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These Go To Eleven! An Exploratory Analysis of the 'Loudness War' within Audio Recordings

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Bachelor of Arts

Sociology

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Advisor: Timothy J. Dowd, Ph.D.

An abstract of
A thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Department of Sociology

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Abstract

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In recent years, the music industry has increasingly engaged in certain audio editing practices that increasingly change and influence sound quality during the process of music production. These practices have developed into a trend commonly referred to as the ‘loudness war’—a phenomena distinguished by louder recordings and increased ‘sonic homogeneity’—the narrowing range of sound between the highest and lowest sound levels on an audio recording. Through performing a content analysis observing numerous non-scholarly print and internet resources, the ‘loudness war’ emerges as a trend affecting a wide range of industry personnel, whose cause is attributed to just as many parties—including record labels, radio stations, engineers, musicians and consumers. Further, this thesis follows its qualitative study with a quantitative, longitudinal statistical analysis of the ‘loudness war’ in compacts discs from 1982 to 2008. In doing this, this study found that the dynamic range of compact discs has decreased over time, while recording loudness has simultaneously increased. This trend is especially notable in compact discs of the Pop/Rock genre, which are distinguished by greater sonic homogeneity, while compact discs in the Soundtrack genre offer similar, but limited evidence in the same direction. Overall, this study aim to not only filling a gap in the sociological literature pertaining to the ‘loudness war,’ but also serves as a foundation for future analyses in this area.

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## 1. Introduction

When an artist creates, he or she partakes in making something original that previously did not exist. No matter how large, small, significant or inconsequential that creation may be, what sociologists call a ‘cultural object’ is born – be it a song, a painting, or a novel (Griswold 1994). With each new cultural object, there exists a certain potential for a message to be delivered from an artist to others—an idea, a concept, a notion that possesses an ability to impact a given audience. An artist can choose to transmit a particular message with his composition in whatever way he or she sees fits. Similarly, a receiver of a cultural work can decide to interpret its accompanying message in whatever manner he or she chooses. In this regard, the meaning of cultural objects resides in a highly subjective arena—one that is accessible to endless varieties of creators and receivers. Regardless of an individual’s basis of cultural knowledge—whether with a virtuoso’s magnum opus or a beginner’s first song, the familiarity of a full-fledged patron of the arts against a casual listener—one fact that prevails is a newfound exchange of ideas open to all, open to interpretation by anyone and everyone.

Much of the time, the flow of a cultural object is not as simple as an artist directly sharing his creation with a given audience. Rather, the passage of creative works goes through many other individuals before reaching a consumer. For instance, when viewing a visual medium, a cultural consumer can best absorb and understand the original intent of a creative work when it is beheld in the same light as the artist’s initial design. If an onlooker proceeded to observe a painting while wearing shutter shades or unfocused lenses, not only would one’s view objectively be obscured, but it would also distort the artist's subjective intention. Looking at George Seurat's *A Sunday Afternoon on the Island of La Grande Jatte* without a clear lens would undoubtedly conceal the meticulous placement of each precisely placed point. Likewise, if someone looked at Vincent Van Gogh's *Starry Night* or Pablo Picasso's *The Old Guitarist* for the first time, and the brilliant blues within these masterpieces had been toned down, that person would probably question the so-called genius of such painters, let alone have an altered interpretation of the original message sent by these works.

While the above instances are merely hypothetical, they are here to make the following point. If any changes of that magnitude were permanently made to a painting receiving a relative amount of mass exposure, because a corporate executive or copyright owner decided that this alteration might deliver more profits, the general art community throughout the world would be up in arms! Attempts to influence and manipulate the purity of the original message and its potential reception by cultural consumers would undoubtedly be questioned, if not abhorred, by many. Yet, change the setting from the visual arts to music, and these hypothetical examples become reality, without as much as a few whispers by handful of non-academic journalists regarding the substantial alteration of musical recordings.

In recent years, the music industry has increasingly engaged in certain audio editing practices that increasingly change, if not compromise, the quality of music released within mass markets. In particular, two procedures—compression and clipping—have become extensively employed in the audio production process as a common course of action. Compression and clipping themselves are not inherently bad for music quality, and in fact these practices can be constructive if implemented in the right way. Many have contended, however, that these practices are in fact not being used properly, resulting in a general decay of sound quality.

These practices have developed into the phenomena commonly referred to as the 'loudness war.' The emergence of the 'loudness war' has resulted in a trend distinguished by louder[1] records and increased 'sonic homogeneity'—the narrowing range of sound between the highest and lowest sound levels on an audio recording. This development has allowed for a 'war' to emerge between different parties in an attempt to make the loudest recordings, in order to gain the attention of consumers and others. While the bulk of this paper will go into extensive detail on the 'loudness war,' it will be helpful to briefly discuss compression, clipping, and their relation to this trend. Compression results when the distance between the high and low peaks of an audio signal is reduced, often with the intention of increasing the overall amplitude of a sound. On the other hand, clipping occurs when peaks and troughs of an audio signal are removed altogether. In brief, compression condenses the audio signal, while clipping modifies the sound wave. Together, these two practices work together to increase the level of loudness (amplitude) in a sound.

For various reasons that will be discussed throughout this thesis, record labels utilize compression and clipping to make their records louder. Record labels have often tended to adopt the mentality that increased volume—the level of loudness a recording is listened at—is more conducive to selling more records. Over time, different record labels have attempted to make their music louder than their competitors, in order to predetermine the mastered volume level, thereby catching the attention of consumers. In

[1] Loudness is defined here as an increase in amplitude within a given sound.

their perpetual efforts to have records at higher levels of loudness, record labels have started a battle in which each label attempts to one-up each other. Thus, the origin of the ‘loudness war’ developed as a recurrent audio editing trend driven in the interest of increased profits.

For numerous reasons, these audio editing practices carry substantial implications for the music released by performers and heard by many. As one writer sees it, “Without the peaks, Haydn's "Surprise Symphony" wouldn't be much of a surprise. Without the peaks, Elvin Jones' drums wouldn't carry the same emotional impact” (“Declaring an End to the Loudness Wars” 2008). Despite the major repercussions that arise from these processes, they are often overlooked, and are even unheard by many consumers. These practices carry major implications on the music released and listened to for numerous reasons, of which my research will investigate. Before turning to the two focuses of my thesis research, I first outline the historical context in which the ‘loudness war’ has developed.

## 2. History of the ‘Loudness War’

Some argue that the current ‘loudness war’ has long roots extending as far back as the early 1960s. At that time, record companies noticed a recurring trend that louder songs playing in jukeboxes tended to receive more attention than quieter ones (Southall 2006). Radio stations also became affected by this trend, as record labels would send their compilations of new singles to radio stations on a single vinyl record. Producers and artists competed with each other to have the loudest single on that one record, so that their works would have a better chance of being noticed. This radio competition was not only amongst singles on a compilation, but also with songs played on the radio, as competing parties in the industry desired to have their music be played louder than everyone else's music (Donahue 2008).

The 'loudness war' for vinyl records, however, was limited by the era's technological capabilities. Due to their technological limitations, vinyl records have a limited dynamic range—the difference between the highest and lowest pitches on a recording—which resulted in a trade-off between loudness and playing time. One online journalist stated, "The louder a song was, the wider the groove needed to be in order to accommodate the larger amplitude…gaining loudness meant sacrificing playing time…playing time usually won out over loudness" (Sreedhar 2007). Despite the ongoing trade-off, radio still created a demand for louder recordings—increasing the use of "hot" records, whereby mastering a record solely emphasized loudness over playing time. "Hot" records typically only contained one song per side of an LP (Sreedhar 2007).

The emergence of compact discs (CDs) brought about the introduction of digital audio, eliminating the primary problems associated with vinyl records—surface noise and limited dynamic range (Sreedhar 2007). Where there was once variability on a record due to the trade-off between loudness and playing time, digital technology brought forth a new and unique set of technological boundaries.  Compact discs have the ability to handle loudness levels without sacrificing playing time, however, they hold definite limits to loudness and dynamic range—digital zero dB—at which point distortion begins to occur (Levine 2007). While compact discs definitely possess some advantages over vinyl records, there are still sizeable limitations inherent within this medium.

Once compact discs overtook vinyl records during the 1980s as the predominant audio format available in mass markets, the ‘loudness war’ slowly regained the momentum that was stalled by vinyl’s limitations (Donahue 2008). Upon the emergence of compact discs, albums were initially mastered[2] with an emphasis on maintaining the wide dynamic range and high fidelity found in the oriinal studio recordings, even if that came at the expense of loudness and the final product sounding ‘too quiet’ (Rowan 2002). As average sound levels began to increase slowly over time, elimination of ‘headroom’—the distance between peaks and digital zero—occurred (“The Death of Dynamic Range” 2008). The loss of headroom contained major implications, as one mastering engineer expressed, “Over time, musical peaks, and then average volume, crept closer and closer to that limit, in time exhibiting squashed dynamics, increased clipping, and flat-topped waveforms—a new ‘wall of sound’” (Jones 2005). Once an album’s loudness level reaches the digital zero limit, the only way to raise the average levels of songs without having their loudest parts clipped was to compress the peaks (Sreedhar 2007).

Many individuals not only see the ‘loudness war’ as key historical trend in audio editing, but also a cause for concern in both the present and future. Crossing the digital zero ‘wall’ results in distorted sound in ways that will be discussed in later further detail. Music that is released today typically has a dynamic range only a fourth to an eighth as wide as that of the 1990, meaning that the new one is likely to sound four to eight times as loud as the older recording (Smith 2008). If this trend continues, sound quality will further deteriorate due to the heavily abused practices of compression and clipping. As a

[2] Mastering entails finalizing and transferring recorded audio from a source containing a final mixed recording to a data storage device.

result, louder, less dynamic music will become the rule, rather than the exception. Listeners will suffer the consequences, in a number of ways discussed over the course of this thesis.

## 3. Focus and Goals of This Thesis

This thesis observes the ‘loudness war,’ its related audio editing practices, attitudes of those working in relation to this trend, and the resulting consequences faced by consumers. These techniques’ primary use is to increase the overall loudness of compact discs through the manipulation of sound recordings. This topic is important because it involves the transfer of music from producers to consumers, and can modify the final released product, often in a similar manner to the altercation in paintings mentioned in the introduction. A variety of non-scholarly resources—ranging from music periodicals to informal studies of song wavelengths—has been published discussing this trend; however, none of these articles are scholarly, nor are they comprehensive in their measures of this phenomenon. My goal is to address a gap in academic literature concerning music production by thoroughly examining the ‘loudness war.’ This paper will look at the audio editing practices used since the emergence of compact discs, the technology’s impact on sound quality, and the resulting consequences faced by consumers. In order to gain a comprehensive understanding of this phenomenon, my approach to studying the ‘loudness war’ is twofold.

First, I plan to analyze the previously mentioned non-scholarly resources, which consist of articles found in websites ranging from professional music periodicals to informal studies about song wavelengths. My goal is to analyze these authors’ views on audio editing practice usage over time, seeing their perceptions of how these audio editing practices affect both the music itself and the consumers' experience with this music. With a better idea about attitudes and opinions held towards the 'loudness war,' I then plan to analyze quantitatively the 'loudness war' itself, measuring sound levels of popular music compact discs from 1982 to 2008, in an attempt to determine the validity of opinions surrounding this prescribed trend.

Numerous scholars have researched the various means by which the corporate interests of the music industry, combined with their control of music production, may have led to increased homogeneity. For example, scholars have observed the increasing dominance of a handful of recording companies and how they have influenced the amount of performing acts available, the gender and racial composition of those acts and the range of music material within their hit songs (Dowd 2004a). Essentially no scholarly literature, however, has explored the uses of audio editing practices as a tool frequently implemented by the music industry–practices that could likewise lead to a type of homogeneity in which recordings are similar in terms of the acoustic dynamics. My research will explore a mostly overlooked technological practice as well as continue research concerned with the flow of cultural goods between producers and consumers. Given this, it is helpful to describe previous research pertaining to this thesis before turning to my own work.

## 4. Literature Review of Relevant Sociological Perspectives

Much sociological thought regarding popular music has arisen from the 'production of culture' perspective. This perspective and its related approaches have thoroughly been discussed in previous academic literature (Peterson and Anand 2004, Dowd 2004b). Sociologist Richard Peterson described this perspective as a "complex apparatus which is interposed between cultural creators and consumers" (Peterson 1978: 295). Cultural objects, such as music recordings, exist and circulate as a result of the collective works of many. While a single person may often be the initial creator of a composition, many others may also have an impact on the recording, production, and distribution of a given song. Consequently, the path of a cultural object between its creator and consumer can be hindered and filtered by numerous different individuals (e.g. mastering engineers, music producers) and organizations (e.g. radio stations, record labels). While some of these effects are the results of the musician and others related in hands-on creation of the music, others are involved in this process through the business side of the music industry.

