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ARTICLE

Pivot Mixing: Tempo Modulation in Electronic Dance Music

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Abstract

Electronic dance music is usually produced and played at fixed tempi. However, tempo modulation occasionally appears within a recorded track or DJ performance. This article explores tempo modulation in electronic dance music production and performance, maps out how the technique operates, and explores the technique's wider potential. Pivot mixing, where a tempo shift is created by reinterpreting a pivot loop as different note values, can be particularly effective in an electronic dance music context when the pivot is expressed as repetitive material carried across the tempo shift. Many modulations between familiar dance music tempi are possible with conventional note values and can serve as DJ tools yet are largely underutilized. Tempo modulation is not a prevalent characteristic in electronic dance music but when it does occur the technique is highly effective and temporally engaging. Pivot mixing expands the temporal vocabulary of electronic dance music from beatmatching in temporal unisons to temporal intervals.

Keywords: electronic dance music; techno; tempo modulation; dj; music production

1. Introduction

Electronic dance music is usually produced and played at fixed tempi. Tempo modulation, a change of tempo between two sections of music, occasionally appears as a production technique within a track or as a DJ technique to mix tracks. Tempo modulation is not a prevalent characteristic in electronic dance music but in tracks and performances where it does occur the technique is highly effective and temporally engaging. Pivot mixing, a term and concept introduced by the author for a specific application of tempo modulation in DJ performance, helps to explain current practices and provides a map for their expansion.

The term electronic dance music is used in this article in a broad way to include a broad range of genres and styles such as techno, house, trance, and drum and bass, as well as other musics played at clubs, raves, and festivals. Electronic dance music is a term commonly used in existing research and is more established than the more recent term electronic music and dance, especially when referring to musical rather than cultural issues.

This article explores tempo modulation in electronic dance music and proceeds in four parts. The first part provides a brief history of tempo modulation, its terminology, and applications in instrumental and popular music. The second part presents an overview of tempo modulation in electronic dance music common practice and introduces technical details such as tempo ratios, pivot polyrhythms, and formulae for combinations. The third

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part explores pivot mixing, a DJ performance technique whereby a sustained loop functions as a pivot between two tempi. In this article, a pivot refers to unchanging musical material around which the tempo is changed. For example, a quarter note loop at 100 bpm can be reinterpreted as a dotted quarter note loop at 150 bpm. A description of the mathematical characteristics of a suitable pivot will help to explain how pivot mixing can leverage a wide variety of tempo ratios. This part concludes with an explanation of how pivot mixing can be executed with standard DJ equipment. The fourth part includes autoethnographic accounts of my experience performing pivot mixing in the Berlin techno scene and concludes with a discussion of potential readings of tempo modulation in electronic dance music. While tempo modulation can apply to electronic dance music in general, the technique is discussed in this article with a particular focus on techno.[1] This article includes an ethnographic component, whereby the author conducted interviews with two leading techno artists, Chris Liebing and DVS1, about techno production and performance.

Research on techno and electronic dance music 'has tended to focus on their cultural, historical and sociological aspects' (Bergemann 2011, 5), that is, contextual rather than textual matters. Key publications on electronic dance music culture in general include Brewster and Broughton (2014), Thornton (1996), and Sicko (2010). Notable publications focused specifically on techno culture include *Der Klang Der Familie* (Denk and Thülen 2014), *Lost and Sound: Berlin, Techno und the Easyjetset* (Rapp 2009), and *Detroit: Techno City* (Rietveld and Kolioulis 2019). A modest yet expanding body of research has explored specific elements of electronic dance music production and performance, with a particular emphasis on rhythm. Zeiner-Henriksen analyses the 'poumtchack' pattern (2010), the steady alternation of kicks (bass drums) and hi-hats featured ubiquitously in techno and other electronic dance music genres. Electronic dance music often features euclidean rhythmic patterns (Jordà et al. 2016, 367; Toussaint 2005) and microrhythms (Brøvig-Hanssen et al. 2022; Danielsen et al. 2023). Butler (2006) explains rhythmical features of techno such as polyrhythmic patterns and metric dissonance through the framework of 'pulse layers' (Krebs 1999). Butler (2014) offers insight into electronic dance music performance but does not delve into production details. Smith (2021) analyses the function of continuous processes in electronic dance music such as filter movements. There are, to this author's knowledge, no previous studies on tempo modulation in electronic dance music. DJs, when they do use tempo modulation, often do so to blend genres with different tempi, such as techno with drum and bass. This creative practice is explained, expanded, and formalised in this study as the concept of pivot mixing.

2. Tempo modulation history

A brief history of tempo modulation reveals a crucial aspect of rhythmic groupings, that their prevalence depends on cultural trends. Consequently, tempo modulations that rely on common groupings are more likely to appear in common practice. Conversely, tempo modulations that rely on less common groupings are rarer. Grouping structure is a highly influential system of rhythmic organization proposed by Lerdahl and Jackendoff 1983, whereby groups of pulses are set against a background metrical grid. Rhythmic groupings and temporal relationships are intimately linked, as the first describes the number of pulses in a group and the second describes the proportional relation between two groupings. In this article, tempo modulation refers to establishing a new tempo by reinterpreting a pivot. A pivot is musical material, typically isochronous, with note duration as its salient feature. An

[1] 'Techno may be understood as an up-tempo [electronic dance music] genre of approximately 120 to 150 beats per minute (bpm) focused on repetitive, hypnotic groove layers that together constantly animate its sixteenths grid ... within a four-to-the-floor framework'. (Bougaïeff 2026)

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isochronous rhythm is a pattern 'where all intervals between events are equal, like those of a metronome' (Ravignani and Madison 2017, 2). Except for simple edge cases that involve doubling or halving the tempo, pivots create polyrhythms. A tempo modulation ratio expresses the proportions between the tempo before and after the modulation. This ratio is generated by two levels of temporal relationships. The first level, a pair of polyrhythms, expresses the relationships between the pivot duration and the pulse of each tempo. The second level, a tempo modulation ratio, expresses the relationship between the two polyrhythms. The relationship at the heart of tempo modulation, that between initial and new tempo, usually expresses a ratio of natural numbers. For example, a tempo modulation from 140 to 168 bpm expresses a 5:6 ratio. The detailed connections between tempo modulation ratios and polyrhythms will be explored in a later section. For now, it is enough to understand that .tempo modulation effects a change of tempo, a change of tempo can be expressed as a ratio, and ratios emerge from polyrhythms.

Rhythmic groupings theory begins in the 13th century with Magister Lambert, who held that ternary alone was the rhythmic ideal and that duple rhythm was unplayable (Apel 1949, 292). The appearance of duple meter, notably in the 14th-century *Ars Nova* treatise (c. 1322), made nascent forms of tempo modulation possible. Busse Berger's *Mensuration and Proportion Signs* (1993) provides a comprehensive study of temporal relationships in early music. The combination of duple and ternary meter enables syncopation, hemiola, and vertical 2:1 or 3:1 temporal relationships between voices. Music from the *Ars Nova* and *Ars Subtilior* periods features metric alterations by adding or subtracting tactus values, a process that changes the meter but not the tempo. Tinctoris, in his *Proportionale Musicae* (1473), placed 'rhythmic proportions on par with the harmonic ones' (Busse Berger 1993, 168), thereby highlighting an important link between rhythm and harmony that has been expanded on by later theorists. By the late 15th and early 16th century, proportions in use include 2:1, 3:1, 4:1, 3:2, 4:3, 9:4, and 9:8. Busse Berger notes that John Hothby's motet *Ora pro nobis* 'includes the fractions 5:2, 5:4, and 7:4' (1993, 168), and the motet is described by Brand as 'an exercise in proportional notation' (2010, 778). Similarly, a piece from Morley's *Plaine and Easie Introduction to Practicall Musicke* (1597), transcribed into modern notation by Wuorinen (1964) includes 5:4 and 7:8 tuplets. By the 16th century, temporal proportions were now 'used in a linear fashion as opposed to the vertical relationships seen earlier' (Fawcett-Lothson 2012, 16), thus creating changes of tempo. Weisberg cites 1:2 as a common tempo modulation in Bach between adagio and allegro sections (1993, 51). Bouchard mentions the continued practice of 1:2 tempo modulations in 19th-century music and provides examples of 2:3 tempo modulations in Beethoven (Bouchard 2008, 45). Lau's study of meter changes in Brahms' Lieder (2015) reveals an abundance of 2:3 and 3:4 relationships and a single instance, in op. 85, no. 3, of a 5:6 relationship. While 19th-century music does increasingly feature tuplets, for example, in Chopin, these tend to function as florid embellishments of a duple or ternary meter rather than exotic meters or changes of tempo.

