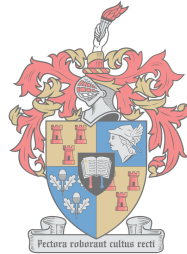


Mastering Paradigms: A South African Perspective

by

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March 2018

Declaration

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Date: March 2018

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Abstract

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Mastering is considered to be an important and necessary step in audio production. However the exact definition and role of mastering is uncertain. This study aimed at exploring the concept of mastering in search of a definition. It further aimed to determine if South African audio professionals understand what mastering is, what its subprocesses are and what it should achieve.

Uittreksel

Meesterskepping: 'n Suid-Afrikaanse Perspektief

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Meesterskepping word gesien as 'n belangrike en nodige stap in die klank produksie proses. Ten spyte hiervan is daar gereeld onsekerheid oor die definisie en rol van meesterskepping. Hierdie studie poog om 'n definisie van meesterskepping vas te stel. Verder ondersoek die studie of die Suid Afrikaanse klank industrie 'n goeie begrip het van wat meesterskepping is, die prosesse betrokke daarby en uiteindelik wat dit beoog om bereik.

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Chapter 1

Introduction, background and context

1.1 Introduction

Audio professionals agree that mastering is an important and necessary step in producing professional audio program (Shelvock, 2012:1). However, Strong (2011:299) suggests that the exact definition and role of mastering in the audio recording process is uncertain. This sentiment resonated with the researcher and supported the initial motivation to embark on the study. It had become commonplace for the researcher to have conversations about mastering with audio professionals that ended in uncertain and vague explanations of the role and outcome of mastering. It seemed evident that audio professionals often constructed their own understanding of mastering based on their own experiences. Their own attempts, as well as shared experiences, invariably shaped an understanding of the component functionalities and the sequence of these functionalities in the mastering process. Although revered, it begs the question if accurate assumptions have been made regarding mastering. Mastering is not a single action but consists of various component functionalities (Shelvock, 2012:13). Therefore the accuracy of the assumptions made regarding mastering will also extend to its component functionalities.

This investigation aimed at exploring the various views regarding the component functionalities of mastering, as well as the sequence and interface of these functionalities. It aimed at uncovering the dynamics of mastering by exploring various audio recording professionals' understanding of the processes involved. This aim was pursued by exploring the historical development and background of mastering, as well as the problems regularly experienced in the mastering process. This aided in contextualising the understanding of master-

ing and in identifying the proper research questions and objectives. A clear research problem statement was constructed and will in turn dictate the most appropriate and relevant research methodologies.

1.2 Background and motivation

Audio production is a complex system and relies on “a number of elements interacting richly” to yield, in this case, a final pleasing product (Cilliers & Spurrett, 1999:258). This complex system had intrigued the researcher for a long time. The exploration that resulted from this intrigue invariably introduced the researcher to the final sub-process called mastering. Finding this specific process fascinating due to the relatively little effect¹ it can have on audio, but the immense influence it seemed to have on audio, led the researcher to the formal exploration of this concept. The desire for clarity regarding the definition and role of mastering in professional audio recording experienced by the researcher was echoed by fellow professionals, students and musicians. Enquiries often returned vague responses and informal conversations often ended in misconceptions of what mastering is supposed to achieve and how it should be achieved. A very common feature of conversations were boasting of internationally mastered products. The insistence on mastering outside South Africa triggered a serious question around the clear understanding of mastering in South Africa. This led the researcher to start to question firstly, how much mastering was happening in South Africa and secondly, what was understood of what exactly mastering is and what is it supposed to do. These questions would inform the third question, which was why mastering in South Africa was considered inferior. It seemed unclear whether this was caused by a lack of practical knowledge, such as equipment, techniques and software or theoretical knowledge, such as the physics of sound, psychoacoustics and the theory of signal processing.

Further exploration resulted in many misconceptions around mastering, a fact that is evident when exploring the online forums. One popular forum for audio professionals is found on the website www.gearsllutz.com, which contains many conversations alluding to the misconceptions around mastering. These include, but are not limited to, the belief that the audio waveform of mastered audio should look a specific way, that only a limiter is necessary to effectively mas-

¹ The word ‘effect’ here refers to the fact that in the mastering process the engineer does not have the ability to change the separate parts of the audio and as such cannot really change anything other than tweak the audio program in its entirety.

ter audio program and the belief that only expensive hardware is able to achieve professional mastering. The following excerpt from a user on the forums, with the pseudonym Neonreymun, prove one of these popular misconceptions, that mastering can be done simply by applying a plugin with mastering presets to the master output bus in a DAW.

I recently purchased iZotope Ozone 7 advanced to master my own mixes [. . .] the problem I'm having is with the loudness of my masters [. . .] they become way too loud. This never happens with my reference tracks and I am wondering why it happens to my stuff (Neonreymun, 2017).

It is clear from this excerpt that the user had difficulty delivering a professional product using only this plugin. Another excerpt from the forum shows that many inexperienced audio professionals favour the idea of mastering while mixing (Theillusionist, 2017). Yet another example is found where a user states that “changing the EQ was not in the scope of the mastering process” (Duckdodgers, 2017), a known and important component functionality of mastering. The forums also point to many users lacking knowledge of loudness as seen in a conversation between professionals and a DJ whom, when asked if his audio needs to conform to any loudness standards, answered “I don't really care, it just needs to sound huge when I'm playing it out tonight” (Aperunner, 2011). All of the above culminated in a research question asking whether audio professionals, specifically in South Africa, have a clear understanding of what mastering is.

Only an extensive study of the available audio recording literature yielded any clear definitions of mastering. This is conceivably due to the history of mastering, evolving along with audio technologies. Shelvock (2012:10) explains that initially the role of the mastering engineer was rather basic, however with the advances in technology their responsibilities increased. It stands to reason that only with the increase in responsibility did the role of mastering become noteworthy, calling only then for more literature, which in turn offered a clearer definition of the role. Although this study can not aspire to necessarily solidify a final definition of mastering, it does aim to prove the need for further and more focused enquiry. Through critical engagement with the available literature, the study aimed to facilitate an understanding of what mastering entails and its role and value in the production of audio programme. Furthermore the study intended to empirically ascertain the current understanding of mastering in South Africa.

1.3 Research questions and objectives

Given the background to and the envisaged outcomes of the intended investigation of mastering as an integral component of the audio recording process, the following research questions and objectives were formulated. These questions and objectives stand as the basis for the construction of the research problem statement. It was used to identify the most appropriate research methodologies. These in turn were used as the framework within which the investigation could be conducted to produce scientifically defensible conclusions. Conclusions and recommendations would add to the body of scientific knowledge on the subject of mastering especially within the South African context. The research questions, throughout the enquiry, were focused around three distinct areas of concern. The first is the understanding and general definition of the entire concept of mastering. The second area focuses on the sub-processes that make up mastering. It explores the variety of tools and techniques that enable the mastering engineer to have such a profound impact on audio programme. Thirdly the focus turns to the value proposition in mastering and the buy-in from audio professionals regarding this value proposition. Based on the above the following questions emerged:

1. What level of importance do recording professionals attached to mastering as a component of the audio programme production process?
2. To what extent is mastering considered to be concerned with more than just volume?
3. How much of the processing, sonic improvements and eventually dynamic range manipulation in the mixing component of audio production could produce equally professional audio programme?
4. What essential tools or processes constitute professional mastering and is a proper understanding of the individual processes necessary in order to produce professional audio programme?
5. Will mastering necessarily improve the quality of an existing audio product?

1.3.1 Research objectives

The research objectives again follow the three areas of concern and are organised as such. The first area focuses attention to a broader understanding of mastering. A clear definition is sought. The sub-processes that constitute mastering are challenged next. Lastly the

value proposition of mastering is explored, centred loosely around the idea of aesthetics or rather sonic balance, loudness and even the supposition of monetary success. Therefore the research objective were formulated as below.

Mastering

1. To determine the level of importance that recording professionals attach to mastering as a unique component of the audio production process.
2. To determine whether the consensus amongst professionals leans toward mastering requiring a certain scientific knowledge or experience of sound production or acoustics.

Elements of mastering

1. To determine whether a proper understanding of the various steps in or sub-processes of mastering are perceived to be essential for achieving the desired or intended quality outcomes of mastering.
2. To determine what equipment is being perceived as being required or essential for achieving the proper quality outcomes.

The value proposition

1. To determine whether recording professionals agree that mastering can or will assure the quality of audio programme, or improve the quality of existing audio programme.

Audio production is a complex process in that it consists of many different component functionalities in order to achieve the objective of producing professional audio programme. Any investigation of mastering will of necessity therefore have to be multi-faceted. It will have to entail the identification of the requisite functionalities and will have to consider the inter-relationship between these functionalities. The component functionalities of mastering address specific elements of audio production that will invariably ensure professional audio programme.

One of the critical determinants of the various elements mentioned above is the available technology. Evolving developments in technology have facilitated a similar evolution in the responsibilities of mastering (Shelvock, 2012:10). The uncertainty perceived by the researcher of the role of mastering in audio production in the South African recording industry must consequentially be put to question. The research findings aimed at providing a scientifically defensible

theoretical and technological knowledge base which will be used to address this perception. With the necessary theoretical and technical knowledge of mastering the South African audio industry will stay competitive and relevant in a global economy. The challenge is therefore to develop a defensible body of scientific knowledge to understand the South African recording industry and to develop a theoretical knowledge based from which to measure understanding.

1.4 Problem statement

Due to the above mentioned personal exploration on the topic of mastering the researcher uncovered uncertainty and misconceptions around the topic. This was found in both personal conversations, informal searches and in the available academic literature. Strong (2011:299) phrased is clearly in his statement that

The only problem is that most people have no idea what mastering is. It's been presented as some mysterious voodoo that only people who belong to some secret society and have access to a magical pile of gear can do.

The researcher further discovered a tendency of undervaluation of the South African audio industry's ability to produce high quality mastered audio programme. This and other misconceptions informed the research which aims to determine the level of knowledge and understanding of audio practitioners in South Africa of mastering, the practical implication and the value that it contributes to professional audio programme. Their understanding of the component functionalities of the process of mastering as well as their understanding of the value of mastering for professional quality audio programme led to the following research question that underlies this investigation:

Do audio recording practitioners in South Africa possess adequate theoretical or technical knowledge of the concept and the processes involved in mastering?

1.5 Research methodology

Research is referred to as a process of systematic inquiry in order to determine the meaning and truth of any subject. There exists multiple tools suited specifically to this goal and to specific research prob-

lems. This study set out to test whether South African audio professionals had a clear understanding of mastering. The study was designed to firstly determine if respondents belonged to the group called audio professionals and secondly to discover what theoretical and technical knowledge respondent had of mastering and its component functionalities.

In order to address these questions, a research methodology had to be established that would facilitate this discovery. The study required quantitative data to “present a picture of the specific details of a situation, social setting or relationship”, in this case the current understanding of mastering in South Africa (Neuman, 2013:38). This pointed to a descriptive study which employs “data-gathering techniques ...[such as]...surveys, field research, content analysis and historical-comparative research” (Neuman, 2013:39). The study used a traditional survey methodology as presented by Punch (2003:3). This falls under the broader educational methodology which is rooted in the positivist paradigm employing an objectivist approach to finding truth from empirical data (Riyami, 2015:412). In this case primary empirical data was collected by means of a structured survey. In summary the study employed an explorative empirical investigation in the form of a descriptive, quantitative survey research design, within an explorative survey methodology as prescribed by Mouton (2001:34). This determined the understanding that South African audio professionals have of mastering, its component functionalities and the benefits it offers.

1.5.1 Demarcation of the study

This research investigation focussed on the proper understanding of the concept of mastering. As such the investigation attempted to produce a clear and concise theoretical definition. It further aimed at contextualizing the understanding of mastering within the South African audio industry. It fell outside of the scope of this research document to explore mastering in the international context in spite of it identifying the trends in practice and perceived developments in technology which have informed mastering as we know it today.

The evolution of technology and its applications, such as the sophistication of software, are currently giving rise to trends in audio production that could conceivably require a re-definition of audio production in the foreseeable future (Burgess, 2013:242). The study focused on the current trends and currently established practises for the purpose of defining mastering, its component functionalities and its value proposition.

Greater interaction between the different parts of the production process is becoming increasingly popular (Betts, 2016)². This means that the mix engineer will increasingly tend to confer with the mastering engineer about creative elements of the mix. Mastering engineers will increasingly offer or be asked for creative inputs into the production process. This is a new trend and not a common occurrence in mastering in the past based on the reviewed literature. These conceivable trends, although exciting and fascinating will however not constitute part of the scope of this investigation as such. These trends allude to very interesting changes in the industry and the researches acknowledges that further research into this could be necessary in the future.

1.6 Structure of the thesis

This investigation started by exploring the available literature to present a synthesis of what is understood by mastering. This was based on the history of mastering and its evolution into a separate functionality, based on the technological applications that were developed together with the new emerging technologies. An attempt was made to examine the evolution and adaptation of the mastering functionality as a substantially important support mechanism for audio recording and audio production. Once mastering had been contextualised, the investigation began to facilitate a clear understanding of the current role of mastering in the audio production process and a clear and concise definition of mastering as it is understood at present was presented.

The study explored the available literature in a review spanning three chapters. These three chapters together form a picture of the current understanding of mastering. It offers a complete synthesis of the available literature of mastering focused around the following themes:

A historical overview of mastering: Mastering is at its essence an expression of necessity. It emerged and evolved based on this necessity. This section offers a synthesis of the available literature on mastering and provides context on its emergence and evolution. This chapter will also provide a conclusion on the evolution. Although this study does not aim at providing a final professional definition of mastering, the explorative nature

² This is a video interview on the Sound on Sound website with Mandy Parnell. She is an established mastering engineer having mastered albums by Björk, Aphex Twin, Snoop Dogg and The White Stripes

of the study aims to provide some insight into a definition. This section will offer a glimpse into the current iteration.

Key concepts explained: Mastering exists in a specialised technological world. This section introduces the reader to this world and explains the relevant concepts of which mastering consists. Equalisation will be examined in depth because of the critical importance thereof. Dynamic range manipulation will centre around the use of compression and limiting, which are the most important tools in this field. Since mastering is concerned with the production of an audio product that is competitively loud, the investigation will also explore the concepts of loudness and the current standards related to loudness in the industry. Together with equalisation and compression, the study will turn its focus to an exploration of the role of noise reduction.

Mastering Tools & Techniques: Given the fact that recording in general and mastering specifically is heavily reliant on technology and its various applications, it will be necessary to also address the matters of the tools and electronic equipment required for effective mastering. Audio professionals engaged in mastering often follow a different approach to and understanding of the tools and equipment to that followed by other audio production participants. Mastering also employs tools specifically suited to mastering. The different use of shared tools, as well as more specialised ones, gives a glimpse into mastering. It offers an insight into the outcomes that mastering aims to achieve which explains much of what it is.

Thereafter, study offers a clear and extensive explanation of the research methodology and design and introduces the reader to the research problem. This section will also provide an in-depth explanation of the data collection and sampling. The analysis of the data is then presented along with explanations of the measurements of validity, reliability as well as ethical considerations. The investigation concludes with a review of the findings. An attempt was made to present a scientifically defensible conclusion drawn from the survey outcomes. This is discussed along with the recommendations that could be made with impunity.

1.7 Summary

The study was motivated by a perception by the researcher that a lack of clarity exists around the topic of mastering. Although held in

high regard, the confusion lead to many misconceptions evident in conversation in person and online. The study was envisaged to shed light on the topic and offer insight into this problem within the South African context.

The study was focused around a set of research questions that in turn were formulated into specific research objectives. The objectives centred around three areas of concern, namely the definition of mastering, its sub-processes and its value proposition. These together informed the research question that asked whether audio practitioners in South Africa posses proper technical and theoretical knowledge of mastering.

The study aimed at exploring the topic through the available literature, focusing on an historical overview, an exploration of the relevant concepts and the tools and techniques used. Using a descriptive, quantitative survey design, the study set out to gain insight into the understanding of mastering in South Africa.

Chapter 2

Literature review

2.1 Introduction

It is clear from an extensive search in the available literature that mastering *per se* has in the past not been well researched and very little specifically relevant literature exists on the subject, especially literature relevant to South Africa. Whereas only a handful of academics have published on the matter of mastering in recent years, Shelvock (2012) indicates in his dissertation, citing works by Brown (2009), Doyle *et al.* (2005), Bennett *et al.* (2005), Millard (2005), Moorefield (2005), Sterne (2003), Thompson (2005) and Warner (2003), that an in-depth analysis of mastering based on empirical research, is conspicuously absent from much of the audio technology literature. This deficiency characterised by academics as "the apparent lack of scholarly attention" is also mentioned by Nardi (2014:8) in his work *The Gateway of Sound*. Nardi (2014) specifically refers to Shelvock (2012), Papenburg (2011) and to himself as of the few current academics who have written theses and dissertations in this field of study. The academic texts relating specifically to this field of study are limited to the work of Katz (2007), Katz (2002), Owsinski (2008), Rumsey (2010), Rumsey (2011) and Cousins & Hepworth-Sawyer (2013).

In order to assure a thorough understanding of mastering, this literature review will firstly explore the history of mastering. It is common cause that the unprecedented rapid development in technology has substantially impacted the recording industry in general and mastering in particular. The next section of the literature review will therefore be aimed at extracting a contemporary definition of mastering from the various accessed literature and academic texts. Once an in-depth understanding of the activities of the modern mastering engineer has been achieved, the literature review will explore

the key concepts and the operational processes involved. This section will also examine the relevant theories and techniques employed and will explore the existing literature in an attempt to clarify the various conceptual elements that make up the concept of mastering. As part of this examination of the subordinate theoretical concepts, the technical aspects that are often avoided when investigating mastering will be exposed and analysed. These concepts will be examined briefly in order to more completely contextualise the concept of mastering. The chapter will conclude with an in-depth exploration of the actual operational processes employed in mastering in order to expose a clear understanding of what a mastering engineer does. A clear understanding of what needs to happen to audio for it to be considered to have been properly mastered will also be sourced. The literature review will further examine the specific tools and equipment used, as well as the optimum use of these tools in the mastering context. The literature review section of the study will reference all material relating to mastering although care will be taken to focus on the most recent literature and the most up-to-date studies in what is considered a very technological field.

2.1.1 What is mastering?

It is important at this stage to create a clear image of mastering as it is regarded by professionals at the moment. This proves difficult as it is still very often seen as an illusive concept clouded in mystery and myth. Even experienced audio technicians struggle to define, describe or concisely explain its content, context and actual value. Many are vague on the exact processes, intricacies and dynamics as was seen earlier in the statement by Strong (2011:299).

Although finding a clear and concise definition is problematic, the available literature provides multiple definitions that enable the researcher to synthesise a clear picture of mastering engineers involving all the different aspects of their role today. If nothing else it can certainly be agreed that most industry professionals consider mastering to be necessary and even an imperative for professional quality audio. They agree that it will inevitably improve audio by saying that mastering is an important part of the process of producing a recording and allows for delicate fine tuning of the audio product. It is the “final refinement that helps give a finished recording the best sound it can have” says (Clark, 2010:n.p). The aforementioned refinements consist of various tasks, which together will offer said improvement to the audio. These tasks include the assembling of the album in the correct listening order, leaving suitable time gaps between tracks, adjusting the sound levels of each song in relation to the whole album,

adjusting the loudness of the album as a whole, removing extraneous noises and equalisation according to Hilsamer & Herzog (2014:1) and Zager (2011) among others. In performing these tasks mastering engineers act as the bridge between the mixing stage of audio production and the replication phase. The mastering engineer is therefore responsible for preparing the audio for replication. In the *Mastering Engineer's Handbook*, Owsinski (2008:3) defines mastering as

[...] the intermediate step between taking the audio fresh from mixdown ... and preparing it to be replicated or distributed.

Simultaneously Owsinski (2008:3) is of the opinion that “mastering is the process of turning a collection of songs into a record by making them sound like they belong together in tone, volume, and timing”. Timing here refers to the spacing between songs, which although subtle, can make a great difference in the perception of pace when listening to a complete album. In various published interviews Owsinski (2008:3) asks mastering industry professionals to explain what they understand mastering to be. Bernie Grundman¹, an accomplished mastering engineer in the industry today, explains that

[...] mastering is a way of maximising music to make it more effective for the listener as well as maybe maximising it in a competitive way for the industry. It's the final creative step.

The maximisation referred to here is ambiguous, however it can be assumed to mean two things. The interviewee mentions that the audio can be maximised in a competitive way. This comment alludes to loudness and this will become clearer later on in the exploration of the history of mastering. We have ample evidence to suggest that loudness was thought to have a causal relationship to commercial success and in this sense maximising audio to be more competitive clearly means manipulating the dynamics of the audio. Maximising audio to make it more ‘effective’ for the listener hints at something more creative. It implies that a change in the character of the audio will make it more accessible or enjoyable to the listener. Referring back to the first statement that mastering is charged with ‘refining’ audio it now seems to mean something different than merely administrative tasks. Mastering now becomes creative. Clark (2010:n.p)

¹ Grundman is the founder and owner of Bernie Grundman Mastering, founded in 1983. He mastered albums for Terri Nunn, Dr. Dre, Rata Blanca, Lisa Stansfield, Jennifer Warnes and Dark Horse Flyer, to name a few.

states that the purpose of mastering is to “maximise the inherent musicality of a given master recording be it analogue tape, Direct Stream Digital, hard drives or a digital download”. Simple tasks such as changing the order and adjusting the levels will not necessarily ‘maximize’ musicality. For this the engineer needs to make creative adjustments. This is supported by Bob Ludwig (Clark, 2010:n.p) who suggested that

[Mastering] requires someone with knowledge and insight to know whether preparing the recording for the pressing plant and iTunes requires doing a lot, very little or even things creatively to the master.

The creative authorship of the mastering engineer becomes even clearer when Zager (2011:127) states that mastering is a creative process since the sound of the audio can change during the production process. In this, mastering engineers are generally seen as being very creative and having a well trained and perceptive ear. Both in terms of creative influence and operational tasks it is of course necessary to remain meticulous and detail oriented when mastering a product. In this context the mastering engineer will always be concerned with details (Cousins & Hepworth-Sawyer, 2013:204). Katz (2007:12) suggests that

[...] mastering is the last creative step in the audio production process, the bridge between mixing and replication. It is the last opportunity to enhance sound or repair problems within an acoustically designed room, under an audio microscope.

Accordingly Glenn Meadows, another experienced² and famously gifted mastering engineer, describes mastering as a process where one

[...] take[s] the stuff that sounds good on a professional monitor and makes sure it also translates well to the home systems.

These statements all allude to the fact that mastering is understood to be a crucial link between the mixing phase and the physical replication process and that it requires a creative sensibility in order to achieve great results. It is the final chance to adjust, enhance or repair audio programme before delivery. It requires technical knowledge of audio replication methods, knowledge of different distribution

² Meadows is credited with mastering many hit albums as well as running the acclaimed Masterfonics Mastering Studios for over 20 years.

channels and technical understanding to ensure it translates to a variety of playback systems. It also requires the sensitivity to guide the flow of songs and other creative adjustments to bring out the best in any audio.

Although these statements give us an idea of where mastering fits into the process, it fails to explain what mastering actually does to get the desired result. In *The Mastering Engineer's Handbook: The Audio Mastering Handbook*, Owsinski (2008:13) explains that mastering makes use of special tools and equipment that are “very unique to the genre and are often custom-made.” These tools include exceptional monitors (also referred to as loudspeakers) and an acoustically treated room. A properly treated room is required by the mastering engineer in order to reveal any imperfections in the audio. These tools must be supported by a well-trained ear that will be able to analyse audio for problems or imperfections. The mastering engineer actually uses very few tools to manipulate the audio. These include tools such as equalisation, compression and limiting, according to Owsinski (2008:18-25). The researchers Rumsey & McCormick (2006:290) mention that these products are designed to

[...] enable fine tuning of master recordings prior to commercial release, involving subtle compression, equalisation and gain adjustment, or to enable the cleaning up of old recordings that have hiss, crackle and clicks.

The tools that are generally used by mastering professionals therefore include a specific physical environment that facilitates intense and concentrated listening and processing capacity in the form of compression and equalisation.

In summary, it can be said that mastering is understood to be the final step before the product is released for consumption by the public, be that in the form of physical media such as vinyl and Compact Disc or a digital file format such as WAV, AIFF, AAC and MP3. It requires technical prowess and creative sensitivity. It uses a few specialised tools such as high quality audio reproduction equipment to enhance the audio but also requires a proper listening and hearing facility. In addition to this a well-trained listening ability in the mastering engineer is crucial. Mastering has the ability to translate good music into a great audio album, says (Strong, 2011:299). This first explanation of mastering serves as a good foundation of the role of the mastering engineer and the ways in which he/she will approach audio to improve it before replication. The below exploration of the history that birthed the mastering engineer will further solidify this

and stand to contextualise the mastering engineer in the history of audio production.

2.2 A historical overview of mastering

The evolution of technology has been central to the development of the mastering role. This proposition is based on a review of the historical growth of mastering shown below. The role of mastering is therefore firmly rooted in the evolutionary development of technology and the capabilities that new technologies have afforded audio engineers. It also evolved within the context of the consumer. Modern consumers were exposed to various emerging technologies that increased the capability to produce improved audio. Consumers became accustomed to the improved audio and invariably demanded it from audio professionals. The following section offers the evolution of the technologies that informed the audio recording and production industries.

2.2.1 Evolutionary time line

It is common knowledge that before 1948 when the first commercial tape recorders became available, all audio was captured directly onto vinyl medium according to Morton (2004:XII). Since that date a plethora of devices had been invented that enabled recording, all of which required remarkably little intervention in the process of producing audio. The reason for this was because most of these devices allowed recording directly onto the playback medium states Gronow & Saunio (1999:1). Towards the end of the 1940s the ten inch record became popular, standardising recording and playback for a generation of audio users. It was only subsequent to 1948 with the introduction of the Ampex magnetic tape recorder, that mastering started its first truly evolutionary development. Now audio engineers recorded onto tape, however consumers still enjoyed music on vinyl. The role of the mastering engineer was initiated by the capability to transfer the audio from the tape medium to a vinyl medium according to Shelvock (2012:9). The disc cutting process was fairly tedious and required a skilled operator to oversee the transfer process. According to Owsinski (2008:4) this skilled operator was generally referred to as a transfer engineer. In the era of the vinyl medium, mastering was understood therefore to be the art of transferring audio from magnetic audio tape, an electronic medium, to vinyl, a physical medium. The so called cutting of a disk required disc-cutting equipment in the form of a machine that had a turntable and a cutter head called a sty-

lus. This chisel-shaped cutting stylus, usually made from diamond or artificial sapphire, cut a groove in the surface of a blank disc. Until metal-based lacquer discs became popular, the norm was the use of a specially formulated wax as the recording medium explains Borwick (1994:426). This was a highly complex and specialised process, fraught with difficulties. The probabilities of making mistakes was large due to the sensitivity of the lacquer and the difficulty of keeping it to a predetermined level. Too low a level would produce a noisy disk whereas too high a level could result in destroying the disk and possibly also the cutting stylus.

