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Historical development, sound aesthetics and production techniques of the distorted electric guitar in metal music

# Historical development, sound aesthetics and production techniques of metal's distorted electric guitar

Jan-Peter Herbst

## Abstract

*The sound of the distorted electric guitar is particularly important for many metal genres. It contributes to the music's perception of heaviness, serves as a distinguishing marker, and is crucial for the power of productions. This article aims to extend the research on the distorted metal guitar and on metal music production by combining both fields of interest. By the means of isolated guitar tracks of original metal recordings, 10 tracks in each of the last five decades served as sample for a historical analysis of metal guitar aesthetics including the aspects tuning, loudness, layering and spectral composition. Building upon this insight, an experimental analysis of 287 guitar recordings explored the effectiveness and effect of metal guitar production techniques. The article attempts to provide an empirical ground of the acoustics of metal guitar production in order to extend the still rare practice-based research and metal-oriented production manuals.*

*Keywords: guitar, distortion, heaviness, production, history, aesthetics*

## Introduction

With the exception of genres like black metal that explicitly value low-fidelity aesthetics (Hagen 2011; Reyes 2013), the powerful effect of many metal genres is based on a high production quality. For achieving the desired heaviness, the sound of the distorted electric guitar is particularly relevant (Mynett 2013). Although the guitar's relevance as a sonic icon and its function as a distinguishing marker of metal's genres have not changed in metal history (Walser 1993; Weinstein 2000; Berger and Fales 2005), the specific sound aesthetics of the guitar have varied substantially. Due to that special importance, many metal bands invest a lot of energy in creating the optimal guitar sound. For example, after having recorded the guitar performances for their album *Threshold* (2006), the Swedish power metal band HammerFall stated to have re-amped their guitars for three weeks to be completely satisfied (Schwarz 2006). Such an enormous effort is not a unique phenomenon of modern metal productions but emerged quickly within a short period of time in early metal. Whereas Black Sabbath recorded their self-titled album (1970) in just a day (Iommi 2012: 62ff), their fourth album *Sabbath Bloody Sabbath* (1973) already was the result of laborious recording and production experimentation (Iommi 2012: 133ff). Following this trend, the production strategies and ways of guitar playing have changed in metal history to improve the desired "wall of sound" (Mynett 2009a, 2009b).

Research on guitar distortion and metal production is still in its infancy. The rare literature on the distorted electric guitar has paid particular attention to cultural identity, ethnicity and political subversion (Waksman 1999), genre definition (Gracyk 1996), gender (Walser 1993; Bourdage 2010), and communication (Herbst 2014). Within musicology, Walser (1993, pp. 41ff) devoted three pages to distortion while discussing the principles of heavy metal. By spectral analysis of original records and experimental guitar recordings Einbrodt (1997) identified acoustic elements having contributed to the rock guitar sound. Some work explored the perception of distorted guitar chords by theoretical and psychoacoustic analyses (Lilja 2005, 2015; Berger and Fales 2005) and psychological experiments (Juchniewicz and Silverman 2001). So far, the study of Berger and Fales (2005) is the only one concerned with the historical development of the metal guitar sound. With regard to metal production techniques Mynett (2013: 18f) notes that "academic exploration into the processes of music production can […] be viewed as being in an embryonic phase [… and that a] comprehensive study into procedural methodologies for the production of contemporary metal music is 'virtually non-existent'". He continues to claim that publications providing an empirical methodology for pre-production, engineering and mixing approaches are still rare (Mynett 2013: 29). In the same vein, Williams (2015) observes that research on metal production techniques was behind its creative uses.

This article aims to extend the research on the distorted metal guitar and on metal production by combining both fields of interest. At first, it will explore the historical development of the metal guitar sound in order to broaden the exploratory results of Berger and Fales (2005). Then, it will determine how varying production techniques affect the metal guitar sound.

## Method

One possible way of analysing sounds is to describe the listening impression. While this method provides an understanding about the music's effect, computer-assisted tools improve objectivity and may offer deeper insights into the acoustic features behind the perceptual effects (Cook and Clarke 2004). Since there is no universally accepted measure for timbres (Berger and Fales 2005: 182), the acoustic properties volume, pitch, spectral content and envelope must be interpreted. This way, specific timbres or "colours" in the realm of metaphorical perception and verbal description (Zbikowski 2002) like guitarist Edward Van Halen's "brown sound" can be explained by acoustic features.

The main approach in this study relies on spectral content as the overriding aspect of timbre, one that is manipulated in music production. Screenshots of spectra in digital audio workstations are limited because they only capture one moment of the envelope, and the spectral content of different recordings cannot be compared directly. Instead, the recordings were evaluated with the frequency analysis function of Audacity (Hanning window, size 16,384), and the data was imported to Microsoft Excel to undertake statistical analysis. For improved comparability, the spectral content was divided into eight frequency groups while taking into account the spectrum of the metal guitar. Descriptive statistics of these frequency groups allowed comparing recordings, evaluating effects and demonstrating historical developments. Spectrographic analysis with the Sonic Visualiser provided a more detailed exploration of the audio material. Volumes were measured with Adobe Audition 3.

### *Sample*

The first part of the study aimed to gain an understanding of the metal guitar sound from a historical perspective. In line with Berger and Fales (2005), only original recordings with isolated guitar parts were taken into account to minimize interference. The sample is the result of a historically guided Spotify search (e. g. Black Sabbath for 1970s metal) and using the "similar artists" function. Ten tracks each were selected for five categories: 1970s proto metal, 1980s classic heavy metal, 1990s thrash metal, 2000s extreme metal, and 2010s modern extreme metal (see track list in the appendix). Most of the songs were released in the early years of the decades.

The experimental part intended to explore production techniques of the metal rhythm guitar. Metal riffs combine single notes and power chords (a fifth interval with an optional octave). Four versions of two bars of an E note (82 Hz) and an E power chord in eighth-notes plus a sustained power chord were recorded directly into the software (Apple Logic Pro X) to enable re-amping the same performance. Re-amping requires the guitar signal to be recorded directly into the computer. The performance can thus be recorded with different amplifiers, amplifier settings, effects pedals, cabinets and microphones as often as desired. A re-amping box (Palmer Daccapo) is needed to adjust the impedance of the recorded guitar signal to the amplifier. To explore the effect of gear, two distinct guitar models were used: A Gibson Les Paul and a Fender Stratocaster. Both were played with humbucker pickup at the bridge. All five amplifiers (models and settings in the appendix) were based on tube technology. The signal ran into a closed 4x12 Marshall cabinet (1960BV model) with Celestion G12 Vintage 30 speakers and was captured with a Sennheiser MD421 dynamic microphone. Some recordings were made with an additional boosting pedal (Fulltone OCD). All files were exported using the normalisation function. Differentiating between open and palm-muted sounds, ultimately 287 recordings were created; 140 of a single guitar, 75 of two guitars, 40 of four guitars and 32 with different miking.

