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Shredding, tapping and sweeping: Effects of guitar distortion on playability and expressiveness in rock and metal solos

ABSTRACT

'Shredding', the fast and virtuous guitar playing, is a central stylistic element of many rock and metal genres. A recent empirical study reported metal guitar solos having become faster over the last six decades, thus indicating that shredding still is common in metal guitar, as argued in the earlier literature in rock and metal music studies. The present study extends such research by experimentally investigating the effects of distortion on playability, virtuosity and expressiveness based on a multi-methodical analysis from musicology, acoustics and music informatics. The findings contribute to acoustic-based evidence of distortion's simplifying effect that increases the electric guitar's potential as a virtuoso solo instrument. Yet, the results also highlight challenges of distorted guitar playing less commonly considered in research, journalism and performance practice. The article closes by advocating greater acknowledgement of the skills required for distorted metal guitar playing.

KEYWORDS

electric guitar
distortion
playability
virtuosity
expressiveness
rock
metal
experiment

INTRODUCTION

Virtuoso solo guitar playing is a central stylistic element of many rock and metal genres (Walser 1993; Weinstein 2000). Influenced by blues rock solos of Eric Clapton, Jeff Beck and Jimmy Page as well as by classical virtuosity (Walser 1993), early rock and metal guitarists as for instance Ritchie Blackmore, Uli Jon Roth and Glen Tipton quickly expanded the boundaries of fast playing. This trend was continued by players like Randy Rhoads and Yngwie Malmsteen who explored ways of overcoming challenges related to playing technique and by using instrumental technology in their favour. In the studio, Randy Rhoads made it a habit of mixing three tracks of his solos for a more liquid sound (Obrecht 2010), and Yngwie Malmsteen, being influenced by Ritchie Blackmore, scalloped the neck for reduced finger contact with the fretboard, hence allowing faster playing and easier string bending (Frudua 2010).

Virtuosity in metal guitar is mostly understood as 'shredding', which means fast playing combining a range of playing techniques such as alternate and sweep picking, tapping, string skipping, bended tones, artificial harmonics and the excessive use of the vibrato bar (Walser 1993; Waksman 2003b; McIver 2008). Ever since Eddie Van Halen made the two-hand tapping technique famous with his solo piece 'Eruption' (1978), no essentially new playing techniques have been developed on the rock and metal guitar; and even this date is debatable because the techniques can be traced back at least into the 1950s (Slaven and Krout 2016). Guitar virtuosity, thus, has developed by refining existing techniques rather than by creating new ways of playing. The boundaries of speed were pushed by 'hypervirtuosic players' (Walser 1993: 101) of the 1980s such as Steve Vai, Paul Gilbert, Joe Satriani, Tony MacAlpine, Jason Becker, Vinnie Moore, Chris Impellitteri and Michael Angelo Batio. Following this trend of ever-higher speed, some guitar players have succeeded in reaching faster tempi than many of the guitar heroes of the 1980s and 1990s, for example Rusty Cooley who has been nominated for 'being the leading light of the post-Malmsteen shred evolution' in the *Guitar Player* magazine (Blackett 2007). Although such players tend to represent a niche existence and are likely to be favoured by fellow shred guitarists rather than by a general metal audience,[1] lists of the greatest metal guitar players still emphasize technical dexterity as a vital criterion (McIver 2008).

In a recent empirical analysis of guitar solos from the roots of rock through modern metal (1950s–2000s), Slaven and Krout (2016) found evidence for metal solos having become faster over time.[2] The authors did not unfold reasons but technological developments besides a general musical evolution having led to better technical abilities are likely to have played a role. As Walser (1993: 69f) argued in his analysis of Van Halen's 'Eruption' performance, the fluidity of the guitar playing was ensured by an unusual high amount of gain by means of increased amplifier's voltage, resulting in a very distorted lead sound. If distortion takes effect on playability, which is investigated in the present study, technological development like amplifiers' extended capacity to produce distortion (Herbst 2016: 36ff, 58ff) may have contributed to faster solos in rock and metal music.

Distortion, in acoustics and electronics, is defined as 'any change in a signal that alters the basic waveform or the relationship between various frequency components; it is usually a degradation of the signal' (Encyclopaedia Britannica 2016). Pickups, preamplifier, power amplifier and the speakers' non-linear and limited frequency spectrum between 75 and 5,000Hz (Einbrodt 1997:

1. Evidence for this assumption may be the lack of guitarists renowned only for their fast playing in books on greatest guitar players like *The 100 Greatest Metal Guitarists* (McIver 2008).
2. The validity of Slaven and Krout's (2016) study is subject to certain limitations because the number of notes in structures of eight measures was analysed without considering the tempo of the songs.

198) generate distortion in the electric guitar signal chain. With the AC15 presented 1958 by Vox and the early modifications of the Fender Bassman by Jim Marshall in the early 1960s (Stephens 2015), distortion became an essential feature of guitar amplifiers. Since the seventies, an adjustable gain control, liberating distortion from volume, has been implemented in most amplifiers (Doyle 1993: 10). Valve distortion is produced when amplifying the signal beyond the capability of fidelity reproduction. The signal is pushed against the power supply causing clipping which results in a modified waveform (Doyle 1993: 56). The sharp edges of the waveform 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 creates compression, enhances noise, adds harmonic and inharmonic overtones and produces a flatter dynamic envelope (Gracyk 1996: 111ff). The timbre becomes noisier, rougher and present. At the same time, the bandwidth is reduced at the low and top ends, creating a defined and sustained sound (Doyle 1993: 57). This general effect of the guitar amplifier is further extended by the bending stiffness and winding of the string, which produce inharmonic spectra of a few hertz difference from the harmonic partials. Such an inharmonicity, when combined with distortion, produces periodic 'pseudo-noise' central to the characteristic rough sound of distorted guitars (Zollner 2014: 222–24). This basic principle of guitar amplification having derived from overdriven valves still applies today, even though the sound nowadays can be produced by transistor, hybrid and digital modelling technology plus by various overdrive, distortion and fuzz pedals (Herbst 2016: 35–43).[3]

Although distortion is an indispensable part of rock and metal guitar playing (Walser 1993; Weinstein 2000; Herbst 2017), its effect on playability has found little academic attention so far. Walser (1993) studied the appropriation of classical virtuosity into heavy metal and offered some close readings of musical notation to compare structural similarities of solos by Ritchie Blackmore, Eddie Van Halen, Randy Rhoads and Yngwie Malmsteen to classical compositions. Although he discussed playing techniques, he was more interested in motifs of classical appropriation, cultural dialogue and structural aspects than in the means of expression facilitated by the distorted sound. Solely concentrating on the distorted rhythm guitar, Berger and Fales (2005) explored contributing factors of metal's 'heaviness' and traced its development from the 1970s to the 1990s. Herbst (2017) extended this line of research by tracking changes in metal rhythm guitar aesthetics between 1970 and 2016 while taking a closer look at engineering and production techniques. From historical and cultural perspectives, Steve Waksman explored the distorted sound as a process of appropriation and further development, for instance, famous uses of feedback by Pete Townshend and Jimi Hendrix (Waksman 2003a) and Van Halen's tapping (Waksman 2001, 2003b), albeit without close analysis of distortion's influence.

