Auditory loudness perception and the consumption of popular music between 1980 and 2010

Dong Ho Kwak

Auditory loudness perception and the consumption of popular music between 1980 and 2010

Dong Ho Kwak

A mini-dissertation submitted in partial fulfilment of the requirements for the degree

MMus (Music Technology)

Department of Music
Faculty of Humanities

University of Pretoria

Supervisor: Mr Murray de Villiers

September 2015

Abstract

This quantitative study investigates the possible correlation between auditory loudness perception and commercial success in the music industry by measuring and comparing the loudness levels of the top 10 and the bottom 10 singles from the Top 100 Billboard Year End Chart between 1980 and 2010.

A total of 140 singles from 1980 and 2010 (with 5 year intervals) were measured in terms of integrated loudness, momentary maximum loudness and loudness range. The variables were measured using the computer software based processing of iZotope Ozone Insight and Waves Loudness Meter (WLM) on Cubase 5 Digital Audio Workstation (DAW) platform. The data were analysed for any observable trend in terms of loudness level, commercial success and consistency between iZotope Ozone Insight and WLM.

The analysis clearly showed the steady increase in loudness level over time. Between the top 10 and the bottom 10 singles, there was no statistically significant difference. Therefore the results of this study illustrated that, for the Top 100 Billboard Year End Chart, there is no evidence of any correlation between the perceived loudness and the commercial success (sales).

Acknowledgements

- SABC Media Library: the manager and the staff, for all the trouble they went through to collect the right CD recordings for data collection, and their valuable inputs for this study.
- The department of Statistics (University of Pretoria): for very quick replies to all the emails and clear guidance which made the understanding of statistics straightforward.
- Murray de Villiers (University of Pretoria): for putting up with all the long emails, text messages and positive advice for this study.
- Tarryn Denton: for last minute help and strict guidance, and enthusiasm and interest for this study.
- Prof H.H. van der Mescht (University of Pretoria): for the motivation, supervision, support, guidance and proof reading.
- Dr C. Panebianco-Warrens: for long and open discussions, knowledgeable advice and guidance, and constructive inputs for this study.
- Grace, Hong: for continuous support, inspiration, encouragement, and assistance for data collection.

.

Contents

List of abbreviations

AES	Audio Engineering Society
BLV	Between Listener Variability
CRC	Communications Research Centre Canada
DAW	Digital Audio Workstation
dB	Decibel
dBFS	Decibels Full Scale
EBU	European Broadcasting Union
EBU R128	European Broadcasting Union Recommendation 128
GLM	General Linear Model
ISO	International Organization for Standardization
ITU	International Telecommunications Union
ITU-R BS.1770	International Telecommunications Union-Radiocommunication Broadcasting Service (Sound) 1770
LU	Loudness Unit
LUFS	Loudness Unit Full Scale
RLB	Revised Low-frequency B-curve
SABC	South African Broadcasting Corporation
SAS	Statistical Analysis Software
SPL	Sound Pressure Level
SRG	Special Rapporteur Group
WLM	Waves Loudness Meter
WLV	Within Listener Variability

Concept clarification

Decibel (dB) Decibel means tenth of a Bell which is a telephone communication measurement unit (named after the inventor, Alexander Bell). The unit is used to measure Sound Pressure Level (SPL). (Huber 2010: 58.)

High Pass Filters (HPF) HPF attenuates the lower frequencies of the audible spectrum and allows specific frequency bandwidths to pass at full level (Huber 2010:480).

Leq Leq is defined as equivalent continuous sound level (Lund 2011b:9). It is the Sound Pressure Level (SPL) in decibel (dB) which indicates the average of the total sound energy over a specific period of time (Bernard 1987:2).

Root Mean Square (RMS) The human ear perceives loudness in relation to the average volume level rather than peak level. In order to visually represent the estimated auditory loudness, the mathematical Root Mean Square function is applied to show the average volume level of sound. (Izhaki 2008:95–96.)

Sound Pressure Level (SPL) It is the acoustic sound pressure within a limited area. SPL is directly related to the auditory loudness: when SPL increases, the loudness level also increases. (Huber 2010: 59.)

Weighting (filters) It is utilised, when measuring SPL, to imitate the natural frequency response of human hearing as illustrated in the Equal-loudness contour. There are different weighting curves employed on SPL meters. dBA is one of the most common weighting curves applied when measuring SPL. This curve represents the response of human hearing at 40 phons according to the Equal-loudness contour. (Stark 2005:73–74.)

List of figures

List of tables

Keywords

Auditory loudness perception

Billboard Top 100 Year End Charts 1990–2010

Consumption of popular music

EBU R128 recommendation

ITU-R BS.1770

iZotope Ozone Insight

Loudness measurement

Loudness War

Music consumption

Progressive loudness escalation

Waves Loudness Meter

Chapter 1
Introduction

1.1 Background to the study

In a competitive music recording market, artists and record companies strive to differentiate themselves from their competitors with each new album release, especially in the popular music (which refers to music that has wide appeal) genre (Middleton 2001:128–129). One of the ways that artists and record companies routinely attempted to improve the sale of recorded music was to manipulate the audio dynamics of the recordings to be perceived as to sound louder than those of their competitors (Campbell & Toulson 2009:2; Shepherd 2014). In the 1960s, when jukeboxes and seven inch diameter single track vinyl disc recordings (also known as singles) were still popular, record companies realized that these louder sounding singles gained more attention from the listeners than softer singles (Tesler 2008:4).

This trend of progressive loudness escalation, which is often referred to as the Loudness War phenomenon or as Loudness Race, became increasingly noticeable in recorded music from 1990 to 2010 (Katz 2007:71; Vickers 2011:346). The phenomenon developed more rapidly as a result of the technological advances (Vickers 2010:1). Prior to 1990, the technological restrictions in the audio recording process, such as signal-to-noise ratio and audio distortion, resulted in recordings with a limited amplitudinal range. Subsequently, the technological evolution of digital-based technologies in the 1990s provided technology for advanced dynamic processing. In addition, Digital Audio Workstations (DAWs) were increasingly preferred over analogue-based systems (Deruty & Tardieu 2014:49; Vickers 2010:2–3). Audio amplitudinal dynamics manipulation includes the following technologies (Deruty & Tardieu 2014:42; Katz 2011):

- audio dynamics compression (such as brickwall limiting);
- added audio dynamic distortion;
- aggressive high–frequency equalization;
- analogue over-saturation and digital clipping; and
- peak waveform normalization.

This phenomenon resulted in reduced dynamic range and audio quality. Consequently, there have been numerous oppositions to the Loudness War within the professional audio producing community (Shepherd 2014). A noteworthy study that is an example of the opposition to the Loudness War is Dave Viney's master's dissertation *The obsession with compression* (2008). Viney investigated the relationship between audio dynamic compression and commercial success which will be discussed further in Chapter 2 (Viney 2008:54). Although the author of this study encountered the dissertation by Viney only some time after the study had begun, it inspired this research extensively.

1.2 Aims of the study

This study aims to:

- measure and analyse popular music in terms of loudness and investigate the correlation between loudness and sales position;
- evaluate the existing research by Viney in terms of validity and comprehensiveness through conducting similar research where the loudness of selected singles from music sales charts is measured;
- expand on Viney's research by utilising a larger music corpus spread over a specific period of time;
- examine and compare some of the popular loudness measurement plug-ins, and specifically the two plug-ins (due to convenience and availability): iZotope Ozone Insight and Waves Loudness Meter (WLM); and
- create more awareness in the music industry, especially in South Africa, about what perceived loudness is and how it affects the music recording industry and its market.

Contrasting to Viney's research where *randomly* chosen singles derived from the UK Music Week charts were used, this study investigates the correlation between loudness levels of the top 10 and the bottom 10 singles from the Top 100 Billboard Year End Chart between 1980 and 2010 (http://www.billboard.com/charts/year-end) that were *deliberately* chosen.

1.3 Research questions

The foregoing discussion led the author of this study to formulate the following main research question:

- To what extent does the loudness of commercial music recordings affect music sales as reflected by the sales chart position of the popular music industry between 1980 and 2010?

In order to answer the main research question, the following sub-questions should be investigated:

- What is the average loudness trend of the top 10 of the Top 100 Billboard Year End Chart between 1980 and 2010?
- What is the average loudness trend of the bottom 10 of the Top 100 Billboard Year End Chart between 1980 and 2010?
- Is commercially successful recorded music louder than less successful recorded music between 1980 and 2010, and if so, to what extent?
- Is there any consistency between the loudness measurement plug-ins iZotope Ozone Insight and Waves Loudness Meter?

1.4 Delimitations of the study

Amongst the numerous aspects that had to be carefully considered for this study was the issue of sample size. This was regarded as the most important. The progressive loudness escalation was most prominent from 1990 to 2010 (Deruty 2011), therefore the singles that make up the Top 100 Billboard Year End charts from 1990 to 2010 were chosen to be measured and analysed.

The singles from the charts were selected at five year intervals: 1990, 1995, 2000, 2005 and 2010. The reason for selecting five year intervals is due to the scope of the sample data. The statisticians for this study agreed that five year intervals give enough data to perform statistical tests and analysis.

The top 10 and bottom 10 from 1980 and 1985 were also measured and compared to the recorded songs between 1990 and 2010 to observe any significant loudness changes over time, and any anticipated loudness escalation before 1990 (Hjortkjær & Walther-Hansen 2014:37).

For the purpose of this study, the top 10 charted singles will be regarded as being more commercially successful than the bottom 10 of the Top 100 Billboard Year End Chart.

Chapter 2
Literature review

In this Chapter, the complexity and subjectivity of loudness perception is investigated. A considerable amount of literature has been published on loudness perception and how it is affected by different aspects. These aspects can be divided mainly into two variabilities: Between Listener Variability and Within Listener Variability. Following the discussion of different elements of loudness perception, some of the notable literature on the impact of the loudness perception in the Loudness War is reviewed in this Chapter.

2.1 Loudness perception

Loudness perception is a complicated phenomenon that relates to the way the human brain perceives sound (Olson 1972:18). Loudness can be described in different ways:

- Loudness is “one of the response functions of the human hearing mechanism: the magnitude of the resultant sensation when a sound or noise of any quality or structure impinges upon the human ear” (Olson 1972:18);
- Loudness refers to the “perceptual level of audio intensity that is being created inside the listener’s brain” (Katz 2007:166);
- Loudness is a “complex subjective impression and, since loudness relates to human perception, it can be prone to phenomena such as Between Listener Variability and Within Listener Variability” (Camerer 2011).

Various sources define loudness perception as complex and subjective, and there are multiple elements that should be taken into consideration when investigating loudness perception. For instance, human’s ears are more sensitive to some frequencies than to others. It is widely known that the human hearing is most sensitive in the frequency range of 1 KHz and 5 KHz (Norcross, Lavoie & Thibault 2011:3). Other elements that can affect the perception of loudness include amplitude, spectral, optical, temporal and spatial aspects. The next section explores how these aspects can influence the human ear with regard to loudness perception.

2.2 Auditory loudness perception and human hearing

With a decrease in the Sound Pressure Level (SPL) the perception of the frequency range also decreases particularly in the low and high frequency ranges (Zemack 2007:4). The human hearing response to audio amplitude intensity in terms of frequency can be shown graphically by the Equal-loudness contours as illustrated below:

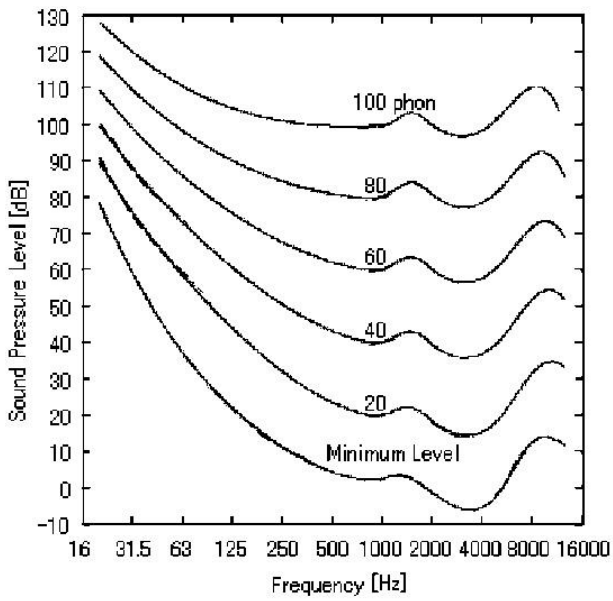


Figure 1. Human hearing response according to the ISO 226:2003 Standard Equal-loudness contour (ISO 2003)

The contour exhibits the non-linearity of the perception of loudness with respect to audio frequency. For example, a 63 Hz signal has to be about 40 dB louder than a 1 KHz signal for humans to perceive the two signals as the same loudness. (Camerer 2011; ISO 2003.)

For audio loudness or SPL measurement, in order to imitate the human hearing response that is "frequency dependent" at different intensity levels and non-linear, different frequency dependent filters and weightings are applied (Skovenborg & Nielsen 2004:7). For instance, M-weighting is utilised to calibrate cinema sound systems and D-weighting is used for aircraft engine noise measurements but rarely utilised for other purposes (Zemack 2007:7–8). The following figure shows the different frequency response curves of various filters (Skovenborg & Nielsen 2004:7):

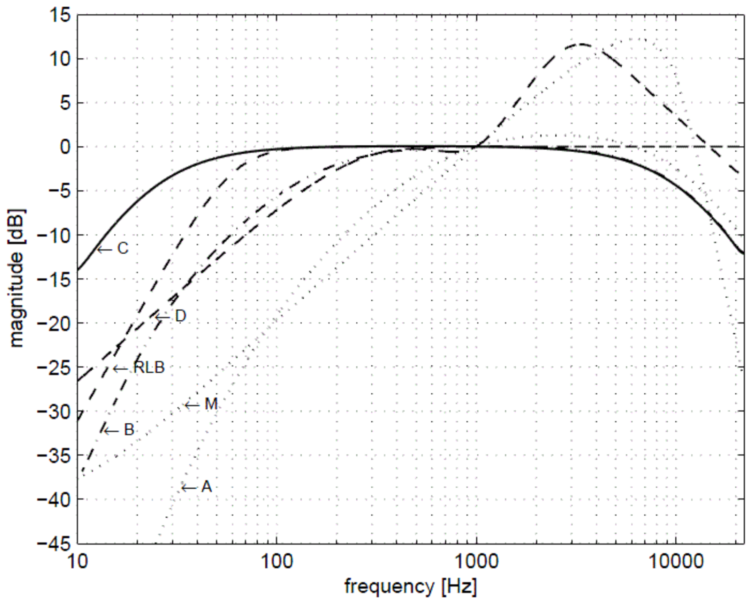


Figure 2. Frequency response of A, B, C, D, M and RLB weighting filters (Skovenborg & Nielsen 2004:7)

These filters typically apply High-Pass Filters (HPF) that imitate the human hearing response where the lower frequency part of the spectrum is less sensitive (Skovenborg & Nielsen 2004:7). In simple terms, when the playback or volume level is low, some parts of the frequency spectrum are less likely to be heard or not heard at all. For instance, well-known audio experts such as Florian Camerer and Bob Katz mentioned at different audio seminars that they experienced a piece of music as sounding better when it was even slightly louder to which they attribute as a result of the human hearing response (Camerer 2011; Katz 2009). But the awareness of a delicate change in loudness can be subjective and diverse, depending on levels of prior ear training. Moreover, the experience will vary depending on listening environments (Vickers 2010:7).