Paul Hirsch's culture industry system model (1972) provides an early example of the 'production of culture' approach through its look at the flow of cultural goods from creation to consumption and back, identifying the major players in the mass media industry. Hirsch's model helped to demonstrate how key decision-makers formulate decisions in product selection based on past successes, which were consequentially decided via ongoing consumer feedback. Using what decision-makers currently perceive as hits, their choices in turn shape future releases and subsequent dissemination (Hirsch 1972, pp. 639-59). Knowing this, his diagram helps to emphasize the route a cultural product will pass through, thus depicting a system where various gatekeepers "regulate and package innovation… transform[ing] creativity into predictable, marketable packages" (Griswold 1994, p. 72).

In the years following Hirsch's work surrounding the culture industry system, many scholars have further contributed to the 'production of culture' perspective. The 'production of culture' approach aims to reveal the instances in which 'cultural objects' are impacted, examine the individuals involved in the creation process, and understand how these patterns work in order to make a cultural object's production more predictable. R.A. Peterson and N. Anand (2004) provided a detailed summary of the work within this perspective. In particular, their work examines research done within what Peterson previously identified as six major "facets of production"— law and regulation, organization structure, occupational careers, market, industry structure and technology. These facets highlight broad areas in which gate keeping occurs in the 'production of culture' theory. In essence, much work builds upon Hirsch's model by detailing these factors and their role within the cultural industry system.

The gate keeping factors observed in the 'production of culture' approach, as seen in the early formulation of the cultural industry system by Hirsch, has brought about a widespread assortment of scholarly literature, falling in line with these "facets of production" which result in further predictability of the flow of cultural goods. This literature includes discourses on industry structure through record labels, distributors, and their use of business and management strategies (Negus 1998). Keith Negus discusses organization structure through practices used by major corporations that predominantly control the record industry. For instance, he discusses the manner in which record label personnel strategically place their music into particular genres in order to maximize profit and decrease uncertainty, thereby turning a cultural object into a more objective, measurable good. Law and regulation have been discussed in great detail, including Tom

McCourt and Patrick Burkhart's work (2003) on the case of Napster as an innovative and emerging form of online music distribution at the turn of the 21st century. In this case, record companies launched legal battles against these new forms of distribution that were contesting their market dominance. In doing so, they strived (and in the case of Napster succeeded) to have regulatory laws implemented in for their own self-interest. Gabriel Rossman (2004) cites a detailed description of how the market of country music fans demanded that the Dixie Chicks' music be dropped from the radio airplay after making critical political comments about former President George W. Bush Jr. Not only did the market play a role in the face of uncertainty in this instance, forcing the Dixie Chicks to realign themselves with the adult contemporary market, but it also reflected on the occupation careers of musicians, and exhibiting how their roles as musicians can interrupt the type of music they choose to offer.

Furthermore, two of the facets indentified by Peterson and Anand are relevant for the purposes of my research. Numerous sociologists have researched the manner in which the structure of the recording industry has implications for homogeneity. Sociologist Timothy Dowd has further elaborated on these industry structures in his own research through his analysis of the different factors that can either constrain or facilitate musical production. Specifically, portions of his work have examined the implications of a "concentrated" industry structure marked by the domination of only a handful of firms. During the 1940s to the mid-1950s, these corporations pursued conservative strategies, including the reliance on certain stars and genres, as well as attempts to prevent competition from rising organizations. These corporations became increasingly dependent on these practices as their dominance grew, producing more homogeneity through fewer new acts, limited amounts of women and narrow amounts of African-American performers. Between the mid-1950s to 1990, these powerful corporations changed their strategies in response to the outbreak of genres like Rock and R&B, implementing a less conservative strategy (Dowd 2004b). As a result, the music produced and released by corporations became less homogenous in the case of performers and musical content. It remains to be seen, however, is if the industry structure after 1990 reflects strategies increasing or decreasing homogeneity.

Substantial literature has also been directed toward the final facet relevant for the production of music—technology. When looking at technology in past works, Dowd has examined the ways in which new media technologies became widespread and accepted within a mass market. In this area of his research, Dowd examined the processes and influences that allowed for new formats to become widely institutionalized. For example, Dowd discussed the development of vinyl records in the mid-20$^{th}$ century, and how the different technological limitations of 78rpm, 45rpm, and 33$^{1/3}$ rpm records caused each format to be accepted on the mass-market in different time periods (Dowd 2005). Additional literature focuses more on the implication of digital technologies for music production and dissemination. Gabrielle Cosentino (2006) addressed the creative processes behind the iPod, highlighting the technological processes behind its formulation, detailing the rise of the portable music player and how it emerged to become a widely accepted listening device. Martin Peitz and Patrick Waelbroeck (2005) focused their research on the Internet's role as a technology changing the way people consume music, citing P2P servers, online retailers and other Internet-based organization in changing the way music distribution occurs.  Within the above mentioned works addressing technology, their focus remains on how musicians and organizations tend towards the same technological formats for releasing music recordings. In this regard, homogeneity exists within their use of technological practices. However, they tend to overlook whether sonic homogeneity exists as a result of these technological formats.

When looking at the 'production of culture' and its emphasis on homogeneity, especially in regards to industry structure and technology, it would seem that the 'loudness war' would be a prominent topic in this strand of literature, given that the trend dates back nearly 50 years. Yet, only in the past decade has there been *anything* written about the 'loudness war,' nearly all of it coming from non-scholarly sources. These individual articles have not comprehensively exhausted 'sonic homogeneity' as an issue, either focusing on specific nuisances without much regard for the big picture, or offering general overall details at the macro-level without any exploratory depth. Furthermore, there has been an extremely inadequate look at the 'loudness war' from a quantitative perspective. This is vital in understanding this phenomenon in order to know the degree in which the 'loudness war' occurs at, as well as determining the direction of the 'loudness war'—that is, whether or not dynamic ranges are in fact decreasing over time. Of the little analysis does on this level, nearly all of that has come in the form of case studies comparing 'good' and 'bad' examples of this the 'loudness war.' While this approach serves as a great informal introduction to this phenomenon, it by no means provides any substantive evidence on the degree these practices occur over time—something that my research addresses.

## 5. Research Questions

The common denominator within ‘production of culture’ research remains that the final products passing through the culture industry system can become less innovative and more predictable. A variety of limiting factors in the ‘production of culture’ method are collectively produced and disseminated by corporate institutions as a means to decrease the uncertainty and risk involved on their end. The issue of sonic homogeneity presents an additional implication that exists within the music industry inhibiting a cultural object’s passage from creator to consumer. Despite being overlooked in the past by researchers, the audio editing practices impacting sound quality should follow suit with other tools manipulated by music industry institutions—leading to increased predictability and decreased creativity and innovation.

The purpose of this thesis is to create an exploratory analysis outlining the practices and implications of the ‘loudness war.’ With that intent in mind, my research foci are twofold: a qualitative study assessing the outlooks and attitudes of industry personnel regarding the ‘loudness war;’ and a quantitative, longitudinal statistical analysis of the ‘loudness war’ from 1982 to 2008. By examining this phenomenon in two different manners, I hope to address a gap within academic research concerning this ongoing practice, and that this broad study offers a starting point for future research into this practice.

By assessing the current views scattered across numerous types of music industry personnel and participants, the qualitative portion of this paper will attempt to provide a thorough content analysis of the outlooks held in regard to this practice. In particular, this article will focus on the following five areas:

1. *Technological processes associated with sonic homogeneity*
2. *Associated parties involved and their views on the use of technology*

3. *Reasons for the emergence of the 'loudness war'*
4. *Observed implications and effects*
5. *Reactions and solutions to sonic homogeneity*

With these five sub-sections, my goal is to aggregate views and foci of those familiar with the 'loudness war,' and combine them into a fluid framework representing these trends and their intrinsic properties.

Once the first section of this paper establishes a detailed representation of the 'loudness war' in its entirety, a quantitative examination will be conducted in order to understand the characteristics of the phenomenon *itself.* That is, I will be measuring the dynamic range and loudness of compact discs. While the qualitative component of this paper functions as a comprehensive view of the 'loudness war' from up close, this statistical examination measuring the dynamic range of recordings will hopefully offer a more concrete and objective supplement supporting the existence of the 'loudness war.'

From this point forward, this paper will proceed by first looking at the qualitative section. Here I will elaborate on the methodology and subsequent results. I will then continue into the quantitative portion, again detailing my methodology and findings. Once both components have been exhausted, this paper will conclude with a discussion of the general implications of my findings, as well as suggest additional routes for which the 'loudness war' could be further studied.

## 6. Qualitative Analysis of Attitudes and Outlooks from Industry Participants

### ***<u>6.1 Qualitative Methodology</u>***

In order to understand fully the processes and views surrounding sonic homogeneity and the ‘loudness war,’ I looked at a variety of non-scholarly internet articles. These sources arose from several different areas, ranging from newspapers and magazines, to engineering and audiophile websites. Depending on the source of a given article, the content ranged from a broad and general overview to a detailed analysis of specific technological aspects. The wide variety of articles contributed to a data set that was both in-depth and exhaustive of all issues concerning sonic homogeneity.

I was able to find 23 articles pertaining to the research at hand. In finding these stories, I utilized search engines including Google, Yahoo, Wikipedia and MSN to find articles pertaining to this subject. Once I found some initial articles, I used their bibliographies to uncover further articles pertaining to this issue. I continued finding content in this manner until I had exhausted all possible avenues. While this is a relatively small set of articles, this can simply attributed the overall lack of literature of any kind pertaining to this issue. Once these articles had been gathered, I thoroughly read each article with the goal of extracting both common themes and specific details. To simply put it, my goal is to unveil the basic accounts of others better understand the who, what, where, when, why and how regarding the ‘loudness war.’ In order to extract relevant data of these articles, content analysis was used to explore perspectives on the five areas mentioned:

1) *Technological processes associated with sonic homogeneity:* This examines the techniques applied in the various stages of recording production, both looking at

the specific uses of technology and their ensuing impact on the final cultural object created.

*2) Associated parties involved and their views on the use of technology:* Here we look at the different parties involved in the technological practices, consider what stance each group holds, and determine the motivation behind each group's respective position.

*3) Reasons for the emergence of the 'loudness war:'* This point deliberates what factors are responsible for why loudness is so desirable in music, and why the ever-increasing demand for louder music has occurred for decades.

4) O*bserved implications and effects:* This part discusses the repercussions and consequences of increasingly louder music, entailing both the music itself and the listeners that are exposed to louder music.

*5) Reactions and solutions to sonic homogeneity:* Finally, we see the reaction of certain groups, past solutions and their effectiveness, and future courses of action needed to deter the 'loudness war.'

Having these five criteria in mind, I performed a content analysis on the articles, reading each article in search for the details within these criteria. When one area was mentioned, I proceeded to examine that section further and mark down the details of that criterion, entering it into a detailed table. Once I read through all 23 articles, I added the results for each area of discussion, which are presented in the subsections below.

## ***6.2 Qualitative Results***

TABLES 1-5 show the results of the content analysis performed on the 23 non-scholarly articles. The five tables below each contain the respective sub-categories for the five respective areas mentioned above. Within each of the five major areas looked at, numerous factors were cited. However, this paper will only go over the ones that either occurred more frequently or that were deemed of significant interest to the issue of sonic homogeneity.

**6.2.a Technological Processes Associated with Sonic Homogeneity**

Two main methods—compression and clipping—are identified as the main technological audio editing practices used in the 'loudness war.' As journalist Mark Donahue (2008) states, "Much of the loudness revolution has been brought about by new technology in the studio. High quality digital limiters and compressors have completely changed the way we think about compression and loudness…it is incredibly easy to do more harm than good." As TABLE 1 shows, all but one article referenced compression, and approximately half of the articles cited clipping.

*6.2.a1. Compression*

Audio compression can be defined as "bring[ing] up the lower level [audio] signals while generally, but not always, maintaining the higher amplitude signs at their present levels" ("Current Trends in the Recording Format Arena" 2008). This process increases the average volume level of a recording, and can enhance the sound of a record if used properly. When employed correctly, the practice is referred to as 'normalization'—the "way to get the audio as loud as it can be without changing the dynamics whatsoever…it is the proper technique to get the hottest signal on CD with no distortion of the signal at all” (Rowan 2002). As writer Joe Gross comments, “When compression is used with discretion, it can be an ‘invaluable’ tool for recording engineers” (2006). Recordings can have their average volumes increased, while not sacrificing any of the song’s dynamic range.

Unfortunately, as part of the ‘loudness war,’ compression is not typically used with a priority to preserve the full dynamic range of a recording. Once you hit the ‘brick wall’—digital zero—the only way to make the recording louder is to continue compressing the audio signal (Speer 2001). Instead of maintaining the full dynamic range of a song, compression during the mastering process attempts to make a recording as loud as possible. In doing so, “quiet sounds and loud sounds are now squashed together, decreasing the recording’s dynamic range, raising the average loudness as much as possible” (Gross 2006). *Rolling Stone* writer Robert Levine points out that in sacrificing sound quality for loudness, “Compressed sounds initially seem more exciting. But the effect doesn’t last. The excitement in music comes from variation in rhythm, timbre, pitch, and loudness. If you hold one constant, it can seem monotonous” (Levine 2007).

