



HAL
open science

Dig That Lick: Exploring Patterns in Jazz with Computational Methods

Lucas Henry, Klaus Frieler, Gabriel Solis, Martin Pfeiderer, Simon Dixon,
Frank Höger, Tillman Weyde, Helene-Camille Crayencour

► **To cite this version:**

Lucas Henry, Klaus Frieler, Gabriel Solis, Martin Pfeiderer, Simon Dixon, et al.. Dig That Lick: Exploring Patterns in Jazz with Computational Methods. Jazzforschung/Jazz Research, 2021, Vol. 50. hal-03084838

HAL Id: hal-03084838

<https://hal.science/hal-03084838>

Submitted on 15 Nov 2021

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Dig That Lick: Exploring Patterns in Jazz with Computational Methods

Lucas Henry, Klaus Frieler, Gabriel Solis, Martin Pfeleiderer, Simon Dixon, Frank Höger, Tillman Weyde, Hélène-Camille Crayencour

The matter of pattern in musical improvisation has been central to jazz studies for as long as there has been academic work on the subject. Ethnographers have analyzed the ways musicians describe learning and using licks and riffs, music theorists and cognition scholars have debated the function of pattern in improvisational creative processes, and a series of fan-generated YouTube videos have shown the remarkable popularity of one seven-note melody, described simply as “The Lick.” And yet, many questions remain about such material and its actual usage in jazz improvisation. How much of an improvisation is made up of stock patterns played verbatim and patterns strongly associated with certain musicians? Do patterns and licks rise and fall in use over time? Does the extent or type of pattern use change with the stylistic context? Does pattern usage change as musicians age? This paper reports on three case studies from a collaborative project using computational methods to answer historical and theoretical questions regarding the socio-musical role of licks in jazz. After outlining the concept and existing research on patterns and licks in jazz improvisation we introduce the computational approach, the database, and the interactive analysis webtools. Then, in line with the theme of *Jazz Journeys*, usage and transmission of three particular licks are traced in three case studies. The first lick originated with the main bebop musicians (Charlie Parker, Dizzy Gillespie), but is still used by modern post-bop players (Michael Brecker, Chris Potter). The second lick is a common and short cadential formula using chromatic approaches that can be found in all jazz history. In the third case study, the concept of “post-Coltrane” improvisation is scrutinized by looking at an extended ascending Dorian scale played by Coltrane in his solo on “Blue Trane” (1957). By presenting these three examples we intend to stimulate novel research on jazz improvisation using corpus-based methods and computational tools.

Patterns – Licks

At least three terms are in common use to describe repeated melodic material from which jazz improvisers create solos: “pattern”, “riff”, and “lick”. Of these, “pattern” is the most open term, the least determined, and also the most commonly used. Tucker and Jackson, for instance, use it—but not “lick”—in their entry for Jazz in the standard reference work, the *New Grove Dictionary of Music* (Tucker and Jackson 2001). However, they refer exclusively to rhythmic patterns as a determinant of style in jazz. “Riff” is the narrowest and most specific of the three terms, being used to describe a specific kind of pattern, i.e., short, repetitive, most often connected with swing-era head arrangements (e.g., Shypton 2007: 306-307; Baraka 1963: 62, 170, 183, 217; Gioia 1997: 183; DeVeaux 1997: 190-92). “Lick” sits between the general term “pattern” and specific term “riff”. Witmer offers a clear and concise definition in

a *New Grove* entry on the topic: “A term used in jazz, blues, and pop music to describe a short recognizable melodic motif, formula or phrase.” (Witmer 2001). Nearly every other use of the term follows this definition, albeit with some further parsing. Martin and Waters (2006) use “lick” and “formula” interchangeably. Benson says, “A lick can consist of a short melodic motif or a more extended unit; it may end in a full cadence, but most likely it is part of a larger melodic/harmonic scheme. The fact that licks are ubiquitous in jazz improvisations is precisely the reason that the term “lick” can mean almost any musical pattern that is in some way recognizable and that is not, strictly speaking, part of what we might call the ‘tune itself’” (2008: 137). Beyond simply defining licks as patterns, there seems to be a consensus that licks are learned (though sources are not always a matter of consensus), stored in the memory (though relatively few researchers have a theory of memory as such that would allow them to expand on this somewhat vague notion), and deployed in performance (again, how that happens is not entirely a matter of consensus).

Given these terms and definitions, we can say that there are several different types of licks/formulas/patterns, and each has been used (or could be used) to understand creation and meaning of improvised material in jazz. We can consider those that are specific (licks, quotations, riffs that occur in whole across solos and seem to be understood as borrowed—see Berliner 1994), the generic (licks, patterns, formulas that occur in whole or in part across solos but may not be understood to be borrowed—see Pressing 1988), the variant (formulas and patterns as frameworks that improvisers use to create new or seemingly new material—see Gushee 1977, Johnson-Laird 2002, Berliner 1994), the referential (quotations, patterns, or formulas that suggest style or refer directly to another performer or work—see Berliner 1994), the intentional (deliberate choices by an artist—see Berliner 1994, Monson 1996), and the reflexive (unintentional choices made by the performer—see Norgaard 2011, Pressing 1988). These various definitions can and have been employed in various ways for various research questions.

