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Sonic Signatures in Metal Music Production
Teutonic vs British vs American Sound

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Introduction

Popular music studies have seen a rising interest in what could be called »sonic signatures« or »signature sounds«. According to Zagorski-Thomas (2014: 66), the »use of the term in music has been to describe the character of a particular individual or group's performance style and output, but can also relate to a record company or a producer.« He gives the example of producer Phil Spector, who worked with the same pool of musicians, and the Motown label with their iconic band the Funk Brothers, who recorded in the Snakepit studio. Other signature sounds from characteristic instruments and effects devices shape popular music genres (Brockhaus 2017). Even countries and cities can have signature sounds (Simmons 2004; Owsinski 2006; Zagorski-Thomas 2012; Massey 2015; Herbst 2019, 2021), e.g. Philly soul. Many approaches for analysing a recording and its meaning have been pursued. Based on auditory analysis, von Appen (2015), Helms (2015), and Zagorski-Thomas (2015) have interpreted potential decisions in the production process concerning their creative and commercial reasons. But as Morey's (2008) analysis of the Arctic Monkeys' demos has shown, even highly skilled production experts and musicologists can be wrong in their assumptions and interpretations. Interview statements and production recollections (e.g., ›Produce Like a Pro‹[1] or ›Nail the Mix‹[2]) by those involved in the production help to mitigate some of these problems, but there may still be forgotten details, vague memories, or mystified stories (Thompson/Lashua 2016). An ethnographical approach (Meintjes 2003; Davis 2009; Bates 2016), in which the recording and

1 https://www.producelikeapro.com/
2 https://nailthemix.com/

engineering processes are observed first-hand, could be a solution, although studio access during all phases from recording to final mastering is commonly restricted, and research interest often only emerges after a record is released. An alternative to observation-based field work is to test assumptions through practical re-enactment of the recording, mixing, and mastering processes of a production (Meynell 2017). The outcome will be even more accurate when collaborating with the original engineers and having access to unpublished data like multi-tracks as well as specialist production resources and skills (Hammond 2018).

This article is part of a larger research project on ›Teutonic metal‹, which is metal music from Germany and neighbouring countries (Elflein 2017; Herbst 2019). Previous qualitative research (Herbst 2019, 2021) with influential ›Teutonic producers‹ such as Karl ›Charlie‹ Bauerfeind[3], Harris Johns[4], and Siegfried ›Siggi‹ Bemm[5] as well as other professional metal producers like Lasse Lammert[6] and Mark Mynett[7] suggests that, during metal music's globalisation in the mid-1980s and 1990s, German metal diverged from the two main cultures of origin, Great Britain and the USA. Indications of a ›German metal sound‹ were also found in a recent *Rock Hard* interview with Dennis Ward, a German-based metal music producer from America:

> Oh, indeed, there definitely is one. Just a few days ago I got a request, one of the kind I often receive. The band was from Italy and they wanted me to make them sound like ›all the great German metal bands‹. This probably is the best evidence. But I cannot explain what exactly makes up this sound given that Accept sound totally different to Helloween. There must be some common element. Maybe this kind of music from Germany is produced with more reverb, roomier and not so dry and ›in your face‹ like much of the music coming from the US. (Schiffmann 2018; translation by the author)

Based on the experience of the aforementioned producers, the characteristics of metal from Germany, Great Britain, and the USA were investigated in previous research (Herbst 2019, 2021). Comprehending culture-specific sonic signatures nevertheless proved to be a challenge in light of the large variety of variables: bands, song structures, arrangements, tempos, studios, recording and mixing techniques. The present article takes a different approach by

3 Producer of Angra, Helloween, Gamma Ray, Running Wild, Blind Guardian, Rage, Saxon, Motörhead, and Venom.
4 Producer of Kreator, Sodom, Tankard, Voivod, and Saint Vitus.
5 Producer of Angel Dust, Kreator, Morgoth, Samael, Moonspell, Rotting Christ, and Theatre of Tragedy.
6 Producer of Gloryhammer, Alestorm, MessengeR, Svartsot, Primitai, and Rumahoy.
7 Producer of Rotting Christ, Godsized, Paradise Lost, and My Dying Bride.

exploring a practice-led methodology. Producing three pastiche mixes—›Teutonic‹, American, and British—of the same multi-track recording allows to directly compare the sonic signatures of the full arrangements and their individual parts. This methodology also considers the practical challenges that mixing and mastering engineers face in the real world when crafting music with specific sonic signatures in mind, something that can easily be overlooked from a mere musicological point of view.

Geographically associated sonic signatures

In popular music performance and production, equipment and engineering techniques are widely associated with geographical areas. Guitar players commonly associate amplifiers from the UK (Marshall, VOX, Orange, Laney) with a British sound and those from the USA (Fender, Mesa Boogie, Peavy) with an American sound (Stent 2019). This is mainly due to the history of rock music, as both countries manufactured original amplifiers early on (Burrluck/Seabury 1996). Since they were less expensive, renowned bands played amplifiers from domestic manufacturers in the formative phase of rock (Brosnac 2004: 56). Deviating circuit designs, valves, speakers, and cabinets create sounds that vary in distortion characteristic, frequency spectrum, and dynamic response (Brosnac 2004; Stent 2019). In the digital world, geographical origins are used in amplifier simulations to classify impulse responses (›sonic fingerprints‹) of guitar cabinets and speakers. Normally, these include American and British characteristics, but some also distinguish a German sound that is most closely associated with the manufacturer Engl, sometimes Diezel.