### *6.2.a2 Clipping (Limiting)*

Another tool used in the ‘loudness’ war is clipping. Once a recording is compressed to the point where the highest (peaks) and lowest (troughs) audio signals hit the digital zero level, the sound is normalized—so that any further compression of the original sound file will result in distortion. The digital zero limit cannot be surpassed, and if a song signal attempts to, it will result in extreme distortion (“Declaring an End to the Loudness War” 2008). At this point, clipping can be used to increase loudness, albeit with the consequence of lower sound quality. Clipping "squeezes the sound range to one level, removing the peaks and troughs that would normally separate a quieter verse from a pumping chorus" (Sherwin 2007). FIGURE 1 provides a visual example of a sound wave before and after it has been "peak limited." As the example shows, clipping can substantially alter a recording. Joe Gross further discusses these implications in his piece, stating:

> When a sound wave squares off…, [it] means digital distortion, which different CD players handle different ways. Some just won't play that frequency, resulting in loss of dynamic range (you're literally not hearing the *whole* song). Some digitally distort, which is quite an unpleasant, static-like sound indeed. Some really old CD players skip the song entirely. (Gross 2006)

So while compression alters the average sound levels by bring the peaks and troughs of a signal closer together, clipping attempts to increase average sound levels by literally deleting the peaks off of a sound wave—actually destroying parts of the original sound wave in order to increase loudness.

### 6.2.b Associated Parties Involved and their Views on the Use of Technology

Four different parties play important roles in the previously mentioned cultural industry system. Each group not only has their own respective influence on the recording itself, but also faces implications as a result of the audio editing practices impacting sound quality. TABLE 2 shows that record labels and artists are mentioned frequently in the articles. While mastering engineers and consumers are not as frequently mentioned, their roles are of particular interest in understanding sonic homogeneity's overall impact. For each of the following groups, their roles and positions surrounding the technological impact on sonic homogeneity will be discussed. However, their motives for engaging in their perspective roles will only be discussed slightly in this section, as these explanations will be further looked at in subsequent sections.

*6.2.b1.Record Labels*

According to the 23 articles, the main supporters of technological tools aiding the 'loudness war' are the record labels. Rip Rowan believes that record labels utilizing this practice are less invested in the aesthetic side of music, instead merely "picking up on musical trends" and "replicating" them in other artists. He goes into greater detail in saying:

> Record labels have never really understood what makes a record "sound good" and frankly, few even care. Many of the people who sign artists don't understand their music at all….Over the past few years, record labels have increasingly attempted to dictate to the artist and producer the target volume level of the CD… Not caring to understand even the basics of audio, [they] simply demand more volume (typically from the mastering engineer) and really don't understand – or care – about the consequences of their demands. (2002)

In their pursuit for louder records, these companies are using "digital technology to turn the volume on CDs up to '11.'" By having increasing the volume, labels take the decision to turn up the volume out of the listeners' hands, opting to take control and make the volume louder themselves (Sherwin 2007).

*6.2.b2 Artists*

Many artists, in an ongoing battle to distinguish themselves from other artists, fully support this practice, in order to have their music stand out. While they are similar to the record labels with their support, they typically do not solely advocate this practice manipulating consumers (their own fans). Instead, this results primarily in competition with other artists. One engineer comments on this inter-artist competition by claiming that '"bands keep asking for it…They'll walk in with a handful of CDs and say, 'I want it to be loud as this one.' The last five years it's gone absolutely mad" (Gross 2006). In another article, artists respond to their own mastered work, wondering why their final product "doesn't sound as loud as Mariah Carey's record or Aerosmith's record or whatever band they listen to" (Jones 2005). The artist's rationale, in becoming part of this trend, appears to be out of fear of being at a relative disadvantage compared to other artists and their loudness levels. Artist involvement in the 'loudness war' appears reactionary, rather than causing the trend—a role that the record labels initiate.

However, not all artists fall victim to this war. In fact, some artists oppose this, such as Chris Walla of Death Cab for Cutie, who in opposing the 'loudness war,' responds that this feels like a "lonely battle," but does not want to record albums "as loud as possible simply because other bands are doing so" (Masterson 2008). Other artists that oppose this trend have taken steps to end the 'loudness war,' but these artists' actions will be looked into in detail in a later section.

*6.2b3 Engineers*

Engineers, on the whole, believe in using technology to bring out the best in music, by making it louder without expending dynamic range. Despite their personal beliefs on the issue, however, engineers shared the perspective that mastering is a "service industry," where the "client drives the master" (Jones 2005). Since record labels hire them to master a recording, mastering engineers feel that they have no choice but to follow through on the given order, even if that means going against their principles on the issue. That fear is only one part of their dilemma:

> Mastering engineers are caught in a Catch-22. If they do not deliver a product that is appropriately LOUD, then they are considered inept by the labels and are shunned. If they refuse to destroy the artist's music, then they aren't being "team players" and quickly fall out of favor. But if they provide what the customer demands (and remember, the label, not the band, is the customer) then they ruin a perfectly good piece of music, and they know that sooner or later, people are going to figure out why the sound is so horrible, and then the mastering engineer will be blacklisted for having followed orders (Rowan 2002).

As shown in this Catch-22, engineers face tremendous pressure in their work from other groups. Despite their own beliefs regarding sound quality, they are usually left with no choice but to fulfill their client's orders, or else risk having their own reputation either discredited or potentially face becoming "blacklisted" from future work.

*6.2b4 Consumers*

While not many articles discussed the consumer, they are an essential category to look at, as they are the receivers of everything that the previous three groups collectively produced. Some listeners "demand loud in-your-face recording…driv[ing] some of this" ("Current Trends in the Recording Format Arena" 2008). On the other hand, many consumers, unaware of the existence the 'loudness war,' may hold the idea that loudness existing in a compressed recording makes a song sound 'better' ("Declaring an End to the Loudness Wars" 2008). Most of these '*uninformed consumers'* (as I refer to them), do not know that they have the option between loudness and poor quality, or loudness with superb quality. Naïve to the fact that there is a better alternative, consumers show demand for the loudness that they are accustomed to loudness and poor quality.

**6.2c Reasons for the Emergence of the 'Loudness War'**

The 23 articles observed further explanation concerning the reasons that the previously mentioned groups would choose to endorse the technological practices that help sustain the 'loudness war.' TABLE 3 shows a relatively dispersed list of reasons, compared to TABLES 1 and 2. All five of these categories have approximately at least one-third or more of the articles mentioning them. Three of these—the 'Louder is Better' Perspective, Grabbing the Listener's Attention, and the Loudness Competition—will be explained together for the sake of descriptive clarity.

*6.2c1 'Louder is Better' Perspective, Grabbing the Listener's Attention, and Loudness*

The 'Louder is Better' perspective helps to explain why some players in the music industry either incite or sustain the loudness trend and why the compression and clipping processes are frequently used. While there is no precise, exact answer to where or how this perspective emerged, several different ideas offer support for why this trend exists. One way this may have started is through looking at how humans perceive sound. While the details of this field—psychoacoustics—fall outside the realm of this thesis, one generally accepted principle derived from this discipline is "that the louder sound will always grab our attention, and for short periods of time, sound better to us" (Donahue 2008). Another article adds onto the notion of sound perception, stating, "The roots of the loudness wars most likely took hold when someone realized that a very small increase in level is perceived by most listeners as sounding 'better.' And if a little is good, the thinking must have been, more will be better still" ("Declaring an End to the Loudness Wars" 2008).

As this view took hold, players in the music industry began to recognize and utilize this common notion. To these supporters, increasing the volume of a recording made perfect sense, as “The louder a song is overall, the more it stands out from ambient noise and the more it grabs your attention” (Sreedhar 2007). Raising the volume louder, creating “deafening tunes [that] are hard to ignore,” improves the odds that their music would grab listeners’ attention (Rowan 2008). As some record labels and artists started to raise their music’s average loudness levels, other competitors began to notice, and tried to raise their loudness levels even higher, in order to get noticed above their rival labels and artists who made the first move. Each group had an interest in doing this, as they “…want[ed] to have a loud product that stands out against its competition in a CD changer or a music store’s listening station” (Foti 2001). The end result developed into a volume contest known as the ‘loudness war’ (Levine 2007).

*6.2.c2 Radio*

The ‘loudness war’ expanded not only into personal CD changers or music stores, but also over the radio. The volume contest continued over this medium, with competitors believing that “…if a CD is pushing the absolute digital max it will somehow be louder or better on the air and presumably win more airplay and thus sell more copies to the public.” Because of this, there is a “belief that a ‘super-loud’ record will sound better and magically turn a song into a hit” (Graham 1999). Once again, the drive to have the loudest recording spiraled into the trend seen today as the ‘loudness war.’

However, the efforts pushing the ‘loudness war’ to the radio are relatively ineffective, mostly due to a tendency I shall refer to as ‘Radio Misperception.’ While record labels and artists continue to push for louder recordings, partially so that they can outdo their counterparts on the radio, many are in fact misinformed. This flawed belief is exposed by several of the articles, including one written by mastering engineer Bob Speer, who comments:

> Radio is the great leveler. It takes songs that are soft and dynamic, and brings them up in level to compete with the so called loud songs…Radio compressors are designed to drive peaks down. They will view a loud song as one huge peak and will reduce its overall level…Loud songs don't sound louder on the radio. They sound softer and distorted. The exact opposite of what was intended. (2001).

Therefore, not only do record labels and artists waste time and resources on compression and clipping for the radio, but they make their music sound *worse* than if would it have been left alone, since they had narrowed a given recording's dynamic range already through the initial use of compression (Foti 2001).

*6.2c3 Changes in Consumer Listening Patterns*

Music listeners have undergone a shift in the environments where they listen to and consume music. In the past, before the emergence of compact discs, the bulkiness of vinyl records restricted people in the type of places where they could listen to music. Record players were typically found and used in the homes of listeners, which tend to be relatively quiet as well as an ideal listening environment (Hennion 2001). However, the rise of portable media has allowed for music to be heard in numerous other places, many of which allow for consumers to be "…listening to songs in less-than-ideal environments on a constant basis" (Sreedhar 2007). These "less-than-ideal" places (e.g. in the car, while exercising) have enough background noise to the point where it becomes hard to hear certain parts of songs possessing a wide dynamic range. Compression makes a song louder, and allows one to hear the entire range by default since there is a smaller dynamic range. Sreedhar remarks on these changes by saying, "[with compression] listeners are now able to hear the entire song above the noise without getting frustrated by any inaudible low parts" (Sreedhar 2007).

### 6.2d Observed Implications and Effects

This section looks at the consequences resulting from the technological practices used in editing sound quality. TABLE 4 shows that lower sound quality and louder average sound, two items that go hand in hand, were discussed the most. Beyond those, three other points were relevant for their own individual reasons.

#### *6.2d1 Lower Sound Quality and Louder Records*

As the 'loudness war' increasingly employed both compression and clipping, lower sound quality and increased loudness simultaneously swelled. For this point, rather than debating what is 'good' or 'bad' sound quality, this paper will opt to list several highlights from the abundance of comments describing the implications of lower sound quality and increased loudness:

- "obscures sonic detail..." (Levine 2007)
- "tidal wave of aural blandness…" (Smith 2008)
- "The music loses something when pushed to extreme volumes…sacrificing its nuances and emotion for attention-grabbing sound." (Masterson 2008)
- "Overcompressing stuff gives everything a flatness…If loud sounds are the same as quiet sounds, you've destroyed any excitement or natural dynamics that the band creates." (Gross 2006)
- "It's like walking along a street and passing a construction zone where they have a jackhammer going. Due to the consistently loud noise, you have no choice but to cover your ears until it stops. Compare that to a fireworks display. You may cover your ears during the explosions, but

otherwise, things are much quieter and you could actually amplify the sounds around you and not damage your hearing…The high peaks get limited down so that the radio station doesn't exceed the signal level which it can transmit, but otherwise the rest of the audio actually gets raised in level, so that it comes out louder in the air." ("The Death of Dynamic Range" 2008)

- In December, 2001, several prominent individuals in the recording industry served on a panel to judge the best engineered CD for the Grammy's. After listening to over 200 CDs, they couldn't find a single CD worthy of a Grammy based on the criteria they were given. Everything they listened to was squashed to death with heavy amounts compression. What they wound up doing was selecting the CD that had the least amount of engineering. In reality, the winner didn't win because of great engineering, he won simply because he had messed with the signal the least. (Speer 2001)

This expansive list is not leaving out comments in favor of lower sound quality and louder records in an effort to show only one side of the argument. The matter of fact, however, is that there were no comments supporting lower sound quality and increase loudness.

*6.2d2 Ear Fatigue*

Louder music, as the result of compression, can have a negative physical effect on listener's ears, called ear fatigue. This occurs as compressed music "may tax our hearing, because the ears are never given a chance to rest" (Masterson 2008). If compressed music is consistently played loudly over time, ear fatigue can potentially have negative long-term consequences to one's hearing. This is more likely to occur with compressed recordings, rather than music with a wide dynamic range, because compression, taking the peaks and valleys out of sound, raises the average sound levels and creates a "full-on all the time aural assault" on the ears (Donahue 2008).