## Metal guitar sounds

*Distortion*

The defining sonic phenomenon of the metal guitar is distortion. A number of elements distort the signal: String vibration, pickups, cables, effects pedals, preamplifier and power amplifier tube distortion, speaker distortion, and microphone choice and placement (Berger and Fales 2005: 184). A reason little known for the electric guitar's distinct sound is the inherent inharmonic spectrum of the strings that is created by its bending stiffness and winding (Zollner 2014: 222ff). Frequency content a few hertz apart from the fundamental note and its partials produces periodic "pseudo noise" creating a rough impression. The pickups' windings and amount of coils alter the basic signal before entering the amplifier. Overdrive, distortion and fuzz pedals may be added to increase the voltage gain or to produce transistor clipping. Tube distortion is achieved when the signal is amplified beyond the capability of fidelity reproduction. The signal is pushed against the power supply causing clipping and resulting in a modified waveform (Doyle 1993: 56). The edges are rounded off by the power valves and output transformer, predominantly intensifying even harmonics that add warmth and presence (Doyle 1993: 57). Pushing the signal against a barrier enhances noise, adds harmonic and inharmonic overtones, and produces a flatter dynamic envelope of a more complex waveform (Gracyk 1996: 111ff). The timbre becomes noisier, rougher, more compressed and present. The speaker further alters the sound as it functions as a mechanical filter reproducing frequency mainly between 75 and 5,000 Hz (Einbrodt 1997: 198). Speakers compress the sound since the stiffness of the cone prevents reproducing the full dynamic range (Chappell 2010: 54). The speaker breakup at the edge of the cone further contributes to distortion (Williams 2015: 49f). The cabinet also affects the sound; open boxes are sounding ambient and closed ones are having more low-end (Chappell 2010: 38).

*Heaviness*

The potential of the guitar as a main distinguishing element of metal genres grounds from its perception of "heaviness". As Berger (1999: 58) notes, the history of metal is characterised "as a progressive quest for ever-heavier music". Although such heaviness is subject to individual perception, diverse understandings within music scenes and structural elements, the characteristic guitar timbres associated with metal genres must be considered with special care. One necessity for heaviness is the right frequency spectrum. Low frequencies provide the powerful sonic weight, and sculpting it for retaining transparency and note definition is challenging (Mynett 2012). High frequencies are of equal importance because they contribute to aggressiveness. Berger and Fales (2005) observed the energy cut-off of guitars to have risen from around 5 kHz in the 1970s to 8.3 kHz in the 1990s, and they concluded high frequency energy to correlate with perceived heaviness. Two further elements determining heaviness are distortion (Berger and Fales 2005; Mynett 2013) and high volumes (Walser 1993: 45; Weinstein 1991: 23; Williams 2015) as a result of distortion's compression effect. Distortion "simulates the conversion of the guitar from an impulsive to a sustained or driven instrument, and this transformation may be part of the acoustic correlate to the perceptional experience of heaviness" (Berger and Fales 2005: 194). Structurally, the power chord contributes to heaviness because distortion intensifies difference tones one octave below the root. Hence, distortion extends the guitar signal in the highs and lows (Walser 1993: 43), which makes it the central factor of heaviness.

*Production*

Producing metal guitars is subject to a set of genre-specific conventions. Dynamic microphones are common for recording guitar sounds because they tolerate high sound pressure levels (Chappell 2010: 56ff). The microphone's distance to the speaker is important for a number of reasons. Close miking increases the intensity of the bass frequencies due to the proximity effect (Hall 1980: 384f); hence, the right distance is necessary for a defined low-end (Mynett 2009a: 132f). Furthermore, close miking minimises the perceived distance to the sound source contributing to a direct sound (Bartlett and Bartlett 2009: 105). Adjusting the microphone to the speaker cone is of equal relevance. Pointing at the centre of the cone intensifies the higher frequencies; off-centred microphones are capturing more middle and bass frequencies (Bartlett and Bartlett 2009: 125). Another important element of metal productions is the number of guitar tracks. Provided that the rhythm is accurate and synchronous, doubling results in a thicker sound due to enhanced frequency coverage (Mynett 2012) and wider stereo image (Hamidovic 2015: 61). Conventionally, the tracks are panned to the stereo channels to maximize the transparency and size of the production (Mynett 2013: 51).

After recording the tracks, fine-tuning aims at balancing the frequencies with the other instruments to increase intelligibility (Izhaki 2013: 5) and to shape the guitar sound beyond "real" performances. Equalising is necessary as distorted guitars cover a frequency range of more than five octaves beginning at around 60 Hz (Izhaki 2013: 256). Mynett (2009b: 120ff) and Hamidovic (2015: 57) suggest using a high-pass filter between 65, 105 or even 140 Hz to make space for the bass instruments. With regard to particular frequency areas, the *mid bass* range (60-120 Hz) is associated with power and boosting it may enhance the thumping sound of the cabinet (Hamidovic 2015: 63). The *upper bass* (120-250 Hz) contains most fundamental notes of the rhythm guitar in standard tuning and some resonance of the cabinet. It also contributes to power. Containing the first partials, the *lower mids* (250-1,000 kHz) are decisive for the instrument's timbre but they may hinder transparency (Izhaki 2013: 256). According to producer Colin Richardson the *mid* frequency area (1-2 kHz) is vital for the "in your face effect" (Taylor 2011). The *high mids* (2-4 kHz) are responsible for volume, definition and presence (Izhaki 2013: 266). The *lower highs* (4-6 kHz) are necessary for contributing definition and intelligibility while also ensuring closeness and directness (Mynett 2012). The *highs* (6-10 kHz) mainly contain high-order partials and noise that hold the risk of reducing intelligibility when being attenuated (Hamidovic 2015: 63). The *air* area (10-20 kHz) mostly contains noise and some edge (Izhaki 2013: 256).

Since distortion reduces dynamics, many metal producers like Richardson refrain from adding compression to the mix (Martinelli 2008). Others like Andy Sneap utilise multiband compressors to prevent the low-end build-up produced by palm-muting with a bass-heavy sound (Hamidovic 2015: 59). Adding overdrive pedals is another trick to increase intelligibility (Mynett 2009a: 132f). As Richardson explains, they "tighten the whole sound up. There's a certain place where you've got to wind the pre-amp up to get the gain, and putting the Tube Screamer on allows you to use a little bit less gain. When you're tuning in E, this isn't so necessary, but when you're down to B, or C, or C sharp, it seems to put it all together" (Martinelli 2008).

## Historical development of metal guitar sounds

When metal emerged around 1970, the standard guitar models Stratocaster, Les Paul and SG were already available. More specialised models were introduced in the 1980s. Manufacturers like Marshall were already in business, so that early metal guitarists had access to amplifiers designed to produce distortion. During the 1970s, tonal control of the amplifiers was improved by the extension of equalisation, adjustable pre-gain stages, and presence and resonance controls (Herbst 2016: 36). The rack systems of the 1980s allowed combining different preamplifiers and power amplifiers. Until the mid-1990s, it was difficult to find amplifiers like the Peavey 5150 that produced the desired heaviness within the spreading extreme metal genres (Martinelli 2008). In the last 20 years, the number of amplifiers designed for metal has vastly increased.