In audio engineering, several geographical references exist too. The classic Urei/Universal Audio 1176 FET compressor set to ›all buttons in‹ is known as ›British mode‹, characteristic for aggressive wave-shaping (Felton 2012). There is also the myth of a British equaliser, which is characterised by a special bandwidth behaviour that allows engineers to apply more extensive boosts without unpleasant artefacts on British mixing desks as opposed to American consoles (Winer 2012: 282). However, this proportional bandwidth is not a unique feature of all British consoles: the British SSL 4000G has it, while the E series does not. Besides, it also exists on some American devices, such as the API. As mentioned before, even some cities are known for their specific signature: New York style compression, for instance, is a recognised term for parallel compression (Owsinski 2006: 58). This is a technique in which unprocessed and processed tracks are mixed together to achieve a full-

bodied effect without significantly affecting the important transients. Owsinski (2006: 3f) describes distinct mixing styles of Los Angeles, New York, and London that differ in their approach to compression, effects layering, and spatial staging, but admits that the uniqueness of these signatures gradually diminishes. Similar trends can be found in mastering practice. Interviews with leading engineers indicate that until the turn of the millennium, the East Coast could be distinguished from the West Coast due to distinct styles within the USA. This is not possible anymore, however. As Meadows observes: »it's all blended in to be a big jumble of sound, and you almost can't pinpoint anybody's characteristic fingerprint anymore. Everybody has basically the same kind of tools and is doing the same kind of thing to satisfy the customers« (Meadows in Owsinski 2008: 219).

Examining British and American sonic signatures, Zagorski-Thomas (2012) concluded that productions from these countries differed considerably in the 1970s but then gradually assimilated from the 1980s onwards. Back in the 1970s, American producers had a higher track-count, tended to record more live, and preferred close-miking, while British engineers applied more traditional room techniques, valued mono-compatibility, and strived for a warm and ›fat‹ sound, often created in large studios. American producers generally opted for an intense and controlled sound, created in smaller spaces with more acoustic treatment. Distinctive sounds were also due to the use of different desks and microphones in each country. However, the international availability of production resources and staff mobility since the 1970s has increasingly blurred these distinctions.

Previous research on Teutonic metal (Herbst 2019, 2021) has confirmed some of the geographically associated sonic signatures for the UK and the USA and shed light on the German music industry and metal scene. The three veteran producers Johns, Bemm, and Bauerfeind—all decisive for the rise of the metal labels Noise, Century Media, and Steamhammer—felt that in the 1980s equipment comparable to that in America and Great Britain was available in Germany. Yet, tariffs charged on imports increased the prices of mixing consoles, microphones, and amplifiers in the three nations disproportionally (Zagorski-Thomas 2014: 118). This affected the choice of guitar amplification, as producer Bauerfeind explained:

The basic character [of the guitar sound] is determined by the amp, they all have different characters, Marshall, Engl, [Mesa] Boogie and so on … And this is what shapes styles within metal, i.e. in melodic metal you have the even distortion of Engl amps. In more rock-based metal, you have Marshall sounds, which by far don't distort so evenly. … British and American players liked the [Peavy] 5150, and Americans [Mesa] Boogie, of course. The [Mesa Boogie] Rec-

tifier is the typical sound of America. And Germany is Engl for sure, it is Engl country, that's a trademark! Everybody in Germany was interested in sounding original, not sounding like everybody else. This was easy to achieve because everybody who played Engl had a sound of their own, this was the Teutonic metal sound. (Bauerfeind in Herbst 2021)

Most other producers in the study shared this view (Herbst 2019, 2021), confirming that they deliberately selected amplifiers for their sonic associations. Apart from amplifier circuits and valves, Bauerfeind was convinced that a country's utility frequency[8] had an audible impact on the guitar tone. Using an electrical ›variac‹ transformer, the power line could be artificially lowered from 60 to 50 Hz to achieve European sounding distortion, a technique applied by some American engineers and many European producers when recording in the USA.

Drum sounds differed between the countries too. Both American and British productions tended to sound ›wooden‹ (e.g., Armored Saint »Never Satisfied«, 2000) but the British even more so (e.g., Iron Maiden »Be Quick or Be Dead«, 1992). This impression is achieved by emphasising middle frequencies instead of the high and low end. In American and British production styles the snare drum was the most prominent instrument of the kit, while the kick drum was the focus of Teutonic productions. From a technical point of view, the differences resulted from the tunings, recording techniques, and processing approaches. According to Bauerfeind, kick and snare—the two most important drum sounds—needed to have a particular sound to fit a Teutonic aesthetic. He compared the kick with a ›cannon shot‹, a sound rich in low end, compressed, and loud in the mix. As early as the late 1980s, sample reinforcement enabled this aesthetic prior to the advent of digital audio workstations (DAW). By then, Teutonic productions were already internationally known for loud and deep kick drums. This drum aesthetic can be heard, for example, on Helloween's influential »I Want Out« (1988) and Gamma Ray's »Last Before the Storm« (1993). The snare sound was also different between countries. Whilst British and American productions tended to feature a higher pitched snare, Teutonic metal artists followed the aesthetic of two influential German bands, the Scorpions and Accept, who used a low tuned snare with a centre frequency around 130 Hz and a loud snare wire rattle to create a sound resembling a ›pistol shot‹. Early examples of this sound are the Scorpions' »Longing for Fire« (1975) and Accept's »Breaker« (1981). These low tunings extended to the toms, which required large shells and double ply (Remo Pinstripe) heads. Good examples to

8 The utility frequency is 60 Hz in North America, 50 Hz in Europe.

compare these drum sounds in the same genre and period are American Jag Panzer's »Call of the Wild« (1997), British Shadow Keep's »Corruption Within« (2000), German Gamma Ray's »Somewhere out in Space« (1997), and Italian Rhapsody's »Flames of Revenge« (1997).[9] Two records by the German power metal band Rage are even more revealing. *Welcome to the Other Side* (2001) was self-produced by the band members for their respective parts. The drums by American Mike Terrana are high-pitched, bouncy, and fusion-like. When this album failed to convince the audience due to lack of Teutonic production attributes, Bauerfeind was hired to achieve a Teutonic signature on *Unity* (2002). The songs »Paint the Devil on the Wall« (2001) and »Down« (2002) demonstrate the differences.