At this stage, mastering was as much about improving the sound quality of the recordings as understanding what could get lost when transferring from tape to disc. The prevention of audio quality loss in the transfer process took precedent over any artistic sonic manipulation. In time mastering engineers improved their ability to compensate for possible losses. They were able to ensure that as much material as possible was transferred. Mastering was also concerned with ensuring that the song-to-song levels were equal. Any song level changes that were thought to be necessary would be made by the mastering engineer in an editing cubicle where the changes would be recorded onto a new copy of the lacquer that would be cut from the first copy. The new version would then be used as the master copy.

2.2.2 Tape recording and the transfer engineer

During the process of transferring audio from one medium to the next, the transfer engineer often found ways of maximising the loudness of the recordings sparking the first step in affecting the sonic quality of the audio. They achieved this mainly by applying equalisation and compression. The producers as well as artists usually noticed the difference in loudness and the louder versions ended up being more popular with the general public ostensibly because they thought that the louder product sounded better on radio, in turn influencing the commercial success of audio. This perceived correlation between loudness and commercial success gave rise to a paradigm that louder was better. This did much to popularise mastering as something mysteriously artful and of paramount importance. According to Owsinski (2008:4) a mastering engineer now described a creative person who was able to enhance the sonic character of the recording as opposed to simply transferring it from one medium to another. Being able to achieve this enhanced version of audio denoted a good mastering engineer.

Ampex later released another device called the Selective Synchronous, or Sel-Sync, device which made over-dubbing possible. Sel-Sync played a very big part in the formalisation of the involvement of the mastering professional in recording, where mastering engineers differed greatly in terms of knowledge and skill to recording engineers. This trend of formalising the role of the mastering engineer was further solidified in approximately 1957 when the stereo vinyl record became available commercially. Record production for large scale vinyl consumption further necessitated the expertise of a mastering engineer, according to Owsinski (2008:4). Mastering to tape meant that tracks were mixed down to an analogue stereo master recording according to Borwick (1994:409), which would then be edited into the correct playing order. The tape recording would then be sent to a cutting room, where level control and equalisation changes would be made as it was transferred to a lacquer disc. This process did much to formalise and evolve the role of the mastering engineer.

Audio consumption of vinyl decreased with the influx of commercial tape players. This crucial evolution played a big role in the consumption behaviour as it allowed audio to be played on much smaller devices. The home tape player eventually gave way to the Compact Disc around 1982. Compact Disc, or CD, replaced older consumption methods on a large scale and with this change of the delivery medium, came a change in the tools and equipment that were required as well. Although audio processing processes such as compression was still a basic tool, new technologies offered new possibilities and these required a change in tools. One such possibility was the option to encode information onto the discs. This is called *PQ* coding. The supplementary information coded onto the discs is referred to as metadata and allows for information such as song titles and other information to travel along with the music on the disc. The mastering engineer started using new tools which enabled these new possibilities such as the Digital Audio Workstation (DAW) which was invented by Sonic Solutions in 1989. Before that technologies such as Digital Audio Tape (DAT) played a similar role but with less capabilities.

The move into the digital age saw another evolutionary development for the mastering engineer. The role of mastering was now slightly redefined as it consisted of more than it did before. The new technologies enabled the mastering engineer to use existing tools more efficiently and also offered exciting new capabilities. This invariably meant that the mastering engineer, who was once simply a transfer jockey, was now a much more important figure without whom a commercial audio product would not be the same. It stands

to reason that a more modern definition of the mastering engineer is called for. The following section aims at providing clarity on the new 'evolved' mastering engineer.

2.3 A new definition of mastering

There is much evidence that points to an evolved version of the mastering engineer, one who plays a more complex role in the current audio production landscape. This sentiment is echoed elegantly by Nardi (2014:14) who states that

[...] mastering engineers not only mediate between music makers and music listeners, but they also negotiate between technology, human agency in general and creativity in particular on a daily basis.

Evolutionary changes in technology has influenced the role of the mastering engineer offering increased capabilities. Regardless, mastering is still described by its overarching objectives, however complex the means to achieve these objectives. In essence mastering is still first and foremost aimed at creating unity in an audio album and at delivering a high quality final product says Moylan (2002:349). Under the umbrella of these overarching objectives lurks various elements that offer a clearer understanding of this complex role. The following exploration of the separate elements will provide even more insight into understanding clearly what mastering is.

2.3.1 From transfer jockey to creative influencer

The review of the history of mastering in the previous section shows that an evolution took place over the last few decades. Throughout its history, mastering was focused entirely on the distribution of audio programme. It was technically quite complex and required a lot of knowledge, skill, patience and attention to detail. Mastering was conceived because of severely limited technology and was indeed limited by the technological capabilities that existed at any given point in time. At its most fundamental it did not change even with the advent of newer technologies. Savage (2011:211) explains that audio is mastered in order for it to be delivered to the manufacturer to replicate as Compact Disc or any other form of distribution. The Compact Disk was surely a big technological advance, but in fact also had its own limitations which necessitated an agent to ensure quality before mass production. A critically important consideration is

ensuring that the quality of the audio is not compromised in the production process says Moylan (2002:349). The mastering engineer's function according to Strong (2011:300) is broadly speaking to ensure that the audio is changed into the chosen format in order for it to be distributed for public consumption. All the while mastering is concerned with assuring that the loudness between tracks are the same without jeopardising the quality of the audio programme says Moylan (2002:349).

Over the course of history the technological developments have afforded the mastering engineer more alternatives in achieving its objectives. It has given the mastering engineer greater capability to intervene and to contribute to the final sound quality of audio. This capability saw a fundamental change in the role of the mastering engineer. With these technological developments the technical transfer was complimented with something more creative, what is referred to as "the last creative step" by Moylan (2002:349). This has given the mastering engineer more influence over the final audio product and with that has made the role of the mastering engineer that much more important.

With the focus changing to creative influence, a new type or class of mastering engineer is emerging says Zager (2011:137-138). He suggests that mastering today is as much creative as it is technical. Nardi (2014:22) confirms that creative aspects of mastering such as "aesthetic sensitivity, creative thinking and decision-making" now gets as much attention as technical. Of course new technologies also pose new challenges and even with the new focus on creativity, the technical competence of the mastering engineer is still very much at the centre of his or her skill set, knowledge and understanding. With the increase in technological capability comes the opportunity for even more creative ability to affect and improve audio before consumption.

Audio processing techniques like compression that was first used to control the audio level when transferring to vinyl has since become a creative tool to improve the sound quality of audio programme according to Owsinski (2008:5). This understanding once again supports the move of the mastering engineer from simple transfer jockey towards creative agent with the ability to heavily influence the sound of the audio (Zager, 2011:137). The mastering engineer indeed enjoys much creative influence according to Nardi (2014:14) who states that mastering is at the intersection of "the moment of creation [...] and the moment of consumption" and will be able to significantly affect both the quality and the saleability of a final artistic product. Mastering is also the art of compromise according to Katz (2007:99) who explains that it requires an understanding of the sonic possibil-

ities and to make decisions based on the needs of the music. This is undoubtedly a far cry from the purely technical role of the transfer engineer of the past.

2.3.2 The art of pre-mastering

It is clear from the preceding section and the literature contained therein that today mastering is as much a creative endeavour as anything else. This supposition is supported also by Moylan (2002:350) when he states that mastering is concerned with the technical as well as the artistic aspects of recording and requires equal amounts of critical considerations when it comes to listening and hearing. A breakaway term is now identified by Nardi (2014:9) who suggests that there is a specific new component to the role of mastering within this bigger production process characterised as ‘pre-mastering’. This contrasts with the traditional mastering role as it consists of the creation of a glass master disc to be used in the reproduction process explains (Owsinski, 2008:70). Pre-mastering refers specifically to the more creative components of the mastering process such as equalisation and dynamic treatment, in contrast with the so called ‘administrative tasks’ such as PQ coding and applying fades, according to (Nardi, 2014:9).

Pre-mastering is especially focused on achieving tonal balance and equalisation which is reminiscent of the delicate equalisation used to balance frequency variations between the inner and outer grooves of a vinyl. Pre-mastering employs compression as a tonal balancing tool which was historically employed to “keep audio above the noise floor and [...] to protect the cutter head” explains (Moylan, 2002:349). The modern and experienced engineer can help an artist to mould the audio’s sonic character and tonal balance by carefully balancing level, dynamics and equalisation according to (Huber & Runstein, 2013:563).

It is quite clear from this discussion that mastering is understood to be something that can enhance audio before replication. What might now be referred to as pre-mastering has at its core the task of improving audio in the sense that it might be enhanced and that any problems can be repaired. Mastering today will usually alter a recording (Moylan, 2002:349-350).

2.3.3 Mastering: the audio doctor

Apart from the creative and administrative tasks that comprise mastering, there is also an expectation that the mastering engineer can and will fix any problems with audio that are identified. This could

entail a creative intervention, as is often the case, but could equally entail the restoration and removal of noises in audio. The restorative role of mastering involves various processes including compression, EQ and cleaning up hiss, click and crackle (Rumsey & McCormick, 2006:290). Mastering relies on various diverse but inter-related techniques to address the matter of problematic noise in audio. These techniques are used to augment and repair recordings by removing small impurities such as clicks and noises, as well as addressing background noises such as hissing sounds explains Moylan (2002:351). The restoration function has been greatly increased in the present digital environment where tools exist that enable the mastering engineer to make fine adjustments to address audio imperfections.

2.3.4 Dictated by delivery

Effective mastering is inevitably determined by the mediums on which audio is being made available for public consumption. The heart of the mastering engineer's role is and always has been the activity of preparing audio for public consumption and equally of ensuring that the quality does not degrade. Similarly Bregitzer (2009:183) states that the purpose of masterings is to "make mixes come alive when played back over ordinary speakers or radio". This is even more so the case in the current technological climate where music is consumed online or on a variety of devices. It becomes increasingly difficult to predict how audio will be consumed and preparing audio for the vast variety of consumption mediums that are available at present. Fortunately there are industry standards that guide the mastering engineer in focussing on the most appropriate formats and mediums.

It stands to reason that different formats require different treatments, but often the same treatment can be applied to all formats depending on the specific requirements of the various formats. Mastering for CD and AAC can often benefit from the same treatment depending on the mix and mastering style according to Rumsey (2013:80). In a case study of different mastering engineers Nardi (2014:19) found that engineers who claimed that 30-40% of the music they work on has to be given a separate master for iTunes. Fortunately industry standardised systems such as 'Mastered for iTunes' have been established that standardises the treatment of audio. More importantly these standardised systems give audio professionals the tools to apply their personal choice of treatment of audio programme and then to audition the results says Rumsey (2013:83). This allows mastering engineers the chance to adjust the master in order to achieve exactly the envisaged quality outcomes.

2.3.5 Summary

Although the literature search revealed a gap in the knowledge base specifically focused on mastering it was possible for the researcher to synthesise a fairly clear understanding of the concept. For the purposes of this study a definition is necessary to use as a measuring staff against which the South African context can be judged.

The preceding sections reveal that mastering is indeed an indispensable part of professional audio production. It offers the last chance to refine audio before mass production. This refinement refers to administrative tasks that will ensure good presentation of the final audio product, which in most cases will consist of a collection of different audio. Mastering is charged with the unity of this collection and the aforementioned administrative tasks will ensure this unity. The refinement also refers to other processes that will influence the audio to be competitive in the industry and that will address the technical specifics of a variety of delivery mediums. In this, mastering engineers exerts some creative authorship at their discretion in order to enhance the audio programme.

This calls for an individual that is technically savvy, knowledgeable on a variety of audio standards and technical specifics and most of all creative. Creativity will define a good mastering engineer, one that knows how much or how little to do in order to achieve the best results. Against this broad understanding of mastering and the role it plays in audio production it is now possible to explore the understanding South African audio professionals have of the concept of mastering, the approaches it might follow and the processes it might employ.

Chapter 3

Literature review : key concepts defined

As the science and art of audio technology evolves, the lexicon can quickly become rather convoluted. Consequently it is important to explore key concepts that facilitate a proper understanding of the scope of the knowledge and skill that the mastering engineer need to possess.

The following section will address the key concepts and topics that relate to mastering and contextualise it in the greater audio production process. It will firstly consider the basic physics of sound and how this is perceived by the human ear. This is important in order to understand the concept of loudness which is central to mastering. Loudness standards as well as tools to control the perceived loudness will be discussed below together with other influential concepts such as equalisation. The complex process of digitising physical sound is imperative to mastering and will be explored. The previous section explained that mastering is concerned with reducing and controlling noise and as such the different technicalities around noise reduction will also be explored. Lastly the august theme of delivery formats and their technicalities will be addressed. All of the above mentioned elements make up the base of knowledge that is required for mastering and this knowledge base will be challenged in the understanding of South African audio professionals later in this research document.

3.1 Physics of sound

Sound is produced in waves of energy called sinusoidal waves. These waves have three characteristics which are crucial to an understanding of the specific sound that is produced. These are amplitude, rate of rotation or frequency and starting position or phase.

Amplitude refers to the “amount of compression and rarefaction of the air which results from the string’s motion and is related to the loudness of the sound when it is finally perceived by the ear” (Rumsey & McCormick, 2006:2). Understanding loudness and the control thereof, is extremely important to mastering.

Frequency represents the “number of repetitions of the cycles in the unit of time. As the frequency increases our sensation of ‘tone-height’ or pitch increases” (Roederer & Roederer, 1979:19). A higher frequency will translate to a higher sounding note and conversely a lower frequency to a lower note. Frequency is measured in hertz and with both amplitude and frequency data one is able to calculate the wavelength of sound. The wavelength, indicated by λ , is calculated using the following formula where f is frequency measured in hertz and c is the velocity of sound in the medium, Howard & Angus (2009:15) points out:

$$\lambda = \frac{c}{f}$$

Phase refers to a time delay between two or more wave forms and the manner in which sound levels add together either correlated or uncorrelated according to Huber & Runstein (2013:49). When correlated the pressure waves add together. This is called constructive inference. When uncorrelated they cancel each other out and this is known as destructive inference explains Howard & Angus (2009:28). The effects of phase play a significant role in audio as it explains physical anomalies such as beats, which is a phenomenon where out of phase sounds cause cancellations of sound creating audible dips in the volume. If frequency differences between two tones are “smaller than a certain amount, the resonance regions overlap and one hears only one tone of intermediate pitch with a modulated or ‘beating’ loudness” suggests Roederer & Roederer (1979:27). The amplitude modulation of the vibration pattern causes the perceived loudness modulation called a first order beat. Mastering is tasked with ensuring the phase correlation of the final product and uses special equipment to measure the phase.

The physics of sound waves play an integral part in all audio production phases but specifically in mastering where the design of the studio is of paramount importance. Where audio recording professionals need to understand the physics of waves to ensure the best audio is captured, the mastering engineer will have an expert knowledge of this for the previously mentioned reason, sound restoration,

the choice and placement of monitors (which will be discussed later) and very importantly in the understanding of how the human ear perceives sound. This will guide the mastering engineer in manipulating audio in order to achieve the best results.

3.2 Psychoacoustics and the human ear

Psychoacoustics is concerned with the extraordinary system of sound recognition in the brain and the hearing system. According to Moore (1995:42) this system consists of the air moving a membrane in the ear that creates a signal that is converted inside a complex inner ear system and is then interpreted as electrical energy in the brain. The following section will explore the human hearing mechanism, knowledge of which is crucial to a proper understanding of how loudness is perceived by the human ear.

3.2.1 Human hearing

Sound consists of waves of energy that creates a vibration that causes a sound wave to travel through the air and to finally reach the ear where it is 'heard'. A sound is heard when the outer eardrum begins to vibrate as the "small pressure oscillations of the air in the auditory canal" (Roederer & Roederer, 1979:22) impact on it. This seemingly simple process entails an elaborate chain of events involving five steps. Together these enable us to hear sounds.

The outer and middle ear Sound is channelled into the ear canal by the outer ear or the pinna. The pinna is curved and consists of grooves which aid the collection of sound into the ear canal explains Olien (2005:8). The pinna is responsible for the modification of the sound before it enters the ear canal, especially at high frequencies and additionally, according to Moore (2012:23) plays a major role in the localisation of sound.

Sound is then channelled into the ear canal which acts as a resonator (Møller, 2000:20). The outer eardrum transmits the vibration to "three little bones called the malleus, incus and stapes or hammer and the anvil and stirrup" explains Gould (1990:16). These bones act as "amplifiers multiplying the force 15 times due to the lever arrangement of the bones." This arrangement, as well as the "area difference between the tympanic membrane" and the oval window of the inner eardrum, assists in the impedance matching of the outer and inner ears and ensures optimum transfer of energy (Rumsey & McCormick,

2006:2). According to Møller (2000:22) the “middle ear acts as an impedance matching transformer which matches the high impedance of the cochlear fluid to the low impedance of air”.

The inner ear These vibrations generated in the outer ear are transferred through the inner ear and impact the ossicles, which in turn transmits the vibrations through the two tubes named the scala tympani and scala vestibuli, through a membrane at the entrance to the cochlea called the oval window. The cochlea consists of a duct or tube that is wound up like a snail’s shell and is partitioned longitudinally into two tubes by the basilar membrane, about 350mm long, which holds the actual sensor organ called the organ of Corti, and the corresponding nerve endings. They are “filled with an incompressible fluid called the perilymph” (Moore, 1995:44).

According to (Roederer & Roederer, 1979:31) the vibration travels from the bone chain, through the oval window to the nerve cells. Once it reaches the oval window, it becomes vibrations of the perilymph fluid found in the cochlear duct. This movement is then converted to electrical signals at the nerve cells which the brain perceives as sound.

The basilar membrane contains of an area of maximum sensitivity for each frequency. This is called the resonance region. The most flexible area of the basilar membrane lies close to the apex and it is this region that is most sensitive to lower frequencies. The higher frequencies will affect the stiffer area nearer the oval window at the entrance to the cochlea. The change in area caused by changing frequencies is interpreted by the brain as a change in pitch explains *inter alia* Bregman (1994:235).

It is notable that the frequency range most crucial to humans is approximately 20 Hz–20 kHz which covers about 65% of the basilar membrane (12–35 mm from the base) says Roederer & Roederer (1979:31-32). He continues to explain that the displacement of the resonance region is determined by frequency ratios and not the differences between them. This is known as a logarithmic relationship.

Transduction and the hair cells The organ of Corti consists of hair cells which convey details about timbre and intensity of a sound (Stevens *et al.*, 1965:47). Moore (2012:34-35) explains that the hair cells in the organ of Corti consists of outer and inner hair cells but it is the inner hair cells that relay the majority of information about sound and the outer hair cells assists in fine

tuning. He further states that the inner ear contains hair cells called stereocilia which are connected to each other and the inner ear by 'tip links' which, when affected, allows potassium ions to flow into the cell, altering the voltage and thereby stimulating neural activity in the auditory nerve.

The organ of Corti can be said therefore to translate energy from mechanical to electrical and also sends an encoded rendering of the sound to the brain including information about the frequencies, the intensity and the timbre as well (Stevens *et al.*, 1965:47). The organ of Corti relays the entire range of frequencies audible to man from its protected place inside the temporal bone inside the cochlea. Two sets of nerve fibers carry a myriad of messages between the ears and the brain. These nerves follow enormously complex causeways through the brain, passing through relay stations in the brain where some scientists believe the brain directs the filtering out of certain unimportant signals. There are 30 000 nerve fibres in total, forming the auditory nerve. The brain accumulates sound from birth and builds a memory centre which enables a fully-grown brain to distinguish between some 400 000 signals (Stevens *et al.*, 1965:47-57) .

Critical bands The critical band is defined as the range of frequencies that show elevated thresholds (Gold *et al.*, 2011:35.2.1). Critical bands are explained by Howard & Angus (2009:83-84) as

[...] the frequency difference between the pure tones at the point where a listener's perception changes from rough and separate to smooth and separate.

These critical bands are key to understanding how the ear perceives loudness and how frequencies differ in their perception of loudness. (Gold *et al.*, 2011:35.2.1) states that

[...] many hearing phenomena vary on this scale, and appear to reflect an important aspect of the ear's mechanics and neurophysiology.

The complex system that enables humans to hear audio is fascinating, but in the case of mastering it offers a very important clue as to how to creatively address audio. The sound that travels through the hearing system will invariably be interpreted by the brain and

this is regulated rather heavily by the physical systems mentioned above. Frequency control is a key component of mastering and will influence much of the perceived audio for a listener that might not be readily obvious but will influence their perception of quality and loudness. The critical bands play a key role in how the listener will perceive loudness and an understanding of this will guide mastering engineers in their adjustments of audio programme.

3.3 Loudness

Understanding loudness is an indispensable part of mastering. The previous section mentioned the historical belief that louder audio will sound better and by extension sell better (Owsinski, 2008:5-6). The task of the mastering engineer is to constantly test the limits to make the audio programme seem as loud as possible before the 'needle started to jump' says Zager (2011:128). Even though today new consumption methods remove the physical challenge of a jumping needle the mindset has stayed the same. In order for mastering engineers to exert complete control over the loudness of the audio they need to be able to clearly judge the loudness. To do this certain measurement tools have been devised to understand the perceived loudness of audio programme.

3.3.1 Measurement

Heinrich Barkhausen started experimenting with a measurement of the level of loudness based on the critical-band rate in the 1920s. He devised a scale which was designed to measure the sensation of loudness of any sound (Zwicker, 2007:203). This has led to various experiments to increase understanding of loudness and how it relates to the human ear. Today the most important and prevalent standard of loudness measurement is the decibels (dB) which refers to the sound pressure level as the ear perceives it. It is this acoustical phenomenon that explains how the loudness of a sound is perceived by a person. The eardrum is sensitive within certain limits to pressure and these limits are referred to as thresholds. At the lower end of the range, the threshold will be the point below which a sound is recognisable from the noise floor. In midrange frequencies this threshold equates to a pressure deviation of approximately 20 pascals from the ambient. This number puts the decibel at 0 dB (SPL) using the equation shown below (Mitchell, 2013:26) :

$$L_p = 20 \text{LOG} \frac{0.00002}{0.00002} = 0 \text{db(SPL)}$$

Whereas the perception is that doubling of the loudness of audio requires an increase of 9 - 10 dB the facts are that even a 6 dB increase would actually double the sound pressure according to Rumsey & McCormick (2006:36).

3.3.2 Volume and decibel

Volume and loudness are often confused when discussing the perceived loudness of audio. The word volume is often used when considering loudness and has become part of the consumer terminology. Professionally however, the term leads to confusion and is in fact virtually meaningless. The term volume is often used to refer to the intensity of the sound pressure level or power level and as such refers in fact to the intensity of the electrical signal. It more accurately refers to the cubic dimensions of a space and so it is avoided in the context of audio technology (Davis & Davis, 1989:27). In the context of audio technology terminology the term 'level' is a more appropriate term than the word volume, although even this term is still rather ambiguous. In order to speak clearly the word level should always be used in conjunction with other explanatory terminology and should be accompanied by a unit of measurement such as sound pressure level according to Katz (2007:65).

Sound pressure level refers to the amplitude or energy of a physical sound wave in the atmosphere and is measured in Pa (pascals). According to Katz (2007:65) this measurement refers to absolute pressure units. In audio technology however it is mostly measured in decibels, written as dB (SPL). The decibel is a measure $1/10^{\text{th}}$ of the sound of a Bell and the term used to define this unit of measurement was coined by Alexander Graham Bell (Huber & Runstein, 2013:58).

The decibel is not an absolute like the pascal, but is rather a relative quantity that is actually an expression of a ratio or an expression of the difference in intensities between two level states (Huber & Runstein, 2013:59). The nature of this ratio is logarithmic (Huber & Runstein, 2013:57). The reference is not always stated but the implication usually is 0 dB and the unit is usually Sound Pressure Level or SPL. Because the nature of the decibel ratio is logarithmic when doubling the input voltage one would achieve a 6 dB increase according to the formula given below:

$$20 * \log(2) = 6 \text{ dB}$$

3.3.3 Curves

Loudness refers to how loud audio is perceived to be. This perception is of course entirely subjective and does not necessarily relate to the actual sound pressure level, although it is more often than not related to SPL and decibel (Davis & Davis, 1989:29) (Rumsey & McCormick, 2006:33). The measurement unit that loudness is measured by is called the Phon. The human ears' dynamic range measures at more or less 140 Phons, where 140 Phons is the threshold of pain (Rumsey & McCormick, 2006:33). Loudness is further complicated by the ears' inability to perceive loudness in the same way for all frequencies. In order to understand this, a system of curves has been formulated that represent a more accurate understanding of loudness across the frequency spectrum. The human ear perceives a level increase as an increase in loudness. A sound level meter is used to measure Sound Pressure Level or SPL and a 'weighting' is employed to emulate the human hearing as described in the Fletcher-Munson Equal Loudness Contours. The Equal Loudness Contours was devised by Fletcher & Munson (1933) and their "A-Weighted Curve" is often used when measuring loudness as it more closely represents human hearing (Rumsey & McCormick, 2006:33-34). The acoustic levels of a sound determines its loudness. This in turn will be the determining factor of the electrical level that would drive a loudspeaker. Level in this sense is an expression of power or pressure which we measure in decibels.

Loudness is clearly a complex theme and requires thorough understanding by any audio practitioner. Mastering engineers in particular need to be well versed in the complexities of loudness as it is their charge to ensure that audio programme offers the best version of the artists vision and the maximum listening pleasure for the consumer. Mastering needs to ensure that audio programme conforms to the industry standards which will enable them to meet the aforementioned responsibilities.

3.4 Loudness standards

Having the ability to measure this in real time is of paramount importance to the mastering engineer. Loudness can be measured using different tools and each tool is able to provide the mastering engineer with specific information to judge the physical loudness as well as how that will be perceived by the listener. The available tools to measure loudness ranges from VU meters to RMS meters to more complex modern tools, as will be shown in the discussion below.

VU meter is the simplest level meter and it measures the AC voltage using a logarithmic response. Since the ear perceives sound with a similar logarithmic response, the VU meter is roughly comparable to how the ear perceives volume, which is why it is called volume unit or VU meter (Self *et al.*, 2009:31). This meter is also jokingly referred to as the “Virtually Useless” meter in audio, as it suffers some shortcomings such as the inability to address rich short transients.

Peak Programme Meter (PPM) is also a logarithmic level meter. This meter is designed to respond to peaks quickly and so the attack time is carefully specified. The decay time of the PPM is slow in order for any peaks to stay visible for longer, making the meter easier to read (Self *et al.*, 2009:31). The PPM tracks peaks but does not reveal much about loudness (Mitchell, 2013:36). Because of this most meters will incorporate both average and peak metering.

Roots Mean Squared (RMS) is a way of accurately calculating the true energy level of a signal by squaring all the instantaneous voltages of a waveform and using the square of those values as the RMS value (Davis & Davis, 1989:27).

3.4.1 ITU-R BS.1770

In order to determine loudness, the general or average energy is used. When using only peak energy the loudness can still vary a lot even though the peak levels are equal (Grimm *et al.*, 2010:1). Accurately measuring the loudness of audio is difficult and several metrics have been proposed, such as the European Broadcasting Union’s definition of a loudness range. The loudness range (LRA) is determined by creating a histogram of the loudness within a three second time window (Boley *et al.*, 2010:2). In broadcasting, audio is typically metered using quasi-peak programme meters that have a finite reaction time of 10 ms. This means that shorter signal peaks do not display correctly. Headroom for these transients are created by agreeing to a maximum permitted level of -9 dBFS. This was often not adhered to however, which meant noticeable jumps in audio level between programmes and advertisements (Camerer, 2010:2).