Lund (2011a) also mentioned at an audio seminar that perceived loudness can be highly subjective, and it is important to consider loudness perception in terms of inter- and intra-observer variation. The following terms are used to define listener variability:

- Between Listener Variability (BLV)
- Within Listener Variability (WLV)

BLV refers to the inter-observer variables that can influence subjective loudness like gender, culture and age. WLV refers to intra-observer variables for example a listener's psychological predisposition according to the weather and time of the day (Lund 2007:6). These various qualities can introduce a range of difficulties in measuring loudness objectively. There are experimental studies that illustrate these subjective aspects of perceived loudness, for example:

- An optical and auditory experiment illustrated that the judgement of the subjects show differences in perceived loudness up to 12% when the same sound source was played to them several times and each time with a different colour (Patcouras, Filippou & Fastl 2002:6).
- A study investigating perceived loudness in patients with hearing aids from different age groups (younger than 35 years and older than 45 years) showed high inter-individual variability in the level-loudness functions (Von Wedel, Meister & Walger 2000:190–191).

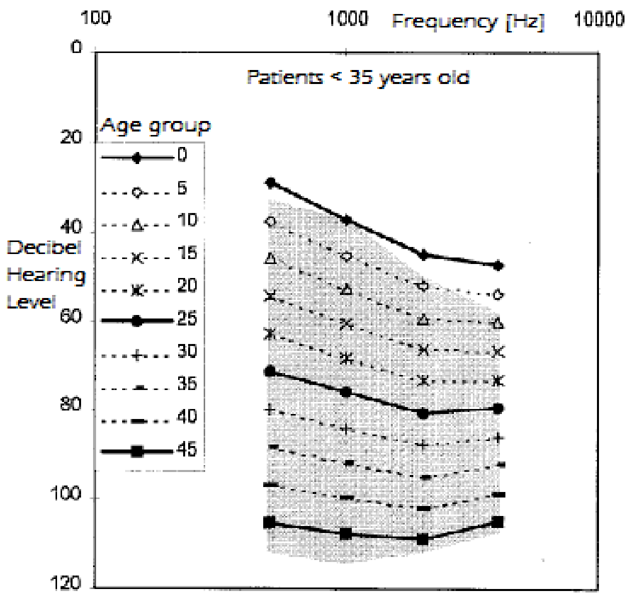


Figure 3. Inter-individual loudness perception variability in terms of frequency (Hz) and intensity (dB) in persons younger than 35 years (Von Wedel, Meister & Walger 2000:191)

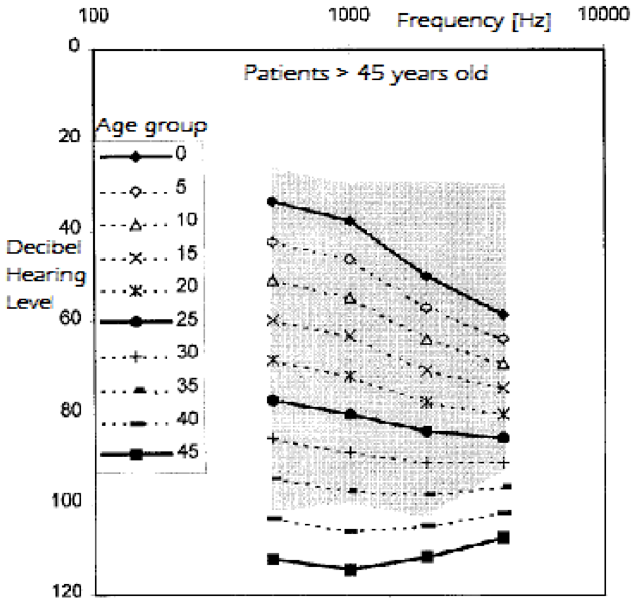


Figure 4. Inter-individual loudness perception variability in terms of frequency (Hz) and intensity (dB) in persons older than 45 years (Von Wedel, Meister & Walger 2000:190)

The results reveal not only the difference in loudness perception in terms of age group (WLV), but also the difference in loudness perception within the same age group (BLV) (Von Wedel, Meister & Walger 2000:193–194).

There are other aspects that can also influence loudness perception. According to Skovenborg and Nielsen (2004:2–3), temporal and spatial aspects influence perception. Some examples of temporal effects are:

- Post-masking effect: This occurs when one sound is perceived differently after another sound than it would be when heard alone.
- Temporal threshold shift: This is temporary reduced hearing ability after extended exposure to high SPLs, for example after attending a loud rock concert.

Spatial aspects can influence loudness perception for example (Skovenborg & Nielsen 2004:3):

- Direction dependent filtering: Filtering induced by the outer ear results in loudness being perceived differently, depending on the position of the source in relation to the lateral of the earlobe.
- Binaural loudness summation: When both ears are actively listening simultaneously, it is possible for a sound to reach one ear before the other.
- Room reverberation characteristics: Listening to a sound in rooms with different acoustic characteristics can affect the perception of loudness.

Loudness perception is subjective and it can be influenced by numerous factors and parameters which introduce difficulties in measuring perceived loudness.

Although it was not directly aimed at the music industry and measuring music recordings, the ITU-R (www.itu.int) recommended an international technical standard algorithm for programme (an entire period of the audio signal that is measured) loudness measurement. The implementation of the standard is intended to better control of the perceived loudness of broadcasting audio materials. (ITU 2012:7.) The recommendation is known as the ITU-R BS.1770, and the latest version is BS.1770-3 published in 2012 (ITU 2012:8).

The **ITU-R BS.1770** is specifically designed for broadcasting audio signals. Several subjective tests were conducted where subjects had to match the loudness of monophonic audio signals to reference signals. (ITU 2012:7–8). The following were some of these tests:

- *Subjective assessment of loudness characteristics* (ITU-R 2003);
- *The subjective loudness of typical program material* (Soulodre, Lavoie & Norcross 2003);
- *Evaluation of objective loudness meters* (Soulodre 2004);
- *Evaluation of designs for loudness-matching experiments* (Skovenborg & Nielsen 2004); and
- *Loudness assessment of music and speech* (Skovenborg & Nielsen 2004).

A number of algorithms were evaluated and Leq(RLB), which was contributed by Soulodre *Evaluation of Objective Loudness Meters* (2004), was found to be the meter that performed the best. ITU-R BS.1770 recommends that the presented algorithms in the document operate in measuring mono, stereo and multichannel audio signals (ITU 2012:8).

2.3 The progressive loudness escalation

As illustrated in the Equal-loudness contour (Figure 1), human hearing is non-linear. Frequently, when the same music was played at two different volume levels, general music listeners tend to choose the louder one because there are more frequencies audible. (Vickers 2011:347). This non-linearity played a key role in the development of the loudness escalation in the popular music industry (Vickers 2011:347), although, there were some of opposing views to the belief that louder is better. The following are some of the most recent arguments:

- In the Evergreen Project analysis by Chris Johnson, he mentions that loudness does not affect sales but "the more strongly they sell, the more likely it is that they will have High Contrast characteristics (a wide dynamic range)" (Vickers 2010:17).
- In a data analysis of the Unofficial Dynamic Range Database (http://www.dr.loudness-war.info/) and Billboard 200 year end charts (1980–2000), it has been found that there is a very weak correlation between loudness and sales (Vickers 2010:18).

In the dissertation by Viney, quantitative loudness measurement and qualitative assessment by 36 professional music producers and audio engineers was conducted. 30 singles were randomly chosen from the UK charts and measured in terms of loudness (Viney 2008:5).

The conclusion of the research was that there is no significant correlation between the measured loudness and commercial success (Viney 2008:10, 54–55). In addition, the qualitative assessment concluded that recorded music with less audio compression was more commercially successful (Viney 2008:54). Viney (2008:55) even branches off and writes that, apart from loudness, there are other unidentified marketing factors, mostly with radio and TV play which affect sales. He states, additionally, that there is no clear single pattern between music sales and its marketing, and the marketing strategies are rather complicated (Viney 2008:55).

Besides the critical study and analysis of the Loudness War, standardising the loudness requirements in order to restrict the Loudness War phenomenon was necessary. For instance, the film industry has a standardised monitoring gain proposed by Ioan Allen in the 1970s: 85 dB SPL at -20 dBFS for a large theatre applications and 79 dB SPL at -20 dBFS for a small home theatre applications (Katz 2000:803–804).

Katz (2000:804–809) suggested an integrated metering and monitoring standard called the K-system which specifies 85 dB SPL pink noise to be at 0 VU point for a given monitoring system. Pink noise is random noise consisting of frequencies of equal strength across the audio spectrum (Buick & Lennard 1995:46). Although the EBU R128 recommendation does not directly address the Loudness War in the music industry, loudness normalisation according to the R128 recommendation spec of -23 LUFS as a reference loudness can be another means to restricting the Loudness War (EBU 2011a; Vickers 2011:350).

Some commercial loudness metering and measurement methods are available to audio engineers that can assist in standardising the loudness levels, for example, the K-system (not exactly a loudness metering method but it helps to manage the loudness level more effectively), the EBU R128 recommendation and the ITU-R BS.1770 standard. These methods or recommendations are mainly based on audio dynamic range and the use of dynamic processing measurement such as crest factor (ratio between peak and RMS) and the application of audio compression (reduction of dynamic range) (Katz 2007:112).

There have been numerous literature that discuss problems caused by the Loudness War and the criticism against the phenomenon. In addition, some of the literature made suggestions of standardisation of perceived loudness measurement by utilising measurement algorithm such as the ITU-R BS.1770. Consequently, a number of software measurement devices became available which is aimed at standardising perceived loudness measurement specifically. However, to the best of the author’s knowledge, there is far too little attention has been paid to assess these measurement devices for its inter and intra consistency and uniformity between different devices. This indicates a potential gap in the research in terms of the performance, consistency and comparison between the current perceived loudness metering and measurement methods which will be discussed further in Chapter 3.

Chapter 3
Research methodology

3.1 Research design

This quantitative study (Maree 2008:149–152; Mouton 2001:155–156) is based on a non-experimental correlational design to determine whether there is any relationship between the independent variables, namely the inherent audio loudness as measured by two different commercially available plug-ins (iZotope Ozone Insight and WLM). This study will investigate the relationship between the three different measurements (integrated loudness, momentary maximum loudness and loudness range), and the dependent variable, record sales as indicated by the top 10 and the bottom 10 singles of the Top 100 Year End Charts by Billboard Chart from 1980 to 2010.

3.2 Music corpus

At the end of each year, Billboard Chart publishes the Top 100 Year End Charts which provide valuable data to the public (recording sales and airplay of each year) on music consumption. The research corpus for the present study is derived from the Top 100 Billboard Year End Charts of 1980, 1985, 1990, 1995, 2000, 2005 and 2010 (see Appendix A).

A total of 140 singles from 1980 to 2010 (with 5 year intervals) were measured for this study. At first, the top 10 and the bottom 10 singles of every year with no discrete time intervals were going to be measured which totalled 620 singles. In conversations with the statisticians who analysed the data for this study and the SABC Radio Media Library manager, it was mentioned that 620 singles are beyond the scope of this study. It was decided that five year intervals will still provide sufficient data for statistical analysis.

The SABC Radio Media Library in Auckland Park in Johannesburg, a national broadcasting centre that has one of the largest collections of vinyl and CD recordings in South Africa, kindly made the original CD recordings available for this study. In terms of the copyright law of the CD recordings, they were not duplicated and were used for research purposes only which was the agreement made between the Media Library and the author of this study.

Only CD recordings were utilised for this study. The majority of the original recordings from 1980 and 1985 were on vinyl. Due to the constraints of the measurement process (digital plug-ins were used for the measurement), re-mastered versions of these recordings on CDs were utilised for the measurements. The dates on which these recordings were re-mastered onto CD varies from 1990 to 2009. This was one of the major concerns as it loses the consistency since the recordings utilised for the measurements are not the original recordings. Nevertheless, data collection continued with what was available for 1980 and 1985 to make a comparison to 1990, 1995, 2000, 2005 and 2010. As a result of these re-mastered CDs, there are a few extreme outliers in the statistical analysis.

Initially the loudness of the top 20 and the bottom 20 (numbers 81 to 100) singles of each year was planned to be measured. However, because of the lack of availability of the original CD recordings, the music corpus was reduced to the top 10 and the bottom 10 singles from each year. A further concern was that some singles were not available in the SABC Media Library within the top 10 and the bottom 10 singles. It occurred more often within the bottom 10 singles. To resolve this issue, the singles which were the closest to the top 10 and the bottom 10 singles were chosen. For example, for the top 10 in 1985, the chart position 12 (*Easy lover* by Phil Collins and Philip Bailey) was chosen because the chart position 6 (*Crazy little thing called love* by Queen) and 11 (*Escape* by Rupert Holmes) were not available at the SABC Radio Media Library.

3.3 Data collection

As discussed in Chapter 2, the measurement of perceived loudness has certain problems mainly due to two variabilities such as BLV and WLV. Nonetheless, algorithms such as the ITU-R BS.1770 have helped to manage more consistent and objective measurements of perceived loudness. For this reason, commercial plug-ins for instance, iZotope Ozone Insight (www.izotope.com) and WLM (http://www.waves.com) are utilised for the loudness measurement. Both plug-ins are compliant with the EBU R128 and ITU-R BS.1770 recommendations.

The music corpus is measured by iZotope Ozone Insight and WLM for three variables. The long-term or integrated loudness, momentary maximum loudness and loudness range. The integrated loudness measurement is a calculation of the average loudness for the entire specified period. The momentary maximum loudness is the measurement of the maximum loudness level within a specific period of time, and the loudness range is the entire loudness range for a total period. (iZotope 2006:16.) The unit used for loudness measurement are LU (Loudness Unit) for relative value and LUFS (Loudness Unit Full Scale) or LKFS (Loudness K-weighted Full Scale). LUFS and LKFS are identical (ITU 2012:2). The recordings are imported temporarily into Cubase 5 (version 5.5.3, 32 bit), and then exported as a wave file according to Red Book specifications (44.1 KHz and 16 bits) while iZotope Ozone Insight and WLM are operated simultaneously.

Default setting used for iZotope Ozone Insight and WLM can be seen in Table 1:

	iZotope Ozone Insight	**WLM**
Version	1.02.120.OSX32-Carbon	9.1.0.9 build 1361
Method	EBU	
Weighting	ITU BS. 1770	
Gate	Gate off	
Target	-24 LUFS	
Other	No pre-filtering selected	

Table 1. iZotope Ozone Insight and WLM default measurement settings

The settings in both plug-ins were reset after every measurement to avoid continuous calculation from preceding measurements.

