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SIDECHAIN COMPRESSION AND THE SONIC CONSTRUCTION OF GROOVE IN ELECTRONIC DANCE MUSIC

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Abstract

This study investigates the role of lateral dynamics processing—specifically sidechain compression and ghost sidechaining—in shaping the sensation of groove within electronic dance music (EDM). While groove has traditionally been associated with micro-temporal variations in live performance, EDM producers often rely on dynamic manipulation to elicit physical responses from listeners. Drawing on theoretical frameworks from embodied music cognition, sensory-motor theory, and record production as musical practice, this research explores how compression techniques influence rhythmic clarity, amplitude modulation, and listener engagement. Through qualitative analysis of three representative tracks—*Music Sounds Better with You* by Stardust, *Tea Leaf Dancers* by Flying Lotus, and *Can't Stop the Feeling* by Justin Timberlake—the study demonstrates how producers creatively use compression to construct groove beyond conventional rhythmic structures. Findings reveal that lateral dynamics processing is not merely a technical tool but a central aesthetic and expressive element in EDM production. This work contributes to a deeper understanding of groove as a sonic, embodied, and production-driven phenomenon, offering insights for music scholars, producers, and educators.

Keywords: *Groove, Sidechain Compression, Spectrogram Analysis, Electronic Dance Music (EDM), Record Production as Musical Practice*

INTRODUCTION

In contemporary electronic dance music (EDM), the sensation of groove is a defining characteristic that compels listeners to move, dance, and engage physically with sound. While groove has traditionally been associated with rhythmic complexity and micro-temporal variation in live performance, its construction in electronically produced music often relies on different mechanisms. Among these, lateral dynamics processing—particularly sidechain compression and ghost sidechaining—has emerged as a powerful tool for shaping groove in the studio.

In this context, ghost sidechaining refers to a dynamic processing technique where an inaudible audio signal—often a metronomic pulse—is used to trigger a compressor, causing other musical elements to 'duck' in amplitude rhythmically. This differs from conventional sidechain compression where the trigger is typically an audible source such as a bass drum.

Despite its widespread use in EDM and related genres, the role of lateral dynamics processing in groove creation remains underexplored in academic literature. Much of the existing research on groove focuses on live performance, timing deviations, and embodied cognition, with limited attention given to the technical and aesthetic dimensions of music production. As Jay Hodgson notes (Hodgson, 2011), there is a pressing need to understand recording and mixing practices not merely as technical processes but as integral components of musical expression.

This study addresses that gap by investigating how lateral dynamics processing contributes to the perception of groove in EDM. Drawing on theoretical frameworks from embodied music cognition, sensory-motor theory, and record production as musical practice, the research examines how compression techniques influence listener experience. Through a qualitative analysis of selected tracks, this paper explores how producers use sidechain compression and ghost sidechaining to modulate amplitude, enhance rhythmic clarity, and elicit physical responses from listeners.

By situating production techniques within broader theoretical and perceptual contexts, this study aims to deepen our understanding of groove as both a sonic and embodied phenomenon. It also highlights the creative agency of producers in shaping musical meaning through dynamic manipulation, offering new insights into the aesthetics of EDM and the evolving role of the studio in contemporary music-making.

LITERATURE REVIEW

In an article published in 2011, Hodgson wrote that lateral dynamics processing in current popular music practice is "as common as tapping and power chord once were in heavy metal". He added that hip-hop producers often used sidechain compression to convert ambient pads into rhythmic material playing the upbeat of the song to support the groove. This technique is also commonly used in EDM.
However, a systematic understanding of how lateral dynamics processing contributes to groove is still lacking. Hodgson also commented that very little attention has been paid to the technical and musical aspect of signal processing in the research on popular music practice and calls for a research program to elucidate recording practice as musical practice.

This section aims to shed light on the technical aspects and aesthetics of signal processing, particularly lateral dynamics processing. The first section of this paper attempts to unravel the concept and the components that constitute groove. This provides a basis in understanding the aesthetics of lateral dynamics processing and how it affects groove. The section is then followed by a brief history of Disco music. This facilitates an exploration into other factors that contribute to groove, particularly in Disco and subsequently EDM.

What is Groove?

A chapter in an Oxford handbook published recently listed three different approaches to define groove (Câmara & Danielsen, 2019). The first approach considers rhythmic qualities or a performance style that listeners perceive as groove (e.g. swing groove, funk groove, laid-back groove, and so on).
One of the characteristics of groove in music is micro-temporal variation in performance, which may be caused by measurable temporal fluctuations amongst the musicians (Keil, 2011). A considerable amount of research has been conducted into the effect of micro-temporal and rhythmic variation on how humans enjoy music (Danielsen, 2010)(Madison & Sioros, 2014)(Sioros et al, 2014)(Witek, 2017). Researchers found that the participants rated music that contains micro-temporal and rhythmic variations as more 'groovy' and enjoyable.

One of the genres that fits this definition is hip-hop music. The swung and laid-back feel in this genre is one of the features that differentiates it from other disco offshoots (Vox, 2020). Early hip-hop producers were able to create this style of groove using the Akai MPC 60 (Walker, 2017). Where sequencers like the Roland 808, used a step-sequencer to program drum beats with a perfectly straight timing, the Akai MPC 60 was the first device to feature quantisation and 'swing'.

Consequently, not only can the user correct the timing of their samples and recorded performance, the MPC can also be used to alter the temporal placement to a specified setting. This attribute is very influential on the common inclusion of quantisation in DAW MIDI sequencers such as Logic Pro (Moores, 2017) Even the presets in some DAWs are inspired by the MPC (Scarth & Curry, 2013). The manipulation of micro-temporal factors using electronic devices such as the one mentioned above proved to be successful as it made listeners more prone to physically react to the music. This brings us to the second interpretation of groove.

