music therapy to have a unique pay grade and career structure (Tyler, 2000).

Today music therapy as a discipline has exploded worldwide to encompass a number of distinctive models, including, but not limited to the following: Field of Play (Kenny), Biomedical (Taylor), Neurological (Thaut), Culture-centred (Stige), Aesthetic (Lee), Community (Ansdell), Complexity-based (Crowe), Music-centred (Aigen), Analogy (Smeijsters), Dialogical (Garred), Feminist (Hadley), Resource-oriented (Rölvsjord), and Humanity-oriented (Ruud). As a result of national organizational bodies, the title of music therapist is protected. That is to say, not just anyone can call themselves a music therapist or even say specifically that they do music therapy work. However, there are a number of music-related scientific investigations that shed light on how music affects the brain and body, which are further discussed in upcoming chapters.

Chapter Three: Music and the Psycho-Physical Body

Music can have a profound effect on both the physical body, the collection of cells that constitute an individual, and the psychological mind, the collective thoughts and feelings of that individual. To begin, one of the first observations about the relationship between music and the body theorized that the construction of various instruments was a direct result of the body's physiology and also that the shape of the music itself, such as the melodic contours and rhythmic density, was a result of the instrument's melodic capabilities (Baily, 1995). Today, humans continue to create and experience music through live performance, and as a result of advances in technology, human beings can also listen to recorded music. Indeed, the ability to hear music in detailed resolution at a whim is a feat that would have been unavailable to the average individual as recently as one hundred and fifty years ago. This ease of musical engagement has resulted in a number of experiments that have elicited direct and precise evidence concerning how music affects the physical body, as well as discovering unconscious psychological effects that can occur in conjunction with physical activity, thereby providing a foundation for integrating music in the context of healthcare for the betterment of patient populations.

On that note, exercise training is one of the most popular contemporary forums for investigating the relationship between music and healthcare and there are four distinct research orientations for investigating the relationship between music and physical activity, which are as follows:

1) The psycho-physical impact of asynchronous, background, music

2) synchronization of physical movement and musical tempo

3) benefits of music in the learning of motor skills

4) the use of music to reinforce desired behaviour

There are also a number of dimensions that affect how music is perceived by individuals, such as tempo, lyrics, melody, harmony, socio-cultural background, personal associations, and personal preferences (Karageorghis, Terry, & Lane, 1999). Through the act of listening to music an individual may be affected by either none, one, some, or all of these dimensions, which would theoretically result in a unique or individualized experience per person.

The effects of music and exercise have been studied both qualitatively and quantitatively, and these studies offer an interesting insight into how music can affect the physical body. To begin, a qualitative investigation into the characteristics and effects of music accompanying exercise was published by Priest & Karageorghis in 2008. Generally, the investigators found that the use of music with exercise can result in elevated enjoyment and adherence, which would be key features in promoting and sustaining a healthy lifestyle (Priest & Karageorghis, 2008). They found that listening to motivational music during exercise contributed to a 'flow' state, which seemed to divert participant's attention away from unpleasant or fatiguing effects of exercise at low-intensity levels (Priest & Karageorghis, 2008; Nakamura & Csikszentmihalyi, 2014).

Interestingly, a similar study by Brownley, McMurray, & Hackney (1995) found the opposite, namely, that music did not have a positive affective response on exercise. However, the participant population in Brownley, McMurray, & Hackney's study distinguishes itself from Priest & Karageorghis' 2008 study, because they had different baseline exercise-related experiences. For example, the 'trained' group in Brownley, McMurray, & Hackney's trial, who were already adapted to the study's exercise tasks, actually reported a more positive effect during the ‘no music’ trial across all intensities of exercise, as opposed to the ‘untrained’ group, which reported strong trends towards the positive role of music during both low and high intensity levels. In the context of physical rehabilitation these are quite valuable results, because the patient’s exercise history and routines would likely be well-known to the clinician and it would be hypothetically possible to tailor a music-based exercise routine that would be best suited for the necessary context, even if that means an absence of music for certain exercise routines.

Analogously, due to the number of confounding factors, there is also no single, absolute quantitative, physiological response to music (Urakawa & Yokoyama, 2005). However, there are some consistent trends that are observable within certain contexts. For example, heart rate variability is a metric that can be readily and easily measured, and it is known that exercise demonstrably affects this measurement, and in fact, the use of both synchronous and asynchronous music was found to provide performance-enhancing benefits. Study results demonstrated that the effects of asynchronous music were more pronounced during low to moderate intensity exercises (Karageorghis, Terry, Lane, Bishop, & Priest, 2012). Interestingly, it was only during synchronous music that participants demonstrated rhythmicity of movement, which coincidentally resulted in efficiency gains and lower relative oxygen uptake.

One explanation for this phenomenon is that the brain limits the amount of information that can be processed in parallel from simultaneous stimuli. For instance, when one attempts to maintain awareness of their heart rate while exercising while listening to music one experiences a sense of cognitive dissociation and the brain will primarily focus on one or the other. Notably, for music that one finds particularly appealing, the brain primarily focuses on the music more than exercise fatigue (Rejeski, 1985; Dyrlund & Wininger, 2008). Conversely, listening to music that one finds unappealing could result in an increased concentration on the physical sensations of exercise, like fatigue (Dyrlund & Wininger, 2008). Overall, the known quantitative effects of music-based exercise are also valuable to consider in the creation and maintenance of exercise routines, not only in the context of physical rehabilitation, but also for maintaining a healthy, balanced lifestyle outside hospitals or other healthcare institutions.

Interestingly, it is only recently that investigations into the relationship between music and the body have begun to incorporate the concept of preferred music. For example, a 2010 exercise study by Nakamura, Pereira, Papini, Nakamura, & Kokubun, found that the genre of music that participants listened to was inconsequential on their exercise performance. Rather, the distinction that resulted in an increased endurance ability was whether or not the participants liked the music to which they were listening. Indeed, when participants listened to preferred music they were able to cycle for longer and conversely, listening to non-preferred music resulted in participants more noticeably perceiving their exertion (Nakamura, Pereira, Papini, Nakamura, & Kokubun, 2010). Interestingly, heart rate did not change between the study's conditions, and during high-intensity exercises music did not influence the physiological response (Nakamura, Pereira, Papini, Nakamura, & Kokubun, 2010).

Beyond exercise, music has also been found to positively affect the human body. For example, a 2006 study found music could be a tool to stabilize and reduce the physical manifestations of both emotions and stress (Yamashita, Iwai, Akimoto, Sugawara, & Kono, 2006). In terms of cortisol levels as a representation of stress, Yamasaki et al. (2012) found decreased cortisol levels peri-operatively while playing music. Similarly, for balancing emotions music can be a valuable component of holistic lifestyle changes that are oriented as a coping mechanism for alleviating chronically pervasive symptoms associated with lifelong illnesses, such as HIV (Frego, 2009) or inflammatory bowel disease (Aldridge, 1996). Even though the music itself does not directly combat the disease at the microbial level, in these cases music can be a catalyst for the promotion of other incidental benefits, such as physical rehabilitation and positive emotion (Frego, 2009), both of which contribute to a higher quality of life. Moreover, given the universality of music's potential application, it can be an effective and potentially lower-risk starting point before trying other forms of treatment.

Furthermore, the benefits of music associated with a holistic lifestyle have also been affirmed in the context of aging and its associated cognitive declines, like dementia. For example, Hammar, Emami, Engström, and Götell (2011a; 2011b) found that singing was an effective way for caregivers to establish a rapport with patients who may be otherwise socially withdrawn. The patient's reception to the caregiver's singing was indicated by smiling, eye-contact, and reciprocation (Hammar, Emami, Engström, & Götell, 2011a). Also, the music tended to have a calming effect on the individuals, as it was generally observed that singing made daily routine activities, like getting dressed in the morning, easier, because the patients were more willing to actively participate (Hammar, Emami, Engström, & Götell, 2011b). Furthermore, the calming effect of music was also perhaps most keenly observed during mealtimes, where observers report music facilitating the mealtime process and reduced instances of problem behaviour, such as raucousness (Johnson & Taylor, 2011).

More specifically, rhythmic entrainment is a technique that has been popularized in conjunction with the use of music within a variety of contexts. Rhythmic entrainment involves using ancillary, non-musically functional, movements in conjunction with music. An individual's movements could convey a response to any number of musical qualities, including tone, structure, expression (Nusseck & Wanderley, 2009), and how the body moves contributes to the perceived aesthetic (Nusseck & Wanderley, 2009). One of the earliest examples of rhythmic entrainment is Dalcroze eurhythmics, which has been a school of pedagogy since the early twentieth century to teach students about musical structures, like rhythm, through embodiment. That is to say, students learn to interpret rhythm through their bodies and movement (Jaques-Dalcroze, 1921).

To be more specific to healthcare, rhythmic entrainment has found success in the context of neurodegeneration and physical rehabilitation. For example, Elefant, Baker, Lotan, Lagesen, & Skeie (2012) found music to be beneficial among an elderly patient population with Parkinson's disease. Their research found that group singing interventions led to improvements in singing quality and vocal range, and they also noted an absence of a decline in speaking quality, meaning that the participants' voices remained intelligible, resonant, and consistent in tone and intensity, thereby demonstrating the wide applicability of musical applications to a broad range of demographics for a variety of uses. Group participation seems to be an important quality of effective rhythmic entrainment. Indeed, although the effect is individualized, achieving the effect is dependent on the subject's willingness to participate, which can be influenced by being part of a group (Mathews, Clair, & Kosloski, 2001).

Thus, it is evident that music can have a profound effect on the human body. It can enable individuals to exercise for longer and/or at higher intensities, which in turn produces a range of incidental health benefits. Music's effects are visible qualitatively and can be measured quantitatively. These effects are evident through changes in the individual's outward demeanour and their emotional state, and also through their physiology. Although these effects are individualized at a personal level, there are some broad trends across large groups. For example, the positive emotional response and social engagement to preferred music among neurodegenerative patient populations, or the physiological response among individuals conditioned to different exercise intensities, suggests that these individual trends are contained under an umbrella of generalized effects for larger study populations.

Chapter Four: Music and the Brain

The human brain is a sensory organ located in the cranium. The effect of music on the brain is different from the mind, because music has a measurable effect the brain's neural structure. In fact, even as an infant the human brain is able to experience music. Indeed, infants' developing brains may experience music and language as a single proto-musical/linguistic hybrid before they learn to exactly differentiate each form of audio (Storr, 1992). The relationship between music and speech can be observed even in adulthood. For example, as speech becomes charged with emotion the speaker's tonal range expands, thereby incorporating musical qualities, even inadvertently (Storr, 1992).

By adulthood the brain has broadly differentiated the processing of music and language to one of two hemispheres, but curiously there is no specialized, or central location for music in the brain (Weinberger, 2004). Various musical processes utilize areas of the brain that would normally be involved in other cognitive processes and different activities engage different areas of the brain in different ways. For example, playing an instrument requires the use of motor skills, which would entail a different cerebral process than simply passively listening to music, particularly if the listener in question has no knowledge of how to play the instrument to which they are listening.

Weinberger (2004) offers quite a succinct overview of how it is that humans are able to hear and cognize sound. Indeed, despite the ear having the fewest sensory cells of any sense organ, the process is really quite extraordinary. When audio first enters the ear the air pressure waves are converted into fluid waves in the inner ear. This conversion is accomplished via the stapes, a small bone that connects the tympanic membrane to the cochlea and pushes into it, thereby creating varying pressures in the fluid inside. Then the basilar membrane runs through the inside of the cochlea, within which are a number of very fine individual hair cells, all of which are tuned to different vibration frequencies. Auditory nerve fibres connect the hair cells to neurons, which are also analogously tuned to different vibration frequencies.

Once the auditory signal reaches the brain it gets processed hierarchically. First, the primary auditory cortex processes the early stages of musical perception, such as pitch and contour, by receiving the input via the thalamus. Thus, the input is "retuned" by one's individualized experiences, which in turn affects further cortical processing. Furthermore, the motor cortex and cerebellum are highly engaged during performance, which are directly related to motor coordination, timing, and rhythmic processing (Weinberger, 2004). Incredibly, these calculations are continuously performed within a fraction of a second and often without the individual being consciously aware of the intracranial processes.

There is some plasticity in the perception of vibration frequencies. Indeed, as one learns the importance of perceiving certain frequencies, one analogously increases one's potential for perceiving that frequency. Furthermore, there is not always an absolute division between the duties of one area of the brain in the processing of auditory vibration frequencies. For example, there is a region in the frontal lobe that processes both music and language together, and also there are some neighbouring hair cells that have overlapping tuning curves. There is even some debate over which hemisphere engages rhythm, because it is believed that the left hemisphere, the hemisphere most often associated with language, is better equipped to process briefer stimuli than the right hemisphere. Interestingly, the act of only listening to music generally engages the left hemisphere more than the right (Weinberger, 2004).

Furthermore, the structural differences between the brains of musicians and non-musicians is also indicative of music-related neural plasticity. For example, the volume of the cortex is generally accepted to be larger in trained musicians than non-musicians, and similarly the motor areas associated with performance are also higher. To that end, some musicians are so highly trained on their instrument that their neural response is specific only to their performance on that instrument. The anterior corpus callosum, which is a bundle of fibres that connects the left and right hemispheres, is larger in musicians than non-musicians and the extent of the increase is directly correlated with the onset of musical training. That is to say, the earlier an individual begins training the greater the increase in interconnecting fibres between the two hemispheres (Weinberger, 2004). Indeed, these observations were affirmed by Amunts et al. (1997), who found that prolonged instrumental practice led to an enlargement of the hand area in the motor cortex, and Halwani, Loui, Rüber, & Schlaug (2011), who found both micro- and macro-scopic differences in white matter volumes in musicians versus non-musicians, specifically in the arcuate fasciculus region, which is significant, because the arcuate fasciculus connects the temporal cortex and the parietal cortex to the frontal lobe, all of which are significantly important musical areas of the brain. Similar results were observed in the cortical spinal tract (Bengtsson et al., 2005; Rüber, 2013) and in the cerebellum (Gaser & Schlaug, 2003; Hutchinson, Lee, Gaab, & Schlaug, 2003).

Other important structures in the brain that are essential for musical processing include the temporal lobes, which are essential to process melody, but unessential in the production of emotional reactions, and the right orbitofrontal gyrus and right parahippocampal gyrus, which are respectively activated by consonance and dissonance (Weinberger, 2004). Also, the cerebral cortex, which is responsible for the conscious perception of sensory information, the frontal lobe, which guides attention, planning and motor preparation, integrating audio and motor information, imitation, and empathy, the parietal lobe, which is responsible for the acquisition of musical skills and expressiveness, and multi-sensory integration, the emotional network, which includes the cingulate gyrus, amygdala, and hippocampus, all of which are responsible for coordinating emotional perception and motivation (Altenmüller and Schlaug, 2015).