Teutonic producers chose studios that supported this ›thundering‹ aesthetic. Such a sound can only be achieved with specific room acoustics that produce pressure points and controlled low frequencies that can be captured by the microphones. Bemm emphasised that his drum sounds stood out because of the glazed tile walls in his Woodhouse Studio (Morgoth »Odium«, 1993). Johns also appreciated hard reflections from concrete or tiled walls, especially reverberation chambers for snare drums and guitars (Tankard »Death Penalty«, 1993). Bauerfeind liked to record at Hansen Studios (Gamma Ray »The Cave Principle«, 1993) and RA.SH Studios, both built into World War II bunkers whose concrete walls had reflection chambers made of pure ferro-concrete walls (Gamma Ray »Rebellion in Dreamland«, 1995). Blind Guardian's »Twilight Hall«—the studio where Bauerfeind now records most of his production—still features these hard, reflective surfaces (Figure 1, p. 7).

In the 1980s and '90s the vocal sounds in Teutonic metal were less characteristic than in American rock and metal productions, which had a unique vocal signature. Typical vocals on American records had a ›bubble effect‹ created by Dolby A, a tape noise reduction unit used as a multiband compressor/expander to boost the top end with the device's encoding stage (AudioThing 2019). A similar effect was commonly achieved with the Aphex Dominator II multiband peak limiter that can be heard on early Skid Rock albums (*Skid Row*, 1989; *Slave to the Grind*, 1991).

9 Rhapsody have been strongly influenced by German metal. They have often collaborated with German producers and session musicians.

Figure 1: Drum recording room of Twilight Hall studio[10]

Apart from the production aesthetics, most of the interviewed producers were convinced of performative differences that were particularly evident in drum playing. In accordance with stereotypes, Teutonic performances were described as ultra-precise and sterile due to the exact internal alignment of drum instruments and the ensemble synchronisation. The snare drum had to be exactly on the grid or even slightly ahead so as not to mask the all-important kick drum, contrary to American and, to a certain extent, British performances. Strongly influenced by jazz and rhythm'n'blues, they tended to be laid-back, with the snare slightly behind the beat. Greek Mikkey Dee is one of the few drummers Bauerfeind has worked with who manages to play both styles. On Helloween's »Just a Little Sign« (2003) he performs in a Teutonic style, on Motörhead's »Stone Deaf Forever!« (2003) he plays in an American/British style.

Methodology

Practice-led, practice-based research and practice as research—these approaches are different variations of a methodology that values the expertise of practitioners as researchers rather than viewing them merely as objects of

10 http://www.blind-guardian.com/popups/images/xmas2009/IMG_4115-resize.jpg. Access 4 June 2019.

study, as is common in traditional qualitative research. In his introductory chapter to the collected edition *Artistic Practice as Research in Music* (Doğantan-Dack 2015), Cook (2015: 13f) points out that the ›performative turn‹ in many arts, humanities, and social science disciplines since the 1970s has had little influence on musicology. In the United Kingdom this changed when the Arts and Humanities Research Council (AHRC) began to recognise the value of such research:

> Practice-led research is a distinctive feature of the research activity in the creative and performing arts. … it involves the identification of research questions and problems, but the research methods, contexts and outputs then involve a significant focus on creative practice. (Arts and Humanities Research Board 2003 in Graeme 2009: 47)

Smith and Dean (2009: 5) further stress that »creative practice—the training and specialised knowledge that creative practitioners have and the process they engage in when they are making art—can lead to specialised research insights which can then be generalised and written up as research.« The popularity of practice-led research brought about a thriving postgraduate community of researcher-practitioners in (popular music) composition and performance. Especially for performance, this practical turn seems significant when music is appreciated »as a temporal act rather than a notational artefact, and as a form of cultural and social practice encompassing a broad spectrum of repertoires, idioms, conditions« (Rink 2015: 128). The same holds true for popular music in recorded and produced form, which is fundamentally shaped—technically and artistically—by recording, mixing, and mastering methodologies. Expert knowledge in the field of music production is therefore highly valuable for decoding sonic signatures into their meaningful elements and the crafting techniques on which they are based.

Previous research on the Teutonic metal sound was limited by the lack of opportunities for direct comparison of sonic features between countries and cultures (Herbst 2019a, 2021). Even if one or two elements such as producer and studio were constant, there were still too many variables impacting the result. This is a problem because subtle details potentially mark significant differences. To overcome some of these methodological issues, this project builds on pastiche mixes to give audible examples of Teutonic, American, and British signature metal sounds from the same material. The sound files are provided in an audio appendix.

The remixed song for this project is »Sleeper Cell« by the Manchester-based band Kill II This, released as a single and video in 2017.[11] Having toured

11 http://kill2this.co.uk/

with American bands such as Anthrax, Slipknot, Machine Head, Megadeth, Fear Factory and with seminal German bands like Running Wild and Hellowween, the band performs at an international level. The recording also meets professional standards. It was recorded in one of Huddersfield University's studios[12] (Figure 2) on a British Audient ASP8024-HE analogue console (Figure 3) by the band's guitarist, Mark Mynett, a senior lecturer in music technology and production.