The International Telecommunication Union (ITU) recognised these problems and set out to create the ITU-R BS.1770 standard. This standard is aimed at establishing an algorithm used to measure the loudness and true peak levels of audio (Grimm *et al.*, 2010:1). The standard defines what is called a K-weighted curve which in essence aims

at matching the objective measurement with the subjective impression. This is achieved by calculating the total mean square energy and showing the result as “Loudness, K-Weighting, in reference to digital Full Scale” (LKFS) (Camerer, 2010:2-3). The BS.1770 LKFS loudness measurement proved suitable to ensure consistent programme loudness level (Grimm *et al.*, 2010:1).

A further challenge was to set a target loudness. Target loudness makes sense only in relation to the peak level of audio. Uniform loudness as well as loudness-to-peak range both require equal attention. Therefore when the maximum digital peak level is set, the level of loudness can be selected accordingly. ITU-R BS.1770-2 uses a gate that is relative to the measurement of programme loudness. This was adopted from the R128 standard. It was again updated in 2012 to version ITU-R BS.1770-3 (Robjohns, 2014).

3.4.2 EBU R-128

The European Broadcast Union (EBU) is an alliance of public service media entities and was established in 1950 (Rumsey & McCormick, 2006:603). R128 is a common, vendor independent loudness recommendation standard developed by the PLOUD¹ group. The R128 standard has established a loudness measurement method that is properly defined and predictable. Here loudness refers to the apparent strength of audio programme. According to Camerer (2010:1) the loudness will also depend on the “level, frequency, content and the duration of the audio, amongst other things”. EBU R128 is based on the ITU-R BS.1770 and furthers the standard by clarifying a specific definition of the target level for normalising loudness. It also specifies a method for gating which will improve the matching of loudness in programmes with long periods of silence (Camerer, 2010:3). The R128 standard addresses various complete mixes rather than just certain components such as dialogue, by specifying three new parameters:

- Programme loudness
- Loudness range
- True peak level

These three parameters together form a set of descriptors to denote audio programme. This harmonises audio levels within broadcast channels to achieve equal universal loudness levels which will

¹ The PLOUD group is a division within the European Broadcast Union dedicated to loudness

benefit the listener. This loudness normalisation method uses the average loudness of a programme to make the level consistent between different audio programmes (Camerer, 2010:1-2).

When a loudness meter has EBU mode, i.e. the capability to measure according to the R128 standard, it must satisfy a set of criteria. These criteria include three time scales:

1. Momentary
2. Short-term
3. Integrated (also referred to as programme loudness).

An EBU meter has to display all three time scales. Programme loudness is measured by employing a distinct gating method which excludes measurement of the same programme material. An EBU meter must also display the Loudness Range (LRA). The measurements are expressed in Loudness Units (LU) and Loudness Units Full Scale (LUFS), which is the same as LKFS. EBU R128 sets the loudness target at -23 LUFS (Camerer, 2010:2).

3.5 Analogue to digital conversion

Many instances of analogue to digital (A/D) conversion and vice versa can be found in the mastering signal chain. Although most audio programme today will be delivered in digital format, it remains necessary to be able to convert from an analogue audio signal to digital and back. The mastering chain requires audio to be converted from digital playback to analogue for processing and back again to digital, depending on the processing equipment being used. Therefore analogue to digital conversion (ADC) could easily be considered the most important process in the mastering studio. The following section will explore ADC, the process of conversion and the technicalities surrounding it.

3.5.1 A/D conversion and sampling

Analogue information is a continuous sequence or continuum of values within a set range dependant on the limitations of a specific system. Analogue information in an electrical form is converted into digital form by means of analogue to digital conversion, more commonly referred to as pulse code modulation and more generally as ADC conversion (Watkinson, 2001:3). When converting an analogue signal to the digital format the Nyquist-Shannon Sampling theorem

is employed. This theorem is a fundamental bridge between continuous signals such as analogue audio and discrete-time signals such as digital signals (Rumsey & McCormick, 2006:210-211). It specifies the necessary rate of sampling that will allow a sequence of samples to accurately capture all the information from the analogue signal. In order to convert an analogue signal to a digital signal the amplitude must be measured at fixed points in time. This is “called sampling and is used to assign a binary digital value to each measurement” (Rumsey & McCormick, 2006:209). As determined by the Nyquist Theorem the sampling frequency should be at least double the highest analogue frequency (Mitchell, 2013:955). Therefore audio for CD has a sampling rate of 44 100 times per second, which according to the Nyquist Theorem yields an maximum audio bandwidth of 22 kHz (Owsinski, 2008:9). In reality the sampling rate used is often much higher, with 44.1 kHz and 48 kHz and even 96 kHz seen regularly in professional audio (Mitchell, 2013:955).

The equation below explains that the sampling rate f_s is the mean number of samples in a second :

$$f_s = 1/T$$

Mastering requires exceptionally high quality converters as this directly influences the quality of the audio. Many workstations and computers have built-in converters, mostly of lower performance quality. The quality of the digital audio signal will be largely determined by the design of the converters (Rumsey & McCormick, 2006:210). If the quality of the converters are high and the design technically good, it is possible to eliminate all the shortcomings of analogue recording such as wow, flutter, noise, print-through, drop-outs, modulation noise and phase errors suggests Watkinson (2001:8).

3.5.2 Aliasing

If too few samples are taken when converting from analogue to digital and *visa versa*, the audio signal can be incorrectly represented and this could lead to faulty conversion. This is called aliasing. Generally speaking aliasing occurs when the audio signal is reconstructed incorrectly during the ADC conversion. The physical effect of this phenomenon is hearing audio that is not supposed to be there moving down in pitch while the original increases. The equivalent of this in the visual media is the well known example of the spokes of a wheel that appear to be rotating backwards while the wheel is rotating forwards and the speed of rotation exceeds the rate of the individual

photographs that make up the film explains Rumsey & McCormick (2006:215-216).

Aliasing can be avoided by applying a filter that removes all audio frequencies above half of that of the sample frequency. It is therefore common to use a sample frequency that is more than double that of the highest frequency. This allows for the gentle roll off so as to avoid the erratic phase response common with steep roll off, especially in lower quality converters that do not employ oversampling. Over sampling has in the past allowed fewer audible side effects, due to higher baseband frequency and shallower anti-aliasing filters (Rumsey & McCormick, 2006:216).

3.6 Digital dynamics

Sampling is one of the processes involved in digitising audio and refers to the converting of the sound wave to a digital format. There is however another aspect to digitising audio signal which deals with the dynamics of the audio being converted. This element is referred to as bit depth. Bit depth determines the dynamic range of the audio and is an example of a process that is left solely to the mastering engineer. It is necessary to reduce the bit depth in order to comply to consumption standards. Although most modern DAWs have tools built in to address bit reduction, this process is left for the mastering engineer who is an expert. They have high quality tools and a specialised listening environment to clearly employ the correct methods of bit depth reduction for the best results.

3.6.1 Quantising

After audio has been sampled, a process called quantising is applied where the sample amplitude of the audio is converted to a binary. This is done by mapping sample amplitude onto a scale of stepped binary values. The quantiser assigns to each sample a value according to a fixed number of quantising intervals. This value is the mid-point of the interval of values that the quantiser determines the sample to be in. Each sample now gets a unique binary number which represents the sample amplitude. An unfortunate and inevitable result of this process is quantising error. This can be obviated by increasing the scale of the binary used. In a 4-bit scale there are 16 possible steps. The number of steps increases to 256 in an 8-bit scale and 65 536 in a 16-bit scale. Therefore more bits equates to a more accurate quantisation, according to *inter alia* Rumsey & McCormick (2006:219).

3.6.2 Bit depth and wordlength

“A number made up of more than one bit is called a binary word” (Rumsey & McCormick, 2006:203). The number of bits in the word is called the wordlength, which contains the “least significant bit on the right-hand and the most significant bit on the left-hand” (Watkinson, 2001:6). The wordlength determines the quality of the sound because more bits in a word equates to a bigger dynamic range. Every bit equate to a dynamic range of 6 dB and a 16 bit scale “yields a maximum dynamic range of 96 dB, 20 bits equals 120 dB and 24 bits a theoretical maximum of 144 dB dynamic range” (Owsinski, 2008:10).

In mastering, the engineer is tasked with delivering a standardised audio product of optimum quality. When the product takes the shape of a CD, it must adhere to certain standards such as a sample rate of 44.1 kHz and a bit depth of 16 bits (Zager, 2011:128). The mastering engineer must ensure that the bit depth reduction does not reduce the quality of the audio programme. A special process is applied in order to ensure that the quality is retained. This process is called dither.

3.6.3 Dither

Converting from analogue to digital comprises two processes. One is sampling of the analogue waveform and the other is quantisation of the amplitude of the signal values so the samples can be represented by binary words of a prescribed length, both of which were discussed above. The process of quantisation however generally results in signal degradation (Lipshitz *et al.*, 1992:355).

Quantising errors are perceived as noise at high signal levels but when the signal falls the noise correlates more closely with the original signal and the noise becomes a distortion of the sound (Watkinson, 1998:238). Dither is the process through which signals are decorrelated. It attempts to prevent the perception of distortion. This is achieved by making the quantiser processing unpredictable and giving the signal a noise floor, similar to analogue audio (Izhaki, 2013:155). The quantising error is not removed but the distortion resulting from quantising error is converted to broadband noise which is much less obvious and favourable (Watkinson, 2001:226). Digital audio systems use non-subtractive dither which does not attempt to remove the added noise upon conversion (Watkinson, 1998:238). This reduces the signal to noise ratio slightly, however the use of noise shaping addresses this issue effectively, says Watkinson (2001:225).

3.6.4 Noise shaping

Noise shaping refers to a procedure where noise components are shifted out of the audible regions of 20 Hz - 20 kHz and into the inaudible upper reaches of the 11.2 MHz bandwidth (Self *et al.*, 2009:519).

In 1999 a consortium of companies developed a set of commercial dithering algorithms for noise shaping. It was called Psychoacoustically Optimized Wordlength Reduction or (POW-R) and was designed to be used in audio bit depth reduction processes. The consortium comprised companies Lake Technology (Dolby Labs), Weiss Engineering, Millennia Media and Z-Systems, who endeavoured to create the most sonically transparent dithering algorithm possible and is found on many popular DAWs today.

Although the processes of bit depth reduction involved the amount of dynamics possible in audio programme it is not to be confused with the mastering engineers ability to change the perceived dynamics of the audio. The ability to creatively affect the audio in order to increase or reduce the dynamic range of audio programme entails a different set processes and the tools to control them. The following section delves deeper into this topic.

3.7 Dynamic range manipulation

Dynamic range is described by Davis & Davis (1989:33) as the difference in decibels between the quietest and loudest instant of audio programme and he adds that “dynamic range defines the maximum change in the audible programme level”. Dynamic range is of paramount importance in mastering because, as mentioned before, the ability to manipulate the dynamic range lies at the heart of mastering. The ability to effectively or even artfully control the dynamics of audio is the “Art of Mastering”. Any processing will invariably have an influence on the dynamics of audio but there exists a tool specifically geared towards this goal generally referred to as Compression. This section will explore the theory of compression. The investigation will seek to explain the art of dynamic range manipulation using compression as a tool. It is referred to as an art, because as Katz (2007:110) state, it is of utmost importance to work delicately with dynamic range. When everything is loud, then really, nothing is loud (Katz, 2007:110), which makes the audio boring and unpleasant to listen to.

3.7.1 Compression

Compression plays a key role in audio production and is a valuable tool in audio mastering. In this context compression refers to the process of manipulating the dynamics of audio. Compression can be used in various ways, but for the purpose of this section of the investigation it will be understood to refer to the process that increases low-level signals while decreasing louder signals (Owsinski, 2008:39). Compression manipulates the output of an input signal. If an input signal increases in level by for instance 10 dB, a compressor could, depending on the settings, only allow an increase of the output to 2.5 dB . A compressor reduces the dynamic range of an input signal by the amount of its ratio (Mitchell, 2013:906). Compression is employed in order to decrease the dynamics of a signal when it rises above a predetermined threshold that is defined by the user. Once the loud signals have been decreased, the overall level is increased, bringing the loud passages back to their original level while increasing the level of the softer passages (Huber & Runstein, 2013:492).

Compressors will often include a set of controls, including:

- Input gain
- Threshold
- Ratio
- Attack
- Release
- Output Gain
- Meter Display

Input gain is the amount of signal that is fed into the compressor. This gain makes the input to the compressor louder, so that it will more easily cross the threshold.

Output gain serves to boost the signal upon output. It will bring the level of the compressed signal up, to 'make up' gain for the loss of level caused by the compressor.

Threshold is the setting on a compressor that indicates the level below which the signal will be left unaffected. Above this threshold level the compressor will process the signal to align with the other settings (Mitchell, 2013:906). The threshold is the point at which automatic gain reduction starts. Below this level the compressor does nothing, but above this level the compressor reduces the volume to the ratio setting (Owsinski, 2005:54-55).

Ratio is the setting that will determine how much compression will occur. If set to 1:1 the compressor will do nothing. With a setting of 2:1, an input increase of 2 dB above the threshold, will output an increase of only 1 dB. A 10:1 setting will only affect the signal once the input exceeds 10 dB above the threshold states Owsinski (2005:54-55). Generally, compressors use gentler ratios such as 1.5:1 - 4:1 in order to increase low level material and subtly “make sounds chunkier” (Mitchell, 2013:906).

Attack time refers to how fast the volume is reduced after the input exceeds the threshold. When a slow attack is used signal peaks might get through and cause distortion where a faster attack time will prevent overload.

Release time determines how fast the volume will return to normal. A fast release time might become audible creating a pumping effect therefore, slower release times are more prevalent (Owsinski, 2005:54-55). The Attack and Release settings are key to getting the most out of a compressor. Generally the attack control setting will influence transient response and percussive sounds. Release time will determine the return of the gain return to zero (Owsinski, 2008:40).

Owsinski (2005:54) considers compression to be an immensely powerful tool in mastering as it can change the tonal characteristics of the sound. It is used to add punch or to smooth out an instrument's sound or you can eliminate noise using compression (Strong, 2011:280). Compression is used to control peaks in the audio programme according to Gallagher (2008:211).

The most prevalent of the different kinds of compression is Downward compression where the level of passages are taken down. Upward compression brings up the levels of lower level passages suggests (Katz, 2007:112).

3.7.2 Limiting

Limiters are essentially the same as compressors, except that it limits the highest level of a sound source. Signals above the threshold are immediately and completely reduced rather than compressed according to Strong (2011:280). Limiters will also invariably have peak detectors to protect from overload by the limiter (Mitchell, 2013:907).

3.7.3 Expansion

Expansion is the opposite of compression in the sense that it increases the level instead of reducing it. Katz (2007:111) explains that it is used to restore the excitement of dynamics which might have occurred after many generations of compression or saturation in a mix. Upward expansion increases the level of high level passages even more. It requires skills and if used carefully can greatly enhance the “dynamics, increase musical excitement or even restore dynamics” says Katz (2007:113). The most frequently used kind of expansion is downward expansion. It is used most often to reduce noise and hiss by reducing low level passages even further (Hodgson, 2010:212). Expanders fulfil the same need as a gate. It often yields better, less noticeable results. By using gentle ratios an expander can provide the same amount of noise reduction as a gate with a far less abrupt change in level (Mitchell, 2013:907).

3.7.4 Multiband compression

Multiband compressors allow manipulation of only the frequency range that one wants to compress without affecting the rest of the frequencies. Most have three or four frequency bands addressing low, mid and high frequency bands and gives one the ability to choose where these bands begin and end (Strong, 2011:280-281).

3.7.5 Creative compression

Compression is a widely used tool in all audio applications and has the ability to address many different aspects of audio production and reproduction. It can be used as a basic tool to increase loudness but as pointed out in the preceding sections it has the ability to transform audio. In this sense it stands next to equalisation as one of the most important creative tools in the mastering engineer’s arsenal. Mastering employs compression in a creative way to address practical as well as creative issues.

The first and most obvious creative application of compression is to increase the low level passages and decrease the louder ones. This could be necessary for a variety of reasons such as ensuring that no details are lost when listening to audio on systems unable to reproduce the full frequency range. The ordinary listening environment cannot reproduce the same dynamic range experienced in real life, therefore the mastering engineer must raise the level of the softer parts and to reduce the loud parts using compression. It might also be used to make delicate inner details more noticeable or to even out

dynamic ranges that might be excessive (Katz, 2007:111). Limiting is a form of compression which can be used to sublimate loud instruments in a mix. The difference between loud and soft in a song should, generally speaking, be less than 6 dB and is usually between 12 dB and 18 dB (Strong, 2011:300).

Compression should be thought of as a tool to affect the inner dynamics of music. While it is used to control the dynamic range of audio, it can also “beef up” or add “punch” to low and mid-level passages (Katz, 2002:3). Compression might also be used to make the audio sound more exciting, fuller or more consistent. Compression is used to make the overall audio more punchy (Owsinski, 2008:5-6). Using compression correctly however has the ability to make audio smoother or more clipped depending on the need (Zager, 2011:128).

It is clear from these statements that compression is a powerful tool that can severely influence the final sound of audio programme. It is also clear that in the hands of an experienced and sensitive mastering engineer the tools can do much creatively to improve audio. In this sense mastering could be considered an artistic endeavour. Inversely it is possible to use these tools incorrectly making audio flat and potentially ruining a mix.

3.8 Equalisation

Whereas compression allows the mastering engineer delicate control over audio, equalisation has the ability to drastically alter the sound of audio programme by completely changing the tonal balance. Mastering is concerned with tonal balance and aims to ensure that audio is as balanced as possible says Owsinski (2008:23). The various songs on an album should relate to each other as well as to the frequency spectrum heard within each individual song (Zager, 2011:128). If the bass of a song is overpowering, the mastering engineer will subtly adjust the tonal balance of the audio until all the frequencies are balanced and sounds clear together. The equalisation or EQ tool is an incredibly valuable tool for the mastering engineer as it allows the most control over tonal balance (Zager, 2011:128). Using equalisation the mastering engineer can add sparkle to the higher frequencies or power to the bottom frequency ranges says Zager (2011:128). Tonal balance means different things to different genres of music and so the mastering engineer is tasked with understanding music genres and how to address the tonal balance for each (Katz, 2007:104). Again this is considered an artful endeavour as it can easily completely change the character of the audio. Mastering engineers often work on the principle that everything affects every-

thing else. For this reason they take a lot of care when making any changes (Katz, 2007:103).

3.8.1 Parametric and shelving equalisation

The mastering engineer has the choice of the two variants of equalisation (EQ), parametric and shelving EQ. These terms or titles originated because of the shape of their respective characteristic curves (Katz, 2007:106). Parametric and shelving are the two most common equalisers used in signal processing (Ding & Rossum, 1995:822). Parametric equalisation was invented by George Massenburg (1972:1). It offers considerable flexibility. Adjustments are made through three controls:

1. Centre frequency
2. Bandwidth, also referred to as ' Q '²
3. Level of boost/cut

The parametric equaliser allows the independent control of all three parameters for each of the frequency bands (Kraght, 1992:1). Not only does it allow independent control but it also allows control of the parameters in a “continuously variable fashion” says Huber & Runstein (2013:482). Regardless of design and model, all parametric equalisers will have the ability to continuously adjust the centre frequency and the amount of boost/cut (Massenburg, 1972:4). Mastering engineers will often employ equalisation, using stepped controls as opposed to continuous controls, which provides much better control to repeat settings. These steps are usually in 1 dB increments but can be as little as 0.5 dB suggests Owsinski (2008:23). The frequency bands often overlap in order to ensure smooth transitions between the bands. This functionality also allows the user to place multiple curves in nearby frequency ranges. The parametric equaliser is extremely flexible and has therefore become the industry standard for mixing desks and digital audio workstations alike (Huber & Runstein, 2013:482).

Shelving equalisation will boost or cut an entire spectrum below the selected frequency. This type of equaliser will be either a low-pass or a high-pass filter which will allow either low or high frequencies to pass through. Instead of a bell shaped Q the shelving equaliser's Q setting refers to a starting frequency above or below which the boost or cut will be applied (Savage, 2011:46). It is often used to address

² The term ' Q ' is derived from 'quality factor', a general term used in physics and engineering that characterises bandwidth.

a very specific sound and is popular for noise reduction of low frequency rumble. Shelving equalisation is popular in mastering (Katz, 2007:106).

3.8.2 Linear phase EQ

Equalisation inherently causes phase shift due to the physics involved which causes distortion (Henriquez *et al.*, 1990:1-2). Digital signal processing has however made it possible to create non-minimum phase shift EQ. The most common of these equalisation processes is linear phase EQ which is characterised by a constant group delay (Miller, 2004:1). Audio processing requires several types of frequency selection filters such as tone controllers, equalisers and crossover filters that ideally should not be allowed to affect the relative phases of a signal's spectral components as this could become audible (Azizi, 1997:1).

Linear phase filters are highly popular with mastering engineers because they do not include the risk of introducing distortion (Katz, 2007:111). Analogue filters have an inherent phase response non-linearity and this must be corrected with phase equalisation all-pass filters that are considerably more efficient in digital signal processing. Digital processing uses FIR (finite impulse response filters, feed forward systems) and IIR (infinite impulse response filters, feedback systems) filters. FIR algorithms are less complex to implement, although they tend to require substantially more computational power (Azizi, 1997:1).

Equalisers such as the parametric equaliser suffer some shortcomings according to Kraght (1992:2) in that they tend to have peaks at each of the frequency band centres and dips in between. This means that any processing, and the resulting dips and peaks it causes, will affect and possibly degrade the audio quality. Changing any one band will cause changes in all the other bands and the group delay will not be constant. The more bands there are the more delay will be present. This can be remedied in digital equalisers built on (FIR) filters where the output is the sum of all the FIR filters (Kraght, 1992:2). The use of FIR filters eliminate phase distortion which can affect the stereo image definition (Vieira, 1996:1).

3.9 Noise reduction

The mastering engineer is tasked with ensuring the best possible final product for delivery to the consumer. As such the mastering engineer will often use specialised tools to remove noise and other

sonic problems from an audio programme. The mastering engineer generally works with the final stereo file and as such has the ability to affect the whole audio file before final delivery, in order to ensure that no extraneous noises are included when sent for reproduction.

3.9.1 Compansion

Compansion is a technique used to reduce inherent noise caused by analogue recording processes. This method first compresses audio before recording it to tape and upon playback the audio is downwardly expanded, hence the name compansion which is a combination of the words compression and expansion. When the compressed material is again expanded, any added noise will also be downwardly expanded and reduced in level, leaving the audio at its original level. The system uses a 2:1 compression ratio in order to lessen the noticeability of tape drop-outs in the expansion process. This ratio is considered by Huber & Runstein (2013:515-516) to be the most suitable compromise between noise reduction level and over-sensitivity to drop-outs.

3.9.2 Single-ended noise reduction

Single-ended noise reduction extracts noise by combining a downward expander with a variable low-pass filter. These kind of devices can dynamically analyse, process and EQ audio programme with nearly no audible effects as it will break up the audio spectrum into frequency bands. When the level within a band falls below the user-defined threshold, it will attenuate. The single-ended system relies on the psychoacoustical principle that music will mask low-level noise within the same band. It is a known psychoacoustical fact that the human ear is more sensitive to noises with a greater variance or range of frequencies than those with only a few frequencies states (Huber & Runstein, 2013:517). The processor will sense when high-frequency content is reduced and will then reduce the frequency bandwidth accordingly, thereby reducing the noise content. Once the high-frequency signal returns, the filter will increase the frequency bandwidth allowing the content to mask the background noise.

3.9.3 Noise gate

Another popular tool with which to control noise is a noise gate. This is a simple tool that only accepts audio signal above a certain threshold. When the signal falls below the threshold, the noise gate will

attenuate the signal effectively, acting as an infinite expander that mutes all background noises according to Guérin (2005:86). Careful attention to the setting is critically important, in order to prevent pumping and breathing effects caused by attack and release times.

3.9.4 Digital noise reduction

Noise reduction has improved considerably with the evolution of the digital domain. Digital Signal Processing (DSP) is often used for noise reduction of noise artefacts such as tape hiss or ticks and pops. Digital noise reduction applications can be used as separate software programs and are also often used as software plugins inside DAWs. These applications are specially designed to achieve noise reduction (Rumsey & McCormick, 2006:290). The noise reduction algorithms can address noise inside multi-track sessions or can be used to process noise in the overall mix that takes place during mastering, to clean up or restore vinyl records and analogue tape for transfer to CD, says Huber & Runstein (2013:518).

Noise reduction applications and plugins make use of Fast Fourier Transform (FFT) for analysis. This mathematically complex algorithm allows the software to analyse the amplitude and frequency domain of audio, in order to reduce hum and hiss. FFT analysis allows software to take a 'snapshot' of selections of audio that contain noise that can be digitally subtracted from the original file, relying on various predetermined parameters. This will allow the footprint noise to be reduced while leaving the original unaffected. Noise reduction can sometimes leave artefacts such as chirping, which sounds similar to birds chirping in the background.

3.9.5 Restoration

Another common aspect of noise reduction is the restoration of audio. This process will include removing noises such as pops and clicks from the audio, a process often relied on when restoring vinyl recordings. Here the software will first attempt to detect high-level clicks, then the programme performs a frequency analysis and attempts to make a plausible guess as to what the damaged amplitude and frequency content was supposed to look like. The new audio is pasted over the damaged section, rendering it unnoticeable or eliminated (Huber & Runstein, 2013:522). Most applications will focus on sounds such as clicks or pops because these sounds can be different and have to be addressed differently.

FFT-based applications have the capability to erase obvious sounds visually. This is done by giving the user the ability to draw, cut and

paste directly onto a spectrogram (Collins, 2014:571). A well known software tool that can be used for mastering is CEDAR which includes examples of restoration plugins specifically aimed at de-hissing, de-cracking, de-thumping, de-noising and de-clicking. This software also includes a visualisation tool for restoration that makes it easy to “touch up” audio material (Rumsey & McCormick, 2006:291). Another popular mastering software application is tc Works Master x series which incorporates advanced dynamics control that is common in these kinds of applications. One example of this is the ability to observe the amount of samples at peak level, which allows the mastering engineer to check for digital overloads (Rumsey & McCormick, 2006:291) points out.

3.10 Delivery standards

The final format or medium in which audio will be consumed, plays a big role in the way in which audio will be mastered. If the audio will be consumed on vinyl, there are specific limitations to keep in mind. If music will be played on a CD, there are also specifications to adhere to. In the present social and recreational environment, a lot of music is consumed digitally, in other words via streaming sites or bought on the internet. This implies the use of MP3 or other digital format standards, each with their own specifications. In South Africa with its vast rural population music is also highly likely to be played on the radio and again one is confronted with standards and limitations. Consequently it is the task of the mastering engineer to understand the requirements of these formats or mediums and to be able to adjust the master audio accordingly. For the purposes of this investigation, the older formats such as vinyl will not be discussed and the focus will be on modern formats, mediums and techniques.