Indeed, the aesthetic response to music is perhaps the most difficult neural response to study because of the highly individualized and subjective nature of personal music experiences (Sachs, Ellis, Schlaug, & Loui, 2016). Interestingly, the aesthetic response to music engages the same dopaminergic pathways (Keitz, Martin-Soelch, & Leenders, 2003), neural network, as for other primary and secondary rewards, such as food, water, sex, or others (Zatorre, 2017), and depends on one's behavioural and personality factors. For example, individuals who reportedly have more emotionally intense experiences have higher tract volumes between the auditory and emotional processing areas in the brain (Sachs, Ellis, Schlaug, & Loui, 2016).

Actually, there is a physical response to this psychological phenomenon, namely when one experiences 'chills' as a result of listening to music. A fMRI study by Salimpoor, Benovoy, Larcher, Dagher, & Zatorre (2011) demonstrated how music engages the brain's dopamine receptors. Interestingly, dorsal neurological activity was evident several seconds before listeners reported experiencing chills, but ventrally, the maximum activity coincided with experiencing chills. Furthermore, similar responses were even elicited by unfamiliar music, though the responses were influenced by how much the listeners believed they would enjoy the music. Even across both conditions of familiar and unfamiliar music, fMRI showed that activity in the striatum and functional connectivity between the striatum and the auditory cortices (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011). The key factor to elicit this response was the belief or perception of the music having a high reward value, or in other words, the listeners being told they would like it. Given that the frontal areas of the brain, as well as the amygdala, are connected to the reward system, these results could demonstrate an insight into explaining how one develops and maintains individualized musical tastes (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011). Conversely, the fact that musical anhedonia, the inability to enjoy listening to music, can exist in individuals with an otherwise normal emotional affect and response range suggests that there are unique musical reward neural pathways, which could depend on less fundamental cortical mechanisms, or that the interaction between auditory perception and cognition is perhaps downregulated. Indeed, there are many examples of psychological disorders that are exacerbated by dysregulation of the reward system, including depression, post-traumatic stress, addiction, and even in certain neurological conditions like Parkinson's disease (Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011), so it is not unprecedented to apply this concept to musical engagement.

With this knowledge of how music engages the brain and vice versa, how the brain perceives music, it is thus possible to begin to conceive how this knowledge could be put to best use for certain populations. For example, a 2000 study by Evers & Suhr observed an increase in serotonin levels as a result of listening to 'self-reported pleasing music.' This study relied on the distinction between pleasant and unpleasant music, as indicated by the participants, which is a concept this is almost entirely synonymous with listening to preferred and non-preferred music. In conjunction with the known effects of music on the physical body it would therefore be possible to tailor a musical program or even programs to better patient populations in a variety of contexts, either separately or simultaneously.

For example, it would be theoretically possible to entrain the brain to facilitate functional and/or structural changes (Schlaug, 2008; Schlaug, Marchina, & Norton, 2009; Wan, Zheng, Marchina, Norton, & Schlaug, 2014), akin to how rhythmic entrainment can facilitate functional changes in the physical body. Indeed, previous systematic reviews were supportive of the idea of music as an adjunct to clinical care, particularly in the context of neurodegeneration. For example, the review by Livingston et al. (2014) concluded that non-pharmacological management decreased overall agitation in the study population and the review by Vink, Bruinsma, & Scholten, (2003) found that several health institutions recommended non-pharmacological, complementary interventions. On that point, a meta-analysis by Zhang et al. (2017) found in the context of a patient population afflicted with dementia that music could have a positive effect on mitigating disruptive behaviour and anxiety, found positive trends for improving cognitive function and quality of life, and observed a decrease in depressive symptoms.

This research has since become the basis for a neurologically based music therapy discipline, namely neurologic music therapy, which advocates that music cognition is related to temporal order learning, spatiotemporal reasoning, and auditory-verbal memory (Thaut, 2010). Indeed, the resilience of music even in the context of neurodegenerative diseases is a valuable asset in cognitive rehabilitation. Neurologic music therapy mechanisms are based on understanding music as a language of cognition and perception that stimulates physiologically complex cognitive, affective, and sensorimotor processes. That is to say, processes that are generalizable and transferable to non-musical brain behaviour and function (Thaut et al., 2009). For instance, music can stimulate the growth of dendrites, increase blood flow and oxygenation, and regulates cognitive timing (Thaut et al., 2009).

Chapter Five: Project Overview

Introduction

This project was an open-label, clinical experiment that was conducted at a teaching hospital in an urban setting from June to August 2017. The study's objective is to improve the quality of life (QOL) of transplant recipients through the provision of iPods and over-ear, noise-cancelling headphones. Individuals enrolled in the study were assigned to one of two study arms, an iPod group and a control group, using a virtual coin toss (Coin Flip, Falcon Solutions, Aditya Neelkanth).

Participants who were randomized to the iPod group indicated through survey what specific music they preferred to listen to and utilized the iPod at their discretion during their time in the hospital. Conversely, participants who were randomized to the non-iPod, or control, group were not provided an iPod. Both groups received the same standard of care and both study groups reported their QOL state through self-report during interviews, which took place every other day, up to a maximum of ten surveys.

This study uses a modified version of the EQ-5D survey, which asks subjects about their QOL state by inquiring about five indicators of QOL, as well as an overall QOL score. The version of the survey that has been adapted for this study omits questions about usual activities, because receiving a transplant is a severe imposition to one's usual activities. The other four QOL variables that were measured by the survey are the following: mobility, self-care, pain & discomfort, and anxiety & depression. These variables were measured on a scale of 1 to 5, indicating severe problems to no problems. The overall QOL life score was measured on a scale of 0-100. The greater value of the QOL variables and the overall QOL score parallel for clear graphic representation.

Methodology

This is a multiple methods interventional study. This study is multiple methods, because the study obtained two separate types of datasets about the participant's experience using the iPods, over-ear, noise-cancelling headphones, and preferred music, and analyzed them together. A methodological schema may be observed in Appendix B.

Ethics Approval: Approval for this open-label, clinical experiment was provided by both the university and the teaching hospital.

Recruitment: First, potential participants were identified from the operating room (OR) schedule, which was provided by the OR department. Patients scheduled for either kidney, liver, lung, or heart transplant, or a combination of these transplant procedures, were approached for inclusion in this study. Once a participant was identified the study coordinator approached the floor nurse to ask the potential participant if they had an interest in participating in an open-label, clinical experiment, and if yes the study coordinator entered the patients room to iterate a brief synopsis about the study and review the consent form with the participant. In the event that a potential participant indicated to their nurse that they were not interested in participating in the open-label, clinical experiment the experiment coordinator did not approach the patient again for the duration of their stay. In some cases the participant asked to be approached again the following day, to which the study coordinator acquiesced.

After reviewing the consent form with the participant, and if the participant was still in agreement about participating, the form was signed by both the study coordinator and the study participant. The study coordinator then made a photocopy of the signed consent form for the participant's personal records and performed a virtual coin toss, which enrolled the participants into one of two study groups, either the iPod group or the non-iPod (control) group. Upon delivering the participant's copy of the signed consent form the study coordinator informed the participant into which study group they had been randomized, and in the event that the participant was randomized to the iPod group the participant was provided with an open-ended form for the participant to indicate their preferred musical selections with as much specificity or generality with which they felt comfortable (Appendix C). That is to say, there was no predetermined list of limited selection from which to chose. All participants were completely free to make whatever musical choices they preferred to listen to. Unless otherwise indicated by the study participants, the study participants were given approximately twenty-four hours to write down their musical selections. In some cases the participants knew exactly what they wanted and indicated that they would prefer an iPod sooner rather than later.

Provision of Study Materials: After collecting the participant's musical selections the study coordinator downloaded the participant's musical selections from the iTunes music library and uploaded them to the participant's designated iPod. In some cases where the participant's selection could not be located the music was downloaded from Youtube, or for convenience some participants opted to listen to their own personal music libraries, but still chose to use the study headphones. In some cases the participants chose more material than was able to be stored on the iPod device. In these instances participants were informed which selections were not included and were reminded that they had the option to subsequently update the music on their device at their discretion.

After all the musical selections were successfully uploaded to the iPod and the device fully charged the study coordinator sanitized the iPod, headphones, and carrier case using sanitary wet wipes. The carrier cases used to distribute the iPods to study participants were small, plain, black lunch boxes made of a soft, plastic material. The material made the cases easy to sanitize, both inside and outside, they were just the right size to contain both the iPod and headphones neatly, and they could be transported easily by the patient if they chose to leave their room and wanted to take the study device with them. Moreover, the cases were discreet enough that if the participant chose to leave the iPod in their room while they were absent there was little chance of theft or the device being misplaced. Photos of the study materials may be observed in Appendix D.

Sample: All participants met the inclusion criteria for transplant surgery and were enrolled between June and August 2017. Since not all study participants were admitted to the hospital simultaneously, it was not necessary for the study to purchase a new personal music system for each patient. Rather, the iPods, headphones, and container were disinfected twice with sanitary wipes before being used by another participant. They were cleaned once upon discharge and once again before being given to the next participant. Participants who were readmitted to the hospital during the course of the study were not invited to resume using an iPod. Overall, a total of 46 participants were enrolled into the study. 25 participants were randomized to the iPod group, 21 were randomized to the control group, and 188 surveys were completed in total for all participants.

Setting: Data collection took place at a teaching hospital in an urban metropolis across two hospital units, a step-down unit and an acute care unit. Patients admitted to the intensive care unit immediately after their transplant procedures were not yet considered eligible for enrolment due to concerns about being not fully aware of what they would be consenting to, being too groggy to reliably report their experiences or even take full advantage of the iPod, and the iPod and headphones interfering with the many pieces of monitoring equipment already attached to the patient.

Data Gathering: Data were gathered through individual in-person interviews, which took place every other day, using a modified version of the EQ-5D Health Questionnaire survey (Appendix E), up to a maximum of ten surveys. In other words, the longest a participant could have been enrolled in the study was potentially 21 days. Over the course of each participant's hospitalization the median amount of surveys completed was 3. On average the survey took approximately 5 to 10 minutes to administer, but some instances were considerably longer. There is no predetermined length of stay for transplant recipients, so conducting surveys every other day with a 24-hour window helped to ensure that the study captured all pertinent data for thorough analysis. Moreover, interacting with study participants every other day provided the participants with frequent opportunities to update the music on their iPod. A full schedule may be observed in Appendix F.

Collection of Study Materials: The iPod, headphones, and carrier case were collected from the participant at discharge. In some instances where the study coordinator was not able to meet with the study participants before they left the hospital building the study participant left the study materials at a central location for pickup, namely the ward's nursing station. Upon collecting the materials the music was removed off the iPod device and all study materials were sanitized again using sanitary wet wipes. Unfortunately, there was one instance where the iPod, headphones, and carrier case were not returned, and this instance is considered to anomalous of the study's protocol.

Summary

Overall, a total of 46 participants were enrolled into the study. 25 participants were randomized to the iPod group, 21 were randomized to the control group. 188 surveys were completed in total for all participants. Over the course of each participant's hospitalization the median amount of surveys completed is 3. On average, the QOL variable that participants responded to having the most severe problems with is mobility, followed by pain and discomfort, then self-care, and finally anxiety and depression. The mean overall QOL score across all data points is 65.84 (Appendix G; table 1).

Results

The data were analyzed both quantitatively and qualitatively. The quantitative analysis was performed by using a linear regression analysis, followed by ANOVA, and Tukey's HSD test. Qualitative data were analyzed by identifying major themes in participant response across study groups.

Linear Regression

Linear Regression Analysis				
QOL Survey Section	**Estimate**	**Standard Error**	**T-Value**	**P-Value**
Mobility	5.448	1.429	3.814	0.00188
Self-Care	3.21	1.35	2.378	0.018473
Pain and Discomfort	0.94	1.577	0.596	0.551745
Anxiety and Depression	5.523	1.592	3.47	0.000651
Overall QOL Score	7.047	7.42	0.95	0.343503
Residual Standard Error	17.2			
Residual Standard Error %	244%			
Multiple R-Squared	0.3438			
Adjusted R-Squared	0.3293			
F-Statistic	23.7			

To begin, it is prudent to first use a linear regression model to determine the overall variance of each independent variable, the QOL indicators (mobility, self-care, pain and discomfort, anxiety and depression), relative to the dependent variable, the overall QOL measurement. Due to there being multiple independent variables an appropriate first test of the data would be a multiple regression analysis, which was performed using R. The output is quite detailed and bears closer scrutiny. Although this output may look difficult to decipher, it is actually quite readable and offers a wealth of information. Here is a summary table of the R readout. The significant P-values are highlighted. A more detailed readout may be found in Appendix H.

The bottom lines of the summary are measurements of how the model fits the data. The residual standard error is 244%. This value is so high, because of the number of independent variables to account for when making a prediction, which all have different strengths of interaction, if at all. Next, the multiple R-squared value indicates that the subject's responses about their mobility, self-care, pain and discomfort, and anxiety and depression, accounts for 32.93% of the trend of the overall QOL measure. Finally, the F-statistic value is 23.7, thereby indicating there is likely a statistically significant relationship between the measures used and what is thought to be underlying these measures.

ANOVA

Analysis of Variance Table			
QOL Indicator(s)	**P-Value**	**QOL Indicator(s)**	**P-Value**
Mobility	2.83E-15	Self-Care + Anxiety & Depression	0.4779651
Self-Care	0.0036006	Pain & Discomfort + Anxiety & Depression	0.09066585
Pain & Discomfort	0.1568739	Mobility + Self-Care + Pain & Discomfort	0.4940892
Anxiety & Depression	0.005089	Mobility + Self-Care + Anxiety & Depression	0.3098525
Mobility + Self-Care	0.705719	Mobility + Pain & Discomfort + Anxiety & Depression	0.0031799
Mobility + Pain & Discomfort	0.2774661	Self-Care + Pain & Discomfort + Anxiety & Depression	0.080938

Analysis of Variance Table			
Self-Care + Pain & Discomfort	0.4915026	Mobility + Self-Care + Pain & Discomfort + Anxiety & Depression	0.8194204
Mobility + Anxiety & Depression	0.8663733		

Data was also analyzed via factorial ANOVA. Notice that R calculates an analysis of variance for every possible combination of the independent variables. The significant interactions are highlighted in the summary table below. A detailed explanation of the ANOVA may be found in Appendix I.

Similar to the linear regression analysis, there are statistically significant interactions between the independent variables of mobility, self-care, and anxiety and depression, and it is also now observable that there are statistically significant interactions between the overall QOL score and combinations of multiple QOL indicators, although these are less strong. For example, one's QOL state of both pain and anxiety, one's state of mobility, pain and discomfort, and anxiety and depression, as well as one's state of being able to self-care, pain and discomfort, and anxiety and depression were all combinations that are indicated to be statistically significant. Interestingly, the combination of all four independent variables was not found to be correlated with the overall QOL score. This statistically insignificant interaction could be attributed to other uninvestigated factors that would impact one's QOL, such as the omitted 'usual activities' variable.

Post Hoc Test (Tukey HSD)

Tukey's HSD Analysis	
Significant ANOVA Interaction	**Significant P-Value Interaction**
Pain & Discomfort + Anxiety and Depression	none
Self-Care + Pain & Discomfort + Anxiety and Depression	none
Mobility + Pain & Discomfort + Anxiety and Depression	none

As a result of the significant interaction found between multiple independent variables on the overall QOL score from ANOVA, it is necessary to perform a post hoc test. To that end, Tukey's HSD test compares the difference between two or more factors, the independent variables, on the dependent variable. The summary table below shows the findings from the analysis and a detailed explanation of Tukey's HSD post hoc test may be found in Appendix J.