The temporal relationships discussed, apart from occasional outliers, are so far mostly 3-limit ratios, that is ratios in which the biggest prime factor of either term is three, such as 2:3 or 9:8. Limit is a term borrowed from tuning theory, introduced by Harry Partch, which 'indicates the highest prime [...] participating in the ratios of a given [...] system' (Wolf 2003, 13). In this article, limit is used to refer to ratios in a temporal system rather than in a tuning system. Fétis (1784–1871) speculated extensively about future rhythmic techniques, yet he 'explicitly dismissed regular divisions of the beat into five or seven parts' (Arlin 2000, 265). His refusal to consider the musical potential of rhythmic groupings with prime factors beyond three may have hindered his ability to fully conceive tempo modulation. Regardless, his theory of rhythm in four *ordres* ('categories') – *unirhythmique* ('monotemporal'), *transirhythmique* ('transtemporal'), *plurithyhmique* ('pluritemporal'), and

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omnirhythmique ('omnitemporal') – lays important groundwork for the study of temporal modulation. Fétis' four categories can be understood respectively as a single tempo, tempo modulation in a 2:3 relationship akin to dominant modulation in harmony, tempo modulation constrained to small 3-limit ratios, and lastly a speculative category that could correspond to tempo modulation with unbounded prime limits. These categories explicitly draw an important parallel between tempo modulation in rhythm and tonal modulation in harmony, echoing Tinctoris, and the trend of 3-limit tempo ratios continues until the 20th century.

Temporal relationships beyond 3-limit ratios are common in 20th-century contemporary classical music, as are complex 'multi-layered polyrhythms' (Wannamaker 2012). Cowell's highly influential *New Musical Resources*, first published in 1930, makes use of the harmonic series to organise rhythm. He proposed a 7-limit scale (Cowell 1996, 107), reproduced in Example 1, to organise tempi. The 60 bpm (M.M.) reference tempo merely serves to illustrate the principle; the ratios can in fact be applied to any reference tempo. Though not exhaustive, Cowell's approach significantly expands available tempo ratios.
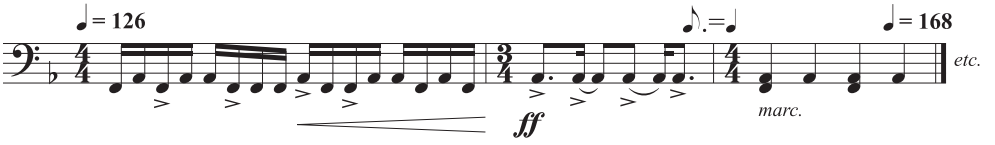
Disambiguating temporal modulation, tempo modulation, and metric modulation facilitates further discussion. I use 'temporal modulation' as a translation of Bouchard's 'modulation agogique', a wide category denoting 'the passage from one mode of organisation of sounds in time to a different mode' (2008, 13) (*tout passage d'un mode d'organisation des sons dans le temps à un mode différent).* Bouchard created a meticulous taxonomy of temporal modulation which includes tempo modulation (a change of tempo, for example, from 129 to 172 bpm), many types of metric modulation (a change of meter, for example, from 2/4 to 6/8), and combined modulation (the simultaneous occurrence of both tempo and metric modulation). Although Bouchard rejects accelerando and ritardando because of the challenge of precisely notating them, they nevertheless qualify as a type of tempo modulation. For a summary of Bouchard's taxonomy and earlier work on tempo modulation from Benadon (2004), see Quinton (2017, 146–61). Osborn analyses changing meters in math-rock and clearly distinguishes their use from tempo modulation (2012, 44). While meter in electronic dance music is a diverse phenomenon that cannot be simply dismissed as 4/4, as Butler explains through metrical dissonance (2006, 138–76), temporal modulation in electronic dance music tends to focus on changes to the tactus and, despite brief potential changes of meter, can often be explained as tempo modulation rather than combined modulation.

Tempo modulation was thoroughly explored in instrumental music by Carter. Bouchard's analysis (2008, 26–27) of Carter's *Eight Pieces for Four Timpani* demonstrates a typical case (see

Scale Tones	Ratios from C	Tempo
C	1:1	60
C#	14:15	64 2/7
D	8:9	67 1/2
D#	5:6	72
E	4:5	75
F	3:4	80
F#	5:7	84
G	2:3	90
G#	5:8	96
A	3:5	100
A#	4:7	105
B	8:15	112 1/2
C	1:2	120

Example 1. Tempo scale from Henry Cowell's New Musical Resources.

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Example 2. Tempo Modulation (3:4) in Elliott Carter, Eight Pieces for Four Timpani, 'Improvisation', mm. 14-16.

Example 2, copied from Bouchard). A dotted eighth note at 126 bpm is reinterpreted as a quarter note at 168 bpm, thereby expressing a 3:4 tempo ratio. The pivot corresponds to a grouping of three 16ths before the shift and four 16ths after the shift.
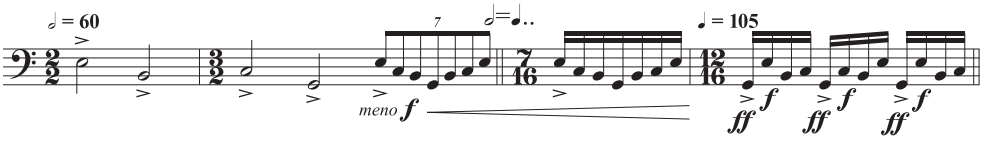
A 4:7 tempo modulation, from 60 to 105 bpm, occurs in the 'March' movement of the same piece. Example 3, also copied from Bouchard's analysis of Carter, features a pivot duration delineated successively in four different ways.

- as a half note in a bar of 2/2 at 60 bpm
- as a septuplet in a bar of 3/2 at 60 bpm
- as a bar of 7/16 implicitly at 105 bpm
- as seven 16ths in a bar of 12/16 explicitly at 105 bpm

The last three, save for the accents, are rhythmically identical. By the last bar, the pivot, now a grouping of seven 16ths, is subsumed in a 12/16 meter with accents on every beat.

Tempo modulation also appears in jazz, rock, and pop. Wynton Marsalis' 1987 recording of 'Autumn Leaves' (1987), 0:00–0:15, includes a quick succession of tempo modulations in the rhythm section – 1:2, 2:3, 3:4, 4:5, 5:6, 6:7, 7:8 – neatly ending up at double-time at the end of the sequence (Hartland 2014, 31). Rage Against The Machine's 'Killing In The Name' (1992) features a 8:9 tempo modulation in the introduction, 0:08–0:24, whereby a pivot first heard in the bass is reinterpreted from a quarter note triplet to a dotted eighth in the bass and guitar riff, thereby shifting the tempo from 110 to approximately 123.75 bpm (Rockwell 2022). Lionel Richie's 'Say You, Say Me'(Richie 1986) features a 2:3 tempo modulation, 2:45–2:54, whereby an eighth note triplet drum fill is reinterpreted as an eighth note groove (Hartland 2014, 30). Despite the rich history of tempo modulation, these techniques have not been much exploited in electronic dance music.

Machine aesthetics, 'whereby the inherent nature of the machine imposes musical and sonic characteristics' (Stevenson 2023), is a key component of electronic dance music, evident in rhythmic precision and perfect repetition. Nancarrow was a pioneer in exploring temporal relationships afforded by mechanical performance. His *Player Piano Studies*, 49 pieces composed between 1948 and 1992, explore vertical temporal relationships in ratios as simple as 3:4 and irrational ratios 'as complex as e/pi' (Scrivener 2001, 160). Study No. 28 notably features a 17:8 vertical tempo relationship, that is, a 17-limit ratio. However, even more than his will to explore rhythmic complexity, it is Nancarrow's choice of instrument that will be relevant in the present discussion; the player piano, an acoustic



Example 3. Tempo Modulation (4:7) in Elliott Carter, Eight Pieces for Four Timpani, 'Improvisation', mm. 54-57.