The temporarily imported and exported wave files were never saved and the Cubase project and audio folders were erased immediately after the measurement. While the data capturing was taking place, the SABC Radio Media Library manager was present at all times for assistance and to check that the original CD recordings were not duplicated.

Many of the singles chosen for the purpose of this study had silence before and after the actual audio signal. In order to ensure the accuracy and consistency of the measurement results, it was necessary to remove these periods of recorded silence.

3.4 Data analysis

The data were analysed by staff from the Statistics Department at the University of Pretoria and presented in graphs. The data were tested for differences over time and between the top and bottom chart groups. Measurements by iZotope Ozone Insight and WLM were tested for consistency, using Statistical Analysis Software (SAS) (www.sas.com). The six response variables, namely integrated loudness, momentary max, and loudness range as measured by the two plug-ins were evaluated.

The six response variables were analysed in a multivariate analysis General Linear Model (GLM), taking both independent variables (time and chart group) into consideration. Since multiple measurements were taken over time, the repeated-measures design (see Appendix D) was used. This design measures the same variables at different times (Field & Miles 2010:690). Therefore, the effect of time (1980 to 2010) and chart group (the top 10 and bottom 10) were tested in a single analysis to investigate the interaction between the two independent explanatory variables.

Box plots are used to summarise the results for the six response variables. Box plots, also known as box-whisker diagrams, show the median, quartiles, interquartile range, outliers and extreme outliers. The bottom quartile indicates the lowest 25% of the results, and the top quartile indicates the top 25%. The middle, the interquartile range, 50% is indicated by the box (see Appendix F). The two whiskers sticking out of the box stretch to the highest and the lowest values at each end. (Dalgaard 2008:75.) Outliers are the unusual cases or values in comparison to the majority of the observations and are indicated with individual points. With box plots, the distribution of the results as well as the symmetry of the results can be clearly seen. (Field & Miles 2010:97.) Therefore, with box plots, the softest and the loudest measurement are easily observable for each top 10 and bottom 10 singles in every year. The average loudness of both top 10 and bottom 10 singles is also discernible by the median and interquartile range. Moreover, the comparison between the top 10 and bottom 10 singles measurements are clearly indicated with the box plots.

The three loudness measures: integrated loudness, momentary max and loudness range were made for each single using both iZotope Ozone Insight and WLM. A matched pair t-test, also known as dependent-means t-test (Field & Miles 2010:270), was used for a comparison between the iZotope Ozone Insight and WLM measurements. The t-test compares whether two matched means are statistically different from one another, and takes into account the difference between the group means and the variance within each group (Field & Miles 2010:269). The measurements for each of the 140 singles, regardless of the chart position or year, were analysed to test whether the two means (averages) for iZotope Ozone Insight and WLM are different from each other.

In order to identify the probability of statistically significant differences between the two measurement groups, p-values are reported together with the t-test results. The p-value indicates whether there is a statistically significant difference between two compared measurements or variables. A p-value of less than 0.05 or 5 percentage is used as a cut-off for assessing whether there is a statistically significant difference. (Watkins, Scheaffer & Cobb 2011:390, 496.)

Chapter 4
Results and discussion

In this Chapter, the results of the data analysis of the integrated loudness, momentary maximum loudness, loudness range measurements, and the comparison of the measurements between iZotope Ozone Insight and WLM are discussed. As mentioned in Chapter 3, box plots are used to illustrate the results of the analysis. Summaries of the GLM and t-test are presented in tables, the complete results are included in Appendix D for reference.

4.1 Integrated loudness measurement of the top 10 and the bottom 10 singles

The initial GLM included the analysis of the combined integrated loudness measurements for the top 10 and the bottom 10 singles. Figure 5 is a visual representation of the development of the loudness escalation trend over the entire time period selected. It shows the combined integrated loudness levels of both the top 10 and the bottom 10 singles measured by iZotope Ozone Insight over time period of 1980 and 2010.

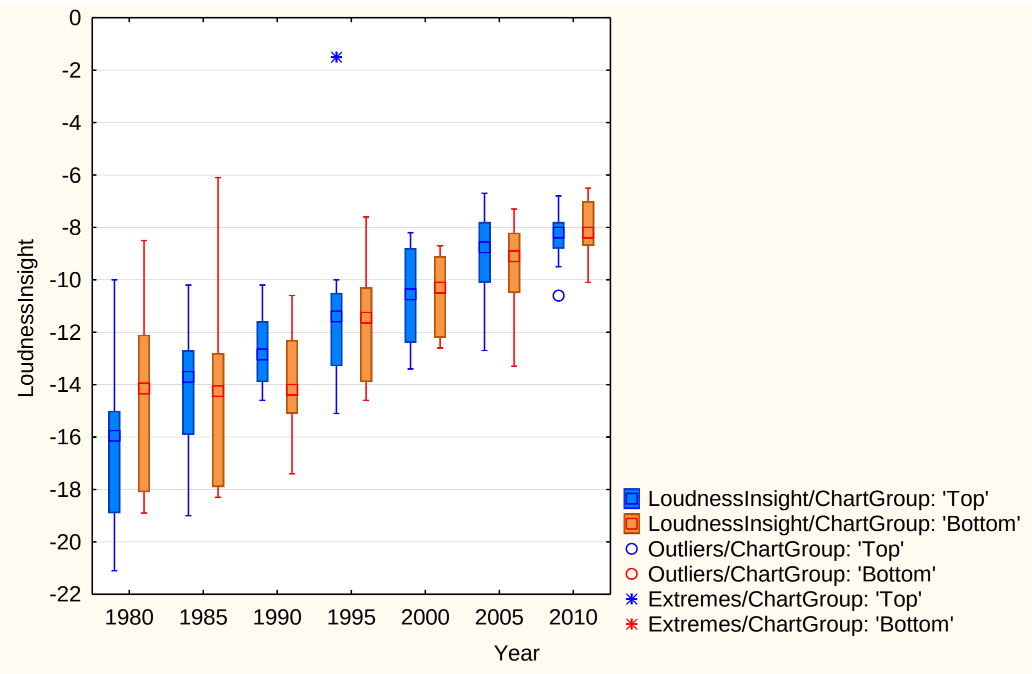


Figure 5. Box plot of combined integrated loudness measurements with iZotope Ozone Insight grouped by year and categorized by chart group (data.sta 10v* 140c). LoudnessInsight indicates the loudness level measured by iZotope Ozone Insight

Figure 5 shows a clear loudness level increasing over time. It is also evident from the analysis, there was no obvious or consistent difference between the top 10 and the bottom 10 singles. In some years, the top 10 singles were louder than the bottom 10 singles for example in 1990, 2000 and 2005. But in 1980, 1995 and 2010, the top 10 singles were softer than the bottom 10 singles or have similar average loudness level as the bottom 10 singles.

LoudnessInsight	Year	Interaction	ChartGroup
MANOVA F value (p-value)	44.99 (<0.0001)	1.2 (0.37)	
Univariate F value (p-value)	24.22 (<0.0001)	0.98 (0.43)	0.19 (0.66)

Table 2. Summary of LoudnessInsight GLM results

The results of the GLM analysis of the LoudnessInsight measurements confirm that there were statistically significant differences between these measurements over time, p-value less than 0.05. The differences between the top 10 and the bottom 10 chart groups were not statistically significant and there was not a significant interaction between Year and ChartGroup.

The range of the data is indicated by the whiskers in the box plot in Figure 5. In 1980 and 1985, the wide range of the lower and upper whiskers deviates from the average range of the whiskers in other years. This shows that some singles were unusually louder or softer than the average in the specific year which was anticipated prior to the data collection. The majority of the singles measured for 1980 and 1985 were re-mastered versions which tend to be louder than their original recordings. Regardless, the mean loudness measurement value in 1980 and 1985 was still relatively softer than the singles from the next 20 years. This was also observable in Figure 6 which is the analysis of the integrated loudness measurement by WLM.

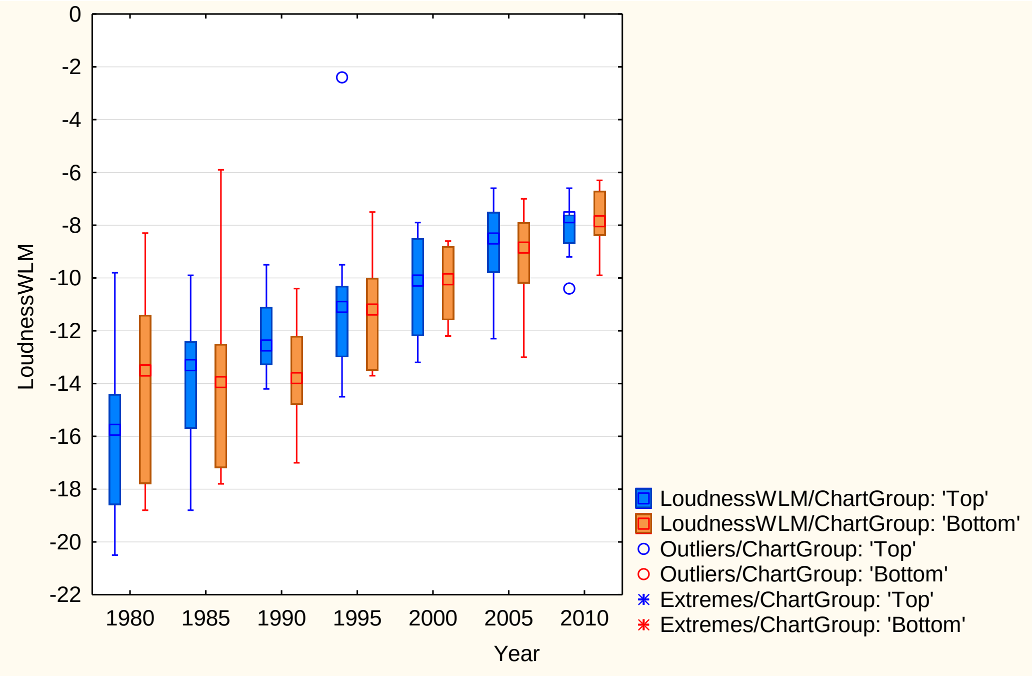


Figure 6. Box plot of combined integrated loudness measurements with WLM grouped by year and categorized by chart group (data.sta 10v* 140c). LoudnessWLM indicates the loudness level measured by WLM

The development of the trend (increasing loudness level) is clear in Figure 6. The increase in loudness level over time in both Figures 5 and 6 confirms the existence of the Loudness War phenomenon, specifically from 1990 to 2010. There was no consistent difference between the top 10 and the bottom 10 singles. The average level of the bottom 10 singles in 1990, 2000 and 2005 were about 1 LUFS or less softer than the top 10 singles from the same years, but the top 10 singles in other years were not always louder than the bottom 10 singles.

There were a few extreme outliers evident in the data, for example, in the top 10 of 1995. In this year, the highest measurement results of the top 10 singles by the iZotope Ozone Insight and WLM were recorded -1.5 LUFS and -2.4 LUFS respectively. In order to see if the extreme outliers influenced the trend, the analysis was done twice, once with the extreme outliers and again without (see Appendix D). The results were only marginally different and there was no effect on the trend as shown in Figures 5 and 6.

To sum up briefly, the box plot and GLM analysis of the data shows the loudness level increasing over time. But there was no statistical difference between the top 10 and the bottom 10 singles.

4.2 Momentary maximum loudness measurement of the top 10 and the bottom 10 singles

The momentary max loudness measurement analysis displays a similar loudness level increasing over time as the results of the integrated loudness measurement analysis. Figure 7 illustrates the results of the analysis of the momentary max measurement for all the singles for each group by iZotope Ozone Insight. The results of analysis of the momentary max loudness are summarised in Figures 7 and 8.

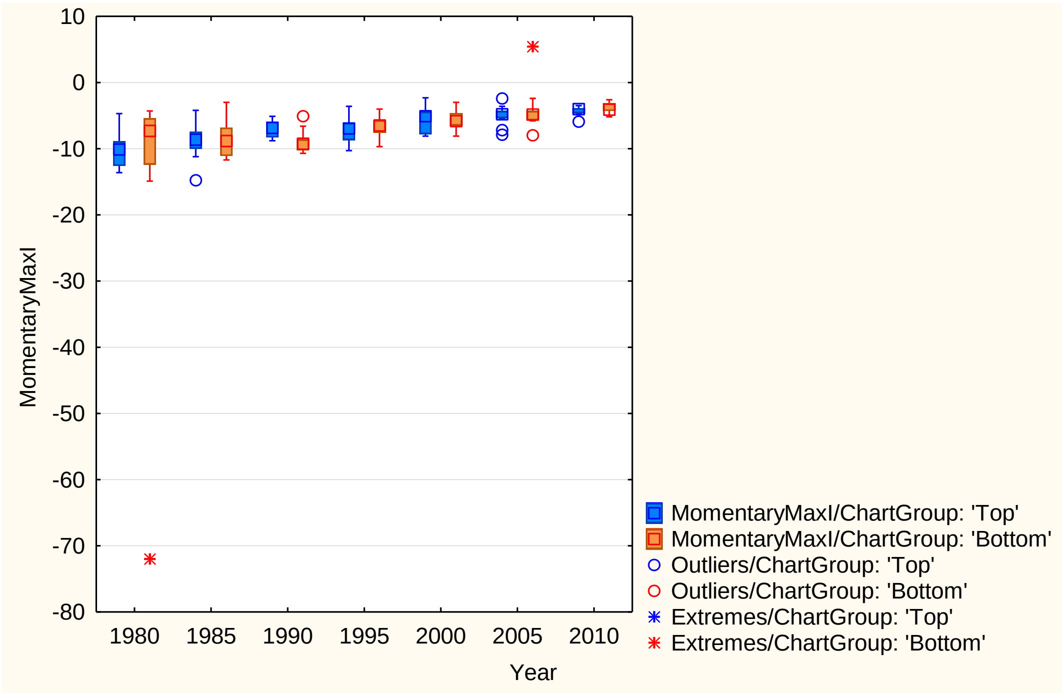


Figure 7. Box plot of momentary maximum loudness measurements with iZotope Ozone Insight grouped by year and categorized by chart group (data.sta 10v* 140c). MomentaryMaxI indicates the loudness level measured by iZotope Ozone Insight

A number of extreme outliers occurred in Figure 7. For instance, in 1980, the lowest value of the bottom 10 singles were -72 LUFS in Figure 7. This might have been a measurement error. In order to examine if the extreme outliers have any significant impact, the GLM analysis was done once again without the extreme outliers, but there was no effect on the trend over time (see Appendix D). However, the extreme outlier made the MomentaryMaxI range larger which made it difficult to observe the progression of the trend developing over time.

Nevertheless, the loudness level increase was still noticeable. The analysis of the momentary max loudness measurement by WLM is shown in Figure 8.