*6.2d3 Lowered Listener Expectations*

The ‘loudness war’s’ impact on records through lower sound quality and increased loudness expands beyond altering individual songs or albums. There is a “gross abuse of a good medium,” which if continued, could result in a “generation of children who are totally unfamiliar with reasonably undistorted music…” (“Current Trends in the Recording Format Arena” 2008). The ominous consequence of “a generation who doesn’t aspire to better because they haven’t been exposed to it” lies ahead if nothing is done to reverse the loudness trend that is ongoing (Greenwald 2008). Furthermore, additional repercussions are occurring at the moment:

> Many people today accept this hot sound because that’s all they know. They weren’t brought up on music that sounds ‘musical’. I can’t believe what we’ve done to our music. We’ve somehow allowed radio, with its limited dynamic range and frequency response, to become the standard for what sounds good. (Speer 2001)

Not only are there potential implications down the road for future generation, but there are also equally important implications relating to the present. People now have lowered expectations, as stated above, because the standards for ‘good’ sound are slowly evolving for the worse.

**6.2e Reactions and Solutions to Sonic Homogeneity**

In this section, numerous reasons have been cited; however, these reasons are speculation at best, as seen by the fact that none of these explanations occur in over half of the articles examined. The following section has been split up into three main sub-categories detailing: what has happened in the past, what has started to happen, and what potentially needs to be changed for the ‘loudness war’ to be stopped and reversed.

*6.2e1 What has happened so far*

Several attempts to improve sound quality beyond that of the compact disc have been made, but with little success. Initially two high-fidelity audio formats—DVD-Audio and Super Audio Compact Disc (SACD)—were thought to be solutions to the 'loudness war,' as they offer not only a greater dynamic range than CD but also higher sampling rates (Sreedhar 2007). Both of these have failed to become integrated within mainstream media production, in part because of the need for special audio equipment in order to play them (Levine 2007). Currently, Blue-Ray audio and Code have emerged as the next two attempts at creating a widely accepted high-fidelity format. Code has sparked interest, as it does not require any special equipment, just a DVD player or DVD-ROM drive (Greenwald 2008). Ultimately, however, the problem with high-fidelity audio formats does not so much lie with the technology itself, but instead remains with the listeners—which will be discussed in detail at the end of this section.

Recently, there has been a significant upturn in the rise and popularity of vinyl records, marking a revival of a once near-obsolete technology. This resurgence can partially be attributed to a small minority of people beginning to look for alternatives to compressed music. This does not mean that a return to vinyl records is the final answer, but as one article phrased it, "It's not necessarily that vinyl sounds 'better,'…It's that it's impossible for vinyl to be fatiguing" (Gross 2006). So in fact, the vinyl revival may just be a sign that some consumers are becoming fed up with the 'loudness war' and are ready for better audio technologies.

*6.2e2 What has started to happen*

Numerous artists have started to see that there is a choice with compression—that it does not need to be used in order to be competitive. Artist T-Bone Burnett believes that "the music industry's decline has left an opening for artists to influence quality standards" (Snider 2008). Various artists have been publicly outspoken regarding compression, including Bob Dylan, who commented on the issue, "You listen to these modern records, they're atrocious, they have sound all over them. There's no definition of nothing, no vocal, no nothing, just like – static" (Sherwin 2007). Some groups have even backed up their beliefs—such as the band Los Lonely Boys—who specifically requested that their hit record not be made loud. With only minimal sound manipulation used, the band managed to sell 2.5 million records. This example stands as evidence that success can be achieved through having a 'quality' record, rather than being noticed due to its loudness.

*6.2e3 What needs to change more before things are different*

All of the groups, reasons and actions described throughout this section make decisions based on the achievement of one goal—reaching consumers. This may be for a variety of reasons ranging from financial to aesthetic, all of which will be engaged based on ideas and strategies that will be most likely to attain the most listeners. Since these actions on the production side of the music industry depend on consumers, that means consumers have the real power in this structure, since they possess the ultimate decision to purchase over-compressed music or not. As one article observed, "Whether the loudness war can end and give rise to the next generation of high-fidelity audio depends heavily on the attitudes of consumers…How songs and albums will sound will depend entirely on whether or not the listener actually cares about the intricacies of the music" (Sreedhar 2007). If anything is going to change, consumers must be ready for change, as higher sound quality is a "function of people demanding better sound quality. That has to happen first before the [recording] industry's going to start producing it" (Sreedhar 2007). Once listeners begin to desire higher sound quality, only then can the 'loudness war' be reversed and sonic homogeneity's demise be declared.

## 7. Quantitative Analysis of the 'Loudness War'

With a deeper understanding of the implications that the 'loudness war' presents, this thesis will move forward with a quantitative analysis of the 'loudness war' to determine the degree of this phenomenon.

### ***7.1 Quantitative Methodology***

In order to better understand the ongoing trends surrounding levels of sonic homogeneity and the 'loudness war' over time, I chose to record and examine average and peak sound levels of compact discs from 1982 to 2008—the time frame that compact discs have been sold in the mass market to consumers worldwide (Dowd 2005). By measuring average and peak sound levels over this 28-year period, I was able to measure the general tendencies of dynamic range over this interval. In terms of measuring sound levels on digital recordings, I will use a computer program called the Tischmeyer Technology Dynamic Range Meter (TT-DRM). This application is available as a free downloadable program, and was utilized in order to find and log the major audio-related statistical categories of the compact discs examined. In short, the TT-DRM provided this study with a way to determine the direction and magnitude of the 'loudness war.'

Using this program, I then measure compact discs' sound levels over this 28-year time period. In choosing compact discs from 1982 to 2008, I opted to look at the five best-selling albums from each year, as determined by the annual year-end *Billboard 200* charts. My reasoning for this album selection was two-fold. First, as I stated above, 1982 marked the year in which Sony released the CDP-101—the world's first compact disc player. In that same year, compact discs found their way into retail stores for the first time. Therefore, this time frame represents the years in which compact discs have impacted mass media consumers, making it necessary to observe trends in compacts discs dating back to its origins. In addition, the need for multiple albums from each year allowed this study to better assess the longitudinal changes in sound levels within this time frame—an approach that has been commonly used by cultural sociologists such as Peterson and Berger (1975) and Dowd (2004a) when looking at time-series data. Next, I relied on the *Billboard 200* Chart—which tracks album sales—in order to determine which albums were the most consumed, and arguably the most relevant albums to the most amount of people each year. Furthermore, choosing popular albums makes the task of finding each disc a more feasible process.

On important matter to point out, however, is that the *Billboard 200* Chart has been a measure of overall album sales, not solely compact disc sales. What this means is that the chart compiles sales figures from all media formats—including vinyl records, cassette tapes and digital album downloads. Since compact discs were not the dominant format in its early years on the retail market, the *Billboard 200* Chart in those respective years may actually reflect a better representation of vinyl sales or cassette tapes. But the *Billboard 200* Chart does not distinguish amongst media formats, so there is no way of *exactly* knowing what compact discs sold the best.

That being said, I do make the assumption that the *Billboard 200* Chart is reflective of the bestselling compact disc sales. My reasoning behind this assumption is simple—even if the bestselling compact discs were not perfectly correlated with this chart, it does give us a rather good estimate of what most media consumers were purchasing in those years. This assumption is further supported by Dowd (2004a), where he notes a fairly strong overlap between album sales and single charts. Therefore, if many people were buying a chart topping album in one format, that same album most likely sold in comparable fashion for other formats, including compact discs. While the exact numbers and rankings may not be perfectly proportionate, these compact discs examined were probably in the same ballpark as their counterpart formats.

The compact discs needed could have been purchased at most record stores, and could have either been in new or used condition, since the quality of digital audio is not necessarily affected by wear and tear. However, all of these albums needed to be from their original pressing to ensure that the sound levels were at representative of the recordings during their initial release date (this means no recently remastered versions of albums). The need for albums from their original pressing was absolutely crucial to this study, so that the analysis of sound levels could be completed properly. If I would have used recently remastered versions of some of the older releases, these would not have been accurate measures of the original sound levels, since they would be marked with current levels of compression. By having the original albums, I was then able to capture the extent of compression and clipping in a longitudinal manner that accurately reflected the levels of sonic homogeneity over time.

With five compact discs for each of the 28 years, my desired dataset originally required the examination of 140 total compact discs. This number was slightly reduced for a couple of reasons. First, five artists during this time frame ended up on in the *Billboard* 200 year-end charts for two consecutive years. This meant that there were five less compact discs than the initially expected amount. Since these artists showed up in two different years, they were included in the averages for both respective years spent in the chart (these albums are essentially 'counted twice' as the result of their lasting impact). Of all the compacts discs on this list, only one album was excluded from this study (Hall & Oates – *H20 (1983)*). This album was not included because it was not released in compact disc format until 1990. This release occurred seven years after the album charted, so I opted to remove it from my dataset for fears of the album being remastered, and consequentially obscuring this study's analysis. When all was said and done, this thesis analyzed 134 compact discs over 28 years (see TABLE 6).

Once the list of compact discs was finalized, the prolonged process of acquiring these CDs took its course. The vast majority of these compact discs were obtained with the help of the Interlibrary Loan internet accessible database (ILLiad), a borrowing service connecting participating libraries worldwide. In using this system, I was able to obtain compact discs for an extended period of time without personally purchasing each one. For the reminder of compact discs not found via other libraries, I attained albums through Emory University own library, as well as my own personal collection of compact discs.

After I acquired each compact disc, I converted the digital audio on the compact disc itself into a .WAV file on my computer—a format that ensures lossless data compression. Having lossless compression is another essential step in accurately analyzing this data, as it ensures that the original sound levels and dynamic range do not become altered in the conversion process. Once each album was converted into .WAV files, I inputted the albums into the Tischmeyer Technology Dynamic Range Meter, which outputted the data needed to proceed with this analysis.

In terms of accruing data, the Tischmeyer Technology Dynamic Range Meter primarily measures two different statistics—dynamic range (DR) and root means square (RMS). Both of these figures are crucial in understanding and interpreting the results. Dynamic range, as described in previous sections, is the distance between the highest and lowest peaks of a sound level, in units of (dB). When dynamic range varies, the punch and clarity of a recording fluctuate accordingly. A higher amount of dynamic range translates into increased dynamics within a piece of music, while a lower amount of dynamic range results in decreased dynamics. On the other hand, root means square can be translated as the loudness of a sound wave, in terms of decibels (dB).

When the TT-DRM computes an estimate of dynamic range, it first measures dynamic range for each individual track on a given album. Then, the TT-DRM also produces the Official Dynamic Range—which can be determined by taking the mean dynamic range of an entire given album, and rounding the result to the nearest integer. The Official Dynamic Range represents the grade of compression of released music in an easy to understand and standardized whole number system. Since this measure, given its emphasis on ease of use, is not that precise, I decided to go through each album and recalculate the average of the dynamic range for each individual tracks, thereby creating a new, more accurate measure, which I refer to as Calculated Dynamic Range.

In a similar fashion to dynamic range, the TT-DRM also determines the root means square (RMS) for each individual track on a given album, providing an estimate for the average loudness within each song. Taking this number, I again took the mean of all the tracks on a given album, producing what I refer to as the Calculated RMS Average. With Calculated Dynamic Range measuring peak volume, and Calculated RMS Average assessing average loudness, I was able to appropriately operationalize measures needed to perform this quantitative analysis this portion of the study.

Before moving onto the results, I had one primarily concern about my dataset that I wanted to grasp more thoroughly. While observing the data closely, I noted that particular albums had certain tracks that appeared to be extremely large outliers (too quiet). These tracks were typically either introductions or interludes, consisting of people primarily talking. Since these tracks were not primarily music-based, including them was not vital, not to mention their tendency to skew the data. As a result, I created two new adjusted measures—Corrected Dynamic Range and Corrected RMS Average. These two estimators are nearly identical to their other respective counterparts, with the exception that both Corrected measures exclude these potential outliers. For the purposes of these two measures, I considered an outlier to be any individual track that fell greater than 4 dB away from the given album's Calculated Dynamic Range or Calculated RMS Average. I chose 4 dB because it seemed appropriate, as it captured most of the talk-heavy tracks that I was concerned with.

With these various indicators defined, I now proceeded to investigate longitudinal relationships within the ‘loudness war’ by running a series of simple and multivariate regressions. In doing this, my aim was to look general trends in dynamic range and loudness, as well as observe how these developments played out over time and across various genres. In order to accomplish this, I relied on two different programs—Microsoft Excel and STATA—for running the statistical analysis. Microsoft Excel handled the descriptive statistics, graphs and some single variable analysis. While Microsoft Excel works well with basic statistical analysis and graphing, its ability to perform regression analysis is limited to single-variable analysis only. Therefore, STATA, a more powerful statistical software package, was used to perform some addition single-variable regression analysis as well as all the multi-variable regression analysis.