Four basic disciplinary approaches are represented in this literature: historical (e.g., DeVeaux 1997, Gioia 1997, Shypton 2007, Martin and Waters 2006, Porter 1997), ethnographic (e.g. Berliner 1994, Baraka 1963, Sawyer 1992), critical/theoretical (e.g., Gushee 1977, Schuller 1958, Gross 2011, Terefenko, Owens, Stewart, Benson 2008, Kenny 1999, Smith 1983, Finkelman 1997), and cognitive (e.g., Pressing 1988, Johnson-Laird 2002, Norgaard 2011, 2014, Goldman 2012, 2013). Each of these has a distinct set of research methodologies, but equally significantly, each is aimed at answering a distinct set of questions. Creativity is the key concept for critical/theoretical and cognitive approaches. These studies all, in one way or another, appear concerned with the question of how the creative act happens in jazz, whether through considering the mental processes involved directly, or through analysis of the resulting musical artifact. Sociability and mediation are the key concepts for ethnographic and historical studies. Whether focused on change over time or on largely synchronically understood structures, these studies generally offer answers to the question: what are the interpersonal networks in which musical improvisation has grown and thrived, and how have technologies been implicated in the process?

A number of questions without consensus answers come up in the literature. For instance, scholars are unresolved over whether pattern use represents creativity or its absence. The crux of this argument stems from readings of Albert Lord's work on oral formulaic composition (Lord 1960), and the underlying assumption that creativity in jazz improvisation means not playing the same thing from performance to performance. Owens initiates this in this much-quoted passage: "...the master player will seldom, if ever, repeat a solo verbatim; instead he will continually find new ways to reshape, combine, and phrase his well-practiced ideas. An awareness of these melodic ideas allows the listener to follow a solo with great insight into the creative process taking place" (Owens 1974, 17; see also Treitler 1974 for the incorporation of oral formulaic theory into music studies). A number of subsequent studies follow this out, some (such as Gushee 1991 and Kernfeld 1983) focusing on the patterns themselves and others (such as Martin 1996 and Smith 1983) arguing that the larger-order compositional process in which patterns can be found is more significant. Finkelman (1997) argues that in making a distinction between formula (the specific melodic sequence) and pattern (the ways in which melodic sequences are deployed), authors have failed to see the significance and creativity of what he calls "pattern-forms" and "formula-ideas," or what we might call "licks."

Similarly, there is no consensus on whether improvising musicians are deploying stored material or running "mental algorithms" (see Johnson-Laird 2002; Norgaard 2011; Norgaard 2014; Norgaard, Spencer and Montiel 2013; and Pressing 1998). Finally, there is some division over whether licks are the tool for beginners, or also in continued use by master performers. Many writers appear to see licks as a core component even of master musicians' improvisational practice/language. Berliner, however, is considerably more restrained on this issue, suggesting that licks are primarily part of the student musician's repertoire (Berliner 1994, 101). Veteran artists may still use them, but Berliner quotes at least one musician (Stanley Turrentine) who describes them as a "crutch," to be used when the creative process is not working for him.

Computational methods for jazz research – the Dig That Lick project

In general, existing work on pattern usage in jazz improvisation has relied on relatively small datasets in one way or another to make their main points. Volume of data, i.e., the numbers of specific performances analyzed, is perhaps not crucial for qualitative studies. A single compelling example of a process of interpersonal musical transfer, e.g., the case of Jaki Byard quoting from a Mingus tune (Monson 1996), speaks first as a uniquely interesting musical event, but also as a kind of ideal type, suggesting the existence of countless other, similar instances across jazz as a whole. That said, with more quantitative work, as the datasets used in the questions at hand grow larger, the more convincing are the findings. This is as true for quantitative approaches such as our own that aim to be in dialogue with qualitative studies. Certainly when considering the social nature of jazz improvisation and learning, a larger and more diverse dataset is an important key to the stability of the results.

The databases and analytical tools of the international Dig That Lick project (DTL, 2017–2020)¹ have the potential to facilitate such larger-scale analyses. The project was dedicated to investigating the usage of patterns and licks in monophonic jazz solos using search algorithms on a large database of jazz solo transcriptions. These transcriptions are created automatically using state-of-the-art melody extraction algorithms based on neural networks and advanced signal processing techniques (Başaran et al., 2018, Frieler et al., 2019). The transcriptions are equipped with extensive metadata based on a specifically designed semantic model. N-grams, i.e., melodic sub-sequences, are extracted from the transcriptions using pitch and interval representations and stored in a database. Similarity algorithms which are grounded in music psychological research are used to retrieve pattern instances for a given query and similarity threshold. The system allows tracing patterns and their variants across the whole database while combining them with the available metadata to make further inferences. The web-based Pattern Similarity Search² interface allows for searching for instances of similar melodic patterns of any length and frequency of occurrence within three jazz databases: the DTL1000 Database with a total number of 1685 automatically transcribed improvisations (including some shorter segments of “tradings” between soloists) from one thousand tracks which were randomly selected from each decade of jazz history (Crayencour et al. 2020), the Weimar Jazz Database³, which contains 456 manually transcribed improvisations by 78 soloists (Pfleiderer, 2017), and 56 transcriptions of Charlie Parker improvisations from the Parker Omnibook (Baker, Rosado, Shanahan & Shanahan, 2016). Additionally, in order to allow for comparisons with other music repertoires the freely available Essen Folk Song collection which contains over 7,000 European folk melodies (Schaffrath, 1995) is provided. Since the automatically generated DTL1000 database does not yet provide for harmonic or metric content, just the melodic aspects of a pattern (sequences of pitches or intervals) are examined, discarding all rhythmic, metric or harmonic context.