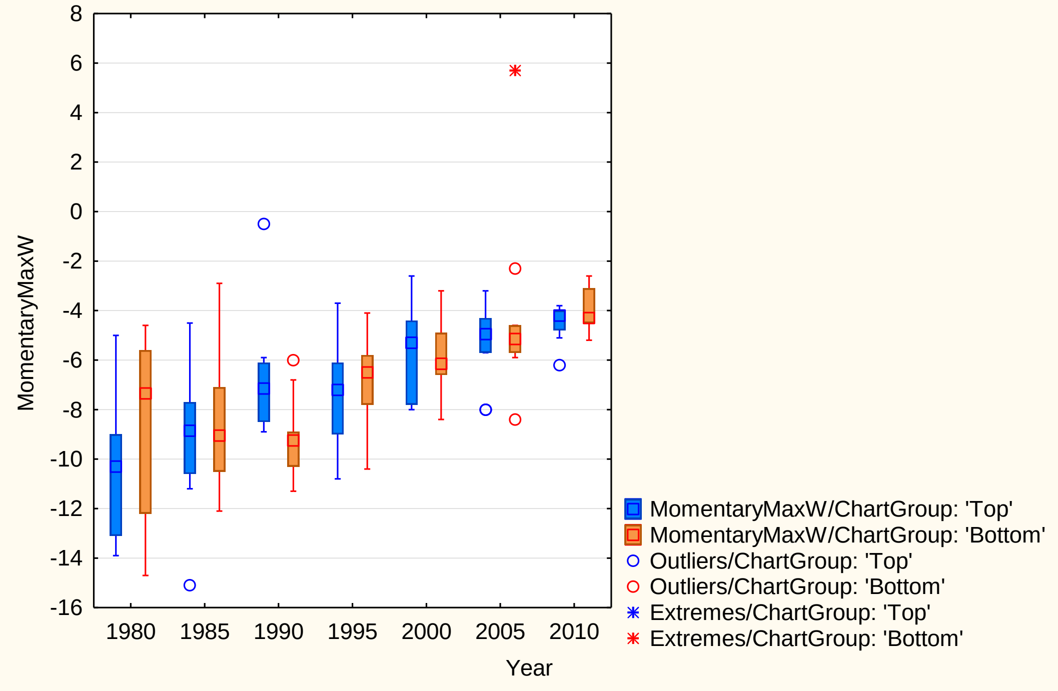


Figure 8. Box plot of momentary maximum loudness measurements with WLM grouped by year and categorized by chart group (data.sta 10v* 140c). MomentaryMaxW indicates the loudness level measured by WLM

The results of the analysis displayed in Figure 8 showed similar locality and spread of data as the integrated loudness measurement analysis displayed in Figures 5 and 6. There was a clear loudness level increasing trend over time, and there was no obvious evidence of any consistence difference between the momentary max loudness value of the top 10 and the bottom 10 singles.

In summary, the results of the analysis for both integrated loudness and momentary max loudness measurements displayed increasing loudness level over time (from 1980 to 2010). As mentioned earlier in this Chapter, there was no consistent evidence that there is any difference between the top 10 and the bottom 10 singes. In addition, it was noticeable that the range of the data became narrower towards 2010 which was shown by the reduced length of the whiskers and the range of the interquartiles. The softer singles within the music corpus chosen and measured for this study (for both top 10 and bottom 10 singles) became louder more rapidly than the louder singles over time since 1980.

4.3 Comparison of the loudness range between the top 10 and the bottom 10 singles

Figures 9 and 10 display the loudness range measurement by iZotope Ozone Insight and WLM.

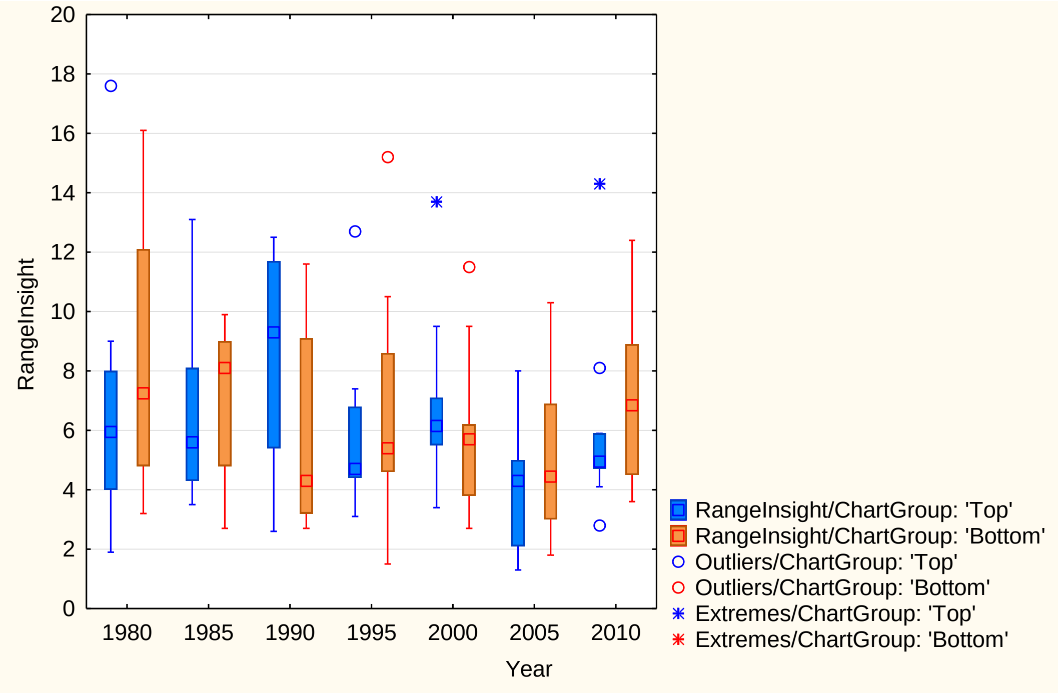


Figure 9. Box plot of loudness range measurements with iZotope Ozone Insight grouped by year and categorized by chart group (data.sta 10v* 140c). RangeInsight indicates the loudness range level measured by iZotope Ozone Insight

Contrary to the results of the integrated loudness and momentary max loudness measurements, there was no clear increase shown in the measurement of loudness range over time and no consistent difference between the top 10 and the bottom 10 singles. For example, the mean values of the bottom 10 singles are frequently higher than the top 10 singles, except in 1990 and 2000.

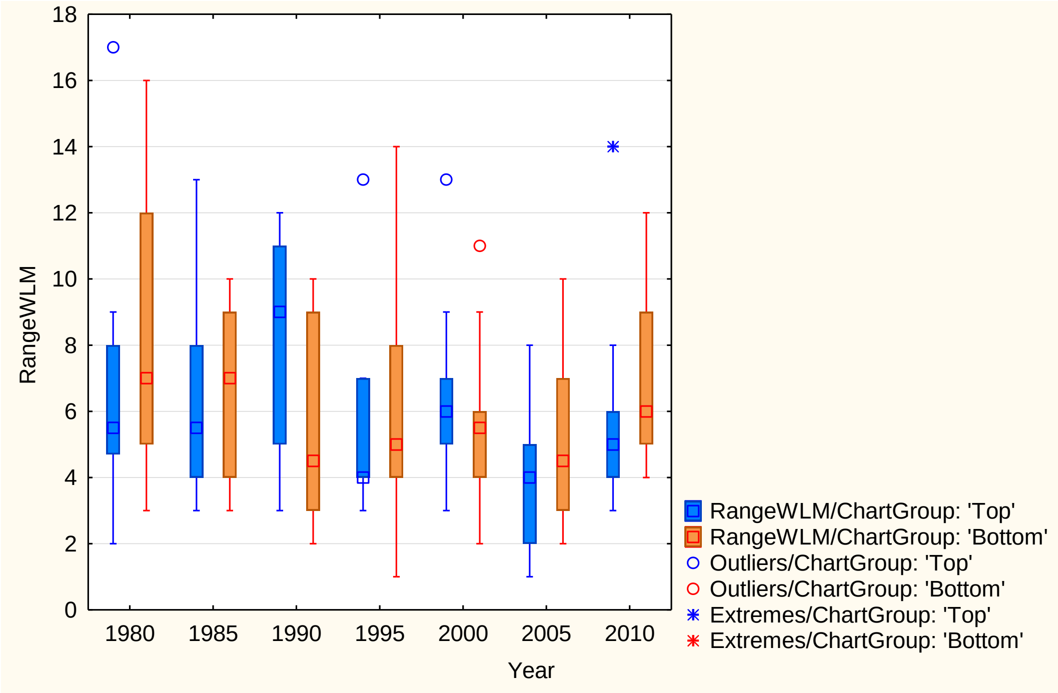


Figure 10. Box plot of loudness range measurements with WLM grouped by year and categorized by chart group (data.sta 10v* 140c). RangeWLM indicates the loudness range level measured by WLM

Also, the spread of the range of the data was often broader with the bottom 10 singles than the top 10 singles. The interquartile range (distribution of the middle 50% of the data) of the bottom 10 singles, for instance, was larger than the top 10 singles. This indicates that the bottom 10 singles have a more diverse loudness range than the top 10 singles. The trend (loudness level increasing) over time was not apparent in both Figures.

4.4 Comparison between iZotope Ozone Insight and WLM measurement plug-ins

The measurements of iZotope Ozone Insight and WLM were analysed and compared to ascertain consistency and accuracy of the measurement results. Regardless of the chart position or time, the integrated loudness measurements of iZotope Ozone Insight and WLM were compared by running a matched t-test. The result of the t-test of the integrated loudness measurement is presented in table 3 (also see Appendix C for the results for momentary max loudness and loudness range).

Variable	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	T	df	P-value
LoudnessInsight	-11.86	3.361	139	-0.35	0.266	-15.6227	138	0.00
LoudnessWLM	-11.50	3.263						

Table 3. T-test results for dependent samples of iZotope Ozone Insight and WLM. The two mean values compared regardless of chart position or time period. The extreme outliers were omitted from the analysis

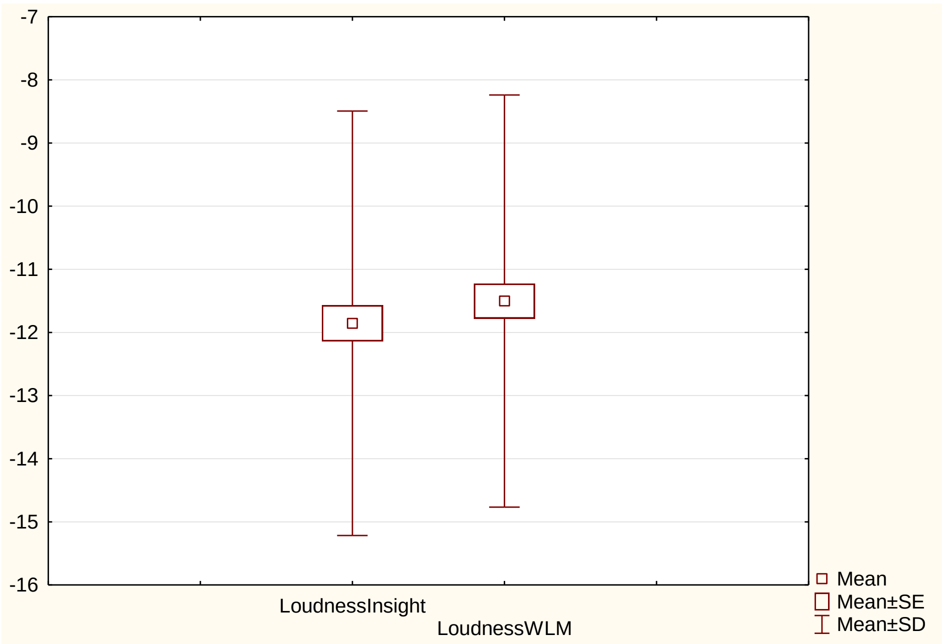


Figure 11. Box and whisker plot for LoudnessInsight versus LoudnessWLM. The two variables indicate the mean difference between iZotope Ozone Insight and WLM

The outcome of the t-test showed that the integrated loudness measurements of iZotope Ozone Insight and WLM are statistically different: t=-15.6227, p=0.0. P-value was less than 0.05 which indicates that the probability of the results being due to experimental error is low. The mean difference between the two plug-ins was less than 1 LUFS. The distribution of the data, in Figure 11, is similar between the two plug-ins, but the two interquartile ranges show a clear distinction.

Chapter 5
Conclusion and recommendations

The Loudness War has been continuously developing since 1980, especially since 1990 due to the technological development which made digital processing easier and cheaper, in the music recording industry. Many artists and record companies attempted to increase the recorded music sales by making the recordings louder than their competitors. This study set out to investigate whether there is any correlation between commercial success and perceived loudness, specifically in the popular music genre. The loudness level measurement of the 140 singles that were specifically chosen for this study have shown that there was a significant difference in the loudness level between 1980 and 2010.

5.1 The average loudness level trend of the top 10 and the bottom 10 singles

The results of the analysis display the steady increase in the loudness level over time. This was shown in the analysis of all three variables: integrated loudness, momentary maximum loudness and loudness range. The following table contains the mean value (combined average of the integrated loudness measurement) by iZotope Ozone Insight and WLM of the top 10 and the bottom 10 of each year from the analysis:

Year	Top 10 singles	Bottom 10 singles
1980	-16.15 LUFS	-14.22 LUFS
1985	-14.03 LUFS	-14.215 LUFS
1990	-12.49 LUFS	-13.87 LUFS
1995	-10.915 LUFS	-11.24 LUFS
2000	-10.495 LUFS	-10.34 LUFS
2005	-9.01 LUFS	-9.425 LUFS
2010	-8.24 LUFS	-7.9 LUFS

Table 4: The mean value of integrated loudness measurement of the top 10 and bottom 10 singles each year

The difference between the loudness level of the top 10 singles in 1980 and 2010 is -7.91 LUFS and the bottom 10 singles in the same years is -6.32 LUFS. It is more than 3 dB difference which is perceived as a doubling of the level of an audio signal (Huber 2010:61).
In spite of some of the extreme outliers in the analysis, the measurement results still show a clear trend as the loudness level progressively increased towards 2010 with statistically significant differences between years. Loudness levels of the top 10 and the bottom 10 singles were not significantly different and increased similarly over time. There was no statistically significant interaction between Year and ChartGroup.

In both integrated loudness and momentary max loudness measurement analysis, the range of the data became narrower towards 2010 (shown by box plots). This means that, at least within the selected music corpus for this study, the Loudness War affected the overall recorded music regardless of its commercial success. This is an important factor that is contributed by the Loudness War.

5.2 Is commercially successful recorded music louder than less successful recorded music between 1980 and 2010, and if so, to what extent?

The average loudness level (regardless of time period) of the top 10 singles measured by iZotope Ozone Insight and WLM was recorded at -11.78 LUFS and -11.46 LUFS respectively. The average loudness level of the bottom 10 singles measured by iZotope Ozone Insight and WLM was recorded at -11.78 LUFS and -11.41 LUFS respectively. There was no significant difference in the mean value between the top 10 and the bottom 10 singles.

In conclusion, there is no evidence that more commercially successful recorded music is louder than the less successful recorded music.