Figure 2: Live room of the recording

Figure 3: Control room with Audient ASP8024-HE desk

12 https://selene.hud.ac.uk/sengbr/Joomla3/index.php/bluerooms-profiles/greenrooms-profile

The multi-tracks are publicly available as part of the online appendix of Mynett's (2017) *Metal Music Manual*[13]. Stylistically, the track can be broadly defined as contemporary metal with fast sub-divisions and double kick parts, melodic singing, and virtual instruments that extend the traditional metal instrumentation. The condensed arrangement[14] comprises 48 tracks: 17 drums, 3 bass, 5 distorted guitars, 6 vocals, 1 synthesiser, 3 mellotron choirs, 1 mellotron strings, 7 virtual strings, 2 pianos. The choirs, strings, and pianos play throughout the song but are quiet in the mix up to the outro. All instruments except the synthesiser, mellotron, strings, and pianos were recorded in an overdub fashion: first the drums, then the guitars, bass, and finally the vocals. Apart from the miked guitar and bass amplifiers, the performances were also recorded as Direct Injection (DI) tracks, which allows re-amping through a ›real‹ amplifier or computer-based amplifier simulation in the later production stages. The song is in a 4/4 metre and changes tempo in the middle eight from 156 bpm to 116 bpm. Although the style is more modern than the music recorded by the German producers, whose experiences informed the theory of a Teutonic signature, it shares enough similarities to explore production features. The pastiche mixes were aimed at the production aesthetics of the 1990s but with a modern mastering level.

Mixing approaches

The three pastiche mixes were created using Avid Pro Tools, the industry standard DAW for metal music. This study understands itself as practice-led (as opposed to ›practice as research‹), which means that the creative output is subordinate to the research interest in creating and comparing versions of three distinct metal sounds. The mixes were approached to facilitate direct comparison in the same Pro Tools project, allowing processing to be varied systematically whilst keeping the signal chain as similar as possible (see Table 1, p. 16, for an overview). Figure 4 illustrates the instrument and pre-master busses of the three mixes; blue for the Teutonic, turquoise for the American, and green for the British mix.

13 https://www.routledgetextbooks.com/textbooks/9781138809321. The permission to use the song in this project was granted by the band.

14 Some tracks like those of all bottom tom microphones were discarded.

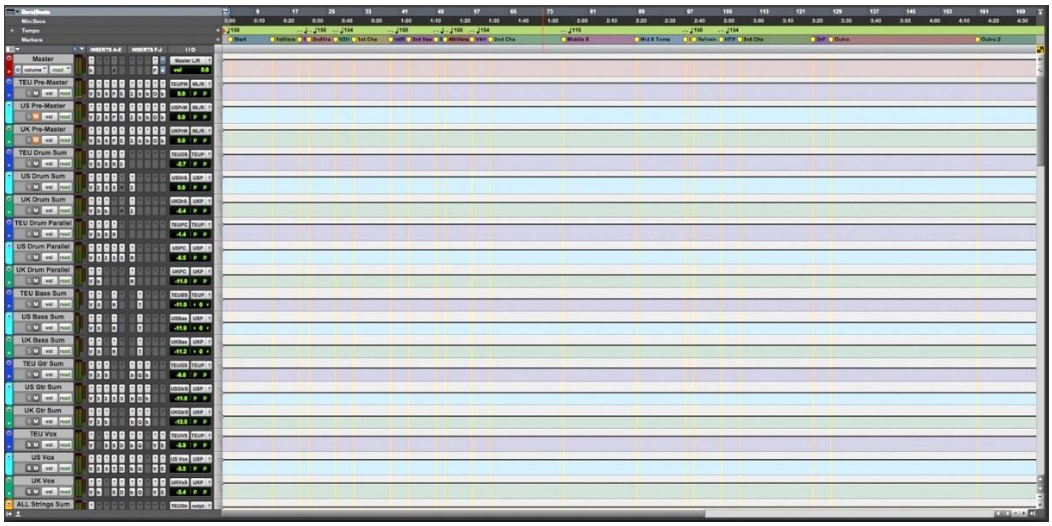

Figure 4: Instruments and pre-master busses of all three mixes

The Teutonic mix was created first. Once it was mixed and mastered, all tracks were duplicated twice and routed to new instrument and pre-master busses (Figure 5). Most tools and settings were identical, apart from key features that were altered.

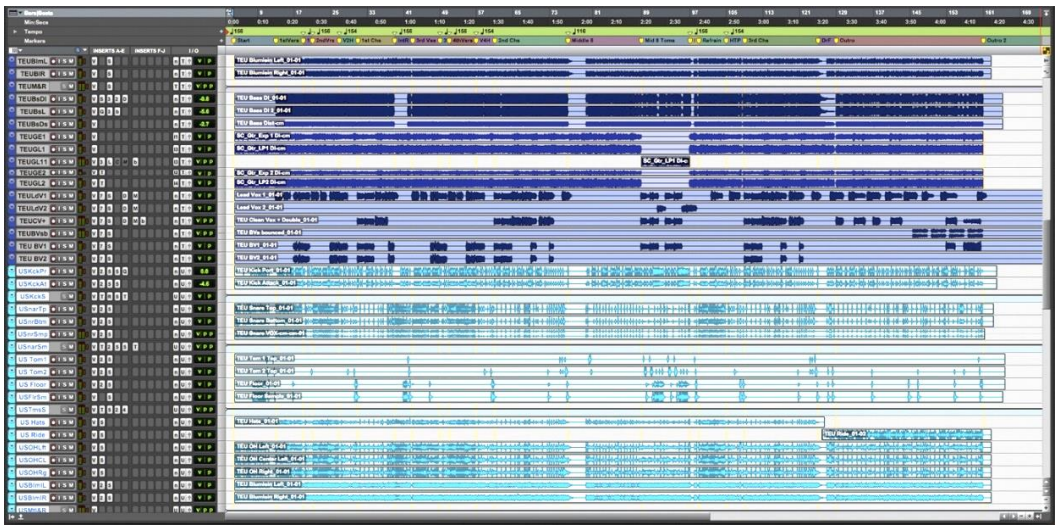

Figure 5: Tracks of the Teutonic original and the duplicated American mix

On all tracks, the first insert was the Slate Digital Console (Figure 6), which was set to an American API 1604 for the American, a Neve 8048 for the British, and a British Solid State Logic (SSL) 4000E for the Teutonic mix due to the lack of a German desk. The SSL is known for »tight but punchy low-end, warm low-mids, and a present midrange«, the API for its »thick and fat tone with incredible vibe and mid-range punch«, and the Neve for its »rich, fat, and warm sound« (Pack 2018). The drive levels were set to maximum (+18 dB) for maximum colouration.