3.10.1 Audio compact discs

CDS have been the norm in the audio industry for many years and has been widely adopted throughout the world. It offers the ability to produce great sounding digital audio but in order to produce a professional commercial compact disc for public consumption, certain standards need to be adhered to. Sony Philips standardised the requirements for audio compact discs, characterised as CDs in the 1980s (Hepworth-Sawyer, 2013). The document specifying these requirements was allegedly bound in red and consequently was given the title of the Red Book Standard. The standard specifies the physical requirements for CD, or CD-DA which refers to digital audio CDs,

as opposed to data discs and other CD formats. The Red Book specifies attributes such as track, sector and block layout, coding and sampling, requires audio to be sampled at 44.1 kHz and to have a bit depth in the range of 65 536 possible values (16 bits). CDs may have up to 99 tracks at a minimum of 4 seconds long and 99 indexes per song records (Hepworth-Sawyer, 2013). There are other 'books' specifying different parameters for other CD standards, such as the yellow book for data discs, the orange book for recordable CD, while the enhanced CD version is guided by blue, green and purple 'books' respectively.

3.10.2 PQ, ISRC and UPC/EAN

When committing the audio data to the CD format where the data stream is written onto the CD, it must contain the digital audio information as well as a sub-code data stream and information to be used for redundant error correction. The sub-code stream contains eight channels labelled P, Q, R, S, T, U, V and W. On standard CDs, only the P and the Q channels are used. The P sub-code data shows where music tracks start and end according to Cousins & Hepworth-Sawyer (2013:205). The track and index number, as well as the time code of the position of each track, will also be encoded on the CD at this point according to Cumming *et al.* (1990). The Q sub-code data contains time information and will also include International Standard Recording Codes (ISRC), media catalogue numbers (EAN/UPC codes) and Copy Prohibit On/Off information. CD-TEXT³ information is contained on bits R-W, as well as information such as karaoke, graphic, and other extra information that are not originally included in red book specification. Most CD players, however, do not support this functionality. (Cousins & Hepworth-Sawyer, 2013:208).

The ISRC code is a unique code that identifies each track based on four criteria. These are the country where it originated from, the legal entity that registered it (e.g. the record label), the year of creation and lastly a unique identification code which is obtained from the registrant (Cousins & Hepworth-Sawyer, 2013:204). This code stays with a recording for its entire life, even when tracks are released as part of a compilation⁴.

A Universal Product Code (UPC) is the unique barcode number printed on the product and is regulated by the Uniform Code Council (UCC). This 12 digit number refers to the whole album, not merely

³ CD-text differs from CDDB which supplies track titles to computer players

⁴ In the case of a compilation some record companies might give a song a new ISRC code specific to the compilation album

one song as is the case with the ISRC and it is encoded with PG information. The UPC is also referred to as the UPC/EAN as the UPC and the European EAN codes are compatible even though EAN uses a 13 digit number. To address this discrepancy the UPC will be encoded with a leading zero.

3.10.3 Disc description protocol

Disc Description Protocol (DDP) is a system commonly used to deliver masters for optical media to the replication plant (Rumsey & McCormick, 2014:303; Cousins & Hepworth-Sawyer, 2013:56). DDP was developed by Doug Carson and Associates (DCA, inc.) in 1989 with the purpose of defining a standard for delivering multimedia data to optical media.

This format allows the mastering engineer complete control over the final CD to be printed, including parameters such as the length of the gaps between tracks, crossovers if applicable, PG coding and so forth. DDP includes error correction to ensure that no errors are transferred to the final CD. It uses MD5 Checksum which is a process that verifies the integrity of the file by giving a unique answer to an embedded equation in the file. A DDP 2.0 file intended for CD would have to conform to the specifications of Red Book Audio and will usually contain five items:

- Organisation files labelled:
 - DDPID
 - DDPMS
 - DDPPQ
- An audio data file
- A CD text information file

3.10.4 Streaming

A recent trend in music distribution is that of streaming services. With the ubiquity of internet access and the increasing affordability of data all over the world almost all commercial releases are now consumed online, as well as other on traditional channels (Camilleri, 2009:6). This means that the mastering engineer must cater for audio to be delivered for streaming via the internet and must treat these new digital formats differently according to (Camilleri, 2009:8). Online streaming requires much smaller files and therefore most streaming services will make use of MP3 or AAC formats. The modern mastering engineer must bear this in mind and must master

audio specifically for these channels supporting the proposition that a proper understanding of audio compression is an imperative for a mastering engineer in the present environment.

The two most popular formats for online consumption are MP3 or AAC as mentioned above. These formats are both lossy compression audio formats meaning that they achieve greatly reduced file sizes by discarding some information in the audio file. The term 'lossy' literally means that you will lose information. This has a very serious effect on the final product which should caution mastering engineers when mastering for these formats. The technology employed however is very advanced and delivers a very good result. Below is a description of these two formats.

MP3 is a form of compressing audio developed by the Moving Pictures Experts Group (MPEG) (Camilleri, 2009:13). The MP3 name is derived from the file extension which distinguishes sound files that were created by employing the MPEG-1 Layer III encoding and decoding software (Self *et al.*, 2009:621). MP3 is a lossy form of compression that relies on the psychoacoustic phenomenon called masking to reduce file size. Masking will render certain sounds inaudible in the presence of a stronger sound and MP3 leverage this to remove these inaudible sounds, thereby greatly reducing the file size (Camilleri, 2009:15). MP3 files make use of a compression ratio of approximately 12:1 giving about 12 hours of music on a CD. Even though the quality is reduced, it offers sound quality similar to that of FM radio (Self *et al.*, 2009:626). MP3 employs the Huffman encoding principle in assembling the MP3 file (Brandenburg, 1999:2).

AAC which stands for MPEG-2 Advanced Audio Coding and is a newer encoder offering several improvements over MP3. AAC not only has the ability to code surround audio but can also accept a bigger range of sample rates from 8 kHz to 96 kHz (Camilleri, 2009:22). AAC has decreased susceptibility for pre-echo artifacts because of temporal noise shaping and also provides more efficient Huffman Coding, allowing smaller file sizes (Watkinson, 2001:318).

There exists a variety of formation for digital distribution, many of which offer no loss of information such as OGG and FLAC however these formats are not as prevalent because of the file size.

3.10.5 Radio

Music played on radio is usually drastically compressed in order to conform all audio. This is done for the benefit of the listener but can have repercussions for the audio programme. Soft and gentle music might have its level increased, making it sound ‘hot’ to use a modern slang word, while extremely high-level audio might get squashed, causing an unpleasant effect (Katz, 2002). Some labels will master special CDs for the distribution to the radio stations.

Since radio signals change the sound of recordings, the mastering engineer and mixing engineer tailor the recordings to meet the sonic restrictions of the medium (Zager, 2011:129). Mastering the audio in such a way to make it “hot and punchy” might however have the opposite effect. It could be argued therefore that mastering for radio is a myth as the now “hot and punchy” audio will get compressed to conform, thereby lessening the mastering engineer’s efforts. According to Katz (2002) “almost no special preparation is required to make a recording radio ready.”

3.11 Summary

It is clear from the preceding sections that there is a large amount of knowledge required to fully understand the role of mastering. The physical act of mastering requires a clear theoretical knowledge of multiple disciplines. Without a proper understanding of the physics of sound the psychoacoustic will seem confusing and without the background of psychoacoustics an engineer will not fully grasp how audio can be manipulated effectively for human hearing.

Understanding the complexities of human hearing will lay a strong foundation for understanding loudness and again how humans perceive audio. Moving into the digital realm again changes many aspects of how we think about sound and because audio is predominantly digital today this is of paramount importance. Digital tools are used daily by the mastering engineer and again a good theoretical knowledge will do much to give the mastering engineer the advantage in using these tools to achieve great audio programme.

Once a solid foundation in the theory of audio is achieved the mastering engineer will apply this to the available tools used in mastering. There are processes and audio processing techniques available to the mastering engineer that will ensure great results. These will be discussed in the following sections. The modern trends will also be explored, which once again is firmly rooted in the theoretical

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knowledge as well as an understanding of the technological advances of the time.

Chapter 4

Mastering tools and techniques

Mastering uses many of the same tools and techniques as the rest of the audio production process. Many of the tools, although similar in concept, are specialised towards mastering needs however. The discussion of these tools and techniques will focus specifically on how it relates to mastering. It will cover the mastering studio, how it is specific to mastering, as well as the specialised equipment found in the mastering studio. It will then explore the mastering workflow focusing on the specific processes involved in mastering.

The chapter aims at providing the necessary insight into the concept of mastering in order to establish a clear understanding of the concept. Through an exploration of the tools used in mastering the study aims at attaining understanding into what mastering does differently from other audio production processes such as mixing. Understanding the workflow of the mastering engineer offers great insight into how the engineers role differs from the mix engineer and what can be expected from mastering.

4.1 The mastering studio

The mastering studio differs significantly from its counterparts in the rest of the recording world (Izhaki, 2013:53). It is often much smaller than recording studios, as it has no need for recording rooms and is usually treated so as to avoid any colouration, which might accentuate certain frequencies (Alten, 2013:32). The Mastering suite, as it is often called, has specialised equipment designed especially to meet the specific needs of the mastering process (Cousins & Hepworth-Sawyer, 2013:43). There are a few important factors involved in the design and construction of a mastering studio. These include its

acoustics, sound reflections, diffractions, and the specialised equipment needed for mastering.

Mastering suites or studios require exceptional playback systems complimented with dependable room acoustics. The playback system needs to be flat and the room consistent through the full frequency range. This most often will call for a properly calibrated subwoofer (Savage, 2011:219-220). Subwoofers are important in the mastering suite as it allows the engineer to properly evaluate the low frequencies prevalent in playback environments like nightclubs. Mixing facilities often do not have these capabilities and it becomes the responsibility of the mastering engineer to ensure the final product is suited to these playback environments.

Mastering suites will contain a few critical tools such as high-quality brickwall limiters and EQ processors (Thompson, 2005:12). Other valuable processing tools will include high quality compressors, multiband compressors and equalisers. It might also contain reverberation processors and analogue saturation simulation software, and multiple software plugins in a DAW. The use of CD burning hardware and software is an essential tool in the mastering studio and the software used for these CD burners will typically have cross-fade, CD numbering, indexing and ISRC-coding capabilities. These burners will also need to burn discs using the DAO protocol (Savage, 2011:219-220).

The following section will explore the basics of a mastering studio. It will focus firstly on the physical space, then on the hardware typically found in these suites and lastly mention will be made of the software that mastering engineers employ.

4.1.1 Room design

The first and foremost ‘tool’ used in mastering is the physical space that it is performed in and, according to (Owsinski, 2008:17) “more time, attention, and expense are initially spent on the acoustic space than on virtually any other aspect.” Katz (op cit.) states that “if you don’t start with a terrific room ...you will ...have problems” (Owsinski, 2008:17). This space has specific requirements starting with the acoustics of the room. The space will be treated acoustically and will conform to certain standards. The room will make use of acoustic treatment using both absorption and diffusion to create the perfect balance between ‘live’ and ‘dead’ acoustics and will ensure that the noise floor conforms to the correct standards. The ultimate goal is to ensure that what the mastering engineer hears in the sweet spot of the room, is totally flat and that no frequencies are being amplified or altered in any way.

Therefore the first thing to consider would be the room acoustics of the mastering space. This space needs to be trusted by the mastering engineer and must be acoustically perfect. This means that the space will not have any frequency build up, standing waves and will not reinforce any frequencies such as low frequencies (Izhaki, 2013:52). The mastering suite will have a rather short reverberation time and will deal with any possible standing waves using diffusers. In a mastering suite, as in any other studio environment, the room should be quiet. Any extraneous noise will distract from the audio being mastered and will invariably influence the quality of the outcome. Katz (2007:114) mentions a noise floor of $NC - 20^3$. Although a quiet room is preferable, he also mentions the value of having a space that emulates real life Katz (2007:114). The mastering engineer might consider also listening to audio in spaces with some ambiance, to assess the audio in a 'real life' scenario.

4.1.2 Acoustic treatment

The use of acoustic treatment will ensure the best possible sound quality in the room. To achieve this a combination of absorbers and diffusers can be used to control the sound in the space, which according to Bob Ludwig, should be fairly large, being about 9 meters long with a five meter ceiling (Owsinski, 2008:17). The use of different kinds of treatment will address acoustic quality. These treatments can include soft absorbers that are applied to the walls and are made of foam or rock wool. Soft absorbers are good for treating high and middle frequencies (Nisbett, 2003:45-46). For low frequencies bass traps and membrane absorbers can be used, which work by having a material that moves in sympathy with low frequencies, thereby dampening the sound energy (Nisbett, 2003:45-46). These methods and the materials will aim to conform the room to standards of absorption. This is measured using the concept of absorption coefficients developed by Dr. Wallace Sabine. The absorption coefficient is a way of measuring the energy lost when sound hits the material. He states that the best example of a perfect absorber would be an open window which would have a coefficient of 100%. Inversely a perfect reflector would be a perfectly reflective wall, which would have a coefficient of 0%. All other materials are measured between these two extreme coefficients (Davis & Davis, 1989:54).

4.2 Monitors

Monitoring is second only to room design. The ability to clearly hear the most exact replica of the music is of paramount importance. A thorough understanding of monitors will help the mastering engineer in choosing the correct pair and knowing if anything problematic occurs.

4.2.1 Loudspeaker design

Mitchell (2013:597) explains that monitors, also referred to as loudspeakers, consist of a transducer, radiator, enclosure and a crossover. The transducer includes a motor, diaphragm and suspension system, which will be used to convert electric energy into mechanical energy and finally into acoustic energy.

Over the years there has been considerable experimentation with these different elements. Different transducer types have been developed, but the dominant transducers in practical loudspeakers are electrodynamic transducers, electrostatic transducers and piezoelectric transducers. The electrodynamic transducer is the most common transducer. It is also referred to as the moving coil system and is attributed to the work of Kellogg and Rice in the 1920s (Davis & Patronis, 2006:307). It is the most widely used because it is easy to implement in anything from cheap transistor radio speakers to PA to top quality studio monitors. The chassis is usually made from pressed steel or from a casting, the cone can be made with almost any material but the most popular material used in transducers is paper pulp. Plastics are also often used for this purpose (Rumsey & McCormick, 2006:81). The most popular plastics used are polypropylene and bextrene (Mitchell, 2013:599).

The folded cone is the cheapest and is made from paper that is rolled and attached at the seam. The moulded paper cone is another alternative, however it is a more expensive and intricate cone to produce. In the 1950's Altec Lansing popularised Biflex cones, which introduces rings to the cone so as to attempt to decouple the outer-cone at high frequencies (White & Louie, 2005:423). The KEF company created a cone using a blend of aluminium and foam. Carbon fibre and epoxy composites was also used by Community Professional loudspeakers, often for outdoor purposes (Mitchell, 2013:599). Mitsubishi also used composite materials for subwoofers, but fabricated them from a honeycomb core and carbon fibre. Kevlar, a fabric resin bonded material, has become a highly popular material for use in midrange drivers.

The electrostatic speaker was popularised in the 1950s, although it was less common than the moving coil, which was easier and cheaper to manufacture. The moving coil was popular due to the sound levels it was capable of producing (Rumsey & McCormick, 2006:81). To produce adequate bass response requires a diaphragm with a considerable surface area. It is widely accepted, however that the sound quality of the best examples of electrostatic or panel speakers, is rarely equalled by other types of speakers (Newell & Holland, 2006:63). Piezoelectric speakers are often used in tweeters, but most popular according to Rumsey & McCormick (2006:82), are ribbon speakers especially for high frequency applications such as tweeters. They say that

A light corrugated aluminium ribbon, clamped at each end, is placed between two magnetic poles, one north, one south. The input signal is applied, via a step-down transformer, to each end of the ribbon. The alternating nature of the signal causes an alternating magnetic field around the ribbon, which behaves like a single turn of a coil in a moving-coil speaker. The magnets each side thus cause the ribbon to vibrate, producing sound waves.

Although there are many options and interesting innovations in speaker design, the moving coil speaker design still remains the most viable option for studio quality sound reproduction systems. In the course of history this speaker has been perfected and there are some considerations pertinent in the mastering context. Because of the pressure equalisation caused by air compression and rarefaction in front and behind a driver diaphragm, it needs to be mounted on a large rigid board, or baffle. A baffle would produce the best results if it were to extend infinitely in all directions but because this is not practically possible, the convention is to install the driver in a meter square sealed box suggests Self (2009:383). The sealed box design gives a figure of eight, three dimensional pattern caused by the cancellation around the sides. The drawback of the sealed box is the constraint of air within which it acts like a spring, effectively stiffening the suspension of the drive unit and raising the resonant frequency. A smaller box would have a stiffer spring, which results in a higher resonant frequency. The simplest form of cabinet is one that has absorptive material such as a plastic foam or fibre inside suggests Rumsey & McCormick (2006:84). The sealed box design can be incredibly accurate in as far as sound production is concerned if it is designed with properly matched drivers and enough damping. A good example of a sealed box monitor used for mastering is the Dunlavy sc-iv.

The alternative to the moving coil configuration is the vented system, also referred to as Bass Reflex. This system has a tunnel or a port, precisely tuned to a frequency, which will cause the air inside to resonate. This will reduce the movement of the speaker at the specified frequency and the port will produce its own low frequency in combination with the drive (Rumsey & McCormick, 2006:84). Two way vented systems are immensely popular. This kind of speaker system splits the audio into two different driver systems designed to best handle a specific frequency range, because no single driver unit can optimally reproduce the full audio frequency range. Bass and mid-range drivers will usually handle everything up to approximately 3 kHz, and high frequency driver units will typically reproduce frequencies from 3 kHz to 20 kHz (Hurtig, 1988:70). High frequency drivers, usually around 2,5 cm in diameter, are referred to as tweeters and usually make use of a sealed cabinet design according to (Watkinson, 1998:159). The crossover is the device that facilitates the splitting of the audio. Three way systems are also commonplace where the midrange frequencies are separated, for example 400 Hz to 4 kHz (Rumsey & McCormick, 2006:90). Subwoofers are often employed in order to accommodate for the low frequencies in an audio (Owsinski, 2008:18). (Savage, 2011:219-220)

4.2.2 Active vs passive

Another consideration in mastering is the choice between active *vs.* passive speakers. Active loudspeakers distribute the different frequency bands to separate amplifiers and speakers (Hurtig, 1988:70). There are some cost and complexity considerations for active speaker design, but this is outweighed by the ability to assure a lower distortion of the signal, greater system design flexibility, improved clarity and better bass. This is because there are less passive components between the amplifier and drivers and better performing amplifiers that need only handle a restricted frequency band. This is mitigated by employing small cones with smaller radiating areas (Rumsey & McCormick, 2006:90).

The directivity of the loudspeaker is the angle of coverage or directionality of the speaker and is an important factor in loudspeaker design (White & Louie, 2005:112). Low frequencies are more omnidirectional, because lower wavelengths are much larger than the speaker enclosure and the sound diffracts around the enclosure. Higher frequencies are closer in size to the enclosure and less diffraction occurs, which results in a more directional sound being produced (Rumsey & McCormick, 2006:97). Higher frequencies have an even narrower dispersion angle and this sometimes causes off-axis

phase cancellation where a short wavelength will be radiated from the closest as well as the furthest side of the speaker cone, causing output levels to fall. Directivity is desirable, particularly in the lateral plane in order to ensure that a usefully wide stereo coverage is produced (Colloms & Darlington, 1997:318).

Monitors play an important role in mastering. Good monitors will allow mastering engineers to clearly hear audio programme so that they can make accurate and creative assessments about loudness levels and the sonic quality of the audio (Savage, 2011:219-220). A monitor is the most important tool for a mastering engineer to be able to uncover as much dissonance as possible and be able to hear every possible detail of the audio (Mitchell, 2013:917). Mastering requires a monitor that has a wide and flat frequency response and a uniform response over the audible range (Colloms & Darlington, 1997:318). The ideal is a response within 6 dB of the 1 kHz level from 80 Hz to 20 kHz (Rumsey & McCormick, 2006:95). This, however, does not tell how a system will sound, it tells nothing of the ability to produce good stereo, smooth treble, tight bass or possible colouration (Rumsey & McCormick, 2006:95). Usually, a rather large monitor is required in order to reproduce wide and flat frequency range at the bottom end of the range (Owsinski, 2008:18). The loudspeaker needed for this must meet certain specifications (Mitchell, 2013:597). The elements to construct a sound reproduction system, being transducers, electronics and a proper acoustic environment, all need to complement each other (Davis & Patronis, 2006:2). Mastering engineers run the risk of overusing processing such as EQ in order to compensate for unsuitable and inappropriate monitors (Owsinski, 2008:18).

4.2.3 Monitor placement

In order to get the most from the monitors in a mastering studio, close attention needs to be paid to how they are placed in the listening environment. When working, mastering engineers are dependent upon their monitoring condition and methods, more than on anything else. If the monitors do not sound accurate in the listening environment or if the engineer interacts poorly with the monitors, then applying any other techniques will be virtually pointless (Owsinski, 1999:61). Bad monitoring can play a significant role in affecting the frequency balance and stereo image due to inaccuracies in the interaural time difference (Glasgal, 2005:1).

The location of the monitors or loudspeakers in a room are also of paramount importance as they can cause resonances that can be

as obvious and problematic as those in the system itself (Colloms & Darlington, 1997:318). The first consideration in placement is how far away speakers should be away from the each other. The general rule is that the speakers should be as far apart from each other, as the listener is from them (Owsinski, 1999:61). The angle is determined largely by taste. Some mastering engineers may choose that their monitors should be angled directly towards them, while others may prefer that the monitors should be angled about 1 to 1,5 meters behind them. This Owsinski (1999:61) states, is to “eliminate some of the hype of the speakers”. Speakers need to be decoupled from the floor and the table so as to avoid comb filter effects from a sound that travels through the floor faster because of the density of the floor. The best way to decouple a speaker, is to place it on approximately 2 cm of open cell neoprene says Owsinski (1999:62). It is also recommended that speakers should be placed with the tweeter on the outside to create a widening effect in the stereo image. In addition to placement which impacts the sound, is monitoring levels. Monitoring at conversational level yields better results, because high monitor levels invoke the Fletcher-Munson equal response curves that can result in unrealistic real-world sounds (Owsinski, 1999:63).

Monitor calibration is equally an important part of the mastering studio. The monitors need to be placed correctly in order to hit the so called sweet spot , which is where the mastering engineer will be situated. This spot should be equidistant from both monitors and the monitors should both be angled in towards this spot. The monitors also need to be at the same height as the listener’s head. All of this will ensure that the sweet spot gets the best possible projection of the sound. It will also ensure that the stereo image created by the two monitors, is perfect. The next step in monitor calibration is to ensure that the monitors play at the same volume. This is mostly a problem with active monitors that have a volume pod built in. In the case of passive monitors, this step will entail ensuring that the SPL produced is calibrated to the meters preventing the mastering engineer of making incorrect judgments in level adjustments. The ideal listening level is between 78 and 85 dBFS.

4.3 Mastering hardware

The ideal mastering studio will contain specific hardware in order for the mastering engineer to be able to properly process the audio. The following discussion will explore the hardware commonly found in a mastering studio.

4.3.1 Playback device

The first piece of hardware usually to be found in the mastering studio, is a playback device. This will be a device that is used to play the audio received by clients. In modern mastering, this more often than not takes the form of a computer with accompanying software, although in some cases this might still be a CD player, a DAT tape player or even a vinyl player. Considering the modern trend of delivering audio digitally, the most likely current playback device will be the Digital Audio Workstation. In this type of device one usually finds that many different audio software programs may be used, but they all contain similar functionalities. The most important consideration is however that they should be able to play a variety of audio formats and specifications. The mastering engineer will obtain the audio to be delivered in the sample rate and bit-depth it was mixed in, although the playback devices should be able to handle any possible sample rate and bit-depth.

4.3.2 Signal routing hardware

Even the most impressive mastering studio would be crippled by inefficiency if not for the signal routing device. Often called a “digital audio patchbay, a distribution amplifier, a router, a format converter, and a channel switcher” this device is “essentially a digital router or patchbay that allows patching one digital device to another (or many others) at the push of a button” (Owsinski, 2008:16). In recording studios patch bays are open and the engineer can freely route audio as needed. Although this is sometimes found in mastering studios as well, mostly a mastering engineer will only use a finite amount of equipment. Therefore, in most mastering studios the patching is set up permanently. Mastering studios generally employ a specialised mastering console which will act as a monitor control as well as a signal routing hub. The mastering console will include analogue and digital options to accommodate all audio processing equipment and will also include powerful A/D converters. Often these patch bays are digitally controlled, giving the engineer the ease of simply pressing a button in order to include a certain processor in the signal chain. This has the benefit of quick auditioning and A/B tests when applying different processing. Importantly the switching between different options should happen without glitches and any audible effects. A professional grade console might also include mid-side encoding and decoding, surround support, multiple monitor selections, mute, solo, dim and polarity reverse options, A/B switch with level trims and a

level meter.

4.3.3 Converters

The A/D converter is yet another key piece of hardware in the mastering studio. Audio will be converted to and from analogue and digital throughout the mastering process and therefore the converters used for doing this is of utmost importance says Thompson (2005:12). In the mastering studio, the audio might be received in either digital or analogue format although today it is almost certainly going to be digital files. These files will be played back into the mastering console using the playback device. Often a good mastering console will handle the conversion although many professional mastering studios will have dedicated converters in the signal chain. The audio might be converted many times or only once, depending on the studio, the engineer and what is necessary for the audio.

4.3.4 Processors

The mastering studio will employ a variety of devices to address different aspects of the audio. It will have stereo compressors, multi-band compressors, limiters, high-frequency limiters (de-essers) and exciters and might even have different makes of the same kind of compressor in order to have more options with different audio and genres. Similarly, it is not uncommon for a mastering studio to have a few different equalisers. Parametric and linear phase equalisers will be found alongside outboard digital equalisers and then the engineer might still employ software equalisers as well, if necessary.

4.3.5 Monitors

It was seen in the previous section that monitors are an important piece of hardware in the studio. They need to have a flat frequency response through the whole frequency spectrum. Mastering monitors also need to be able to produce a much larger frequency range than mixing monitors, in order to enable the mastering engineer to properly hear all the frequencies from the low to the high. Mastering monitors will have extremely accurate phase response and stereo imaging.

Popular mastering monitors are the Bowers and Wilkens flagship 800 series, which include the famous diamond dome tweeters as well as a three-way vented box system, which houses separate drivers that are designed specifically to produce a specific frequency range.

Other popular monitors are the Lipinski, Tyler Acoustics, ATC Loudspeaker, Duntech and Dunlavy systems, to name a few. The Lipinski Signature monitor system consists of three segments. The middle monitor can be used alone in small or prosumer setups, however professional mastering suites will employ all three segments. This will provide the engineer with eight drivers that will ensure unrestricted bass performance. Dunlavy, although out of business today, made the sc-vi monitor system that still stands as a standard in mastering studios throughout the world. These huge 'coffin-like speakers' feature a series of boxes connected by internal braces. Each set is housed in a separate sub-enclosure. The designer of these speakers, John Dunlavy patented a design for a cabinet that uses a dampening method using felt of varying thickness, to achieve virtually inaudible cabinet diffraction effects. All of these monitors are famously flat in frequency response and are able to produce an incredible range of frequencies.