5.3 Consistency between the loudness measurement plug-ins, particularly iZotope Ozone Insight and Waves Loudness Meter

The difference between the measurement results of the two plug-ins was statistically significant. The difference was less than 1 dB which is practically significant for some of the highly trained and experienced audio engineers who have claimed that there is a change in the quality of the audio. Since 1 LUFS is equivalent to 1 dB (EBU 2011b:7, ITU 2012:7), it would be a subtle change in perceived loudness and subjective especially when BLV and WLV are taken into consideration. For example, Bob Katz mentioned in an AES meeting that he accidently found that the same audio signal, playing at 0.2 dB louder, had more depth, space and inner detail than the original audio signal (Katz 2009; Vickers 2010:5).

However, it is debatable whether it is significant for general music consumers. The author of this study doubts that subtle loudness level changes as small as 0.2 dB will have an impact and influence the perception of loudness drastically for general music consumers. Nevertheless, the mean difference between the two plug-ins is statistically and technically considerable, and more commercially available meters should be tested for their consistency.

5.4 Answering the main research question: To what extent does the loudness of commercial music recordings affect music sales as reflected by the sales chart position of the popular music industry between 1980 and 2010?

The evidence from this study suggests that there is no statistically significant difference between the loudness of the top 10 and the bottom 10 singles of the Year End Billboard charts from 1980 to 2010. Therefore, as the top 10 singles are considered more commercially successful than the bottom 10 singles, in conclusion there is no clear evidence of any relationship between the loudness and the commercial success (sales).

5.5 Recommendation for further research

The following are suggested topics for further research:

- Comparison of the top 10 and the bottom 10 of the Top 500 charts
- Different marketing strategies for a recording company, apart from making a recording louder than its competitors, to gain commercial success in the music industry.
- The comparison of the consistency between commercially available loudness meters using the ITU-R BS.1770 algorithm.

List of sources

Bak, N. 2004. *Completing your thesis: A practical guide*. Pretoria: Van Schaik.

Bernard, P. 1987. *Bruel and Kjaer application notes: Leq, SEL: what?, why?, when?* http://www.bksv.com/doc/bo0051.pdf. Accessed 20 July 2015.

Camerer, F. 2011. EBU R128 Introduction. Presentation at *Rome Calling*. Audio Seminar. http://www.youtube.com/watch?v=iuEtQqC-Sqo. Accessed 16 December 2013.

Campbell, B. & Toulson, R. 2009. *The life and death of dynamic range: Who decides how loud?* Proceedings of the art of record production conference. Cardiff. Wales. November.

Dalgaard, P. 2008. *Introductory statistics with R*. New York: Springer.

Deruty, E. 2011. Dynamic Range & The Loudness War. http://www.soundonsound.com/sos/sep11/articles/loudness.htm. Accessed 13 April 2014.

Deruty, E. & Tardieu, D. 2014. About dynamic processing in mainstream music. *Audio Engineering Society*, 62(1/2): 42–55.

EBU. 2011a. *EBU R128*: *Loudness normalisation and permitted maximum level of audio signals*. EBU Technical Recommendation R128. http://tech.ebu.ch/docs/r/r128.pdf. Accessed 12 October 2012.

EBU. 2011b. *Loudness metering: 'EBU Mode' metering to supplement loudness normalisation in accordance with EBU R 128*. Supplementary information for R128. Accessed 12 October 2012.

Field, A. & Miles, J. 2010. *Discovering statistics using SAS*. London: SAGE.

Hjortkjær, J. & Walther-Hansen, M. 2014. Perceptual Effects of Dynamic Range Compression in Popular Music Recordings. *Audio Engineering Society*, 62(1/2): 37–41.

Huber, D. M. 2010. *Modern Recording Techniques*. 7th ed. Oxford: Focal Press.

ISO. 2003. *ISO 226:2003*. *Normal Equal-Loudness-Level Contours*. 2nd ed. Geneva: International Organization for Standardization. http://www.sengpielaudio.com/Acoustics226-2003.pdf. Accessed 26 April 2013.

ITU. 2006. *ITU-R BS.1770*. Geneva: International Telecommunications Union. http://www.itu.int/rec/R-REC-BS.1770-200608-I/en. Accessed 12 October 2012.

ITU. 2012. *Recommendation ITU-R BS. 1770-3: Algorithms to measure audio programme loudness and true-peak audio level*. http://www.itu.int/rec/R-REC-BS.1770-3-201208-I/en. Accessed 12 October 2012.

Izhaki, R. 2008. *Mixing audio: Concepts, practices and tools*. Oxford: Focal Press.

iZotope. 2006. *iZotope Insight: Help guide*. Accessed 14 June 2015.

Katz, B. 2000. An Integrated Approach to Metering, Monitoring, and Levelling Practices. *Audio Engineering Society* 48(9): 800–809.

Katz, B. 2007. *Mastering Audio: The art and the science*. 2nd edition. Oxford: Focal Press.

Katz, B. 2009. About the "Loudness War". Presentation at the 127th AES convention. New York. Part 1: http://www.youtube.com/watch?v=XCd6MHlo_iA. Accessed 5 March 2012.

Katz, B. 2011. Loudness: War and Peace. http://www.youtube.com/watch?v=u9Fb3rWNWDA&feature=related. Accessed 28 October 2012.

Lund, T. 2007. *Level and distortion in digital broadcasting*. Risskov: TC Electronic. https://tech.ebu.ch/docs/techreview/trev_310-lund.pdf. Accessed 21 March 2014.

Lund, T. 2011a. EBU R128 in Transmission and Production. Presentation at *Rome Calling*. Audio Seminar of the year 2011. http://www.youtube.com/watch?v=cs0Vq9XrT2U. Accessed 21 December 2013.

Lund, T. 2011b. *ITU-R BS.1770 Revisited*. http://www.tcelectronic.com/lundt013011. Accessed 20 July 2015.

Maree, K. 2008. *First steps in research*. Pretoria: Van Schaik.

Middleton, R. 2001. Popular music. *The New Grove Dictionary of Music and Musicians*. 2nd edition. Edited by S. Sadie. Vol. 20. 128–166. New York: Macmillan.

Mouton, J. 2001. *How to succeed in your Master's and Doctoral Studies: A South African guide and resource book*. Pretoria: Van Schaik.

Norcross, S., Lavoie, M. & Thibault, L. 2011. *A status report on loudness control technologies and standardization for broadcasting: report submitted to the Canadian Radio-television and Telecommunications Commission in relation to the Broadcast notice of consultation CRTC 2011-102*. Ottawa: CRC Report.

Olson, H.F. 1972. *The Measurement of Loudness*. http://www.technicalaudio.com/pdf/Audio_Magazine_issues_articles/Harry%20F.%20Olson%20-%20The%20Measurement%20of%20Loudness.pdf. Accessed 25 April 2013.

Patcouras, C., Filippou, T. & Fastl, H. 2002. *Influences of color on the loudness judgement*. http://www.mmk.ei.tum.de/publ/pdf/02/02pat5.pdf. Accessed 25 April 2013.

Sengpiel. 1994. *Fletcher–Munson is not Robinson–Dadson*. http://www.sengpielaudio.com/Fletcher-MunsonIsNotRobinson-Dadson.pdf. Accessed 26 April 2013.

Shepherd, I. 2014. Loudness War Myths Explored: 1 – Louder is better (and sells more copies). http://productionadvice.co.uk/louder-better/. Accessed 13 April 2014.

Skovenborg, E. & Nielsen, S.H. 2004. *Evaluation of Different Loudness Models with Music and Speech Material*. Presentation at the 117th AES Convention. San Francisco. http://www.tcelectronic.com/media/1014016/skovenborg_2004_loudness_m.pdf. Accessed 1 January 2014.

Stark, S.H. 2005. *Live sound reinforcement: a comprehensive guide to P.A. and music reinforcement systems and technology*. Boston: Thomson Course Technology.

Tesler, P. 2008. Ear Ache. *Current Science*, 94(2): 4–5. http://search.proquest.com/docview/195877320?accountid=11774. Accessed 13 November 2012.

Vickers, E. 2010. *The Loudness War: Background, Speculation and Recommendations*. Presentation at the 129th AES Convention. San Francisco. http://www.sfxmachine.com/docs/loudnesswar/loudness_war.pdf. Accessed 25 April 2014.

Vickers, E. 2011. The Loudness War: Do louder, hypercompressed recordings sell better? *Audio Engineering Society*, 59(5): 346–351.

Viney, D. 2008. *The Obsession with compression*. A research project dissertation. Master's Degree. London College of Music. Faculty of Arts. Thames Valley University.

Von Wedel, H., Meister, H. & Walger, M. 2000. Untersuchungen zur Hörflächenskalierung im Rahmen der Hörgeräteversorgung. *HNO: Journal of the German Society of Oto-Rhino-Laryngology, Head and Neck Surgery* 48(3): 189–194. http://link.springer.com/article/10.1007%2Fs001060050031. Accessed 13 November 2012.

Watkins, A., Scheaffer, R. & Cobb, G. 2011. *Statistics from data to decision*. 2nd edition. New Jersey: John Wiley & Sons.

Zemack, M. 2007. *Implementing methods for equal loudness in radio broadcasting*. Master of science thesis. School for computer science and communication (KTH): Stockholm. http://www.speech.kth.se/prod/publications/files/3098.pdf. Accessed on 12 October 2013.

Appendix A: Top 10s and bottom 10s of the Billboard Top 100 Year End Charts (1980, 1985, 1990, 1995, 2000, 2005 and 2010)

(http://www.billboard.com/charts/year-end and http://www.bobborst.com/popculture/top-100-songs-of-the-year/)

Song Position – Artist's name – Song title

1980: Top 10		
1	Blondie	Call Me
2	Pink Floyd	Another Brick In The Wall
3	O. Newton-John	Magic
4	Michael Jackson	Rock With You
5	Captain & Tennille	Do That To Me One More Time
6	Queen	Crazy Little Thing Called Love
7	Paul McCartney	Coming Up
8	Lipps, Inc.	Funkytown
9	Billy Joel	It's Still Rock And Roll To Me
10	Bette Midler	The Rose

1980: Bottom 10		
90	Neil Diamond	September Morn
91	George Benson	Give Me The Night
92	Anne Murray	Broken Hearted Me
93	Kenny Rogers	You Decorated My Life
94	Fleetwood Mac	Tusk
95	Prince	I Wanna Be Your Lover
96	Charlie Daniels Band	In America
97	Boz Scaggs	Breakdown Dead Ahead
98	Barry Manilow	Ships
100	Tom Petty and The Heartbreakers	Refugee

1985: Top 10		
1	Wham!	Careless Whisper
2	Madonna	Like A Virgin
3	Wham!	Wake Me Up Before You Go-Go
4	Foreigner	I Want To Know What Love Is
5	Chaka Khan	I Feel For You
7	Tears For Fears	Everybody Wants To Rule The World
8	Dire Straits	Money For Nothing
9	Madonna	Crazy For You
10	a-ha	Take On Me
12	Phil Collins and Philip Bailey	Easy Lover

1985: Bottom 10		
85	Debarge	Who's Holding Donna Now
90	Jermaine Jackson	Do What You Do
92	Bruce Springsteen	Born In The USA
93	Tina Turner	Private Dancer
94	Aretha Franklin	Who's Zoomin' Who
95	Sting	Fortress Around Your Heart
96	Lionel Richie	Penny Lover
97	Don Henley	All She Wants To Do Is Dance
98	Madonna	Dress You Up
100	Sheena Easton	Sugar Walls

1990: Top 10		
1	Wilson Phillips	Hold on
2	Roxette	It must have been love
3	Sinead O'Connor	Nothing compares 2 u
4	Bell Biv Devoe	Poison
5	Madonna	Vogue
6	Mariah Carey	Vision of love
7	Phil Collins	Another day in paradise
8	En Vogue	Hold on
9	Billy Idol	Cradle of love
10	Jon Bon Jovi	Blaze of glory

1990: Bottom 10		
85	D-Mob With Cathy Dennis	C'mon And Get My Love
86	Paula Abdul	(It's Just) The Way That You Love Me
88	Michael Bolton	When I'm Back On My Feet Again
89	Keith Sweat	Make You Sweat
90	New Kids On The Block	This One's For The Children
91	Aerosmith	What it takes
92	Kiss	Forever
93	The Time	Jerk out
97	Motley Crue	Without you
98	Prince	Thieves in the temple

1995: Top 10		
1	Coolio	Gangsta's paradise
2	TLC	Waterfalls
3	TLC	Creep
4	Seal	Kiss from a rose
5	Boyz II Men	On bended knee
6	Real McCoy	Another night
7	Mariah Carey	Fantasy
8	Madonna	Take A Bow
9	Monica	Don't Take It Personal (Just One Of Dem Days)
10	Montell Jordan	This Is How We Do I

1995: Bottom 10		
90	Melissa Etheridge	Like The Way I Do-If I Wanted To
92	Stevie B	Dream About You-Funky Melody
93	Rednex	Cotton Eye Joe
94	Boyz II Men	Thank You
95	Pretenders	I'll Stand By You
96	N II U	I Miss You
97	Da Brat	Give It 2 You
98	Brandy	Best Friend
99	Soul Asylum	Misery
100	Van Halen	Can't Stop Lovin' You

2000: Top 10		
1	Faith Hill	Breathe
2	Santana feat. R.T.	Smooth
3	S. feat. P. GandB	Maria Maria
4	Joe	I wanna know
5	Vertical Horizon	Everything you want
6	Destiny's Child	Say my name
7	Savage Garden	I knew I loved you
8	Lonestar	Amazed
9	Matchbox Twenty	Bent
10	Toni Braxton	He wasn't man enough

2000: Bottom 10		
91	Sammie	I like it
92	Kevon Edmonds	24 /7
93	LFO	Girl on TV
94	Lil bow wow feat. Xscape	Bounce with me
95	Dixie Chicks	Cowboy take me away
96	Aaliyah	I don't wanna
97	*Destiny's Child	Independent women part I
98	Samantha Mumba	Gotta tell you
99	Jennifer Lopez	Waiting for tonight
100	Mary Mary	Shackles

2005: Top 10		
1	Mariah Carey	We belong together
2	Gwen Stefani	Hollaback girl
3	Mario	Let me love you
4	Kelly Clarkson	Since u been gone
5	Ciara feat. Missy Elliott	1, 2 step
6	Kanye West feat. Jamie Foxx	Gold digger
7	Green Day	Boulevard of broken dreams
8	50 Cen feat. Olivia	Candy shop
9	The Pussycat Dolls feat. Busta Rhymes	Don’t cha
10	Kelly Clarkson	Behind these hazel eyes