Before moving forward, I would like to comment briefly that for the purposes of this thesis, my interpretation of the statistical analysis will be completed in a rather exploratory light. What I mean by this is that I will not be looking to test particular pre-stated hypotheses as supported or disproven, but rather I will approach the results looking for significant, overarching trends. Since there have been no previous quantitative studies of the ‘loudness war’ to my knowledge, I feel that this approach will be best suited for this relatively unexplored topic, so that this research could potentially serve as a foundation for future research in this area.

## ***7.2 Quantitative Results***

### *7.2.1 Dynamic Range*

TABLE 7 displays basic descriptive statistics of the three different measures of dynamic range previously discussed. The three measures are extremely similar, and while I expected this to occur with Official Dynamic Range and Calculated Dynamic Range, Corrected Dynamic Range's proximity somewhat surprised me. Corrected Dynamic Range, which corrects for outliers, reflected little change from Calculated Dynamic Range, meaning that my outlier concerns were not validated. Therefore, I decided to use Calculated Dynamic Range as my primary measure of dynamic range, due to this measure's inclusion of all tracks, thereby assessing each album faithfully and more comprehensively.

The mean Calculated Dynamic Range is 10.12, with a standard deviation of 2.83. The minimum Calculated Dynamic Range was found in Green Day's *American Idiot* (2005) at 4.485. In other words, *American Idiot* was the album with the least dynamic range. Calculated Dynamic Range reached a maximum with Dire Straits' *Brothers in Arms* (1986) at 15.889. As the result of this number, *Brothers in Arms* had the most dynamic range of any album in this sample. One important point to note here is that the higher dynamic range tended to occur early in our data set, while the lower dynamic range came later.

### *7.2.2 RMS Average*

TABLE 8 displays basic descriptive statistics of the two different measures of root means square previously discussed. The two measures are extremely similar, which was somewhat unexpected. Calculated RMS Average, which corrects for outliers, reflected little change from Calculated RMS Average, meaning that my outlier concerns were not validated. Therefore, I decided to use Calculated RMS Average as my primary measure of root means square, due to this measure's inclusion of all tracks, thereby assessing each album faithfully and more comprehensively.

The mean Calculated RMS Average is -13.04 dB, with a standard deviation of 3.76 dB. The album with the minimum Calculated RMS Average was Dire Straits' *Brothers in Arms* (1986) at -23.064 dB, making this the quietest (least loud) album recorded in the sample. Calculated RMS Average reached a maximum of -6.556 dB with Daughtry's eponymous release *Daughtry* (2007), earning this album the distinction of being the loudest album measured. Again, we see a similar trend to that of dynamic range, this time inversed, where the quietest album emerges earlier in the data set, while the loudest recording occurs much later.

The statistical results for both Dynamic Range and Calculated RMS Average have also been shown in the following GRAPHS 1-4. GRAPHS 1-2 depict Dynamic Range over time (years), where both figures show a general decline in dynamic range over time. GRAPH 1 displays individual albums in our dataset, while GRAPH 2 presents the annual average Dynamic Range over time. GRAPH 2 exhibits to us a similar decrease in dynamic range over time, which was expected since this graph is based off the average of the albums found in GRAPH 1.

GRAPH 3-4 depict Calculated RMS Average over time (years), illustrating a general upward trend in Calculated RMS Average as time progresses. Unlike GRAPH 1-2, GRAPH 3 does have an increased amount of outliers. That being said, the direction of GRAPH 3, still denotes a substantial upward trend of increased loudness. GRAPH 4, similar to GRAPH 2, presents the annual average Calculated RMS Average over time.

Like GRAPH 3, GRAPH 4 displays an upward trend towards increased loudness, also with some outliers. Despite these outliers, GRAPH 4's general trend remains pretty evident.

Before moving onto my regression analysis, I will define and discuss my independent "predictor" variables that influence the proposed outcomes of my dependent variables (Dynamic Range, Calculated RMS Average). First, I will look at the time of the release date—that is the year in which an album was released. This variable is rather straightforward and easy to define, but remains a crucial part of this study. In particular, the year of the release date sets up the analysis of Dynamic Range and Calculated RMS Average over time, allowing to be observed as a longitudinal study.

The other main "predictor" variable examined was genre—the categorization of the type of music an album entailed. While genre can often be a subjective term lacking concrete meaning, it can also be a useful way of broadly classifying different types of music. My purpose in using genre in this study was to determine whether or not different genres were more likely to have decreased Dynamic Range or increased Calculated RMS Average. In defining genre, I used Allmusic—an online music database—to provide pre-existing genre labels for artists of the albums observed. While a number of different sources could have been used to classify genre for these albums, I chose Allmusic due to their comprehensive collection of artist and album information as well as my familiarity with their website. When compiling the genre label for each album, several main genres emerged as the predominant types of music in the *Billboard 200* between 1982 to 2008. TABLE 9 offers some basic descriptive figures, just to give an idea of the genre breakdown within this dataset.

After looking over the total number of albums in each genre in TABLE 9, it became evident that Pop/Rock, R&B, Country, Rap and Soundtrack had large enough numbers within their respective categories to warrant a regression analysis, while Vocal, Jazz, Latin and Reggae simply did not have enough observations to perform additional studies. That is not to say that these genres are not worth looking at, but rather this sample did not have enough occurrences of albums in those genres to continue further analysis.

### *7.1.1 Regression Models: Dynamic Range*

With conceptions of these two independent variables—album release date and genre—in mind, this thesis will now continue onto a regression analysis. The following are a number of regression models that were proposed in order to examine various relationships concerning the 'loudness war.'

First, I assessed the relationship between Calculated Dynamic Range and time (years). For this and subsequent regression models involving Calculated Dynamic Range, the independent variable is assigned to years, and the dependent variable is reflected in Calculated Dynamic Range. The regression model looking at Years against Calculated Dynamic Range is as follows:

**Equation 1**: $Calculated\ DR = B_0 + B_1(Year)$

Each observation for the dataset used in Equation 1 is an individual album. On the other hand, Equation 2 observes Calculated Dynamic Range in conjunction with the annual average for each year's Calculated Dynamic Range, in order to observe trends at the yearly level.

**Equation 2**: $Annual\ Average\ Calculated\ DR = B_0 + B_1(Year)$

Equations 3-7 test the relative levels of Calculated Dynamic Range in various genres over time. Using the genre criteria discussed earlier, these five equations are multi-variable regression models showing how time and a particular genre impact Calculated Dynamic Range.

**Equation 3:** $Calculated\ DR = B_0 + B_1(Year) + B_2(Pop/Rock)$

Equation 3 observed albums denoted as Pop/Rock and evaluated their Calculated Dynamic Range against the Calculated Dynamic Range of all other albums (non-Pop/Rock albums).

**Equation 4**: $Calculated\ DR = B_0 + B_1(Year) + B_2(Country)$

Equation 4 observed albums denoted as Country and evaluated their Calculated Dynamic Range against the Calculated Dynamic Range of all other albums (non-Country albums).

**Equation 5**: $Calculated\ DR = B_0 + B_1(Year) + B_2(R\&B)$

Equation 5 observed albums denoted as R&B and evaluated their Calculated Dynamic Range against the Calculated Dynamic Range of all other albums (non-R&B albums).

**Equation 6**: $Calculated\ DR = B_0 + B_1(Year) + B_2(Rap)$

Equation 6 observed albums denoted as Rap and evaluated their Calculated Dynamic Range against the Calculated Dynamic Range of all other albums (non-Rap albums).

**Equation 7**: $Calculated\ DR = B_0 + B_1(Year) + B_2(Soundtrack)$

Equation 7 observed albums denoted as Soundtracks and evaluated their Calculated Dynamic Range against the Calculated Dynamic Range of all other albums (non-Soundtrack albums).

**Equation 8**: $Calculated\ DR = B_0 + B_1(Year) + B_2(Pop/Rock) + B_3(Soundtrack)$

Equation 8 adds an additional genre to the previous models shown in Equations 3-7. Without getting too far ahead, Pop/Rock and Soundtrack are in Equation 8 because they proved to be statistically significant, while the other genres did not. I will address this in greater detail below.

Moving forward to the regression models concerning Dynamic Range, the results that emerge from Models 1-8 provided substantive information concerning patterns in the dataset (TABLE 10). Model 1 indicates that $R^2$=.7019 pointing out a strong relationship of Calculated Dynamic Range decreasing over time, showing much of the variance explained by this regression model. The linear model depicts an average decrease of 0.3 DR per year from 1982 to 2008. With a standard error of .0173, the effect of that variable remains statistically significant at the 99% confidence level ($p<.01$, two sided test).

Model 2 specified an even stronger relationship of Calculated Dynamic Range decreasing over time, with $R^2$=.8626. Model 2 also shows an average decrease occurring at approximately 0.3 DR per year from 1982 to 2008. With a standard error of .0246, this predictor variable remains statistically significant at the 99% level ($p<.01$, two sided test) as well. In comparison to Regression 1, this model (Regression 2) has a higher $R^2$, yet both compare similarly in terms of their coefficients and standard errors, with each proving to be quite significant.

Of models 3-7 concerning genre, I found several notable things worth mention. In all these models, time unsurprisingly continued to be statistically significant at the 99% level ($p<.01$, two sided test), with all decreasing dynamic range at approximately 0.3 DR per year. While each of these five models tested a different genre, only Models 3 and 7 (Pop/Rock and Soundtrack) provided statistically significant findings, while Models 4-6 (Country, R&B, Rap) were not found to be significant at any meaningful level.

Model 3's interpretation shows that Pop/Rock albums are less dynamic than non-Pop/Rock albums, having 0.82 DR less than its counterparts. Model 7 illustrates that Soundtracks tend to be more dynamic than non-Soundtrack albums, having 0.93 DR more than albums outside of this genre. Model 8 places both statistically significant genres into the same regression model. While Pop/Rock remains consistent with its comparable results in Model 3, Soundtrack did not hold up in this model. Here we see Pop/Rock having an independent effect of reduced dynamic range, whereas Soundtrack does not have such independence.

*7.1.2 Regression Models: Root Means Square*

I also considered the relationship between Calculated RMS Average and time (years). For this and subsequent regression models involving Calculated RMS Average, the independent variable is assigned to years, and the dependent variable is reflected in Calculated RMS Average. The regression model looking at Years against Calculated RMS Average is as follows:

**Equation 9**: $Calculated\ RMS\ Average = B_0 + \ B_1(Year)$

Each observation for the dataset used in Equation 9 is an individual album. On the other hand, Equation 10 observes Calculated RMS Average in conjunction with the annual average for each year's Calculated RMS Average, in order to observe trends at the yearly level.

**Equation 10**: $Annual\ Calculated\ RMS\ Average = B_0 +\ B_1(Year)$

Equations 11-15 test the relative levels of Calculated RMS Average in various genres over time. Using the genre criteria discussed earlier, these five equations are multi-variable regression models showing how time and a particular genre impact Calculated RMS Average.

**Equation 11:** $Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(Pop/Rock)$

Equation 11 observed albums denoted as Pop/Rock and evaluated their Calculated RMS Average against the Calculated RMS Average of all other albums (non-Pop/Rock albums).

**Equation 12**: $Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(Country)$

Equation 12 observed albums denoted as Country and evaluated their Calculated RMS Average against the Calculated RMS Average of all other albums (non-Country albums).

**Equation 13**: $Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(R\&B)$

Equation 13 observed albums denoted as R&B and evaluated their Calculated RMS Average against the Calculated RMS Average of all other albums (non-R&B albums).

**Equation 14**: $Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(Rap)$

Equation 14 observed albums denoted as Rap and evaluated their Calculated RMS Average against the Calculated RMS Average of all other albums (non-Rap albums).

**Equation 15**:

$Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(Soundtrack)$

Equation 15 observed albums denoted as Soundtracks and evaluated their Calculated RMS Average against the Calculated RMS Average of all other albums (non-Soundtrack albums).

**Equation 16**: $Calculated\ RMS\ Average = B_0 +\ B_1(Year) +\ B_2(Pop/Rock + B3(Soundtrack)$

Equation 16 adds an additional genre to the previous models shown in Equations 11-15. Without getting too far ahead, Pop/Rock and Soundtrack are in Equation 16 because they proved to be statistically significant, while the other genres did not. Again, I will address this in greater detail in a subsequent section.

When looking at next set of regression models associated with Calculated RMS Average, the findings from Models 9-16 provided further substantive information concerning our dataset, in similar fashion to that of Models 1-8 (TABLE 11). Model 9 indicates that $R^2$=.5886, showing a moderately strong correlation of Calculated RMS Average increase over time. This model portrays an average increase of 0.37 dB per year from 1982 to 2008. With a standard error of .027, this variable remains statistically significant at the 99% confidence level ($p<.01$, two sided test).

Model 10 specified an even stronger relationship of Calculated RMS Average increasing over time, with $R^2$=.8019. Model 10 also shows an average increase occurring at approximately 0.37 dB per year from 1982 to 2008. With a standard error of .0368, this model remains statistically significant at the 99% level ($p<.01$, two sided test) as well. In comparison to Regression 9, this model (Regression 10) has a higher $R^2$, yet both compare similarly in terms of their coefficients and standard errors, with each proving to be rather significant.