For the second definition, the authors interpreted groove as having the ability to impart the pleasurable sensation of wanting to move in response to music activities. Numerous studies have been conducted in the field of embodied cognition in music perception. However, because this article addresses lateral dynamics processing, which is prominent in EDM, the literature survey for this study focuses more on physical movements in this genre.

One research project, for instance, found that large-scale variations, such as the removal and reintroduction of textural layers or drum breaks in EDM, enhances the experience of groove by giving the listeners a sense of anticipation (Solberg & Jensenius, 2017)(Witek, 2009). The author further suggested that up-beat groove-based music, a characteristic of most EDM, represents the perception of groove more closely as it made the listeners want to move and dance. Furthermore, in EDM the feeling of wanting to move to the music is induced even though the listeners are alone and sitting still, similar to home listening conditions (Solberg, 2015). Adding to this, it was reported that the participants of an experiment produced more physical movements when dancing to EDM compared to jazz, funk and Latin music (Burger & Toiviainen, 2018). It is therefore clear that EDM contains groove, even though in some cases it may not contain micro-temporal variations.

The third definition of groove is as a state of being. It refers to a pleasant state in which creating music or moving to the music becomes effortless. Unlike the previous two definitions, there is no quantitative measurement for this approach because of the contemplative nature of this interpretation. An interesting anecdote was given by a researcher posted in a question on an internet forum about the mental process of getting in the groove. The answer was somewhere along the lines of "if you don't feel it, you'll never understand it" (Zagorski-Thomas, 2007a). This definition is more suited for musicians and dancers as they do understand the feeling of "being in the groove", especially in music related activities such as playing their instrument or dancing in a performance.

In the final section, the authors provided a list of factors that contribute to groove. Most of these factors relate to the metric and rhythmic qualities of the music. The authors analyzed several groovy tracks to validate their definitions. This was done by notating the rhythm of the instruments, measuring the deviation from the

intended pulse, and examining the subdivisions and rhythmic grouping. However, towards the end of the chapter the authors voiced that there might be other elements of groove.

One detail worth mentioning is that the handbook only analysed music created by a single or group of musicians playing their instruments. This is not always the case with EDM whereby in most situations it is composed and performed by one DJ using electronic devices. For these examples, there are no micro-rhythmic inconsistencies because the musical elements are mostly sequenced and quantised. Yet, as indicated by its popularity in dance venues, this genre is considered groovy. Therefore, this research proposes that the two qualities mentioned are not groove's only determinants. This notion is explored in the following sections.

Although EDM often lacks the micro-temporal nuances found in live performance, its ability to evoke movement and engagement suggests alternative mechanisms at play. One such mechanism is the strategic use of bass, particularly in club environments where sound systems and production aesthetics emphasize low-frequency energy. To explore this further, we begin with a historical overview of EDM's sonic lineage, tracing its roots to disco.

Bass and EDM (In the Clubs)

To understand how bass contributes to groove in EDM, it is essential to examine the genre's historical and cultural foundations. EDM spans numerous sub-genres, each characterized by its use of electronic devices and its emphasis on facilitating dance experiences. Between 1998 and 1999, researchers identified over 300 EDM sub-genres (McLeod, 2001). One feature that they all share is a near-total reliance of electronic devices to create music.

For this study, EDM refers to electronically produced music designed specifically for dancing. It is beneficial to learn a brief history of EDM to understand the aesthetic of its production.

EDM traces its roots to disco, sharing features like four-on-the-floor bass drums, repetitive structures, record-centricity, and DJ-driven production using electronic instruments. The quote below eloquently summarises the rise and fall of Disco;

> *…Disco emerged as an outgrowth of the Stonewall Rebellion of June 1969 and unfolded as predominantly male gay subculture; that the dance movement was subsequently co-opted, commodified and tamed by films such as Saturday Night Fever (1977), which established it as a safe haven for straight courtship; and that the commercial overkill that followed the runaway success of the RSO movie culminated in an overtly homophobic backlash that turned on the culture's perceived latent gayness.* (Lawrence, 2011)

One of the defining aspects of Disco music compared to its counterparts in the late 70s is powerful bass. During this period, a typical mastering process usually involved using a high pass filter to remove the sub frequencies (Ketterer, 2015). As a result, the music released in the 70s and 80s is usually quite weak, relatively speaking, in the low frequencies. However, in the height of the disco era an American audio equipment manufacturer, dbx, introduced the Model 100 (Papenburg, 2016).

The dbx model 100 is able to synthesise the ultra-low frequencies based on the mid-low frequencies available in the track, enhancing the low frequency content of the mix during playback without needing to re-mix the music in the studio. It became very popular in the discos and, coupled with the sound system in the venues which were specially designed to be capable of reproducing sub frequencies, unwittingly made powerful bass a characteristic of dance music.

Other than the dbx 100 processor, the introduction of 12-inch singles onto the market also contributed to the signature sound of dance music. Disco music publishers favoured using this format to release their music because it enabled longer duration of music to be played. It was also popular amongst DJs because it facilitated continuous dancing (Osbourne, 2016). Furthermore, the wider space in the groove not only enabled the signal level to be boosted but also the bass frequencies in Disco releases

After the death of Disco, clubs played music which had similar characteristics but was marketed under the name 'dance music' to disassociate it with gay connotations (Frank, 2007). Dance music spread across America and eventually split into three different sub-genres, notably; house in Chicago, garage in New York and techno in Detroit (Daub, 2014).

Even then, the aftermath of disco's unfavourable undertone that lead to its demise was so pervasive that the DJs had to find new ways to attract patrons to frequent night clubs. One method was to play music continuously for hours to keep the party-goers dancing (Snoman, 2009).