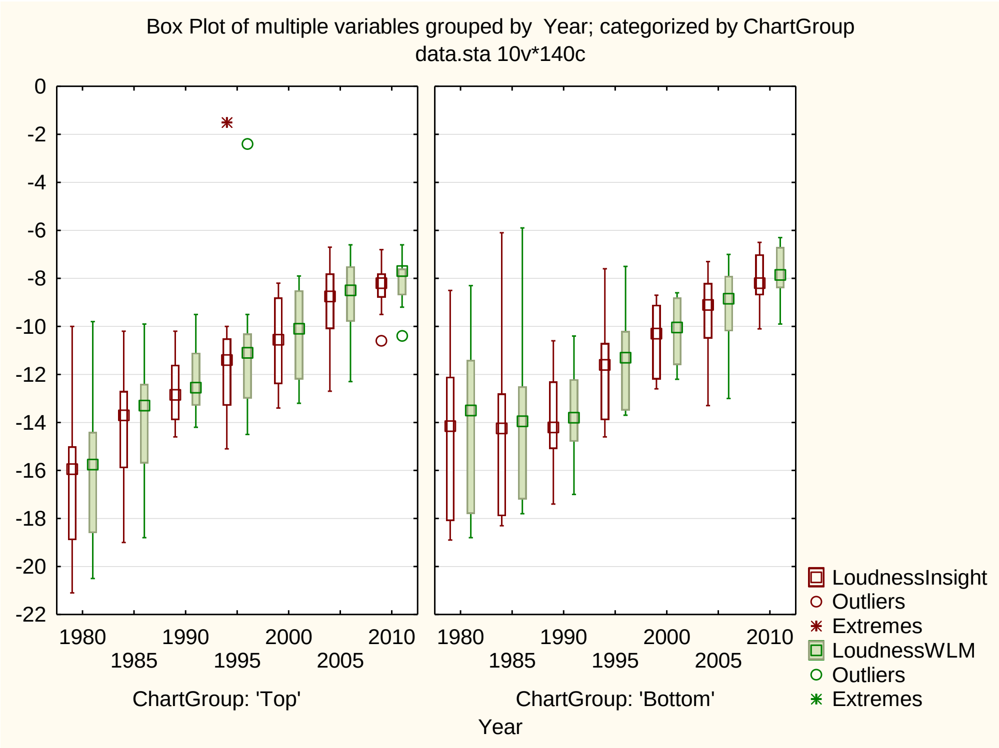
2005: Bottom 10		
88	Sean Paul	We Be Burnin'
89	The Click Five	Just the Girl
91	Omarion	O
92	Mike Jones	Back then
93	Jay-Z/Linkin Park	Numb/Encore
94	Ja Rule feat. R. Kelly & Ashanti	Wonderful
95	T-Pain	I’m sprung
97	112 feat. Foxy Brown	U already know
98	Faith Hill	Mississippi girl
99	Ludacris	Number one spot

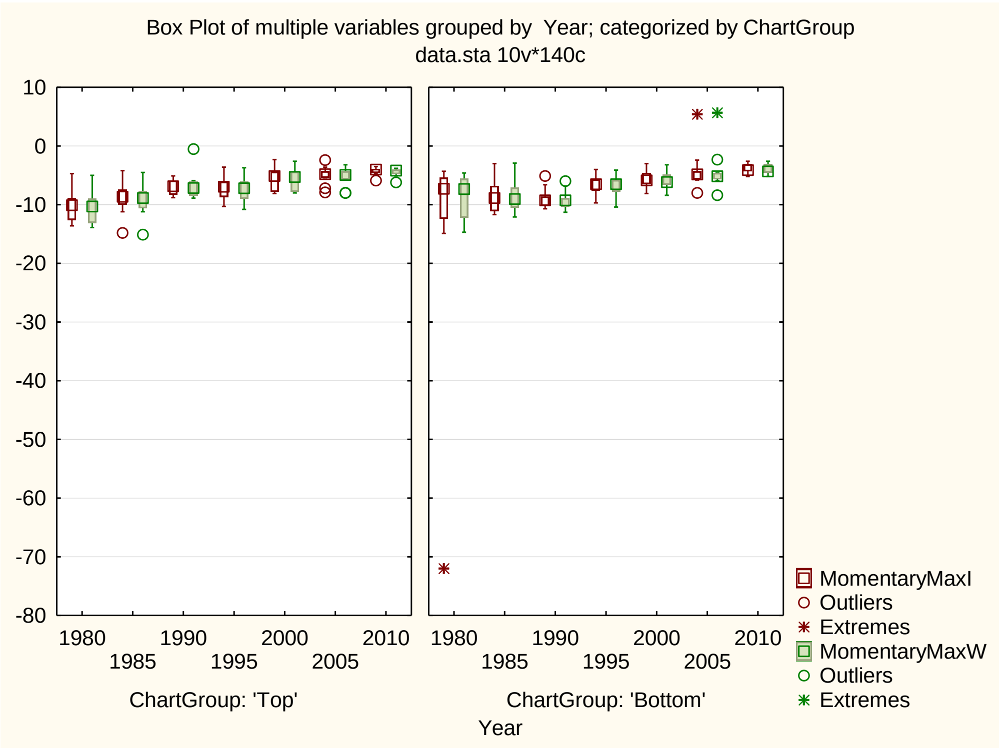
2010: Top 10		
1	Ke$ha	Tik tok
2	Lady Antebellum	Need you now
3	Train	Hey, soul sister
4	Katy Perry feat. Snoop Dogg	California gurls
5	Usher feat. Will.i.am	OMG
6	B.o.B feat. Hayley Williams	Airplanes
7	Eminem feat. Rihanna	Love the way you lie
8	Lady Gaga	Bad romance
9	Taio Cruz	Dynamite
10	Taio Cruz feat. Ludacris	Break your heart

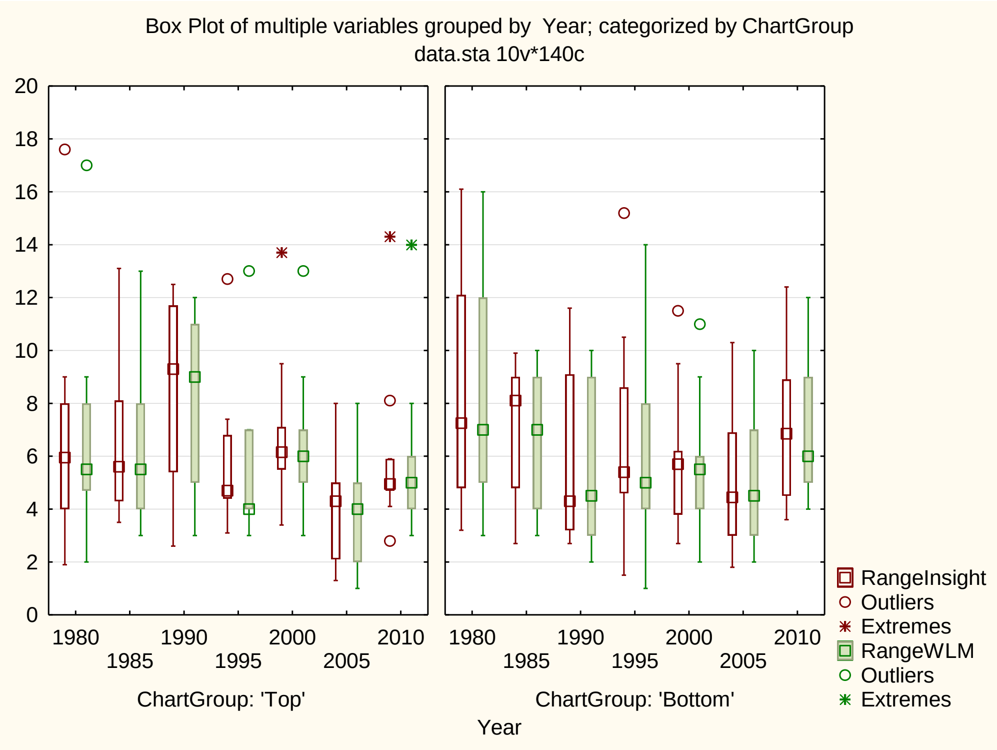
2010: Bottom 10		
88	Carrie Underwood	Undo It
89	Sean Kingston and Justin Bieber	Eenie Meenie
90	Lil Wayne feat. Drake	Right Above It
91	Miranda Lambert	The house that built me
92	The Band Perry	If I die young
93	Paramour	The only exception
94	Lady Antebellum	American Honey
95	Sara Bareilles	King of anything
96	Daughtry	Life after you
99	Alicia Keys	Try sleeping with a broken heart

Appendix B: Box plot groups over time

Comparison between iZotope Ozone Insight and WLM:





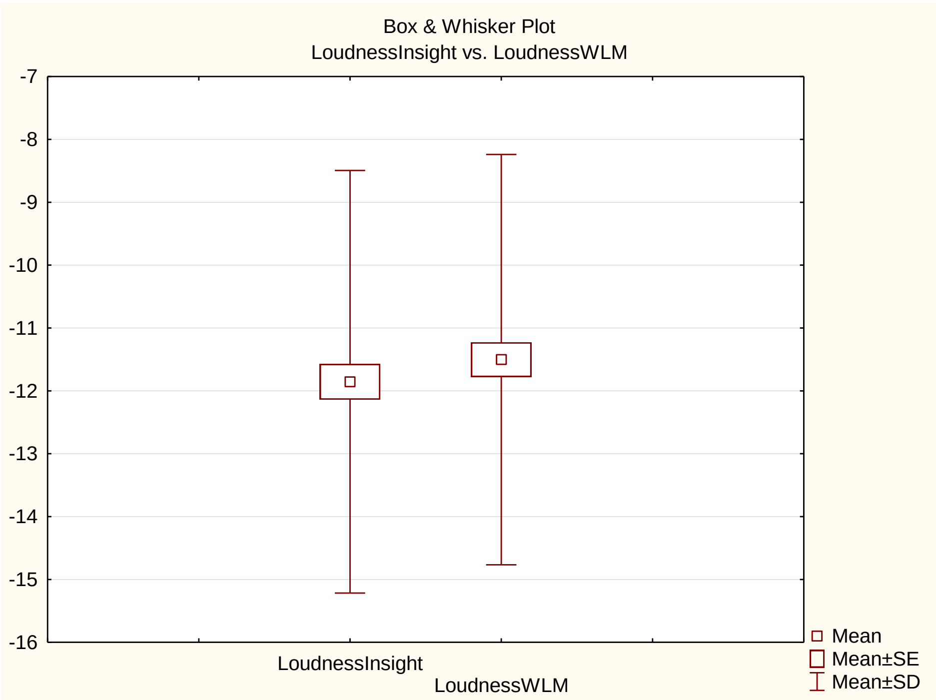

Box Plot of multiple variables grouped by Year; categorized by ChartGroup
data.sta 10v*140c
20
18
16
14
12
10
8
6
4
2
0
1980
1985
1990
1995
2000
2005
2010
ChartGroup: 'Top'
ChartGroup: 'Bottom'
Year
RangeInsight
Outliers
Extremes
RangeWLM
Outliers
Extremes

Appendix C: Matched t-test result

Integrated loudness:

Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000						
	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df
LoudnessInsight	-11.8554	3.361594					
LoudnessWLM	-11.5029	3.263477	139	-0.352518	0.266031	-15.6227	138

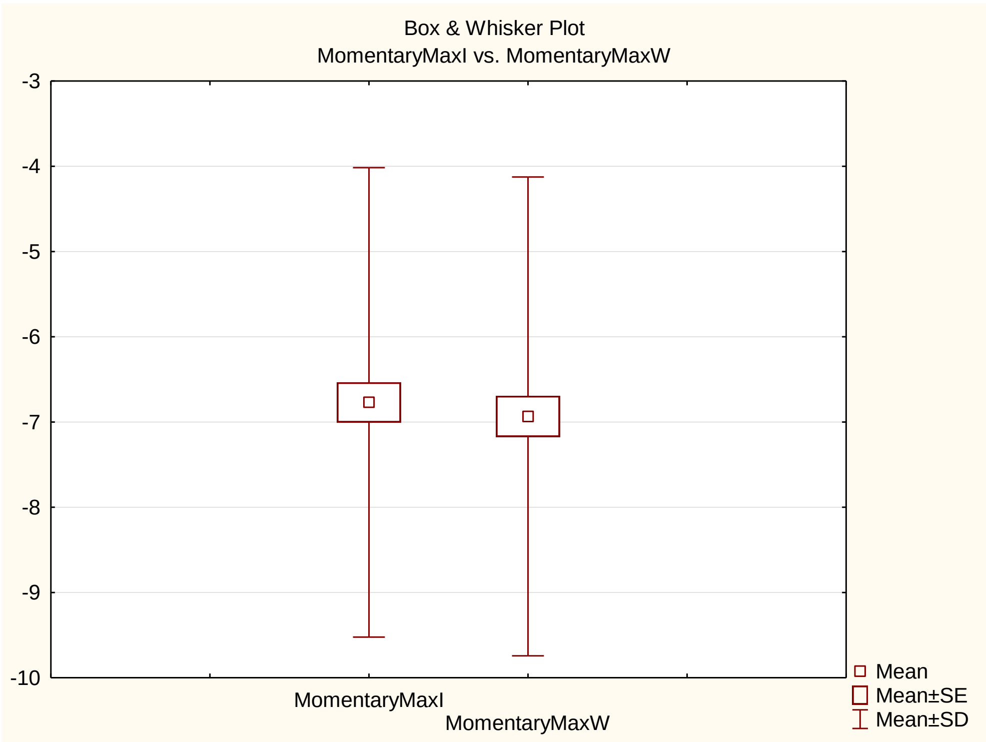
Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000		
	p	Confidence -95.000%	Confidence +95.000%
LoudnessInsight			
LoudnessWLM	0.00	-0.397135	-0.307901



Momentary max:

Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000						
	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df
MomentaryMaxI	-6.76957	2.753064					
MomentaryMaxW	-6.93406	2.808317	138	0.164493	0.479172	4.032689	137

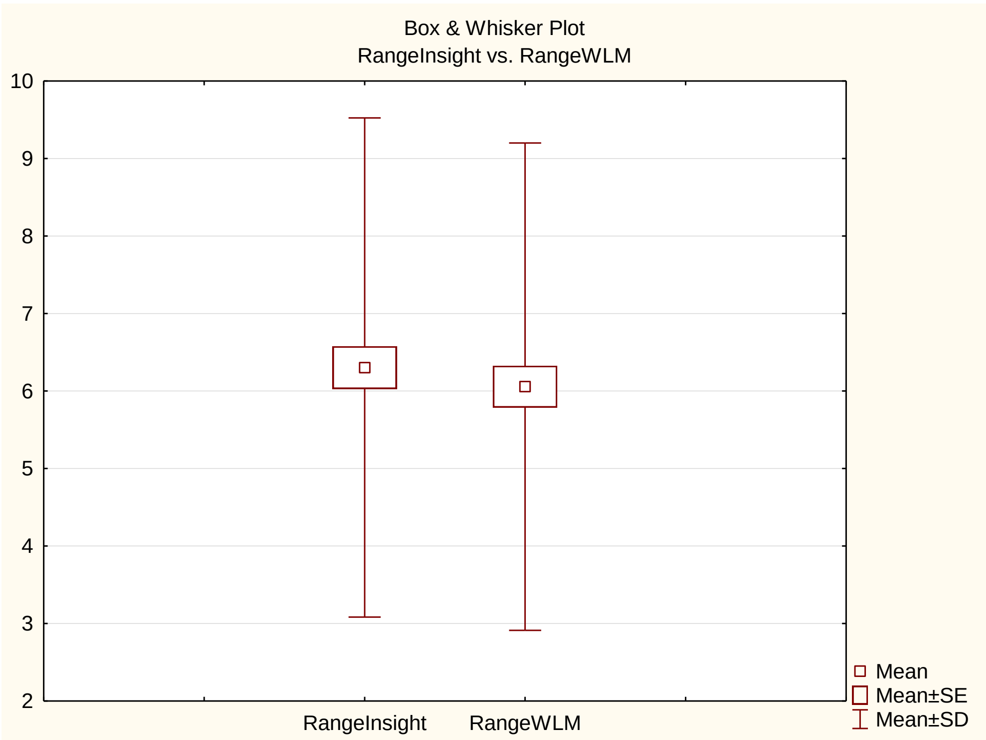
Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000		
	p	Confidence -95.000%	Confidence +95.000%
MomentaryMaxI			
MomentaryMaxW	0.000091	0.083834	0.245152