In early stages of metal production, analogue multi-tracking with 16 to 24 tracks and suitable microphones existed. Unlike many other genres that value analogue equipment, metal has flourished by the chances of digitalization, and metal producers like Sneap (Martinelli 2006) and Richardson (Taylor 2011) have embraced the potential of technological innovations. Not only was the clarity improved, the extended disk space allowed extensive layering of tracks, and digital effects helped to manipulate the material (Williams 2015). Contrary to the movement towards digitalization in metal production, most metal guitarists continued relying on traditional tube amplifiers (Herbst 2016: 78ff). Potential reasons are the musicians' wish to maintain the traditional values of rock culture regarding authenticity (Moore 2002: 219) or the sonic benefits of the analogue technology of guitar equipment (Doyle 1993: 56f).[i] Against the backdrop of the developments of guitar technology, studio devices and techniques discussed, a comparative analysis of original recordings will now track changes of the metal guitar sound from 1970 to 2015.

*Tuning*

Tuning down the guitar is highly effective to extend its low-end, darken the timbre and gain power (Mynett 2013: 44). The fifty sample tracks reveal that down-tuning has been uncommon until death metal spread in the 1990s. These findings are surprising since Black Sabbath already experimented with this technique in 1971 to produce "a bigger, heavier sound" (Iommi 2012: 94). In the sample of 1970s proto metal, only Sabbath's "Into the Void" (1971) has an alternative tuning. Differences in band tunings explain some variability in the 1980s classic heavy metal sample. Six recordings are in standard tuning, three are tuned down a semitone and one two semitones. Thrash metal in the 1990s merely differs from heavy metal as seven tracks are in standard tuning and three are tuned down between one and three semitones. A significant change occurred in the 2000s death metal sample. It contains tunings between three and five semitones below standard, most of them around C or B. An indication for this trend being time-related rather than genre-related is that most death metal (e. g. Bolt Thrower, Cannibal Corpse) and grindcore (e. g. Napalm Death) bands of the 1990s tuned down between one and three semitones. A rare exception was Carcass using B tunings. Consequently, the trend continued with tunings of the 2010s modern extreme metal sample revolving between B and Ab. Tuning down the instrument is lowering the fundamental frequency from 82 Hz (E) to 52 Hz (Ab), which not only affects the guitar sound immensely, but also forces the bass guitar to move down as well.

*Loudness*

The loudness of vinyl recordings in the 1970s and early 1980s was limited because of the analogue technology. Digital mastering since the mid-1980s enabled louder records with more compression. As loudness is one of the defining characters of metal (Williams 2015: 57), the increasing volume from 1970s proto metal to modern extreme metal is hardly surprising (Table 1). Similar to tuning, the major changes occurred in the 2000s when the options of digital recording extended rapidly. The small volume differences between 1970s and 1990s recordings may result from the remastering of 1970s and 1980s releases that are distributed nowadays. The lower loudness of modern extreme metal (2010s) compared to 2000s death metal may indicate that the "loudness war" in metal (Williams 2015) could be over.

*Table 1: Average loudness (RMS) of isolated guitar tracks of original metal recordings*

| | Proto metal (1970s) | Classic heavy metal (1980s) | Thrash metal (1990s) | Death metal (2000s) | Modern extreme metal (2010s) |
|---|---|---|---|---|---|
| Average RMS and standard deviation | −16.99 dB<br>2.93 | −14.85 dB<br>3.14 | −13.75 dB<br>2.22 | −9.90 dB<br>2.00 | −10.39 dB<br>1.10 |
| Difference to proto metal (1970s) | | 2.14 dB | 3.24 dB | 7.09 dB | 6.60 dB |

### *Layering of guitar tracks*

The sample shows a clear trend regarding the number of rhythm guitar tracks in metal history. Most 1970s proto metal recordings contain two guitar tracks that are panned to the sides of the stereo channels. Some Deep Purple songs differ from that convention as one guitar is substituted by a rock organ. Within all heavy metal tracks of the 1980s, two tracks are standard. Most thrash metal recordings of the 1990s share this convention. According to listening impression, Iron Maiden, Annihilator and Forbidden are exceptions; their productions are characterised by a particularly heavy guitar sound at that time. It is also worth noting that some 1980s productions (Accept, Running Wild, Saxon) have thick layers of reverb on the guitar tracks that increase the instruments' density while negatively affecting its intelligibility. In 2000s death metal and modern extreme metal four rhythm guitar tracks seem required for fulfilling the criteria of heaviness. However, determining the actual number of tracks proved to be difficult; some recordings might even contain more than the standard four guitars.

From the very beginning, metal artists have experimented with the number of guitar tracks as an effect. Many of the sample recordings contain isolated guitar parts with a reduced number of tracks on one of the stereo channels in intros and breaks. When the guitar enters the second stereo channel, the impression of a "wall of sound" is emphasised.

### *Spectral features*

Heaviness is defined mainly by spectral features (Berger and Fales 2005; Mynett 2012, 2013). Table 2 and Figure 1 provide numerical and graphical overviews of the spectral characteristics of the guitars of the genres. To increase the comparability, ratios between the frequency groups will be discussed in particular because they allow comparing spectral compositions. Absolute values have been normalized for better comparability. The upper bass (120-250 Hz) was set as reference value because it contains the fundamental notes in standard tuning.

Comparing the spectral development reveals clear trends. The mid bass (60-120 Hz) has increased in relation to the upper bass. In compliance with the listening impression, the major expansion of the low-end occurred from 1980s heavy metal to 1990s thrash metal, and even more from 2000s death metal to modern extreme metal. The lower mids (250-1,000 Hz) and mids (1-2 kHz) are much more relevant in proto and heavy metal than in genres that are more recent. The trend to scoop out the mids for increased heaviness might be the reason (Mynett 2013: 45f). This aesthetics started in the 1980s when in heavy metal the intensity of the lower mids declined, both in relative ratios and in absolute values. However, some early recordings like Black Sabbath's "Into The Void" (1971) or Saxon's "Never Surrender" (1981) already have a scooped sound similar to later productions (Figure 2). The percentages of the higher mids (2-4 kHz) and lower highs (4-6 kHz) are similar in all genres except for 1980s heavy metal, which seems to focus on these frequency ranges. Comparing proto and heavy metal indicates that the first changes in guitar aesthetics were not an emphasis on the low-end but a slight mid-scoop as well as an extension of the higher mids and lower highs. This complies with Berger and Fales (2005) observation of an increasing heaviness through intensified treble frequencies. The highs (6-10 kHz) remained nearly unchanged while the importance of air (10-20 kHz) has significantly decreased in the last fifty years. The high standard deviations, however, indicate different aesthetics within the genres' high to air area, especially in productions of the 2000s and 2010s. That limitation in mind, a general guideline for a contemporary metal guitar sound is to focus on the mid and upper bass by combining a low tuning, a powerful amplifier and a big to oversized speaker cabinet, and to shape the frequency curve in a progressive decline. Presence is not as prominent as in heavy or thrash metal for not to brighten up the sound too much, which would lessen the bass-heavy impression. Nonetheless, the primary partials (energy cut-off 1, see below) are loud due to high distortion levels. The sound is less scooped but generally shifted downwards.