4.4 Mastering software

Although mastering historically made use of only outboard devices for processing, it has evolved together with developments in technology and today employs various software tools to achieve the same results. Mastering makes use of DAWs similar to recording and mixing, but there is now software available that is specifically designed for mastering and restoration of audio Thompson (2005:12) points out. This software allows for the better fine-tuning of recordings by making use of more subtle compression, equalisation and gain capabilities. These applications also employ restoration tools for the cleaning up of recorded audio with hiss, crackle and clicks (Rumsey & McCormick, 2006:290).

4.4.1 Software plugins

DAWs generally include a large variety of basic tools that enables the mastering engineer to record, edit and manipulate audio. Present day DAWs also have the ability to use specialised software applications within the DAW environment that are referred to as plugins. Mastering makes use of software plugins optimised for mastering Savage (2011:219-220) points out.

Plugins are well suited to mastering because of the fact that in mastering processing is applied to single files of completed, mixed audio, negating the concern for the latency that is found in mixing

with many plugins. Certain plugins will use phase-aligning algorithms that produce high-quality processing but will also cause a significant delay. This does not pose the same problem in mastering suggests Savage (2011:219-220).

Certain plugin suites will include a full set of tools with which to address some of the important mastering needs, such as noise removal tools and spectral repair capacity. The spectral repair tool is extremely powerful and gives the mastering engineer the ability to isolate sounds within the audio. With this tool, it is possible to remove coughs emanating from the audience and other extraneous noises. Other plugins that are available include phase coherence meters, loudness meters, and dither tools.

4.5 The mastering process

Mastering consists of various steps ranging from basic 'administrative tasks' to very technical tasks to more creative steps to improve audio programme. All of these steps together will make up a final mastered audio product, ready to be sent out into the commercial world. Mastering is defined by Huber & Runstein (2013:563) as the

task of shaping and arranging the various cuts of an audio project into a final form that can be replicated into a saleable product.

In line with this definition it is understood to consist of various activities or processes, both technical and creative, all aimed at achieving the best sound from audio. The following discussion will deal with the known technical and creative elements involved in mastering. The technical and administrative processes of compiling and mastering an album will be discussed first and thereafter the creative processes and techniques will be explored.

4.5.1 The Basics

Undoubtedly the first step that the mastering engineer will have to take is to spend time auditioning the audio. This is a critically important step and will require an exceptionally good and trustworthy monitoring system and physical facility, as discussed above. When auditioning the audio, the engineer will have to make judgements regarding certain matters related to and emanating from the audio and then to begin the mastering process. This is usually not an exceptionally long process in terms of time and often mastering engineers will

spend no more than an hour on one song. The length of time taken for this process will of course depend on the skill of the mastering engineer, but is also determined by the need to ensure the hearing of the engineer does not become too used to the audio, which could conceivably contaminate the judgements that are made. The listening process will be examined in more depth later in this discussion

4.5.2 Heads, Tails and Other Administrative Tasks

After the initial evaluation, the next step is to make sure that the silence before the start of each song and the silence at the end are tidied up. This might seem like an unnecessary and less than onerous task, but it can have a significant effect on the music. Very often audio will have some room-tone noise or background ambience which might not be noticeable during playback, but might become obvious and bothersome with a long fade in. A too short fade-in on the other hand might seem to be abrupt where the audio consists of very soft and delicate music. The mastering engineer must consider these and other related matters and must also be sensitive to the audio programme material indicates Katz (2007:94).

Digital audio offers tools that could address the problem of unwanted noises from the musicians such as the various shaped curves in most DAW fade tool arsenals. Here again, the mastering engineer must employ sensitivity and an understanding of the material to decide on the correct shape and length to use to suite the audio.

Fading a piece of music out can be a delicate process as a very short fade out on certain types of music will cut off the reverberation, which in turn will seem to be too abrupt and unnatural. Again room-tone noise or hiss artifacts will become very noticeable if too long a fade out is used. A common practice is to fade slowly at the start of the fade-out and then to speed up towards the end, imitating the natural hand movement of a person controlling a physical fader suggests Katz (2007:95). The mastering engineer might even create an artificial tail using added reverberations in some instances.

The mastering engineer will, after 'cleaning up' the beginning and end of the song, instruct the software where each song must begin and end, where and how long the gaps between songs should be and what the name of each song is (Cousins & Hepworth-Sawyer, 2013:196). This step is especially important when the audio is to be delivered on CD. Mastering engineers employ subtle precision often making use of the tempo and time signature of a track to determine when the next track should start. This very subtle detail will go unnoticed to the average listener, however this is what makes a mastered product seem to be polished.

At this point the mastering engineer will ensure acceptable phase alignment by playing audio back in mono at the beginning of the session. The stereo image will drift between the speakers if there are any problems with the phase, which will clearly indicate a matter that has to be attended to by the mastering engineer according to Hodgson (2010:203).

4.5.3 Assemble song order

Once each song has been checked and tidied up, the mastering engineer will decide on the order of the individual songs that are to be included on an album (Owsinski, 2008:5-6). Here the focus will be on the flow of the songs and what Katz (2007:88) describes as the "...gestalt..." of the album, which refers to its "sound, its feel and its ups and downs." If songs with similar emotional feel are played directly one after the other, it might bore the listener or result in a perception of fatigue. Katz (2007:89) explains that an album can be seen as being similar to a concert, in that it has sets or collections of songs that enforce a mood or feeling. He recommends that the ideal would be to start an album on a high note with a high energy song, work towards a crescendo and end the album with a more relaxed or subdued feel.

After the song order has been decided the gaps between songs will be finalised. This affects the feel or emotional journey of the album. These gaps allow a certain reset of the listener's mood and as such needs to be treated with care. Spacing can also be seen as punctuation in the flow of an album. Using this analogy, the space could clearly end a musical statement and mark the start of a new musical communication. Although there are no concrete rules in deciding the length of the gaps, the material will guide it where faster songs might have shorter gaps between them than slower songs. The key for the mastering engineer is not to be guided by their own emotions when making these choices.

4.5.4 Level matching

Once the songs have been tidied up and arranged, the mastering engineer will check that all the levels between songs match and that there are no sudden boosts (Zager, 2011:128) (Owsinski, 2008:5-6). Dynamic processing goes hand in hand with level matching so that the mastering engineer must verify if any dynamics processing is necessary. After processing is applied, the mastering engineer will leave the monitors at the chosen gain and adjust the rest of the songs accordingly (Katz, 2007:95).

4.5.5 Dynamic range control

Dynamic range control refers to controlling the final output level as well as adjusting the range of the dynamics. Mastering engineers will affect both these elements, based on what is necessary for the material. The mastering engineer will use different tools to achieve different effects and will often use a combination of tools to assure the quality of the final product.

4.5.6 Gain staging

The mastering studio will contain numerous different devices aimed at addressing certain aspects of the audio. Each of these devices in the chain, will add gain to the audio and this gain staging is important as it could possibly add noise to the audio. The mastering engineer will use the gain circuitry of the mastering console or desks, as well as the high-end tools used in mastering, to subtly increase the gain of the audio¹. Different circuitry will sound different and will affect the audio differently and therefore care must be taken when introducing any new tool into the signal chain.

4.5.7 Dynamic range tools

The mastering engineer will always rely on tools like compressors, limiters and exciters to affect the dynamic range of the audio. The mastering engineer must attempt to increase the audio level with limiters and compressors and might sometimes also use exciters to increase the dynamic range. The mastering engineer will use a variety of tools to increase the level of softer passages and/or lower the loud passages, sometimes even adjusting the gain in what can be called “manual compression”, according to Katz (2007:114). The mastering engineer will assess the audio and where necessary reduce the dynamic range or compress in order to get a more excited sound that is fuller or more coherent. This usually helps to lift out some of the softer details of the audio says Katz (2007:114).

4.5.8 Tonal balance control

The task of equalising in mastering is different from the highly creative steps in mixing a song. The focus in equalising is on the tonal balance more than on creating interesting effects and making certain

¹ This is explained concisely by Warren Sokol of Universal Studios at <https://www.youtube.com/watch?v=lo00D1bu56o>

instruments prominent. The mastering engineer must aim at verifying and ensuring accurate tonal balance. The term 'tonal balance' used here is ambiguous and needs some clarifying. The assumption would be that tonal balance means all frequencies enjoy equal attention, but as was mentioned earlier, the work done by Fletcher and Munchen proved that human hearing is logarithmic, and therefore different frequencies need different treatment. It is also known that individual taste becomes relevant in deciding what can be seen as quality audio and what one person finds aesthetically pleasing often seems at odds with what the technical meters show or what another person may find to be pleasant. High frequencies may appear as being harsh and unenjoyable and often high frequencies are rolled off in both orchestral and pop music is the view of Katz (2002). Mid-frequencies also need special care as they can easily become overbearing and make audio sound flat. Katz (2002) explains that mid-frequencies are incredibly important for rock music and reducing them too much can easily make rock music sound empty. Similarly, bass-frequencies often need attention as they can have too little or too much power, which will affect the perceived quality of the music. It is generally accepted that different genres of music require different treatment and therefore it is important for the mastering engineer to be well versed in all kinds of music.

4.5.9 EQ techniques

One hugely important aspect of equalisation is that everything affects everything else. Contrasting ranges will interact with each other so that boosting something in the lower frequencies will affect the mid and higher frequencies. This means that care should be taken and usually in mastering, other than in mixing, very small increments of changes will be made from as little as 0.5 dB at a time. Different genres will require different approaches and so the mastering engineer must have a great knowledge of all music in order to effectively adjust it.

4.5.10 Advanced techniques

The mastering engineer, for the most part, will use similar tools as the mixing engineer but often he will use these tools slightly differently or in complement with multiple other tools to reach the desired effect. Tools such as artificial reverberation for instance, which is widely used in mixing, might be subtly applied in mastering (Gallagher, 2008:212).

4.5.11 Multi-band compression

One advanced tool that is popular in mastering is the multi-band compressor. This tool is used in order to affect the tonal balance similar to equalisation, however it allows a much more refined way to address tonal balance issues. Unlike simple EQ the multi-band compressor will only affect the audio based on certain parameters and so allows great control and delicacy.

4.5.12 Mid-side processing in mastering

Mid-side (ms) processing is another tool used in recording that is cleverly employed by mastering engineers. ms is a recording placement technique where a cardioid microphone is used as the front facing microphone and a microphone with a figure of eight polar pattern is placed at a 90-degree angle. The two signals are then combined to produce a stereo signal by adding the middle microphone signal with the side signal for the left side of the stereo and for the right side the side signal is subtracted from the middle signal by reversing the polarity (Izhaki, 2013:192). Using ms processing the mastering engineer can separate the side and centre content and manipulate these separately and then increase the mid-level, decode it back to left and right and in so doing increase the vocal which is usually in the centre. This technique can be applied for many different creative effects from reverberation, increased loudness and clarity, and more advanced EQ (Shelvock, 2012:43).

4.5.13 Noise reduction

The mastering engineer will proof the audio to ensure there are no clicks, pops and other forms of distortion (Owsinski, 2008:6). Software programs can eliminate some forms of distortion and extraneous noise (Zager, 2011:128). There exists many techniques for reducing noise. One such technique, referred to as surgical equalisation manipulation, is the practice of carefully increasing or decreasing very narrow frequency bands, to help remove or attenuate unwanted noise (Hodgson, 2010:210).

4.6 Modern mastering trends

Throughout the history of mastering there has been a tendency towards evolution and adaptation. With every evolutionary step the role acquires new abilities and in turn expectations. The study has

found two recent trends that are significant. Both of the trends allude to a change in the role of mastering.

4.6.1 Mastering consultant and stem mastering

Mastering engineers today are seen more and more as part of the production team as opposed to only the last step. More interaction between mastering and the other production steps have become increasingly popular and often the mastering engineer will be consulted on a mix much earlier in the process according to Katz (2007:109). He suggests that a mastering engineer must be an expert in mixing and he advises mix engineers to “form an alliance with a mastering engineer, which can review the first mix and alert to potential problems”. This emerging paradigm has resulted in the practice of giving the mastering engineer a more active part in the mixing process to influence the final audio more effectively. It is clear from interviews with modern mastering engineers such as Mandy Parnell (Betts, 2016) that they have a new, more involved role. In this online interview Mandy explains that she is a “sounding board for the producer and artist”. Similarly the mastering engineer Evren Göknar who won an Grammy Award for his work in the audio environment states that involvement in the production process can “can streamline the expectations for the album, and alleviate stabbing in the dark for a sound” (Baby, 2012)

The second popular trend in mastering today is that of stem mastering. Also called separation mastering, the paradigm of stem mastering is rapidly gaining popularity in modern mastering according to Izhaki (2013:53). Stem mastering has its origins in the time when recalling a session was much more difficult than it is today (Cousins & Hepworth-Sawyer, 2013:194). When using this approach the mix engineer will provide the mastering engineer with stems, characterised also as sub-mix parts of the final mix, as opposed to the final stereo mix. These stems might have certain instruments such as percussion or strings grouped together. These stems or sub-mixes can then be recombined afterwards to create a final mix (Savage, 2011:218).

4.6.2 Automated Online Mastering

A novel and increasingly popular evolution in mastering is to have the audio automatically mastered online via a website. This trend has been made possible by a much faster and more reliable internet transmission capability. These online mastering services use a complex algorithm to analyse and then to process audio. In most cases, this is focused more on loudness than on the delicate matter of tonal

balance that ensures professional mastering, but for many types of music, this could conceivably be sufficient.

One major issue with a service such as this is that the same algorithm will of necessity have to be applied to all genres of music and this could be problematic as the algorithm may not be suitable for all genres of music. This means that this type of service cannot be sensitive to all music styles and will not give a similar character to all types of music. More importantly, an algorithm cannot be sensitive to the natural ebb and flow of musical dynamics and lacks musical understanding. The algorithm will usually attempt to normalise the audio and achieve a competitive loudness. The service also cannot guarantee compliance with modern standards such as Mastered for iTunes or R128 under all circumstances and it cannot perform delicate detection of inter-sample peaks and distortions that are difficult to detect.

4.6.3 Home mastering

Due to the availability of affordable digital tools many artists today will choose to do much of their audio recording and mixing at home. The multitude of tools available to the public that can produce professional grade results have stimulated a similar approach in mastering. Many audio professionals working from smaller home based studios currently opt to master their own audio using a complete 'in-the-box' approach using software and plugins in a DAW. This trend is on the increase but whether it will replace mastering any time in the near future is debatable. One positive outcome of this phenomenon is that audio professionals are beginning to understand more and more about mastering which in turn will substantially influence the decisions they make with regard to the rest of the audio production process. Even if it does not mean the demise of 'professional' mastering as such, it will undoubtedly improve audio in the industry.

4.6.4 Modern Delivery Formats

The most prevalent modern standard for audio consumption is digital distribution. Online consumption is the norm in the modern environment and it is safe to say that digitalisation has already disrupted the industry. Digital consumption, be it MP3 downloads or streaming, has enabled the music production to change as well. Even though there is not a technical transfer process onto a physical medium, the mastering engineer's job is focused around optimising audio for the different available standards and of course the creative elements and tonal balance. Already a substantial democratisation of the industry

is taking place because of technology. It is amazingly easy to share audio with the world using the internet. It is equally easy to obtain software that will enable anyone to add *pg* coding to audio. In fact, even the word *pg* coding has come into disuse, because the physical limitations of the *cd* is no longer a factor to be taken into consideration in mastering audio. There is also a newly proposed sound recording metadata standard called Recording Information Notification (RIN) by the Digital Data Exchange consortium (DDEX). This new standard will attach an XML-file to an audio that is able to describe all aspects of a recording including the participants, players, instruments, equipment used, time, location, length and other technical or creative elements. This standard is designed to become part of the *DAW* which will enable anyone to 'code' this information onto a consumable file.

4.6.5 Hardware Trends

The use of high quality audio processing hardware has always been and still is a fundamental part of mastering. Only the best analogue to digital converters are used and mastering is famous for using extremely expensive compressors, limiters and equalisers. A good example of this is the famous Manley Laboratories Massive Passive Equaliser unit which at the time of writing this study cost around R80 000. Even though most audio production equipment is indeed expensive this cost far exceeds what most studios would pay for something that can be done with a software plugin.

The use of software plugins to replace hardware tools are very prevalent throughout the audio industry and many software tools can achieve wonderful results similar to that of their hardware counterparts. That aside, the advantages of hardware and analogue is still very evident in mastering. Some characteristics of analogue equipment is hard to emulate. In mastering the use of high-end converters, compressor and limiters, as well as specialised equalisers, is still popular and is even considered to be a prerequisite for 'professional' mastering by some professionals.

4.6.6 Headphones *vs.* Monitors

It is clear that technology is constantly evolving, changing and improving and this is equally true of the headphone technology. Manufacturers are today producing extremely accurate, high-end headphones that rival expensive monitors. Some popular models such as the Sennheiser HD-600 has a frequency range of 12 Hz–39 000 Hz. The use of headphones also gives a very direct sound without being

impacted by any room colouration, which is very advantageous for inspecting audio. Headphones can be tremendously effective in revealing flaws or problems in audio, which is a boon for mastering. Using headphones obviates the need for an expensive acoustically treated room, allowing the mastering engineer to be able to lower their costs.

The use of headphones will, however, undoubtedly cause a loss of spatial awareness, which is important in mastering. Even though headphones offer the capability of revealing flaws and problems, it is important to acquire a sense of the head-related transfer function and the sound of audio in a room. Headphones will also complicate the judgment of loudness and it is a generally held perception that the use of headphones alone is not sufficient to assure audio quality and cannot therefore be sustainable for professional mastering. Conversely using good quality headphones in conjunction with an acoustically well treated room and high quality monitors will substantially enhance the mastering engineer's arsenal of capabilities and would most likely promote the quality of the audio that is produced.

4.7 Summary

Providing a clear and current definition of mastering has been a challenge since the onset of this study. This chapter has explained much about what the mastering engineer does and what he uses to achieve the best results. It has explained that mastering requires a good balanced room with very revealing flat frequency response monitors. Mastering requires high quality hardware to convert, process and balance audio programme. It often employs specific hardware and software tools to delicately influence audio such as multiband compressors, mid-side processors and noise reduction tools. Modern technology has introduced new trends in mastering such as online mastering services which have the potential to greatly influence the audio production landscape. Therefore the mastering engineer must be knowledgeable with regard to diverse aspects such as the mastering process dynamics, the capability of the available equipment, *au fait* with the emerging technology developments, psychoacoustics and many other fields, but also be very adaptable and flexible in the application of this knowledge and the requisite skills that makes mastering an art. Finally it is also very clear that the mastering engineer must be an adaptable and flexible person who can accommodate the constant advancement of technology, technique and approach and how these impact on audio production.

This chapter set out to explore the specific tools and processes in mastering. The aim of the chapter was to gain insight into the concept of mastering by exploring the tools used. Getting a clear understanding of the processes that make up mastering offers even greater insight into understanding the concept. The insights gained in this chapter, as well as the previous two chapters has aided in creating a clear current definition of mastering.

The following chapters will contextualise the synthesised view of mastering from the preceding chapters. It will show the relevance to the study and position the synthesised definition against the research question and the insights gained from the surveyed audio professionals.

Chapter 5

Research design and methodology

5.1 Introduction

Scientific investigation is often borne of a mundane idea. A simple question gives rise to a full scale enquiry aimed at answering a simple question. In order to ensure maximum accuracy and efficiency of the process of enquiry a research strategy is designed to guide the study. This design is described by De Vos *et al.* (2002:77) as

a blueprint or detailed plan of how a research study is to be conducted, operationalising variables so they can be measured, selecting a sample of interest to study, ...[and].... collecting data to be used as a basis for testing hypothesis and analysing the results.

This description of what research design entails is supported by Hague (1996:46) who expands on the above definition by distinguishing between a quantitative or a qualitative research approach. Supported by *inter alia* Becker (1998) and Neuman (2000) he states that quantitative research is generally concerned with the 'what', 'where' and 'when' of human behaviour. They suggest that it assumes the meaning and relates primarily to the measure and description of the properties, as well as the relationship between phenomena. They are supported by Bryman & Cramer (1994). According to Neuman (2000) quantitative research is appropriate for:

1. Descriptions of phenomena or the characteristics of the subject being studied
2. Estimates of the proportion of the population that displays these characteristics

3. Unearthing associations and relationships among the variables being studied
4. Discovering causal relationships among variables

This investigation aims to explore the content, dynamics and relative value of the construct of mastering. The above mentioned definition of a quantitative research approach suggested that a descriptive, quantitative survey research design would be the most appropriate approach to this investigation.

Equally an explorative survey methodology was decided on as this was deemed to be the most appropriate approach and a generic empirical research design format, as outlined by De Vos *et al.* (2002:127) to conduct what was considered to be conventional empirical quantitative research, following the following procedural steps:

1. Identifying the research population
2. Developing a data collection tool such as a questionnaire
3. Selecting a sample, usually randomly selected
4. Collecting the data
5. Analysing and interpreting the data that is collected

It was also decided that the investigation would rely on a traditional survey methodology as described by Punch (2003:3) which would consist of a problem specific questionnaire constructed by the researcher based on the various literature available with regard to mastering. It was further decided that the collected data would be statistically analysed through standardised analytical methodologies using the Statistical Package for the Social Sciences (SPSS) to identify the probable components of the construct of mastering, the perceptions of South African audio professionals of the construct of mastering and their understanding of the value of mastering for the production of a high quality audio product.

5.2 Research problem

5.2.1 Motivation for the research

This study was inspired by an intent interest in the topic of mastering. It let the researcher to engaging in fervent exploration both in academic texts as well as conversations and casual internet searches. A theme of uncertainty soon became prevalent. Asking the direct question '*What is mastering?*' often returned either a total glorification or disdain. Further probing uncovered common misconceptions of mastering. Predominant among the misconceptions is the belief

that mastering only makes audio louder and that a simple computer algorithm can achieve the same results.

Chief among the common misconceptions is the question of loudness. The most prevalent unenlightened belief is that mastering serves only to increase the loudness of the audio up to the highest level. Second on the list is the belief that mastering does not need to make use of any specialised equipment. The claim states that with the increase in high-end software emulators and improved audio technology in general that already many software plugins and applications can achieve the same result as their hardware counterpart. Furthermore the unnerving belief that automated software applications can achieve the same results as a trained person with specialised tools and knowledge is growing in popularity¹. Websites that offer ‘instant mastering’ are increasing in popularity as they offer to add ‘that special something’ for a very affordable price.

South African musicians seem almost more at ease with a notion like online mastering services than investing their time and money in a local mastering engineer. When funds are readily available musicians often remarked that they are sending the work ‘overseas’. This implies an undervaluation of the local mastering ability. Misconception such as these have the potential to greatly influence the South African music industry.

5.2.2 Research question

These observations informed the research which aims to determine the level of knowledge and understanding audio practitioners in South Africa have of mastering, the practical implication and the value that it contributes to professional audio programme. It led to the following research question that underlies this investigation:

Do audio recording practitioners in South Africa possess adequate theoretical or technical knowledge of the concept and the processes involved in mastering?

¹ Reference to these misconceptions are readily available in online forums. One example on the gearslutz website <https://www.gearslutz.com/board/electronic-music-instruments-electronic-music-production/1143339-whats-point-mastering-track.html> shows a user boasting in his post that “There is no strict separation between mixing and mastering” indicative of misinformation about mastering

5.3 Sampling

Being able to define and describe a theoretical research population remains one of the most critically important problems that need to be addressed in scientific research. A succinct theoretical definition of a research population is that it is the composite of all the sources from which data or information can conceivably be elicited that could facilitate the proper understanding of the research problem. These sources are traditionally categorised as either primary or secondary sources of research data, where secondary sources are those that already exist and primary sources are those from which the research data needs to be extracted indirectly by means of some mechanical or instrumental device such as a questionnaire. In most social research investigations these primary sources of research data are comprised of individual persons who are perceived to be in possession of the requisite data. The requisite research data for a scientific investigation does not necessarily have to be factual data, but can of course be comprised of attitude, perceptions or opinions. For the purpose of this investigation it is understood that most of the individuals who are engaged in audio recording in one way or another and are impacted, either directly and indirectly, by the need to refine an audio product, can be construed as being primary sources. Given the relatively limited size of the recording industry in South Africa most, if not all, of those engaged in professional audio recording and production would have a sound idea of who the sources or persons are who can be understood to be adequate sources of research data. They can thus be included in the definition and description of the research population.

There is no specific data base of persons engaged in mastering. The directory of audio business organisations and independent service providers were used as a source from which to broadly identify the quantum of the research population. Equally various national audio production facilities as well as audio technology educational institutions in South Africa were contacted to obtain contact information of persons who could possibly be included in the research population. Practising recording musicians with knowledge and experience of audio recording were also identified from various sources and included in the research population.

It is an important understanding of the nature of research that in the majority of public investigations, it is not practically possible to include each and every source of research data in a defined research population. This might be due to reasons of *inter alia* time, cost, access and even geographic distance. It is not possible to ex-

tract the requisite research data from all sources. Consequently the only practical means of assessing the research problem in such as public investigation, is to identify and select a sample of sources that is representative of the research population in term of size, structure and whatever other characteristic that is relevant to the research problem. The data elicited from such a research sample can be extrapolated to the research population with impunity as being fully representative of the research population. As such proper sampling as well as the selection of an appropriate, relevant and defensible sampling approach and methodology, is of critical importance in scientific investigations.

The selection of recording professionals for inclusion in the research sample for this investigation was determined by the availability of contact details of the various persons directly involved in audio production, as well as any persons indirectly impacted by mastering. The latter was understood to include recording as well as non-performing musicians such as orchestrators, arrangers and composers. The size and structure of the research sample was determined by the available data base of recording professionals and other involved in recording, rather than the size and structure of the research population. This allowed for a positivist, convenience sampling approach and methodology. Consequently the representativity of the research sample could not be determined numerically using the size and structure of the research population, which suggested the alternative approach that entailed a statistical model determination of representativity.

This positivist, convenience approach to the determination of a research sample was therefore random and the structure and size of the sample unstructured, as suggested by Kitchenham & Pfleeger (2002). Therefore the investigation of necessity relied on a random, unstructured and non-probabilistic sample. Because of the unknown quantum and nature of the research universum and the random, unstructured nature of the research sample, the representivity of the research sample could be put to question. In order to address this problem, the study subjected the data to a simple test of sample adequacy by means of the application of the Kaiser-Meyer-Olkin test of sample adequacy, suggested by *inter alia* Dziuban & Shirkey (1974). Unfortunately, the dataset was deemed to be too small for either multivariate regression analysis methodologies such as Principle Component or Factor Analysis and therefore basic descriptive statistics were relied on to analyse the data.

5.4 Data collection

Data collection is by definition the approach to and methodology used for the collection of the raw data. The data that is collected is envisaged to be needed for statistical analysis and thereafter the assessing and evaluation of the defensibility of the research problem statement.