Jauk (2007) criticized popular music studies for having neglected to study the connection of sound, performance and interpretation. The literature on the electric guitar confirms his critique. Most research on the instrument has focused on cultural identity and ethnicity (Waksman 1999), gender (Frith and McRobbie 1978; Walser 1993; Waksman 1999; Bourdage 2010) and communication (Gracyk 1996). Further academic and journalistic literature examined technological issues of the electric guitar (Einbrodt 1997; French 2012), the amplifier (Doyle 1993) and production aspects (Mynett 2012; Williams

3. Compared to valve amplifiers, devices with transistor technology produce hard clipping of the waveforms that are amplified by the speakers with greater fidelity (Doyle 1993: 56f). Transistor technology thus may sound harsher and react differently to playing (Doyle 1993: 56f; Berger and Fales 2005: 185). Nowadays, modern modelling and simulation devices such as the Kemper Profiling Amplifiers can emulate valve amplifiers with great fidelity.

2015). Within rock and metal music studies, research on the electric guitar has mainly been limited to descriptive observations of the importance of the distorted sound (Cope 2010). Detailed information about the distorted guitar's acoustic properties, and how they affect the instrument's playability and expressiveness, is scarce. Especially for cultural study–oriented research, knowledge about the pragmatic requirements of the instrument is needed to interpret guitar performances within a larger context. Likewise, in musicology and music theory, the acoustic foundation must be considered when analysing musical structures of genres based primarily on technology like rock and metal (Gracyk 1996).

This article investigates the effects of distortion on the playability of the electric guitar with a special focus on the core techniques: picking and legato. After studying the acoustic changes of the guitar signal by different forms of distortion, the playing techniques are analysed based on two case studies. The main interest lies in evaluating how distortion alters guitar playing regarding aspects of accuracy, fluidity, dynamics, phrasing and clarity, which potentially affect the guitarist's capability to play fast. The findings support claims raised in cultural studies (Waksman 2003b), music theory (Walser 1993) and empirical musicology (Slaven and Krout 2016) and provide insights into the mechanisms on how distortion facilitates playing. However, the results highlight challenges of distorted guitar playing which are easily overlooked as demonstrated in journalistic guitar literature (Baxter 2002) and in instructional material (Culpepper 1996). Being based on two samples, the present study does not focus on how advancements in amplifier technology, distortion pedals or pickups may have influenced the history of guitar playing and the evolution of shred guitar. It rather investigates the 'mechanisms' of distortion regarding playability and therefore uses samples and equipment that have been common in rock and metal since the early 1980s.[4] Such an understanding is a major requirement for explaining the technological influence on the ever-faster shred guitar – a question having to be answered in future research.

METHOD

Analysing how guitar distortion takes effect on playability required a multi-methodical approach. Structure-oriented methods barely capture tonal aspects sufficiently (Moore 2001: 34f), but exactly these were expected to be essential for playing technique and phrasing. Hence, the reciprocal relationship between traditional musical parameters, aspects of sound and signal processing had to be considered. This was achieved by an acoustic analysis in combination with structural and listening analyses. The first step was to create three-dimensional spectrograms with the *Sonic Visualiser* (Cook and Leech-Wilkinson 2009). Those enabled a detailed view on physical phenomena by visualizing the development of the instrument's spectral content in time (McAdams et al. 2004). Second, the spectrograms were combined with waveforms produced with *Audacity* for a better understanding of how spectral and dynamic parameters intertwine. The resulting figures served as objective visual representations and guaranteed that quality criteria such as repeatability and transparency were met (Cook and Clarke 2004: 4). Third, individual tones played with different techniques were exported from the audio project for extracting their acoustic features. A music information retrieval script, the MIR toolbox (Lartillot and Toiviainen 2007), was computed within the *Matlab* runtime environment. It allowed extracting defining features of the envelope

4. Although amplifiers using transistor technology were already available since the beginning of metal, they will not be included in this article in order not to include more variables. Besides, most metal guitarists still prefer valve technology (Herbst 2016: 300f).

such as attack phase and attack time to gain more insights into the process of tone production. Dynamic measurements of the recordings (dBFS) were calculated separately with *Adobe Audition 3* to compare issues like compression and musical accents. Finally, all visual and statistical data were combined for triangulation. With this multi-dimensional approach, it was possible to investigate the interaction of musical structure, sound, listening impression and playing qualitatively.

Following an experimental design, excerpts of songs, representing some of the most common playing techniques of the electric guitar, were re-recorded. 'Groove Or Die' (1997) by guitar virtuoso Andy Timmons was chosen for its technical challenges and its appropriateness to illustrate alternate, sweep and palm muted picking in one lick. The intro solo of Queen's 'I Want It All' (1989) was an ideal example of legato techniques due to its swiftness and short length. To analyse the acoustic effects of guitar distortion, the experimental recordings were produced with different sounds. Compared to analysing original recordings, the experimental approach allowed greater control on the variables potentially influencing playability, particularly gain level, and minimized interferences with other band instruments and guitar tracks. Every performance was recorded with direct injection into the sequencer software Apple Logic Pro 9 via a Presonus FirePod audio card. Using a Palmer Daccapo box, each performance was re-amped with a clean and with a distorted sound in the crunch channel with different gain settings. Re-amping means that a performance can be re-recorded with different amplifiers, cabinets and microphones. A Marshall JCM 2000 TSL 100-watt valve amplifier was used, and a Fulltone OCD pedal was added for the distorted sound. The signal ran into a 4×12 Marshall 1960BV cabinet with Celestion G12 Vintage 30 speakers and was recorded with a Shure SM57 dynamic microphone in close position. This setup represented a basic signal chain that has been common in metal music since the 1970s with characteristic differences and trends within the decades. For improving the comparability of the recorded audio files, the volumes were normalized at –0.1 dBFS. Since normalization reacts to peak levels, which are altered by the compression effect of overdrive and distortion, comparing the average loudness (RMS) of the recordings could only be achieved by approximation. 'Groove Or Die' was recorded with a Fender American Standard Stratocaster with a Seymour Duncan SH-4 (Jeff Beck) humbucker in bridge position, and 'I Want It All' was played with a Gibson Les Paul Standard with stock Gibson 490T humbucker at the bridge. The decision for selecting the guitars was made under the following considerations: on the one hand, using two different models introduced a further variable, reducing comparability between the playing techniques. On the other hand, however, the guitars were chosen because of their similarity with those in the original recordings and because of being standard models in rock and metal music history. Since a case studies design could not provide generalizable results in any case, two guitars were used to show that distortion affects playability irrespective of models differing in sound and handling.