Another approach was to play music at high levels that dominated over other sounds that might distract patrons (Fikentscher, 2000). Unfortunately, high sound pressure levels in the higher frequency regions is uncomfortable to listen to and caused patrons to leave. To counter this, the DJs started using the three-way crossover to increase the level of the bass while simultaneously decreasing the high frequencies, enabling them to play the music louder without hurting the ear. All these factors have resulted in the bass drum becoming the dominant element in dance music. This still remains the case.

The cultural prominence of bass in dance music venues is matched by its perceptual power. Beyond its sonic dominance, bass frequencies have been shown to influence listener behaviour and emotional response. The following section delves

into the cognitive and physiological effects of bass, revealing its role in shaping groove through embodied experience.

Cognitive Effect of Bass

Beyond its cultural and sonic prominence, bass in EDM has drawn scholarly attention for its profound impact on listener perception and physical response. Recent studies have begun to uncover how low-frequency sounds influence movement, emotion, and the sensation of groove. In one experiment, a louder bass drum caused the intensity of the participants' physical movements to increase, while reducing the bass-drum level produced the opposite effect (Van Dyck et al, 2010). Therefore, bass-heavy music can be considered more groovy, consistent with the second definition of groove. In another experiment, the participants rated music where audio filters do not eliminate low-frequency energy 'groovier' and more likeable (Lustig & Tan, 2019).

Furthermore, low-frequency contents in music can impart a sense of power to the listener. The result of five experiments in a study concluded that bass-heavy music conjures a sense of power and can impart power-related cognition and behaviour (Hsu et al, 2015). Heightened feelings of power, status and dominance are typically associated with more animated and energetic physical gestures (Burgoon & Dunbar, 2006)(Carney, 2020). This may explain the participants' intense movements, which contributed to the perception of a groovier mix.

Contemporary DJs also recognize the importance of bass and apply it creatively in their production and live performance. However, the application is not as some might expect, in that it does not involve overemphasising the bass, but rather removing it altogether. Zeiner-Henriksen (2012) described the technique used as follows:

> *On the dance floor, the impact of the bass drum is, for example, shown through a common technique used by the DJs: its removal (or filtering out of low frequencies). This has an immediate effect on the dancers: the intensity of their movement decreases and their attention shifts to the DJ as they await the bass drum's return. The DJ may keep the crowd in suspense for quite some time while slowly building up to the climactic moment when the bass drum is re-introduced and the crowd delightfully satisfied returns to the dancing.* (Zeiner-Henriksen, 2012).

This technique is also described elsewhere (Solberg, 2014). The DJ aims to enhance the emotional intensity of the groove which they have created through layering and introducing new variations. Once the music reaches the intensity intended by the performer, the bass drum is totally removed from the groove. A filter

is also then used to gradually remove the lower frequencies, creating a sense of 'upwards movement' (also known as the build-up). The DJ may build the intensity in this section by adding a 'drum roll effect' and white noise sweep before a short silence. The bass is then re-introduced together with all of the previous musical features.

Contemporary bass manipulation in dance music evolved from disco, which initially lacked low-frequency content. During the first epoch of dance music when the music was lacking low-frequency contents, the producers synthesised bass frequencies from the low-mids and accentuated it throughout their performance to keep the patrons dancing. Today, producers often remove bass entirely during a build-up to heighten emotional intensity before its return.

At present, the importance and effect of bass drum in EDM has been explored. Therefore, it is worth presenting relevant literature that may facilitate an understanding of the cause of this phenomenon. A theory was proposed about a biological reason for why humans tend to physically react to low-frequency stimuli (Todd & Lee, 2008).

According to them, humans have positive and negative reactions to vestibular stimuli caused by physical movements. A few examples of positive reactions to low-intensity movements include the rocking motion in cradles and rocking chair that causes relaxation, bungee jumping and dancing using medium-intensity movements. At high intensity, the physical movements create negative reaction, for example motion sickness.

The author adds that the vestibular system is sensitive to low-frequency vibrations which may explain listener's preference for the bass drum in dance music (Todd, Rosengren & Colebatch, 2008). Most people have been involved in music related activities that produce positive vestibular stimulation since a young age. For example, it is typical for mothers to sing lullabies while rocking their baby. As they progress with age and gain comprehension, babies are motivated to positively react to music by dancing and given encouragement in the form of cheers and laughter. Years of activities involving movements coupled with music from the early age create a form of classical conditioning by associating music with low-intensity movements. By listening to music, we will habitually bob our head or dance to gain positive reactions from the stimuli.

To recapitulate, one of the factors that has been explored that contributes to groove in EDM is the bass drum. Powerful bass drums were historically associated with disco and night clubs for a number of practical reasons. However, it soon became a stylistic choice for Disco and dance music production. This is driven by the positive reactions to the low frequency content of the music from the audience. Scholars have noted the importance of low frequencies in groove and produced a few theories to explain its cause. Contemporary DJs then found new methods to further

enhance the effect of low frequencies during their live performances by removing and re-introducing in the mix.

Having established the significance of bass and dynamic processing in shaping groove, we now turn to the theoretical frameworks that underpin this study. These perspectives—embodied music cognition, sensory-motor theory, and record production as musical practice—offer a multidimensional lens through which to analyze groove in EDM.

Insights into the cognitive and emotional impact of bass provide a foundation for understanding its creative application in studio production. Producers have developed innovative techniques to replicate and enhance these effects, using compression and dynamic manipulation to construct groove. The next section examines how these practices evolved, highlighting the aesthetic and technical strategies behind bass-driven EDM.

Bass and EDM (In the Studio)

As disco and club culture gained influence, producers aimed to recreate its immersive, bass-driven experience in studio recordings. This led to innovative mixing techniques that foregrounded the bass drum, shaping the groove through dynamic manipulation and compression. One example is given by Tony Swain in an interview describing his approach to mixing Imagination's 1981 single 'Body Talk';

> *…Morgan Khan who ran Street Sounds, when I mixed it, he was going to the clubs all the time and he sat with me and he drove me as well: he's going to me 'we need to go louder'. People ask me 'how did you get that sound?'. Obviously, it was the attack of the bass drum, and that was due to the DBX 160 we used; but it wasn't just that, it was the fact that we got a balance and then we put it up another 6 dB. So when we thought it was right we put it much higher; so it dominated the mix, and drove it.* (Wells, 2015).