Loudness range:

Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000						
	Mean	Std.Dv.	N	Diff.	Std.Dv. Diff.	t	df
RangeInsight	6.303650	3.220555					
RangeWLM	6.056204	3.143922	137	0.247445	0.419397	6.905795	136

Variable	T-test for Dependent Samples (Omit outliers.sta) Marked differences are significant at p < .05000		
	p	Confidence -95.000%	Confidence +95.000%
RangeInsight			
RangeWLM	0.000000	0.176586	0.318304



Appendix D: Repeated measures with extreme outliers omitted

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight and WLM loudness omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information

Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	19

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight and WLM loudness omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	LoudINS 1980	LoudINS 1985	LoudINS 1990	LoudINS 1995	LoudINS 2000	LoudINS 2005	LoudINS 2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.04256295	44.99	6	12	<.0001
Pillai's Trace	0.95743705	44.99	6	12	<.0001
Hotelling-Lawley Trace	22.49461390	44.99	6	12	<.0001
Roy's Greatest Root	22.49461390	44.99	6	12	<.0001

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.62527918	1.20	6	12	0.3704
Pillai's Trace	0.37472082	1.20	6	12	0.3704
Hotelling-Lawley Trace	0.59928562	1.20	6	12	0.3704
Roy's Greatest Root	0.59928562	1.20	6	12	0.3704

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight and WLM loudness omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	1.10292481	1.10292481	0.19	0.6651
Error	17	96.61271429	5.68310084		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight and WLM loudness omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F	
						G - G	H-F-L
Year	6	812.1176190	135.3529365	24.22	<.0001	<.0001	<.0001
Year*ChartGroup	6	32.9470927	5.4911821	0.98	0.4411	0.4179	0.4305
Error(Year)	102	570.0909524	5.5891270				

Greenhouse-Geisser Epsilon	0.6003
Huynh-Feldt-Lecoutre Epsilon	0.7817

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information

Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	18

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	MaxINS1980	MaxINS1985	MaxINS1990	MaxINS1995	MaxINS2000	MaxINS2005	MaxINS2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=4.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.05695621	30.36	6	11	<.0001
Pillai's Trace	0.94304379	30.36	6	11	<.0001
Hotelling-Lawley Trace	16.55734837	30.36	6	11	<.0001
Roy's Greatest Root	16.55734837	30.36	6	11	<.0001

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=4.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.46242629	2.13	6	11	0.1312
Pillai's Trace	0.53757371	2.13	6	11	0.1312
Hotelling-Lawley Trace	1.16250680	2.13	6	11	0.1312
Roy's Greatest Root	1.16250680	2.13	6	11	0.1312

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	0.88781349	0.88781349	0.20	0.6595
Error	16	70.48425000	4.40526562		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F G - G	Adj Pr > F H-F-L
Year	6	418.3616508	69.7269418	15.25	<.0001	<.0001	<.0001
Year*ChartGroup	6	48.9203810	8.1533968	1.78	0.1106	0.1584	0.1408
Error(Year)	96	438.9020000	4.5718958				

Greenhouse-Geisser Epsilon	0.5365
Huynh-Feldt-Lecoutre Epsilon	0.6876

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information		
Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	19

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	MaxWL M1980	MaxWL M1985	MaxWL M1990	MaxWL M1995	MaxWL M2000	MaxWL M2005	MaxWL M2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.08515347	21.49	6	12	<.0001
Pillai's Trace	0.91484653	21.49	6	12	<.0001
Hotelling-Lawley Trace	10.74350222	21.49	6	12	<.0001
Roy's Greatest Root	10.74350222	21.49	6	12	<.0001

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.51187960	1.91	6	12	0.1607
Pillai's Trace	0.48812040	1.91	6	12	0.1607
Hotelling-Lawley Trace	0.95358441	1.91	6	12	0.1607
Roy's Greatest Root	0.95358441	1.91	6	12	0.1607

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	1.98901337	1.98901337	0.48	0.4959
Error	17	69.80903175	4.10641363		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Momentary Maximum omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F G - G	Adj Pr > F H-F-L
Year	6	402.1036224	67.0172704	13.61	<.0001	<.0001	<.0001
Year*ChartGroup	6	63.2013668	10.5335611	2.14	0.0551	0.0965	0.0775
Error(Year)	102	502.2637460	4.9241544				

Greenhouse-Geisser Epsilon	0.5751
Huynh-Feldt-Lecoutre Epsilon	0.7395

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Range omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information

Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	17

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Range omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	RangeINS1980	RangeINS1985	RangeINS1990	RangeINS1995	RangeINS2000	RangeINS2005	RangeINS2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=4

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.31928145	3.55	6	10	0.0377
Pillai's Trace	0.68071855	3.55	6	10	0.0377
Hotelling-Lawley Trace	2.13203291	3.55	6	10	0.0377
Roy's Greatest Root	2.13203291	3.55	6	10	0.0377

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=4

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.68299514	0.77	6	10	0.6082
Pillai's Trace	0.31700486	0.77	6	10	0.6082
Hotelling-Lawley Trace	0.46413926	0.77	6	10	0.6082
Roy's Greatest Root	0.46413926	0.77	6	10	0.6082

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Range omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	1.9362092	1.9362092	0.27	0.6116
Error	15	107.9755556	7.1983704		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
Insight Range omit Extremes - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F	
						G - G	H-F-L
Year	6	125.3750280	20.8958380	1.99	0.0749	0.1192	0.0971
Year*ChartGroup	6	71.4775490	11.9129248	1.14	0.3482	0.3468	0.3490
Error(Year)	90	944.0283333	10.4892037				

Greenhouse-Geisser Epsilon	0.5693
Huynh-Feldt-Lecoutre Epsilon	0.7576

Appendix E: Repeated measure comparisons

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM loudness comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information		
Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	20

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM loudness comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	LoudWL M1980	LoudWL M1985	LoudWL M1990	LoudWL M1995	LoudWL M2000	LoudWL M2005	LoudWL M2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.04421730	46.83	6	13	<.0001
Pillai's Trace	0.95578270	46.83	6	13	<.0001
Hotelling-Lawley Trace	21.61558466	46.83	6	13	<.0001
Roy's Greatest Root	21.61558466	46.83	6	13	<.0001

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.57028376	1.63	6	13	0.2155
Pillai's Trace	0.42971624	1.63	6	13	0.2155
Hotelling-Lawley Trace	0.75351302	1.63	6	13	0.2155
Roy's Greatest Root	0.75351302	1.63	6	13	0.2155

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM loudness comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	0.0600714	0.0600714	0.01	0.9221
Error	18	110.0864286	6.1159127		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM loudness comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F G - G	Adj Pr > F H-F-L
Year	6	808.1268571	134.6878095	24.15	<.0001	<.0001	<.0001
Year*ChartGroup	6	31.5014286	5.2502381	0.94	0.4686	0.4431	0.4590
Error(Year)	108	602.2345714	5.5762460				

Greenhouse-Geisser Epsilon	0.6460
Huynh-Feldt-Lecoutre Epsilon	0.8454

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Range comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)

Class Level Information		
Class	Levels	Values
ChartGroup	2	Bottom Top

Number of Observations Read	20
Number of Observations Used	20

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Range comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance

Repeated Measures Level Information

Dependent Variable	RangeWL M1980	RangeWL M1985	RangeWL M1990	RangeWL M1995	RangeWL M2000	RangeWL M2005	RangeWL M2010
Level of Year	1980	1985	1990	1995	2000	2005	2010

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year Effect
H = Type III SSCP Matrix for Year
E = Error SSCP Matrix

S=1 M=2 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.50043293	2.16	6	13	0.1148
Pillai's Trace	0.49956707	2.16	6	13	0.1148
Hotelling-Lawley Trace	0.99826980	2.16	6	13	0.1148
Roy's Greatest Root	0.99826980	2.16	6	13	0.1148

MANOVA Test Criteria and Exact F Statistics for the Hypothesis of no Year*ChartGroup Effect
H = Type III SSCP Matrix for Year*ChartGroup
E = Error SSCP Matrix

S=1 M=2 N=5.5

Statistic	Value	F Value	Num DF	Den DF	Pr > F
Wilks' Lambda	0.76032781	0.68	6	13	0.6668
Pillai's Trace	0.23967219	0.68	6	13	0.6668
Hotelling-Lawley Trace	0.31522219	0.68	6	13	0.6668
Roy's Greatest Root	0.31522219	0.68	6	13	0.6668

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Range comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
ChartGroup	1	1.2635000	1.2635000	0.18	0.6753
Error	18	125.4372857	6.9687381		

Repeated measure comparisons May 2015
Dong Ho Kwak T14060 Loudness data May 12, 2015
WLM Range comparisons - by Year and ChartGroup

The GLM Procedure (SAS proc GLM)
Repeated Measures Analysis of Variance
Univariate Tests of Hypotheses for Within Subject Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F	Adj Pr > F	
						G - G	H-F-L
Year	6	114.181000	19.030167	1.74	0.1183	0.1475	0.1247
Year*ChartGroup	6	66.621000	11.103500	1.02	0.4189	0.4064	0.4165
Error(Year)	108	1180.303714	10.928738				

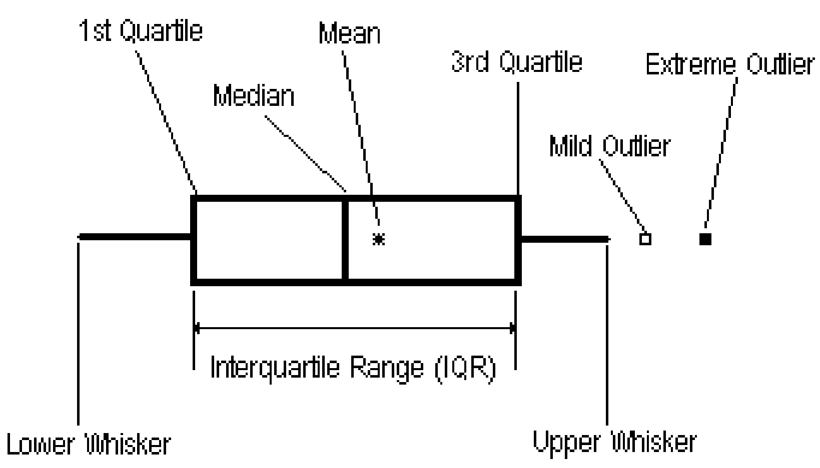
Greenhouse-Geisser Epsilon	0.6924
Huynh-Feldt-Lecoutre Epsilon	0.9261

Appendix F: Box plots (notes from the department of Statistics, University of Pretoria)

A box plot (also known as box-whisker diagram) graphically illustrates the distribution of a variable. Box plots show the median, the quartiles and interquartile range, outliers and extreme cases of individual variables.

The graph is constructed in such a way that the distance between the lowest line and the edge of the shaded box indicates the lowest 25% of scores (bottom quartile). The shaded box indicates the distribution of the middle 50% of scores, while the top edge of the box up to the top part of the line indicates the top 25%. (The "whiskers" hence extend to the smallest and largest observations, hence indicating the range of the data.) The median is indicated by a line inside the shaded box. Outliers, that is, unusual values with respect to the majority of the observations, are indicated as separate points and identified by the case numbers.

This visual display of the five values (smallest value, lower quartile, median, upper quartile and largest value) gives a clear indication of the locality, spread and symmetry of the observations.



Whiskers extend to the furthest observations that are no more than 1.5 IQR from the edges of the box. Mild outliers are observations between 1.5 IQR and 3 IQR from the edges of the box. Extreme outliers are greater than 3 IQR from the edges of the box.

Appendix F: Results of iZotope Ozone Insight and WLM measurements

1980 Top

				Integrated		*Momentary*		Loudness Range	
Chart #	**Artist name**	**Song name**	**Track length**	***Insight***	***WLM***	***Insight***	***WLM***	***Insight***	***WLM***
1	Blondie	Call Me	3:33	-17.1	-16.7	-13.6	-13.7	2.8	3
2	Pink Floyd	Another Brick In The Wall	4:02	-21.1	-20.5	-11.7	-12.3	9	9
3	O. Newton-John	Magic	4:30	-15.7	-15.5	-9.8	-9.8	6.3	6
4	Michael Jackson	Rock With You	3:40	-10	-9.8	-4.7	-5	5.9	6
5	Captain & Tennille	Do That To Me One More Time	3:50	-15.1	-14.7	-8.9	-9	8	8
6	Queen	Crazy Little Thing Called Love	2:42	-15	-14.4	-7.8	-8.1	6	5
7	Paul McCartney	Coming Up	5:08	-13.8	-13.8	-9.2	-9.5	4	4.7
8	Lipps, Inc.	Funkytown	3:56	-16.2	-16	-12.6	-13.1	1.9	2
9	Billy Joel	It's Still Rock And Roll To Me	2:57	-18.9	-18.6	-13.6	-13.9	5.5	5
10	Bette Midler	The Rose	3:42	-20.7	-19.4	-10.4	-10.8	17.6	17

1980 Bottom

90	Neil Diamond	September Morn	3:53	-11.8	-11.1	-5.4	-5.6	12.1	11
91	George Benson	Give Me The Night	3:42	-12.6	-12.4	-5.6	-5.7	5.3	5
92	Anne Murray	Broken Hearted Me	3:58	-12.1	-11.4	-6.6	-6.8	11.9	12
93	Kenny Rogers	You Decorated My Life	3:36	-15.6	-14.5	-8	-7.9	16	16
94	Fleetwood Mac	Tusk	3:34	-13.1	-12.5	-4.3	-4.6	9.2	9
95	Prince	I Wanna Be Your Lover	2:58	-15.2	-14.9	-72	-8	4.9	5
96	Charlie Daniels Band	In America	3:18	-18.9	-18.8	-14.9	-14.7	3.2	3