5.4.1 Research instrument

The raw data required for this investigation was collected by means of an online, unstructured questionnaire that was developed from the available literature and previous research findings relating to mastering as proposed by Kitchenham & Pfleeger (2002). The questionnaire was constructed to elicit the perceptions, opinions and knowledge of the respondents with regard to the various factors or aspects related to mastering as a functionality in recording audio, that were identified from the literature.

5.4.2 Structure

The questionnaire was divided into four sections. The first section of the questionnaire aimed at collecting biographical information. The second section aimed at eliciting the respondent's perceptions, opinions and knowledge of mastering. The third section included a number of questions aimed at eliciting the respondent's opinion of the value of mastering as well as whether mastering could or would improve recorded audio or detract from its potential value. The fourth section of the questionnaire contained a single, open ended question where respondents were enabled to provide further data or information that they considered relevant to the investigation or that they desired to share with the researcher. This final question was optional and the majority of the respondents chose not to respond to it.

In addition to providing biographical details relevant to the investigation, the respondents were also required to respond to a series of questions relating to the level and extent of their knowledge, experience, skill and general expertise with regard to mastering. The third component of the questionnaire included questions relating to technical matters such as the specific tools or equipment required for proper mastering as well as to the processes perceived to be imperative for mastering. This section also contained questions relating to the hardware used in mastering and comparing this to equipment used elsewhere in audio production. These questions determined a theoretical as well as a more practical and technical understanding of

mastering. This group of questions also included an 'I don't know' response option, based on the premise that this would obviate guessing on the part of the respondents, which could conceivably have caused the data to be skewed and the response pattern to reflect a bias.

5.5 Validity and reliability

It is unequivocal from the literature relating to research methodology that the validity and reliability of the raw data that is collected by means of the research instrument are key considerations. The simple rationale for this supposition is that if the raw data is not valid and reliable, then the analysis of that data and inferences extracted from it will be invalid and unreliable. Conclusions drawn will be invalid and unreliable to the extent that it is scientifically indefensible and actually useless.

To be able to procure valid and reliable raw data, the research instrument by means of which this data is elicited from the sample of respondents, must also be valid and reliable. In practical terms this means that if the research instrument was designed to collect data relating to the opinions of the respondents about a specific subject or research topic the data that is elicited must be exactly and precisely those opinions and nothing more or less. It is to this end that the literature indicates that questions in a research questionnaire must be direct, clear, concise and must at all costs avoid confusion with regard to the intent of the question. Theoreticians discussing research questionnaires often warn against what is referred to as 'questions within questions'.

5.5.1 Correlation index

The measure of the validity of a research instrument in the form of a questionnaire, will usually contain two components, the content and concept validity. Whereas these two components can be seen to be two sides of the same coin, they are usually measured by means of a single mechanism, a so called correlation matrix. Such a correlation matrix contains cross tabulations of the response values elicited from the respondents for the various questions. The simple mathematical formula suggests that if the response values for a specific question is cross tabulated with the same response values, it will render a perfect correlation of 1.0 or more simply stated a 100 percent correlation. The same mathematical equation suggests that it is highly improbable that such a perfect correlation would be found between the response value for different questions, and for this reason the

theoretical threshold for an acceptable value of positive correlation has been statistically determined to be 0.80. Correlation indices between 0.075 and 0.80 are generally understood to indicate marginal correlation values and it is left to the discretion of the researcher to interpret such a finding. Correlations below 0.75 are usually held to indicate that the questions are uncorrelated or in practical terms in the contest of validity, that they will not actually elicit the same data from the respondent. A correlation index of 0.80 is understood therefore to be a confirmation of both content and construct validity.

5.5.2 Reliability test

Reliability on the other hand is understood to mean that if a test or some other measuring instrument is applied to a sample of respondents and is then applied again to the same sample after some time, the exact same results will be obtained, i.e. the variables that are measured will provide the exact same result. Because of this definition of reliability the generic measure of reliability is characterised as the test-retest method of measuring reliability. Some theorists also include the words 'the same or similar' with regard to both the measuring instrument or the respondent sample. The inclusion of these words in the definition are rejected by academic researchers on the understanding that even if the test, research instrument or the sample is highly similar, it suggests that there are some variance that could and probably will impact the results in some way.

In most empirical research investigations the test-retest methodology for evaluating reliability will be somewhat suspect, for a whole variety of practical reasons especially in public survey types of investigations where the probability of being able to convince the same sample of respondents to complete the same questionnaire twice in a row, is highly probably. This constraint is exacerbated in private surveys and also with small samples caused by the unpreparedness of potential candidates to participate in the investigation. For this reason the general approach has for a long time been to rely rather on statistical reliability measures such as *inter alia* the Cronbach's Alpha measure of reliability, which is the approach used in this investigation.

5.6 Data collection process

The contact details of potential respondents were identified from the available sources including the directory referred to before. Contact details mostly consisted of e-mail addresses. Contact was then made

by a polite formal e-mail letter to all the potential respondents introducing them to the envisaged investigation, explaining the objectives of and motivation for the investigation and requesting them to participate in the investigation (See Appendix A). The e-mail letter explained that they had been identified as audio professionals who might be willing to participate in an academic research project as the basis for a postgraduate study. They were assured that their participation would be totally voluntarily, they were assured of the anonymity of their participation and the protection of their privacy in the sense of the data being used solely for the academic purpose stated in the letter. They were assured that their responses would not be communicated to their employers where this was applicable or to any other person or organisation without their explicit, prior, written consent. The email letter contained an internet link to a secure online survey questionnaire accessible only to the researcher. By following the link the respondents were directed to the questionnaire which they were requested to complete and submit online. Respondents were only allowed to complete the survey questionnaire once to avoid possible contamination of the data elicited by their first completion after re-consideration or discussion with other possible respondents.

5.7 Data analysis

After receipt of all the completed questionnaires, the data in the form of the individual responses to the questionnaire was collated and recorded on a data base in the form of a data matrix. Because only a very small number of 36 properly completed and therefore valid questionnaires were received, the limited data base of raw data obviated the use of more complex and valuable inferential analytical methodologies such as Principal Component or Factor analysis to extract meaning and draw conclusions from the raw data. This shortcoming forced the researcher to rely on simple descriptive analytical methodologies such as frequency or distribution tables. They would allow the calculation of the so called measures of central tendency such as the means, medians, modes and standard deviations, that facilitate the extraction of meaning from the raw data in the form of patterns of trends. These frequency tables also allow the comparison of the distributions against the theoretical normal distribution curve. Whereas the distribution of the responses were shown not to be normal, it confirmed a deviation or variance from the theoretically normal distribution. This allowed the presumption of the problem statement that recording professionals do not have an adequate understanding of the content or value of mastering as a component of

recording, was supported.

The representativity of the sample of respondents, from whom raw data was elicited, could not be verified by comparison with the numerical structure and size of the research population. The Kaizer-Meye-Olkin measure of sampling adequacy was used to evaluate the adequacy of the small sample of responses that were obtained. The small sample of respondents data sets also suggested the use of non-parametric inferential statistics to test for reliability and the existence, strength and direction of association between the variables. Consequential to this assumption use was made of the Cronbach's Alpha index of reliability and the Chi-squared measure of association, to test for evidence of dependence or association. It also tested the strength and direction of the association and whether the association is strongly or weakly positive or negative and *visé versa*. The reliability of the data collected in this investigation and therefore of the conclusions that could be drawn from it, are put to question by the findings of the Cronbach's Alpha index that showed a measure marginally below the acceptable threshold of 0.80 and the Chi-square measure that indicated that an explicit association could be seen to exist.

Although the findings of the inferential statistical analysis of the raw data must be put to question and do not appear to allow scientifically defensible conclusions to be drawn, the data and the descriptive statistics calculated from this data did in fact reveal, *prima facie*, a great deal of information and did in fact allow the supportable conclusion that the research question is valid. As such the data also allowed certain inferences to be drawn on a face value scrutiny of the distribution of the responses and the measures of central tendency. It appeared that a very small number of the questions from the questionnaire² were found on reconsideration of the findings to be quite ambiguous and resulted in similar answers being given as to the previous questions. Consequently the responses to these questions were not included in the final data base, as this information was found to be a duplication and were therefore considered to be redundant.

5.8 Ethical considerations

This study considers the privacy of the participants as of utmost importance. The confidentiality of participant information was ensured at all times. All contact information was kept strictly confidential.

² A total of four questions suffered from ambiguous and possibly misleading phrasing.

The study also gave participants the choice whether they want to reveal their identities and no participant information was shared or was made visible to any other participants. All information gathered in the study is stored safely on a private server accessible only by the researcher. The few participants who elected to include their names will not be mentioned in any correspondence and will remain private at all times. The survey was opened for participation only for a pre-determined window of time and has since been removed from public access which further reduced the chance of any information becoming visible.

5.9 Summary

The research design and methodology stands as a blueprint and guide for the study and as such this study was based entirely on the descriptive, quantitative survey research design. The survey followed an explorative format to identify the research population and thereafter collect the relevant data in order to empirically address the research question.

The analysis of the data, after being subjected to validity and reliability measures, was based on various instruments within the humanities research paradigm and although the data sample prevented certain measurement instruments the study was able to extrapolate with relative certainty answers to the research questions and thereby meet the research objectives.

Chapter 6

Findings

6.1 Introduction

It is common cause that the rationale for statistical and other analysis of the raw data that was collected by means of a questionnaire, is to extract meaning from that raw data. This is generally characterised as the primary analysis of the data and is *de facto* the fundamental basis of the research investigation aimed at the assessment of the problem statement or the hypothesis in empirical research. There are however various ancillary statistical methodologies that are traditionally employed to either extract meaning from the raw data and to confirm the veracity of that data or not. These additional ancillary methodologies address matters such as the reliability and validity of the data. It addresses the scientific defensibility of the conclusions that can be drawn from the data and the statistical adequacy of the sample so that representativity of the data and the conclusions can be presumed with impunity. It allows inferential deductions to be made about aspects such as the inter-dependence of and association between variables, as well as the direction and intensity of such an association, if it is indeed found to exist.

The statistical analysis embarked on in this investigation aimed at addressing the research questions and pursuing the research objectives related to the understanding, knowledge and perceptions of South African audio professionals with regard to mastering as a component of audio recording. The following sections will assess the data retrieved from the survey and scrutinise its validity and representativity. The research question focuses around four key questions: The audio practitioner, theoretical knowledge, technical knowledge and the processes involved in mastering. The first section will address the data set to determine if the respondents are indeed audio professionals. The theoretical and technical knowledge sections will ex-

tract from the survey the relevant findings to address the prevalence of knowledge. Finally the questions in the survey that reflect the understanding of the processes that make up mastering are reviewed.

6.2 Analysis of data

Before the findings can be explored it is necessary to determine the usability of the data and determine the statistical tools to be used to extract meaning from the data set. The raw data that was obtained from the responses to the questionnaire were imported into an SPSS data base. The data was then coded to translate it into quantitative format in order to facilitate statistical analysis using standardised statistical methodologies. The first consideration was whether either a regression analytical methodology such as Principal Component or Factor Analysis could be applied to the data. Both the physical scrutiny of the sample size and structure and the finding of Kaiser-Meyer-Olkin measure of 0.702 indicate that this methodology would not be suitable. The application of the Kolmogorov-Smirnov test as well as the Shapiro-Wilk test for normal distribution to the data indicated a significant variance from a normal distribution. Consequently the data was exported into frequency distribution tables from which the measure of central tendency could be calculated.

6.2.1 Sample representativity

The numerical respondent sample size was substantially less than the target of 100 respondents envisaged for the sample in the research design. Therefore the amount of data that was collected was ostensibly inadequate to allow a *prima facie* assessment of the numerical representativity of the respondents sample. Based on a comparison of the size and structure of the research sample versus that of the research population, it was apparent that an alternative approach would have to be taken to assess the representativity of the respondent sample in this investigation.

It is common cause however that a low response rate and a consequentially small research sample, does not necessarily imply that the data or the conclusions extracted from that data must be rejected as being of no or little value, a proposition supported by Schouten *et al.* (2009). He states that a marginal statistical representativity shown by a KMO measure of 0.702 where the lower threshold for the KMO to indicate adequate representativity is generally held to be 0.70, suggesting that both the data, as well as findings and conclusions extracted from it, could in fact be relied on statistically as being

acceptable for purposes of evaluating the defensibility of the research problem statement (See Table 6.1)

Kaizer-Meyer-Olkin test:	0.702
Bartlett's test of sphericity :	Approximate Chi-Square 9.98
	Degrees of freedom 4
	Significance Level 0.042

Table 6.1: KMO and Bartlett's test for sphericity for all questions in the questionnaire

A review of the biographical data revealed that the respondents in the research sample were all recording musicians or audio professionals, suggesting that they were respondents with an adequate knowledge and experience of the theory and practice of audio production and that they represent the target population of audio professionals. Their knowledge, perceptions and opinions as well as their experience are adequate reflection of the general level of knowledge and understanding of mastering. In this way the findings are representative of and can be extrapolated to the research population, being the whole industry, with impunity. This presumption is supported by Kruskal & Mosteller (1979) who indicated that representativity should be understood to indicate that the research sample must be seen as a miniature of the population and as being typical thereof. Virtually all the respondents indicated that they have been involved in the recording and production of commercial audio products for a number of years and that all these products were mastered by some means or another.

It is evident of the responses to the questionnaire that the respondents all have a clear, practical knowledge of the workings of the audio industry and all the component processes of audio recording. This leads to the conclusion that, although the respondents sample could not be said to be representative given the academic parameters set for representativity, the statistical measure suggest marginal representativity and the biographical findings supported the acceptability of the respondents as sources of data for further consideration.

It can be said with some certainty that in spite of the above mentioned shortcoming of the investigation, the conclusions and inferences drawn from the raw data after descriptive statistical analysis, unquestionably allow the assessment of the research questions and

ultimately the research problem statement.

Cronbach's Alpha	N
0.81	36

Table 6.2: Reliability statistic for the whole questionnaire

6.3 Audio professionals

The order to accurately address the research questions, a clear understanding of what constitutes an audio professional is necessary. This definition, discussed previously indicates which questions need to be asked. The survey questioned respondents with the aim to reveal information about themselves to determine if they can be considered audio professionals.

6.3.1 Biographical details

The relevant frequency distribution table shows that the average age of the respondents ranged between 26–35 years of age group, with 7 respondents being younger than 25, 13 respondents being between 36 and 45 years of age, 14 being between 46 and 55 years of age and only 2 above the age of 55 years. This confirms that the sample was fairly evenly spread across the various age groups. From this can be deduced that the responses obtained from the sample should not be biased in favour of one age group or another. If the whole sample of respondents were, for example, from the youngest age group, the responses may have demonstrated a bias in favour of the newest approaches to mastering such as those influenced by digitalisation. Conversely an age bias in favour of the older age group of respondents could conceivably have shown a bias in favour of the traditional approaches to mastering. With a fairly even age group distribution the premise is that the responses represent a spread of knowledge, understanding and perceptions that could be understood to represent the whole of the industry and all the age group mastering engineers active in it.

6.3.2 Professional roles

Of the respondent sample 20% of the respondents were self declared recording engineers, 18% were mixing engineers by their own account, 10% were mastering engineers and 8% were identified as being live sound engineers, while the rest were ostensibly practising mastering professionals without specific identification. More than half of the respondents, 58%, were also identified as being musicians which means that 48% were non-musicians. This allows the conclusion that the respondents sample was in fact reasonably representative of all the people involved in recording and mastering in the industry. Equally this indicates that most of the respondents are indeed professionals in the audio technology field according to their qualifications, training and experience and that the deduction can be made that the data was elicited from a proper spread of respondents representative of all those involved in the industry. This finding is supported by the knowledge that most of the respondents were also practising recording musicians thereby adding to the supposition of proper representativity of all the knowledge skill and experience in the audio industry.

6.3.3 Commercial exposure

When asked about the commercial recordings respondents were involved in, the results show that the majority of respondents had been involved in between one and five commercial recordings. Of these commercial audio products, almost all were mastered according to the original mastering technology, knowledge and skill. This suggests that audio professionals place great importance on mastering as they almost invariably have their commercial productions mastered, and also that they rely on traditional approaches and its traditional foundations.

6.4 Theoretical knowledge

The following section of the investigation draws focus to the knowledge of the theory that supports and surrounds professional mastering. The section also considers the value proposition of mastering. This research objective, although not explicitly stated in the research question has been a focus throughout the study.

6.4.1 Education

The findings revealed that in terms of both formal music education and music background, the largest number of the respondents were trained by means of practical, private music lessons aimed at performing with little if any theory of music included. A number were found to have had some school level music education, but that only a very few had any tertiary level music education. This indicates that a large part of the South African audio professional society has not received any form of formal musical or audio technological education, at either graduate or post graduate level.

6.4.2 Opinion and value

The opinions of the audio professionals relating to the concept of mastering, its importance and its value were elicited. Almost all the respondents responded positively to the relevant questions about the positive effect of mastering, indicating a good general understanding of the importance and also the value of audio mastering. The results of these questions are summarised below:

Question	% in agreement
Mastering is necessary	100 %
Mastering improves audio	94 %
Mastering improves the equalisation of audio	86 %
Mastering will make audio louder and more present	97 %
Mastering will make audio sound better on radio	94 %

Table 6.3: Importance and value of mastering

When asked if mastering can improve a recorded component of a specific mix, 58.3% accurately replied in the negative, and 41.7% replied in the positive, suggesting a slightly negative bias in favour of those that did not support the understanding that mastering could or would improve an audio. In spite of this slight negative bias balance appears to exist between the two groups. A similar question asking if mastering could influence only one sound in a mix returned a similar result, with 55.6% being biased in favour of the supposition, indicating what can be said to be a somewhat unrealistic expectation of mastering. The findings demonstrated that the common perception that recorded audio can be 'fixed' in a mix and similarly there

seems to be an expectation that mastering can fix glaring problems in a mix, is flawed. The findings suggested that it is more than likely that a mastering engineer will rely on a mixing engineer to correct any flaws in the mix and to make the changes needed to address any problems.

6.4.3 Value & expectations

An overwhelming 91.7% of the respondents agreed with the proposition reflected in the relevant questions that mastering generally aims at improving audio but rarely seeks to completely or drastically change the audio. They indicated that they do not expect the mastered audio to be substantially different from the original mixing studio. A total of 97.2% of the respondents indicated that they did not think that mastering should drastically change the audio. Equally a total of 63.9% of the respondents indicated that in their view mastered audio would probably be financially more successful than a unmastered one. The responses to the questions that constituted the question set relating to the perceptions of the value of mastering are shown below in Table 6.4 which shows that the respondents perceive mastering to be a very valuable intervention and a necessary step that will invariably benefit the audio, will delicately increase its volume and will improve equalisation. The last response shown in this table shows that 81% of respondents also agreed that mastering could conceivably damage audio. These findings show a good understanding of the benefits that mastering can offer and the danger of possibly damaging the audio if mastering is not properly done.

Question	Positive responses
Is mastering necessary?	100 %
Does mastering make audio louder and more present?	97 %
Does mastering improve audio?	94 %
Does mastering improve equalisation?	86 %
Can mastering damage audio?	81 %

Table 6.4: Questions relating to an understanding of the value of mastering

6.5 Technical knowledge

6.5.1 Equipment

It was clear from the findings that although mastering equipment is understood to be generally similar to recording and production equipment, the former is also understood to be specialised and specific to the processes in mastering. The findings showed a clear understanding of this, which is crucial in determining whether the data sample has an accurate understanding of mastering or not. Respondents were asked a variety of questions relating to equipment, for example whether mastering studios require specialised equipment, to which 86.1% replied positively. This is an encouraging statistic and even if the specifics of the equipment are unclear the understanding that mastering has different needs to mixing, is indeed a positive indicator of knowledge and understanding. Respondents were asked to select all the equipment from a list that they thought is used in a mastering studio. Table 6.5 shows the findings to this question which suggests that respondents correctly identified the most commonly used equipment in mastering, such as compressors, limiters, equalisers and digital to analogue converters. A small number of the respondents correctly identified crucial pieces of equipment, such as monitor controller and patch bays, which control the signal flow in the mastering studio. The number of respondents that indicated the use of a subwoofers suggests a cause for concern because even with high end monitoring, the mastering engineer must be able to accurately reproduce very low frequencies, which only a subwoofer can produce.

When asked if mastering studios could deliver good work with only one piece of specialised equipment, 88.9% of the respondents indicated that this is not possible and 75% indicated that multiple pieces of equipment would be necessary in a subsequent question. This demonstrates that the sample indeed understands the equipment used for mastering is specialised and necessary. Of the pieces of equipment that were presented as the most important, monitors and room acoustics were chosen by an overwhelming majority of respondents. 41.1% chose monitors and 36.1% chose room acoustics. In conjunction with this is the question asking, rather obviously, if ears might be the most important piece of equipment in the mastering studio to which an overwhelming 83.3% replied yes. Upon further inspection of monitors it showed that only 41.7% of respondents understood that mastering monitors are different to those used in other parts of audio production, but 61.1% indicated that the acoustics in a mastering studio would differ from recording or mixing studios.

Hardware equipment	Percentage	% of cases
Compressor	10.5 %	82.9 %
Limiter	10.2 %	80.0 %
Equalisers	9.8 %	77.1 %
Reverberation	4.0 %	31.4 %
Linear phase equalisers	7.6 %	60.0 %
Parametric equalisers	9.1 %	71.4 %
Digital to analogue conversion	8.4 %	65.7 %
Specialised monitors	10.5 %	82.9 %
Wordclock devices	3.3 %	25.7 %
Patchbay	3.6 %	28.6 %
CD player	1.8 %	14.3 %
Monitor controller	5.5 %	42.9 %
SubWoofers	6.5 %	51.4 %
Stereo compressor	9.1 %	71.4 %

Table 6.5: Hardware used in mastering

Mastering equipment uses stepped potentiometers in order to simplify recalling settings. This is an important distinction from other audio production equipment but one that most respondents could not make. In answering this question, the majority (63.9%) of respondents did not know. Of the remaining 36.1 %, 19.4 % indicated that stepped pots are used.

Only 38.9% of respondents indicated that mastering uses specially designed consoles. 27.8% indicated that they do not know. Mastering does indeed make use of specially designed consoles.

6.5.2 Software

On the matter of using software alone for mastering respondents were divided with the larger percentage response of 52.8 %. A mere 27.8 % indicated that this would not be possible and the remaining 19.4 % were undecided. There is no correlation between the respondents' profession and the opinion about mastering with only software.

Asking respondents to select all the software options that apply to mastering yielded the result shown in Table 6.6. This indicates that the majority of the respondents correctly identified the most common software applications used in mastering. A small percentage of respondents indicated the use of software tools that are not part of mastering.

Software plugins	Percentage	% of cases
Parametric equaliser	8.6 %	79.4 %
Linear Phase equaliser	8.9 %	82.4 %
Compressor	8.6 %	79.4 %
Multi-band compressor	9.6 %	88.2 %
Reverberation	4.5 %	41.2 %
Limiter	9.2 %	85.3 %
Expander	5.1 %	47.1 %
Stereo effect plugin	4.5 %	41.2 %
Phase coherence meter	7.3 %	67.6 %
Loudness meters	9.6 %	88.2 %
Transient modulator	2.2 %	20.6 %
Mid-side processing	6.7 %	61.8 %
Bass boost	2.5 %	23.5 %
Tube emulator	4.1 %	38.2 %
Guitar amp	1.0 %	8.8 %
Autotune	0.6 %	5.9 %
Tape saturation	6.1 %	55.9 %
Delay	1.0 %	8.8 %

Table 6.6: Software plugins used in mastering

6.5.3 Tools

The responses to the various questions relating to the mastering tools show that 86% of the audio professionals who participated in the investigation agree that mastering uses special equipment that won't be found in many other studios. 89% indicated that in order to achieve professional quality outcomes reliance on only one piece of equipment will not assure the desired results and 75% of the respondents indicated that a mastering studio needs a multiple of specialised equipment designed specifically for the mastering process. When asked to rank equipment needed for mastering in order of importance the respondents returned the order of importance shown in Table 6.7 which indicates that the most important equipment identified by the respondents are monitors and room acoustics.

Mastering equipment ranked	%
Monitor	42 %
Room acoustic	36 %
Compressor	8 %
A/D converters	8 %
Digital audio workstations (DAW)	6 %

Table 6.7: Important mastering equipment ranked

The findings shown by the responses to the questions relating to the general understanding that a specific mastering studio will probably have a number of specially developed tools, but that every studio will invariably have tools that are other than those included in the table above, showed that the respondents agreed to a large extent with the views expressed in the literature. The few stock items that are generally found in every mastering studio that were identified in the literature and ranked by the respondents in order of importance are shown in (Table 6.8).

Hardware tools ranked	%
Compressors	100 %
Specialised Mastering Monitors	81 %
Limiter	78 %
Equaliser	69 %
Stereo Compressor	69 %
Subwoofer	50 %
Monitor Controller	42 %
Reverb	31 %
Patchbay	28 %
Wordclock	25 %

Table 6.8: Mastering hardware tools ranked

6.6 Mastering processes

Mastering consists of both administrative components functionalities and creative ones. Of the more administrative type task, the respondents indicated that track levelling is the most important (See Ta-

Process	Percentage	% of cases
Compression	17.7 %	91.2 %
Limiting	17.1 %	88.2 %
equalisation	17.7 %	91.2 %
Delay	1.1 %	5.9 %
Reverberation	4.0 %	20.6 %
Gain Riding	6.3 %	32.4 %
Gain Automation	7.4 %	38.2 %
Dithering	13.7 %	70.6 %
Sample Rate Conversion	14.9 %	76.5 %

Table 6.10: Processes that form part of the mastering process

ble 6.9). They correctly identified *pq* coding, fades and choosing song order as also being important steps.

Tasks	Percentage	% of cases
Choosing song order	13.2 %	44.1 %
Adding fades to start & end of songs	22.8 %	76.5 %
Editing	6.1 %	20.6 %
<i>pq</i> coding	16.7 %	55.9 %
Adjusting instrument levels	3.5 %	11.8 %
Adjusting track levels	19.3 %	64.7 %
Quantizing	9.2 %	8.8 %
De-essing	12.3 %	41.2 %
Adjusting vocal	3.5 %	11.8 %

Table 6.9: Administrative mastering tasks

A small percentage of respondents indicated de-essing as a step, which although not incorrect, is not a very common tool at the mastering stage. 72.2 % of respondents indicated that adding metadata (also called *pq* coding when in reference to *cd*) is part of mastering. When asked to indicate which processes form part of mastering, respondents correctly indicated equalisation, compression and limiting as the most important. Respondents also indicated correctly that Dither and Sample Rate Conversion play a big role in the process of mastering. Only 5.9 % of respondents thought that delay is part of the mastering process, which is encouraging as delay is mostly a mixing tool (Table 6.10).

The respondents indicated correctly that mastering will often rely on gain staging to affect quality audio and to increase loudness gradually with 44.4% answering 'yes' when asked if gain circuitry can be used as a tool in mastering (38.9% answered no).

The respondents indicated that mastering will probably not add any effects to audio (61.1%) and rarely add reverberation to audio (52.8%). 58.3% agreed that mastering will work with high sample rates and 24-bit files. 63.9% of respondents were convinced that noise reduction is a key part of mastering. 88.9% of respondents correctly agreed that mastering engineers are experts in delivery formats and the specifications and technicalities thereof.