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automaton driven by piano rolls, rolls of paper with holes punched in patterns, is the progenitor of the modern digital audio workstation (DAW) that is at the heart of electronic dance music. Machine music, whether it be mechanically or electronically produced, is a medium particularly well suited for rhythmic precision and adventurousness. Digital precision enables not only a distinct style of mechanical groove but also the perfect execution of tempo modulation in electronic dance music.

Three types of temporal modulation relevant to electronic music emerge from this historical survey: continuous, irrational, and rational. Two of these types include unprepared temporal modulations, changes of tempi 'without connecting material' (Hobert 2010, 21).

(1) Continuous Tempo Modulation: continuous tempo changes
   (a) Accelerando: gradual tempo increase
   (b) Ritardando: gradual tempo decrease
   (c) Florid: sequence of gradual tempo changes
(2) Irrational Tempo Modulation: discrete tempo change expressed by an irrational number
   (a) Prepared: modulation with an irrational pivot (e.g. e/pi) (Scrivener 2001, 160)
   (b) Unprepared: no pivot material
(3) Rational Tempo Modulation: discrete tempo change expressed by a ratio of whole numbers
   (a) Prepared: modulation with a rational pivot (e.g. 3/4)
   (b) Unprepared: no pivot material

Continuous tempo modulation is perhaps the most common type of tempo modulation in electronic dance music and constitutes an example of 'continuous processes [that] contribute to the emotional waves experienced when listening to the music' (Smith 2021). Irrational tempo modulation remains to this author's knowledge largely hypothetical as an intentional technique in electronic dance music, although it can be created unintentionally by failing to beatmatch in a DJ performance, resulting in two records playing in a complex tempo relationship colloquially known as a 'trainwreck' (Veen and Attias 2011). Discrete tempo modulations, regardless of whether the tempo ratio is irrational or rational, can occur suddenly and unprepared, or they can be prepared with pivot material. Prepared rational tempo modulation corresponds to tempo modulation as it is most commonly understood, as a 'change of tempo by means of a shared durational unit' (Benadon 2004), and appears in electronic dance music most commonly with 2:3 and 3:4 ratios. Therefore, unless otherwise noted, 'tempo modulation' will continue to refer to a prepared rational modulation. Pivot mixing is the application of a prepared, rational modulation in electronic dance music, especially in DJ performance.

3. Tempo modulation in electronic dance music
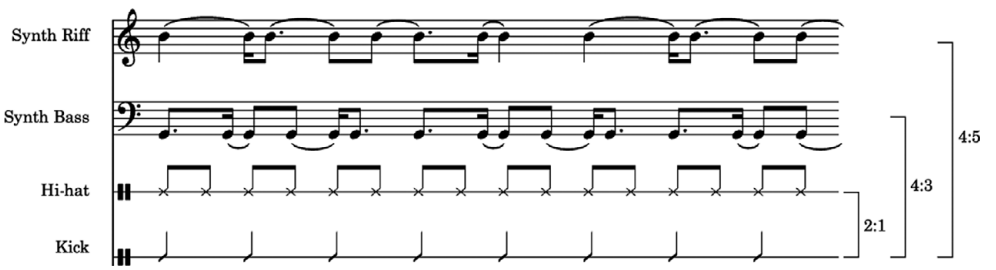
Understanding pivot mixing requires first understanding several defining rhythmic and metric characteristics of electronic dance music: pulse trains, kick drums, polyrhythms, steady tempi, and repetition. Electronic dance music, especially techno, ubiquitously features 'pulse trains', a term introduced by the author (2026) and defined as prominent articulations of a steady pulse, especially on the sixteenths grid. The term 'pulse train', while similar in concept to 'pulse layer' used by Krebs (1999) and defined by Butler as 'the fastest regular layer of motion within a given musical passage' (2006, 327), or to 'metrical level' introduced by Lerdahl and Jackendoff (1983), is favoured for four reasons. Firstly, a pulse train can correspond to any pulse layer. Secondly, the term 'layer' is already used in electronic

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dance music production to refer to a sound playing in rhythmic unison with another sound. Layers are typically used to thicken a timbre. Thirdly, the term 'pulse train', borrowed from digital signal processing, evokes a propulsive horizontality matching the mechanical isochronous sound of techno and has its own specific use case in this context, whereas alternative terms evoke a vertical superposition and typically refer to notated instrumental music. Finally, a pulse train refers not only to the pattern of an isochronous rhythm, but also to sonic material explicitly reifying the rhythmic pattern, with every onset played by a sound, whereas an isochronous rhythm can refer strictly to a pattern independent of sound.

A steady kick is a core feature of countless dancefloor genres, including house and techno. As Butler remarks, a 'repeating [kick] pattern is almost always present' (2006, 34). Genres predicated on syncopation, such as jungle and its many offshoots, do not feature kicks in quarter note pulse trains but nevertheless maintain a metronomic tactus. The term 'kick', or 'kick drum', is preferred because it is commonly used in electronic dance music production and often implies an intricately designed electronic sound played with metronomic precision, marking a distinction from the more general term 'bass drum' which typically refers to instrumental music. Zeiner-Henriksen writes that the 'poumtchack' pattern, a steady stream of alternating downbeats and upbeats typically produced with kicks and hi-hats, 'not only marks out the rhythmic pulse but communicates the basic rhythmic structure' (2010, 137). Techno DJ and producer Chris Liebing, when asked what an essential element for a techno track might be, replied without hesitation that it is the kick (2024). Although rare edge cases of electronic dance music may '[remove] the kick-drum altogether' (Ralston 2019), kicks, especially in quarter note pulse trains, are doubtlessly normative.

Polyrhythms are an essential feature of techno and electronic dance music in general. In this article, a polyrhythm is defined as the relationship between two pulse trains. Example 4 demonstrates a hypothetical realisation of four different pulse trains emerging from groupings of 4/16, 2/16, 3/16, and 5/16. Ratios on the right-hand side indicate the ratio formed between each pulse train and the tactus (the beat, typically expressed by a kick). While a pulse train is an unbounded sequence, a polyrhythm is a bounded cycle defined by its ratio. The synth bass, for example, an unbounded pulse train proceeds in note values corresponding to 3/16, a dotted eighth, creates a 4:3 polyrhythm against the kick. The synth bass plays four times in the same duration as three kicks before they are once again in phase and the cycle is repeated. The synth riff, a 5/16 pulse train, similarly creates a 4:5 polyrhythm against the kick. While the definition of polyrhythms normally excludes duple relationships such as 2:1, these ratios are also important when calculating tempo relationships. We can either refer to these ratios as temporal relationships or simply expand the definition of polyrhythm to include duple relationships. Polyrhythms in electronic dance music are clearly audible as the periodicities of different sounds. Butler explains that in techno, 'as long as our tendency to hear drums as timekeepers remains active, we will hear a number of different times being kept at once' (2006, 99). Any of these different pulse trains can be used as a tempo modulation pivot.



Example 4. Polyrhythms generated by groupings of 2, 3, and 5 sixteenths.

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A steady and perfectly accurate tempo is an essential characteristic of electronic dance music. Individual tracks are usually produced at a single unwavering tempo. Entire genres can be defined by tempo range, in addition to other characteristics such as rhythmic patterns and timbre aesthetics. Techno is usually between 130 and 140 bpm, while house is generally slower, and drum and bass is usually around 170 bpm (Alspach 2020). House and techno often feature steady kicks, while drum and bass features various syncopation patterns. The bpm at which a DJ habitually plays can be a mark of identity or a point of pride, as DJs often focus on a narrow tempo range for months or even years of their career. Fans and journalists take notice when a scene (Bennett and Peterson 2004) speeds up or slows down (Macdonald 2018). Playing even 10 bpm faster or slower than current trends is a significant change. Techno DJ performances often stay at a single tempo or focus on a narrow range of tempi.

Repetition and groove, for centuries a secondary concern in European music, is embraced in electronic dance music as a primary focus, a rich celebration of body movement (Burger and Toiviainen 2020) and patterns inspired especially by West African musics, among others (May 2006). While microrhythm, in combination with grid-based rhythms, has been established as a crucial feature of groove in electronic dance music (Brøvig-Hanssen et al. 2022), microrhythm is not a relevant component of tempo modulation. Repetition in electronic dance music can be leveraged, by way of repetitive pivot material, to create clear and accessible tempo modulation effects. This approach makes it possible to create tempo-shifting tracks and DJ tools,[2] while also mitigating the risk that tempo changes can pose to sustaining entrainment and maintaining a groove.