97	Boz Scaggs	Breakdown Dead Ahead	4:04	-18.1	-17.8	-12	-12.2	4.8	5
98	Barry Manilow	Ships	4:02	-18.8	-18	-12.4	-12.5	16.1	16
100	Tom Petty and The Heartbreakers	Refugee	3:22	-8.5	-8.3	-4.7	-5	4.6	5

1985 Top

Chart #	**Artist name**	**Song name**	**Track length**	***Insight***	***WLM***	***Insight***	***WLM***	***Insight***	***WLM***
1	Wham!	Careless Whisper	5:03	-16.2	-15.9	-9.3	-9.6	8.6	8
2	Madonna	Like A Virgin	3:11	-12.7	-12.5	-8	-8.1	4.3	4
3	Wham!	Wake Me Up Before You Go-Go	2:11	-11.6	-11.4	-7.4	-7.7	4.9	4
4	Foreigner	I Want To Know What Love Is	5:06	-13.2	-12.6	-5.4	-5.5	13.1	13
5	Chaka Khan	I Feel For You	8:37	-15.9	-15.7	-11.2	-11.2	3.5	3
7	Tears For Fears	Everybody Wants To Rule The World	4:09	-14.2	-14	-9.7	-9.7	4.7	5
8	Dire Straits	Money For Nothing	4:06	-12.9	-12.4	-7.7	-7.7	8.1	8
9	Madonna	Crazy For You	3:44	-10.2	-9.9	-4.2	-4.5	6.9	7
10	a-ha	Take On Me	3:38	-19	-18.8	-14.8	-15.1	6.3	6
12	Phil Collins and Philip Bailey	Easy Lover	5:05	-15.9	-15.6	-10	-10.6	3.9	4

1985 Bottom

85	Debarge	Who's Holding Donna Now	4:28	-17.6	-17.3	-11.3	-11.3	9	9
90	Jermaine Jackson	Do What You Do	5:38	-6.1	-5.9	-3	-2.9	2.7	3
92	Bruce Springsteen	Born In The USA	4:03	-17.9	-17.2	-11.7	-12.1	8.6	8
93	Tina Turner	Private Dancer	4:01	-13.5	-13.1	-6.8	-7.1	9.9	10

94	Aretha Franklin	Who's Zoomin' Who	4:44	-18.3	-16.1	-11.1	-9.7	7.7	6
95	Sting	Fortress Around Your Heart	4:36	-12.9	-12.5	-6.1	-6.2	9.1	9
96	Lionel Richie	Penny Lover	5:34	-18.1	-17.8	-10.1	-10.5	8.5	8
97	Don Henley	All She Wants To Do Is Dance	4:30	-12.8	-12.6	-7.2	-7.4	4.8	4
98	Madonna	Dress You Up	4:01	-15	-14.8	-9.5	-9.7	4.2	4
100	Sheena Easton	Sugar Walls	3:58	-12.5	-12.3	-8.2	-8.4	4.9	4

1990 Top

Chart #	Artist name	Song name	Track length	*Insight*	*WLM*	*Insight*	*WLM*	*Insight*	*WLM*
1	Wilson Phillips	Hold on	3:40	-10.2	-9.5	-5.1	-0.5	11.8	12
2	Roxette	It must have been love	3:38	-12	-11.7	-6.6	-7	5.4	5
3	Sinead O'Connor	Nothing compares 2 u	5:10	-14.6	-13.9	-5.9	-5.9	12.5	12
4	Bell Biv Devoe	Poison	4:21	-12.8	-12.7	-8.7	-8.8	2.6	3
5	Madonna	Vogue	5:18	-14.4	-14.2	-8.2	-8.2	7.8	7
6	Mariah Carey	Vision of love	3:30	-11.6	-11.1	-5.8	-6.1	10.7	10
7	Phil Collins	Another day in paradise	5:23	-12.9	-12.4	-6.2	-6.3	8.8	9
8	En Vogue	Hold on	5:04	-13.7	-13.1	-8.8	-8.9	9.8	9
9	Billy Idol	Cradle of love	4:41	-11	-10.8	-7.1	-7.3	3.2	3
10	Jon Bon Jovi	Blaze of glory	5:41	-13.9	-13.3	-8.3	-8.5	11.7	11

1990 Bottom

85	D-Mob With Cathy Dennis	C'mon And Get My Love	3:49	-13.3	-13.1	-9.2	-9.5	2.7	2
86	Paula Abdul	(It's Just) The Way That You Love	4:01	-13.8	-13.5	-8.6	-9	3.9	4

		Me							
88	Michael Bolton	When I'm Back On My Feet Again	3:50	-17	-16.3	-10.6	-10.6	11. 6	10
89	Keith Sweat	Make You Sweat	5:20	-15.1	-14.8	-9.3	-9	3.5	3
90	New Kids On The Block	This One's For The Children	3:58	-17.4	-17	-10.7	-11.3	7.3	7
91	Aerosmith	What it takes	5:10	-10.6	-10.4	-6.6	-6.8	4.7	5
92	Kiss	Forever	3:53	-14.6	-14.1	-10.2	-10.3	9.1	9
93	The Time	Jerk out	6:49	-12.3	-12.2	-8.7	-8.9	3.1	3
97	Jive Bunny	Swing the mood	4:48	-11.2	-11.1	-5.1	-6	3.2	3
98	Prince	Thieves in the temple	3:21	-15.1	-14.5	-9.8	-10.1	10.1	10

1995 Top

Chart #	**Artist name**	**Song name**	**Track length**	***Insight***	***WLM***	***Insight***	***WLM***	***Insight***	***WLM***
1	Coolio	Gangsta's paradise	4:02	-14.5	-14.3	-10.3	-10.8	4.7	4
2	TLC	Waterfalls	4:41	-13.3	-13	-8.7	-9	4.6	4
3	TLC	Creep	4:28	-1.5	-2.4	-7.5	-7.8	5.3	5
4	Seal	Kiss from a rose	4:48	-10	-9.5	-3.6	-3.7	12.7	13
5	Boyz II Men	On bended knee	5:30	-11.2	-11	-6.1	-6.3	7.4	7
6	Real McCoy	Another night	3:56	-10.5	-10.3	-6.4	-6.6	4.4	4
7	Mariah Carey	Fantasy	4:04	-11.6	-11.2	-5.6	-6	6.8	7
8	Madonna	Take A Bow	4:28	-10.6	-10.5	-6.1	-6.1	4.7	4
9	Monica	Don't Take It Personal (Just One Of Dem Days)	4:19	-15.1	-14.5	-9.5	-10.1	3.3	3
10	Montell Jordan	This Is How We Do It	3:56	-11.9	-11.4	-7.5	-8	3.1	3

1995 Bottom

90	Melissa Etheridge	Like The Way I Do-If I Wanted To	5:26	-8.3	-8.1	-4.6	-4.7	5.1	5
92	Stevie B	Dream About You-Funky Melody	4:04	-13.9	-13.6	-7.1	-7.4	10.5	10
93	Rednex	Cotton Eye Joe	3:10	-7.6	-7.5	-4	-4.1	1.5	1
94	Boyz II Men	Thank You	4:14	-11.8	-11.6	-7.8	-7.8	5.4	5
95	Pretenders	I'll Stand By You	3:16	-10.7	-10.2	-6.5	-6.3	8.6	8
96	N II U	I Miss You	4:01	-14.6	-13.5	-5.7	-5.8	15.2	14
97	Da Brat	Give It 2 You	3:13	-14.1	-13.7	-9.7	-10.4	1.8	2
98	Brandy	Best Friend	4:48	-11.6	-11.3	-6.4	-6.5	4.6	4
99	Soul Asylum	Misery	4:24	-11.3	-11.1	-7.6	-7.9	6.8	7
100	Van Halen	Can't Stop Lovin' You	4:08						

2000 Top

Chart #	**Artist name**	**Song name**	**Track length**	***Insight***	***WLM***	***Insight***	***WLM***	***Insight***	***WLM***
1	Faith Hill	Breathe	4:08	-12	-11.4	-4.9	-5.3	13.7	13
2	Santana feat. R.T.	Smooth	3:53	-8.6	-8.4	-4.5	-4.7	3.4	3
3	S. feat. P. GandB	Maria Maria	4:20	-9.3	-8.8	-4.3	-4.4	6.1	6
4	Joe	I wanna know	5:04	-12.4	-12.2	-5.8	-6.4	4.1	4
5	Vertical Horizon	Everything you want	4:16	-8.2	-7.9	-4.4	-4.4	7	7
6	Destiny's Child	Say my name	4:29	-13.4	-13.2	-7.8	-8	6.2	6
7	Savage Garden	I knew I loved you	4:10	-11.8	-11.4	-8.1	-8	5.9	6
8	Lonestar	Amazed	4:02	-13.2	-12.8	-7.9	-7.8	7.1	7
9	Matchbox Twenty	Bent	4:16	-8.8	-8.5	-5.3	-5.3	5.5	5

10	Toni Braxton	He wasn’t man enough	4:29	-8.9	-8.7	-2.3	-2.6	9.5	9

2000 Bottom

91	Sammie	I like it	4:11	-12.2	-11.7	-5.9	-6.3	6.2	6
92	Kevon Edmonds	24-Jul	4:33	-9.1	-8.8	-3.7	-3.7	6	6
93	LFO	Girl on TV	4:08	-8.7	-8.6	-4.6	-4.9	3.8	4
94	Lil bow wow feat. Xscape	Bounce with me	2:56	-9.7	-9.6	-5.1	-5.7	2.7	2
95	Dixie Chicks	Cowboy take me away	4:51	-12.3	-11.6	-5.8	-6	11.5	11
96	Aaliyah	I don’t wanna	4:17	-12.6	-12.2	-8.1	-8.4	6.2	6
97	*Destiny’s Child	Independent women part I	3:40	-9	-8.6	-3	-3.2	5.4	5
98	Samantha Mumba	Gotta tell you	3:20	-10.8	-10.5	-6.5	-6.6	9.5	9
99	Jennifer Lopez	Waiting for tonight	4:06	-10.9	-10.6	-7.1	-7.3	2.7	3
100	Mary Mary	Shackles	3:12	-9.8	-9.5	-6.1	-6.3	5.1	5

2005 Top

Chart #	**Song name**	**Artist name**	**Track length**	***Insight***	***WLM***	***Insight***	***WLM***	***Insight***	***WLM***
1	Mariah Carey	We belong together	3:19	-11.6	-11.3	-7.9	-8	4.1	4
2	Gwen Stefani	Hollaback girl	3:19	-8.5	-8.3	-5.1	-5.3	2.1	2
3	Mario	Let me love you	4:11	-10.1	-9.8	-5.4	-5.7	4.5	4
4	Kelly Clarkson	Since u been gone	3:08	-8.5	-8.2	-4.3	-4.3	8	8
5	Ciara feat. Missy Elliott	1, 2 step	3:22	-12.7	-12.3	-7.2	-8	6.8	6
6	Kanye West feat. Jamie Foxx	Gold digger	3:28	-7.8	-7.5	-5	-5.1	1.3	1
7	Green Day	Boulevard of broken dreams	4:20	-6.7	-6.6	-3.6	-3.8	4.1	4

8	50 Cen feat. Olivia	Candy shop	3:31	-9.1	-8.7	-4.3	-4.8	2.1	2
9	The Pussycat Dolls feat. Busta Rhymes	Don't cha	4:32	-9	-8.8	-2.4	-3.2	4.7	4
10	Kelly Clarkson	Behind these hazel eyes	3:18	-7.4	-7.3	-4.6	-4.8	5	5

2005 Bottom

88	Sean Paul	We Be Burnin'	3:32	-8.2	-7.9	-5.2	-5.3	2.7	3
89	The Click Five	Just the Girl	3:52	-8.7	-8.5	-5.7	-5.7	3.6	3
91	Omarion	O	4:40	-10.5	-9.9	-4.3	-4.6	6.9	7
92	Mike Jones	Back then	4:04	-11.4	-11.3	-8	-8.4	1.8	2
93	Jay-Z/Linkin Park	Numb/Encore	3:25	-7.4	-7.5	-4.9	-5	3.6	4
94	Ja Rule feat. R. Kelly & Ashanti	Wonderful	4:24	-8.9	-8.7	-4.3	-4.8	7.7	7
95	T-Pain	I'm sprung	3:51	-13.3	-13	-4.8	-5.3	10.3	10
97	112 feat. Foxy Brown	U already know	3:16	-10.5	-10.2	5.4	5.7	5.3	5
98	Faith Hill	Mississippi girl	3:52	-7.3	-7	-2.4	-2.3	6.2	6
99	Ludacris	Number one spot	4:50	-9.3	-9	-5.8	-5.9	3	3

2010 Top

Chart #	Song name	Artist name	Track length	*Insight*	*WLM*	*Insight*	*WLM*	*Insight*	*WLM*
1	Ke$ha	Tik tok	3:19	-8.4	-8.3	-4.8	-5.1	5.5	5
2	Lady Antebellum	Need you now	4:37	-8.5	-7.8	-3.9	-4	14.3	14
3	Train	Hey, soul sister	3:36	-7.8	-7.6	-4	-4.1	4.7	5
4	Katy Perry feat. Snoop Dogg	California gurls	3:55	-7.9	-7.6	-3.6	-3.8	4.8	5

5	Usher feat. Will.i.am	OMG	4:08	-10.6	-10.4	-5.9	-6.2	4.8	4
6	B.o.B feat. Hayley Williams	Airplanes	3:00	-8	-7.6	-4	-4.3	5.1	5
7	Eminem feat. Rihanna	Love the way you lie	4:23	-9.5	-9.2	-4.4	-4.8	8.1	8
8	Lady Gaga	Bad romance	4:53	-8.8	-8.7	-4.6	-4.7	5.9	6
9	Taio Cruz	Dynamite	3:23	-7.5	-7.2	-3.9	-4.1	4.1	4
10	Taio Cruz feat. Ludacris	Break your heart	3:06	-6.8	-6.6	-3.5	-3.9	2.8	3

2010 Bottom

88	Carrie Underwood	Undo It	2:58	-6.5	-6.3	-4.1	-4	4.5	5
89	Sean Kingston and Justin Bieber	Eenie Meenie	3:22	-8.8	-8.4	-4.1	-4.2	9	9
90	Lil Wayne feat. Drake	Right Above It	4:32	-7.5	-7.4	-4	-4.4	3.6	4
91	Miranda Lambert	The house that built me	3:47	-10.1	-9.9	-4.6	-4.8	8.3	7
92	The Band Perry	If I die young	3:36	-8.5	-8	-5.2	-5.2	6.9	6
93	Paramour	The only exception	4:27	-8.6	-8.5	-4.3	-4.4	8.9	9
94	Lady Antebellum	American Honey	3:44	-8.7	-8.2	-2.6	-2.6	12.4	12
95	Sara Bareilles	King of anything	3:27	-7.9	-7.7	-4.3	-4.5	5.4	5
96	Daughtry	Life after you	3:26	-6.7	-6.5	-3	-3.1	6.8	6
99	Alicia Keys	Try sleeping with a broken heart	3:52	-7	-6.7	-3.1	-3	4.5	4