CHARACTERISTICS OF GUITAR DISTORTION

To investigate the changing acoustic features of a clean guitar signal with different amounts of distortion, a bended tone from D5 (587Hz) to E5 (659Hz) with vibrato has been analysed. Although such a small sample cannot be representative, it still allows exploring characteristics of distorted sounds and the effect of gain levels. Harmonic structures of the rhythm guitar are excluded from the analysis since they are more complex because of combination tones (Lilja 2015). Figure 1 displays the spectrograms and waveforms of three sounds played with a Les Paul guitar.

Since the guitar is a pitched instrument, it produces periodic waves, which are illustrated in the spectrogram. The lowest is the fundamental and the higher vibrations are partials following the harmonic series. The number of partials, their relative intensities and the temporal development shape the timbre (Pierce 1996). In the spectrogram of the clean guitar, the fundamental and the first three overtones make up the primary frequency range of two octaves (E5 = 659Hz to E7 = 2,637Hz). The overdriven guitar is similar to the clean signal; the first four partials are dominant, yet several more overtones are present. As expected for natural sounds, the higher partials decay faster (Pierce 1996: 52). In comparison to the clean and overdriven signal, the distorted guitar differs substantially. The quiet upper partials added by overdrive are greatly intensified by distortion and fill a frequency range of almost five octaves (E5 = 659Hz to D10 = 18,323Hz). Both overdriven and distorted recordings have a noise band that in the spectrogram can be identified by undefined aperiodic 'speckles' in the area up to 5kHz. This is the frequency range of a guitar speaker. It filters out the unpleasant hiss in the presence of spectrum and prevents distortion to generate too much sharpness. However, regardless of the limited frequency range of the speaker, overtones up to 20kHz have been produced by distortion created by the additional overdrive pedal. Some higher partials like the A9 (13,290Hz, –35dB) are almost as loud as the first overtone E6 (1,319Hz, –25dB). All differences between the sounds demonstrate distortion's compression effect not to be linear throughout the frequency range. A small increase in gain amplifies the lower partials in the bass and middle register, and higher distortion levels are required to intensify the higher integer multiples. A great deal of distortion is necessary to sustain the upper partials over the whole vibration process, making the signal piercing also more apt to melodic playing. Not whole frequency bands but mainly the harmonics are intensified by amplifier distortion. Otherwise, the sound would generally be perceived as too sharp (Bacon 1981: 147; Doyle 1993: 56f).

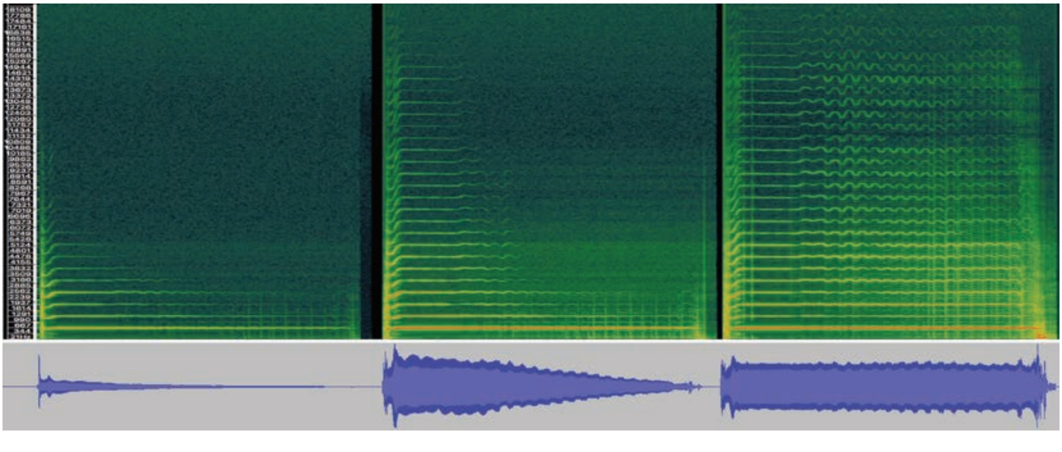

Figure 1: Spectrograms (top) and waveforms (bottom) of an E5 tone; left: clean, middle: overdrive, right: distortion; 21–18,000Hz.

Small acoustic changes greatly affect the sound and potentially the playability. Acoustic feature extraction of the three sounds was utilized to compare their envelopes, dynamics and timbres. The attack phase is crucial for the sound of instruments, whilst in the sustain phase most instruments are indefinable (Hall 1980: 120). Increasing gain from clean to overdrive extends the *attack time*, defined as the time needed from string contact to maximum peak (Lartillot and Toiviainen 2007: 114), from 32ms to 48ms. Further gain hardly extends the attack time (distortion 50ms). The *attack phase* as the time between the initial attack and the release phase (Lartillot and Toiviainen 2007: 122) is even more affected by gain level. Unlike the attack time, the attack phase reacts to all gain levels (clean 0.5s, overdrive 1.77s, distortion 3.53s).[5] Interpreting the envelope, distortion level may correlate negatively with attack definition because of the less precise attack times and phases and the greater noisiness due to the increased level of plectrum noise by compression. The noisiness of such picking can be identified in the spectrograms (Figure 1). Regarding dynamics, the gain level affects the average *RMS power* with greater increase between clean and overdriven (141 per cent) than between overdriven and distorted (71 per cent) sounds (clean –27.86dB, overdrive –11.55dB, distortion –6.77dB). The *brightness* of a timbre can be computed by the spectral centroid as the mean frequency of a spectrum (McAdams et al. 2004: 191). The clean sound (1,855Hz) is placed between overdrive (1,321Hz) and distortion (2,118Hz), and it highlights a characteristic feature easily overlooked in the spectrograms (Figure 1). Non-linear distortion does not solely add overtones but changes the loudness relation of the partials too. A close spectrographic analysis of the clean and overdriven recordings shows that the lowest harmonics of the overdriven signal are louder by approximately 6dB. Consequently, the intensified lower partials balance out the amplified upper partials for a moderately distorted sound and they lower the spectral centroid. For a heavily distorted sound, the emphasized lower partials still exist, yet they are outweighed by the substantial amplification of the higher partials. This altered frequency spectrum may be beneficial for the transparency of heavily distorted sounds that is hampered in the attack phase.