3.1. Continuous tempo modulations

Accelerandi and ritardandi are perhaps the most well-known types of temporal modulation in electronic dance music. DJs, for example, can pitch turntables or CDJs (a brand of digital turntable) up or down, thus increasing or decreasing the tempo throughout a performance. Tracks in the electronic dance music repertoire can be found that incorporate accelerandi, ritardandi, or both, for a variety of purposes: as an intensification effect without a specific tempo destination, for example in Moby's 'Thousand' (1993) and in Hardhead's 'New York Express' (1994); as a means to lead from a beatless introductory section to a main beat, for example in Eric Prydz's 'Opus' (2015) and in Deadmau5's 'Strobe' (2009); in at least one case, nsi.'s 'Risset' (2008), as a Risset rhythm (Stowell 2011); and sometimes to connect sections with distinct tempi. The following examples focus on tracks with sections at distinct tempi. Lil Louis' 'French Kiss' (1989) first slows down,[3] 5:11–5:52, from 128 bpm to approximately 42 bpm. The music proceeds with a full bar at 42 bpm, a tempo at which 16th hi-hats articulate a 168 bpm pulse train. The track later accelerates, 6:10–7:18, from 42 bpm back to 124 bpm. These two tempi, 42 and 128 bpm, nearly exactly form a 1:3 ratio. Planet Soul's 'Set U Free (Fever Mix)' (1995) features two ritardandi and an unprepared tempo modulation. The first ritardando proceeds from 126 bpm to 120 bpm, 3:23–3:39, corresponding to a 21:20 tempo ratio. The next section, 3:39–4:43, proceeds at 120 bpm. The second ritardando, 4:43–5:01, proceeds from 120 to 98 bpm, a relationship very close to both 5:4 (which would be 120 to 96 bpm) and 6:5 (which would be 120 to 100 bpm). Finally, an unprepared tempo modulation (6:15) shifts the tempo back to 126 bpm. This final shift, from 98 to 126 bpm,

[2] DJ tools are records traditionally produced especially for use in DJ performance rather than, or in addition to, listening on their own. DJ tools could include very loop-oriented tracks with no breakdowns, or records consisting entirely of dozens, or hundreds, of locked grooves, or in this case, tracks featuring tempo modulation.

[3] See Hawkins (2003) for a broader analysis of 'French Kiss' which, however, does not include a detailed discussion of continuous tempo modulation.

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corresponds to a 7:9 tempo ratio. Although these are too few examples to establish statistical significance, these anecdotal findings suggest that the ambitus of continuous tempo modulations tends to express relatively small ratios.

3.2. *Prepared rational tempo modulations*

Tempo modulation (prepared rational tempo modulation) occurs most frequently in electronic dance music production and performance in 2:3 and 3:4 ratios, matching historical trends. Both ratios will be demonstrated through examples from electronic dance music common practice. Tempo modulation will be revealed to serve not only as an expressive device and mechanism to introduce new relationships in a temporal palette, but as a fundamental shift in tempo and genre. The power of tempo modulation to create and resolve stylistic ambiguity in electronic dance music emerges as one of the technique's powerful affordances.

A tempo ratio can be generated by the relationship between two polyrhythms, and each polyrhythm corresponds to a relationship between a pivot and the tactus (the beat). It is therefore useful to adopt polyrhythm notation to identify pivot note values, for example, an eighth note corresponds to a 2:1 polyrhythm and a dotted eighth corresponds to a 4:3 polyrhythm. The formula to generate a tempo ratio from two polyrhythms A:B and C:D is BC:AD. For example, the 2:3 tempo ratio can be generated by a pivot that shifts from 2:1 to 4:3 because BC = 1 × 4 = 4, AD = 2 × 3 = 6, and the resulting 4:6 ratio is equivalent to 2:3. Example 5 tabulates pivot combinations that generate a 2:3 tempo ratio. Parentheses are placed around the word poly to account for 1:1, a rhythmic pattern that cannot be considered a polyrhythm. The BC:AD formula is crucial as a compositional tool to find pivots underpinning more complex ratios such as 21:20, as in 'Set U Free' as described above. This ratio, for example, can be generated by a 4:7 to 3:5 pivot (a double dotted quarter note in the origin tempo pivoting to a quarter note tied to a quarter note triplet in the target tempo) because 7 × 3 = 21 and 4 × 5 = 20. Regardless of the complexity of the ratios involved, the variety of notes values revealed by the BC:AD formula is also useful when analysing pivot material.

Mosca's 'On The Night In Question' (2021) is structured in two main parts, the first at 135 bpm and the second at 90 bpm (see form chart Example 6). Section B, 3:05–3:26, can be understood either as 12 bars in 4/4 at 135 bpm, or 8 bars in 4/4 at 90 bpm. Ambiguity of tempo constitutes a temporal extension of Butler's concept of ambiguity of metrical type, that is 'the larger context in which the patterns are to be interpreted' (2006, 130). The first interpretation of section B, at 135 bpm, segments the section into a series of phrases of diminishing durations: 16, 8, 8, 4, 4, 4, and 4 beats. Each phrase begins with a kick. A syncopated clap occasionally plays on the second upbeat. The first and last phrases include a turnaround whereby two filtered kicks articulate the two last beats in a brief crescendo. The second interpretation of section B, at 90 bpm, considers the isochronous hi-hats as eighth

Pivot origin (poly)rhythm	Pivot target (poly)rhythm	Tempo ratio	Pivot origin (note value)	Pivot target (note value)
A:B	*C:D*	*BC:AD*		
3:1	2:1	2:3	eighth triplet	eighth
3:2	1:1	2:3	quarter triplet	quarter
3:4	1:2	2:3	half triplet	half
2:1	4:3	2:3	eighth	dotted eighth
1:1	2:3	2:3	quarter	dotted quarter
1:2	1:3	2:3	half	dotted half

Example 5. Pivot pairs generating a 2:3 tempo ratio.

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Section	A	B	C	D
Time Stamp	0:00-3:05	3:05-3:26	3:26-3:58	3:58-6:20
Tempo	135		90	
Tempo Ratio	3:2			
Pivot Timbre	—	Hi-Hat		—
Pivot Value	—	4:3	2:1	—

Example 6. Mosca, 'On The Night In Question,' form chart.
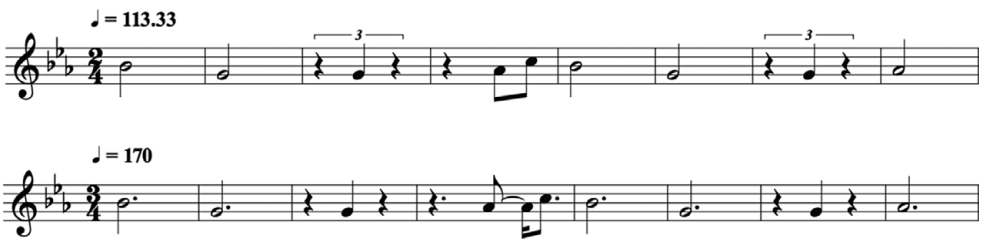
notes grouped in common time. Regardless of when exactly the tempo shifts in the listener's mind and body, the 3:2 modulation clearly hinges on the 4:3 to 2:1 pivot pair articulated by the hi-hat. The ambiguity is resolved in section C; every two-bar loop begins with a kick on the first beat, followed by a clap on the second beat. Finally, the last two-bar loop, 3:53–3:58, features a rhythmic reduction whereby the hi-hat only plays on the beat in a 1:1 rhythm, conclusively establishing the new tempo of 90 bpm. Section D, 3:58–6:20, drops with a full beat at 90 bpm, a tempo that is maintained until the end of the track.

Machinedrum's 'Sleepy Pietro (feat. Tigran Hamasyan)' (2020) is structured in sections alternating between 113.33 and 170 bpm, expressing 2:3 and 3:2 tempo ratios, and ends with a section at 56.66 bpm, expressing a 3:1 tempo ratio (see form chart in Example 7). The track is particularly notable for using elaborate pivot material, transcribed in Example 8, that is not an isochronous rhythmic pattern but rather uses a variety of note values. The pivot is transcribed in 2/4 and 3/4 meters merely to depict the tempo relationship between sections and does not suggest an intention from the composer.