By default the Tukey's HSD analysis is performed at a 95% confidence interval and omits replications. It is observable from the full R output that Tukey's HSD test does not indicate a statistically significant interaction for any combination of these variables. Although there are some instances when certain values of the independent variable(s) can be correlated with the overall QOL score, the lack of consistent interaction across all levels of the factor suggests the interaction is statistically anomalous.

Graphic Representation

The graphs below (Appendix K) are a representation of the study variable scores per group per day. The Y-axis represents the study variable (overall QOL, mobility, anxiety & depression, self-care), and the X-axis represents the interview surveys that were completed at discrete time points. Each participant has a unique colour, which is consistent across all four graphs. The interview surveys were constructed in such a way that the response 'no problems' for the independent variables are represented as a 5 and 'severe problems' as a 1. This paradigm parallels the dependent variable, the overall QOL score, which naturally associates an elevated score with the desired outcome for inpatients, and cleanly organizes the data to expectedly trend towards the top right of each graph.

Upon first observation the graphs appear to be relatively similar. The majority of data points are clustered towards the left, which is consistent with the fact that the median number of surveys completed is 3. One may also observe that there is the consistent trend among all groups that the values tend towards the top-right, which is broadly indicative of an overall improvement in the participant's QOL, both overall and across the individual variables. Closer inspection of the individual QOL variables suggests a steeper trend towards the top-right of the graphs in the iPod group compared to the control group.

Interestingly, the results for the self-care (fig. 4) variable appear to be the most dissimilar to the other graphs (fig. 1-3). In this graph one can see that among the responses from the iPod group there is actually a greater concentration of data points towards the bottom left versus the control group. One explanation for this anomaly could be that self-care is less likely to be directly affected by listening to preferred music with an iPod device. For example, as opposed to the anxiety and depression scores, which some participants reported to be directly affected by listening to music, self-care (eating, dressing, and bathing by oneself) is perhaps a secondary variable indirectly affected by listening to music, and perhaps could be directly affected by the direct effect that listening to preferred music would have on the anxiety and depression variable.

Qualitative Analysis

Methodology: The collection of qualitative data was more open-ended than the collection of quantitative data. Upon reaching the end of the quantitative portion of the survey participants were asked if they had any additional comments they wanted to share that they felt had not yet been addressed by the survey. As previously stated, the approximate length of time it took to administer the complete survey was approximately 5 to 10 minutes, but in some instances the qualitative responses lengthened the time to complete by approximately an additional 5 to 10 minutes. The qualitative section of the survey was always completed immediately after the quantitative portion and in the same face-to-face manner and surveys were always completed individually.

The reason for the increased amount of time needed to complete the qualitative portion of the survey was that follow-up questions were based on the participant's response and thus, were unique to that participant at that time. The decision to use an informal, exploratory style of questioning for qualitative results was made to parallel the participant's open-ended experience of listening to personal, preferred music in a natural, organic manner. Moreover, collecting qualitative data as a conversation enabled the participants to feel that the study was not simply routine, and often the responses at this portion of the survey would be much more enthusiastic. To that end, qualitative data was recorded via writing during conversation and after each interview was completed the surveys were stored in a secure facility. A table of major themes among the responses from both groups of participants may be observed in Appendix L.

Analysis: After completing the data collection phase of the study qualitative data were transcribed and manually analyzed for common key word responses. Furthermore, both similarities and differences associated with these key word responses were comparatively analyzed across the entire study population, as well as within each of study group.

To begin, some of the major themes that emerged from the responses of the participants in the control group include the following: feeling tired or not sleeping well, feeling unstimulated or bored, noting the positivity of familial company, feeling disturbed by external noise, and some participants noted that they would have preferred to have had an iPod, while others indicated that they felt having an iPod would not have affected their inpatient experience, which are overall unique anecdotal responses specific to the control group.

The reasons for these particular responses are perhaps that the individuals in the control group possibly had more time to concentrate on feeling bedridden, unstimulated, and dependent, because of the lack of a stimulus to preoccupy them otherwise. However, although there was a general trend of individuals indicating that they would have much preferred to have been randomized to the iPod group and that they would have used that music to relate to and reflect on their experience in the hospital, there was also a group of participants in the control group who felt that if they had been provided an iPod it would not have made a difference to their inpatient experience. Nevertheless, it is difficult to state definitively for these few individuals how accurate their assessment of music might have been relative to their inpatient experience. On the one hand it is true that these individuals know themselves better than anyone else, and indeed, some individuals declined to participate in the study entirely, because they were not interested in listening to music, but on the other hand, some individuals who were randomized to the iPod group underestimated how much they would enjoy the device and how much of an impact it would have on their experience, and perhaps this may have been the case with some of these individuals who thought that music would not affect their experience as well.

In contrast, some of the major themes that emerged from the responses of the participants in the iPod group include the following: feeling comforted or relaxed, listening to music at night and using the music to help fall asleep, blocking out external noise, providing a sense of choice, using music as a compliment to accompany other activities, stimulating memory, feeling like oneself, and overall enjoyability despite some technical issues, such as limited battery life.

Overall, the most popular common response among participants from the iPod group was that listening to their personal, preferred music did indeed help them to relax. Participants rationalized that the music had this effect, because they associated a sense of calmness with listening to familiar music that they chose. Moreover, listening to this music that they chose helped them feel more like themselves, particularly after going through the transplant procedure. By passing time through the activity of listening to the iPod, one participant reported that they avoided overthinking about being in the hospital, which allowed them to mentally distance themselves from the experience of being an inpatient. In fact, even family members reported that their loved ones in the hospital seemed to be in good spirits and attributed that observation to the use of the iPod.

For participants randomized to the iPod group the genre of musical selections did not seem to affect the degree or quality of response, and indeed, the distinction between preferred and non-preferred music seemed to resonate analogously across all participants. For example, the total variety of music selected across all participants covered genres as diverse as classical, jazz, rock, and hip-hop, with some participants even having multiple genres of music on their iPod while they were in the hospital. Overall, participants reported that they would have been less comfortable or even averse to listening to non-preferred music, because they would have associated that activity with being more of a disturbance than a pleasure.

Furthermore, there are also some unique responses from participants who received the iPod, which are worth noting. For instance, one individual reported that the shuffle feature was particularly enjoyable, not only because it was always a surprise what song would come on next and therefore prevented the act of listening to the iPod itself from becoming mundane, but because the concept of choice was too overwhelming so soon after surgery. To this individual, it was a relief to lose oneself in the music without making a conscious effort to be absolutely engaged at all times, and knowing that the entire selection of music available to be listened to was only music that was preferable also helped this individual disengage from the reality of having immediately come from survey and being in hospital to only concentrating on receiving the pleasure of listening to the music.

Another uniquely notable response came from an individual who reported that they used the iPod to mitigate silence instead of noise. For this individual the ward was too silent and when the participant became bothered by the lack of external auditory stimulation they used the music on the iPod as a stimulus to mitigate their sense of anxiety. Using the iPod in this way was totally unique to this participant. There were also some other participants who did not report being affected by ward noise, but these individuals did not also report being negatively affected by silence either.

Perhaps the single most memorable response came from an individual who had been randomized to the control group. Although this individual was not provided with an iPod or headphones with personal, preferred music, this individual had prepared for their hospital visit by bringing in their guitar to play while they were admitted. This individual discussed playing their guitar and singing as a form of physical rehabilitation, and also noted the positive feelings they experienced from playing. They explained how the guitar enabled them to connect socially with others on the ward and even went so far as to say that, "guitar will save your soul." Although this individual was not randomized to the iPod group, they were apparently already living very close to the study's ethos and aesthetic.

There is another common theme present across each of the aforementioned examples, which is being oneself. It is evident personal, preferred music, and perhaps even all music, has the potential reconnect us to ourselves. Indeed, after experiencing such a traumatic event like major organ surgery, it can be difficult to regain a sense of one's self. A transplant can be a physical and emotional upheaval, so using music to mitigate any sense of physical or psychological distress, stimulate prior memories, provide comfort, and facilitate sleep, actually does "[remind] me of who I am," according to one particular study participant from the iPod group.

There were also some common responses between the two groups. Multiple participants in both groups reported being adversely affected by noise in the hospital, but it was only the participants in the iPod group who indicated that they had some recourse, which was using their preferred music to mitigate ward noises. Similarly, participants in both groups reported sleeping problems, but only participants in the iPod group reported using music as a means to help sleep.

The sense of well-being that was reported from being able to sleep while using music, in some cases the iPod was reportedly on all night, was a stark contrast to the anecdotes of the control group, none of whom reported feeling relief from or assisted by pharmacological remedies.

Related to disturbance, one aspect of the iPod that many participants reported enjoying was the over-ear, noise-cancelling headphones, because they noted that they could use the device as much as they wanted without worrying about disturbing their neighbours. In contrast, some participants from both groups reported that they felt disturbed by their neighbours' use of the television, for example. One conscientious participant even used the headphones to plug into their television out of consideration for their roommate.

Interestingly, but not unexpectedly, the most specific common responses between the two study groups are entirely related to the transplant experience. For example, similar responses provided by both study groups includes the following: experiencing pain, a lack of independence, immobility, nausea, swelling, and anxiety. This clear thematic division in the participants' responses suggests that there is also an appreciable qualitative difference in providing transplant patients with personal, preferred music, as opposed to not providing it to them.

Chapter Six: Conclusions, Limitations, and Next Steps

There were a number of positives associated with this project. To begin, the interdisciplinary nature of the investigation is one component that makes this experiment stand apart from other similar ventures. Indeed, this study is an equal collaboration of psychology, nursing, and music disciplines, all of which were crucial in realizing this project. Input from the psychology discipline was useful for creating the methodology, the nursing discipline was helpful for negotiating approval with the research ethics boards, and the music discipline for providing much of the background literature.

Furthermore, this project succeeded in addressing some of the criticisms of earlier, similar studies. This project succeeded in dividing a patient population into a study group and a control group, and in fact, it enrolled more patients into just one study arm than had previously been enrolled in the entirety of some previous, published research studies.

Another positive that came out of this experiment was the interactions with the patients themselves. After they were informed about the nature of the research, many individuals seemed excited and expressed a desire to receive an iPod. One participant was particularly enthusiastic and claimed to have told his doctor about this project. He believed that, "music should be offered in a hospital like a glass of water." On another occasion one particular individual told me that he enjoyed doing the surveys, because he didn't have anyone who came to visit him, so answering the studies questions and talking about his feelings about the music to which he was listening were personal interactions that made his time in the hospital go faster.

On the whole, the positive interactions with the participants was one of the most rewarding parts of conducting this project. Many participants relayed memories in reference to explaining how a particular song made them feel. One patient talked about how she used to sing professionally when she was younger, another one relayed how he pretended to be a journalist to sneak backstage at a concert and meet his idol, and upon discharge, one participant even asked to have their photo taken with the project coordinator, so they could remember taking part.

Finally, perhaps the most important interactions with the participants were the discussions relating to the study itself. Participants provided invaluable feedback about their experience in this experiment, which could be utilized for the betterment of similar projects in the future.

Limitations

Although this study succeeded in providing personal, preferred music to transplant patients in a hospital setting, there were some limitations to this study that could be improved for similar endeavours in the future. There were four main areas of limitations, which are the following: methodological, technical, sample, and ethical.

Methodological: To begin, one limitation was the decision to conduct the in-person surveys every other day. The justification for this schedule was out of consideration for the participant population. However, some participants would decline to participate in surveys for either personal or health reasons even beyond the immediate post-transplant phase. To account for this contingency, surveys were admissible up to twenty-four hours beyond the scheduled completion date, but as a result, surveys were not always strictly completed every other day.

Another methodological limitation was the structure of the survey questions. Some survey questions distilled multiple variables into a single response, which some participants felt was not entirely representative of their experience. For example, during questions about, “Pain and Discomfort,” and “Anxiety and Depression,” some participants noted that they only felt anxiety and no depression, or vice-versa. Similarly, for the “Self-Care,” question, some participants noted that they had different degrees of problems with the different examples provided by the survey. For example, some participants noted that they had no problems eating, but needed help to dress. Also, some participants noted that they had not yet even tried to bathe, so they were unsure if they had any problems with that activity or not.

Unfortunately, one iPod and headphone device was lost over the course of the study. On the whole, loss was mitigated through diligence and fore planning. Most often the iPods were collected before the patient was completely discharged home, but in some cases this was not always possible and the participants were asked to leave the iPod at the nurses’ station on their way out. Ideally it would have been preferable to not place that imposition on the participant population or hospital staff.

Technical: There were also some technical limitations concerning the iPods and headphones themselves. First was the battery life. A number of participants reported that the batteries died unexpectedly while they were listening and they didn’t have any means to recharge the iPod. The iPod chargers were not provided to the study participants for practical reasons. The charge cables that accompany the iPod shuffle devices are quite small and extremely short. Not only are they very easy to lose, but they are impractical to use for someone who may be bedridden and unable to easily access an electrical outlet. The unexpected interruption of one’s favourite music was surely an unwelcome surprise and then being unable to listen to the device for sometimes up to a day was reported by some participants as unfavourable.

Overall, the over-ear, noise-cancelling headphones were quite well-received. However, some participants indicated that they preferred earbuds and suggested that offering a choice between the two might be an ideal solution in a future study. One participant complained that the wires from the headphones interfered too much with all the other lines, wires, and tubes around them, so perhaps one day even wireless technology may be useful, if allowed in the hospital bed.

It was not possible to accurately track precisely what music the participants were listening to and when they were listening to it. Scrobbling is a technique that allows one to track digital music listening habits in this manner. However, this technology is not inherent to any current model of iPod device and third-party technology can not be installed onto iPod shuffle devices. Thus, the amount of musical selection data that was collected was limited to the participant's indicated choices and their self-reported listening habits.

Sample: There were also some limitations as a result of the participants themselves. For example, some participants utilized music or similar auditory stimuli even though they were not randomized to the iPod group. Some participants reported listening to nature sounds, the radio, CDs, and one person even had a guitar that they brought in to play.

Conversely, at least one participant who was enrolled to the iPod group did not listen to the iPod at all. Moreover, since the surveys were completed with information provided by self-report it is possible, though believed unlikely, that participants were not entirely honest about their experience in the hospital. Participants may have unintentionally forgotten to iterate information about their (non-)musical in-hospital experiences or misremembered their experience in retrospect. On the whole, it is believed that participants responded in good faith.

Participants who deviated from their group's protocol were not removed from their study group. In some cases the provision of music to participants who had been randomized to the non-iPod group was sanctioned by a doctor, which overrode the protocol of this study. In these instances participants were asked to speculate about the difference between listening to music as they were versus how they imagined listening to music on an iPod.