5. Regarding picking and legato techniques, the exceptionally long attack phases can be explained by string bending and vibrato. These measures show how much the envelope is affected by phrasing and indicate that long tones differ from tones in fast melody lines.

EXPERIMENTAL ANALYSIS

Picked tones

Picking with a plectrum is the standard technique for producing tones. The way a plectrum is used takes great effect on the resulting sound (Einbrodt 1997: 171ff). Picking strength correlates with volume and affects the distortion level of the amplifier. Thickness and picking angle influence the noisiness. A horizontal picking with a thick plectrum produces a defined sound, whereas a slanted picking with a thin plectrum creates a scratchy and less articulated sound (Herbst 2016: 34). The position where the string is hit also matters; the closer to the bridge the brighter (Hall 1980: 189ff). The effect of distortion on plectrum techniques is analysed exemplarily with 'Groove Or Die' (1997) by Andy Timmons (Figure 2).

The E-minor arpeggio in the first bar poses a challenge when played with a plectrum. Standard alternate picking consists of downstrokes and upstrokes. Since this technique requires larger movements when changing the strings, sweep picking is commonly used by rock and metal guitarists for arpeggios and melodies with one tone per string (Govan 2002b: 34ff). With this special technique, the picking follows the stroke direction. In the second bar, an

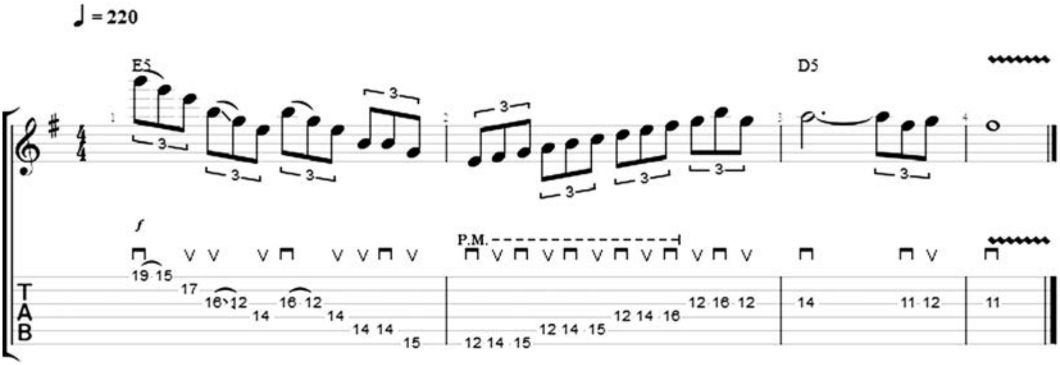

Figure 2: First part of form part A of Andy Timmons' 'Groove Or Die' (1997).

ascending scale is played with palm muted alternate picking. Palm muting is performed by dampening the strings with the picking hand at the bridge to produce a muffled and more percussive sound (Govan 2003: 25f). With a fast tempo of 220bpm, eleven tones per second are played. This challenging speed demands for a closer analysis of the relation between technique and sound.

The left area of Figure 3 displays the first bar with sweep picked tones, the right area shows the second bar played with palm muting, followed by open picked tones. In the clean recording, the open picking produces clear partials that slightly overlap and lead to a fluid perception. The palm muted tones have an accented attack phase followed by a short and quieter decay phase. Although this clean palm muted sound has less partials potentially reducing clarity, by listening impression, this sound is clearly articulated. It can be expected that the gaps created by muting enhance the aural separation of fast tones. The distorted sound apparently differs in its greater number of partials with higher intensities. As the 'Characteristics of guitar distortion' section suggested, distortion produces more noise in the attack time and this noise continues in the decay phase irrespective of the picking technique. Regarding the sweep picked and open tones, the differences between the sounds are found less in the spectrogram than in the dynamic waveform. The fluid impression of the clean sound is enhanced by the sustaining effect of compression in the distorted sound. The distorted tones do not decay and connect without any gaps for the sweep picked tones and with small gaps for the open picked tones, resulting in a legato sound. For the palm muted tones, the differences between the sounds are greater in the spectrogram. In the distorted sound, the first overtones are louder, and there are several upper partials. Due to compression, the distorted tones are loud in all phases of the envelope, and they connect with shorter pauses. Thus, palm muted tones played with distortion are perceived as more fluid than with a clean sound.

To triangulate the visual analyses with acoustic features extracted from the recordings, the mean values of three open picked tones (G4, B4, G4), three palm muted tones (D4, E4, F#4) and three sweep picked tones (E4, B3, B3) are compared.[6] With the clean sound, the picking style partially affects the attack phase. Whereas open and sweep picking hardly differ (open 144ms, sweep 140ms), the muted picking produces a substantially shorter attack phase (80ms). In contrast, with the distorted sound, the palm muted tones are not reduced to an equal extent compared to open tones (open 168ms, sweep 146ms, palm mute 143ms). Regarding dynamics, the palm muted tones are

6. The tones have been selected because of their picking style. Unintended influence of different pitches cannot be excluded and may explain some variance. They prevent spectral centroids to be compared.