The pivot melody features three different note values which, in the context of a tempo modulation, create three different polyrhythm pairs. The first pair, 1:2 and 1:3, is used in measures one, two, five, and six. The second pair, 3:2 and 1:1, is used in measures three and seven. The third pair, 2:1 and 4:3, is used in measure four. The pivot is rhythmically engaging on three levels: intrinsically through this variety of note values, extrinsically through the changing temporal context of different sections, and structurally through motivic variations that characterise different sections. In sections A and B, the pivot is played in its

Section	A	B	C	D	E	F	G
Time Stamp	0:00-0:17	0:17-0:51	0:51-1:24	1:24-1:42	1:42-2:32	2:32-3:06	3:06-3:24
Tempo	113.33	ambiguous	170		113.33	170	56.66
Tempo Ratio	2:3		3:2		2:3		3:1
Pivot Timbre	Piano		Synth	Piano + Synth	Piano	—	Piano
Pivot Melody	Original Form		Variation	Original Form	Variation	—	Half-time

Example 7. Machinedrum, 'Sleepy Pietro (feat. Tigran Hamasyan),' form chart



Example 8. Machinedrum, 'Sleepy Pietro (feat. Tigran Hamasyan),' pivot melody.

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original form, without variation. In section C, the note in the third measure is displaced by a 1/8th, a displacement that could be understood as a very brief instance of displacement dissonance (Butler 2006, 107–8). In section E, the first two measures of the pivot remain intact and are used as a familiar motif that anchors the phrase, while the rest of each 8-bar cycle is devoted to a florid piano solo. Finally, section G features a solo coda with the pivot melody played at half-speed. In addition to its multiplicity of rhythmic functions, the pivot material is played by several different sounds and transformed by many effects, adding the dimensions of timbre and space to its development.

While sections A and E are clearly at 113.33 bpm, and sections C and D clearly at 170 bpm, section B not only reflects temporal ambiguity, but also shows that such ambiguity can arise even from pulse trains competing in a 2:3 relationship, one of the simplest ratios. Section A establishes a tempo of 113.33 bpm with a kick playing on every beat. Every other kick coincides with a pivot note in the first two measures. The pivot melody contains at least two rhythmic cells that strongly suggest a duple meter; the first two measures are half notes, and the turnaround, at the end of measure 4, has two eighth notes. After this duple passage, section B retains the steady kick but introduces sextuplet subdivisions and, most importantly, a drum and bass backbeat snare pattern on the sextuplet pulse train, which corresponds to 16ths at 170 bpm. A new tactus emerges, articulated by a combination of kick and snare hits. The temporal ambiguity is resolved at the turnaround at the end of section B, when a hi-hat clearly articulates the 170 bpm tactus followed by the section C drop which introduces new layers of percussion at 170 bpm and a slow bassline. The combination of the turnaround, the new percussion, and the driving bassline together completes the shift to the new tempo. A listener is likely to dance to two beats in every pivot measure in section A, and either two or three beats in sections B, depending on their preferred perception between slow ternary and fast duple. Section C, by its inclusion of more prominent duple drum and bass percussion patterns at 170 bpm, would seem likely to elicit dancing to three beats per measure of the pivot melody.

The 3:4 ratio also appears in electronic dance music common practice. Before analysing example tracks from the repertoire, it is once again useful to create a table of pivot pairs (see Example 9).

Departure Lounge's 'Nu Odyssey' (1997) alternates between two genres (see form chart in Example 10), whereby the 11-minute track starts off as house at 124 bpm for nearly three minutes, modulates in a 3:4 ratio to drum and bass at 165.33 bpm for two and a half minutes, then modulates back in the 4:3 reverse ratio to 124 bpm for five more minutes of house. The pivot material, exemplifying a pulse train, consists of a synth stab followed by delays, a type of echo effect very common in electronic dance music, which slowly decrease in volume. The pivot is first introduced in section B at 2:16 as a 4:3 polyrhythm (dotted eighths) against the steady kick. The track is notable for a pivot solo in section C, during which the pivot plays on its own without any competing rhythmic materials whatsoever, a monophony completely

Pivot origin (poly)rhythm	Pivot target (poly)rhythm	Tempo ratio	Pivot origin (note value)	Pivot target (note value)
A:B	*C:D*	*BC:AD*		
4:1	3:1	3:4	sixteenth	eighth triplet
2:1	3:2	3:4	eighth	quarter triplet
1:1	3:4	3:4	quarter	half triplet
4:3	1:1	3:4	dotted eighth	quarter
2:3	1:2	3:4	dotted quarter	half
1:3	1:4	3:4	dotted half	whole

Example 9. Pivot pairs generating a 3:4 tempo ratio.

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Genre	House			Drum and Bass			House	
Section	A	B	C	D	E	F	G	H
Time Stamp	0:00-2:16	2:16-2:51	2:51-3:14	3:14-3:26	3:26-4:58	4:58-5:41	5:41-5:53	5:53-10:46
Tempo	124		Ambiguous	165.33			124	
Tempo Ratio	3:4			4:3				
Pivot Timbre	—	Synth stab delays			—	Synth stab delays		—
Pivot (Poly)rhythm	—	4:3	Isochronous	1:1	—	1:1	4:3	—

Example 10. Departure Lounge, 'Nu Odyssey,' form chart.

free of rhythmic dissonance. The simplest temporal interpretation of section C would be to group stabs in duple time, thus implying a tempo of 165.33 or half-time at 82.66 bpm. The previous context of 124 bpm, however, seems to retain a powerful presence despite the absence of any signifiers.

Section C is thus ambiguous as it contains solo material that in isolation would presumably be interpreted at one tempo but is in context likely interpreted at another tempo. It's only in section D, when drums are introduced at 165.33 bpm, that a new context is established and we can unequivocally interpret the pivot material as a 1:1 rhythm (quarter notes). The reverse tempo modulation, a 4:3 ratio from 165.33 to 124 bpm, occurs between sections F and G, this time without a pivot solo. The 4:3 ratio, as noted by Cowell, is analogous to a sub-dominant; therefore, the journey from home tempo, 124 bpm, to foreign tempo, 165.33, and back again, constitutes a process analogous to a tonal modulation from tonic to sub-dominant and back. Not only is tempo modulation used as a formal device, but the two modulations are executed differently to introduce variation, an element of surprise on the way back to the home tempo. Finally, the synth stabs appear occasionally in section H but they no longer function as pivot material, yet another instance of contextual variation, whereby an unchanging material acquires new meaning by a change of context.

The three-part structure of Dirtyphonics' remix of 'Polygon' by ShockOne (2010) is an inversion of that previously described in 'Nu Odyssey'. 'Polygon' starts out fast at 175 bpm, modulates in a 4:3 ratio down to 131.25 bpm, the temporal sub-dominant, and modulates back in a 3:4 ratio to conclude at 175 bpm. The tempo modulations are deployed within buildups, larger musical gestures 'designed to create tension and a heightened emotional intensity among clubbers' (Solberg 2014, 61) that can incorporate stereotypical successions of note value halvings or other diminutions, applied in this case to synth, snare, and kick sounds, and an intensification through various dynamic, timbral, and effect transformations. Even though the surface texture of the buildups somewhat camouflages the tempo modulations, the tempo shifts can be analysed as occurring at two precise moments (see form chart in Example 11), one is the transition from section B to C and the other is the transition from section E to F.

These two moments merit attention for the judicious choice of pivot pairs hinged around them. The pivot polyrhythms are listed in the form chart in the order they appear in each section as part of buildup note value diminution sequences. Section E, for example, starts with four bars of a four-note synth loop playing in eighth notes (a 2:1 polyrhythm). The next two bars shorten the synth pattern to two notes but maintain the 2:1 polyrhythm. Finally, the two notes of the synth play double in speed for the last two bars of section E, resulting in a 4:1 polyrhythm (sixteenths). Section F starts with the synth and kick together playing as a temporally ambiguous pulse train. Shortly thereafter, by the end of the first four bars, the ambiguity is resolved by the introduction of a snare drum on the second and fourth beat. The pivot pulse train, still expressed by the synth and kick, is now firmly established as a 3:1 polyrhythm (eighth triplets) at 175 bpm. The tempo modulations in 'Polygon' are further notable for their layered pivot timbres composed of two sounds, synth and kick, that before a

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Genre	Drum and Bass		ambiguous	Electro-House		ambiguous	Drum and Bass	
Section	A	B	C	D	E	F	G	H
Duration (bars)	32	8	8	48	8	16	8	96
Time Stamp	0:02-0:47	0:47-0:58	0:58-1:12	1:12-2:40	2:40-2:54	2:54-3:17	3:17-3:27	3:27-5:45
Tempo	175		131.25			175		
Tempo Ratio	4:3			3:4				
Pivot Timbre	—	Synth + Kick		—	Synth + Kick		—	—
Pivot (Poly)rhythm	—	3:2	2:1, 4:1	—	2:1, 4:1	3:1, 4:1, 8:1	—	—

Example 11. ShockOne, 'Polygon (Dirtyphonics Remix),' form chart.

buildup each have their own distinct patterns, and during the building merge into a rhythmic unison, effectively becoming two layers of a single sound that articulates the pivot rhythms.