Among models 11-15 observing genre, a handful of details are worth discussing. In all these models, time unsurprisingly continued to be statistically significant at the 99% level ($p<.01$, two sided test), with all increasing root means square at approximately 0.37 dB per year. With each of these five models testing a separate genre, only Models 11 and 15 (Pop/Rock and Soundtrack) provided statistically significant results, while Models 12-14 (Country, R&B, Rap) were not found to be significant at any meaningful level.

Model 11's interpretation shows that Pop/Rock albums tend to be louder than non-Pop/Rock albums, having roughly 1.3 dB more than its counterparts. Model 15 illustrates that Soundtracks tend to be quieter than non-Soundtrack albums, having about 2.28 dB less than albums outside of this genre. Model 16 places both statistically significant genres into the same regression model. What emerges here is that while both Pop/Rock and Soundtrack remain statistically significant, they find significance at lesser level than Models 11 and 15 respectively. Thus, Model 16 shows that Pop/Rock is still louder than non-Pop/Rock albums, but not as loud as Model 11 predicted (1.09 vs. 1.30). The same thing happens in Model 15 when discussing Soundtrack—Model 16 shows that Soundtracks are still quieter than non-Soundtrack albums over time, but not as quieter as Model 15 indicated (-1.71 vs. -2.28).

## 8. Discussion

Through my work in this thesis, I hope that I have illustrated the importance of looking at music making as a collective process—observing the influence of musical as well as non-musical personnel. As my qualitative analysis of shows, the 'loudness war' is a trend affecting a wide range of industry personnel, whose cause is attributed to just as many parties—including record labels, radio stations, engineers, musicians and consumers. These are not just opinions without any basis, but rather an empirical phenomenon that has been objectively shown over time. I show this through my quantitative analysis of best-selling albums, in which dynamic range of compact discs has decreased over time, while their loudness has increased. This trend is especially notable in Pop/Rock compact discs, which are distinguished by greater sonic homogeneity, while Soundtrack compact discs offer similar, but limited evidence in the same direction.

This thesis not only addresses a gap of literature on sonic homogeneity, but also adds to a long line of work within the 'production of culture' perspective, particularly within the technological 'facet.' Much of the recent research concerning technology has shown positive developments in terms of technology causing popular music to become less homogenous. Dowd's work emphasizes this trend towards heterogeneity, as corporations in the late-20$^{th}$ century had begun to revise their strategies, resulting in greater performer and musical diversity. Other scholars have contributed to the notion that digital music technologies, including the rise of portable music players and online music distribution, have had positive implications in the same regard. Most of these scholars, however, have largely overlooked the negative consequences of audio editing practices for digital formats, including compact discs.

In essence, this thesis hopes to call attention towards a practice that has remained under the radar for much too long. In the eyes of many individuals, record labels may be seen as crossing a potentially taboo line by using audio editing practices to change original artistic creations for the purpose of financial interests. Recall my analogy of music to paintings, and remember that these practices are the equivalent to taking out the vivid colors within a Vincent Van Gogh painting or removing the brilliant chaotic randomness of a Jackson Pollack masterpiece. From the perspective of the creator, these aesthetic changes for non-aesthetic reasons potentially conflict.

But the story of the ‘loudness war,’ more importantly, implicates consumers in multiple ways. Consumers are the bearers of these practices as well as the subjects of deteriorating sound quality year after year. All this occurs in the attempts for corporations to sell more compact discs. In fact, however, the industry that produces music is potentially jeopardizing their one and only product. As the ‘loudness war’ has progressed, ordinary consumers become increasingly used to poor sound quality, and eventually settle for lowered listening expectations. If this continues, this may result in what was quoted earlier—a “generation of children who are totally unfamiliar with reasonably undistorted music…” (“Current Trends in the Recording Format Arena” 2008). Hopefully, this thesis can create awareness and enlighten individuals of these ongoing practices so many are unaware of.

Thus, this research, beyond filling a gap in the sociological literature, serves as a foundation for future analyses in this area. My hope remains that this initial, exploratory research can illustrate the gravity of the ‘loudness war,’ and possibly encourages other scholars to investigate this area in greater detail. While I believe my research has provided a starting point regarding the ‘loudness war’ and its inherent issues, this examination is a framework that needs walls to be constructed before we fully understand everything pertaining to this large-scale phenomenon.

Areas of potential future research directly related to this thesis could stand to see a more intricate look a number of different areas. First, an expanded study of genre differences in the 'loudness war' would help to bring light on the practice in different types of music. In particular, genre within the 'loudness war' should examine a wider range of genres, with more specific types of music (de-emphasizing broad, catch-all genre labels). Along similar lines, I would be curious to determine whether or not the 'loudness war' is prevalent just in popular genres, or if this phenomenon disseminate into less popular genres (e.g. classical, experimental). Furthermore, a comparative study of original compact discs and re-mastered editions would prove quite interesting, since the content remains constant, leaving only the audio editing practices to be varied.

While this study was conducted in a Sociological framework, this research really stands as an ideal project that would tremendously benefit from interdisciplinary research in a number of diverse fields, including the following:

> -*Music:* Beyond its obvious relation to music, many possible paths of research have been discussed above, including notions artistic creation, musicianship, production and engineering. Music as a research institution stands in the crosshairs of the 'loudness war,' since music is the medium being affected. Within music exists not only the problem, but the potential steps towards amending these trends.
>
> -*Physics*: At the heart of music and the 'loudness war' lies the science behind this rather intricate phenomenon. Outside of mine own and many Sociologists' expertise remains the physics behind music. While I have attempted in my own research to place the physics of this trend in understandable terms, this area of research would most definitely be served by a thorough investigation of the 'loudness war' from the perspective of experts in physics and acoustic studies.
>
> -*Psychology*: This paper has gone into much detail about the 'loudness war' and its attempts to unconsciously turn up the volume for consumers without them realizing it. While this paper has shown an upward trend in loudness and a decreasing trend in dynamic range, an interesting path of future study could examine *how* these changes are *perceived*. Especially with those unfamiliar with this phenomenon, how does the individual react to today's music—louder and less dynamic—as opposed to older music—quieter, but with more clarity? My inquiries here would not only lean towards the choice of the individual given two alternative, but the *degree* in which this phenomenon is observed to the untrained, unaware ear.

> -*Neuroscience*: Along the lines of psychological interests, Neuroscience's role could take those stated concerns one step further, and analyze not just expressed perception and awareness of the 'loudness war,' but observe brain function in relation to loudness. Does louder music provide enjoyment as well as a better euphoric enjoyment initially, as several of the articles noticed? And if so, are the record labels engaging in a practice inherently in support or against human tendencies toward loudness and a lack of clarity.

> -*Marketing*: From the standpoint of the labels, the 'loudness war' has accelerated over the years in part due to the notion that indirect, nearly subliminal marketing could impact consumers just enough to increase sales. But is this really a feasible, if not effective practice?

Beyond future research possibilities in studying sonic homogeneity, the imperative matter returns to the fact that the 'loudness war' is a trend that may compromise the nature of recorded music—one that needs to be addressed sooner, rather than later. As I have said earlier in this paper, I hope that this research sparks interest in a phenomenon in dire need of awareness. If consumer consciousness in regard to the 'loudness war' stays at its current levels, nothing will change, and the notion that financial interests trump artistic creation will continue to reign supreme. Ultimately, however, cultural consumption remains in the hands of individuals—a key fact that provides hope for change as more consumers learn about the state of the 'loudness war.'

## Bibliography


Jarl A. Ahlkvist and Robert Faulkner. 2002. "'Will This Record Work for Us?': Managing Music Formats in Commercial Radio." *Qualitative Sociology* 25: 189-215.

Anderson, Tim. "How CDs are remastering the art of noise." The Guardian. 18 Jan. 2007. 19 Nov. 2008 <http://www.guardian.co.uk/technology/2007/jan/18/pop.music#article>.

Blair, J.J. "Brickwall Limiting." EQ. Feb. 2007. 21 Nov. 2008 <http://www.eqmag.com/article/brickwall-limiting/feb-07/25512>.

Gabrielle Cosentino. 2006. "'Hacking' the iPod: A Look Inside Apple's Portable Music Player." Pages 185-207 in *Cybersounds: Essays on Virtual Music Culture*, edited by Michael D. Ayers. New York: Peter Lang.

"Current Trends in the Recording Format Arena." 19 Nov. 2008 <http://www.audioholics.com/ education/audio-formats-technology/current-trends-in-the-recording-format-arena-p1>.

"The Death of Dynamic Range: A Chronology of the Compact Disc Loudness Wars." 21 Nov. 2008 <http://www.mindspring.com/~mrichter/dynamics/dynamics.htm>.

"Declaring an end to the Loudness Wars." 19 Nov. 2008 <http://www.barrydiamentaudio.com/loudness.htm>.

Donahue, Mark. "The Loudness War." PerformerMag. 19 Nov. 2008 <http://www.performermag.com/loudness.php>.

T.J. Dowd. "Concentration and Diversity Revisited: Production Logics and the U.S. Mainstream Recording Market, 1940 to 1990." *Social Forces* 2004a. 82 (4): 1411-1455.

T.J. Dowd. "Production Perspectives in the Sociology of Music." *Poetics: Journal of Empirical Research on Culture, Media, and the Arts*. 2004b. Volume 32 (3-4): 235-246.

T.J. Dowd. "From 78s to MP3s: The Embeddedness of Technology and the U.S. Market for Prerecorded Music." *The Business of Culture: Emerging Perspectives on Entertainment, Media, and Other Industries*. 2005. Mahwah, NJ: Lawrence Erlbaum. 205-224

Paul du Gay and Keith Negus. 1994. "The Changing Sites of Sound: Music Retailing and the Composition of Consumers." *Media, Culture & Society* 16: 395-413.

"Fans Complain After "Death Magnetic" Sounds Better on "Guitar Hero" Than CD." Rolling Stone. 18 Sept. 2008. 21 Nov. 2008

<http://www.rollingstone.com/rockdaily/index.php /2008/09/18/fans-complain-after-death-magnetic-sounds-better-on-guitar-hero-than-cd/>.

Foti, Frank, and Robert Orban. "What Happens to My Recording When It's Played on the Radio?" Omnia Audio. June 2001. 19 Nov. 2008 <http://www.omniaaudio.com/tech/mastering.htm>.

Graham, George. "Whatever Happened to Dynamic Range on Compact Discs." 1999. 19 Nov. 2008 <http://georgegraham.com/compress.html>.

Greenwald, David. "T Bone Burnett may have Neil Young and Bob Dylan sings a new tune." Los Angeles Times. 30 Aug. 2008. 21 Nov. 2008 <http://www.latimes.com/ entertainment/news/music/la-et-code30-2008aug30,0,9296.story>.

Griswold, Wendy M. Cultures and Societies in a Changing World. 2004. New York: Pine Forge P, 1994.

Gross, Joe. "Everything Louder Than Everything Else." XL Recording. 2 Oct. 2006. 19 Nov. 2008 <http://www.austin360.com/music/content/music/stories/xl/2006/09/28cover.html>.

Hennion, Antoine. 2001. "Music Lovers: Taste as Performance." *Theory, Culture & Society* 18: 1-22.

Hirsch, Paul M. "Processing Fads and Fashions: An Organization Set Analysis of Culture." American Journal of Sociology 77 (1972): 639-59.

"Imperfect Sound Forever." Stylus. 19 Nov. 2008 <http://www.stylusmagazine.com/articles/weekly_article/imperfect-sound-forever.htm.>.

Jones, Sarah. "The Big Squeeze." Mix. 1 Dec. 2005. 19 Nov. 2008 <http://mixonline.com/mag/audio_big_squeeze/>.

Levine, Robert. "For Tom Petty Fans, the True Sound of Vinyl, Also Captured on a CD." New York Times. 23 June 2008. 19 Nov. 2008 <http://www.nytimes.com/2008/06/23/ business/media/23petty.html?_r=1&oref=slogin>.

Levine, Robert. "The Death of High Fidelity." Rolling Stone. 27 Dec. 2007. 19 Nov. 2008 <http://www.rollingstone.com>.

Masterson, Kathryn. "Loudness war stirs quiet revolution by audio engineers." Pop Matters. 4 Jan. 2008. Chicago Tribune. 19 Nov. 2008 <http://www.popmatters.com/pm/article/ loudness-war-stirs-quiet-revolution-by-audio-engineers>.

Tom McCourt and Patrick Burkhart. 2003. “When Creators, Corporations, and Consumers Collide: Napster and the Development of On-Line Music Distribution.” *Media, Culture & Society* 25: 335-350.

Negus, Keith. 1998. “Cultural Production and the Corporation: Musical Genres and the Strategic Management of Creativity in the US Recording Industry.” *Media, Culture & Society* 20: 359-379.

Peterson, Richard A. "The Production of Cultural Change: The Case of Contemporary Country Music." Social Forces 45 (1978): 295.

Peterson, Richard A., and N. Anand. ‘‘The Production of CulturePerspective.’’ Annual Review
of Sociology 30 (2004): 311 – 34.