Also, some participants declined to complete some of the scheduled surveys. Participant reluctance was a known risk in conducting the study, because it is such an extreme upheaval to undergo a transplant operation, and indeed, nearly every participant who provided consent, approximately twenty-four to forty-eight hours post-operation, appeared to have low energy. In fact, several indicated that they were tired from their procedure and thus, during the early post-transplant phase participants were generally more reluctant to talk and complete a survey because it was either too much of an imposition or it was an unwanted intrusion during their acute recovery.

During the final section of the survey, the portion for additional comments, some participants were far more verbose than others. One participant reported having difficulty speaking, which limited the interview process in that case. Sometime participants seemed to have difficulty focusing precisely on the question. For the first five questions, which could be condensed to a numerical scale, it was generally possible for these participants to distill their narrative experience into an answer, but in some cases they totally declined or only provided a range. One possible remedy may be more stringent questions, or perhaps allowing some participants to complete the survey through writing.

Ethical: This study does not take into account any pre-existing or historical conditions that participants may have had, which could have influenced the results. For example, although some participants reported that they suffered from depression since before their transplants, these details were not recorded. In essence, there is no relative baseline for each QOL variable. Similarly, an individual who may be suffering from chronic pain would more likely and more consistently report greater problems with pain and discomfort than a different individual without that condition. Thus, because qualitative responses are subjective, what a statement means to one individual will almost certainly be different for another individual.

This project also informed patients via consent that no information would be collected beyond what was stated during the surveys. This limitation on the amount of available demographic information hampers the study's ability to parse the data across potential sub-groups. However, in the interests of patient confidentiality and honouring a professional agreement, even information like gender, which could be inferred from the names on the consent forms, should remain confidential.

Next Steps

Analogous to the study's limitations, the next steps to undertake study improvements may be grouped to the same categories. Indeed, this project can be a valuable foundation for an improved methodology of personal, preferred music prescription to post-surgical transplant patients.

Methodological: In regard to the administration of the in-person interviews, it may be preferable to break out the categories, and even the distinctions within the questions, of the EQ-5D survey. Indeed, some participants responded that in their opinion the questions in their current state did not entirely address their QOL state at that time. For example, in the self-care category some participants reported having different degrees of difficulty with washing, dressing, and eating, but the question forces the response to equate each of these three activities, when in fact it is unrealistic to conclude that eating, washing, and dressing oneself are always equally doable. Similarly, participants distinguished between the labels of pain and discomfort, and anxiety and depression. Some individuals would highlight that they had only pain or only discomfort, or only anxiety or only depression.

Related to further studying the precise relationship between physiology and the response to preferred music, it would be fascinating the observe the effect of listening to preferred music in hospital from a neurological perspective. Listening to preferred music engages all areas of the brain, and the differences in neurological response between listening to preferred music verses noise in a non-hospital setting, so hypothetically the effect would be amplified, because multiple participants in the non-iPod group reported feeling unstimulated by being in the hospital.

Technological: A future project could utilize better technology to more accurately track participants' listening habits. Newer generation iPods such as the iPod Touch do allow for installation of third-party applications, but these devices are considerably more expensive than the Shuffle model.

Nevertheless, the ability to install and utilize third-party applications from a single localized device allows for some intriguing possibilities. For example, it would then be possible to more precisely correlate a participant's listening habits with their physiological response. For example, Fitbit technology is an accessible, non-intrusive means of tracking basic physiology, such as heart rate, distance walked (both linear distance and number of steps), and sleep habits. The ability to track sleeping habits would be an intriguing and valuable metric, given the number of qualitative responses that mentioned using music in sleep-related contexts. In fact, Fitbit is complementary to the EQ-5D survey. The distance walked metric is relevant to the mobility variable, the heart rate is relevant to the anxiety and depression variable, and since a number of participants in the iPod group reported using the iPod to help them sleep, correlating sleep habits with listening habits would be a new area of investigation. The Fitbit app can be concurrently installed on iPod Touch devices with scrobble technology.

This study could also be improved by being able to cater to more non-Western musical selections. For the most part, the musical selections provided by the participants conformed were relatively well-known accessible artists or genres, but if a participant had requested music without an English title and using non-English characters, it would have been difficult, perhaps even impossible, to locate without a specialized keyboard input system or even a basic knowledge of the language.

Sample: The over-ear, noise-cancelling headphones used in this study had noise-cancelling technology built into them, but this feature was not always utilized by the participants. Some participants reported that they did not notice a difference between whether or not the noise-cancelling feature was enabled and other reports indicated that the noise-cancelling technology was not absolute, and that noise still got through. Nevertheless, participants who did report receiving relief from ward noise via the use of the headphones suggested that it was due to the padding around the headphone's speakers. Noise-cancelling technology can quickly scale upwards in expense for relatively little, or even debatably noticeable, improvement, but headphones with a larger amount of padding that offer high-resolution playback can perform just as adequately to reduce external noise for a fraction of the cost.

Although this study did not encounter any limitations due to being unable to address certain cultural preferences, because the need did not arise, it may have been that the musical selections provided by the study would have been inadequate for a particular individual. Future studies could avoid this limitation by proactively ensuring they are sensitive to others' cultures.

Ethical: In order to widen the scope of investigation it would be necessary to properly inform the appropriate research ethics boards, as well as fully inform the study population of what data would be collected, and report this information on the appropriate study documents, such as the consent form and study protocol. Information that might be pertinent to future investigations could include medical and medication history that is directly relevant to the study survey. Any future studies that would be considering incorporating neurological imaging would have to observe proper imaging protocols as well.

Conclusions

In conclusion, this study succeeded in providing personal, preferred music to 46 transplant patients in a hospital setting. In total the study completed 84 surveys for the control group and 104 surveys for the study group, and therefore the study collected a grand total of 188 data points. The median amount of surveys completed per participant is 3, though some participants completed 10, which was the maximum number possible. On average study participants reported the most severe problems with mobility followed by pain and discomfort, then self-care, and finally anxiety and depression.

The graphic representation supports the statistical analyses. Indeed, one can observe some apparent visual similarities between the control group and the study group across each comparison of the QOL indicators and the overall QOL score. For example, in all graphs the measurements tends towards the top right, thereby indicating a general, reported improvement over time, but the data points are densely clustered and therefore difficult to properly appreciate without more precise investigative tools.

Quantitatively, there are measurable differences between the two study groups' independent variables, the QOL indicators, and the dependent variable, the overall QOL score, when compared via linear regression and ANOVA, but when these interactions were investigated more closely using Tukey's HSD post hoc test the interactions were not found to be statistically significant. Indeed, the linear regression analysis indicated that the residual standard error is 244%, the multiple R-squared value is 32.93%, and the F-statistic value is 23.7.

The factorial ANOVA analysis confirmed these values and also provided additional measurements. Namely, sum of squares and mean squares values for all combinations of interactions. The ANOVA analysis four highly significant P-values for the interactions between mobility and overall QOL, as well as anxiety and depression and overall QOL. Significant P-values for the interactions between Self-Care and overall QOL, as well as and Self-Care,Pain and Discomfort, Anxiety and Depression, and overall QOL. Less significant interactions between overall QOL and Pain and Discomfort, Anxiety and Depression, as well as overall QOL and Mobility, Pain and Discomfort, Anxiety and Depression. Turkey's HSD test was performed post hoc on the significant interactions of multiple QOL indicators on the overall QOL score. Each instance of post hoc testing observed no significant interaction.

There are also notable qualitative differences reported between the two study groups. Indeed, more people in the control group reported feeling bedridden, unstimulated, and noted that they needed assistance for self-care. There is a general trend of individuals indicating that they would have much preferred to have been randomized to the iPod group and that they would have used that music to relate to and reflect on their experience in the hospital. In contrast, the iPod group generally reported that their music had a calming effect, and that listening to music that they liked and chose helped them feel more like themselves, particularly after going through the transplant procedure. Also, a number of participants in the iPod group reported using their music to minimize external ward noise. Perhaps the greatest qualitative difference between the two groups is that many participants in the iPod group reported using the device to help them sleep, which was not directly investigated by the study's measurement tools. These participants reported that they would listen to music either until they felt so sleepy that they slept as soon as turning off the device, or even that they would fall asleep while the music was playing. Interestingly, the genre of musical selections did not seem to affect the degree or quality of response. Indeed, the distinction between preferred and non-preferred music seemed to resonate analogously across all participants.

Moreover, there are also some notable similarities between the two groups experiences. For example, the study intervention was not observed to be an influential factor in coping with pain and discomfort. Additionally, ANOVA also showed multiple interactions of study variables that had no significant interaction on the overall QOL score. These quantitative results were also reflected in the qualitative analysis, in which almost no participants reported using their music as an analgesic. Finally, both groups of participants noted feeling disturbed by noise. The source could have been either from the ward noise, their neighbours, or both, but only the study group reported a sense of relief from the noise by being able to use the iPod and headphones.

There are some limitations to this study, which are can be broadly grouped into methodological, technical, sample, and ethical limitations. Fortunately, these limitations can be addressed in future studies that utilize a similar methodology. The study's methodological limitations include conducting the in-person surveys every other day, when it perhaps may have been more beneficial to conduct them daily. Although, this would be more of an imposition on the study population, it would offer the investigation a greater understanding of the daily inpatient experience with personal, preferred music, and allow the study population more opportunities to interact with the study coordinator if they needed to change the music on the iPod or recharge it. Another methodological limitation was the format of some of the survey questions. Some questions could perhaps be expanded so as to more accurately reflect participant responses. For example, “Anxiety and Depression,” could be two separate sections, “Anxiety,” and “Depression,” and the examples used in the “Self-Care,” section, namely bathing, eating, and washing oneself, could either be addressed more specifically, or include more examples of what self-care is, to better iterate that this is an aggregation of everything to do with taking care of oneself. Unfortunately, the study lost one iPod and headphone device, but overall, loss was mitigated through diligence and foreplanning. Loss could be perhaps entirely eliminated by better tracking the devices and having more time available onsite to interact with the study population.

There were three main technological limitations, i.e., the battery life of the iPod device, the lack of a choice of earbuds over the over-ear, noise-cancelling headphones, and the integration of scrobbling technology. Some participants noted during their interviews that their iPod’s battery had died and that they had been unable to listen to their music until the study coordinator recharged their device for them. Some participants requested to be provided with the charging cable, but the cable was not provided on account of its small size, for sanitation, and methodological homogeneity, because participants who are immobile may not be able to access the facilities to charge the device. The decision for the study to not provide earbuds was made for similar reasons, but especially for the much more difficult task of properly sanitizing the earbuds between participants. Another technological limitation was the lack of an ability to track exactly what music participants listened to and when. The technology that is necessary to accomplish this feat is called scrobbling, but it is not possible to integrate third-party software with the study’s iPod touch devices. Some later generation models of iPod would be able to have scrobbling technology installed, and it is also possible to build a custom MP3 player using a raspberry pi computer and open source software, which could be tailored as precisely as one wants to the needs of their investigation.

Additionally, there were some limitations with the study participants themselves. For example, the decision to use self-report relies on the accuracy of the patient's memory and their honesty. However, it is believed that all study participants answered in good faith. Also, some participants deviated from the study protocol. Some participants in the control group listened to the radio or used their own device to access the internet, and at least one participant who was randomized to the study group did not listen to their iPod at all. Some participants did not use the noise-cancelling feature on the headphones, though this was because they felt that perhaps the feature was not entirely effective, so this could be a technological limitation of the headphones themselves. Sometimes participants also declined to answer study surveys, which limited the insight and accuracy of the analysis, but often when participants declined they reported declining due to pain or tiredness from their procedure. In some cases participants were asleep, out on pass, or unavailable due to a procedure, so in these instances surveys were not completed.

Furthermore, there were also some ethical limitations, such as not taking into account any participants' pre-existing or historical conditions and medications that are directly relevant to the study survey's questions. The investigative scope could be widened by properly informing the necessary research ethics boards, as well as fully inform the study population of what data would be collected, and not proceeding until receiving approval.

Altogether, perhaps the most exciting expansion of studying the precise relationship between physiology and the response to personal, preferred music, would be to observe the effect of listening to preferred music in hospital from a neurological perspective. Investigating the effects of personal, preferred music on the brain is a relatively new endeavour and there may yet be compelling, new discoveries that could inform how to better administer music to improve everyone's health.

Bibliography

Aldridge, D. (1996). Music therapy and inflammatory bowel disease. In *Music therapy research and practice in medicine: From out of the silence* (pp. 173-186) London; Bristol, Pa: Jessica Kingsley.

Allen, L., & Shealy, N. (2005). An exploration of the effects of toning and quartz crystal bowls on the energetic balance in the body as measured electrically through the acupuncture meridians. *Subtle energies & energy medicine journal archives,* 16(2), 5-8.

Altenmüller, E., & Schlaug, G. (2015). Apollo's gift: new aspects of neurologic music therapy. *Progress in brain research,* 217, 237-252.

Alter, D. A., O'Sullivan, M., Oh, P. I., Redelmeier, D. A., Marzolini, S., Liu, R., ... & Bartel, L. R. (2015). Synchronized personalized music audio-playlists to improve adherence to physical activity among patients participating in a structured exercise program: a proof-of-principle feasibility study. *Sports medicine - open,* 1(1), 23.

Amunts, K., Schlaug, G., Jäncke, L., Steinmetz, H., Schleicher, A., Dabringhaus, A., & Zilles, K. (1997). Motor cortex and hand motor skills: structural compliance in the human brain. *Human brain mapping,* 5(3), 206-215.

Baily, J. (1995). Music and the body. *The world of music,* 37(2), 11-30.

Bengtsson, S. L., Nagy, Z., Skare, S., Forsman, L., Forssberg, H., & Ullén, F. (2005). Extensive piano practicing has regionally specific effects on white matter development. *Nature neuroscience,* 8(9), 1148-1150.

Bernatzky, G., Presch, M., Anderson, M., & Panksepp, J. (2011). Emotional foundations of music as a non-pharmacological pain management tool in modern medicine. *Neuroscience & biobehavioral reviews,* 35(9), 1989-1999.

Blake, E. C., & Cross, I. (2008). Flint tools as portable sound-producing objects in the upper palaeolithic context: an experimental study. *Experiencing archaeology by experiment,* 1-19.

Bringman, H., Giesecke, K., Thörne, A., & Bringman, S. (2009). Relaxing music as pre-medication before surgery: a randomised controlled trial. *Acta anaesthesiologica scandinavica,* 53(6), 759-764.

Brownley, K. A., McMurray, R. G., & Hackney, A. C. (1995). Effects of music on physiological and affective responses to graded treadmill exercise in trained and untrained runners. *International journal of psychophysiology,* 19(3), 193-201.

Cadigan, M. E., Caruso, N. A., Haldeman, S. M., McNamara, M. E., Noyes, D. A., Spadafora, M., & Carroll, D. L. (2001). The effects of music on cardiac patients on bed rest. *Progress in cardiovascular nursing,* 16(1), 5-13.

Chang, F. Y., Huang, H. C., Lin, K. C., & Lin, L. C. (2010). The effect of a music programme during lunchtime on the problem behaviour of the older residents with dementia at an institution in taiwan. *Journal of clinical nursing,* 19(7-8), 939-948.