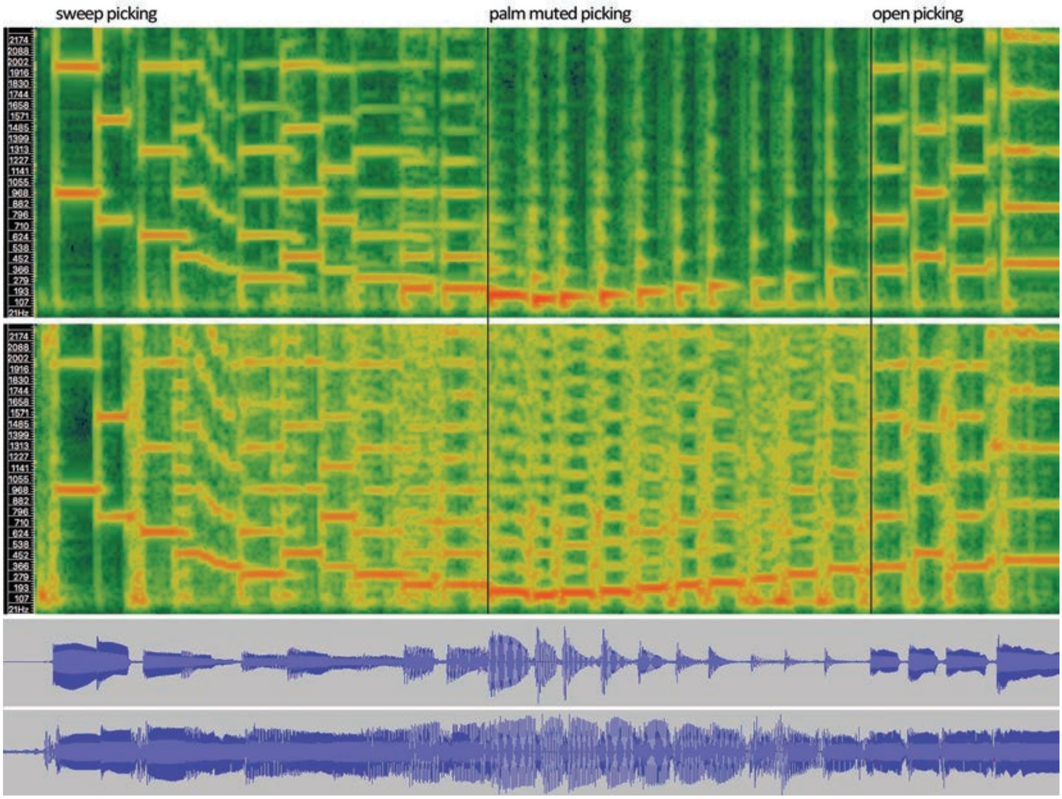

Figure 3: First two bars of 'Groove Or Die' (1997); 21–2,200Hz; top: clean, bottom: distortion.

considerably more quiet with the clean sound (open –26dB, sweep –24dB, palm mute –42dB), whereas all picking styles produce the same loudness with the distorted sound (open –19dB, sweep –19dB, palm mute –20dB). Considering the visual and computational results, the differences between the playing techniques are greater for clean sounds. Hence, distortion tends to even out the differences between the playing techniques.

Regarding the effects on playability, distortion sustains the tones irrespective of technique and thereby facilitates a more fluid sound. As the previous feature analysis has indicated, the attack time and phase are extended and accompanied by noise, resulting in a less articulated attack. These findings comply with the spectrographic and dynamic representations. Consequently, a sloppy playing, which is physically defined as the lacking synchronization of both hands occurring at fast tempi, is more likely to be masked by distortion. Since distortion obscures the execution and (lacking) precision, it may allow playing beyond technical abilities. Besides, irregular attack volumes as well as lacking articulation of accents and dynamics will be compensated by compression. All these effects can change the guitar from a staccato into a legato instrument sharing similarities with a bowed string instrument (Middleton 1990: 30ff; Walser 1993: 63ff) expanding but also limiting the expressive potential of the guitar. In a fast line, high distortion levels may reduce clarity by shortening the pauses when longer pauses would enable the tones to be perceived individually rather than as a melodic blur. This negative effect can be lessened by palm muting. Although the spectral content does not differ significantly between distorted open and muted playing, small qualitative differences were found in the spectrogram. Palm muting creates gaps that allow cognitive tone separation while also sustaining the accented tones to retain the general fluid impression that facilitates playing. Depending on precision, the combination of muted picking and distortion leads to either masking the lacking synchronicity of both hands or to producing a precise and powerful sound when played accurately. The fundamental is physically emphasized and supported by its first overtones, creating a full and yet defined sound. As a positive side effect, muting reduces unwanted string noise, which is a challenge arising from compression. Excessive use of distortion, however, is likely to mask the tones with noise at the expense of clarity, even if the playing is accurate.

Legato

Guitar legato techniques such as hammer on, pull off, two-hand tapping, slides and string bending reduce the amount of picking, which would disrupt the flow of tones.[7] Legato is commonly used for its smooth effect as well as for technical reasons. The effects of distortion on legato are analysed with the intro solo of Queen's 'I Want It All' (1989). The first two bars of the solo (Figure 4) are particularly interesting regarding virtuoso playing; with a tempo of 92bpm, 32nd notes equate nearly thirteen tones per second. On every string, only the first tone is picked, the other are played with hammer on and pull off.

In both experimental recordings displayed in Figure 5, there is barely any noise in the attack and decay phases of the legato tones. The bended tones are picked and compared to legato, obtain louder and more sustained noise. These inharmonic components are also found in the legato phrases, which can be explained by picked tones in the lines, particularly when strings are changed. These observations indicate that the fluid impression of legato is a result of an almost noiseless sound. Comparing acoustic features of picked and legato tones played in a phrase reveals the attack phase being less extended by distortion for legato (10 per cent extension) than for regularly picked tones (28 per cent extension). This shorter attack phase contributes to the smooth sound of legato.

The spectrogram and waveform representations (Figure 5) give some hints for an easier playability of legato techniques with a distorted sound. In the clean recording, the picked tones show greater intensity throughout the whole range of harmonics than the legato phrases. Based on listening impression,

7. All legato techniques are variations of playing tones on one string. A guitarist uses 'hammer on' by picking a tone and then playing a higher tone solely by impulsive fretting. 'Pull off' works vice versa, a higher tone is picked and then pulled off to a lower tone on the same string.

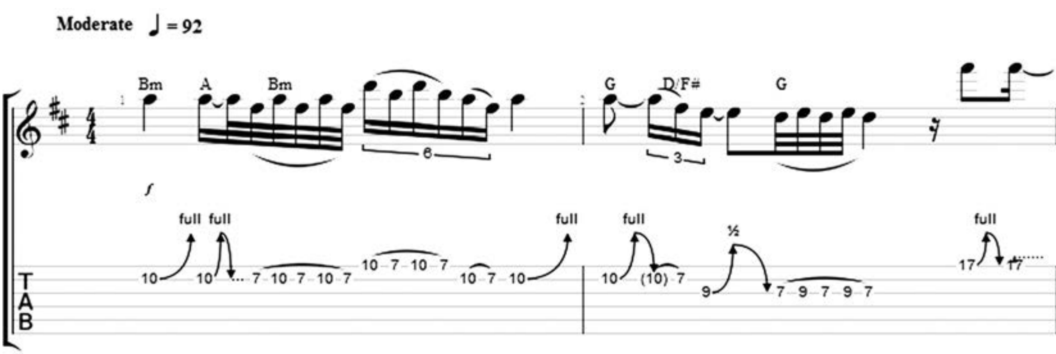

Figure 4: First two bars of the intro solo of Queen's 'I Want It All' (1989).