With regard to the consistency of idiomatic guitar sounds within the subgenres, the standard deviations of the frequency groups are conclusive. The high values within 1970s proto metal demonstrate that the sounds differ between the recordings and bands. 1980s heavy metal seems to be more formulaic than 1990s thrash metal. Due to the high standard deviations within some frequency groups, there potentially is overlapping between the thrash, death and modern extreme metal sounds. Since the 2000s, productions vary greatly in their intensity in the highs and air areas. Consequently, the difference between the genres compared to 70s proto metal reveals the highest standard deviation in the air, followed by the upper and mid bass due to the great differences between 1970s / 1980s and more contemporary guitar sounds.

*Table 2: Development of metal guitar sounds from 1970 to 2015*

| | | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs | Air | Energy cut-off 1 | Energy cut-off 2 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Proto metal (1970s) | M | −40.29 | −35.09 | −39.39 | −47.03 | −47.49 | −60.02 | −76.02 | −89.34 | 4.66 | 8.20 |
| | SD | 7.54 | 4.59 | 3.61 | 6.45 | 4.08 | 5.97 | 7.21 | 4.75 | 0.48 | 1.38 |
| | Ratio | 87% | 100% | 89% | 75% | 74% | 58% | 46% | 39% | | |
| Classic heavy metal (1980s) | M | −39.40 | −34.71 | −41.99 | −44.34 | −42.41 | −53.21 | −75.84 | −95.18 | 5.43 | 13.31 |
| | SD | 3.58 | 2.11 | 3.77 | 2.11 | 3.30 | 3.41 | 5.83 | 7.39 | 0.44 | 2.94 |
| | Ratio | 88% | 100% | 83% | 78% | 82% | 65% | 46% | 36% | | |
| Thrash metal (1990s) | M | −33.83 | −31.38 | −43.03 | −46.34 | −42.69 | −55.56 | −73.62 | −96.70 | 5.32 | 14.23 |
| | SD | 5.00 | 3.14 | 4.53 | 3.66 | 5.00 | 6.05 | 6.26 | 6.06 | 0.51 | 3.62 |
| | Ratio | 93% | 100% | 73% | 68% | 74% | 56% | 43% | 32% | | |
| Death metal (2000s) | M | −32.95 | −30.01 | −41.59 | −45.66 | −42.02 | −51.16 | −71.88 | −100.95 | 5.99 | 14.42 |
| | SD | 4.85 | 2.18 | 4.07 | 4.87 | 1.11 | 3.14 | 6.50 | 13.93 | 1.17 | 3.61 |
| | Ratio | 91% | 100% | 72% | 66% | 71% | 59% | 42% | 30% | | |
| Modern extreme metal (2010s) | M | −32.05 | −31.62 | −42.65 | −44.59 | −45.09 | −53.04 | −73.85 | −105.81 | 6.45 | 12.40 |
| | SD | 4.20 | 2.41 | 2.43 | 1.76 | 2.39 | 5.24 | 7.42 | 12.05 | 1.49 | 3.03 |
| | Ratio | 99% | 100% | 74% | 71% | 70% | 60% | 43% | 30% | | |
| Difference to proto metal | Classic | 0.89 | 0.38 | −2.60 | 2.69 | 5.08 | 6.82 | 0.18 | −5.85 | 0.77 | 5.11 |
| | Thrash | 6.46 | 3.70 | −3.63 | 0.69 | 4.80 | 4.47 | 2.40 | −7.37 | 0.66 | 6.03 |
| | Death | 7.35 | 5.07 | −2.20 | 1.37 | 5.47 | 8.86 | 4.14 | −11.62 | 1.33 | 6.22 |
| | Modern | 8.24 | 3.46 | −3.26 | 2.44 | 2.40 | 6.98 | 2.17 | −16.47 | 1.79 | 4.20 |
| | *SD* | *2.87* | *1.72* | *0.56* | *0.81* | *1.20* | *1.56* | *1.41* | *4.13* | *0.45* | *0.80* |