To execute a search, the user enters a pattern on a virtual keyboard or as a list of text elements and chooses an interval or MIDI-tone (pitch) representation. Then, the tool provides a list of pattern instances described by metadata, with links to audio snippets for aural inspection. Not only identical pattern instances, but also similar patterns that differ in one or more tones from the query, can be searched for. Similarity is estimated using the Levenshtein distance (edit distance). This distance measure has been shown in various studies (e.g., Frieler & Müllensiefen, 2006; Grachten & Arcos, 2004; Gulati, 2016) to be a good approximation to similarity judgements of melodies by human experts. The similarity search operates on a database of the complete set of pitch and interval n-grams of up to 20 elements that were previously extracted from the databases. For the three jazz databases, this amounts to about seven million distinct n-grams with about ten million instances both for MIDI pitch and interval representations. By entering a pattern, similar n-grams can be retrieved from the database. To further control the result set, the search interface provides options for parameters such as “minimum similarity”, “maximum length difference” (allowing for similar n-grams of differing length), or the preservation of melodic contour and pitch range. All searches can also

¹ <http://dig-that-lick.eecs.qmul.ac.uk/>

² https://dig-that-lick.hfm-weimar.de/similarity_search/

³ <https://jazzomat.hfm-weimar.de/dbformat/dboverview.html>

be refined using metadata filters for performers, instruments, recording year, style, etc. Search results are presented in tabular form together with two graphical representations allowing for visual inspection – an n-gram network graph and a timeline chart. Results can also be exported. Finally, there is an application programming interface (API) that allows executing similarity search from within external program scripts.

Case Study 1: A typical bebop lick

The interval pattern $[-1, -2, -1, 3, 3, 3, -1, -2]$ (represented in semitones, see fig. 1) can be considered a typical bebop pattern with a distinctive recognizable structure. In fact, it is the fifth-most frequent non-trivial pattern, i.e., a pattern which is not a trill, a tone repetition or a simple scale, of length 8 or longer across the three jazz databases. It can be found as patterns M20 and M40 in Owens's work on Charlie Parker (Owens 1974). In order to find variants of the pattern, it was submitted as a query to the similarity search system and the DTL1000, WJD and Omnibook databases. A similarity threshold of 0.7 and a maximum length difference of 2 was used, and overlapping instances⁴ were filtered out as well as instances that span across phrase boundaries, i.e., only patterns that do not cross a phrase boundary and which differ in at most 2 intervals in length and have a similarity of least 0.7 (on a scale of 0 to 1) are included in the result set. Likewise, all instances lacking a three-interval nucleus in the center were discarded. This resulted in a set of 311 instances of 132 different variants of the lick, 105 in the DTL1000 database, 115 in the Omnibook, and 91 in the WJD.

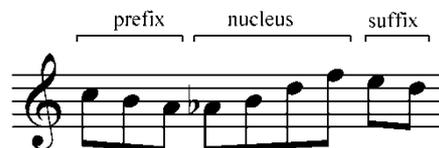


Figure 1: Interval pattern $[-1, -2, -1, 3, 3, 3, -1, -2]$ in staff notation, starting with C.

⁴ The pattern search engine uses similarity values between zero and one, where one means identity. The similarity threshold indicates the minimum similarity an n-gram should have with the search pattern to be included in the result set. As similarity calculation uses the Levenshtein distance, which allows for sequences of different lengths, the interface also provides the possibility to specify an upper bound of length difference between the search pattern and sequences (within the similarity threshold; these two values are coupled). Furthermore, if length differences are allowed and the similarity threshold is lower than one, the result set can contain (strings of) n-grams that will overlap. For example, consider you are searching for the string ABC in a text corpus with similarity threshold 0.75 and a maximum length difference of 0. Then, a sequence ZABD in the corpus contributes the strings ZAB and ABD to the result set, but these two matches have an overlap of two elements (AB). The interface allows for filtering out these overlapping instances using different configurable criteria. The default setting will return only the string ZAB that occurs earlier where both candidates have the same length and the same degree of similarity.

Looking at a timeline plot (Fig. 2) of all instances of the pattern variants found in the WJD and the DTL while disregarding the Parker Omnibook, the number of instances played by Charlie Parker (24 instances) is still striking. Sonny Stitt (17), Dexter Gordon (15), Sonny Rollins (11), Dizzy Gillespie (8) and Stan Getz (8) are also heavy and early users, with Dizzy Gillespie producing four instances in one solo alone (“Be-Bop”, 1945). Interestingly, more recent post-bop players such as Michael Brecker (3 instances), Chris Potter (3), and Wynton Marsalis (3) have this pattern in their repertoire, too. However, the pattern variants are not equally popular across the main jazz styles as annotated in the WJD ($\chi^2(7) = 127.3, p < 0.001$), as it is much more likely to be found in bebop and hard bop solos (about 68%) than in any other styles. This justifies the denomination of the pattern as a “typical bebop lick”, although the earliest instance can be found with swing tenor sax player Chu Berry (in his solo on “Body and Soul”, 1938).