Clark, M., Isaacks-Downton, G., Wells, N., Redlin-Frazier, S., Eck, C., Hepworth, J. T., & Chakravarthy, B. (2006). Use of preferred music to reduce emotional distress and symptom activity during radiation therapy. *Journal of Music Therapy,* 43(3), 247-265.

Crawford, I., Hogan, T., & Silverman, M. J. (2013). Effects of music therapy on perception of stress, relaxation, mood, and side effects in patients on a solid organ transplant unit: A randomized effectiveness study. *The arts in psychotherapy,* 40(2), 224-229.

Danzon, P. M., & Furukawa, M. F. (2008). International prices and availability of pharmaceuticals in 2005. *Health affairs*, *27*(1), 221-233.

de Dreu, M. J., Van Der Wilk, A. S. D., Poppe, E., Kwakkel, G., & van Wegen, E. E. (2012). Rehabilitation, exercise therapy and music in patients with Parkinson's disease: a meta-analysis of the effects of music-based movement therapy on walking ability, balance and quality of life. *Parkinsonism & related disorders,* 18, S114-S119.

Dyrlund, A. K., & Wininger, S. R. (2008). The effects of music preference and exercise intensity on psychological variables. *Journal of music therapy,* 45(2), 114-134.

Eitner, S., Sokol, B., Wichmann, M., Bauer, J., & Engels, D. (2011). Clinical use of a novel audio pillow with recorded hypnotherapy instructions and music for anxiolysis during dental implant surgery: a prospective study. *International journal of clinical and experimental hypnosis,* 59(2), 180-197.

Elefant, C., Baker, F. A., Lotan, M., Lagesen, S. K., & Skeie, G. O. (2012). The effect of group music therapy on mood, speech, and singing in individuals with Parkinson's disease—A feasibility study. *Journal of music therapy,* 49(3), 278-302.

EuroQol Research Foundation. "EQ-5D Instruments." EQ-5D, 28 Apr. 2017, euroqol.org/eq-5d-instruments/.

Evers, S., & Suhr, B. (2000). Changes of the neurotransmitter serotonin but not of hormones during short time music perception. *European archives of psychiatry and clinical neuroscience,* 250(3), 144-147.

Frego, R. D. (2009). Dancing inside: Dalcroze eurhythmics in a therapeutic setting. *Musical experience in our lives–things we learn and meanings we make,* 313-330.

Gaser, C., & Schlaug, G. (2003). Brain structures differ between musicians and non-musicians. *Journal of neuroscience,* 23(27), 9240-9245.

Gerdner, L. A., & Schoenfelder, D. P. (2010). Evidence-based guideline. Individualized music for elders with dementia. *Journal of gerontological nursing,* 36(6), 7-15.

Ghetti, C. M. (2011). Active music engagement with emotional-approach coping to improve well-being in liver and kidney transplant recipients. *Journal of music therapy,* 48(4), 463-485.

Good, M., Stanton-Hicks, M., Grass, J. A., Anderson, G. C., Choi, C., Schoolmeesters, L. J., & Salman, A. (1999). Relief of postoperative pain with jaw relaxation, music and their combination. *Pain,* 81(1-2), 163-172.

Good, M., Stanton-Hicks, M., Grass, J. A., Anderson, G. C., Lai, H. L., Roykulcharoen, V., & Adler, P. A. (2001). Relaxation and music to reduce postsurgical pain. *Journal of advanced nursing,* 33(2), 208-215.

Halwani, G. F., Loui, P., Rüber, T., & Schlaug, G. (2011). Effects of practice and experience on the arcuate fasciculus: comparing singers, instrumentalists, and non-musicians. *Frontiers in psychology,* 2, 156.

Hammar, L. M., Emami, A., Engström, G., & Götell, E. (2011a). Communicating through caregiver singing during morning care situations in dementia care. *Scandinavian journal of caring sciences,* 25(1), 160-168.

Hammar, L. M., Emami, A., Götell, E., & Engström, G. (2011b). The impact of caregivers' singing on expressions of emotion and resistance during morning care situations in persons with dementia: an intervention in dementia care. *Journal of clinical nursing,* 20(7-8), 969-978.

Hanser, S. B. (2009). From ancient to integrative medicine: Models for music therapy. *Music and medicine,* 1(2), 87-96.

Harford, F. K. (1891, September). Music and illness [Letter to the editor]. *British medical journal,* 2(1603), 667.

Hicks-Moore, S. L. (2005). Relaxing music at mealtime in nursing homes. *Journal of gerontological nursing,* 31(12), 26-32.

Hutchinson, S., Lee, L. H. L., Gaab, N., & Schlaug, G. (2003). Cerebellar volume of musicians. *Cerebral cortex,* 13(9), 943-949.

Jaques-Dalcroze, E. (1921). *Rhythm, music and education.* New York, NY: GP Putnam's Sons.

Johnson, R., & Taylor, C. (2011). Can playing pre-recorded music at mealtimes reduce the symptoms of agitation for people with dementia?. *International journal of therapy and rehabilitation,* 18(12), 700-708.

Karageorghis, C. I., Terry, P. C., & Lane, A. M. (1999). Development and initial validation of an instrument to assess the motivational qualities of music in exercise and sport: The brunel music rating inventory. *Journal of sports sciences,* 17(9), 713-724.

Karageorghis, C. I., Terry, P. C., Lane, A. M., Bishop, D. T., & Priest, D. L. (2012). The BASES expert statement on use of music in exercise. *Journal of sports sciences,* 30(9), 953-956.

Katz, J. B. (2014) Music therapy: Some possibilities in the indian tradition. In P. Horden (Ed.) *Music as medicine: The history of music therapy since antiquity* (pp. 84-100), Aldershot; Brookfield, VT: Ashgate.

Keitz, M., Martin-Soelch, C., & Leenders, K. (2003). Reward processing in the brain: a prerequisite for movement preparation?. *Neural plasticity,* 10(1-2), 121-128.

Kneafsey, R. (1997). The therapeutic use of music in a care of the elderly setting: a literature review. *Journal of clinical nursing,* 6(5), 341-346.

Konkani, A., & Oakley, B. (2012). Noise in hospital intensive care units—a critical review of a critical topic. *Journal of critical care,* 27(5), 522.e1-522.e9.

Kramer, C. (2000a). Soul music as exemplified in nineteenth-century German psychiatry. In P. Gouk (Ed.), *Musical healing in cultural contexts* (pp. 137-148). Aldershot; Brookfield, VT: Routledge.

Kramer, C. (2000b) Music as cause and cure of illness in nineteenth century europe. In P. Horden (Ed.) *Music as medicine* (pp. 338-352) Aldershot; Brookfield, VT: Ashgate.

Leardi, S., Pietroletti, R., Angeloni, G., Necozione, S., Ranalletta, G., & Del Gusto, B. (2007). Randomized clinical trial examining the effect of music therapy in stress response to day surgery. *British journal of surgery: Incorporating european journal of surgery and swiss surgery,* 94(8), 943-947.

Livingston, G., Kelly, L., Lewis-Holmes, E., Baio, G., Morris, S., Patel, N., ... & Cooper, C. (2014). Non-pharmacological interventions for agitation in dementia: systematic review of randomised controlled trials. *The british journal of psychiatry,* 205(6), 436-442.

Madson, A. T., & Silverman, M. J. (2010). The effect of music therapy on relaxation, anxiety, pain perception, and nausea in adult solid organ transplant patients. *Journal of music therapy,* 47(3), 220-232.

Mair, V. H. (2006). Prehistoric european and east asian flutes. In Anderl, C. & H. Eifring (Ed.), *Studies in chinese language and culture: Festschrift in honour of christoph harbsmeier on the occasion of his 60th birthday* (pp. 209-216). Oslo, NO: Hermes Academic Publishing.

Mathews, R. M., Clair, A. A., & Kosloski, K. (2001). Keeping the beat: use of rhythmic music during exercise activities for the elderly with dementia. *American journal of alzheimer's disease & other dementias,* 16(6), 377-380.

Mitchell, L. A., & MacDonald, R. A. (2006). An experimental investigation of the effects of preferred and relaxing music listening on pain perception. *Journal of Music Therapy,* 43(4), 295-316.

Montello, L. (2002). *Essential musical intelligence: Using music as your path to healing, creativity, and radiant wholeness.* Wheaton, IL: Quest Books.

Moreno, J. (1991). The music therapist: creative arts therapist and contemporary shaman. In D. Campbell (Ed.), *Music: Physician for times to come* (pp. 67-185) Wheaton, IL: Quest Books.

McClellan, R. (2000) "Music, cosmology, and the inner sound." *The healing forces of music: History, theory, and practice.* Rockport, MA: Element.

Nakamura, J., & Csikszentmihalyi, M. (2014). The concept of flow. In *Flow and the foundations of positive psychology* (pp. 89-105). New York, NY: Oxford University Press.

Nakamura, P. M., Pereira, G., Papini, C. B., Nakamura, F. Y., & Kokubun, E. (2010). Effects of preferred and nonpreferred music on continuous cycling exercise performance. *Perceptual and motor skills,* 110(1), 257-264.

Nilsson, U., Rawal, N., & Unosson, M. (2003). A comparison of intra-operative or postoperative exposure to music: a controlled trial of the effects on postoperative pain. *Anaesthesia,* 58(7), 699-703.

Nilsson, U. (2008). The anxiety-and pain-reducing effects of music interventions: a systematic review. *AORN journal,* 87(4), 780-807.

Nusseck, M., & Wanderley, M. M. (2009). Music and motion: How music-related ancillary body movements contribute to the experience of music. *Music perception: An interdisciplinary journal,* 26(4), 335-353.

Park, H., & Specht, J. K. P. (2009). Effect of individualized music on agitation in individuals with dementia who live at home. *Journal of gerontological nursing,* 35(8), 47-55.

Parker-Pope, T. (2007, November 9). A little more sweat, maestro. *The new york times,* Retrieved from http://well.blogs.nytimes.com/2007/11/09/a-little-more-sweat-maestro/?_r=0.

Pavlicevic, M. (2000). Improvisation in music therapy: Human communication in sound. *Journal of music therapy,* 37(4), 269-285.

Priest, D. L., & Karageorghis, C. I. (2008). A qualitative investigation into the characteristics and effects of music accompanying exercise. *European physical education review,* 14(3), 347-366.

Rejeski, W. J. (1985). Perceived exertion: an active or passive process?. *Journal of Sport Psychology,* 7(4), 371-378.

Rorke, M. A. (2001). Music therapy in the age of enlightenment. *Journal of music therapy,* 38(1), 66-73.

Rossato-Bennett, M., Mcdougall, A., Scully, R. (Producer), & Rossato-Bennett, M. (Director). (2014). *Alive inside* [Motion Picture]. United States of America: City Drive Films.

Rüber, T., Lindenberg, R., & Schlaug, G. (2013). Differential adaptation of descending motor tracts in musicians. *Cerebral cortex,* 25(6), 1490-1498.

Sachs, M. E., Ellis, R. J., Schlaug, G., & Loui, P. (2016). Brain connectivity reflects human aesthetic responses to music. *Social cognitive and affective neuroscience,* 11(6), 884-891.

Salimpoor, V. N., Benovoy, M., Larcher, K., Dagher, A., & Zatorre, R. J. (2011). Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nature neuroscience,* 14(2), 257.

Schlaug, G. (2008). From singing to speaking: why patients with Broca's aphasia can sing and how that may lead to recovery of expressive language functions. *Music percept.,* 25, 315-323.

Schlaug, G., Marchina, S., & Norton, A. (2009). Evidence for plasticity in white-matter tracts of patients with chronic broca's aphasia undergoing intense intonation-based speech therapy. *Annals of the new york academy of sciences,* 1169(1), 385-394.

Shiloah, A. (2014) Jewish and muslim traditions of music therapy. In P. Horden (Ed.) *Music as medicine: the history of music therapy since antiquity* (pp. 69-83), Aldershot; Brookfield, VT: Ashgate.

Sorrell, J. A., & Sorrell, J. M. (2008). Music as a healing art for older adults. *Journal of psychosocial nursing and mental health services,* 46(3), 21-24.

Storr, A. (1992). *Music and the mind.* New York, NY: The Free Press.

Sung, H. C., & Chang, A. M. (2005). Use of preferred music to decrease agitated behaviours in older people with dementia: a review of the literature. *Journal of clinical nursing,* 14(9), 1133-1140.

Sung, H. C., Chang, A. M., & Lee, W. L. (2010). A preferred music listening intervention to reduce anxiety in older adults with dementia in nursing homes. *Journal of clinical nursing,* 19(7-8), 1056-1064.

Thaut, M. H., Gardiner, J. C., Holmberg, D., Horwitz, J., Kent, L., Andrews, G., ... & McIntosh, G. R. (2009). Neurologic music therapy improves executive function and emotional adjustment in traumatic brain injury rehabilitation. *Annals of the new york academy of sciences,* 1169(1), 406-416.

Thaut, M. H. (2010). Neurologic music therapy in cognitive rehabilitation. *Music perception: An interdisciplinary journal,* 27(4), 281-285.

Thomas, D. W., Heitman, R. J., & Alexander, T. (1997). The effects of music on bathing cooperation for residents with dementia. *Journal of music therapy,* 34(4), 246-259.

Tong, A., Morton, R., Howard, K., & Craig, J. C. (2009). Adolescent experiences following organ transplantation: a systematic review of qualitative studies. *The journal of pediatrics,* 155(4), 542-549.

Tyler, H. (2000) The music therapy profession in modern Britain. In P. Horden (Ed.) *Music as medicine: the history of music therapy since antiquity* (pp. 375-393) Aldershot; Brookfield, VT: Ashgate.

Ugras, G. A., & Öztekin, S. D. (2007). Patient perception of environmental and nursing factors contributing to sleep disturbances in a neurosurgical intensive care unit. *The tohoku journal of experimental medicine,* 212(3), 299-308.

Urakawa, K., & Yokoyama, K. (2005). Music can enhance exercise-induced sympathetic dominancy assessed by heart rate variability. *The tohoku journal of experimental medicine,* 206(3), 213-218.

Van de Winckel, A., Feys, H., De Weerdt, W., & Dom, R. (2004). Cognitive and behavioural effects of music-based exercises in patients with dementia. *Clinical rehabilitation,* 18(3), 253-260.

Vink, A. C., Zuidersma, M., Boersma, F., Jonge, P., Zuidema, S. U., & Slaets, J. P. J. (2013). The effect of music therapy compared with general recreational activities in reducing agitation in people with dementia: a randomised controlled trial. *International journal of geriatric psychiatry,* 28(10), 1031-1038.

Vink, A. C., Bruinsma, M. S., & Scholten, R. J. (2003). Music therapy for people with dementia. *The cochrane library.*

Voss, J. A., Good, M., Yates, B., Baun, M. M., Thompson, A., & Hertzog, M. (2004). Sedative music reduces anxiety and pain during chair rest after open-heart surgery. *Pain,* 112(1-2), 197-203.

Wall, M., & Duffy, A. (2010). The effects of music therapy for older people with dementia. *British journal of nursing,* 19(2), 108-113.