The four tracks analysed so far reveal the surprising versatility of what is ultimately a single temporal relationship. The two tracks exemplifying the 3:4 ratio and its reverse 4:3, 'Nu Odyssey' and 'Polygon', together leverage three distinct pivot pairs, 4:3 to 1:1, 3:2 to 2:1, and 4:1 to 3:1. This rich variety demonstrates not only the analytical utility of pivot pair tables but also the compositional affordances of a simple tempo modulation ratio. The two tempo ratios, 2:3 and 3:4, on which all four examples rely, are in fact so closely related as to be considered two facets of a single construct. The 2:3 and 3:4 tempo ratios are, together, temporal octave complements. Two tempo ratios can be added together by the following formula A:B + C:D = AC:BD (which is different from the earlier formula BC:AD for obtaining a single tempo ratio from two pivot polyrhythms). For example, 2:3 + 3:4 = 6:12. The resulting 6:12 ratio reduces to 1:2, which is double time, the temporal equivalent of an octave. This result makes intuitive sense when approached with tuning terminology, whereby 3/2 is a fifth, 4/3 is a fourth, and adding a fifth and a fourth results in an octave. Furthermore, the 4:3 polyrhythm, four dotted eighths against three quarters, is merely a double-time version of the 2:3 polyrhythm, two dotted quarters against three quarters. Although 3:4 can be considered for these reasons a variation of 2:3, the two tempo ratios are nevertheless replete with executive possibilities.
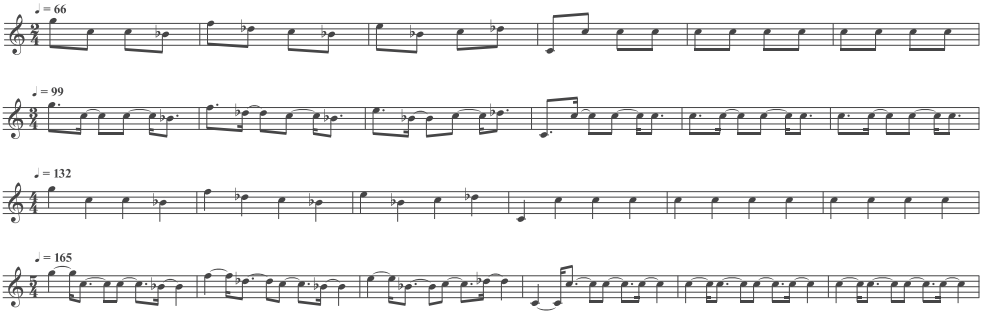
Tempo modulation in ratios beyond 2:3 and 3:4 was until recently all but absent in electronic dance music and will be explained through examples from the author's own repertoire. Consequently, one of the research methods underpinning the next examples is analytic autoethnography, an approach to research 'in which the researcher is (1) a full member in the research group or setting, (2) visible as such a member in published texts, and (3) committed to developing theoretical understandings of broader social phenomena' (Anderson 2006). Following these guidelines, a previous article (Bougaïeff 2026) described how I became a member of the Berlin techno scene over the course of a decade. I write in this section in the first person to make myself visible and to show my presence in the setting, drawing links between my experience and the wider phenomenon of tempo modulation in electronic dance music.

My track 'Nexus' (2020) is structured (see form chart in Example 12) as a journey spanning four tempi, 66, 99, 132, and 165 bpm, which express a 2:3:4:5 tempo ratio series. The temporal modulations in 'Nexus' do qualify as combined modulations, as each tempo section clearly features a different meter. However, given the 'tendency to hear drums as timekeepers' (Butler 2006, 99), what matters first and foremost for the dancing audience member wishing to move in time with the music may be more the tactus rather than the meter or phrase length of any one particular sound. I therefore analyse 'Nexus' as a series of tempo modulations. The track is notable for leveraging the same pivot material, a long isochronous synth melody, across all sections (see Example 13).

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Section	A	B	C	D	E	F	G
Meter	2/4	4/4	5/4	3/4	4/4	5/4	4/4
Duration (bars)	12	18	12	24	24	12	4
Time Stamp	0:00-0:22	0:22-0:54	0:54-1:16	1:16-2:00	2:00-2:43	2:43-3:05	3:05-3:13
Tempo	66	132	165	99	132	165	132
Tempo Ratio	1:2	4:5	5:3	3:4	4:5	5:4	
Pivot Material	Melody	Melody	Melody	Melody	Melody	Melody	Melody
Pivot (Poly)rhythm	2:1	1:1	4:5	4:3	1:1	4:5	1:1

Example 12. Nicolas Bougaïeff, 'Nexus,' form chart.



Example 13. Nicolas Bougaïeff, 'Nexus,' pivot melody.

I used the melody throughout to elevate pivot material from its typical role as a temporary hinge across a tempo shift to a formal role in structuring and temporalizing the entire track. This approach, while distinct from Carter's 'long-range polyrhythms' (Aylward 2009), accomplishes a similar purpose of using polyrhythmic relationships to structure a piece. In the case of 'Nexus', the pivot material acts as a structural anchor, a stable element around which the temporal context changes. This approach allows repetition, a defining characteristic of electronic dance music in general and techno in particular, to be contrasted not only by timbral variations but also by new metrical interpretations resulting from temporal variations. Tempo can thus be freely wielded as an expressive parameter while pivot material provides a clear and steady pulse train, another defining characteristic of electronic dance music. This approach makes it possible to create tempo-shifting tracks and 'DJ tools' (Butler 2006, 204), while also mitigating the risk that tempo changes can pose to sustaining entrainment and maintaining a groove.

The 4:5 ratio, as exemplified in 'Nexus', merits particular attention. The introduction of primes larger than 3 affords a greater variety of tempo modulation ratios. Many pivot pairs generating these ratios, however, necessitate tuplets foreign to electronic dance music in general and certainly to techno in particular. The table of pivot pairs generating the 4:5 tempo ratio featured in 'Nexus' (see Example 14) shows that many combinations involve quintuplets. The table also shows which pivot pairs enable a tempo shift strictly with binary note values, that is, note values aligned to a binary pulse train, in this case the 16ths grid. Indeed, the 4:5 tempo ratio in 'Nexus' is executed with a 1:1 to 4:5 pivot pair. As previously mentioned, a 4:5 polyrhythm can also be expressed as 5/16. Not only is it more efficient to speak of five sixteenths, rather than in traditional terms as a quarter tied to a sixteenth, 5/16 is terminology perhaps more familiar to any electronic dance music producer.

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Pivot origin (poly)rhythm	Pivot target (poly)rhythm	Tempo ratio	Pivot origin (note value)	Pivot target (note value)
A:B	C:D	BC:AD		
5:1	4:1	4:5	sixteenth quintuplet	sixteenth
5:2	2:1	4:5	eighth quintuplet	eighth
5:4	1:1	4:5	quarter quintuplet	quarter
1:1	4:5	4:5	quarter	quarter tied to sixteenth
1:2	2:5	4:5	half	half tied to eighth
1:4	1:5	4:5	whole	whole tied to quarter

Example 14. Pivot pairs generating a 4:5 tempo ratio.