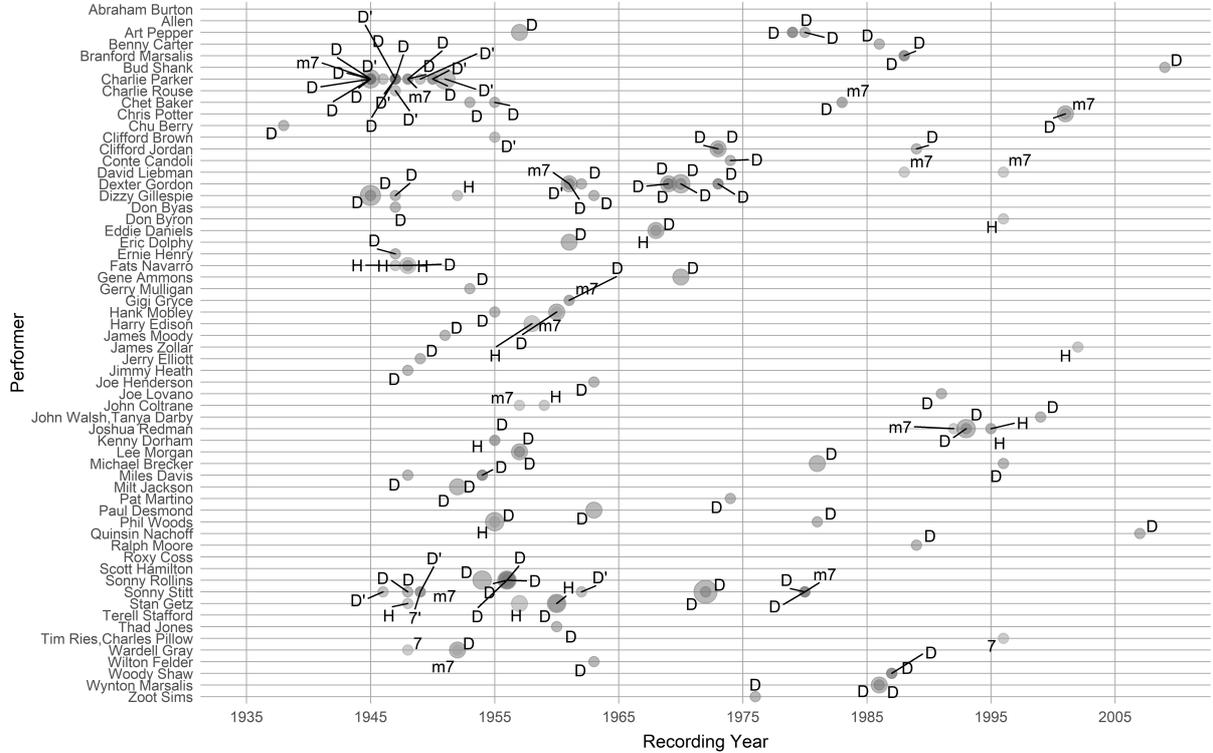


Figure 2: Timeline of instances of the lick and its variants with performer on the y-axis and recording year on the x-axis. Labels and transparencies indicate nucleus type, while size represents frequency (see text for details).

In order to analyze the variants of the lick further, pattern nuclei were classified by the seventh chord they represent, and prefixes and suffixes of the nuclei were ranked by frequency. This allowed constructing unique tags of the form “nn-X-mm”, where “nn” is the frequency rank of the prefix, “mm” is the frequency rank of the suffix, and “X” is the nucleus code: *D* for a diminished arpeggio [3, 3, 3], *D'* for its first inversion [-9, 3, 3], *H* for half

diminished chord [3, 3, 4], 7 for a dominant seventh chord [4, 3, 3] and 7' for its first inversion [-8, 3, 3], and finally *m7* for a minor seventh chord [3, 4, 3].

Out of the $4^3 = 64$ possible four-tone chords with combinations of ascending minor/major thirds and descending minor/major sixths only six occurred as nuclei in our result set, with the original *D* [3, 3, 3] being the most common with 248 instances (70 %), followed by its first inversion *D'* [-9, 3, 3] with 42 instances (13 %). No sixth was found on any other than the first position. Together, this is an indication for the stability and specificity of the pattern. For the prefixes, 43 different versions could be found with the original [-1, -2, -1], the far most common with 174 instances (56 %). The suffixes came in 31 variants and the original [-1, -2] was the most common with 140 instances (45 %). A pattern network using Edit-Distance-based similarity of all patterns can be found in Fig. 3. Here, a similarity cut-off of 0.8 is used and the node size is proportional to Freeman centrality, the number of connections of a node to other nodes. The original pattern (01-D-01) is in the center, as expected.

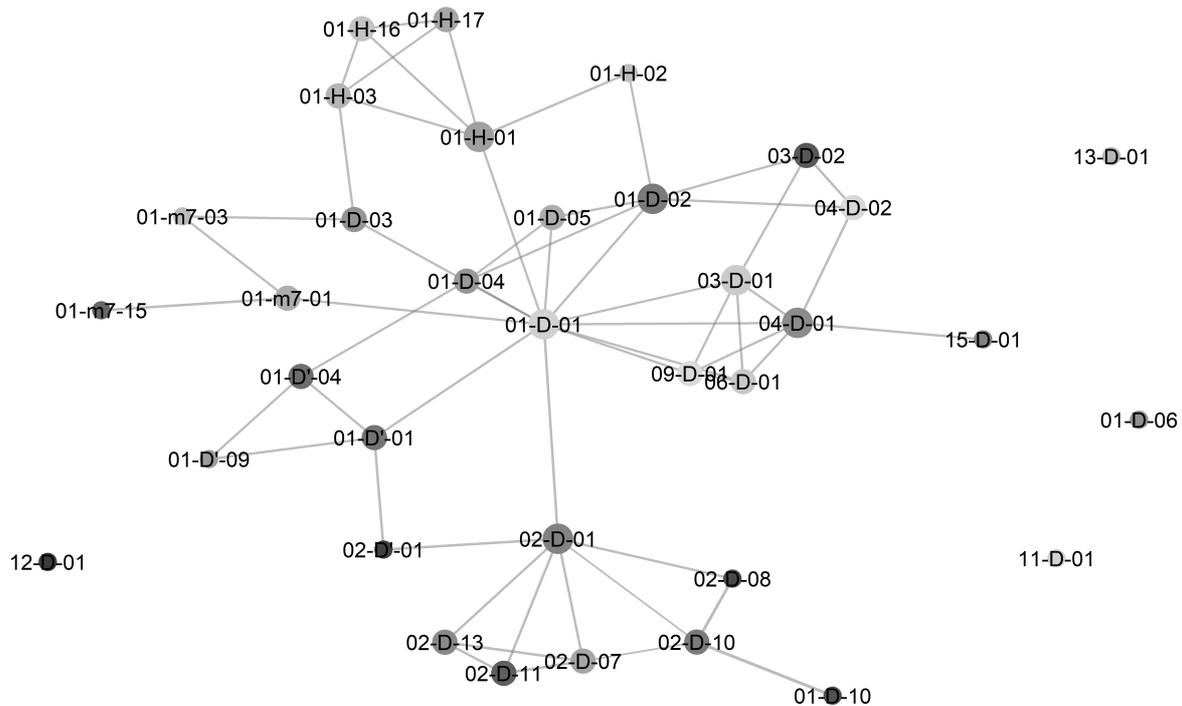


Figure 3: Similarity network of the most common lick variants with at least two instances. Similarity cutoff was set to 0.8. Transparency and size of the node correspond to the degree of the node (Freeman centrality, number of connections to other nodes). See text for detailed explanation of the labels.