6.7 Further interpretations

In order to draw scientifically defensible conclusions from the findings extracted from the raw data by analysis, it was necessary to discover whether any associations could be found to exist. By performing cross tabulations and calculating the Chi-squared index the existence of as well as the strength and direction of any associations could be identified. A rather weak but positive association was indeed found to exist and the Chi-Squares measure shown in Table 6.1, provided evidence of positive dependence. This finding allowed a number of interesting inferences to be drawn as discussed below.

6.7.1 Professional mastering engineers - value proposition

The first findings gleaned from the responses to the relevant questions revealed that a number of the respondents were identified as being professional mastering engineers. Their responses to the respective questions are shown in the table below:

Industry	% Pro Software
Recording engineer	63.2 %
Musician	52.6 %
Mixing Engineer	52.6 %
Mastering Engineer	31.6 %
Non-performing musician	21.1 %
Live Sound Engineer	15.8 %

Table 6.12: Audio professionals that support predominantly software mastering

Value: Mastering engineers agree that:	% of cases
Mastered audio will sound better on FM radio	88.9 %
Mastering will alter an audio mix	77.8 %
They use both solid state and tube circuitry	77.0 %
Noise reduction is an important part of mastering	77.8 %
Software is a viable alternative to hardware	66.7 %
Room acoustics is the most important consideration	55.6 %
Mastering can fix problems in an audio mix	44.4 %

Table 6.11: Value proposition

Almost all the mastering engineers agree that mastering required special equipment. The majority of mastering engineers were ambiguous about whether stepped controllers are used in a mastering studio or not, indicating some uncertainty. While this might appear to be a shocking statistic, it ostensibly alludes to the prevalence of software in all parts of audio production.

6.7.2 Software mastering

That there is an association between the title of the audio professional and the perception that mastering can be done effectively using only software and plugins was inferred from the findings. This can be seen in Table 6.12, professionals that associate themselves as mastering engineers do not agree that mastering can be done using only software and plugins.

However non-performing musicians such as producers and arrangers do seem to agree in the possibility and success of mastering with software and plugins alone. It is interesting to note that live

sound engineers, who are traditionally the furthest removed from the process of mastering in the audio production line, seem to be the least supportive of the use of software alone. Conversely recording engineers who are the most closely aligned with mastering are apparently the most supportive of the use of software (see Table 6.11).

Although many respondents were found to consider it possible to master audio using only software, these same respondents indicated that mastering often uses gain circuitry as a dynamics range manipulation tool. Some evidence was found of an association between using software plugins and using gain circuitry as shown by the findings of a general Chi-square measure of 9.968a at $df = 4$ and $p = 0.041$. This information can seem contradictory but points to a hybrid mentality currently. This idea seems logical in a world slowly transitioning more and more to the digital space. Audio professionals do however apparently conceive of a future that is driven primarily by software, which seems to be in line with the popular current industry trends.

The measures of association that were found regarding the possible damage that mastering can cause, produced interesting findings. Of all the respondents who indicated that mastering can cause damage to audio programme, a significant percentage (41.4%) were audio professionals who have been involved in more than 40 commercial recordings. This finding seems to support the supposition that in order to have made over 40 commercial audio products, one would have to have been in the industry for more than 20 years and that having been in the industry longer, will necessarily equate to having seen more damaged audio and that indeed it is not an uncommon occurrence for audio to be noticeably damaged from being mastered. Whereas a similar percentage (47.4%) of professionals indicated that mastering could be done using only software and plugins there seem to be more support for the supposition discussed above. The trend suggested by these findings towards more reliance on software in mastering could be interpreted as being indicative of the emergence of a new era in mastering where skill will be more important than simply having access to expensive equipment.

6.7.3 Education

It is somewhat puzzling that the findings extracted from the analysed data did not seem to find any association between mastering and formal, academic education. There is some indication that mastering professionals with little if any formal, academic education of some sort or another seems to have produced more professional audio than their counterparts with formal academic education. As this finding

does not seem to support the traditional paradigm that education will or should properly prepare one in the professional industry, it must be put to question. The findings suggest a presumption that some of the relevant questions in this regard could have been misconstrued, and further suggests that research into this matter is necessary. This finding suggests the alternative paradigm, that professional mastering is dependent on practical and theoretical knowledge accumulated from experience and exposure. This is potentially the more effective approach to the training of professional mastering engineers. In spite of this finding, it is probable that a specialised formal tertiary education would offer a sound basis for the preparation of competent mastering engineers.

6.8 Summary

The size of the research sample did not meet the envisaged number of 100 and this obviated the use of more complex and sophisticated statistical analysis to extract meaning and to allow the drawing of inferences and conclusions. The study opted for less complex descriptive statistical analysis, which produced findings that allowed an interesting insight into the practise of mastering as it exists at present.

The findings reveal much about the respondents in terms of their professions, experience and commercial exposure and education. It is clear that the mastering professionals that participated in this investigation did have a basic theoretical and practical knowledge base. They were shown also to have considerable practical experience, which added to their fundamental knowledge. It was also quite clear from the findings that these mastering professionals have an adequate knowledge and understanding of the uses, role and value of the various new applications of technology and the equipment that has been developed for the recording industry that have found a use in mastering. Equally the recent developments of additional facilities such as software and plugins seem to be understood quite well, as well as the advantages these offer and the risks that they pose for mastering in terms of potential damage. This allowed inferences to be made about the audio production industry allowing the research questions to be addressed.

Finally it is quite clear that mastering professionals fully understand the value of mastering in audio production and that the role of the mastering engineer is evolving and will probably change in the future with emerging developments in the field.

Chapter 7

Conclusions and recommendations

7.1 Introduction

This investigation set out to determine the perception South African audio professionals have of mastering. Ultimately the research question was based around the hypothesis that audio recording practitioners in South Africa do not have adequate theoretical or technical knowledge of the concept of mastering and its processes. This assumption is based on the initial exploration of the theme of mastering by the researcher, as described earlier.

The previous chapter showed the findings to the separate areas specific to the research question. In the first chapter the study revealed specific research questions and stated the aim is to explore them within a broader structure. This broad structure consisted of the definition and validity of 'audio professionals', the theoretical and technical knowledge of the concept of mastering, the processes that are used in mastering and lastly the understanding of the perceived value of mastering. In summary, the broader structure pertained to the following areas of concern: the importance of mastering in audio production, the extent to which loudness is the main aim, the various processing, the ability to achieve similar result in the mixing phase and finally the various sub-processes included in mastering.

It was clear from the findings that audio professionals consider mastering to be a vital part of the audio production process. Mastering is understood to be an opportunity for a final separate step to improve audio. It is a tool to ensure compatibility in the professional audio industry. Respondents indicated that mastering offers the chance to improve tonal balance as well as loudness optimisation and as such offers professional audio programme. They understood

the most crucial mastering component functionalities and correctly indicated that monitoring stands as chief among them.

In answer to the research question, it was found that most respondents understood the component functionalities of mastering and could distinguish clearly between mastering and other activities involved in audio production. Therefore it was found that audio production practitioners in South Africa do possess adequate knowledge of mastering and its component functionalities. There is however less certainty around the specific details of mastering, as can be seen below which objects this final simplistic conclusion. The findings indicate a good general knowledge but fail to prove with impunity that audio professionals in South Africa are adequately informed on mastering. The following sections aims to provide final thoughts on the research objectives.

7.2 Theoretical, technical and practical knowledge

Statistical analysis of the data allows the conclusion that audio professionals in South Africa do indeed have an understanding of what mastering entails. The investigation was based on a hypothesis that many audio professionals would have only a vague understanding of what mastering is and are inadequately informed on the theoretical and technical aspects that underpins mastering. However, the findings show that this supposition is unfounded. The almost universal understanding amongst audio professionals seem to be that mastering requires exceptional listening capabilities. Equally, almost all the respondents agreed that both monitors and room acoustics are immensely important in the mastering process and vast majority placed great importance on exceptional hearing as the most important personal quality that a mastering engineer needs to process; they clearly differentiate between hearing and listening, which demonstrates a sound, if only practical, understanding of the psychoacoustics of the human ear.

An interesting finding is that a small percentage of respondents seemed to have impossibly high, and in fact almost unrealistic, expectations of what mastering can achieve. Respondents in this group perceived mastering as a safety net that could potentially radically improve audio programme. Some respondents were convinced that the process of mastering could even affect individual instruments within a mix, which is impossible. This points to a lack of understanding of mastering and expresses a need within the industry for

more knowledge. Both theoretical knowledge of audio principles and a practical knowledge of the processes are needed and would ensure more realistic expectations.

The findings showed that many of the respondents did not, however have a clear understanding of the actual inner workings of a mastering studio. The majority of the respondents were able to identify the most obviously important equipment required, but failed to identify signal routing hardware, which Owsinski (2008:16) claims is “universal among major mastering studios”. Many failed to adequately demonstrate knowledge of monitoring specific to mastering. They were uncertain on matters such as mastering specific hardware tools that measure their values differently than in recording. Many respondents indicated a sound understanding of the importance of good monitors in a mastering studio although many failed to identify subwoofers as necessary for effective mastering, a fact supported by *inter alia* (Owsinski, 2008:18,219-220) Savage (2011:219-220). Respondents stated that mastering can be done on the same monitors as those used for recording and mixing. This points to a reasonable level of theoretical knowledge, potentially acquired indirectly by exposure to audio production rather than through formal academic education, but a poor practical or working knowledge as a consequence of personal inexperience.

7.3 Mastering process

The mastering process includes various sub-processes, requires a large number of considerations and will obviously differ from project to project as far as the mastering requirements are concerned. In spite of this understanding of the complexity of mastering, it is also common wisdom that mastering can and will only be possible for any project, if certain basic or fundamental activities are undertaken and aspects are considered. The investigation explored these activities and considerations and it also examined some specific and newly emerging sub-processes.

The supposition on which the investigation was based, was that mastering relies on specially designed consoles. These consoles, or digital patchbays play a significant role in any mastering process as they allows the control of signal flow and some even contain sample rate converters Katz (2007:232). The finding was however that only a small number of the audio professional respondents were actually aware of this. This finding indicates a lack of practical knowledge.

Similarly it was a foundational supposition of the investigation that feeding the audio into the console was the first step in mastering.

This is also done with CD players or computers. Only a small number of audio professionals in the respondent sample seemed to have this understanding, being a further indication that the levels of theoretical and practical knowledge of the audio professionals involved in the investigation was questionable. The study recognises that much of the lack of understanding can be attributed to the rapid increase in the use of computers in mastering studios and the increase in the number of files being delivered digitally, negating the need for any form of ingestion into a console.

Gain staging plays an important role in mastering and is commonly used as a tool to increase volume transparently. The data elicited from the respondents seemed to indicate that they were unsure of this. This suggests a lack of proper understanding which is necessary to work with modern standards such as R128. This and new standards like the iTunes -17 LUFS act to normalise the levels which impacts on mastering outcomes (Bregnert *et al.*, 2011:1).

When asked to indicate which processes form part of mastering, most of the respondents were able to correctly indicated that equalisation, compression and limiting were amongst the component processes of mastering. Equally, almost all of the respondents were able to indicated correctly that dither and sample rate conversion plays a big role in the process of mastering, suggesting a reasonably sound understanding of the practice of mastering. Whereas these sub-processes constitute the heart of the mastering process the two sets of findings mentioned suggests a sound understanding of the practice of mastering by the audio professionals, but less than adequate theoretical knowledge. The data also revealed a fair understanding of the quality of files used in mastering and the fact that audio should be delivered to the mastering engineer in high sample rates and bit-depths, also supporting the above mentioned conclusion.

According to the responses to the questions relating to the 'administrative' processes involved in mastering, the audio professionals who took part in the study seemed to be clear on the tasks expected of a mastering engineer and how audio should be delivered. This is a conclusion drawn from the responses to the relevant questions relating to the functions involving PQ coding, metadata, fading and track levelling.

The findings extracted from the responses to the questions in the relevant section of the questionnaire, indicate that all the audio professionals favoured the recent trend towards more 'in-the-box' processing, meaning that mastering is done with software in a DAW on a computer instead of playing the audio through specialised equipment. The findings however suggest that a substantial audio of pro-

professionals do still consider hardware as playing a leading role in professional mastering. Equally the questions relating to software indicated that respondents do not understand that certain workstations are designed specifically for mastering. This could conceivably be a consequence of the evolution of modern trends in commercial audio consumption.

7.4 Value offering of mastering

One of the fundamental premises on which the investigation was based, was that South African audio professionals have a great respect for and acceptance of mastering as a key process in recording audio. The findings of the investigation was that it is clear that audio professionals see mastering as having great value and as something that contributes greatly to professional audio programme, thus providing support for the premise mentioned above. All the respondents indicated that mastering is absolutely necessary. Over 90 percent of respondents indicated that mastering improves audio in general as well as in specific areas such as equalisation, radio play and audio in cars. More than half of the audio professionals agreed that mastered audio will be more financially successful¹. This proves that audio professionals understand that mastering can and will add tremendous value to the audio and that they value mastering as an art that can greatly improve and benefit their audio products.

7.5 Conclusion of research question

The findings discussed in this study indicate that the research problem cannot be supported entirely. The study posed a questions to detemine if audio professionals in South Africa have a clear understanding of mastering. The hypothesis was that most audio professionals do not have a clear understanding, a supposition based on the experience of the researcher and also found in forums and other conversations regarding audio production. After the survey of audio professionals in South Africa it seems clear that the hypothesis cannot be supported and the research question is answered. Audio professionals in South Africa have a fairly clear understanding of the concept of mastering, its component functionalities and the value that it offers.

¹ The study does not contain enough data to test this hypothesis. The study presents this as an opinion of the respondents.

The findings of the study is, however not entirely conclusive. The findings show that many audio professionals do have a theoretical and technical knowledge of mastering as well as of the value that it can and probably will add to the audio, although there clearly seems to be a need for more knowledge and understanding of the practical applications and processes of mastering. The need for further clarity is amplified by the possible future evolution of mastering and the role it can play in professional audio programme.

7.6 Limitations of the investigation

The study set out to survey 100 respondents in order to apply inferential statistical analysis in the form of regression methodologies such as Principal Component of Factor Analysis. Due to a smaller than expected sample size of 36 more simple descriptive methodologies had to be relied on. In this sense the original research plan was forced to be slightly modified not to fit a specific timeframe but to be able to extract meaningful data with the data data available. Although evidence was found of statistical reliability at the marginal level it was not possible to determine representativity by means of the usual empirical methodologies. Therefore the data and consequential findings must be put to question. It is clear that a larger sample size would have procured substantially more data, made proper statistical analysis possible, and could more specifically have addressed the research questions in chapter one.

The investigation relied successfully on a structured questionnaire to collect raw data for further statistical analysis and the extraction of meaning in the form of patterns and trends. It is trite that an interview approach to data collection using a pre-determined set of open ended questions may have provided much more detailed and relevant information. Because of the limited resources available for the investigation and the substantial implications in terms of time, money and geographical travel that an interview approach would have demanded, this approach was decided against. It could conceivably have provided much needed information on the recording industry in general and on mastering specifically, specifically with regard to formulating a new definition of mastering. Further research into the role of mastering is undoubtedly necessary in the changing and evolving recording and mastering landscape.

The study made use of a questionnaire designed based on the available literature. The questions were arranged together in sections aimed at addressing specific research questions. Although a calculation of a correlation coefficient matrix that confirmed the content and

construct validity of the questions in the questionnaire, a perusal of some of the questions showed that some phrasing of the questions could have been slightly confusing and could have been given more attention.

7.7 Recommendations for further research

The investigation was concluded with an open ended question at the end of the questionnaire so that respondents could supply additional information, express opinions or suggests items for further exploration and discussion. Only a few of the respondents availed themselves of this opportunity, probably for practical or personal reasons, and the little information that was in fact provided was of so little use, that it was ignored.

7.7.1 Software based mastering

The trends identified from the findings of the investigation hints at a more software based focus and certainly the history of mastering proves that adaptability lies at the core of mastering.

The recommendation is that further research should be conducted with a focus on the changing role of the mastering engineer. This changing role should be set against the evolution of technology and the results achieved by emerging new software. This has enormous implications for aspirant mastering engineers who at the moment will have to spend huge amounts of resources just to enter the field of mastering. Without the need for expensive equipment one might see many more mastering engineers enter the industry in South Africa, which would have a profound effect on the South African audio industry.

7.7.2 Mastering consultation

Another key recommendation relates to the premise that the mastering engineer should play an increasing role in the overall recording process. Further research should be aimed at determining whether this is indeed a positive role change or not. The recommendation would be to engage in open ended discussions in order to extract as much possible insight and not to limit the data collection by adherence to standardised research methodologies.

This investigation has shown unequivocally that mastering is considered valuable and necessary by almost all sources of information including the respondents who completed the research ques-

tionnaire. A follow-up investigation should determine how the role of mastering will remain valuable and necessary, if indeed anybody can get their mix to sound great and can master the mix at the same time. If mastering is to become the gatekeeper at the doors of loudness and general quality then further investigation could provide valuable insights into size and shape of this role.

7.8 Mastering in South Africa

The study emanated from multiple conversations, personal and online, and various other sources indicating a lack of understanding of mastering. Although the findings have pointed out that there are still misconceptions around the specifics of mastering, generally the audio professionals in South Africa have a fairly good understanding of mastering and that they value it to the point of reverence. The question remains why then, if professionals understand what mastering is do they seem unsure about it. And if they are sure it will contribute to their audio programme why are they unable to concisely state what mastering will specifically do to the audio programme.

Previously, the study stated that there exists a conception among audio professionals that mastering done outside of South Africa is better. It is the recommendation of the researcher that more probing be done to determine the truth in this. Further academic understanding is necessary of the quality of international mastering as opposed to local mastering. It is the belief of the researcher that South African mastering professionals have the potential to deliver mastering products of the same quality as international mastering engineers. The research is of the opinion that the common agreement of international mastering being better, is false.

7.9 Summary

The investigation was based on the premise that South African audio professionals are uncertain about the content of the construct of mastering probably because they do not have adequate knowledge and understanding of what mastering entails, its tools and processes and the value it offers audio production in terms of assurance of international quality standards.

The research findings demonstrated that this hypothesis is flawed. The findings were that at least a portion of South African audio professionals do in fact have an adequate knowledge and understanding of the content and dynamics of mastering, have an adequate knowl-

edge and understanding of the tools and equipment used in mastering and the way these should be applied, as well as an understanding of the value of mastering. There was undoubtedly some ambiguity emanating from the research findings, but overall the findings answered the research question in that South African audio professionals do indeed have a fairly clear understanding of what mastering is.

Whereas the aim of scientific and academic research is to build upon the existing body of scientific knowledge about a subject or phenomenon the contribution made by this investigation to the body of music technology knowledge, will undoubtedly enhance the understanding of mastering. The study hopefully contributed to the awareness of mastering in the South African context and the knowledge that South Africa has many skilled and capable mastering professionals. The study contributed to the body of academic knowledge of mastering in South Africa and hopefully promoted the role of mastering and the value it adds to professional audio.

Appendices

Appendix A

Letter to Respondents

Email Subject : Invitation to take part in a survey on Audio Mastering in South Africa

Dear [Insert Respondent Name]

You have been identified as an audio professional who might be willing to take part in a survey on the perceptions of audio mastering in South Africa. This survey forms part of a post graduate research project in Music Technology at the University of Stellenbosch.

It will be greatly appreciated if you would take a few moments to respond to the questions and statements in the link below. The information which you agree to supply will be used only for the study and any personal information will remain confidential.

You are not required to provide your name or any other details that would allow any person other than the researcher to identify you. Therefore please accept my personal assurance that all information provided by yourself will be dealt with as being anonymous and with complete confidentiality. No information provided by yourself will be made available to any other person, under any circumstances.

This assurance should confirm that it will not be possible for any person, organisation, institution or employer to trace the findings of this survey back to any respondent, and that you can therefore be assured that you need not be concerned that the findings of the research could ever be used against you or to your detriment in any way.

Please accept my gratitude and appreciation for your participation in this research survey. You can be assured that the information provided by you will make a significant contribution to the body of scientific knowledge related specifically to audio production in South Africa and generally to sound engineering, by promoting the theoretical construct and practice of mastering.

Sincerely,
Dawid de Villiers

Full hyperlink to the survey :

<https://docs.google.com/forms/d/e/1FAIpQLSdgdmsHQQwdqdcXjiHgu7mDUfrcJyDRRHnqry5KrmP5332G0A/viewform>

Appendix B

Survey

Please note that this is just a representation of the questionnaire which will be hosted online and will function with a select button which will automatically collate the data into a spreadsheet for analysis.

B.1 Section A: Biographical details

This section will consider the eligibility of participants and allow extrapolation based on professional categories.

What is your age group?

- a) 18 - 25
- b) 26 - 35
- c) 36 - 45
- d) 46 - 55
- e) 56 - 65
- f) Older than 65

What is your professional title?

- a) Musician
- b) Non-Performing musician i.e. Composer/Producer/Arranger
- c) Recording Engineer
- d) Mixing Engineer
- e) Mastering Engineer
- f) Live Sound Engineer
- g) Other (if other, please specify :)

Please indicate your level of music education.

- a) Secondary music education
- b) Tertiary music education

- c) No music education
- d) Secondary Audio Technology Education
- e) Tertiary Audio Technology Education
- f) Other (please specify :)

How many commercial recordings have you been involved in? For example, performed, produced, recorded, mixed or mastered

- a) 1–5
- b) 5–10
- c) 10–20
- d) 20–40
- e) 40+
- f) Other (please specify :)

What was your role in the commercial recordings you were involved in?

- a) Tracking Engineer/Assistant
- b) Mixing Engineer
- c) Producer
- d) Other (please specify :)

How many of the commercial recordings you were involved in were mastered?

- a) 0
- b) 1–5
- c) 5–10
- d) 10–20
- e) 20–40
- f) 40 or more

B.2 Section B: Opinion and perception

This section will test different opinions of participants and determine their perception of what mastering does. This section will pose questions that will pit mastering against the other steps of the production of commercial audio such as mixing.

Do you think mastering will improve the recorded sound of any of the instruments in your mix?

- a) Yes
- b) No

Do you think mastering will improve the equalisation of audio programme?

- a) Yes
- b) No

Do you think mastering will make your audio sound louder or more present?

- a) Yes
- b) No

Do you think mastering will make your audio sound louder?

- a) Yes
- b) No

Do you think mastering can fix problems in the mix?

- a) Yes
- b) No

Do you think mastering is something that will alter your mix?

- a) Yes
- b) No

Do you think mastering applies processes that a recording/mixing facility does not have access to?

- a) Yes
- b) No

Do you think the mastering engineer can considerably influence any one sound in your mix?

- a) Yes
- b) No

Do you think the mastering engineer will add additional audio to your programme?

- a) Yes
- b) No

B.3 Section C: Mastering equipment

This set of questions will determine basic opinions of mastering and general understanding of the equipment used.

Do you think Mastering requires specialised equipment that contributes to the improvement of the audio?

- a) Yes
- b) No

Please indicate the equipment used in mastering. Select all that apply.

- a) Outboard Compressors
- b) Outboard Limiters
- c) Outboard Equalisers
- d) Outboard Reverberation Units
- e) Linear Phase Equalisers
- f) Parametric Equalisers
- g) ADC Converters
- h) Specialised Monitors
- i) Special Computer Software

Mastering studios only need one high quality piece of audio processing equipment such as a compressor.

- a) True
- b) False

Mastering studios must have multiple specialised audio processing devices in order to ensure good quality.

- a) True
- b) False

Which of the following is the most important in a Mastering Studio?

- a) Monitors
- b) Analogue-to-Digital converters
- c) Good room acoustics
- d) Amplifier
- e) DAW understanding
- f) Compressor

Good ears are the most important piece of gear in a mastering studio.

- a) True
- b) False

This set of questions determines the understanding of monitors and room acoustics in mastering.

Does a mastering engineer use the same monitors found in recording / mixing facilities?

- a) Yes
- b) No

Will the acoustics in a mastering studio differ from that of a recording / mixing facility?

- a) Yes
- b) No

This set of questions determines the understanding of Software used in Mastering

Mastering can be done effectively using only software and plugins.

- a) True
- b) False

Please indicate which of the following software tools or plugins is part of mastering

- a) Parametric Equaliser
- b) Linear Phase Equaliser
- c) Multi-band Compressor
- d) Reverberation
- e) Limiter
- f) Expanders
- g) Stereo effects
- h) Phase (coherence) meters
- i) Loudness meters
- j) Transient Modulator
- k) Mid-Side Processing

Please indicate which of the following software programmes are used in mastering

- a) Ableton
- b) Pro Tools
- c) Izotope RX4
- d) Waveburner
- e) Sadie
- f) Wavelab
- g) Logic Pro
- h) Reaper
- i) Sequoia

Noise Reduction is an important part of Mastering.

- a) True
- b) False

B.4 Section D: Mastering processes

This section will test participant knowledge of the processes audio programme undergoes in mastering. The section will also discern participant knowledge of software and hardware processes in mastering.

The questions in this section relate to the components of mastering and the processes as per the research statement.

Please indicate which of the following audio processing is part of mastering:

- a) Compression
- b) Limiting
- c) Equalisation
- d) Delay
- e) Reverberation

Please indicate which of the following is part of the mastering process:

- a) Choosing song order
- b) Adding Fades at the beginning and end of songs
- c) PQ coding
- d) Adjusting Instrument levels
- e) Adjusting track levels

Would a mastering engineer be tasked with adding any effects to audio?

- a) Yes
- b) No

Will a mastering engineer add reverberation to audio at any point in a song / album?

- a) Yes
- b) No

Mastering is tasked with ensuring each song on an album matches the others in terms of volume.

- a) True
- b) False

Mastering will always work with a high quality 24-bit audio files.

- a) True
- b) False

Mastering engineer will deliver files in 16-bit, 44.1 Khz.

- a) True
- b) False

Mastering engineers use specialised equipment for bit reduction processing such as dithering.

- a) True
- b) False

Mastering engineers are specialists in noise reduction such as removing pops and clicks from a recording.

- a) True
- b) False

Mastering is responsible for pg Coding.

- a) True
- b) False

Mastering engineers are experts in understanding the technicalities of different delivery formats such as iTunes, CD (Redbook standard), streaming requirements and vinyl requirements.

- a) True
- b) False

Mastering engineers will measure the loudness by using which of the following.

- a) Ears Only
- b) Peak Level Meters
- c) Rms Level Meters
- d) Loudness Meters using LUFS

How do Mastering engineers deliver the final product to the client?

- a) Upload wav files to a specified internet location or server
- b) Deliver a Physical CD
- c) Upload a DDP file to a specified internet location or server

Mastering engineer will add metadata such as ISRC codes and track names to the final audio files once the mastering has been completed.

- a) True
- b) False

B.5 Section E: The value of mastering

This section will identify the expected value proposition of mastering.

Do you think Mastering is necessary?

- a) Yes
- b) No

Do you think Mastering improves the audio?

- a) Yes
- b) No

Do you think Mastering can damage the audio?

- a) Yes
- b) No

Have you ever been disappointed in audio that you recorded / created that had been mastered?

- a) Yes
- b) No

Do you expect mastered audio to be louder?