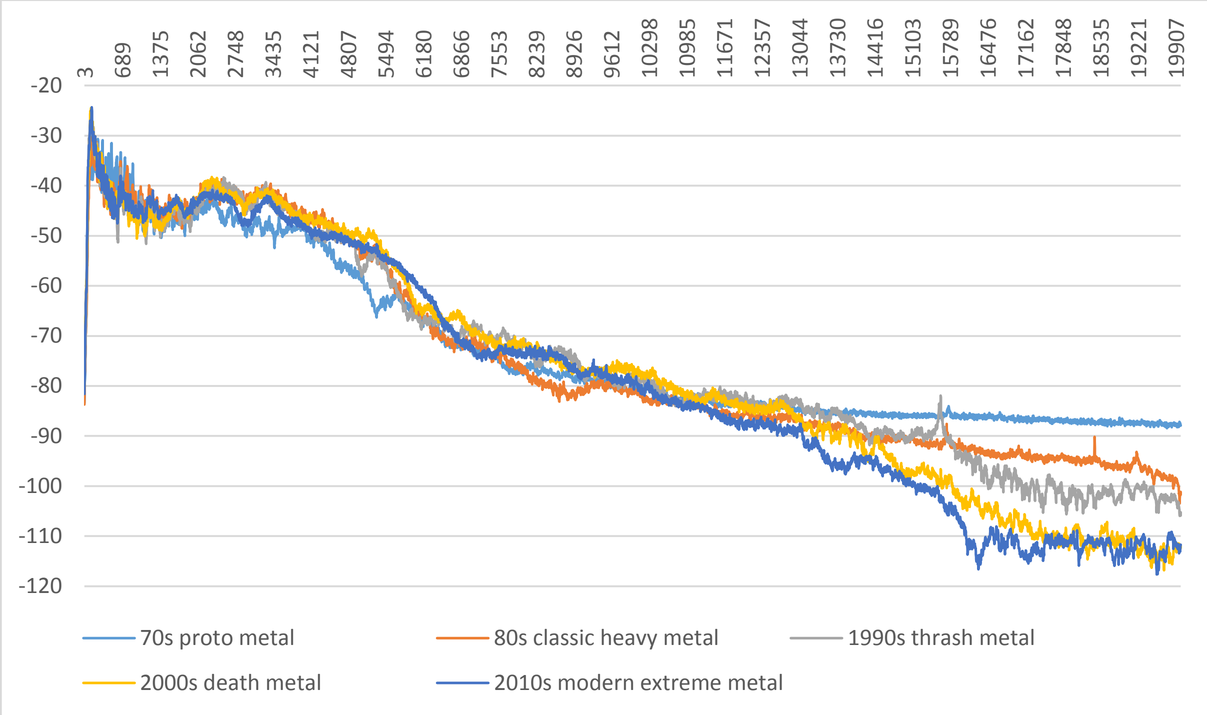


*Figure 1: Average frequency curves of the genres.*

A central criterion of heaviness in Berger and Fales (2005) exploratory study was the energy cut-off. Most recordings of the present study have two cut-off areas regardless of genre belonging. The first cut-off marks the end of the fretted notes and primary partials, the second marks the fading of the quieter upper partials. Some recordings only have one clear cut-off, which could result from excessive limiting. Overall, the sample does not support Berger and Fales (2005) finding that in early metal productions the guitars' frequency ends abruptly, contrary to a gradual fading in later releases. In 1970s proto metal, the main frequency range stops around 4.66 kHz, which is slightly lower than the reproduction capability of most guitar speakers. Over the fifty years, the main frequency spectrum has extended by almost 40% to 6.45 Hz, although with an increasing variance. The second cut-off frequency has increased even more, however, not linear. The biggest extension was from 1970s proto to 1980s heavy metal by 60%, from 8.20 to 13.31 kHz. Heavy, thrash and death metal hardly vary; modern extreme metal shows a slight decrease in high-energy content.

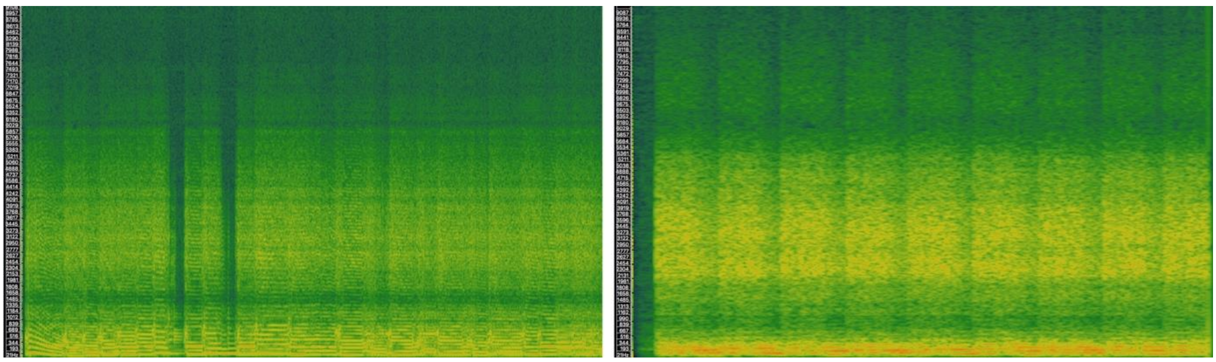

*Figure 2: Scooped sound in Black Sabbath's (1971) "Into The Void" (left) and Deeds of Flesh's (2003) "Disintered Archaic Heap" (right); 2048 window; 21-9,000 Hz.*

## Experimental exploration of production techniques

The historical analysis has demonstrated major changes in metal guitar sound aesthetics. Many of today's metal productions require highly professionalised routines to keep developing the quality and heaviness of the guitar sound. Engineers and producers can draw upon production manuals (Owsinski 2006; Izhaki 2013) that provide general guidelines. Beyond printed literature, advice is available in online music production forums. Nonetheless, hardly any professional literature on metal production exists (Mynett 2013). Rather than trying to present formulas, the experimental exploration will investigate the effectiveness and effect of various production techniques as an orientation for creating the desired sounds. The focus is on the deviation that can be achieved (Table 3) along with qualitative changes in the spectrum.[ii]

*Table 3: Standard deviation of gear choice, playing techniques and miking on frequency*

| Sound | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs | Average SD |
|---|---|---|---|---|---|---|---|---|
| Guitars (n = 20) | 0.26 | 0.30 | 0.09 | 0.10 | 0.07 | 0.21 | 0.26 | 0.19 |
| Amplifiers (n = 20) | 1.63 | 0.59 | 1.52 | 1.65 | 2.10 | 2.43 | 2.52 | 1.78 |
| Playing technique (n = 10) | 0.96 | 0.39 | 1.91 | 3.94 | 5.36 | 6.02 | 5.89 | 3.50 |
| Equaliser (n = 20) | 0.63 | 0.31 | 2.60 | 2.34 | 0.61 | 0.25 | 1.05 | 1.11 |
| Overdrive pedal (n = 20) | 1.95 | 0.39 | 1.60 | 3.14 | 3.46 | 4.28 | 7.86 | 2.57 |
| Distortion level (n = 80) | 2.10 | 1.30 | 1.06 | 1.86 | 2.90 | 3.41 | 4.85 | 2.50 |
| Microphone direction (n = 12) | 0.21 | 0.12 | 0.44 | 1.09 | 1.63 | 1.80 | 4.50 | 1.40 |
| Microphone distance (n = 20) | 0.74 | 0.38 | 0.97 | 0.35 | 0.84 | 2.59 | 2.65 | 1.21 |

### *Guitars*

The small standard deviation of 0.19 indicates that different guitars are the least effective variable for increasing frequency coverage. The largest variance between the Stratocaster and the Les Paul is in the bass and treble registers. Without the averaging effect of the frequency groups, Figure 3 displays that both guitar models do not fundamentally differ. In compliance with the experimental studies of Einbrodt (1997) and Herbst (2016), the distorted Les Paul produces more overtones, which results in a greater intensity above 2 kHz. More distortion also leads to an assimilation of both models (Einbrodt 1997: 141). Yet, the guitars react differently to distortion level ($SD = 0.70$), with greatest effect in the middle and upper bass, lower highs and highs.

Interpreting the small effect of different guitars needs considering a number of aspects. To begin with, the attack phase is not represented adequately, which is crucial for the distinct percussiveness of the Stratocaster compared to the mellow sound of the Les Paul (Jauk 2007: 282f). Moreover, the Les Paul is 4 to 5 dB louder in the bass and treble registers while the Stratocaster is more dominant in the 200 to 600 Hz area. Since 6 dB are perceived as twice as loud (Hall 1980: 114), these differences do result in distinguishable sounds that contribute to dimensionality of the sonic wall of guitar. It also must be noted that due to methodical reasons the effectiveness of the other variables (Table 3) is greater than the guitar because they produce changes with a greater bandwidth. The instruments' formants are much subtler, and differences in the first six to eight partials affect the guitar sound considerably (Roederer 1973: 128).