In simpler terms, once the mix was balanced, producers often pushed the bass faders to their peak—just below clipping—to make low frequencies dominate. This is done without adjusting the other faders.

Alternatively, the engineer can use a multi-band compressor to separately compress different frequency bands to raise the overall level of the mix. Because the bands are processed independently from one another, compression of the loud bass drum does not trigger 'pumping' unlike a single-band compressor. As a result, the overall mix can be perceived as being louder.

Decades ago, pumping was considered to be an undesirable effect and often treated as a problem to be prevented or fixed. However, the situation changed when

producers started to creatively incorporate it in their works towards the late 1990s. One of the first published works that extensively featured pumping in the mix was a song titled *Music Sounds Better with You* by 'Stardust'. The producers used an Alesis 3630 compressor on the master bus of their bass-heavy track in an attempt to make it louder (Rogerson, 2019). It remains unclear whether this was a deliberate choice or a workaround due to limited equipment.

The bass drum was so dominant in the mix that it triggered compression that is not only audible in the vocal track but also throughout the whole mix. The pumping effect became a distinctive feature that likely contributed to the song's commercial success in 1998. As a result, other producers then emulated the same approach.

One of the acts that followed the same method was Daft Punk (one half of whom was a member of Stardust). The duo used the same mixing approach for their second studio album entitled 'Discovery'. Pumping is clearly audible in the first single, 'One More Time'; most notably on the vocal and the brass samples starting from 45 seconds onwards. The level of the brass and the vocals are attenuated every time the bass drum is present, similar to the characteristics of the song released by Stardust cited earlier. Among the other producers that also featured overt pumping in their mix are Benny Benassi, Eric Prydz, David Guetta and Avicii. Not long after, this creative use of compression could be heard in genres other than dance music. It had also spread to other genres as well such as experimental hip hop and even contemporary popular music, as heard in Justin Timberlake's *Can't Stop the Feeling*, for example.

As discussed earlier, the role of the bass drum in EDM has evolved—from excess in disco to strategic absence in modern dance music. That is to say that in the early days of disco, low-frequency contents had to be synthesised from the low-mids contents, which were made louder using three-way crossovers before being made the dominant element in a mix. Finally, it was totally removed in a section during live performance to further enhance the experience.

This phenomenon can also be observed in studio production, whereby it evolved from the use of excessive bass drum to trigger pumping to pumping without an audible trigger. This effect can be achieved by a method commonly known as 'ghost sidechaining' (Casper, 2018)(Messitte, 2018)(Reaperblog, 2016). One example of this technique can be heard in the track released by Purity Ring titled 'Fineshrine' in which pumping is audible on the ambient pad, even when the bass drum is absent. Beyond its technical and aesthetic applications, bass in EDM also exerts a profound influence on listener perception and physical response. To further understand this phenomenon, we examine the cognitive and neurological effects of low-frequency sound, drawing on recent research in music psychology and embodied cognition.

THEORETICAL FRAMEWORK

This study draws on three interrelated theoretical frameworks to analyze how lateral dynamics processing contributes to the perception of groove in EDM: Embodied Music Cognition, Sensory-Motor Theory of Rhythm and Beat Induction, and Record Production as Musical Practice. Each framework is grounded in research that enriches our understanding of groove as both a sonic and embodied experience.

Embodied Music Cognition

Embodied music cognition posits that musical experience is deeply rooted in bodily interaction. In this view, groove is not only heard but physically felt, prompting involuntary responses like foot tapping or head nodding. Marc Leman and colleagues (2013, 2014) have argued that rhythmic structures and dynamic modulations (e.g., sidechain compression) enhance this embodied response by aligning musical stimuli with the listener's motor system.

Molnar-Szakacs and Overy (2006) introduced the Shared Affective Motion Experience (SAME) model, suggesting that the mirror neuron system mediates how musical structure communicates emotion and meaning through embodied simulation. Similarly, Cox (2011) proposed the mimetic hypothesis, asserting that listeners covertly simulate the motor actions required to produce the sounds they hear, engaging the motor system even in passive listening.

Empirical studies by Maes et al. (2013, 2014) further support this view, showing that body movements can bias emotional perception of music and that action-perception coupling is central to music cognition. These findings support the idea that groove arises from the interplay between sound and bodily movement.

Sensory-Motor Theory of Rhythm and Beat Induction

The sensory-motor theory, first articulated by Todd et al. (1999), emphasizes the role of the vestibular system in rhythm perception. It suggests that rhythm perception stems from linking sound with internal motor representations, making it a form of simulated motion.

Todd and Lee (2015) refined this theory into four propositions: rhythm perception is vestibular in nature; listening engages both external movement and internal motor imagery; a limbic-motor pathway underlies the "urge to move"; and vestibular-based reward for rhythmic movement is innate. These ideas explain why bass-heavy EDM tracks often elicit strong physical responses.

Phillips-Silver and Trainor (2005) demonstrated that even infants' rhythm perception is shaped by movement, while Grahn and Brett (2007) used fMRI to show that beat perception activates motor areas like the basal ganglia and supplementary

motor area. Repp and Su (2013) synthesized research on sensorimotor synchronization, confirming that beat induction is a multisensory, motor-driven process.

Collectively, these studies offer a biological basis for understanding groove as a sensorimotor experience—particularly relevant in bass-driven genres like EDM.

Record Production as Musical Practice

Record production is now widely regarded as a musical practice in its own right. Scholars such as Hennion (1989) and Zagorski-Thomas (2007b) argue that producers shape musical meaning through aesthetic decisions in the studio, treating production techniques as compositional tools.