Figure 6: Virtual Channels; ›Brit 4k E‹ is the SSL 4000E, ›US A‹ is the API 1604, ›Brit N‹ is the Neve

The Teutonic mix used the Waves SSL 4000E channel strip for equalisation and compression (Figure 7). The equaliser is parametric with adjustable frequency centres and bandwidth, also known as ›Q factor‹, and the compressor has a soft-knee response (Waves 2019a: 4). The American mix used API equalisers and compressors, also by Waves. Since they exist only as separate units, the filtering was done with API 550B and 560 equalisers, which have fixed frequency centres and non-adjustable bandwidths. Unlike the SSL equaliser, however, the API 550 series is equipped with a »›Proportional Q,‹ which intuitively widens the filter bandwidth at lower settings and narrows it at higher settings«, letting one »push the API 550 harder than you normally would other equalizers« (Waves 2019b: 6). The API 2500 compressor also differs from the SSL: although adjustable, only the hard-knee behaviour was used, resulting in more aggressive waveshaping. Additionally, it has a ›Thrust‹ setting that »inserts a High Pass Filter at the RMS detector input, limiting compression response to lower frequencies while applying additional compression to higher frequencies« (Waves 2019c: 6). The settings were transferred from the SSL channel strip to the API as authentic as possible, which was not always possible with the equaliser settings, since the SSL allows free choice of frequency, while the API has predefined frequency steps such as 50 Hz, 100 Hz, 200 Hz (see Figure 7). The sound neutral FabFilter Pro-Q3 equaliser was used for additional, more surgical low end control. The British mix used a Neve VCX console strip by Brainworx, since there is no emulation by Waves. The compressor threshold was medium-knee and the equaliser bandwidth adjustable, as with the SSL.

The master busses were completely identical except for one compression unit. The Teutonic and British master used the Waves SSL 4000G buss compressor, famous for its ›glue effect‹, whilst the American master had another instance of the API 2500 on it (Figure 8). Both had a 2:1 ratio and moderately fast attack time of 10 ms, but differed in their release times. The SSL featured automatic release, the API was set to a medium release time of 300 ms. The rest of the mastering chain consisted of multiband (Waves C6) and neutral broad-band compression (PSP MasterComp), equalisation (Brainworx Hybrid and 2098), stereo widening (Brainworx 2098), clipping (Stillwell Event Horizon), saturation (PSP Vintage Warmer), maximisation (Sonnox Oxford Inflator), and limiting (Brainworx Limiter).

Figure 7: SSL channel strip, API equaliser, and Neve channel strip

Figure 8: SSL 4000G buss compressor and API 2500 compressor

Additional vocal and bass compression was applied with Waves' emulation of the UREI/Universal Audio 1176 FET and Teletronix LA-3A electro-optical compressor. The compressors and a Waves PuigTec MEQ-5 mid-range equaliser were set to a utility frequency of 50 Hz for the Teutonic and British mixes and 60 Hz for the American mix. According to the manufacturer, this setting should affect noise behaviour and tonal colouration (Waves 2019d: 4). The American vocals were treated with AudioThing's (2019) Type A, a simulation of the Dolby A tape noise reduction unit. In every other respect, the vocal chains were identical in all three mixes. The reverb and delay effects on the vocals were all ›ducked‹ (lowered) by 6 to 10 dB with a compressor during singing to increase clarity, so that the full effects are only heard at the end of the vocal phrases. The stereo image was widened by 120 % for the Teutonic and American versions and by 110 % for the British production, based on America's renowned ›wall of sound‹ aesthetic that was adopted by Teutonic producers.

Since the same tracks were used in each mix, the sounds of all drum shells had to be altered artificially. For an audible difference between the three production styles, the shells were re-tuned with the Waves Torque plugin. The British kit remained unaltered; the Teutonic kick was tuned down by 450 cents, the snare by 210 cents, and the toms by 145 cents, whereas the American kick was pitched up by 100 cents, the snare by 200 cents, and the toms by 240 cents. These values were a compromise between stylistically appropriate sounds and acceptable quality. Clean snare hits were blended with the same hits from the room tracks to create a multi-sample instrument that added natural ambience to the snare sound without a reverb plugin. This snare sample was used on all mixes but with the different tunings. Only the Teutonic mix had kick drum sample reinforcement with the kit's own kick sound. Furthermore, the low tom track was duplicated and trimmed to isolate the attack portion. This sound served as another sample on the Teutonic kick to add high frequency drum-stick transients to the low tuning, a production trick by Bauerfeind. To simulate the loud snare wires in Teutonic productions, a duplicate of the bottom snare track was also bandpass filtered, parallel distorted, and envelope shaped (with the German SPL Transient Designer) to reduce the attack and lengthen the sustain phase. Toms were edited manually to remove spill in all mixes. Kick and snare tracks were gated in the American (with Waves' C1 gate) and Teutonic (with SSL channel strip) mixes for the controlled sound it creates. In each mix, the volumes of the individual instruments were adjusted according to the theory: loud kick and moderate snare for the Teutonic mix, moderate kick and loud snare for the American and British mixes.

Changing the room characteristics proved more difficult. In a metal music production, all instruments and voices are normally close-miked (Mynett 2017), so the room does not have a strong influence on the final sound. This does not apply to the drums. Since the overhead and room tracks in this project already had imprinted characteristics, further reverb on the main drum buss was only added to the Teutonic mix for a tiled wall characteristic. The parallel drum busses of all mixes were reverberated with the Waves Renaissance Reverb, slightly longer in the Teutonic (1.65 seconds) than in the American and British mixes (1.25 seconds).

Performance-wise, the snare was moved five milliseconds forward in the Teutonic mix to give space to the kick drum transients, in the American mix it was moved five milliseconds back for a laid-back feel, and the British snare was left unchanged (Figure 9).