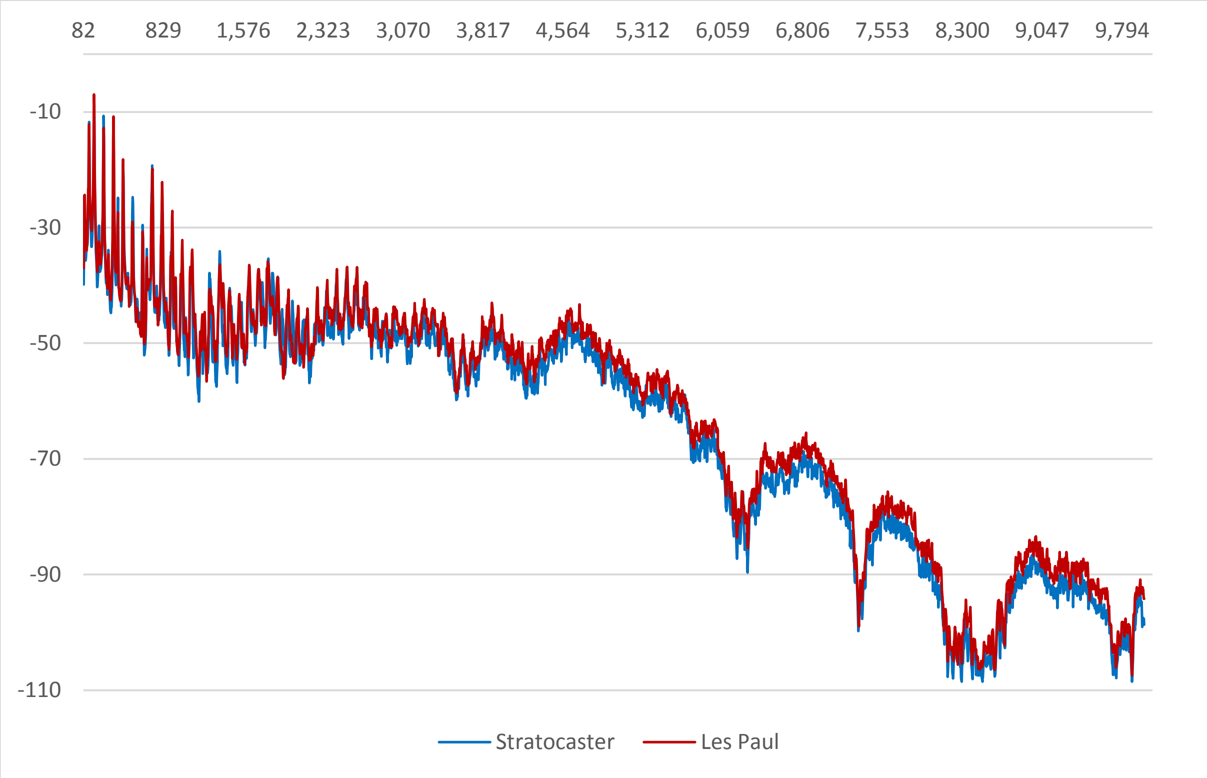


*Figure 3: Frequency response of a Stratocaster and a Les Paul guitar with a medium distorted sound.*

### *Amplifiers*

With a standard deviation of 1.78, combining different amplifiers is an effective way to shape the sound of the guitar and to enhance frequency density. The results reveal amplifiers to differ increasingly in higher frequencies. Furthermore, the devices vary in the mid bass area, which is important for the low-end of contemporary metal sounds. This variance yet is mainly a result of the Peavey 5150 model with its bass-laden sound. The upper bass hardly varies. As the ratios show, the lower mids differ considerably, which may be explained by the frequency reduction between 200 and 500 Hz as a characteristic feature of amplifier models and manufacturers (Lemme 1995: 34).

*Table 4: Spectral features of amplifiers*

| Amplifier model | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| Laney | −35.51 | −28.35 | −42.86 | −51.59 | −55.17 | −67.51 | −95.99 |
| | 80% | 100% | 66% | 55% | 51% | 42% | 30% |
| Marshall | −33.30 | −27.40 | −44.06 | −52.50 | −54.36 | −65.42 | −93.90 |
| | 82% | 100% | 62% | 52% | 50% | 42% | 29% |
| Mesa | −34.71 | −28.89 | −39.85 | −49.76 | −55.23 | −68.20 | −97.08 |
| | 83% | 100% | 72% | 58% | 52% | 42% | 30% |
| Orange | −35.56 | −29.04 | −41.12 | −52.18 | −57.31 | −68.69 | −95.52 |
| | 82% | 100% | 71% | 56% | 51% | 42% | 30% |
| Peavey | −31.24 | −28.79 | −40.78 | −48.14 | −50.88 | −62.06 | −89.86 |
| | 92% | 100% | 71% | 60% | 57% | 46% | 32% |
| SD | 1.63 | 0.59 | 1.52 | 1.65 | 2.10 | 2.43 | 2.52 |

### *Playing technique*

Although open and palm-muted playing depends highly on the composition, with a standard deviation of 3.50 playing technique is very effective for controlling the sound (Table 5). As with most variables, the upper bass is affected least, but palm-muting can effectively improve the low-end bass. In combination with the reduced middle and treble frequencies, a powerful sound can be achieved.

*Table 5: Spectral features of playing technique*

| Sound | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| open | −35.02 | −28.88 | −39.83 | −46.89 | −49.23 | −60.35 | −88.58 |
| | 82% | 100% | 73% | 62% | 59% | 48% | 33% |
| muted | −33.11 | −28.10 | −43.64 | −54.77 | −59.95 | −72.40 | −100.37 |
| | 85% | 100% | 64% | 51% | 47% | 39% | 28% |
| SD | 0.96 | 0.39 | 1.91 | 3.94 | 5.36 | 6.02 | 5.89 |

*Equaliser and overdrive pedal*

Equalising and adding an overdrive pedal to the signal are common techniques to shape the guitar sound. Both effects were compared to the original recording. The EQ was set to slightly scoop the sound by boosting 100 Hz (+5 dB; Q 0.60), cutting the mids around 850 Hz (−4 dB; Q 0.30), and intensifying the highs around 4 kHz (+3.5 dB; Q 0.64). The overdrive pedal had volume on 6, drive on 3, tone on 5.5, and high pass selected. The equaliser had a medium overall effect (*SD* = 1.11) and altered ratios by ca. 4-5% (Table 6). By comparison, the overdrive pedal had a large effect (*SD* = 2.57) altering the ratios by 7-8%. By decreasing the low-end and considerably boosting the middle and higher frequencies, the pedal improved note definition and intelligibility.

*Table 6: Effect of equaliser and overdrive pedal compared to original sound*

| Sound | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| Original | −34.06 | −28.49 | −41.73 | −50.83 | −54.59 | −66.38 | −94.47 |
| | 84% | 100% | 68% | 56% | 52% | 43% | 30% |
| Equaliser | −32.81 | −29.11 | −46.93 | −55.52 | −55.81 | −66.88 | −96.56 |
| | 89% | 100% | 62% | 52% | 52% | 44% | 30% |
| Overdrive pedal | −37.97 | −29.27 | −38.54 | −44.55 | −47.67 | −57.81 | −78.75 |
| | 77% | 100% | 76% | 61% | 61% | 51% | 37% |
| SD original and EQ | 0.63 | 0.31 | 2.60 | 2.34 | 0.61 | 0.25 | 1.05 |
| SD original and overdrive | 1.95 | 0.39 | 1.60 | 3.14 | 3.46 | 4.28 | 7.86 |

*Distortion level*

Setting the optimal distortion level is crucial for heaviness and transparency. With a standard deviation of 2.50, the gain also effectively modifies the sound. The results indicate that increasing distortion levels in the same amplifier channel tends to scoop the mids (Table 7). Creating heavy distortion with additional pedals results in a slightly different, less scooped sound that is rather focused on the middle frequency groups with less low-end and more treble.