Hennion positioned the producer as a mediator between artistic creation and audience reception, while Zagorski-Thomas introduced concepts like phonographic staging and functional staging, showing how production choices reflect listener contexts and genre expectations.

Anthony (2017) extended this view by treating mixing as a performative act, where the mixer "plays" the studio like an instrument. This aligns with embodied cognition, where tactile interaction with gear—like adjusting compression—becomes part of musical expression.

In the context of EDM, lateral dynamics processing—such as sidechain compression and ghost sidechaining—is not merely technical but deeply expressive. These techniques modulate amplitude and rhythm, shaping groove perception and eliciting physical responses. By framing production as musical practice, this study highlights the creative agency of producers in constructing groove through dynamic manipulation.

METHODOLOGY

This study uses qualitative analysis to examine how lateral dynamics processing shapes groove in EDM. The methodology is structured around three theoretical frameworks: Embodied Music Cognition, Sensory-Motor Theory of Rhythm and Beat Induction, and Record Production as Musical Practice.

Track Selection

Three tracks were chosen for their historical and stylistic significance in groove and compression techniques.

- *Music Sounds Better with You* by Stardust: This track is known for its master bus compression, which means applying compression to the entire mix output to achieve amplitude modulation and varying compression release

times and gain reduction levels, contributing to groove through dynamic variation. It is widely considered the first published work to popularize creative pumping in production.

- *Tea Leaf Dancers* by Flying Lotus: This track uses ghost sidechaining, where compression is consistent and not triggered by the syncopated bass drum, creating a steady groove independent of rhythmic variation. It also features compression that is more extreme compared to the previous example. Furthermore, the producer reportedly used sidechain compression instead of master bus compression. Therefore it might exhibit different spectral characteristics.
- *Can't Stop the Feeling* by Justin Timberlake: The final analysis is the song titled *Can't Stop the Feeling* by Justin Timberlake, chosen to further investigate the characteristics of ghost sidechain. For this example, ghost sidechaining is audible in the opening section of the track, particularly on the piano. The amplitude of the piano pulsates, indicating the downbeat of the rhythm. This clearly results from post-production processing. Destructive audio processing is typically disfavoured; therefore, the piano track would have been recorded without any effects applied.

Analytical Procedure

Analyzing sidechain compression's impact on groove requires effective audio signal visualization. Traditional amplitude or time-domain plots often fail in mixes where dominant bass drums obscure compression effects on subtler elements like ambient pads. In such cases, amplitude reduction is not clearly visible due to signal overlap.

Spectrogram

This study adopts a time-frequency representation plot, commonly referred to as a spectrogram, to overcome these limitations. Specifically, the constant-Q transform (CQT) is used instead of the more conventional short-time Fourier transform (STFT). The CQT offers several advantages:

- Logarithmic frequency bin spacing, which aligns better with musical pitch perception and provides higher resolution in lower frequencies.
- Variable window lengths, resulting in improved temporal resolution for high frequencies and better frequency resolution for low frequencies.
- Enhanced visual clarity, especially for bass-heavy content, which is crucial for analyzing groove in EDM.

The CQT spectrogram mimics human hearing, providing better low-frequency resolution and sharper timing at high frequencies. This makes it particularly suitable for music analysis, where perceptual accuracy is key.

By using CQT-based spectrograms, this study ensures that the visual data aligns closely with both the musical structure and listener perception, providing a robust foundation for analyzing groove-related dynamics.

Listening Analysis

Listening analysis identified groove features perceptible by ear but not always visible in visual data. Each track was listened to multiple times using both studio monitors and high-fidelity headphones to ensure accurate perception of dynamic changes, rhythmic nuances, and spatial effects. Particular attention was paid to how sidechain compression and ghost sidechaining influenced the rhythmic feel, movement-inducing qualities, and overall groove.

The researcher focused on the interaction between the bass drum and other elements such as ambient pads, vocals, and melodic instruments. The analysis considered how amplitude modulation affected the sensation of groove, especially in terms of timing, pulse, and the physical urge to move. Observations were cross-referenced with visual data from spectrograms to validate auditory impressions and ensure a comprehensive understanding of groove construction.

Production Context

Understanding the production context of each track was essential to interpret the technical decisions behind groove-enhancing techniques. This involved examining available interviews, production notes, and documented practices of the producers involved.

For example, Stardust's *Music Sounds Better with You* is widely recognized for its use of master bus compression, which was manually adjusted during mixing to create dynamic pumping effects. This hands-on approach reflects a tactile engagement with the music, aligning with theories of embodied cognition.

Flying Lotus's *Tea Leaf Dancers* showcases ghost sidechaining, where an inaudible trigger track is used to induce consistent compression, independent of the syncopated bass drum rhythm. This technique allows for a steady groove that contrasts with the rhythmic complexity of the audible elements.

Justin Timberlake's *Can't Stop the Feeling* employs ghost sidechaining on the piano, using a metronomic trigger to create a pulsating amplitude effect. This production choice enhances rhythmic clarity and groove perception, even in the absence of a dominant bass drum.

These production strategies were analyzed not only for their technical execution but also for their aesthetic and perceptual impact, reinforcing the idea that groove in EDM is as much a product of production technique as it is of musical composition.

Theoretical Integration

Embodied Music Cognition

Embodied music cognition informed the analysis of groove as a physical experience. In *Music Sounds Better with You*, rhythmic pulsation and dynamic shifts were linked to bodily movement. *Tea Leaf Dancers* demonstrated how ghost sidechaining maintains a steady groove despite complex rhythms. In *Can't Stop the Feeling*, pulsating piano amplitude enhanced rhythmic clarity and encouraged physical engagement.