Figure 9: Snare timing of all three mixes

The guitar sounds (two tracks of Gibson Les Paul and two of Gibson Explorer, each of them panned hard left and right) were recorded with Direct Injection (DI) tracks, allowing the use of amplifier simulations. Half of the guitars in the Teutonic mix were sent through an Engl E646 Victor Smolski amplifier (by Engl), the other half through an Engl 530 (by Brainworx), all with Engl cabinets. The guitars of the American mix went through two different Mesa Boogie Rectifier simulations (by Brainworx), each with nationally branded impulse responses (Figure 10). The British guitars were amplified with a Marshall JCM800 simulation (by Brainworx) with different settings and impulse responses. The Engl, Mesa Boogie, and Marshall amplifiers added distorted colours to the bass tracks, depending on each country.

Figure 10: American Mesa Boogie Dual Rectifier amplifier with American cabinet

In general, processing was limited to frequency and dynamic range control, some algorithmic reverb and delay effects (Valhalla Vintage Verb, Soundtoys Echoboy) and de-essing (Massey, Waves, Brainworx) on the vocals, bass shaping (Waves Renaissance Bass), saturation (PSP Vintage Warmer), and distortion (Soundtoys Decapitator). The mastering was influenced by the original track, but with very loud −6.5 LUFS (loudness units relative to full scale) it

was still two loudness units quieter, a decision taken to improve clarity. When soloing individual tracks in the audio export, the mastering chain was kept active to maintain the sound features as much as possible, but less compression was applied due to quieter programme levels.

Table 1: Comparison of the main sound colouring processing for each country

General Mixing	Teutonic	British	American
Virtual console	*SSL 4000E*	*Neve 8048*	*API 1604*
Equaliser	*SSL 4000E*, *Waves PuigTec MEQ-5 (50 Hz)*	*Neve VCX4000E*, *Waves PuigTec MEQ-5 (50 Hz)*	*API 5504000E*, *Waves PuigTec MEQ-5 (60 Hz)*
Compressor	*SSL 4000E, Waves 1176 (50 Hz)*	*Neve VCX, Waves 1176 (50 Hz)*	*API 2500, Waves 1176 (60 Hz)*
Instruments and Vocal Processing			
Vocal refinement	—	—	*AudioThing Dolby A*
Guitar and bass amplification	*Engl E646, 530*	*Marshall JCM800*	*Mesa Boogie Rectifier*
Drum re-tuning	Kick −450c, snare −210c, toms −145c	—	Kick +100c, snare +200c, toms +240c
Drum reverb	*Waves RVerb with tiled wall on main and parallel buss*	*Waves RVerb on parallel buss*	*Waves RVerb on parallel buss*
Drum gating	*SSL 4000E*	—	*Waves C1*
Drum reinforcement	Snare sample with room ambience, *kick sample (from kick and low tom)*, *fake snare wires*	Snare sample with room ambience	Snare sample with room ambience
Drum performance	*Snare 5 ms ahead*	—	*Snare 5 ms back*
Mastering			
Virtual console	*SSL 4000E*	*Neve 8048*	*API 1604*
Stereo widening	*120 %*	*110 %*	*120 %*
›Glue‹ compressor	*SSL 4000G*	*SSL 4000G*	*API 2500*
Multiband compressor	Waves C6	Waves C6	Waves C6
Broadband compressor	PSP MasterComp	PSP MasterComp	PSP MasterComp
Clipper	Stillwell Event Horizon	Stillwell Event Horizon	Stillwell Event Horizon
Saturation	PSP Vintage Warmer	PSP Vintage Warmer	PSP Vintage Warmer
Equaliser (Stereo)	Brainworx Hybrid	Brainworx Hybrid	Brainworx Hybrid
Equaliser (Mid/Side)	Brainworx 2098 (Amek 9098)	Brainworx 2098 (Amek 9098)	Brainworx 2098 (Amek 9098)
Maximiser	Sonnox Oxford Inflator	Sonnox Oxford Inflator	Sonnox Oxford Inflator
Limiter	Brainworx Limiter	Brainworx Limiter	Brainworx Limiter

Note: Processing in italics differs between one or more of the mixes

Comparing the mixes

On a global level, all three mixes (*audio examples 2-4*) of the same multitracks (*audio example 1*) have clearly diverging sounds resulting from the production choices described above. All artificially created sonic signatures seem to work musically and technically and bear similarities with productions from respective countries in the 1990s. The analysis of the spectra with two- and three-dimensional representations was inconclusive, so the following comparison is mainly based on listening perception.

In the corresponding literature, the tone of the electric guitar is described as decisive for the quality and classification of metal (Berger/Fales 2005; Herbst 2017). Indeed, the guitar sounds of the three versions are distinct and immediately attract attention (*audio examples 5-7*). The British and American amplifiers fulfil their expectations: the British Marshall fills the spectrum of the mix with its distinctive midrange and thus occupies a prominent place in the arrangement. The American Mesa Boogie is the exact opposite with its ›scooped‹ sound, heavy in the bass and rich in treble. It hardly competes with the snare drum and tom transients and leaves more space for the vocals. Despite its rich low end, the bass guitar is intelligible due to the careful low end control; the same holds true for the British mix. Interestingly, the kick in the American mix seems to be located above the guitars, an unusual effect that rearranges the frequency spectra of the instruments. The Teutonic guitar sound of Engl has more presence in the top end without neglecting the other frequencies. In comparison—and in line with the common view—, it sounds brighter and somewhat ›sterile‹. Despite the pronounced presence, the Engl's bass frequency resembles the American Mesa Boogie but is more strongly disguised by the top end, making the Teutonic guitar tone the brightest.