For further structural analysis, we extracted chord contexts, metrical positions, absolute pitch values and chordal diatonic pitch class information (Frieler, 2017) for the first tones of the

nuclei. As this information is not available in the DTL1000 database, the following results pertain only to the WJD and Omnibook databases.

This analysis shows a remarkable consistency. 79 % of all nuclei start on a beat (WJD: 59 %, Omnibook: 95%), while the distribution over the beats in a 4/4 differs between the Omnibook and the WJD. In the WJD, the nuclei start on many different beat and offbeat positions but most frequently on the third (22 %) and the first (14 %) beat of a 4/4 bar, whereas in the Omnibook the majority start on the second beat (45 %), followed by rather equal shares (15–17 %) for the other beats in a bar.

The most common interval in relation to the root of the chord context for the first note of the nuclei is the third of the chord (55 %), whereas the most common chord context is a C7 chord (18 %), followed by G7 (9 %), D7 (6 %) and F7 (6 %). Generally, a dominant seventh chord was the most common chord context for the nuclei with 64 % of all instances, followed by the minor and minor seventh chords with 16 % in total (the Omnibook has a tendency to notate minor chords where other sources would use minor seventh chords).

From these most common traits (a D nucleus with the most common prefix and suffix, the original 01-D-01 pattern, where the nucleus starts on the second beat of a 4/4 bar and on the third of a dominant seventh chord), a prototypical version of the pattern can be constructed. There are two instances of this prototype in the WJD and three in the Omnibook to be found. The WJD instances are played by Charlie Parker (Fig. 4a) and Sonny Rollins (Fig. 4b).



Figure 4a: Prototypical version of the lick (01-D-01), as played by Charlie Parker in his solo on “Ko-Ko” (1947) in m. 51.



Figure 4b: Another prototypical version of the lick by Sonny Rollins in his solo on “Airegin” (1954) in m. 22.

To sum up, this example here is a typical case of a jazz or bebop lick. It probably originated with one or two players, viz. Charlie Parker and Dizzy Gillespie, and was transmitted throughout the jazz world, and is still in use as of today. A prototypical version could be reconstructed as the most common variant (01-D-01) with the most common metrical and

chordal placement of the nucleus. It is probably not a too far-fetched a statement that all other variants are somewhat adaptations or mutations of this single prototype. Furthermore, this lick shows typical features of (modern) jazz melodic construction in a very concise and compact way, viz., chromaticism and chromatic approaches, four-tone chord arpeggios using upper structure of (dominant seventh) chords, and a zig-zag type melodic movement with two turning points on different metrical positions giving rise to implicit syncopations. In short, this lick seems to be bebop in a nutshell.

Case Study 2: Minor third with a double chromatic approach

The lick presented in this second case study is very short and comprises only the four intervals $[-2, -3, 1, 1]$, corresponding to five tones (see Fig. 5). The total ambitus is that of a descending minor third. The pattern is probably constructed by elaborating the final chromatic step in the short descending diatonic sequence $[-2, -1]$ with a double chromatic approach from below, i.e., $[-1] \rightarrow [-3, 1, 1]$. Chromatic approaches are a well-known technique for jazz solos (cf. Frieler, 2019), which is less common in other styles of music. In the Essen Folk Song Collection, the pattern $[-3, 1, 1]$ occurs only three times, whereas in the combined DTL1000, WJD and Omnibook corpus, 1,205 instances (contained in a single phrase) can be found. The full pattern in question occurs 315 times (contained in a single phrase), which is about three times more frequent than could be expected from the single interval probabilities⁵.

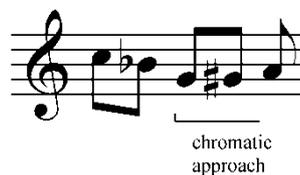


Figure 5: Interval pattern $[-2, -3, 1, 1]$ in staff notation, starting with C.

Chromatic approaches are typically associated with bebop-style melodies, but the distribution over recording years of the instances (Fig. 6) shows that this particular pattern already occurred in traditional and swing jazz, with the earliest instance coming from Johnny Dodds in his clarinet solo on “My Heart” from 1925 in a recording by Louis Armstrong’s Hot Five. But the high time of this lick was in the heyday of cool jazz and hard bop as half of all instances can be found between 1954 and 1962. It continues to be used in the following decades, e.g., Joshua Redman seems to be particularly fond of it. In Tab. 1 the usage statistics

⁵ A sequence of N intervals x_i with probabilities p_i has an *a priori* probability given by the product of single probabilities: $p = p_1 p_2 \dots p_N$. With M elements in a corpus, one could expect to see thus pM instances. The embellished-third-lick has an *a priori* probability of 0.0002, and the combined database has 4,165,185 elements, so the expected number of $[-2, -3, 1, 1]$ patterns is $.0002 * 4,165,185 = 106.6$, whereas the observed frequency is 327. In comparison, the inverted pattern $[2, 3, -1, -1]$ has an expected value of 729 instances in the database, but in fact occurs only 171 times, about a fourth of the expected value.

for the performers with at least five instances are shown. At the top of the list is Lee Konitz with twenty instances, nine of which occur in a single solo alone. It was also quite frequently used by Charlie Parker and Fats Navarro, two of the most influential bebop players. This leads to the assumption that though the lick was already in use before bebop, it was mainly popularized by bebop musicians.