Peterson, Richard A. and David G. Berger. 1975. “*Cycles in symbol production: the case of*
*popular music*.” American Sociological Review 40:158-173.

Pietz, Martin, and Waelbroeck. “An Economist’s Guide to Digital Music. CESifo Economic Studies 51 (2005):359-429

Rossman, Gabriel. 2004. “Elites, Masses, and Media Blacklists: The Dixie Chicks Controversy.”
*Social Forces* 83:61–79.

Rowan, Rip. "Over the Limit." 31 Aug. 2002. 21 Nov. 2008 <http://www.prorec.com/articles/tabid/109/entryid/247/over-the-limit.aspx>.

Rowan, Rip. "Pump Up the Volume." Wired. 19 Nov. 2008 <http://www.wired.com/wired/archive/12.01/play.html?pg=2>.

Sherwin, Adam. "Why music is really getting louder." Times Online. 4 June 2007. 19 Nov. 2008 <http://entertainment.timesonline.co.uk/tol/arts_and_entertainment/music/article1878724.ece>.

Smith, Ethan. "Even Heavy-Metal Fans Complain That Todayâ€™s Music is Too Loud!!!" Wall Street Journal. 25 Sept. 2008. 21 Nov. 2008 <http://online.wsj.com/article/sb 122228767729272339.html?mod=todays_us_page_one>

Snider, Mike. "Musicians push for better sound online and on disc." USA Today. 2 June 2008. 19 Nov. 2008 <http://www.usatoday.com/life/music/news/2008-06-02-better-sound-formats_n.htm>.

Southhall, Nick. "Imperfect Sound Forever." Stylus. 1 May 2006. 19 Nov. 2008 <http://www.stylusmagazine.com/articles/weekly_article/imperfect-sound-forever.htm.>.

Speer, Bob. "What Happened to Dynamic Range?" 2001. 19 Nov. 2008 <http://www.cdmasteringservices.com/dynamicrange.htm>.

Sreedhar, Suhas. "The Future of Music." IEEE Spectrum. Aug. 2007. 19 Nov. 2008 <http://spectrum.ieee.org/aug07/5429>.

**Appendix: Tables, Figures, Graphs**

TABLE 1: Technological Processes Inducing Sonic Homogeneity

| *Category* | *Number of articles found in* | *Percent of articles found in* |
|---|---:|---:|
| Compression | 22 | 96% |
| Clipping (Limiting) | 12 | 52% |
| Equalization (EQ) | 2 | 9% |
| Lax Industry Standards | 1 | 4% |

FIGURE 1: Visual Representation of Clipping in a Sound Wave


("The Death of Dynamic Range")

TABLE 2: Parties associated with the 'Loudness War'

| *Category* | *# of articles found in* | *% articles found in* |
|---|---:|---:|
| Labels | 20 | 87% |
| Artists | 14 | 61% |
| Engineers | 9 | 39% |
| Consumers | 3 | 13% |

TABLE 3: Reasons Behind the ‘Loudness War’

| *Category* | *# of articles found in* | *% articles found in* |
|---|---:|---:|
| "Louder is Better" Perspective | 13 | 57% |
| Grabs Listener's Attention | 10 | 43% |
| Loudness Competition | 9 | 39% |
| Radio | 9 | 39% |
| Change in Consumer Listening Patterns | 7 | 30% |

TABLE 4: Observed Implications in the ‘loudness war’

| *Category* | *# of articles found in* | *% articles found in* |
|---|---:|---:|
| Lower Sound Quality | 18 | 78% |
| Louder Average Sound | 11 | 48% |
| Ear Fatigue | 8 | 35% |
| Lower Listener Expectation | 8 | 35% |
| Radio Misperceptions | 7 | 30% |

TABLE 5: Reactions and Solutions to the ‘loudness war’

| *Category* | *# of articles found in* | *% articles found in* |
|---|---|---|
| Consumer Demand | 9 | 39% |
| Superior Audio Formats | 6 | 26% |
| Artist Initiative | 5 | 22% |
| Revise Industry Standards | 3 | 13% |
| Vinyl Revival | 3 | 13% |
| Increased Awareness (NPO) | 2 | 9% |
| RMS Normalization | 1 | 4% |

TABLE 6: List of CDs used in Statistical Analysis of the ‘Loudness War’

| **Artist** | **Album** | **Year** |
|---|---|---|
| Asia | Asia | 1982 |
| Foreigner | 4 | 1982 |
| Go-Go's | Beauty and the Beat | 1982 |
| J. Geils Band | Freeze-Frame | 1982 |
| John Cougar | American Fool | 1982 |
| Men at Work | Business as Usual | 1983 |
| Michael Jackson | Thriller | 1983 |
| Police | Sychronicity | 1983 |
| Prince | 1999 | 1983 |
| Billy Joel | An Innocent Man | 1984 |
| Culture Club | Colour By Numbers | 1984 |
| Huey Lewis/The News | Sports | 1984 |
| Lionel Richie | Can't Slow Down | 1984 |
| Michael Jackson | Thriller | 1984 |
| Bruce Springsteen | Born in the USA | 1985 |
| Bryan Adams | Reckless | 1985 |
| Madonna | Like a Virgin | 1985 |
| Tina Turner | Private Dancer | 1985 |
| Wham! | Make It Big | 1985 |
| Dire Straits | Brothers in Arms | 1986 |
| Heart | Heart | 1986 |
| John Couger Mellancamp | Scarecrow | 1986 |
| Whitney Houston | Whitney Houston | 1986 |
| ZZ Top | Afterburner | 1986 |
| Beastie Boys | Licensed to Ill | 1987 |
| Bon Jovi | Slippery When Wet | 1987 |
| Bruce Hornsby | The Way It Is | 1987 |
| Janet Jackson | Control | 1987 |
| Paul Simon | Graceland | 1987 |
| Def Leppard | Hysteria | 1988 |
| George Michael | Faith | 1988 |
| INXS | Kick | 1988 |
| Michael Jackson | Bad | 1988 |
| Soundtrack | Dirty Dancing | 1988 |
| Bobby Brown | Don't Be Cruel | 1989 |
| Bon Jovi | New Jersey | 1989 |
| Guns N' Roses | Appetite For Destruction | 1989 |
| New Kids on the Block | Hangin' Tough | 1989 |
| Paula Abdul | Forever Your Girl | 1989 |
| Aerosmith | Pump | 1990 |

| | | |
|---|---|---|
| Janet Jackson | Janet Jackson's Rhytm Nation 1814 | 1990 |
| MC Hammer | Please Hammer Don't Hurt 'Em | 1990 |
| Michael Bolton | Soul Provider | 1990 |
| Phil Collins | …But Seriously | 1990 |
| Black Crowes | Shake Your Money Maker | 1991 |
| C&C Music Factory | Gonna Make You Sweat | 1991 |
| Garth Brooks | No Fences | 1991 |
| Mariah Carey | Mariah Carey | 1991 |
| Wilson Phillips | Wilson Phillips | 1991 |
| Bill Ray Cyrus | Some Gave All | 1992 |
| Garth Brooks | Ropin' The Wind | 1992 |
| Michael Jackson | Dangerous | 1992 |
| Nirvana | Nevermind | 1992 |
| U2 | Achtung Baby | 1992 |
| Billy Ray Cyrus | Some Gave All | 1993 |
| Eric Clapton | Unplugged | 1993 |
| Janet Jackson | Janet | 1993 |
| Kenny G | Breathless | 1993 |
| Soundtrack | Bodyguard | 1993 |
| Ace of Base | The Sign | 1994 |
| Counting Crows | Counting Crows | 1994 |
| Mariah Carey | Music Box | 1994 |
| Snoop Doggy Dogg | Snoop Doggy Dogg | 1994 |
| Soundtrack | Lion King | 1994 |
| Boyz II Men | II | 1995 |
| Eagles | Hell Freezes Over | 1995 |
| Garth Brooks | The Hits | 1995 |
| Hootie/The Blowfish | Cracked Rear View | 1995 |
| TLC | Crazysexycool | 1995 |
| Alanis Morissette | Jagged Little Pill | 1996 |
| Celine Dion | Falling Into You | 1996 |
| Fugees | The Score | 1996 |
| Mariah Carey | Daydream | 1996 |
| Soundtrack | Waiting to Exhale | 1996 |
| Celine Dion | Falling Into You | 1997 |
| Jewel | Pieces of You | 1997 |
| No Doubt | Tragic Kingdom | 1997 |
| Soundtrack | Space Jam | 1997 |
| Spice Girls | Spice | 1997 |
| Backstreet Boys | Backstreet Boys | 1998 |
| Celine Dion | Let's Talk About Love | 1998 |
| Garth Brooks | Sevens | 1998 |

| | | |
|---|---|---|
| Shania Twain | Come On Over | 1998 |
| Soundtrack | Titanic | 1998 |
| Backstreet Boys | Millennium | 1999 |
| Britney Spears | …Baby One More Time | 1999 |
| N Sync | N Sync | 1999 |
| Ricky Martin | Ricky Martin | 1999 |
| Shania Twain | Come On Over | 1999 |
| Britney Spears | Oops!...I Did It Again | 2000 |
| Dr. Dre | 2001 | 2000 |
| Eminem | The Marshall Mathers LP | 2000 |
| N Sync | No Strings Attached | 2000 |
| Santana | Supernatural | 2000 |
| Backstreet Boys | Black & Blue | 2001 |
| Beatles | 1 | 2001 |
| Limp Bizkit | Chocolate Starfish And the HotDog Flavored Water | 2001 |
| Shaggy | Hotshot | 2001 |
| Various Artists | Now 5 | 2001 |
| Creed | Weathered | 2002 |
| Eminem | The Eminem Show | 2002 |
| Linkin Park | [Hybrid Theory] | 2002 |
| Nelly | Nellyville | 2002 |
| Pink | M!ssundaztood | 2002 |
| 50 Cent | Get Rich or Die Tryin' | 2003 |
| Avril Lavigne | Let Go | 2003 |
| Dixie Chicks | Home | 2003 |
| Norah Jones | Come Away With Me | 2003 |
| Shania Twain | Up! | 2003 |
| Alicia Keys | Diary of Alicia Keys | 2004 |
| Josh Groban | Closer | 2004 |
| Norah Jones | Feels Like Home | 2004 |
| Outkast | Speakerboxxx/The Love Below | 2004 |
| Usher | Confessions | 2004 |
| 50 Cent | The Massacre | 2005 |
| Eminem | Encore | 2005 |
| Green Day | American Idiot | 2005 |
| Kelly Clarkson | Breakaway | 2005 |
| Mariah Carey | The Emancipation of Mimi | 2005 |
| Carrie Underwood | Some Hearts | 2006 |
| Mary J. Blige | The Breakthrough | 2006 |
| Nickelback | All the Right Reasons | 2006 |
| Rascal Flatts | Me and My Gang | 2006 |

| | | |
|---|---|---|
| Soundtrack | High School Musical | 2006 |
| Akon | Konvicted | 2007 |
| Carrie Underwood | Some Hearts | 2007 |
| Daughtry | Daughtry | 2007 |
| Fergie | The Dutchess | 2007 |
| Soundtrack | Hannah Montana | 2007 |
| Alicia Keys | As I Am | 2008 |
| Eagles | Long Road Out of Eden | 2008 |
| Josh Groban | Noel | 2008 |
| Lil' Wayne | Tha Carter III | 2008 |
| Taylor Swift | Taylor Swift | 2008 |