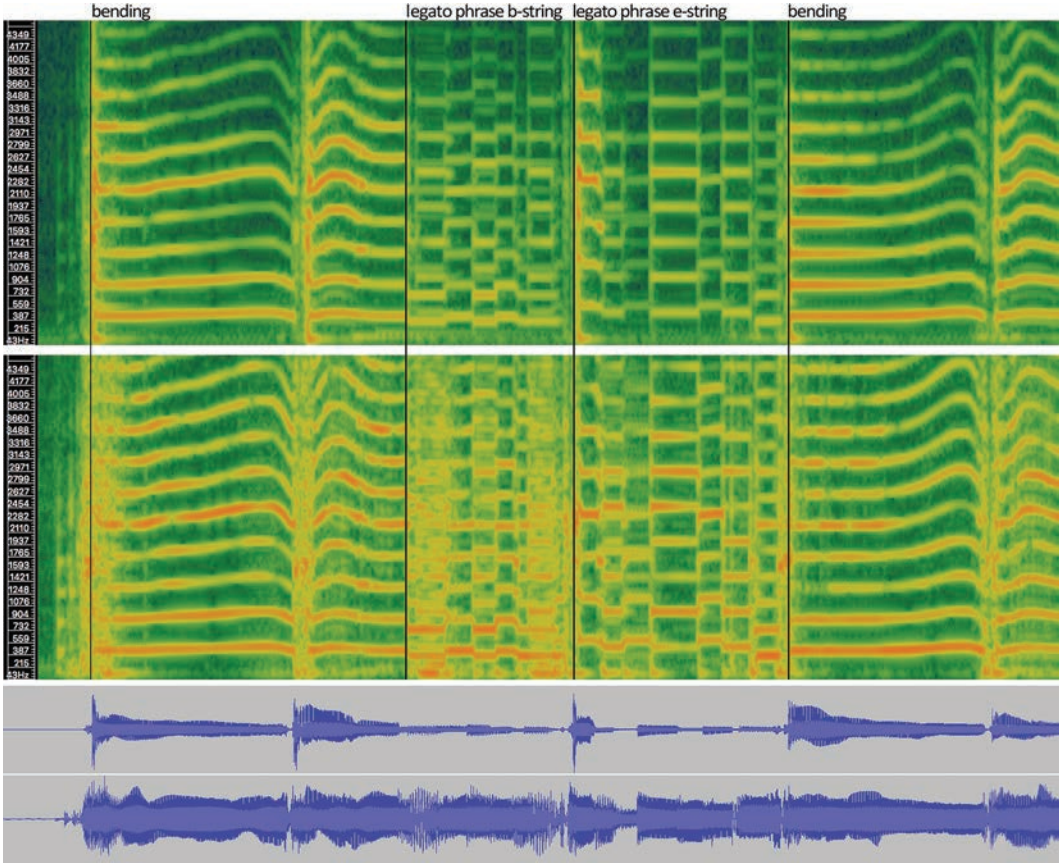

Figure 5: First two bars of 'I Want It All' (1989); 43–4,350Hz; top: clean, bottom: distortion.

the irregular volume of picked and legato tones hampers the latter to be clearly heard in an ensemble context. In the distorted sound, the compression effect strengthens all partials regardless of playing technique. The waveform confirms distortion to shift the percussive impression of the clean to a sustained signal with similar volume of picked and legato tones. The feature analysis shows the difference in volume between picked and legato tones of the sample to be 4.61dB for distorted and 13.29dB for clean sounds. These diminished dynamics resulting from distortion allow the player to use legato in a phrase with different techniques. Because of this effect, two-hand tapping that completely lacks plectrum picking profits greatly from high distortion levels. Other than the volume, the duration of the tone is extended too; the partials oscillate longer at the end of a tone and, additionally, the tone onset is earlier than in a clean sound.[8] Thus, the distorted tones connect, creating a smoothness not possible on the acoustic or clean electric guitar.

8. The extended duration also applies to regularly picked tones and improves the melodic fluidity for distorted sounds in general.

EFFECTS OF DISTORTION ON PLAYABILITY AND RESULTING CHALLENGES

The analysis aimed to explore characteristics of guitar distortion and its effect on playability, virtuosity and expressiveness with a focus on the instrument's core techniques. Previous studies touched on the link between sound and virtuosity in rock and metal solos (Walser 1993; Weinstein 2000; Waksman 2001, 2003a, 2003b) and highlighted that the 'sustain of the distorted electric guitar […] increases its potential as a virtuoso solo instrument' (Walser 1993: 50). In a similar vein, the literature on instrumental education, journalistic literature on the electric guitar as well as discussions in guitar forums biasedly debated guitar distortion's facilitating effect (Govan 2003: 18), sometimes even judged as 'cheating'. Several nuances of this critique are reflected in professional metal guitar players' choice of words like 'fooling' (James Byrd) or 'hide behind' (John Huldt) (Herbst 2016: 314ff).

The present study found acoustic evidence that a higher distortion level decreases the physical effort of playing due to compression, altered attack time and attack phase, and increased sustain. Tapping, feedback and artificial harmonics are techniques whose expressive potential can be harnessed best on the distorted electric guitar. Regarding shredding, the distortion level correlates with fluidity mainly due to the compression effect. Gaps between tones are bridged thus connecting tones, and irregular volumes are balanced out. Differences between playing techniques and subtleties of phrasing like accents are reduced too. Since the guitar basically is a percussive instrument requiring high skills for making it sound legato (Weissberg 2010: 99f), distortion inevitably facilitates fast playing. Further evidence from the player's perspective provides Herbst (2016), who conducted a standardized survey of 418 electric guitarists combined with a qualitative interview with ten professional players. In the standardized survey, the participants evaluated on a five-point scale whether distortion made the playing harder (1) or easier (5). Feedback (M = 4.62; SD = 0.76), artificial harmonics (M = 4.33; SD = 0.88) and legato techniques (M = 4.13; SD = 0.89) were felt to be easier with distortion. Sweeping (M = 3.55; SD = 1.04) and fast alternate picking (M = 3.58; SD = 0.89), in contrast, were rated to be less simplified by a distorted sound. In overall evaluation, the participants tended to slightly consent to the facilitating effect of distortion (M = 3.59; SD = 0.80), even though they were hesitant to agree that distortion generally allowed faster playing (M = 2.57; SD = 1.19). However, they acknowledged using it to mask inaccurate playing (M = 3.47; SD = 1.18). Such means of simplification were used less by more professional players (r = –.198; p < .001). The qualitative interviews demonstrated genre differences. Whereas jazz, blues and classic rock players stressed the reduced expressiveness of too much distortion, metal players like Victor Smolski, Christopher Amott, John Huldt and James Byrd highlighted that distortion 'often supports the playing' (Herbst 2016: 318), still emphasizing the need to practice with a clean sound to work on accurate playing. These statements complied with the standardized survey where players of styles with less distorted guitars rated distortion to simplify playing less (r = –.152; p < .001).