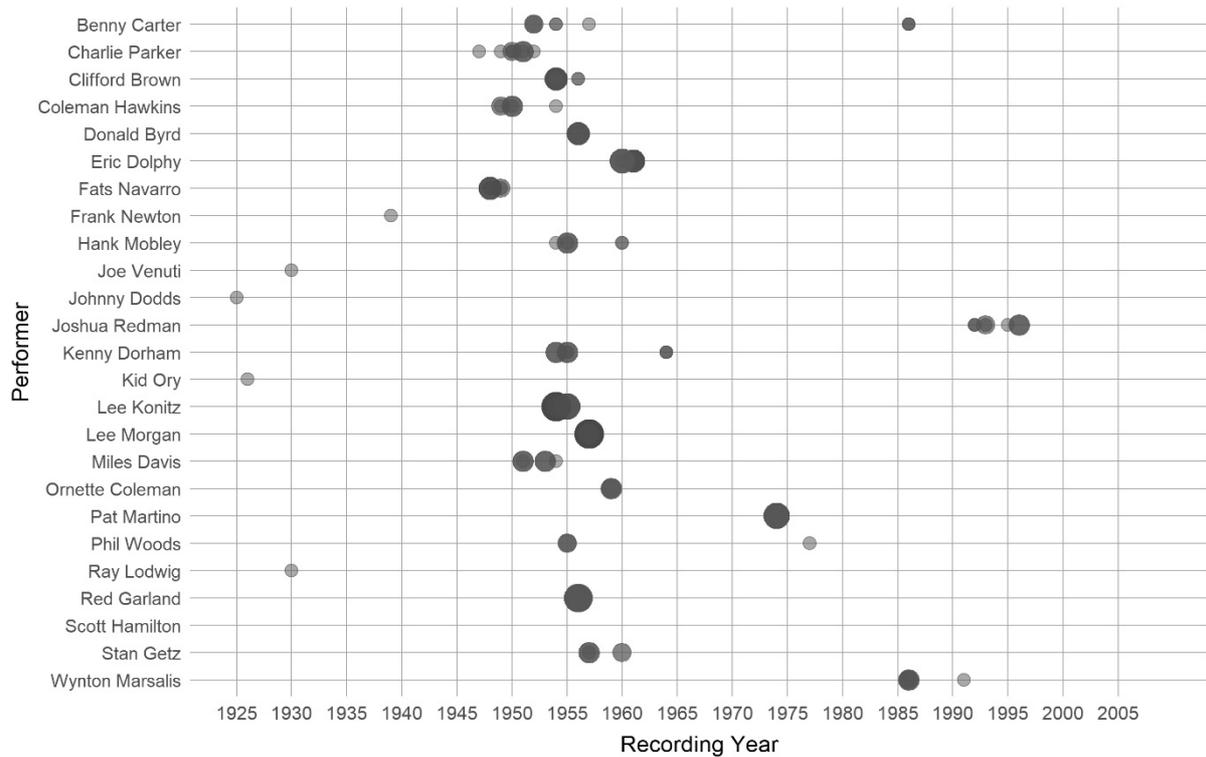


Figure 6. Timeline of instances of the [-2, -3, 1, 1] lick. Only performers with 5 or more instances or before 1940 are shown for reasons of display. Each point corresponds to one solo, with point size proportional to the number of lick instances.

In order to investigate the tonal context in which this pattern is commonly played, we used the instances in the Weimar Jazz Database, because only for these is chordal information available. We extracted the chord context for each tone of the pattern and calculated chordal pitch classes, as in case study 1.

The most common tonal uses can be found in Tab. 2. In over half of the cases, the pattern is played over a single chord, most often a dominant seventh chord. For these cases, there are two main forms: either starting the pattern on the fifth of the chord and descending to the third, or starting on the root and descending to the major 6 (13th). The first form also occurs quite frequently over a major-seventh chord and the latter on minor-seventh chords. These are the most frequent combinations. In 45 % of the remaining cases, the pattern is played over two chords, most frequently V^7-I^7 , $ii^7 - V^7$, V^7-I^{maj7} , or V^7-i^7 . In most of these cases, the

pattern starts on the root of the first chord and lands on the third of the second chord, i.e., the pattern has a certain cadential character.

Finally, it is interesting to see how this short cadential formula is used in the context of longer patterns. To this end, we retrieved all patterns that occur at least 10 times in the combined corpus and contain the pattern (“embedding patterns”). This resulted in a set of 44 patterns with 960 instances. In this set, six maximal embedding patterns, all of length 7, with 64 instances in total can be found. The most common maximal embedding pattern from our dataset is $[-1, -2, -1, -2, -3, 1, 1]$, first exhibited by Fats Navarro in 1949 and then by Charlie Parker in 1952 (Fig. 7), followed by Joe Henderson and Herbie Hancock in the 1960s, but most commonly appearing in the 1990s with players like Joshua Redman (four instances in three solos), Wynton Marsalis (two instances in two solos), and David Liebman (one instance). The other maximal embedding patterns are $[1, -2, -3, 1, 1, 3, 3]$, $[-1, -2, -3, 1, 1, 3, 2]$, $[-1, -1, -1, -2, -3, 1, 1]$, $[-1, -2, -2, -2, -3, 1, 1]$ and $[-3, 1, 1, -2, -3, 1, 1]$. If one relaxes the condition on minimal frequency to at least two instances, the longest maximal embedding pattern is $[-2, -3, 1, 1, 9, -3, 1, 1, -4, -3, -2, -1, 9, -3]$ (Fig. 8), which was played by Fats Navarro in 1948 on “Good Bait (Alternate Take)” and in 1949 on “Lady Be Good”. All in all, this gives a glimpse into a common solo construction technique, where longer patterns are assembled from smaller melodic units.