Durations familiar to electronic dance music producers and audiences can be leveraged for a greater variety of tempo modulations including 5- and 7-limit ratios. The following sequence of pivot polyrhythms, 2:1, 4:3, 1:1, 4:5, 2:3, 4:7, 1:2, contains a useful property: each corresponds to a short duration aligned to the 16ths grid, eschewing triplets and tuplets. Scaling these polyrhythm ratios to match antecedents yields 4:2, 4:3, 4:4, 4:5, 4:6, 4:7, 4:8, a sequence of polyrhythm ratios that, when simplified, yields 2:3:4:5:6:7:8, a sequence of tempo ratios. Arranging these tempo ratios back into individual pairs yields 2:3, 3:4, 4:5, 5:6, 6:7, 7:8, a collection of tempo ratios that can be applied to electronic dance music. Tempo modulation ratios suitable for electronic dance music leverage a pivot that is interpreted as conventional note values, i.e., those quantized to the sixteenths grid, and a shift from an origin tempo to a target tempo where both are appropriate for specific genres. Such note values include eighths (2:1 or 2/16), dotted eighths (4:3 or 3/16), quarter notes (1:1 or 4/16), quarter notes tied to a sixteenth (4:5 or 5/16), dotted quarter notes (3:2 or 6/16), double dotted quarter notes (4:7 or 7/16), and half notes (1:2 or 8/16).

The pivot mixing chart in Example 15 provides a table of these tempo modulation ratios whereby pivots utilise note values that remain quantized to the sixteenths grid in both the origin and target tempi. Two top rows show the pivot duration as the cardinality of sixteenths and as traditional rhythmic figures. Adjacent pairs of pivot cardinalities form tempo ratios and rows below show various hypothetical tempo shift pairs. Each row is identified by 'level', in the left-most column, which corresponds to the bpm increase between each column on that row. The tempo modulations in 'Nexus', for example, are found on level 33. A level can be understood as a family of closely related tempi. An expansion of this table that includes triplets and other tuplets as pivot note values is beyond the scope of this article.

4. Pivot mixing

Four key aspects of pivots have so far been demonstrated: their central role in tempo modulation, their structural potential, the affordance of multiple tempo targets from a single pivot, and the multiplicity of pivot pairs that a single tempo ratio can express. These lead to a powerful affordance of pivot mixing: expanding the spectrum of temporal intervals in DJ performance by definitively unseating unisons from the axiomatic definition of beatmatching and introducing intervals beyond 3-limit ratios. Several renowned DJs and various online educators discuss 'polyrhythmic mixing', a term suggesting a rich variety of temporal relationships. However, the polyrhythmic elements they discuss focus almost exclusively on the 3:4 ratio, with occasional use of the 2:3 ratio, and pivot material is only weakly emphasised. Pivot mixing, in contrast, affords a greater variety of tempo ratios and emphasises pivot material across the tempo shift. The following section will first explore

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	Pivot						
	2	3	4	5	6	7	8
	♪	♪.	♩	♩𝅘𝅥𝅯	♩.	♩..	𝅗𝅥
Level	Tempo						
12	24	36	48	60	72	84	96
13	26	39	52	65	78	91	104
14	28	42	56	70	84	98	112
15	30	45	60	75	90	105	120
16	32	48	64	80	96	112	128
17	34	51	68	85	102	119	136
18	36	54	72	90	108	126	144
19	38	57	76	95	114	133	152
20	40	60	80	100	120	140	160
21	42	63	84	105	126	147	168
22	44	66	88	110	132	154	176
23	46	69	92	115	138	161	184
24	48	72	96	120	144	168	192
25	50	75	100	125	150	175	200
26	52	78	104	130	156	182	208
27	54	81	108	135	162	189	216
28	56	84	112	140	168	196	224
29	58	87	116	145	174	203	232
30	60	90	120	150	180	210	240
31	62	93	124	155	186	217	248
32	64	96	128	160	192	224	256
33	66	99	132	165	198	231	264
34	68	102	136	170	204	238	272
35	70	105	140	175	210	245	280
36	72	108	144	180	216	252	288
37	74	111	148	185	222	259	296
38	76	114	152	190	228	266	304
39	78	117	156	195	234	273	312
40	80	120	160	200	240	280	320
41	82	123	164	205	246	287	328
42	84	126	168	210	252	294	336
43	86	129	172	215	258	301	344
44	88	132	176	220	264	308	352
45	90	135	180	225	270	315	360
46	92	138	184	230	276	322	368
47	94	141	188	235	282	329	376
48	96	144	192	240	288	336	384
49	98	147	196	245	294	343	392
50	100	150	200	250	300	350	400
51	102	153	204	255	306	357	408
52	104	156	208	260	312	364	416
53	106	159	212	265	318	371	424
54	108	162	216	270	324	378	432
55	110	165	220	275	330	385	440
56	112	168	224	280	336	392	448
57	114	171	228	285	342	399	456
58	116	174	232	290	348	406	464
59	118	177	236	295	354	413	472
60	120	180	240	300	360	420	480

Example 15. Pivot mixing chart.

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polyrhythmic mixing and subsequently pivot mixing, that is, it will focus on DJs using this approach to mix existing tracks, rather than producers embedding such approaches within their original works.

American DJ and producer Machinedrum describes his 'formula for polyrhythmic mixing: take the bpm and divide by 3, then multiply by 2. The new bpm's 1/4 notes will sound like triplets over the original bpm' (2023). He is describing a 3:2 tempo modulation, with a 3:2 to 1:1 pivot pair, whereby triplets of quarter notes in the origin tempo sound like quarter notes in the target tempo. While he does not mention pivot material, the modulation he describes corresponds to the same ratio used in 'Sleepy Pietro', a track that demonstrated a sophisticated approach to pivot material.

British DJ and producer Objekt writes: 'there's quite a lot of triplet DnB at 85/170bpm which mixes fine with straight 4/4 stuff at 128bpm for example' (2022). The statement is inexact as 128 and 170 express a 64:85 ratio, a ratio for which no conventional note values exist to form a pivot pair. Perhaps he meant 129 and 172, two tempi which express a 3:4 ratio and can indeed be connected by a 4:1 (sixteenth) to 3:1 (eighth triplet) pivot pair. Objekt further remarks in the same post that he 'kinda cooled off on these kinds of transitions' and that his practice of the technique peaked with his Dekmantel mix (2017). Indeed, between approximately 42:00 and 48:00, Objekt creates temporal ambiguity by introducing triplets and new kick patterns that can be interpreted as duple or ternary rhythm, without ever clearly forcing the perspective. There does not appear to be any pivot material clearly bridging the tempo shifts.

British-born, Berlin-based DJ and producer CCL demonstrates 'transitioning from a house tempo track of [...] 129 bpm to a drum and bass track at 172' (Resident Advisor 2024). The transition, 3:15–4:15, expresses a 3:4 tempo ratio and hinges on a 4:1 to 3:1 pivot pair (sixteenths at 129 bpm are equal to eighth triplets at 172 bpm), the same pivot pair described by Objekt. CCL creates a pivot by looping three beats in a breakdown section of the 129 bpm house track. They cut the bass on the pivot and, thirty seconds later, mix in a ternary drum and bass track with the bass also cut. The transition is fully realised when they drop the bass in the drum and bass track, clearly establishing a new tactus at 172 bpm. They simultaneously remove the pivot from the mix, presumably because the pivot material does not blend so well with the full drum and bass track.

British DJ and producer James Zabiela demonstrates a 3:4 tempo modulation from house to drum and bass with a 4:3 to 1:1 pivot pair (2020). He first creates a pivot by layering two loops: three sixteenths (a 4:3 polyrhythm) of an acid line with the 3/4 loop function on a Pioneer CDJ-3000, and three eighths (a 2:3 polyrhythm) of a synth line with the 3/2 loop function. He notably does not use the sync button to synchronise the two pivot decks and uses the CDJ platter to occasionally readjust the playback position of a pivot layer. The pivot decks are playing at 129.8 and 130.0 bpm, while the drum and bass deck is playing at 173.4 bpm. The tempi, 130 and 173.4 bpm, do not perfectly match a 3:4 ratio, which would correspond to 130 and 173.33 bpm (or 130.25 and 174 bpm). This discrepancy indicates that Zabiela performs the transition by relying on his ear, adjusting the decks with traditional beatmatching skills, as much as on a numerical estimation of the required tempi, which he identifies as 130 and 174 in the video description. The pivot, through Zabiela's astute selection and adept performance, fits perfectly at both tempi and is clearly emphasised. The demonstration, while still reflecting the familiar 3:4 tempo ratio, constitutes a clear example of pivot mixing.