Technological advancements as for instance adjustable preamplifier gain, amplifiers' greater gain capacities, more effective overdrive and distortion pedals and higher output pickups designed for highly distorted sounds (Herbst 2016: 36ff, 58ff, 84ff) seem to be linked with higher distortion levels and faster solos in rock and metal. At least this likely has been the case between the 1960s and the 2000s when, in general, the amplifiers' gain capacities were limited (Doyle 1993). Although this study has not analysed the impact of these technological advancements per se, the general investigation of distortion's characteristics and the experimental analyses have demonstrated how distortion level affects the capability of fast playing. Thus, there is reason to suspect technological innovation to have influenced musical development as presented by Slaven and Krout (2016). Since there is a limit of distortion to be used in musical contexts, and many contemporary metal amplifiers already provide higher gain levels than necessary for most playing styles or advisable for an intelligible sound (Mynett 2012), distortion's simplifying effect is finite and may not be accountable for developments of shredding since approximately the 2000s. What is more, increasing gain levels also require different skills and pose multiple challenges to phrasing. Therefore, regarding distortion as merely facilitating may be short-sighted.

As the analyses have shown, distortion changes the guitar from a percussive to a compressed and sustained instrument. This effect poses serious difficulties to the player for avoiding unwanted tones and noise.

> a heavily overdriven amp is a frisky beast, and the slightest of accidental hand movements at your end can turn into an enormous and unpleasant racket by the time it reaches the speakers. In a context like this, you have to be more conscious than ever of damping all unwanted strings, just to make sure that there's a difference in volume level between when you're playing and when you're not.
>
> (Govan 2003: 26)

Compression increases the noise underground of hum and other non-periodic noise plus vibrating strings not played (Einbrodt 1997: 175). This noise can hamper clarity and heavily interfere with the tones deliberately played – a challenge that is reflected in a statement of ex Arch Enemy's guitarist Christopher Amott.

> I don't like the notes to get too muddy or blend together. Also, when you have an overly distorted tone, little nuances in your playing get lost. […] I've always felt it to be important to be able to control the string noise that can come with playing with distortion. Thus, in my opinion technique is not just how many notes you can squeeze into a solo, but also the ability to execute correct bends and to be able play clean. It is extremely beneficial to work on these things, it will make your playing stand out more and make it come alive.
>
> (Herbst 2016: 321)

The distorted guitar is special among instruments because it is crucial to limit the noise produced by the amplifier and optional distortion devices.[9] Therefore, rock and especially metal guitarists must become experts of sonic control (Govan 2003: 18).[10] Controlling noise requires the dampening of the higher strings not played with the fretting hand and the muting of the lower strings with the picking hand (Baxter 2002: 65f). A great deal of control is needed to synchronize both hands (Govan 2003: 26) and to mute strings not needed while avoiding unintentional palm muting of played tones (Baxter 2002: 65). This challenge also applies to rhythm guitar that must be precisely controlled for being transparent at high speeds.

Another consequence of distortion is that dynamics, as an essential aspect of musical expression, is reduced. More effort than on other instruments is needed to create accents and phrase development. For example, depending on the gain level, a crescendo hardly increases the volume but rather modifies the tonal quality (Govan 2003: 39). Increasing attack strength leads to overdrive and more overtones plus greater noise; a softer attack produces a warmer

9. Although distortion is generally used on the electric guitar, similar challenges may apply to distorted bass guitars or even to distorted vocals common in metal.

10. Even though noise gates help cleaning up the sound, they still require a good muting technique. They also reduce the sound quality.

timbre (Einbrodt 1997: 170ff, 210f). Dynamic articulation with distortion thus needs much more effort to achieve a similar result compared to a clean sound. Accordingly, playing skills cannot solely be equated with fast melody lines; rather, subtle differences in dynamic articulation must be considered too. Such control makes the difference between advanced and intermediate players.

Palm muting is an important technique for articulate playing. It reduces the legato effect inherent to distortion without reducing the compression effect. A powerful tone is produced that is affected by the pressure and position of the hand, controlling the percussiveness and frequency spectrum (Govan 2003: 25). Palm muting also takes effect on intonation forcing the player to listen carefully. In fast melody lines, the deliberate use of this technique can accentuate selected tones, which requires much control. The technique is particularly used on the low strings because it separates the tones, thereby increasing transparency. But since the legato effect is reduced, synchronous playing is demanding. Nonetheless, fast playing without palm muting must not be mistaken to be less challenging. Greater intensity of higher partials increases clarity making asynchronous interaction of both hands apparent easily (Govan 2003: 20).

Another difference between playing with clean and distorted sounds is the extended duration that distortion creates by earlier tone onset and longer time of vibration. Although this effect masks asynchronicity, stopping a tone accurately is harder and may lead to negative effects when transitions between tones are sloppy. Overlapping tones produce roughness because of beating partials, which can also reduce clarity and tone identifiability. This difficulty is particularly prevalent when playing arpeggios with sweep picking (Govan 2002a: 63).

Finally, a well-adjusted amount of distortion can increase the guitar player's expressiveness in many ways. Christopher Amott sees distortion as

> almost an instrument in itself […]. There are many beautiful tones and effects you can get from it, as all the little details of your playing, like pick scrapes and overtones come through stronger than if you were to play with a clean sound.
>
> (Herbst 2016: 321)

An enormous potential of guitar distortion is its means to increase expressiveness by assimilation of vocal phrasing, for example, by imitating a rough impression of blues singing (Walser 1993: 42; Jauk 2009: 268f) and by supporting the personal vibrato by sustain (Jauk 2007: 278f). Just as vocal timbre can be modified to adjust to the desired tonal effect, guitar techniques and controlling the sound can intensify the playing and add further details to the expression. The option to take influence on the tone in the attack, sustain and decay phases allows imitating vocal articulations such as sliding between pitches and controlled vibrato (Herbst 2016: 178ff). Tonal coloration of consonants and vowels can be simulated by the pickup switch and the position of picking (Traube and Depalle 2004). Depending on the picking position, the sound changes as with an equalizer. The sharp sound of a tone played near the bridge and with the bridge pickup is an acoustic homology of the vowel 'i' (Jauk 2009: 268). Adding a wah-wah pedal intensifies the effect and helps to imitate different vowels. Even a sound like the vocal falsetto can be achieved by the different forms of artificial harmonics and feedback (Herbst 2016: 178ff), techniques commonly used in metal rhythm and solo guitar. However, selecting the right sound is essential for supporting the playing and its expressiveness. Too little distortion rather results in a percussive and staccato than in a melodic vocal-like sound often desired in genres like heavy metal, power metal or melodic death metal. Besides, low gain levels may hinder fast lines as a dramaturgic element of the solo outline. On the contrary, too much distortion diminishes the effect of phrasing including dynamics and the contour of wah-wah shaped tones (Herbst 2016: 181ff). Furthermore, excessive use of gain compromises transparency and intelligibility (Mynett 2012). Similar to blues and rock, the distortion level can be adjusted with the instrument's volume control while playing. Controlling the gain to improve expression, however, requires subtler changes as the standard gain levels are higher in metal.