Sensory-Motor Theory of Rhythm and Beat Induction

Sensory-motor theory explained how bass frequencies affect physiological responses. In *Music Sounds Better with You*, master bus compression and varied release times enhanced groove through low-frequency stimulation. *Tea Leaf Dancers* used extreme compression and ghost sidechaining to induce steady movement. In *Can't Stop the Feeling*, a metronomic trigger on the piano reinforced groove through rhythmic clarity and bass modulation.

Record Production as Musical Practice

Viewing production as musical practice emphasized compression as an expressive tool. In *Music Sounds Better with You*, manual adjustments to master bus compression added dynamic nuance. *Tea Leaf Dancers* used ghost sidechaining to maintain a stable groove beyond rhythmic complexity. In *Can't Stop the Feeling*, metronomic ghost sidechaining on the piano created rhythmic amplitude that sharpened groove perception.

This triangulated approach allows for a nuanced understanding of how groove is constructed through production techniques, integrating embodied music cognition, sensory-motor theory, and record production as musical practice.

ANALYSIS OF SELECTED TRACKS

The following analysis section delves into selected tracks to observe how lateral dynamics processing, particularly sidechain compression, is employed to shape groove. By examining these tracks, we aim to bridge the theoretical insights from the literature review with practical examples, highlighting the aesthetic and perceptual effects of these techniques.

Music Sounds Better with You

The first example chosen for this section is *Music Sounds Better with You*. In the previous section, it was mentioned that the producers utilised master bus

compression to achieve the amplitude modulation featured in this track. The spectrogram is provided in Fig. 1, where the bass drum is indicated by a red box and gain reduction is a purple box. The spectrogram reveals varying compression release durations, with the second purple box showing a longer gain reduction than the others. In the second purple box the gain reduction seems to happen for a longer duration compared to the other boxes. Additionally, the amount of compression also seems to be varied, indicated by the different magnitudes of the spectral contents during compression.

One explanation for these characteristics is physical manipulation of the parameters during the song. Varying either the threshold or the ratio will affect the amount of compression while manipulating the release time leads to a longer rise. Manually adjusting audio processors to shape sound characteristics is a common practice. As was established in the earlier sections, DJs manipulate the three-way crossovers to exaggerate the low frequencies of disco tracks following the beat of the bass drum. In live performances, DJs use filters to remove low-frequencies and re-introduce them when intended. In an introspective article, the author reflected that;

… Live Electronic Music is a product of the belief that the body is participating once again in the music making process, that the human is having a physical effect on music, not just pressing buttons to facilitate the playback of recordings. (Vandemast-Bell, 2013)

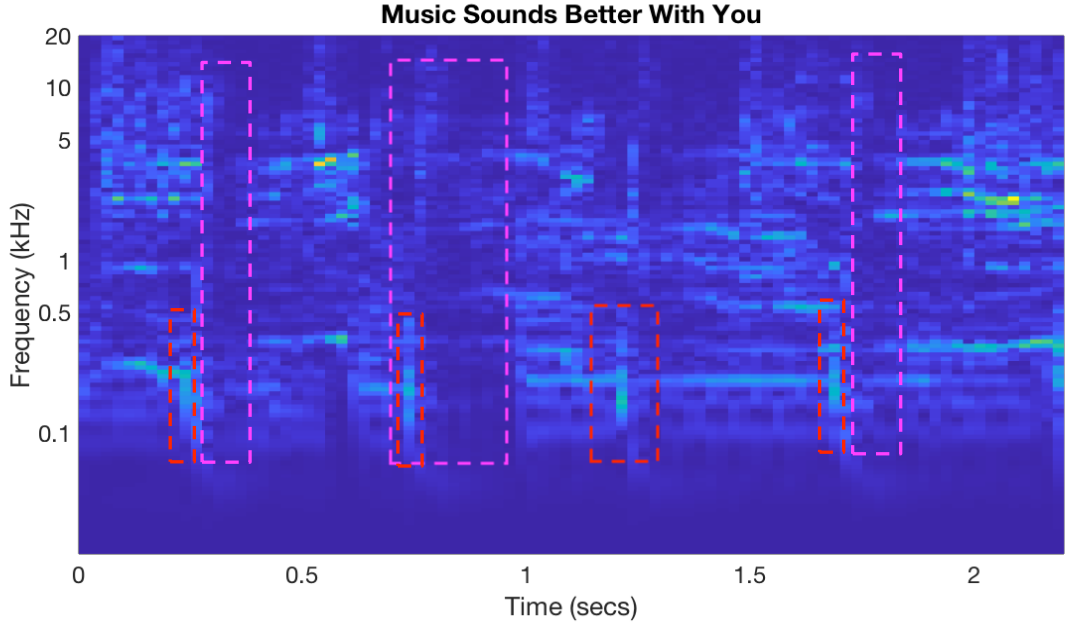

Figure 1 : Constant-Q plot for Stardust's 'Music Sounds Better with You'. The red box indicates bass drum; the purple box is the compression.

Another study summarises that risk and improvisation are indications of an authentic DJ performance and create authenticity when compared to the original material that was sampled (Rietveld, 2016). Thus, by manipulating the controls a producer then will have better emotional connection to the music that they produce. This is because they play a part in the composition, they are not only the enabler. The result will also be unique compared to the source of the audio samples that they have used and will introduce variation into the material. Thus, it might be the case that Stardust adjusted the parameters of the Alesis 3630 applied to the master bus while producing their only composition and produced varying amount of compression throughout.