TABLE 7: Official DR, Calculated DR, Corrected DR Descriptive Statistics

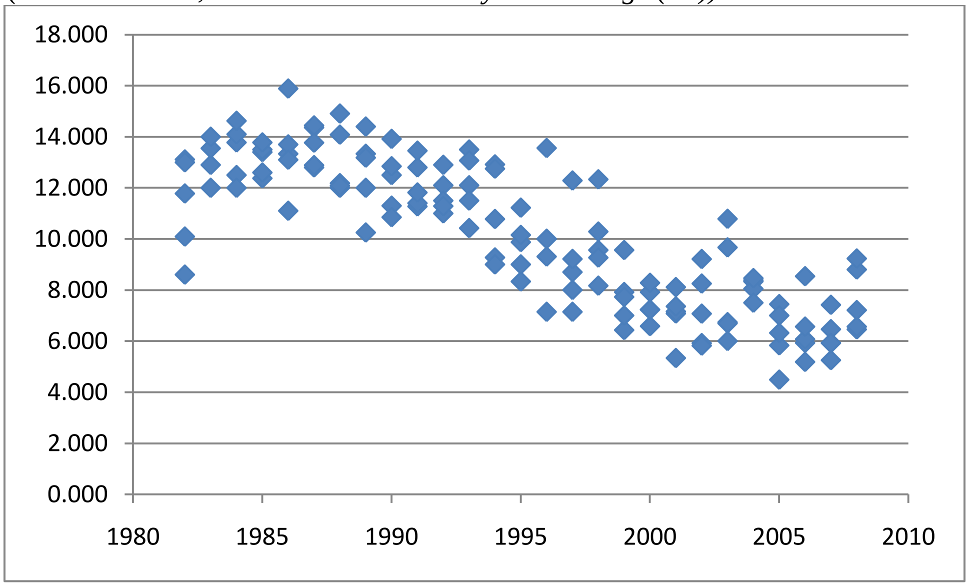
| ***Official DR*** | | ***Calculated DR*** | | ***Corrected DR*** | |
|---|---|---|---|---|---|
| Mean | 10.0671642 | Mean | 10.1170955 | Mean | 9.99402836 |
| Standard Error | 0.24689697 | Standard Error | 0.24455242 | Standard Error | 0.25111012 |
| Median | 10 | Median | 10.1225 | Median | 10.0455 |
| Mode | 13 | Mode | 12 | Mode | 12 |
| Standard Dev. | 2.85803908 | Standard Dev. | 2.83089897 | Standard Dev. | 2.9068098 |
| Sample Var. | 8.16838739 | Sample Var. | 8.0139889 | Sample Var. | 8.4495429 |
| Kurtosis | -1.2808415 | Kurtosis | -1.2615328 | Kurtosis | -1.3370962 |
| Skewness | -0.0117508 | Skewness | -0.0612792 | Skewness | -0.0586579 |
| Range | 11 | Range | 11.404 | Range | 10.89 |
| Minimum | 5 | Minimum | 4.485 | Minimum | 4.485 |
| Maximum | 16 | Maximum | 15.889 | Maximum | 15.375 |
| Sum | 1349 | Sum | 1355.6908 | Sum | 1339.1998 |
| Count | 134 | Count | 134 | Count | 134 |

TABLE 8: RMS (Calculated) Average, Corrected RMS Average Descriptive Statistics

| ***RMS (Calculated) Average*** | | ***Corrected RMS Average*** | |
|---|---|---|---|
| Mean | -13.0433769 | Mean | -12.8572127 |
| Standard Error | 0.324933893 | Standard Error | 0.334694591 |
| Median | -12.772 | Median | -12.772 |
| Mode | -15.542 | Mode | -15.542 |
| Standard Dev. | 3.761381751 | Standard Dev. | 3.87437 |
| Sample Variance | 14.14799268 | Sample Variance | 15.0107429 |
| Kurtosis | -0.90584180 | Kurtosis | -0.9480895 |
| Skewness | -0.20872286 | Skewness | -0.1918301 |
| Range | 16.508 | Range | 16.648 |
| Minimum | -23.064 | Minimum | -23.204 |
| Maximum | -6.556 | Maximum | -6.556 |
| Sum | -1747.8125 | Sum | -1722.8665 |
| Count | 134 | Count | 134 |

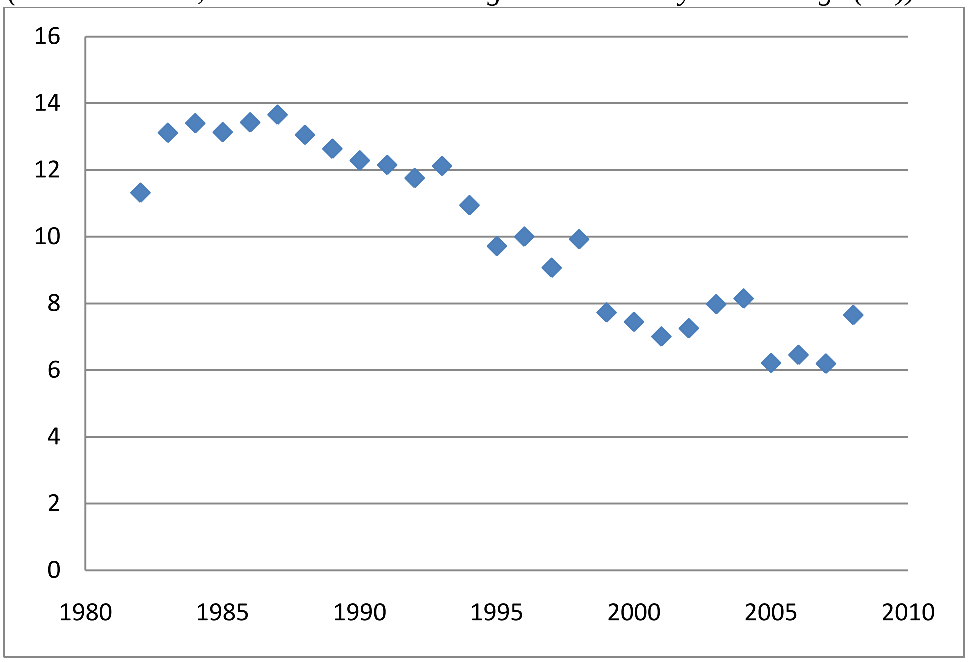
GRAPH 1: Model 1 Graph (Calculated Dynamic Range over Time)

*(X-Axis = Years; Y-Axis = Calculated Dynamic Range (dB))*



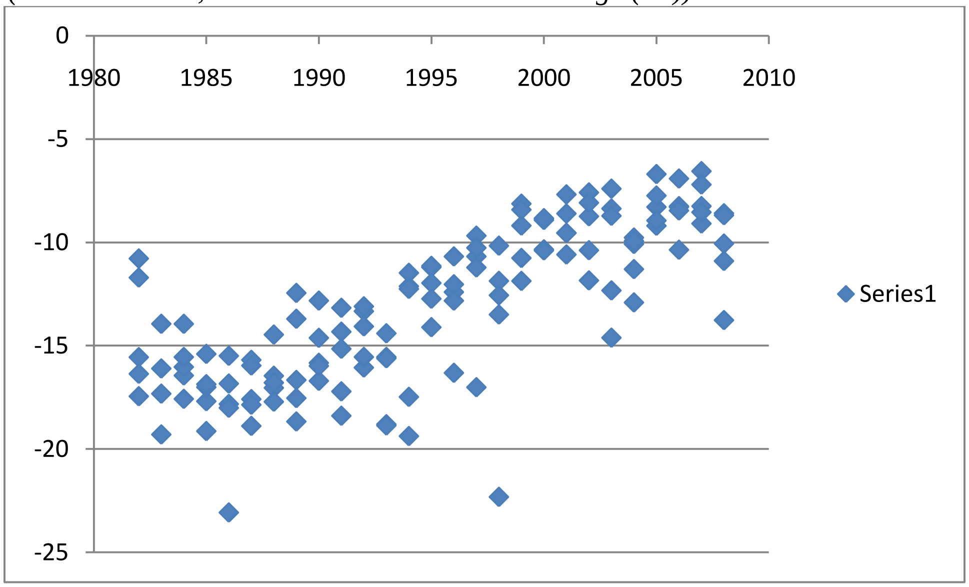
GRAPH 2: Model 2 Graph (Annual Average Calculated Dynamic Range over Time)

*(X-Axis = Years; Y-Axis = Annual Average Calculated Dynamic Range (dB))*



GRAPH 3: Model 9 Graph (Calculated RMS Average over Time)

*(X-Axis = Years; Y-Axis = Calculated RMS Average (dB))*



GRAPH 4: Model 10 Graph (Annual Average Calculated RMS Average over Time)

*(X-Axis = Years; Y-Axis = Annual Average Calculated RMS Average (dB))*

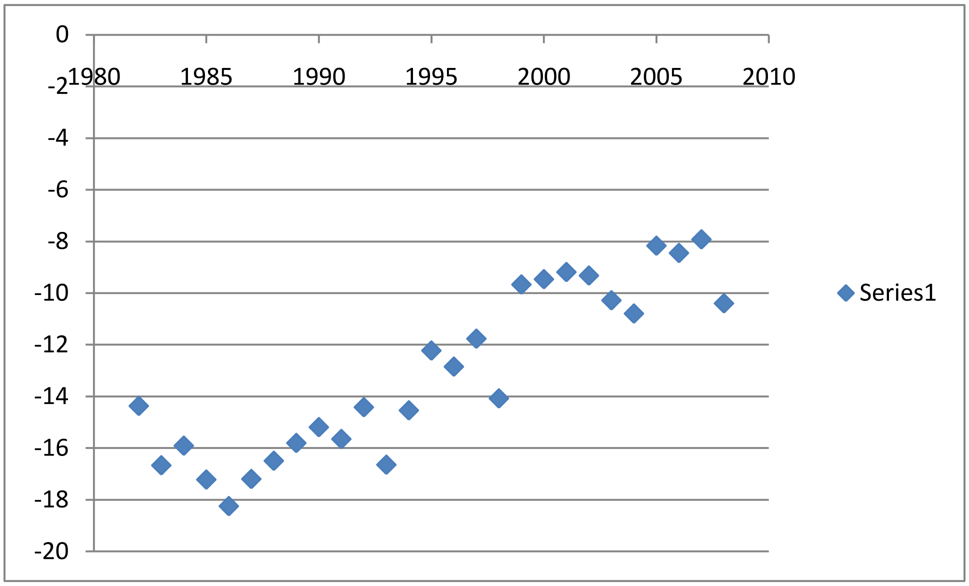


TABLE 9: Genre Breakdown for Album Dataset

| | |
|---|---|
| Pop/Rock | 71 |
| R&B | 23 |
| Country | 14 |
| Rap | 13 |
| Soundtrack | 8 |
| Vocal | 2 |
| Jazz | 1 |
| Latin | 1 |
| Reggae | 1 |
| **Total** | **134** |

TABLE 10: Calculated DR Results Using OLS Regression

| | **(1)** **Calc. DR** | **(2)** **Annual Avg.Calc. DR.** | **(3)** **Calc. DR** | **(4)** **Calc. DR** |
|---|---|---|---|---|
| **Year** | -0.3049 (0.0173)*** | -0.3039 (0.0243)*** | -0.3206 (0.0176)*** | -0.3098 (0.0175)*** |
| **Pop/Rock** | | | -0.8198 (0.273)*** | |
| **Country** | | | | 0.6534 (.4442) |
| **R&B** | | | | |
| **Rap** | | | | |
| **Soundtrack** | | | | |
| **Observations** | 134 | 27 | 134 | 134 |
| **$R^2$** | 0.7036 | 0.8626 | 0.7211 | 0.7067 |
| | **(5)** **Calc. DR** | **(6)** **Calc. DR** | **(7)** **Calc. DR** | **(8)** **Calc. DR** |
| **Year** | -0.3049 (0.0174)*** | -0.3091 (0.0176)*** | -0.3071 (0.0172)*** | -0.3205 (0.0176)*** |
| **Pop/Rock** | | | | -0.7505 (0.2826)*** |
| **Country** | | | | |
| **R&B** | 0.0221 (.357) | | | |
| **Rap** | | 0.5544 (.4609) | | |
| **Soundtrack** | | | 0.933 (0.5636)* | 0.5427 (0.5702) |
| **Observations** | 134 | 134 | 134 | 134 |
| **$R^2$** | 0.7019 | 0.7051 | 0.708 | 0.723 |
| standard error in parentheses<br>* significant at 10% level; ** significant at 5% level;<br>*** significant at 1% level | | | | |

TABLE 11: Calculated RMS Average Results Using OLS Regression

| **Table B** | **(9)**<br>**RMS (Calc.) Avg.** | **(10)**<br>**Annual RMS (Calc.) Avg.** | **(11)**<br>**RMS (Calc.) Avg.** | **(12)**<br>**RMS (Calc.) Avg.** |
|---|---|---|---|---|
| **Year** | 0.3711 | 0.3698 | 0.3959 | 0.3768 |
| | (0.027)*** | (0.0368)*** | (0.0274)*** | (0.0275)*** |
| **Pop/Rock** | | | 1.3045 | |
| | | | (0.4255)*** | |
| **Country** | | | | -0.7691 |
| | | | | (0.6958) |
| **R&B** | | | | |
| **Rap** | | | | |
| **Soundtrack** | | | | |
| **Observations** | 134 | 27 | 134 | 134 |
| $R^2$ | 0.5886 | 0.8019 | 0.6162 | 0.5924 |
| | **(13)**<br>**RMS (Calc.) Avg.** | **(14)**<br>**RMS (Calc.) Avg.** | **(15)**<br>**RMS (Calc.) Avg.** | **(16)**<br>**RMS (Calc.) Avg.** |
| **Year** | 0.3706 | 0.3711 | 0.3762 | 0.3956 |
| | (0.0271)*** | (0.0276)*** | (0.0265)*** | (0.0271)*** |
| **Pop/Rock** | | | | 1.086 |
| | | | | (0.4357)** |
| **Country** | | | | |
| **R&B** | -0.2857 | | | |
| | (0.5567) | | | |
| **Rap** | | -0.0023 | | |
| | | (0.7233) | | |
| **Soundtrack** | | | -2.2756 | -1.7108 |
| | | | (0.8662)** | (0.8792)* |
| **Observations** | 134 | 134 | 134 | 134 |
| $R^2$ | 0.5895 | 0.5886 | 0.6092 | 0.627 |

standard error in parentheses
* significant at 10% level; ** significant at 5% level;
*** significant at 1% level