Figure 7. Most common maximal embedding pattern for $[-2, -3, 1, 1]$ as found in Charlie Parker’s second solo on Kim (1952).



Figure 8. Longest maximal embedding pattern for $[-2, -3, 1, 1]$ as found in Fats Navarro’s solo on Good Bait (Alternate Take) from 1948.

Table 1. Performer statistics of [-2, -3, 1, 1] instances

<i>Performer</i>	<i>Total number of instances</i>	<i>Max. number in single solo</i>	<i>Number of solos</i>	<i>Total number of solos in corpus</i>
<i>Lee Konitz</i>	20	9	4	12
<i>Lee Morgan</i>	15	9	3	7
<i>Eric Dolphy</i>	15	5	6	7
<i>Clifford Brown</i>	14	4	7	11
<i>Charlie Parker</i>	13	3	10	102
<i>Joshua Redman</i>	11	3	8	54
<i>Kenny Dorham</i>	11	3	7	11
<i>Benny Carter</i>	10	2	8	15
<i>Fats Navarro</i>	10	4	6	11
<i>Miles Davis</i>	8	3	4	29
<i>Coleman Hawkins</i>	8	3	5	20
<i>Red Garland</i>	8	8	1	1
<i>Hank Mobley</i>	7	3	5	9
<i>Scott Hamilton</i>	7	5	3	9
<i>Wynton Marsalis</i>	7	3	4	7
<i>Stan Getz</i>	6	3	3	16
<i>Pat Martino</i>	6	6	1	1
<i>Donald Byrd</i>	5	4	2	2
<i>Phil Woods</i>	5	2	3	22
<i>Ornette Coleman</i>	5	3	2	20

Note: only performers with five or more instances are shown.

Table 2. Typical chordal contexts for the [-2, -3, 1, 1] pattern

Chordal diatonic pitches	n	Rel. Freq. (%)	Most frequent chord progression	Example
5 4 2 #9 3	37	21	V ⁷	 <p>Miles Davis “Tune Up” (1953)</p>
1 7 5 b6 6	19	11	V ⁷	 <p>Herbie Hancock “Gingerbread Boy” (1966)</p>
1 7 5 b6 → 3	17	10	V ⁷ → I ⁷	 <p>Clifford Brown “Jordu” (1954)</p>

1 7 5 b6 →3	17	10	$V^7 \rightarrow I^{maj7}$	 <p>Lee Konitz “All the things you are” (1955)</p>
1 7 → 2 #9 3	9	5	$V^7 \rightarrow I^7$	 <p>Clifford Brown “Stompin at the Savoy” (1954)</p>
3 b9 7 #7 1	7	4	ii^{-7}	 <p>Joe Lovano “Little Willie Leapin” (1994)</p>

Case Study 3: Post-Coltrane patterns

After Charlie Parker, John Coltrane was one of the most influential on his contemporaries and later musicians; and moreover, as David Ake (2002: 112-145) has unpacked extensively, influential through the use of at least some of his work as the basis of formal, academic jazz improvisation pedagogy. Choosing to examine Coltrane’s improvisations in a social context is difficult, but with the assistance of the Dig That Lick apparatus, this can be achieved on quite a larger scale than previously possible.

In Lewis Porter’s book on John Coltrane (Porter 1998) is the section where he discusses the influence of Coltrane in the post-Coltrane era. In the epilogue, when talking about Coltrane’s son Ravi and his attempt to find his own voice while playing with musicians who had performed alongside his father, Porter says:

Ravi studied John’s legacy just as musicians all over the world do; not because it is his father, but because there’s no way to be a jazz musician since Coltrane without knowing his music. The challenge is to learn from Coltrane without imitating him. [...] Among the many who developed a distinctive voice out of the Coltrane legacy are Charles Lloyd, Ralph Moore, David Liebman, Joe Farrell, Steve Grossman, Pat LaBarbera, Michael Brecker [...], Bob Berg, Jan Garbarek, and numerous other players of tenor and soprano saxophone. But his influence extends far beyond saxophonists—he affected the whole field of jazz improvisation, influenced the ensemble sound of jazz groups, and set forth an attitude about what jazz is and what it can be. (Porter 1998: 295)

He later goes on to list other post-Coltrane musicians who have used his concepts and techniques to create their own styles of improvisation. These musicians include Chick Corea, Woody Shaw, Greg Osby, and Steve Coleman. (Porter 1998: 295)

However, Porter does not give examples to show how Coltrane influenced these musicians. When Porter gives analytical examples of other musicians’ works in this text, it is only done

in the sections where he discusses those who had early influence on Coltrane in his younger years, and it really only includes Charlie Parker and a handful of classical composers that Coltrane would have encountered in music lessons growing up. When he discusses Coltrane’s influence on the musicians in the post-Coltrane world, it is done primarily ethnographically. With the dataset, combined from the DTL1000, the Parker Omnibook, and WJD datasets, we can expand the process of mapping the musical influence of artists across genre, space and time.

In general, the simpler and shorter the pattern, and the more that the pattern fits within diatonic frameworks, the more results can be found with the similarity search tool. It shows that certain simple patterns are common in jazz, if not Western music in general. Conversely, longer and more complicated patterns yield fewer, if any results. However, one pattern in particular was both long and resulted in 181 matches to similar patterns and 39 exact matches with other solos (see Fig. 9). The lick’s structure is a rising nine-note Dorian pattern in scalar form that does not change contour. What makes this lick particularly interesting to consider is that it is quite simple—a scale pattern—and yet it is nonetheless considerably “lick-ish.” The matter of such a simple lick’s capacity to point back to a specific artist—even one as distinctive and widely-known as Coltrane—is also interesting. Our analysis of the dataset offers the suggestion that in this case the lick does, indeed, at least map onto a framework of Coltrane-influenced musicians and even Coltrane references.