Wan, C. Y., Zheng, X., Marchina, S., Norton, A., & Schlaug, G. (2014). Intensive therapy induces contralateral white matter changes in chronic stroke patients with Broca's aphasia. *Brain and language,* 136, 1-7.

Weinberger, N. M. (2004). Music and the brain. *Scientific american,* 291(5), 88-95.

West, M. (2014) Music therapy in antiquity. In P. Horden (Ed.) *Music as medicine: The history of music therapy since antiquity,* (pp. 51-68), Aldershot; Brookfield, VT: Ashgate.

Will, U., & Turow, G. (2011) Introduction to entrainment and cognitive ethnomusicology. In J. Berger & G. Turow (Ed.) *Music, science, and the rhythmic brain: cultural and clinical implications,* (pp. 3-30), New York, NY: Routledge.

Williams, P. A., Peckham, A., Rudoler, D., Tam, T., Watkins, J. (2014) Evaluation of the alzheimer society of toronto iPod project: Final report. *Balance of care - Research & evaluation group,* 1-58.

Yamashita, S., Iwai, K., Akimoto, T., Sugawara, J., & Kono, I. (2006). Effects of music during exercise on RPE, heart rate and the autonomic nervous system. *Journal of sports medicine and physical fitness,* 46(3), 425-430.

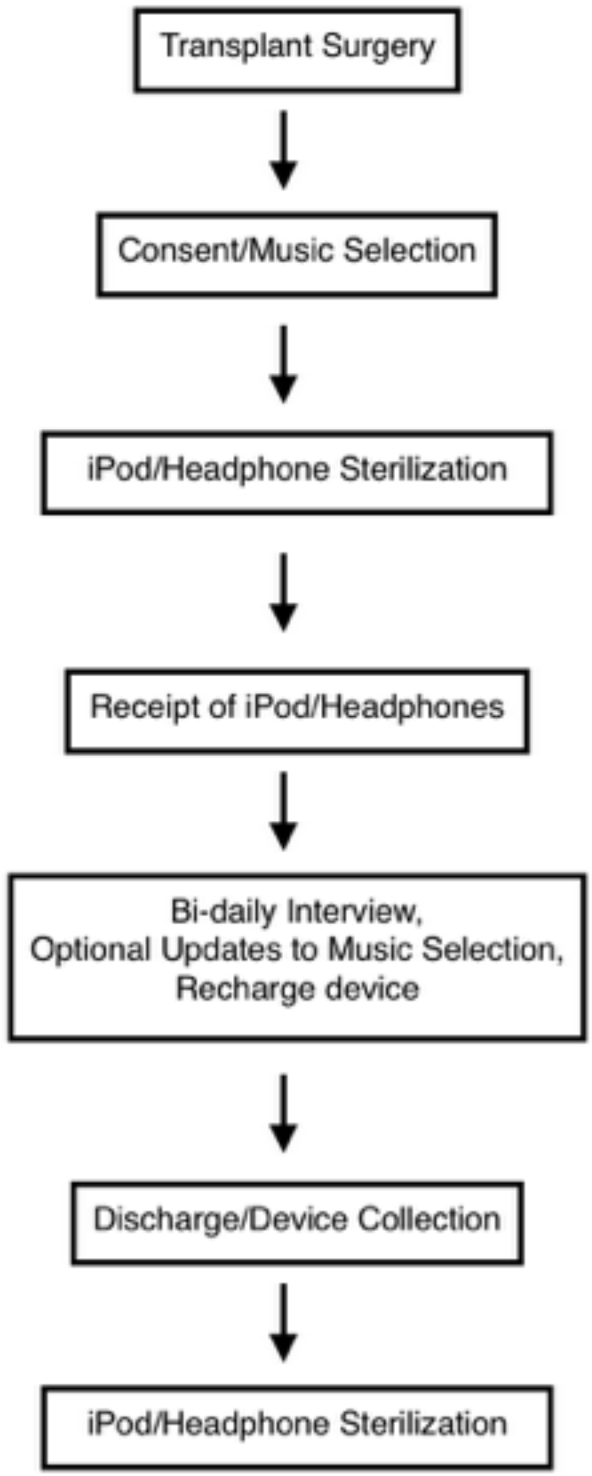
Yamasaki, A., Booker, A., Kapur, V., Tilt, A., Niess, H., Lillemoe, K. D., ... & Conrad, C. (2012). The impact of music on metabolism. *Nutrition,* 28(11), 1075-1080.

Zatorre, R. J. (2015). Musical pleasure and reward: mechanisms and dysfunction. *Annals of the new york academy of sciences,* 1337(1), 202-211.

Zhang, Y., Cai, J., An, L., Hui, F., Ren, T., Ma, H., & Zhao, Q. (2017). Does music therapy enhance behavioral and cognitive function in elderly dementia patients? A systematic review and meta-analysis. *Ageing research reviews,* 35, 1-11.

Appendix A: Historical Timeline

Appendix B: Methodological Schema



Appendix C: Musical Selections Form

Musical Selections

Above: Open-ended musical selection form.

Appendix D: Study Materials

Above: Fourth Generation iPod Shuffle

Above: Sony MDRZX110NC Over-Ear Noise Cancelling Headphones (Black)

Appendix E: Study Survey

Pt. #: ____________ Pt. loc.: ____________ Date: ____________

By placing a tick in one box in each group below, please indicate which statements best describe your own health state today.

Mobility

I have no problems in walking about ☐

I have slight problems in walking about ☐

I have moderate problems in walking about ☐

I have severe problems in walking about ☐

I am unable to walk about ☐

Self Care

I have no problems eating, washing or dressing myself ☐

I have slight problems eating, washing or dressing myself ☐

I have moderate problems eating, washing or dressing myself ☐

I have severe problems eating, washing or dressing myself ☐

I am unable to eat, wash or dress myself ☐

Communication & Sociability

I have no problems communicating or socializing ☐

I have slight problems communicating or socializing ☐

I have moderate problems communicating or socializing ☐

I have severe problems communicating or socializing ☐

I am unable to communicate or socializing ☐

Pain & Discomfort

I have no pain or discomfort ☐

I have slight pain or discomfort ☐

I have moderate pain or discomfort ☐

I have severe pain or discomfort ☐

I have extreme pain or discomfort ☐

Anxiety & Depression

I am not anxious or depressed ☐

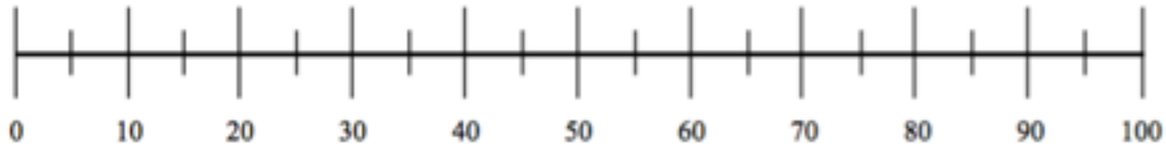
I am slightly anxious or depressed ☐

I am moderately anxious or depressed ☐

I am severely anxious or depressed ☐

I am extremely anxious or depressed ☐

Please indicate by marking an **X** on the scale below how good or bad your health is **today**. The scale is numbered from 0-100. 100 is the best health you can imagine. 0 is the worst health you can imagine.



Score: __________

Please describe the music you were listening to and how you think it affected your responses:

Additional Comments:

Appendix F: Study Interview Schedule

Pt #	Group	D0	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
1	Control	14 Jun 17	15 Jun 17	17 Jun 17	19 Jun 17							
2	Control	15 Jun 17	15 Jun 17	17 Jun 17	19 Jun 17							
3	iPod	16 Jun 17	16 Jun 17	18 Jun 17	20 Jun 17	22 Jun 17						
4	iPod	17 Jun 17	17 Jun 17	19 Jun 17								
5	Control	19 Jun 17	19 Jun 17	21 Jun 17	23 Jun 17							
6	iPod	19 Jun 17	19 Jun 17	21 Jun 17	23 Jun 17							
7	Control	21 Jun 17	22 Jun 17	24 Jun 17	26 Jun 17	28 Jun 17	30 Jun 17	2 Jul 17	4 Jul 17			
8	iPod	22 Jun 17	23 Jun 17	25 Jun 17	27 Jun 17	29 Jun 17	1 Jul 17					
9	iPod	29 Jun 17	29 Jun 17	1 Jul 17	3 Jul 17							
10	iPod	30 Jun 17	30 Jun 17	2 Jul 17	4 Jul 17	6 Jul 17						
11	iPod	30 Jun 17	30 Jun 17	2 Jul 17	4 Jul 17	6 Jul 17	8 Jul 17	10 Jul 17				
12	Control	1 Jul 17	1 Jul 17	3 Jul 17	5 Jul 17	7 Jul 17	9 Jul 17	11 Jul 17	13 Jul 17	15 Jul 17	17 Jul 17	
13	Control	6 Jul 17	6 Jul 17	8 Jul 17	10 Jul 17	12 Jul 17						
14	iPod	6 Jul 17	6 Jul 17	8 Jul 17	10 Jul 17	12 Jul 17						
15	iPod	7 Jul 17	7 Jul 17	9 Jul 17	11 Jul 17	13 Jul 17	15 Jul 17	17 Jul 17	19 Jul 17	21 Jul 17	23 Jul 17	25 Jul 17
16	Control	10 Jul 17	10 Jul 17	12 Jul 17	14 Jul 17	16 Jul 17	18 Jul 17	20 Jul 17	22 Jul 17	24 Jul 17	26 Jul 17	28 Jul 17
17	Control	12 Jul 17	12 Jul 17	14 Jul 17	16 Jul 17	18 Jul 17	20 Jul 17	22 Jul 17				
18	Control	12 Jul 17	12 Jul 17	14 Jul 17	16 Jul 17	18 Jul 17	20 Jul 17	22 Jul 17	24 Jul 17			
19	iPod	17 Jul 17	17 Jul 17	19 Jul 17	21 Jul 17	23 Jul 17						
20	iPod	21 Jul 17	21 Jul 17	23 Jul 17	25 Jul 17	27 Jul 17	29 Jul 17	31 Jul 17	2 Aug 17	4 Aug 17		
21	Control	21 Jul 17	21 Jul 17	23 Jul 17	25 Jul 17	27 Jul 17	29 Jul 17	31 Jul 17	2 Aug 17			
22	iPod	24 Jul 17	24 Jul 17	26 Jul 17	28 Jul 17							
23	iPod	29 Jul 17	29 Jul 17	31 Jul 17	2 Aug 17							
24	Control	2 Aug 17	2 Aug 17	4 Aug 17	6 Aug 17	8 Aug 17	10 Aug 17					
25	iPod	4 Aug 17	5 Aug 17	7 Aug 17	9 Aug 17	11 Aug 17						
26	iPod	5 Aug 17	5 Aug 17	7 Aug 17	9 Aug 17							
27	Control	5 Aug 17	5 Aug 17	7 Aug 17	9 Aug 17	11 Aug 17						
28	iPod	7 Aug 17	7 Aug 17	9 Aug 17	11 Aug 17	13 Aug 17	15 Aug 17	17 Aug 17	19 Aug 17	21 Aug 17		
29	Control	8 Aug 17	8 Aug 17	10 Aug 17	12 Aug 17							
30	Control	14 Aug 17	14 Aug 17	16 Aug 17								
31	iPod	16 Aug 17	16 Aug 17	18 Aug 17								
32	iPod	17 Aug 17	17 Aug 17	19 Aug 17	21 Aug 17	23 Aug 17	25 Aug 17	27 Aug 17				
33	Control	19 Aug 17	19 Aug 17	21 Aug 17	23 Aug 17	25 Aug 17	27 Aug 17					
34	iPod	21 Aug 17	21 Aug 17	23 Aug 17	25 Aug 17	27 Aug 17	29 Aug 17	31 Aug 17				
35	iPod	22 Aug 17	22 Aug 17	24 Aug 17	26 Aug 17							
36	iPod	22 Aug 17	23 Aug 17	25 Aug 17	27 Aug 17							
37	Control	24 Aug 17	24 Aug 17	26 Aug 17	28 Aug 17	30 Aug 17						
38	Control	24 Aug 17	24 Aug 17	26 Aug 17	28 Aug 17	30 Aug 17						
39	Control	24 Aug 17	24 Aug 17	26 Aug 17	28 Aug 17	30 Aug 17						
40	iPod	24 Aug 17	24 Aug 17	26 Aug 17	28 Aug 17	30 Aug 17	1 Sep 17	3 Sep 17	5 Sep 17	7 Sep 17	9 Sep 17	11 Sep 17
41	Control	25 Aug 17	25 Aug 17	27 Aug 17	29 Aug 17	31 Aug 17						
42	Control	27 Aug 17	27 Aug 17	29 Aug 17	31 Aug 17	2 Sep 17						
43	iPod	27 Aug 17	27 Aug 17	29 Aug 17	31 Aug 17							
44	iPod	29 Aug 17	29 Aug 17	31 Aug 17	2 Sep 17	4 Sep 17	6 Sep 17	8 Sep 17	10 Sep 17	12 Sep 17	14 Sep 17	
45	iPod	30 Aug 17	30 Aug 17	1 Sep 17	3 Sep 17	5 Sep 17						
46	Control	30 Aug 17	30 Aug 17	1 Sep 17								

Above: Study interview schedule. The participant's discharge date coincides with their final interview, except in the case of patients 15, 16, 40, who were admitted longer than the maximum amount of scheduled interviews.

Appendix G: Data Summary

```
> summary(ipoddata)
    Subject          Group          Day        
 Min.   : 1.00   Control: 84   Min.   : 1.000  
 1st Qu.:14.00   iPod   :104   1st Qu.: 2.000  
 Median :21.00                 Median : 3.000  
 Mean   :23.61                 Mean   : 3.367  
 3rd Qu.:34.25                 3rd Qu.: 4.250  
 Max.   :46.00                 Max.   :10.000  

      Mob           SelfCare        PainDis     
 Min.   :1.000   Min.   :1.000   Min.   :1.000  
 1st Qu.:3.000   1st Qu.:3.000   1st Qu.:3.000  
 Median :4.000   Median :4.000   Median :4.000  
 Mean   :3.537   Mean   :3.802   Mean   :3.561  
 3rd Qu.:4.000   3rd Qu.:5.000   3rd Qu.:4.000  
 Max.   :5.000   Max.   :5.000   Max.   :5.000  
                 NA's   :1       NA's   :1      
     AnxDep           QOL        
 Min.   :1.000   Min.   : 10.00  
 1st Qu.:4.000   1st Qu.: 50.00  
 Median :5.000   Median : 70.00  
 Mean   :4.356   Mean   : 65.84  
 3rd Qu.:5.000   3rd Qu.: 80.00  
 Max.   :5.000   Max.   :100.00  
                 NA's   :1       
```

Table 1: Summary of raw data. 46 Subjects, 84 surveys completed for control group, 104 surveys completed for iPod group, median number of surveys completed is 3.

Appendix H: Linear Regression

First, the call section is a restatement of the linear model formula used for the analysis. Next, the residuals section is a measurement of the difference between the actual observed values versus the predicted values. Goodness of fit may be determined by a symmetrical distribution across the five data points at a median of zero. In this case the median is not relatively close to zero, thereby indicating that the data is not symmetrical, which is expected, because the mean values of each QOL indicator were greater than 3.