Tea Leaf Dancers

The second example for this section is the song released by Flying Lotus titled *Tea Leaf Dancers*. This track was selected for its more extreme compression compared to the previous example. Furthermore, it was reported that the producer used the sidechain method instead of master bus compression to achieve pumping (Hodgson, 2011). Therefore, it might exhibit different spectral characteristics.
The spectral content for this production exhibits a stark difference compared to the previous spectrogram. The gain reduction is more dramatic, indicated by the loss in magnitude which is shown within the purple box. Pumping that occurs in this song

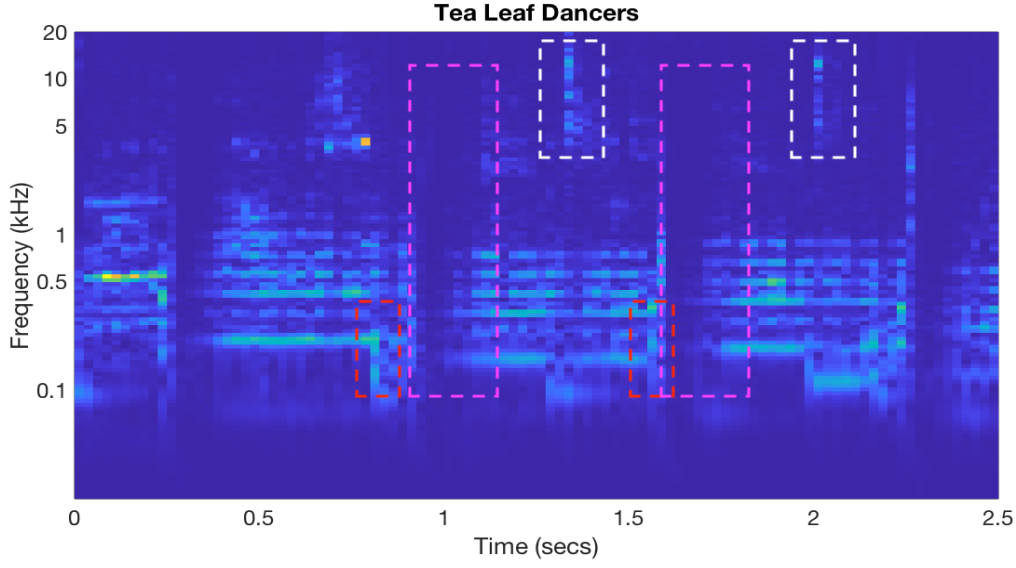

Figure 2: Constant -Q plot for 'Tea Leaf Dancers' by Flying Lotus. The red box indicates bass drum,the purple box is the compression, and the hi-hat is the white box.

is constantly on the downbeat. However, what is interesting is that the bass drum plays a syncopated rhythm. On the first quarter of the measure, the bass drum plays a dotted quaver followed by a semiquaver just before the second downbeat of the bar.

If compression was triggered by the bass drum, compression should then be at a different rhythm and not constant downbeat. The consistent pumping suggests the use of ghost sidechaining rather than bass drum-triggered compression. This is achieved by sidechaining the whole mix down or master bus of the tracks to an inaudible trigger track that plays constant quavers. The threshold and the ratio of the compressor on the mix down (or master bus) is then set to an extreme value. The attack is set to a value which allows the bass drum to be audible on the downbeat for a short duration before the track is pumped.

Using this technique, the syncopated bass drum just before the second downbeat is not affected. The pumping is also at a constant rate, and of a constant level of gain reduction and duration. Furthermore, the possibility of any other tracks loud enough to trigger compression on the master bus are eliminated. This approach yields a distinctly different result from traditional master bus compression.
The spectrogram in Fig. 2 represents one measure of the song. The syncopated bass drum is indicated by the smaller red box, second box from the left. Compression is not as immediate as compared to the other occurrence of bass drum. Moreover, the occurrence of hi-hat in the mix does not trigger compression even though the magnitude seems to be higher than the bass drum. Therefore, it may be the case that ghost sidechaining was used in this production whereby compression is not triggered by the bass drum in the mix but by an inaudible source.

Can't Stop the Feeling

The final analysis is the song titled *Can't Stop the Feeling* by Justin Timberlake, chosen to further investigate the characteristics of ghost sidechain. For this example, ghost sidechaining is audible in the opening section of the track, particularly on the piano. The amplitude of the piano pulsates, indicating the downbeat of the rhythm. This effect is clearly artificial and likely added during post-production. Destructive audio processing is typically disfavoured; therefore, the piano track would have been recorded without any effects applied.

The spectrogram of the short snippet of the introduction (Fig. 3) shows the piano track in the purple box and the hi-hat in the red box. The hi-hat plays accentuated notes on the downbeat which are clearly represented in the plot. The absence of bass drum in the mix allows for a better representation of the piano on the spectrogram because the bass drum will likely have significant spectral overlap. This is more advantageous in the sense that only the piano is represented in that spectrum which allows for an accurate analysis. The spectrogram might suggest the hi-hat triggered compression, but this is unlikely given its presence on both downbeats and upbeats. However, this is not the case because the hi-hat does not only occur on the downbeat but also the upbeat of the measure, yet, no pumping can be observed on the upbeat of the piano track.

Another behaviour that can be observed is the gain reduction that occurs exactly on the downbeat. This can be seen at the onset of the hi-hat and the start of the gain reduction on the piano which produces an implied straight line. This suggests the use of something metronomic to trigger the compression on the piano, with a very fast attack time and slow release on the dynamic processor. In Logic Pro, there is a native synthesised instrument that provides a metronomic click called Klopfgeist. There are a few tutorials online that provides a guide on using this instrument to trigger compression without it being heard in the mix., One of the reasons why it is beneficial to use Klopfgeist to trigger compression is that it will not