I demonstrate pivot mixing with a 5:6 tempo ratio in a video (Bougaïeff 2024b) which received hundreds of thousands of views and generated significant engagement in the form of comments, likes, and direct messages, including from internationally recognised DJs such as Chris Liebing, Kaskade, and Tiga. The 5:6 ratio produces tighter tempo pairs than the 3:4 ratio, resulting in new affordances within ranges suitable for electronic dance music, for

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example, in this case, a transition from techno at 140 bpm to trance at 168 bpm. The first track, Louis The 4th's 'Organza' (2023), is played at 140 bpm and features a staccato 5/16 synth loop that is leveraged as a pivot during a breakdown. The second track, Liso's 'Drench' (2023), is played at 168 bpm and fades in. In context against 'Drench', the pivot now sounds like a 6/16 loop. The pivot creates a 4:5 polyrhythm in the first track and a 2:3 polyrhythm in the second track. Equalising the polyrhythm ratios yields a 4:5 and 4:6 pivot pair, which reduces to a 5:6 tempo ratio. The 5:6 ratio corresponds to the 5 and 6 columns in the pivot mixing chart, where the tempo pair demonstrated in the video, 140 and 168, is found on level 28.

In addition to its use as analytical tool, the pivot mixing chart can also be used as a performance planning tool with a five stage process: firstly find a track with a pivot, secondly identify the loop length of the pivot, third identify the track's tempo as the origin bpm, fourth find the cell nearest to the origin bpm in the column matching the pivot loop length, and fifth and finally choose a target bpm in the row containing this cell. For example, 'Organza' features a synth riff that can serve as a pivot loop, and the track is at 141 bpm. The synth riff outlines a 5/16 loop. The tempo nearest 141 in the 5/16 column is 140. The potential target tempi on this row are 56, 84, 112, 140, 168, 196, and 224. There is no need to calculate the target pivot polyrhythm, as the pivot mixing chart is constructed so that a track at any of the potential target tempi will combine with the pivot in such a way that the pivot loop aligns with the 16ths grid. This method was used to develop the next example.

I demonstrate pivot mixing with a 5:6:7:8 sequence of ratios in a video (Bougaïeff 2024a) that features four tracks, each at a different tempo, mixed around the same pivot. The performance hinges on a 7/16 pivot loop from the breakdown, 2:31-3:21, of my track 'Cognitive Resonance' (Bougaïeff 2017). The pivot is used as a sonic anchor around which I successively mix four tracks, each at a different tempo from level 19 in the pivot mixing chart. The first track, Lurka's 'Heat Mover' (2018), is played at 95 bpm and imposes a 5/16 interpretation of the pivot loop. The second track, Daft Punk's 'Da Funk' (1997), is played at 114 bpm and imposes a 6/16 interpretation of the pivot loop. The third track, 'Cognitive Resonance', is played at 133 bpm and imposes the original 7/16 interpretation of the pivot loop. The fourth track, Shft.rar's 'Dropstep' (2023), is played at 152 bpm and imposes an 8/16 interpretation of the pivot loop.

5. Discussion

Tempo modulation appears in electronic dance music usually in ratios of 2:3 or 3:4, and is most often used to transition between genres, for example, from house to drum and bass. Tempo modulation can be subsumed in a more elaborate musical gesture, as in 'Polygon', or presented with a reduced texture, such as in 'Nu Odyssey'. In either case, tracks incorporating tempo modulation can be used as DJ tools, and pivot mixing allows DJs the same in the absence of a suitable track. Tempo modulation, whether incorporated into a track's production or performed as pivot mixing, provides DJs with a method for changing tempo, and often genre, while ensuring a smooth experience for the audience. Pivot mixing can create temporal ambiguity, especially when special emphasis is placed on a transition and pivot material is played solo. Ambiguity is resolved when a new track is mixed in and forces a temporal perspective.

The term 'pivot mixing' proposes a new perspective on temporal modulation. While the terms 'tempo modulation' and 'metric modulation' both focus on what changes, 'pivot mixing' focuses on what is unchanging. The pivot is the unchanging element, the anchor of stability around which tempo, meter, or both can change. This new perspective nevertheless aligns with repetition and entrainment, key qualities of electronic dance music. Repetitive pivot material creates a sense of continuity, an approach to tempo modulation that is particularly effective for electronic dance music. A repetitive pivot carried across the tempo

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shift provides stability and hedges against the potential risk that tempo changes pose of disrupting a flowing groove. I experimented with these techniques in Berlin nightclubs, through both DJ and live performance, and observed that the audience can and will dance to tracks that use tempo modulation. Leading techno DJ DVS1, regarding tempo modulation in performance, opined that 'most DJs, unless they're playing multiple genres, don't know how to move [between tempi]' (Khutoretsky 2024). He reacted positively to the concept of pivot mixing and video demonstrations of the technique, noting that 'unless the track does [tempo modulation] for [the dj] ... and gives [the dj] an entry point and an exit point ... except for the [pivot mixing] videos you showed me of what you do ... most people don't know how to play with tempo beyond sliding the fader or letting the track do it for them' (Khutoretsky 2024).

Pivot mixing adds a new dimension to familiar musical processes underpinning electronic dance music. Pivot mixing's focus on what is unchanging, the pivot material, suggests a new take on variation processes familiar in electronic dance music. Changing the timbre of unchanging rhythmic and pitch patterns is a staple of techno. As Butler notes, electronic dance music often exploits a pattern 'not so much as an established motive but as raw material for timbral development' (2014, 47). Pivot mixing affords change to an unchanging pattern, a pivot loop, not through timbral but temporal development.

Pivot mixing expands the range of readily available temporal relationships in electronic dance music to include 5- and 7-limit ratios. Temporal modulation, while not overly common, has been shown to appear in electronic dance music common practice, either as continuous or prepared rational modulations. When it is implemented as a prepared rational modulation, it is done so predominantly in a 3:4 ratio, reflecting a major historical trend of an emphasis on 2:3 and 3:4 temporal relationships. It is worth repeating that 2:3 and 3:4, as octave complements, are so similar as to be considered two implementations of the same relationship. An examination of the affordances of pivot loop lengths aligned with the 16ths grid, tabulated in the pivot mixing chart, reveals a rich variety of tempo modulation ratios appropriate to electronic dance music. These pivot loop lengths, exemplified in my track 'Nexus' and pivot mixing videos, demonstrate the viability of 5- and 7-limit tempo ratios such as 4:5, 5:6, 6:7, and 7:8 in the context of electronic dance music.

Pivot mixing enables tempo networks in electronic dance music production and performance. Electronic dance music has been hitherto strongly associated with fixed tempi. Contrary to the status quo, pivot mixing expands temporality in electronic dance music by enabling 'tempo networks' (Benadon 2004) and formal structures found, for example, in Carter's *First String Quartet* (Tingley 1981, 11). Tempo networks can be understood as a parallel to tonal harmony, whereby an origin bpm acts as a tonic tempo and rational intervals enable modulations to related tempi. Tempo networks can be created as local journeys, as in 'Nexus', by exploring several tempi on a same level and perhaps even sharing the same pivot material. Tempo networks can also be created as an expansive journey between levels, for example, by first pivot mixing from 144 to 168 bpm on level 24 and then from 168 to 147 bpm on level 21. Tempo networks thus enable modulation to foreign tempi; the relationship between 144 and 147, for example, expresses a 48:49 ratio.

Terminology from tuning theory provides useful parallels. Just intonation (JI) refers to pitch intervals with ratios of small natural numbers, while rational intonation (RI) includes pitch intervals of any natural number ratios. Similarly, just temporality (JT) and rational temporality (RT) can denote tempo intervals with small natural ratios and any natural ratios, respectively. Ratios in the pivot mixing chart are examples of JT, whereas the 48:49 ratio in the hypothetical expansive tempo network example is an example of RT. Pivot mixing is a technique that leverages both just and rational temporality in electronic dance music. The pivot mixing chart and Cowell's tempo scale are two methods of organising tempo intervals.

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This research suggests three directions for future research: identifying additional methods of organising tempo intervals, conducting perception studies to provide insight into the impact of ambiguity in tempo modulation, and examining how pivot mixing impacts entrainment and the experience of time.

Pivot mixing conclusively expands temporality in electronic dance music. Since Francis Grasso 'made beatmatching a required skill for DJs' (Broughton and Brewster 2007, 58), mixing has been practiced nearly ubiquitously in tempo unisons. Pivot mixing expands the temporal vocabulary of electronic dance music from beatmatching in temporal unisons to temporal intervals. The additional tempo intervals afforded by pivot mixing expand temporality in DJ performance from a single consistent tempo to a sequence of related tempi, from temporal drones to temporal melodies.

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