Next, the coefficients section describes the intercept and slopes of the linear model. In this context the intercept is the average value of the dependent variable, which is the overall QOL score. The estimate is the value predicted by the linear model. The estimate for the independent variables is the slope of the intercept relative to that data trend. In other words, how much of the value of the dependent variable can be attributed to the value of the independent variable.

Then, the standard error is a measurement of how the average and coefficient estimates vary from the actual average value of the response (independent) variable. Ideally this value should be lower than the estimate coefficient, otherwise that could indicate that the predications made by the linear model are not very accurate. In this case, the standard error for three of the four independent variables is lower than the estimate; the exception is the pain and discomfort variable.

Next, the t-value is the number of standard deviations the coefficient estimate is away from 0. The further away the value is from 0, the more possible it is to reject the null hypothesis, or in other words, to state that there is a significant interaction between the two datasets. Again, the values for three of the four independent variables are relatively far from 0, with the exception of the pain and discomfort variable.

Finally, the last column on the right is a column of p-values, which is a measurement of the probability of observing a value that is equal or greater than the t-value in the previous column. Generally, a small p-value of less than 0.05 is considered statistically significant. This is indicated by a period to the right. As per the legend below, if the interaction is more significant R uses either one, two, or three asterisks next to the p-value of the intercept row. In this case there is a strong interaction between participants' ability to self-care and their overall QOL score, and a quite strong interaction between participants' mobility, and anxiety and depression to their overall QOL score.

The residual standard error is a measure of the quality of fit, defined as the average amount that the dependent variable will deviate from the actual regression. This value can be expressed as a percentage by dividing the residual standard error by the intercept. In this case: 17.2/7.047=2.44, meaning that any predication made from this data may be inaccurate by as much as 244%. This value is so high, because of the number of independent variables to account for when making a prediction, which all have different strengths of interaction, if at all. Related to this measurement is degrees of freedom, which is a calculation of the number of data points minus the number of factors.

To continue, the R-squared measurements are a measure of how well the model fits the data. The closer this number is to 1, the better the model accounts for the observed variance. In this case the multiple R-squared value is 0.3438. The adjusted R-squared value indicates that the subject’s responses about their mobility, self-care, pain and discomfort, and anxiety and depression, account for 32.93% of the trend of the overall QOL measure.

Finally, the F-statistic is a measurement of whether or not there is a relationship between the independent and dependent variables. Generally, the further away from 1 that this value is the stronger the indication of a statistically significant relationship. In this case the value is 23.7, thereby indicating there is likely a statistically significant relationship between the measures used and what is thought to be underlying these measures.

```
> summary(lm(ipoddata$QOL ~ ipoddata$Mob + ipoddata$SelfCare + ipoddata$PainDis + ipoddata$AnxDep))

Call:
lm(formula = ipoddata$QOL ~ ipoddata$Mob + ipoddata$SelfCare +
    ipoddata$PainDis + ipoddata$AnxDep)

Residuals:
    Min      1Q  Median      3Q     Max
-51.267  -9.452   2.667  11.125  41.125

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)          7.047      7.420   0.950 0.343503
ipoddata$Mob         5.448      1.429   3.814 0.000188 ***
ipoddata$SelfCare    3.210      1.350   2.378 0.018473 *
ipoddata$PainDis     0.940      1.577   0.596 0.551745
ipoddata$AnxDep      5.523      1.592   3.470 0.000651 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 17.2 on 181 degrees of freedom
  (2 observations deleted due to missingness)
Multiple R-squared:  0.3438,  Adjusted R-squared:  0.3293
F-statistic:  23.7 on 4 and 181 DF,  p-value: 8.917e-16
```

Table 2: Summary of linear regression model. Highly significant P-values for the interactions between mobility and overall QOL, as well as anxiety and depression and overall QOL.

Appendix I - ANOVA

In the ANOVA output the total sum of squares is a measurement that expresses the total variation that can be attributed to the particular factors, the independent variables. Mean squares is a ratio calculated by dividing the sum of squares by degrees of freedom, and the larger the ratio, the more the response, the dependent variable, is affected by the independent variables.

Analysis of Variance Table

Response: ipoddata$QOL

	Df	Sum Sq	Mean Sq	F value	Pr(>F)	
ipoddata$Mob	1	21442	21442.0	75.6220	2.83e-15	***
ipoddata$SelfCare	1	2471	2471.3	8.7160	0.0036006	**
ipoddata$PainDis	1	573	573.3	2.0219	0.1568739	
ipoddata$AnxDep	1	3561	3561.4	12.5604	0.0005089	***
ipoddata$Mob:ipoddata$SelfCare	1	41	40.6	0.1431	0.7057190	
ipoddata$Mob:ipoddata$PainDis	1	337	336.6	1.1871	0.2774661	
ipoddata$SelfCare:ipoddata$PainDis	1	135	134.8	0.4753	0.4915026	
ipoddata$Mob:ipoddata$AnxDep	1	8	8.1	0.0284	0.8663733	
ipoddata$SelfCare:ipoddata$AnxDep	1	143	143.4	0.5057	0.4779651	
ipoddata$PainDis:ipoddata$AnxDep	1	821	821.0	2.8954	0.0906585	.
ipoddata$Mob:ipoddata$SelfCare:ipoddata$PainDis	1	133	133.2	0.4696	0.4940892	
ipoddata$Mob:ipoddata$SelfCare:ipoddata$AnxDep	1	294	294.2	1.0375	0.3098525	
ipoddata$Mob:ipoddata$PainDis:ipoddata$AnxDep	1	2539	2539.0	8.9546	0.0031799	**
ipoddata$SelfCare:ipoddata$PainDis:ipoddata$AnxDep	1	874	873.8	3.0816	0.0809838	.
ipoddata$Mob:ipoddata$SelfCare:ipoddata$PainDis:ipoddata$AnxDep	1	15	14.8	0.0523	0.8194204	
Residuals	170	48202	283.5			

Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Table 3: Summary of ANOVA output. Again, highly significant P-values for the interactions between mobility and overall QOL, as well as anxiety and depression and overall QOL. Significant P-values for the interactions between overall QOL and Self-Care, as well as overall QOL and Self-Care+Pain and Discomfort+Anxiety and Depression. Less significant interactions between overall QOL and Pain and Discomfort+Anxiety and Depression, as well as overall QOL and Mobility+Pain and Discomfort+Anxiety and Depression.

Appendix J: Tukey's HSD Test

Tukey's HSD test operates by comparing the means of each level of each factor to the means of each level within that factor. The pertinent results are reported in the 'diff' and 'p adj' columns on the left and right. The 'diff' column calculates the difference of the two means being compared on the far left, and the 'p adj' column is the adjusted p value for multiple comparisons. If there were a significant interaction one would be able to observe consistently low p-values down the 'p adj' column.

```
> TukeyHSD(aov(ipoddata$QOL ~ factor(ipoddata$PainDis) + factor(ipoddata$AnxDep)))
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = ipoddata$QOL ~ factor(ipoddata$PainDis) + factor(ipoddata$AnxDep))

$`factor(ipoddata$PainDis)`
         diff        lwr      upr     p adj
2-1 -3.600000 -36.081004 28.88100 0.9980916
3-1 -1.650000 -32.686674 29.38667 0.9998955
4-1 11.610390 -19.262704 42.48348 0.8380955
5-1 14.938462 -17.049963 46.92689 0.6995068
3-2  1.950000 -11.595515 15.49551 0.9947303
4-2 15.210390   2.044001 28.37678 0.0146292
5-2 18.538462   2.935092 34.14183 0.0110209
4-3 13.260390   4.226382 22.29440 0.0007354
5-3 16.588462   4.270805 28.90612 0.0025278
5-4  3.328072  -8.571401 15.22754 0.9386646

$`factor(ipoddata$AnxDep)`
          diff         lwr      upr     p adj
2-1 -23.050000 -87.3020191 41.20202 0.8601286
3-1  -7.670981 -60.9214743 45.57951 0.9947168
4-1   4.706268 -48.3617979 57.77433 0.9992052
5-1   6.728718 -45.9774132 59.43485 0.9966887
3-2  15.379019 -22.8244851 53.58252 0.8013870
4-2  27.756268 -10.1925436 65.70508 0.2626890
5-2  29.778718  -7.6622883 67.21972 0.1874958
4-3  12.377249   0.2361847 24.51831 0.0433032
5-3  14.399699   3.9535473 24.84585 0.0018452
5-4   2.022450  -7.4499640 11.49486 0.9766572
```

Table 4: Summary of Turkey HSD output comparing the interaction between overall QOL and Pain and Discomfort+Anxiety and Depression. No significant interaction.

```
> TukeyHSD(aov(ipoddata$QOL ~ factor(ipoddata$SelfCare) + factor(ipoddata$PainDis) + factor(ipoddata$AnxDep)))
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = ipoddata$QOL ~ factor(ipoddata$SelfCare) + factor(ipoddata$PainDis) + factor(ipoddata$AnxDep))

$`factor(ipoddata$SelfCare)`
         diff         lwr      upr     p adj
2-1 -6.725490 -24.0456566 10.59468 0.8214381
3-1  8.217949  -7.6348807 24.07078 0.6097937
4-1 21.466667   7.3524579 35.58088 0.0004184
5-1 24.206863  10.2596919 38.15403 0.0000357
3-2 14.943439  -0.3065755 30.19345 0.0578215
4-2 28.192157  14.7585561 41.62576 0.0000003
5-2 30.932353  17.6743623 44.19034 0.0000000
4-3 13.248718   1.7689241 24.72851 0.0147862
5-3 15.988914   4.7151236 27.26270 0.0012375
5-4  2.740196  -5.9198871 11.40028 0.9067004

$`factor(ipoddata$PainDis)`
          diff        lwr      upr     p adj
2-1 -6.5530216 -36.824627 23.71858 0.9754180
3-1 -5.5295085 -34.455029 23.39601 0.9844956
4-1  0.2816298 -28.491438 29.05470 0.9999999
5-1  0.7681131 -29.044419 30.58064 0.9999942
3-2  1.0235131 -11.600619 13.64765 0.9994415
4-2  6.8346514  -5.436143 19.10545 0.5409174
5-2  7.3211347  -7.220874 21.86314 0.6362571
4-3  5.8111384  -2.608365 14.23064 0.3197894
5-3  6.2976216  -5.182172 17.77742 0.5559088
5-4  0.4864833 -10.603573 11.57654 0.9999513

$`factor(ipoddata$AnxDep)`
          diff          lwr      upr     p adj
2-1 -12.765385 -72.64690125 47.11613 0.9767659
3-1   4.410665 -45.21766370 54.03899 0.9991975
4-1  12.933100 -36.52521025 62.39141 0.9514561
5-1  14.207897 -34.91309771 63.32889 0.9310759
3-2  17.176050 -18.42880482 52.78090 0.6729875
4-2  25.698484  -9.66900178 61.06597 0.2688825
5-2  26.973281  -7.92094088 61.86750 0.2117547
4-3   8.522435  -2.79277897 19.83765 0.2350750
5-3   9.797232   0.06164074 19.53282 0.0477309
5-4   1.274797  -7.55329138 10.10289 0.9946615
```

Table 5: Summary of Turkey HSD output comparing the interaction between overall QOL and Self-Care+Pain and Discomfort+Anxiety and Depression. No significant interaction.

```
> TukeyHSD(aov(ipoddata$QOL ~ factor(ipoddata$Mob) + factor(ipoddata$PainDis) + factor(ipoddata$AnxDep)))
  Tukey multiple comparisons of means
    95% family-wise confidence level

Fit: aov(formula = ipoddata$QOL ~ factor(ipoddata$Mob) + factor(ipoddata$PainDis) + factor(ipoddata$AnxDep))

$`factor(ipoddata$Mob)`
         diff        lwr       upr     p adj
2-1 -8.219814 -24.018553  7.578925 0.6064264
3-1  9.832817  -3.975397 23.641032 0.2885551
4-1 21.204622   8.409083 34.000161 0.0000903
5-1 27.623669  14.020211 41.227128 0.0000008
3-2 18.052632   4.756012 31.349252 0.0022758
4-2 29.424436  17.182739 41.666133 0.0000000
5-2 35.843484  22.759623 48.927344 0.0000000
4-3 11.371805   1.836304 20.907305 0.0106107
5-3 17.790852   7.195852 28.385853 0.0000699
5-4  6.419048  -2.817460 15.655555 0.3128383

$`factor(ipoddata$PainDis)`
          diff        lwr      upr     p adj
2-1 -5.6981997 -34.997734 23.60134 0.9834662
3-1 -1.0589692 -29.055644 26.93771 0.9999730
4-1  1.5244340 -26.324683 29.37355 0.9998824
5-1  0.8538463 -28.001356 29.70905 0.9999899
3-2  4.6392304  -7.579520 16.85798 0.8331679
4-2  7.2226336  -4.654125 19.09939 0.4511962
5-2  6.5520460  -7.522995 20.62709 0.7018357
4-3  2.5834032  -5.565736 10.73254 0.9061137
5-3  1.9128156  -9.198343 13.02397 0.9895491
5-4 -0.6705876 -11.404524 10.06335 0.9998012

$`factor(ipoddata$AnxDep)`
           diff         lwr       upr     p adj
2-1 -24.1902350 -82.1488581 33.768388 0.7792417
3-1  -3.4387303 -51.4734122 44.595952 0.9996587
4-1   7.0531312 -40.8169915 54.923254 0.9942315
5-1   6.5198751 -41.0237639 54.063514 0.9956258
3-2  20.7515047 -13.7100198 55.213029 0.4614544
4-2  31.2433662  -2.9884122 65.475145 0.0917593
5-2  30.7101101  -3.0636017 64.483822 0.0938411
4-3  10.4918615  -0.4600022 21.443725 0.0674882
5-3   9.9586054   0.5356401 19.381571 0.0325806
5-4  -0.5332561  -9.0778602  8.011348 0.9998020
```

Table 6: Summary of Turkey HSD output comparing the interaction between overall QOL and Mobility+Pain and Discomfort+Anxiety and Depression. No significant interaction.