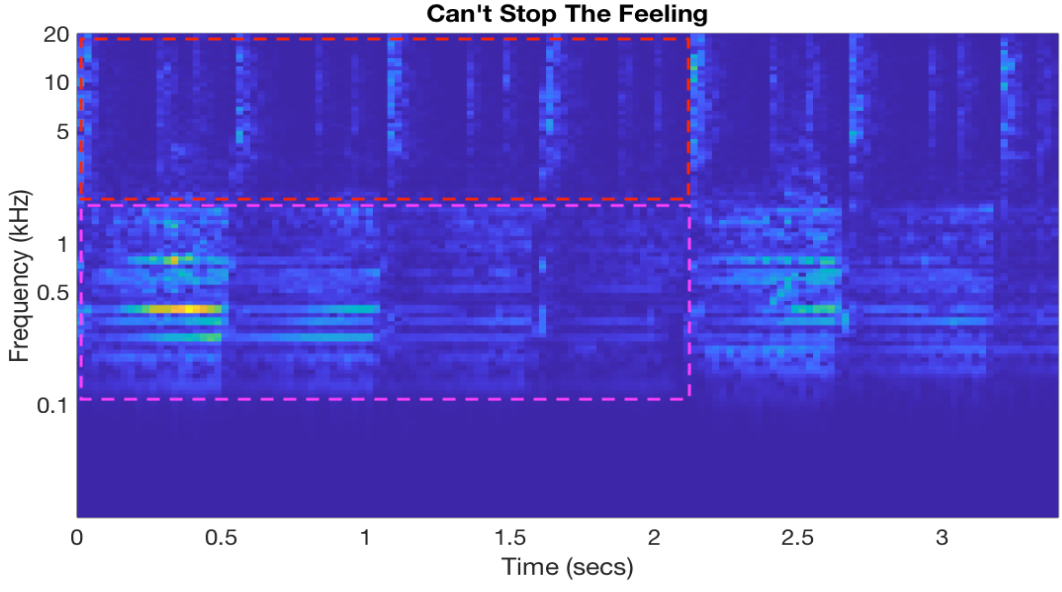

Figure 3: Constant Q plot for Justin Timberlake's 'Can't Stop the Feeling'. The red box is the hi-hat and the purple box is the piano.

be heard in the mix, there is no reason to use any other synthesisers that might use more processing power (imamusicmogul, 2016).

DISCUSSION

The track analyses highlight the varied ways lateral dynamics processing shapes groove in EDM. Manual compression in *Music Sounds Better with You* illustrates tactile engagement with gear, supporting embodied cognition theory. Ghost sidechain technique in *Tea Leaf Dancers* shows how consistent groove promotes bodily entrainment, aligning with sensory-motor theory.

These techniques reflect the shift in groove aesthetics from analog to digital production. The findings indicate that groove is shaped not just by rhythm but also by production decisions. This aligns with the theoretical frameworks discussed in the literature review, emphasizing the role of bass and compression in creating a powerful and engaging musical experience.

Future studies should examine the cognitive and neurological effects of these techniques and their use across genres. Understanding groove as both a technical and experiential construct can enrich music production and scholarship.

CONCLUSION AND RECOMMENDATIONS

This study has examined how lateral dynamics processing—specifically sidechain compression and ghost sidechaining—functions as a creative and structural force in shaping groove within electronic dance music (EDM). By situating these production techniques within the frameworks of embodied music cognition, sensory-motor theory, and record production as musical practice, the research repositions compression not as a mere technical utility, but as a meaningful contributor to listener engagement and rhythmic perception.

The track analyses revealed how different forms of compression interact with rhythmic elements to modulate amplitude, highlight beat placement, and enhance physical responsiveness. Whether through tactile manipulation of a compressor during mixing (*Music Sounds Better with You*), the metronomic precision of ghost triggers (*Can't Stop the Feeling*), or the interplay of syncopation and compression (*Tea Leaf Dancers*), these techniques demonstrate how groove in EDM emerges from both perceptual cues and production intent.

Rather than viewing groove as a product of rhythmic complexity alone, this study highlights how dynamic processing cultivates a sense of movement, tension, and release—critical to EDM's dancefloor appeal. The findings suggest that groove is not only heard but felt, shaped by how sound is staged, compressed, and framed within the studio environment.

RECOMMENDATIONS

Building on the findings of this study, several directions are proposed to advance both scholarly understanding and practical application of groove-related production techniques in EDM and beyond:

Expand Cognitive and Neurological Research on Groove Perception
Future studies should explore the physiological and psychological responses to dynamic processing techniques such as sidechain compression and ghost sidechaining. Empirical research incorporating EEG, fMRI, or motion-tracking technology could provide further insights into how these techniques affect motor engagement, emotional arousal, and rhythmic entrainment.

Cross-Genre Applications of Lateral Dynamics Processing
While this study focuses on EDM, the expressive potential of dynamic manipulation extends to genres such as hip-hop, pop, experimental music, and even ambient or cinematic scoring. Researchers and producers are encouraged to investigate how groove-enhancing strategies can be meaningfully adapted across diverse musical styles.

Development of Pedagogical Tools for Music Production Education
Music technology curricula should integrate concepts from embodied cognition and sensory-motor theory to complement technical instruction. Emphasizing the perceptual and experiential dimensions of groove can help students understand compression not merely as a tool for loudness control, but as a compositional and affective device.

Codification of Best Practices in Groove-Oriented Production
Practical guidelines—drawing on case studies like those in this paper—could be developed to assist producers in achieving groove-rich mixes. Such resources should address compressor settings, trigger design, spectral interaction, and listener perception, encouraging intentional and expressive use of dynamics.

Incorporation of Spectrotemporal Analysis in Music Research and Practice
The use of Constant-Q Transform (CQT) spectrograms proved effective in visualizing groove-related amplitude modulation. Researchers and practitioners are encouraged to incorporate CQT or other perceptually aligned tools to bridge auditory analysis with visual interpretation.

In conclusion, lateral dynamics processing plays a crucial role in shaping groove within EDM. By understanding and applying these techniques, producers can

create music that resonates deeply with listeners, both physically and emotionally. Future research and practice should continue to explore the rich interplay between production techniques and musical experience, advancing our knowledge of groove and its impact on music and society.

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