The bass guitar is a blend of two identical DI tracks, one processed for general tone and consistency and one for low end. Only the distorted third track varies between the three mixes—as do the relative volumes of the bass tracks due to mix requirements. The bass sounds differ in a similar way to the guitar sounds: Teutonic the brightest, American booming with noticeable treble distortion, British ›wooden‹ and pronounced in mid-range (*audio examples 8-10*).

The ways bass and guitars are combined also leads to different flavours (*audio examples 2-4, 11-13*). In the Teutonic mix, the bass is not very present; due to the distinct treble information, it blends with the guitars and it is masked more strongly by the kick drum than is the case in the other mixes.

The bass is slightly more present in the American mix, but still blends with the guitars because of their dominant low end. In the British mix, bass and guitars are the most separated and remain recognisable as independent instruments due to the mid-frequency centre of the guitars.

The drum sounds also differ significantly between the three sonic signatures in accordance with the theory (*audio examples 14-16*). Authentic for the Manchester-based band, the drum shells are unaltered in the British mix. According to the FabFilter Pro-Q3 spectrum analysis, the kick drum's lowest resonance is at 119 Hz, quite high for this instrument and representative of what Bauerfeind described as a ›wooden‹ aesthetic. This is also true for the snare with its high fundamental resonance at 247 Hz. The kick resonance in the American mix is not higher, but due to formant shifts the sound is brighter. The snare drum's centre fundamental is at 271 Hz. In contrast, the Teutonic kick sits at 64 Hz and the snare at 216 Hz; still too high, yet the lower tuning has an audible effect on the entire drum sound. The fake snare wire rattle is effective in achieving the Teutonic signature: low tuning and yet bright because of the present rattle. The diverging tom tunings also have a striking impact on the overall production aesthetic, most clearly in the middle eight tom break. All tunings work within the chosen aesthetic, but the low Teutonic tuning was more challenging to mix as it required multiband compressors for dynamic control. For example, masking was reduced by using a multiband compressor on the bass guitar, side-chained to the kick to ›duck‹ the lowest frequencies of the bass with every kick hit. The kick and snare gating in the Teutonic and American mixes is rather subtle, but the special combination of articulated hits and audible reverberation on the Teutonic drums sounds unique. Regarding the relative volumes of kick and snare, the Teutonic style works with the loud kick and quieter snare just like the more prominent snare functions in the American and British mixes. However, achieving these aesthetics required advanced side-chain multiband compression and dynamic equalisation techniques in the mix. The mastering still defined the limits of what was possible. With a limited dynamic range of seven decibels, any volume increase of kick or snare in the respective mixes was eventually rendered ineffective by the broadband compressors. Multiband compression mitigated this but had a negative effect on other instruments in that frequency range. The best solution to maintain a loud kick drum in the Teutonic production was to combine broadband (SSL) and multiband (Waves C6) compressors with another broadband compressor (PSP MasterComp) equipped with a side-chain filter that ignores bass and sub-bass frequencies. Between the mixes, the cymbals do not differ significantly, since little processing was done except for the rooms that were bandpass filtered in all mi-

xes between 100 and 4,000 Hz and heavily compressed with ten decibels of gain reduction. Apart from the ›dryer‹ 1.25-second reverb in the other two mixes, only the Teutonic mix with a ›wetter‹ 1.69-second reverb time from a tiled room was given a different spatial characteristic. Reverb was applied to both the drum and parallel drum compression busses for the Teutonic mix, but only to the parallel buss in the other mixes. Having had the opportunity to listen to raw tracks of drum recordings in some of the popular German studios, the acoustic pastiche bears similarities to authentic productions. The drums shells are deep but still bright because concrete or tiled walls create an ambience with hard reflections. Even in the full arrangement this room character is recognisable without reducing the clarity too much. It should be noted, however, that the room choices for the American and British drums are somewhat arbitrary, as rock and metal were produced in different sized studios in both countries. Rather important in this context are the tiled walls characteristic of the Teutonic drums.

Performance characteristics could only be simulated rudimentarily by nudging the snare back and forth on the grid (*audio examples 2-4, 14-16*). Empirical research suggest that listeners can distinguish between rhythmic events that are 30 to 50 ms apart (Clarke 1989). Yet the snare already sounded unnatural when it was moved by 10 ms—nothing that should theoretically be perceptible. In the end, 5 ms was chosen; a value still noticeable. To my German/European ear, the unaltered British snare and the slightly rushed Teutonic snare sounded almost identical. The American snare, on the other hand, appeared laid-back and seemed to change the groove significantly. It is worth noting that even rigid quantisation, e.g. with Pro Tools' Beat Detective, does not affect these performance features, as edits are made in ›group-locked‹ mode to avoid phase problems and audible flams. To alter natural characteristics of the performance, an engineer or producer would need to manually change the timing of the snare tracks in a separate step. Whether this is common practice in contemporary metal production practice is unclear. Apart from the perception thresholds of micro-timing, the range of deviation (+/- 5 ms) is also worth discussing. In ›groove-based music‹ like Afro-American soul, funk, and r'n'b, expressive micro-timing ranges between 30 (Danielsen 2012: 158) and 70 (Danielsen 2010: 22) milliseconds, which matches Clarke's (1989) claim of 30 to 50 ms as the threshold for the perception of expressive timing. This project suggests that micro-timing in metal music could be in much shorter ranges[15], but still have a significant effect, making it an overlooked phenomenon in popular music research.

15 These smaller values of micro-timing are probably a consequence of the much faster song tempos in metal music on average.

The vocal sounds (*audio examples 17-18*) differed only slightly, although the American tracks were treated with a Dolby A simulation (by AudioThing) to boost the top end. Of the four bands, only the two highest were used with a boost of 2.3 dB in the third and 2.7 dB in the fourth band. The mix amount was set to 80 %. Despite the relatively low values, the vocals are much more present in the arrangement. Aesthetically, this processing is not optimal for this singer's voice, as it is quite harsh already. Reducing shrieking s, z and c consonants by de-essing and filtering was made more difficult by Dolby A processing. With another singer, however, this technique, common in the USA, would likely make the vocal sound stand out from competing productions.