The points raised illustrate the effects of distortion level on playability and expressiveness and counter the widespread short-sighted view of being merely simplifying. Regarding the benefits and challenges of distortion, no definite ratio can be given for its effects on playing. The findings indicate that distortion helps masking playing weaknesses such as sloppy picking or weak legato. In any case, there are difficulties in articulation uncommon for most other instruments. Beginners are challenged to master the noise inseparable from distortion. Intermediate players may benefit from distortion's characteristics to make the instrument more legato, allowing them to play faster and more fluid. For expanding their means of expression, advanced guitarists need to perfect their skills to overcome the restrictions of distortion such as diminished dynamics, and they must be able to control subtleties like the effects of picking (see Govan 2003). Referring to Herbst (2016) once more, in the standardized survey no correlation could be confirmed between level of professionalism and distortion's simplifying effect (r = .027; p = .588). However, the difficulties of playing with a distorted sound decreased with greater competence, if only slightly (r = −.159; p < .001) (Herbst 2016: 305). Professional metal guitarist James Byrd explains,

> The better one's technique, the less difference it [the level of distortion] it makes. Good technique adjusts itself for equipment differences. If your playing is not articulate and fluid, you may fool some with a lot of gain, but you won't fool a player.
>
> (Herbst 2016: 318)

Yet, considering the differences between players of various levels of professionalism, the challenges of playing with distortion should not be disregarded thoughtlessly when judging electric guitar playing.

The results highlight clear differences between clean sounds and distorted sounds, making it necessary for a player to adjust to the consequences of the sound or even to specialize. That is why common advice in educational books to practice without distortion (Stetina 1990; Culpepper 1996) should be objected. A proper playing technique requires practising with and without distortion. Practising with distortion is indispensable to gain full control and to harness the expressive potential of the instrument. It seems sensible adjusting the gain in accordance with the aesthetic and pragmatic needs of every song. The gain level may even be changed for each form part or phrase by foot switch or the guitar's volume control. Tone choice, articulation and the deliberate use of music technology need to be coordinated because their interaction affects playability and expressiveness. A maximum of distortion cannot be equated with a maximum of expressiveness or playing comfort, yet adjusting the gain level can. Reducing distortion can increase clarity and dynamics; increasing distortion may support the playing, especially when the benefits are needed, such as the sustaining effect for legato techniques and compression and frequency alteration for artificial harmonics and controlled string feedback.

CONCLUSION

The exploration of distortion has been crucial for the electric guitar having become a main instrument in popular music and a cornerstone of rock and metal music. Distortion extended the means of expression pivotal for the guitar's role as a lead instrument and the development of the shred style. Previous studies on the electric guitar have mostly been restricted to descriptive observations of the importance of the distorted sound. Although some work has analysed guitar playing from music theory perspectives, and other studies have explored the physics of rock guitar, few research integrated both strands of research necessary to understand the practice of playing. The present study aimed to fill this gap. It combined musicology, music theory, acoustics and music informatics by following a multi-methodical approach that incorporated visual spectrographic analysis, acoustic feature extraction as well as structural analysis. The results demonstrate elementary connections between the guitar sound and its effect on playability, virtuosity and expressiveness. Future musicological–oriented and cultural study–oriented research on the electric guitar in rock and metal can build on this foundation.

Besides contributing evidence to distortion's impact on the 'shred' guitar, another aim of the study was to raise awareness of the difficulties of distorted guitar playing. Although the analytical focus was on fast playing and therefore emphasized the simplifying effect, the succeeding discussion pointed out challenges. Consequently, distortion should more often be an issue in educational material, and educators and journalists might consider this sound from different perspectives. Understanding the effects of distortion may add to an acknowledgement of the required skills, which might lead to a greater acceptance of rock and metal in diverse educational and academic institutions or music contests. Even though such genres are available and appreciated in many music courses, for example, in the United Kingdom, the United States and the Netherlands, music and guitar programmes in conservatoires and universities of German-speaking countries still tend to be limited to classical music and jazz. This may be similar in other countries as well. Therefore, an extended understanding of distorted guitar playing could help institutionalizing metal music genres with academic arguments in countries not generally accepting metal music in academia. A benefit of opening music courses with specialist education could be better employability for metal guitarists. Finally, rock and metal songs may even serve as teaching material for guitarists of other genres to practice their distorted playing with legato licks by Van Halen, scalar runs by Chris Impellitteri or sweep picked arpeggios by Yngwie Malmsteen.

The generalizability of the results is subject to certain limitations. The analyses of distortion's characteristics and their effects on playability have been undertaken on a small sample and may not be applicable to all musical contexts. As already addressed in the 'Methods' section, using different guitar models added another variable to the set of stimuli, reducing comparability of the results of picked and legato playing. At the same time, two different models were a means of showing that the processes analysed were based in equal parts on the amplification and the instrument itself. The validity of the acoustic feature extraction may be restricted because different pitches were included in the analysis of the three picking techniques. Furthermore, as the playing techniques were analysed only with one example, the results must be considered preliminary. By drawing upon a larger sample, more details might be found that potentially are relevant for distinguishing guitar styles of different subgenres. Future research could explore styles of seminal guitar players with special focus on their uses of technology, distortion, playing techniques and expression. Investigating how specific guitar playing in relation to music technology has influenced the development of rock and metal music subgenres could well be another area in future work. To pursue further the assumption of technological development having influenced the guitarist's capability of ever-faster playing, future studies could follow a longitudinal design, taking into account technological milestones such as the advent of adjustable preamplifier gain, superstrat models and active pickups. Finally, evaluating the playing virtuosity under consideration of the guitar sound would be valuable for obtaining further insights into how personal factors such as being a guitar player might affect the perception.

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