- a) Yes
- b) No

Do you expect mastered audio to be clearer?

- a) Yes
- b) No

Do you think mastering will make your audio sound better?

- a) Yes
- b) No

Do you think mastering will make your audio sound better on Radio?

- a) Yes
- b) No

Do you think mastering will make your audio sound better on car sound systems?

- a) Yes
- b) No

Do you think without mastering your audio will only sound good over very high end playback systems?

- a) Yes
- b) No

Do you think mastering is supposed to drastically change the audio?

- a) Yes
- b) No

Do you expect Mastered audio to increase the dynamic range of your audio?

- a) Yes
- b) No

Do you expect Mastered audio to increase the overall volume of your audio?

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- a) Yes
- b) No

Do you expect the final mastered audio to be very different from your original mix?

- a) Yes
- b) No

Do you expect Mastered audio to be more financially successful?

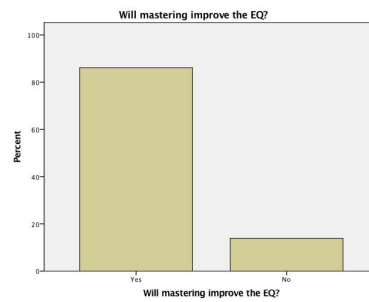
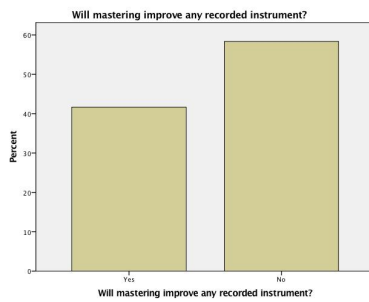
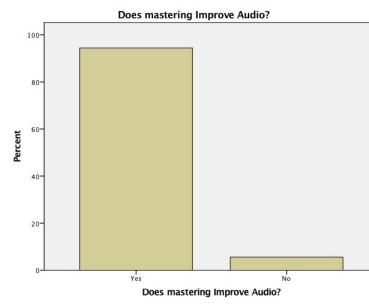
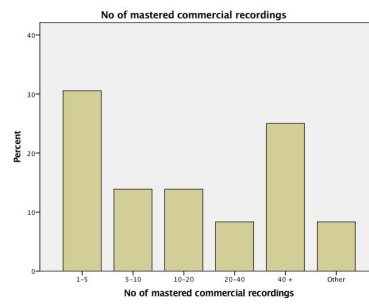
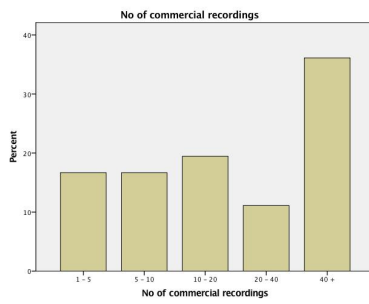
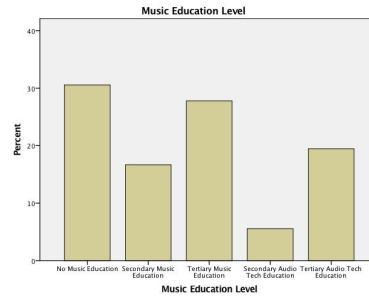
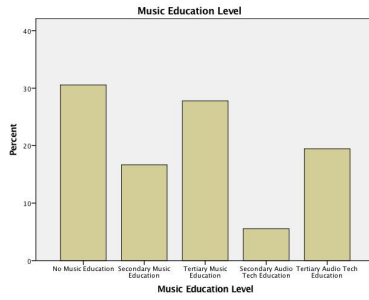
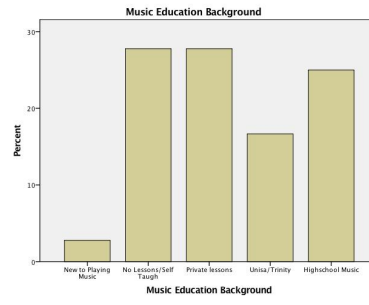
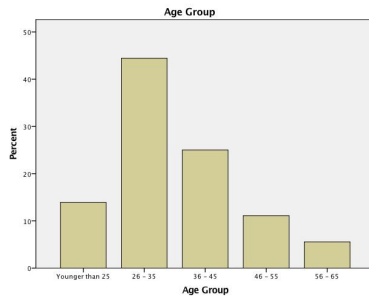
- a) Yes
- b) No

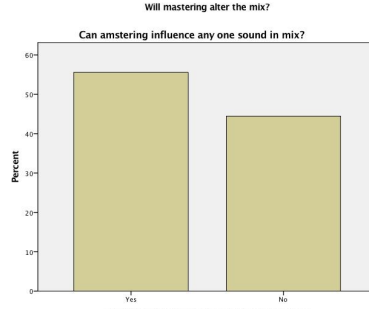
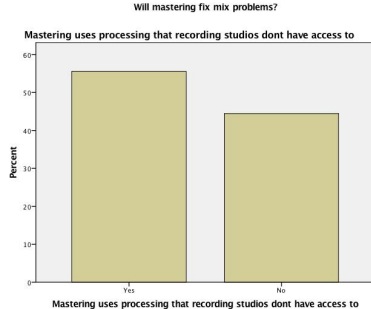
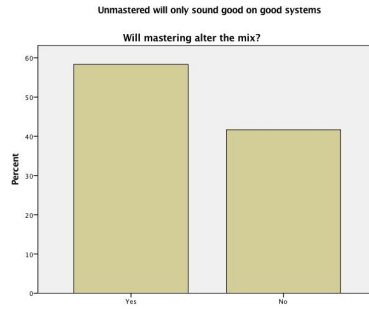
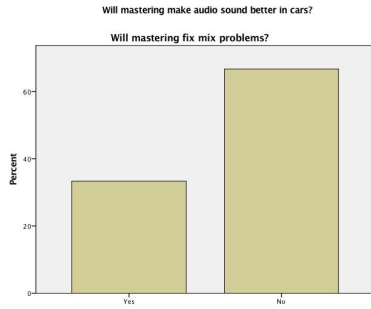
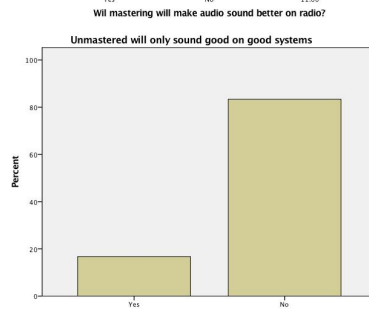
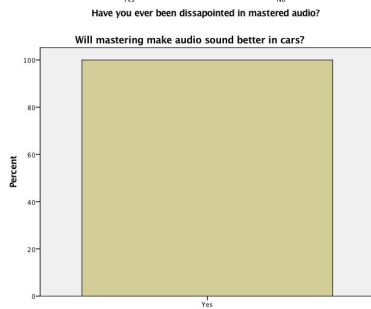
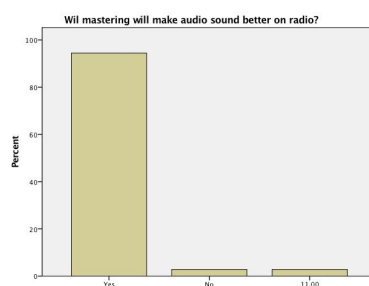
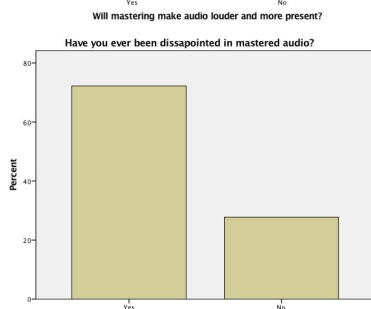
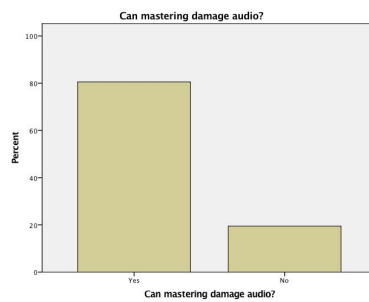
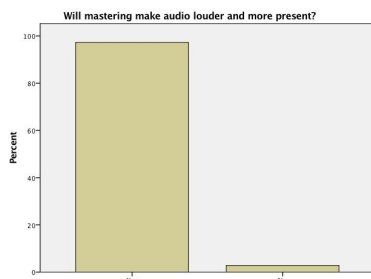
Appendix C

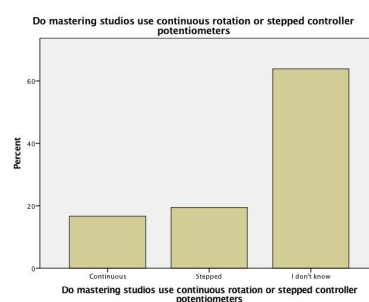
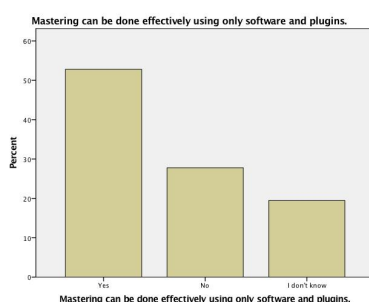
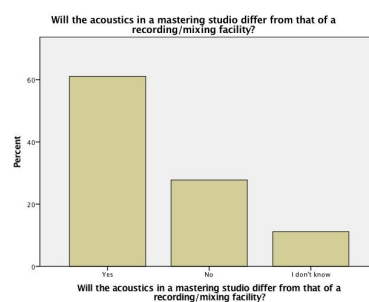
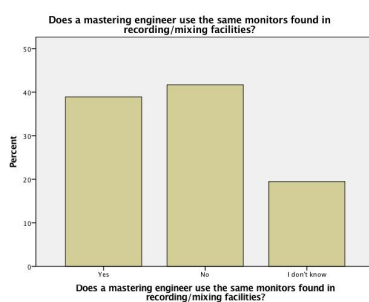
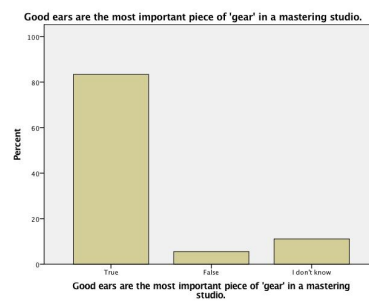
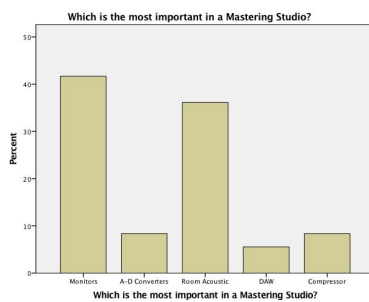
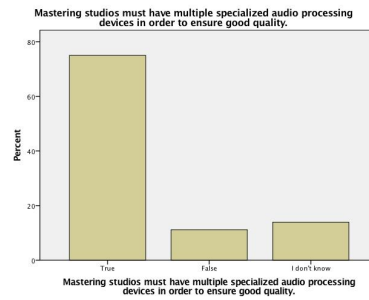
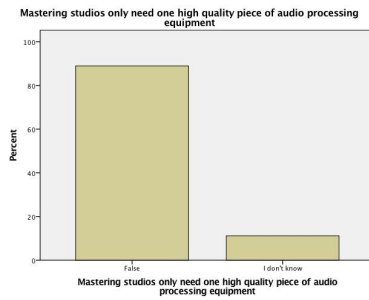
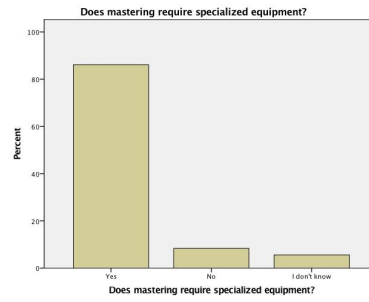
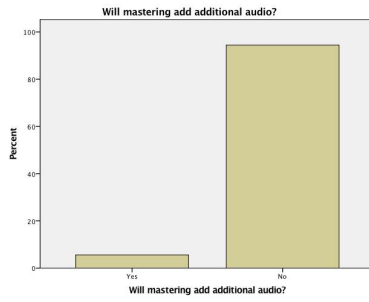
Raw Data

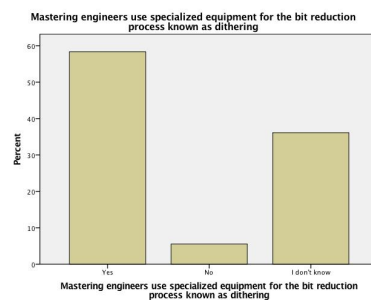
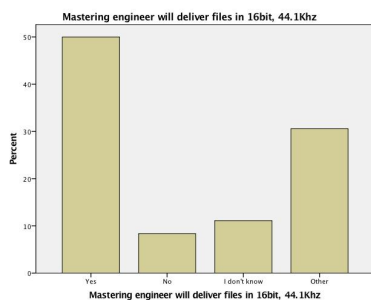
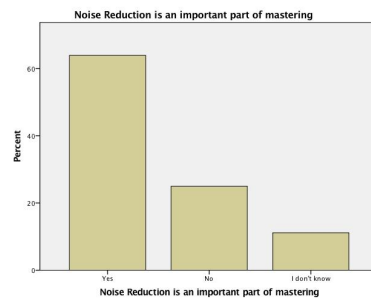
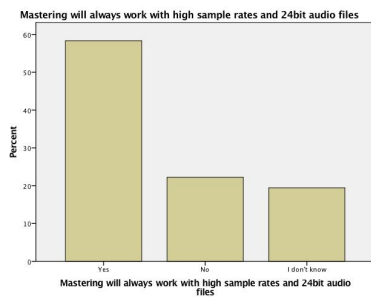
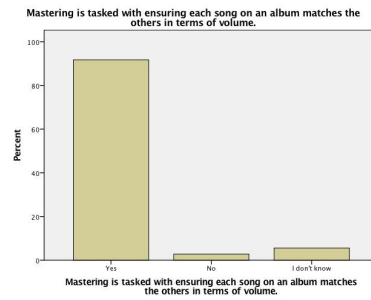
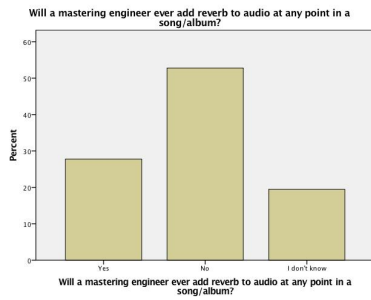
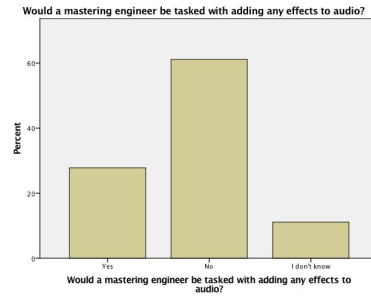
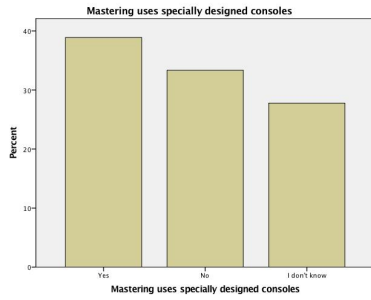
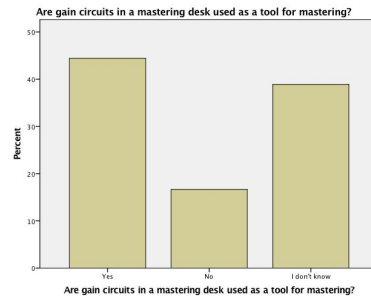
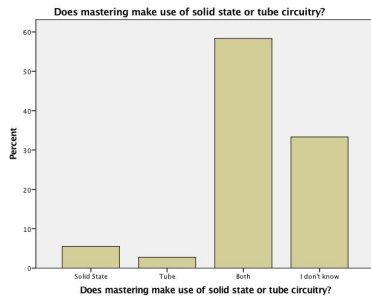
This appendix contains all the raw data used in the study. The data is presented in various ways. The frequencies tables for each value are listed.

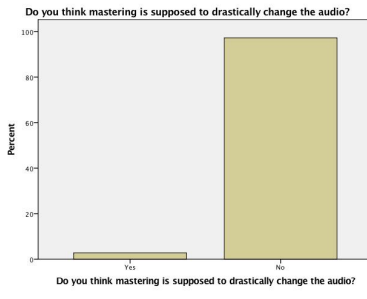
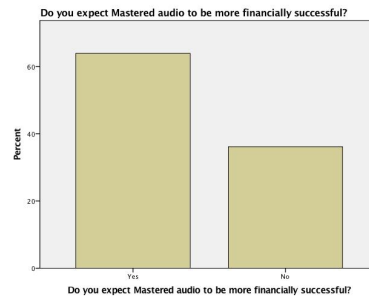
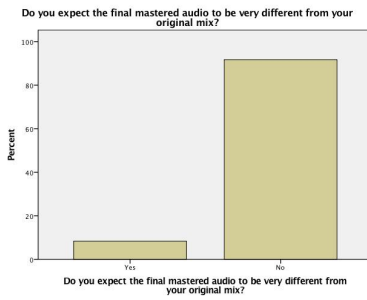
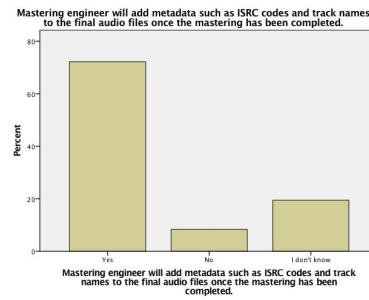
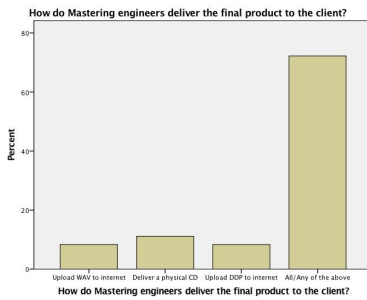
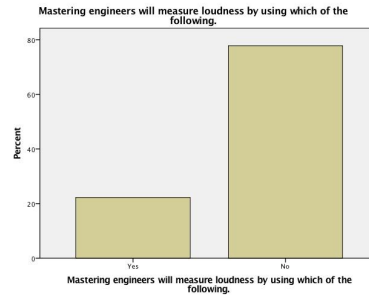
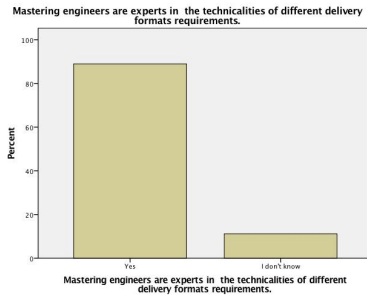
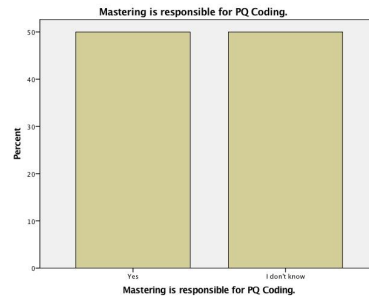
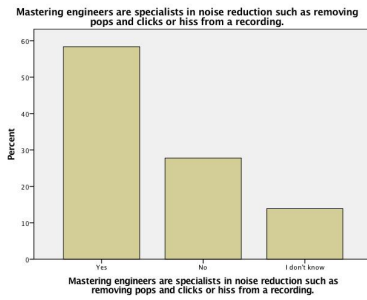
There are frequency tables and bar graphs showcasing ranges of variables. Not all variables were included in the final analysis for reasons stated in the document, however the raw data of these questions are also included.











Professional Title ^a	Professional Title -	Responses		Percent of Cases
		N	Percent	
	Musician	21	24.7%	58.3%
	Rec Engineer	17	20.0%	47.2%
	Mixing Engineer	16	18.8%	44.4%
	Mastering Engineer	9	10.6%	25.0%
	Live Engineer	7	8.2%	19.4%
	Other	4	4.7%	11.1%
	Non-Performing Musician	11	12.9%	30.6%
Total		85	100.0%	236.1%

Figure C.6: Professional title of respondent

2. 2D Bar/Column Plots (Spreadsheet5)

2.1. Hardware

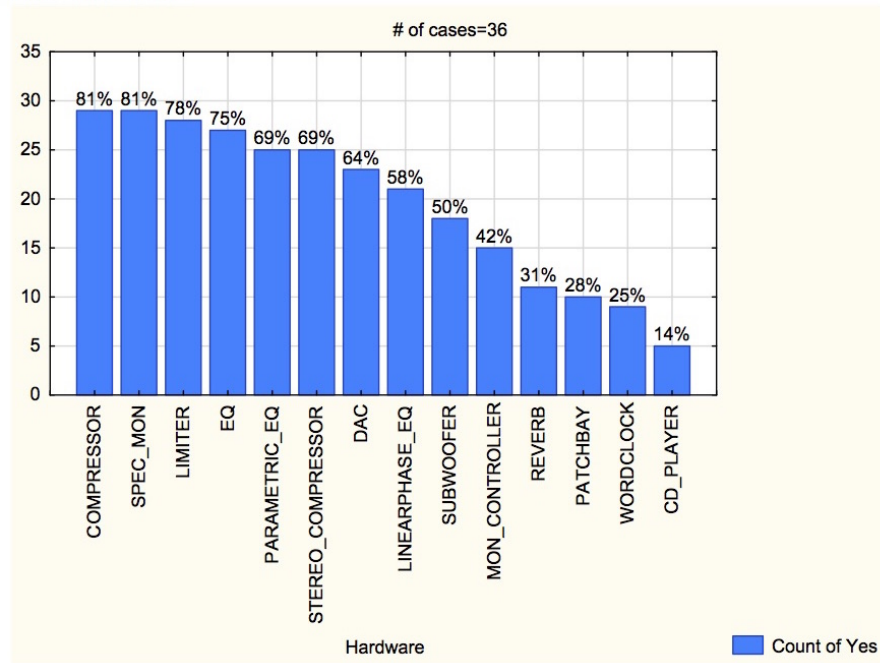
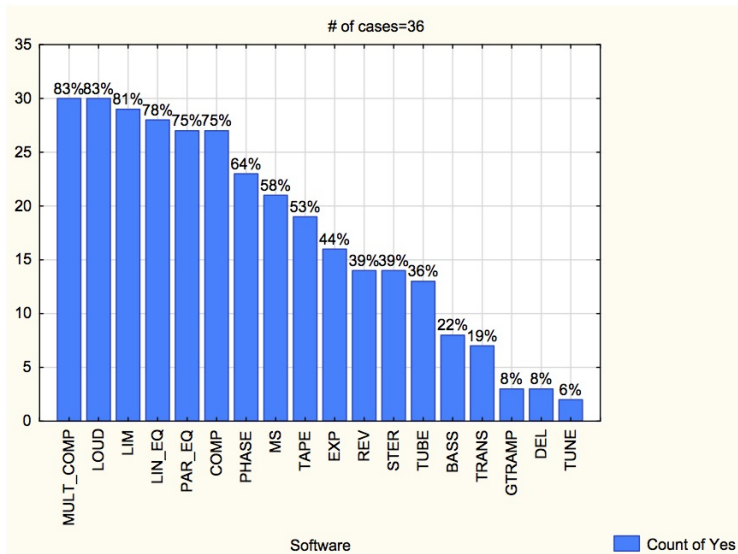


Figure C.7: Hardware used in mastering

2.6. Software



2.7. Software_program

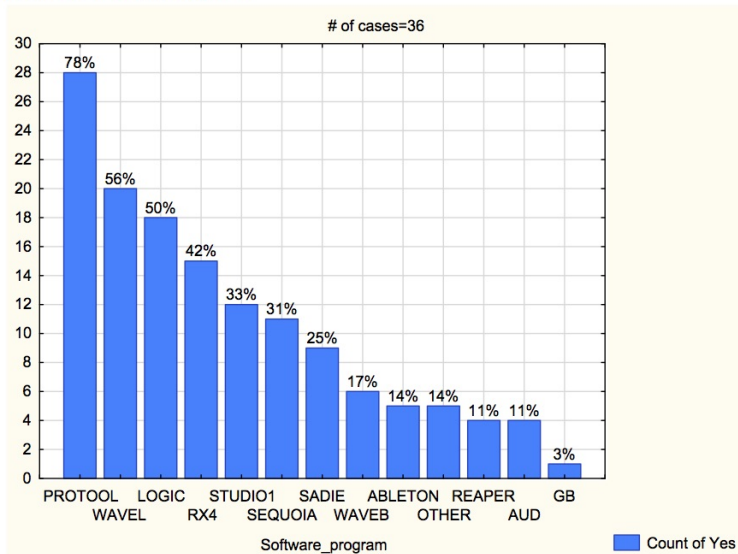


Figure C.8: Software used in mastering

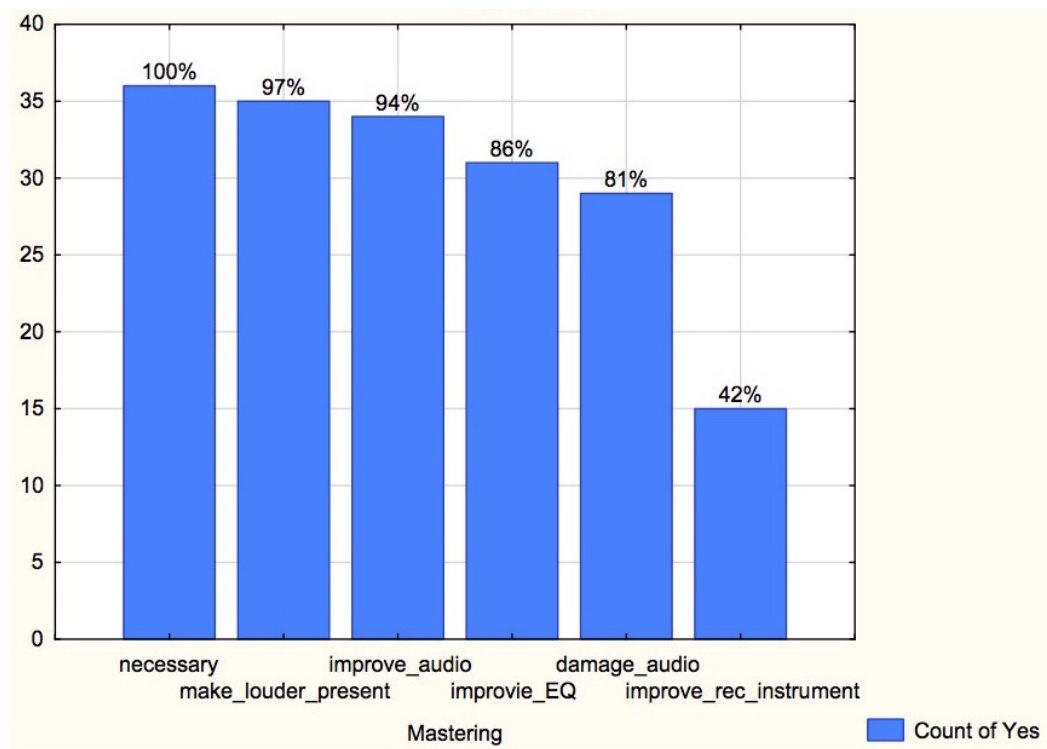


Figure C.9: Mastering value questions grouped

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