*Tab 7: Ratios of different distorted sounds*

| | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| Crunch | 78% | 100% | 81% | 69% | 63% | 52% | 39% |
| Medium distortion | 79% | 100% | 78% | 68% | 63% | 52% | 39% |
| Heavy distortion amp | 81% | 100% | 75% | 66% | 63% | 53% | 39% |
| Heavy distortion pedal | 79% | 100% | 79% | 71% | 67% | 54% | 41% |

Similar to the guitars, the distortion level changes the variance between amplifier models (Table 8). More distortion reduces the distinctive features of amplifiers in many frequency groups like the mid bass, higher mids, lower highs and highs. More deviation is only possible in the lower mids where most amplifiers have their distinctive mid-cut. The amplifiers also seem to be affected differently by distortion; this may explain why some models are better suitable for much distorted sounds. Moreover, the models differ mainly in the low-end and higher frequencies when boosted by a pedal.

*Tab 8: Deviation between amplifiers with regard to distortion*

| Sound | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs | Average SD |
|---|---|---|---|---|---|---|---|---|
| Crunch | 2.97 | 1.65 | 0.85 | 2.47 | 3.87 | 3.84 | 3.75 | 2.77 |
| Medium distortion | 1.48 | 0.97 | 0.55 | 1.62 | 2.45 | 2.62 | 2.64 | 1.76 |
| Heavy distortion amp | 0.76 | 0.85 | 1.60 | 1.17 | 0.80 | 0.71 | 0.71 | 0.94 |
| Heavy distortion pedal | 1.41 | 0.78 | 0.73 | 0.97 | 1.52 | 4.18 | 2.08 | 1.67 |

### *Miking*

Although easy to neglect, miking can hugely affect the guitar sound. Using various microphone distances shapes the sound considerably (Table 9). Moving the microphone away from the speaker reduces the low-end linearly. Regarding the proximity effect, the ratios show that an increase of bass frequencies up to 15 dB, as claimed in studio literature (Albrecht 2010: 23), is likely to be unrealistic. With more distance, the frequency curve increases from the lower mids upwards. Ambience is better captured (Bartlett and Bartlett 2009: 105); it makes the sound less artificial but reduces the directness required for heavy guitars (Mynett 2012).

*Tab 9: Effect of microphone distance*

| | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| 1 cm | 81% | 100% | 69% | 76% | 73% | 59% | 33% |
| 5 cm | 80% | 100% | 69% | 77% | 76% | 63% | 34% |
| 10 cm | 79% | 100% | 70% | 78% | 78% | 67% | 35% |
| 15 cm | 78% | 100% | 72% | 79% | 80% | 69% | 36% |
| 20 cm | 77% | 100% | 73% | 79% | 80% | 70% | 36% |

The microphone position is more common in studio literature (Albrecht 2010; Bartlett and Bartlett 2009). Altering the position affects frequencies beginning with the lower mids while leaving the low-end unaltered (Table 10). The overall effect of positioning (*SD* = 1.40) is similar to the distance (*SD* = 1.21) but affects the frequency groups differently. Hence, a mixture of both improves control over the intended sound.

*Tab 10: Effect of microphone position*

| | Mid bass | Upper bass | Lower mids | Mids | Higher mids | Lower highs | Highs |
|---|---|---|---|---|---|---|---|
| Centre | 81% | 100% | 69% | 76% | 73% | 59% | 33% |
| Between Centre and Cone | 81% | 100% | 70% | 75% | 72% | 58% | 30% |
| Cone | 81% | 100% | 71% | 72% | 68% | 56% | 28% |

### *Layering*

The historical analysis has shown the increasing number of guitar tracks as a central element of contemporary metal guitar sounds. Methodically, it is difficult to capture the layering effect with analytic tools (Herbst 2016: 228ff). Varying guitars, amplifiers and sounds only led to small average standard deviations for doubling (*SD* = 0.21) and quad-tracking (*SD* = 0.19). Even the detailed spectrogram (Figure 4) fails to capture all distinctive features of the wall of sound. For both the open and palm-muted recordings it demonstrates less defined partials in the area between 500 and 5,000 Hz in the quad-tracked recording. With an increasing number of tracks, there may be periodic noise accompanying the partials (Zollner 2014: 222ff). This suggests that reduced definition and extended ambience contribute to heaviness. Regardless of playing technique and in line with the exemplary spectrograms, the differences in the quad-tracked recordings lie in the increased mid bass, high mids, lower highs and highs. For power chords, the effects are even larger but more difficult to spot in a spectrogram (no Figure). These findings demonstrate a tendency of more tracks leading to a scooped sound, which complies with the scooping tendency of higher distortion levels observed before. In addition, the fretted notes of the two-track recording, without taking into account the number of tracks, appear more dynamic so that the greater compression of more tracks may be a contributing factor of heaviness as concluded by Berger and Fales (2005: 194).

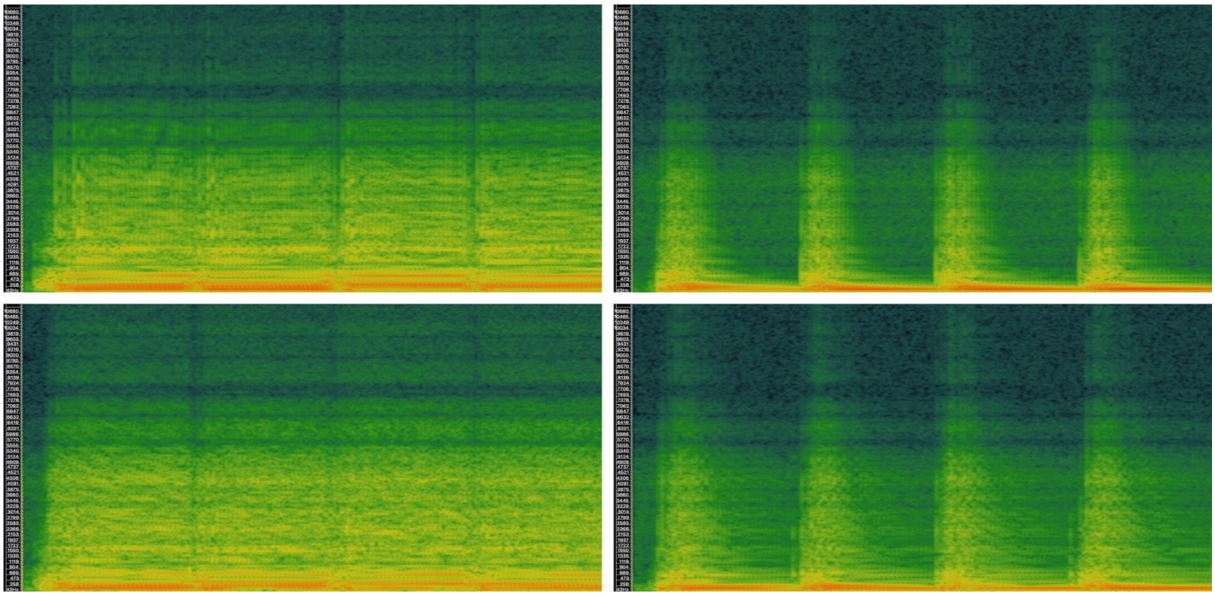

*Figure 4: Comparison of double and quad tracking. Top: two tracks Les Paul with Laney amplifier; bottom: two tracks Les Paul with Laney and two tracks Stratocaster with Marshall amplifier; left: eighth-notes open E2 string; right: eighth-notes palm-muted E2 string. 1024 window; 43-10,700 Hz.*