Appendix K: Graphic Representation

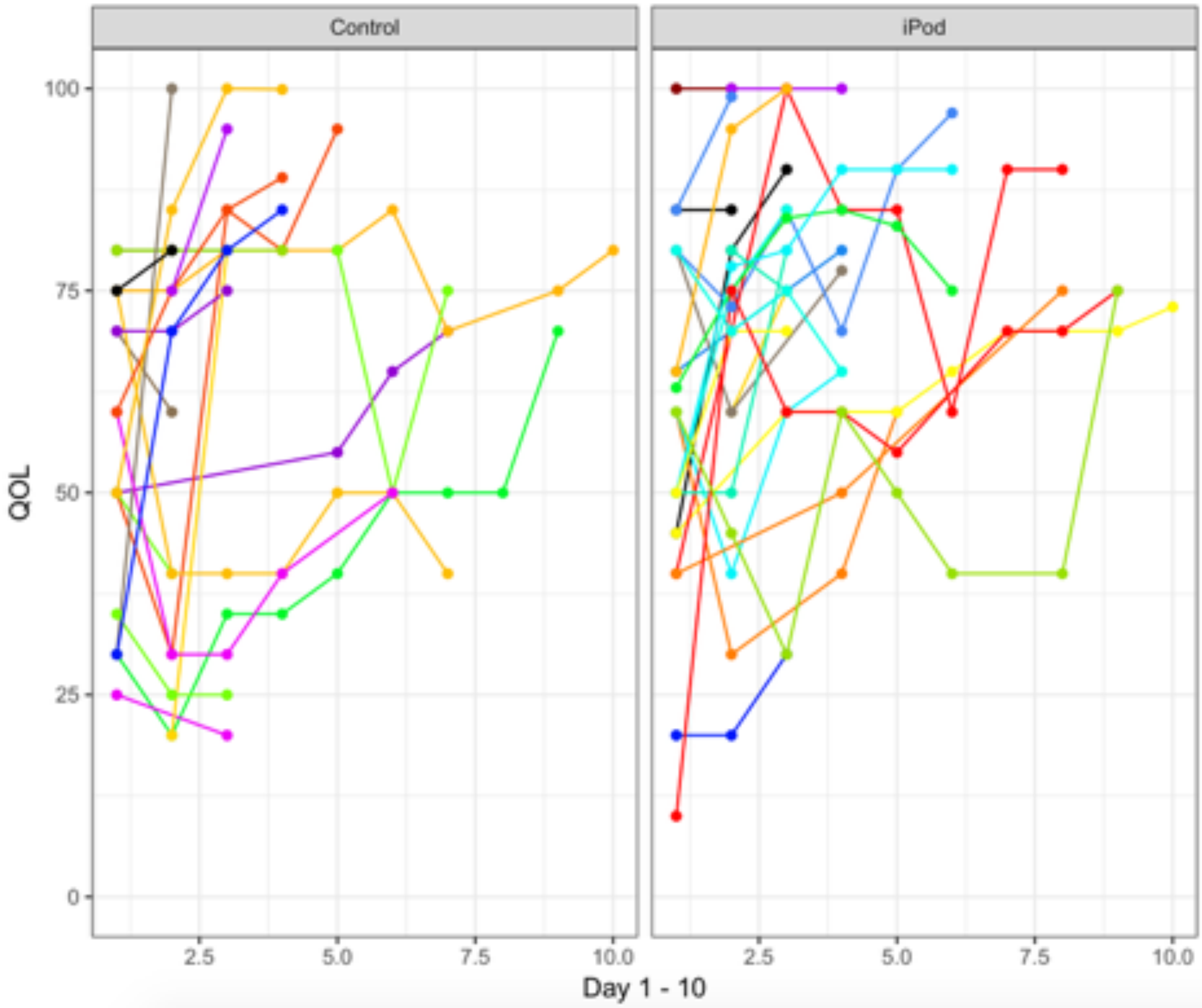


Figure 1: Overall QOL scores over time across experiment arms coloured by participant.

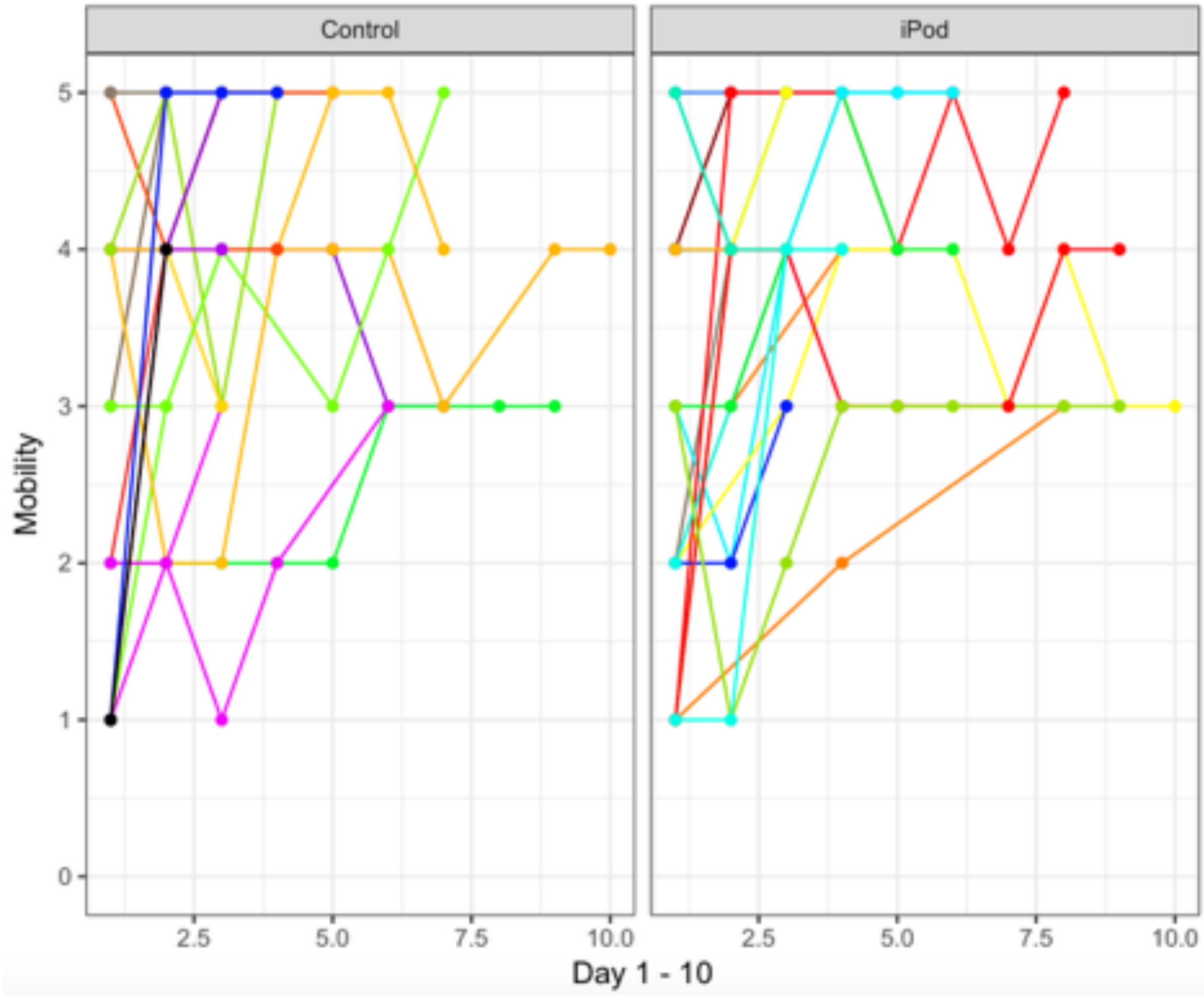


Figure 2: Overall Mobility scores over time across experiment arms coloured by participant.

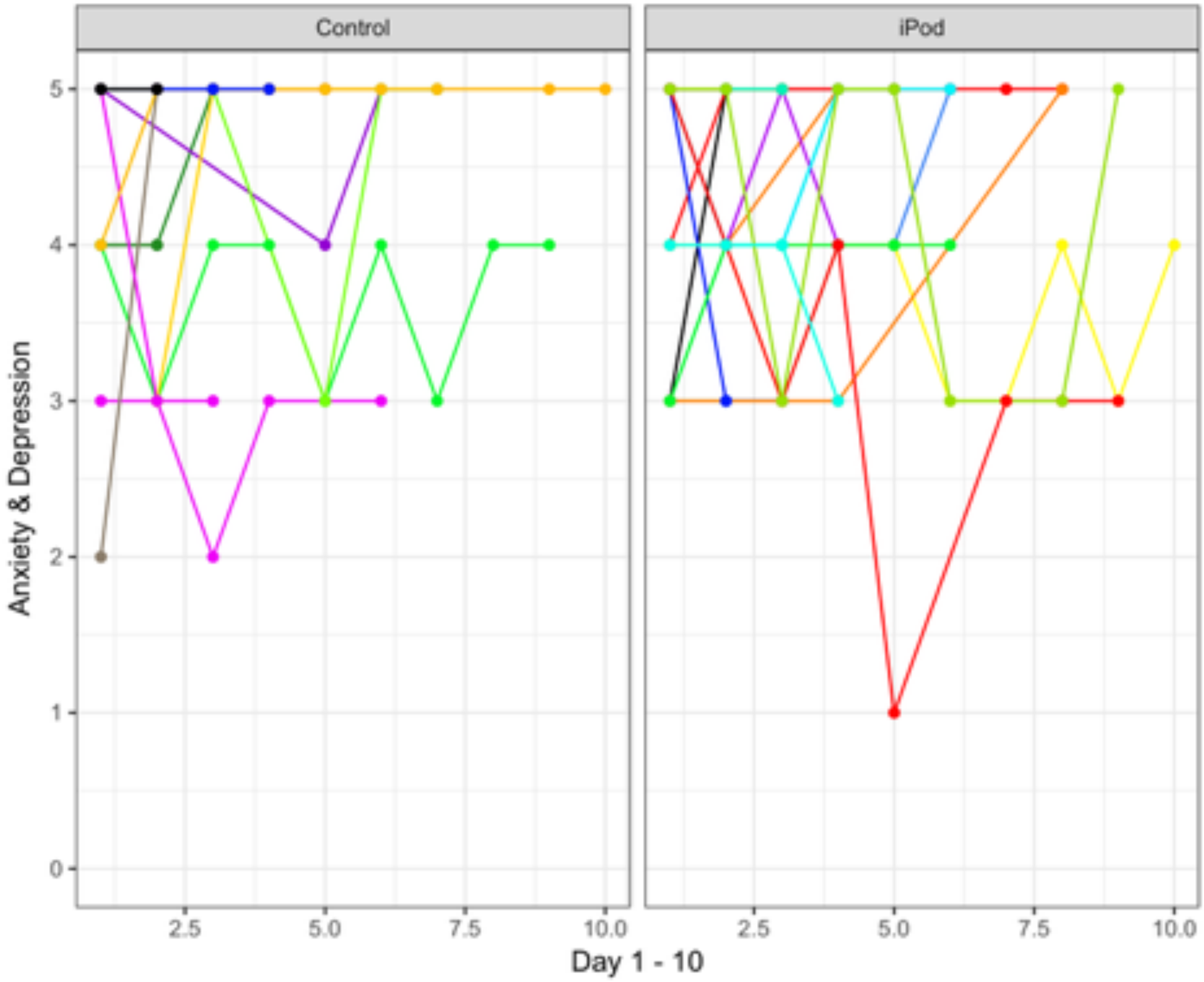


Figure 3: Overall Anxiety & Depression scores over time across experiment arms coloured by participant.

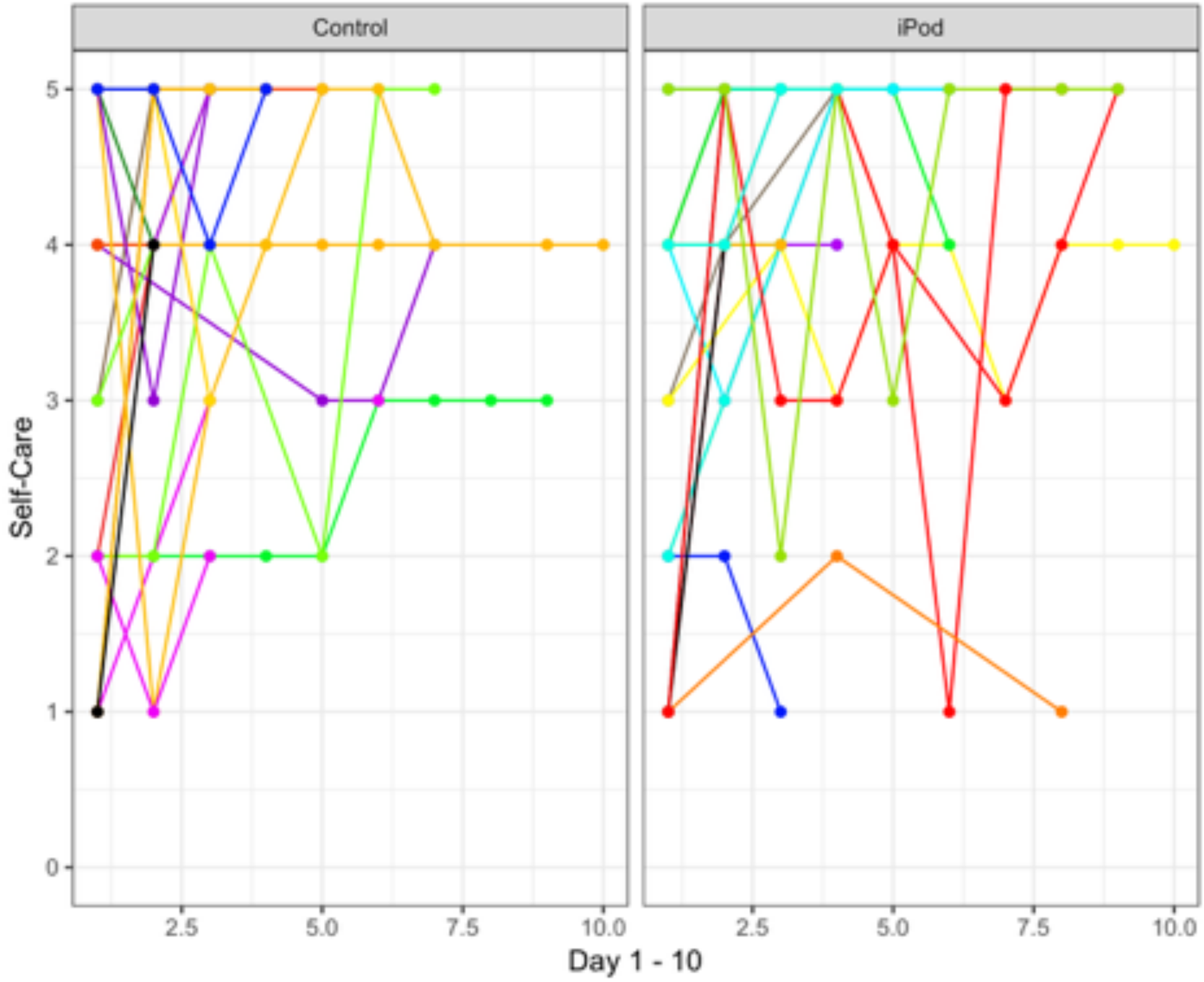


Figure 4: Overall Self-Care scores over time across experiment arms coloured by participant.

Appendix L: Qualitative Thematic Analysis

Control	Both	iPod
• Tiredness, Not Sleeping Well • Unstimulated, Boredom • Positive Familial Presence • Disturbing External Noise • Didn't Want iPod • Wanted iPod	• Pain • Lack of Independence • Immobile • Nausea • Swelling • Anxiety	• Feel Relaxed • Helps to Sleep, Listened at Night • Blocks External Noise • Choice • Technical Issues • Music Complements Other Activities • Stimulates Memory • Feel Like Oneself • Enjoyability

Table 7: Themes of common responses across multiple participants and study groups