The choice of different console characteristics was somewhat arbitrary, as in the formative phase of metal, all desks were available in all three countries. Bypassing all instances of virtual console emulation had little impact on the three mixes, apart from the effects created by volume changes in the signal chain (*audio examples 19-21*). In all cases, the respective emulation made the sound slightly brighter and compressed, but the effect was so marginal that no significant differences were noticeable between the three consoles. Testing the console emulations with sine waves, needle pulses, and white noise revealed larger deviations. The British SSL emulation was slightly louder than the British Neve, which in turn was louder than the American API. The louder the console was, the smaller the loudness range (LR) and peak to loudness ratio (PLR) became, indicating a dynamic compression behaviour. All consoles had different harmonic distortion characteristics. The SSL and API shared some harmonics but differed in other. Despite this obvious colouration on test tones, little of it can be heard in the full mixes. The heavy use of distortion at source level probably prevents this, next to distortion, saturation, and clipping applied in the mixing and mastering stages. This might explain why metal was amongst the first genres to move to digital production technology compared to other band-based genres (Thomas 2015). With heavy distortion and broadband compression, the subtleties of tone are likely to disappear. The utility frequency of vintage compressors (Universal Audio 1176 and Teletronix LA-3A) and equalisers (PuigTec MEQ-5) also did not create an audible difference. The effect of utility frequency on guitar and bass amplifiers could not be tested with the project setup, but according to producer Bauerfeind the effect should be audible.

The diverging equalisers and compressors used in the three mixes had a noticeable effect on the sonic result and workflow. Rather limited was the API 550 equaliser with its fixed centre frequencies. Whilst cuts are often wide, unless one wants to remove ringing or piercing frequencies, boosts are

narrow to strengthen specific qualities of an instrument. This was difficult to achieve in the American mix, especially on the kick and snare drum, as only 40, 50 or 100 Hz could be selected. Musically, this range spans more than one and a half octaves with few opportunities for fine-tuning. This was partly mitigated by using the graphic API 560 equaliser with slightly different centre frequencies. For compression, however, the API's hard knee and ›Thrust‹ filter proved very suitable for the metal genre because it allowed rigid dynamic range control of instruments with various frequency spectra. The SSL and Neve equalisers and compressors were similar in functionality; the SSL brighter in overall tone.

Conclusion

There are many elements that shape the sound of a record, all of which are subject to changes over time in the context of a band's history or due to broader trends in genre aesthetics and production practice. These include performance skills and compositional preferences, recording, mixing and mastering engineer(s), producer(s), the recording studio(s), available equipment, and record label requirements. Therefore, sonic signatures have become less distinct today than in the 1960s and '70s:

> I think there is a distinctly different way that the English and the Americans did things … I don't think our Brit acoustic designers thought the same way as maybe the Americans did … Our rooms sounded different, the way we designed things was definitely different. I think it was the approach that the engineers had. There's definitely a British sound and an American sound … So there was a difference, I think, from both sides of the Atlantic, to do with music, to do with the producers, to do with the engineers, to do with the studios. (Toft in Zagorski-Thomas 2012: 57f)

This study explored sonic signatures in metal music from the USA, UK, and Germany based on interview statements from producers who were crucial for the emerging metal scene in Germany in the 1980s and '90s and are still active today, producing mainly melodic speed, power, and thrash metal. Creating one single pastiche mix that represents a whole country with its numerous bands, engineers, producers, and studios is obviously a reductionist approach. Furthermore, the signatures were mainly determined by the perceptions of German producers, supplemented by the little research that exists on the subject (Zagorski-Thomas 2012; Massey 2015). Even if more account had been taken of the views of British and American engineers and producers, there are still too many variables and different opinions to find a consensus on any

signature. Zagorski-Thomas's (2012) study demonstrated that already by the 1970s, when production conventions differed considerably, professionals did not agree on whether there were national signatures, nor on the respective characteristics. Similarly, the interviewed Teutonic producers were divided on the details of sonic features. Regardless of individual beliefs, the practice-led methodology has shown that the same source material can be modified to create unique sonic signatures based on the mixing and mastering engineer's vision. This does not mean that the recording stage becomes unimportant;[16] it rather highlights the range of possibilities that digital production tools offer in the mixing stage. These tools probably explain why sonic signatures have become less distinct. Mastering engineer Glenn Meadows once claimed that most in the business began using the same tools (Owsinski 2008: 218f). But it could just be the opposite: in fact, there are so many signatures today that larger cultural or geographical areas like cities or countries no longer have a coherent sound, unlike in early metal music when most bands were produced by a handful of professionals in a small number of studios (Herbst 2019). Modern digital signal processing is so powerful that any source material can be transformed beyond recognition. Productions and performances have consequently become hyper-real. Using compression and equalisation with rarely more than 3-6 dB of boosts and cuts, along with original drum tracks without external sample enhancement or replacement, the three pastiche mixes in this study were achieved with minimal processing, yet the results are significantly different. With affordable means, almost anything seems possible today when it comes to sonic transformation, for example shaping guitar sounds with signal processing at source with powerful simulation (Fractal Audio Axe FX, Line 6 Helix) or profiling (Kemper Profiler) technologies (Herbst, Czedik-Eysenberg/Reuter 2018). It is therefore not surprising that the sonic signatures of geographical or cultural areas are becoming less distinct. On the other hand, every engineer, producer, and self-producing artist can have their own signature if they dare to adopt new production methods and not just copy from the past.

16 Despite the powerful tools available for correction, the performances must still be good, possibly even more than in the past, as expectations of virtuosity in many metal genres are constantly rising. However, the recording environment has changed with the small budgets in the industry. Even internationally active bands often lack the budget to record in well-equipped studios, so much of the recording environment is artificially created in the mixing stage.

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