The spectrographic inspection could not detect rhythmic irregularities of double and quad tracked recordings. Nonetheless, these unavoidable small variations must be considered a crucial element of the heaviness of layered guitars. Whereas combining different kinds of equipment results in greater frequency coverage making the signal larger in the vertical dimension, slightly varying rhythmic phrasing extends the duration of the phenomenon in the horizontal dimension. If the performances are similar enough not to be perceived as asynchronous tracks, the sound is felt as a single entity (Albrecht 2010: 47) with more heaviness and less definition. The tempo, playing technique, structure and stereo separation determine when asynchronous playing becomes apparent.

It is a matter of personal preference whether the sounds on each stereo channel should be different. Similar sounds create a balanced impression that is beneficial for the wall of sound. Different sounds may not provide this effect to the same degree, yet they add a vertical dimension to the stereo width. For example, separating a Stratocaster and a Les Paul guitar, or a bass-heavy and a presence-rich amplifier, to the stereo channels creates a diagonal spatial impression. This technique produces a real stereo sound rather than what Owsinski (2006: 21f) describes as “big mono”, a sound with pseudo-stereo sources panned to the sides.

## Synopsis and conclusion

Creating a heavy guitar sound is vital for the powerful effect of many metal genres. This study confirms the still ongoing quest for ever-heavier guitar sounds (Berger and Fales 2005). Innovations in guitar equipment and studio technology as well as structural changes have contributed to different guitar aesthetics in fifty years of genre history. Each genre and decade has an individual sound, yet there are some general trends. Proto metal of the 1970s stood for experimentation, and the sounds can be ascribed to a band rather than to a genre. Classic heavy metal of the 1980s already had a distinctive metal sound but yet different from most of the later recordings of the sample. Compared to proto metal, the energy cut-offs were substantially higher for more aggressiveness, and despite the intensive middle range, classic metal guitarists already started scooping the sound. 1990s thrash metal marked a substantial change in metal guitar history. Although still relying on early metal conventions like standard tuning and two guitar tracks, the sound had considerably more low-end, less mids and more distortion making it heavier than most metal before. Extreme metal of the last fifteen years continued to extent the bass range by using lower tunings along with seven string guitars, new amplifiers and more track layering. It further developed the metal guitar sound by exploiting heaviness while combining traditional practices with new production techniques.

The experimental part of the study closer investigated production techniques. It demonstrated how the instrument's sound could be shaped by equipment and production choices to improve frequency coverage for a dense sound, or to achieve the desired balance between the frequency groups. Even though the basic techniques have hardly changed since early metal, producing a contemporary metal guitar sound requires much balancing at the recording and mixing stages due to the high expectations within the genre and the powerful amplifiers having to be tamed. Focussing on the low-end only is likely to lead to muddiness and lack of power. Although the study cannot provide a formula or replace experience, the results may be a starting point for advancing artists helping them to produce the sound of one of the subgenres discussed, to fix problems, or to shape the sound to the desired direction. Depending on the song and intended sound aesthetics, for instance, it may be more effective recording with a less bass-heavy amplifier, and deliberately setting the microphone position and distance to get the warmth without the amplifier's characteristic emphasis on the bass range; or combining a bass-heavy device with an overdrive pedal and to equalise the missing spectral content. All these combination possibilities and their special effects interrelate with layering. At this point, academic study on guitar production has reached its limit, and individual experimentation must begin.

As Williams (2015: 61) noted, "timbral measurement of specific guitar-related timbres for metal" is a field of research that has been hardly studied so far (Mynett 2009a, 2009b, 2012, 2013). Similarly, only a few production manuals include metal genres (Chappell 2010; Hamidovic 2015). Research and production literature are based mainly on practical experience or are exploratory with small case numbers (Berger and Fales 2005; Williams 2015). The present study contributes to research by providing insights into the development of the metal guitar sound based on a greater sample size, bigger time-span, and more variables such as frequency groups, ratios, tuning and layering. In addition, the experimental investigation makes the first attempt to establish an empirical ground useful for guitarists, engineers and producers. The academic field of metal music studies may benefit from the deeper understanding of the issue, as well as from the acoustic evidence for theoretical and practice-based research, and a new methodical approach for studying metal sounds.

The findings are subject to a number of limitations. Genre analyses bear the risk of oversimplifications, and therefore the results cannot be definitive. A methodological challenge has been the comparative analysis of sound phenomena. Whereas the experimental part could depend on the same structure, the historical analysis was based on different guitar riffs that inevitably affected the frequencies. Methodically, the focus on spectral features meant a limitation on the sustain phase in which instrument timbres differ little. On top of that, dividing the spectral content into frequency groups caused a loss of information. Moreover, the bass guitar and the kick drum as crucial instruments for the genre's perception of heaviness were not considered. To gain deeper insights into the metal guitar, future research should be taking greater account of the differentiation between time and genre, and include the transient design and dynamics. It could also explore the development of aesthetics, playing and production of other instruments aiming at a holistic understanding of metal genres. In conformity with Williams' (2015) and Mynett's (2013) claims, further research is needed to develop methods for researching metal productions and sounds.

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## Appendix

Amplifier settings (all in lead channel)

Laney GH50L: Bass 5, Middle 5, High 5, Presence 5, Gain 7, Drive 6, Level 3

Marshall JCM2000 TSL: Bass 5.5, Middle 7, Treble 5.5, Presence 5, Volume 4, Gain 8

Mesa Boogie Triaxis: Gain 8, Treble 9, Middle 8, Bass 1, Lead Drive 8, Master 9, Presence 9, Voice 0

Orange Dual Terror: Tone 7, Volume 10, Gain 8.5

Peavey 5150: Bass 8, Middle 8, High 5, Vol 2.5, Resonance 8, Presence 4

[i] A recent empirical investigation studying the use of equipment of 413 guitar players indicated significant differences between subgenres of rock and metal (Herbst 2016). Whereas hard rock and heavy metal players are still preferring traditional 100W tube amplifiers with separated head and cabinet, new metal and metalcore guitarists tend to rely on transistor or hybrid technology and rack designs.

[ii] The frequency range ”air“ (10-20 kHz) is not included in the experimental part due to the small effect.