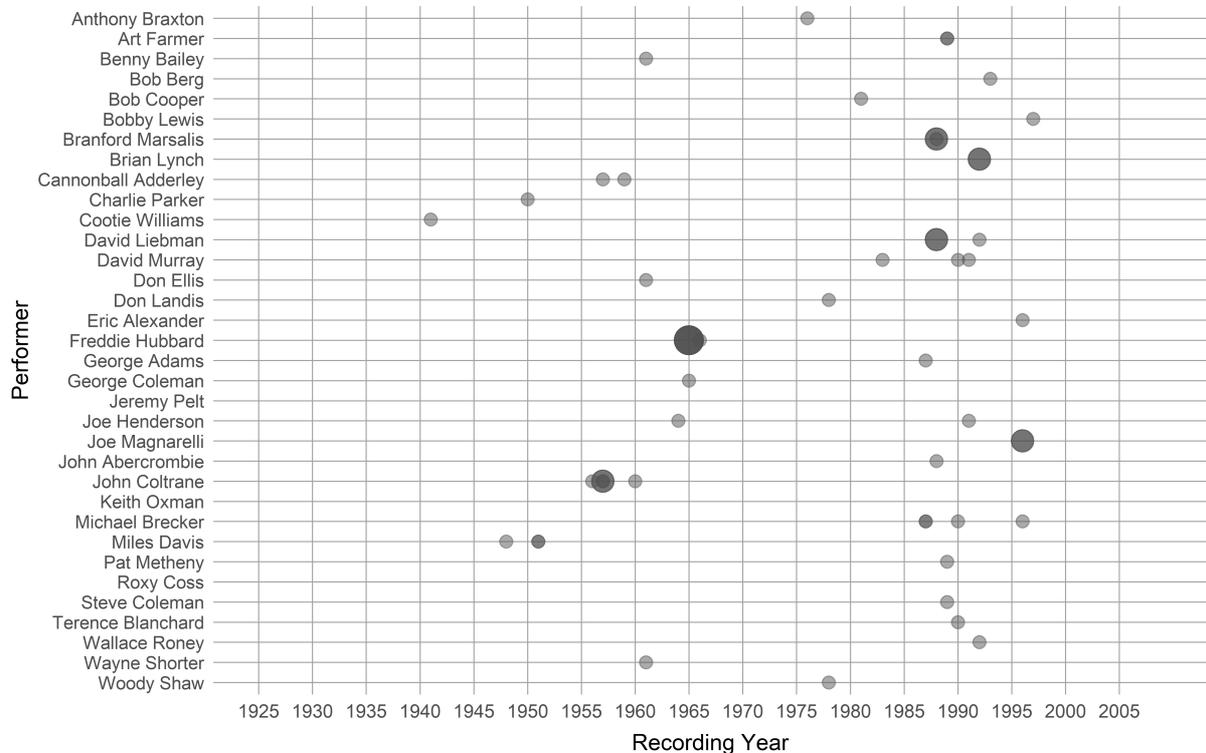


Figure 9. Timeline for all instances of the extended Dorian scale [2,1,2,2,2,1,2,2] in the combined corpus. Each point represents a solo, with point size proportional to the number of instances contained.

When the results of a search for this lick are listed chronologically, Coltrane's iterations of the lick are clearly not the first. Nonetheless, the few instances that predate it—a Cootie Williams solo on a 1941 Duke Ellington Orchestra recording of "Clementine," three solos by Miles Davis, and one instance in a Charlie Parker recording of "An Oscar for Treadwell" all sound different from Coltrane's use. Here rhythm and placement within the solos appear to be crucial differences. Williams's solo, for instance, uses this pattern not as a lick, but as part of a longer passage moving between two more motivic sections. Davis's use of the same note sequence in "Constellation," in the 1948 recording with Charlie Parker, gives it a rhythmic treatment that focuses on the first note (by extending it), producing a quite different effect from the later Coltrane use. Coltrane, himself, first used a similar lick in his solo on "Nuttty", which was recorded in mid-1957, but not released until 1961 on the album *Thelonious Monk with John Coltrane*. It was followed just a few months later on "Blue Trane" from Coltrane's album of the same name. Shortly after that, it was played by as many as 33 players over the next 40 years of solos found in the database, including: Cannonball Adderley, Don Ellis, Wayne Shorter, Joe Henderson, Freddie Hubbard, George Coleman, *Woody Shaw*, David Murray, *Michael Brecker*, Branford Marsalis, *David Liebman*, John Abercrombie, Pat Metheny, *Steve Coleman*, David Newman, Anthony Braxton, Bob Mintzer, and *Bob Berg*—some of whom are musicians in Porter's aforementioned list of players directly influenced by Trane's improvisational theories and formulas (artists included in Porter are in italics). Listening to the results suggests that the overall number of hits can actually be whittled down to roughly 20 nearly exact matches, because not all of the results are performed in the same manner as Coltrane (i.e., too slow, with a distinctly motivic rhythmic profile, part of a very long glissando, etc.); in addition, there are five more that can be seen as close resemblances (i.e., extend further than the pattern in question)⁶. As a result, from even a somewhat limited dataset, we can chart a significant number of performers using the pattern as part of a larger pattern that may sound like a "Trane lick" to the listener.

Notably, while this pattern does generate a small number of hits before 1957, its presence is disproportionately from afterward. Note that much of the material in the combined datasets comes from pre-1957 recordings (over a third in the WJD, about half in the DTL set, and, of course, everything in the Omnibook, since Charlie Parker passed away in 1955). Reducing the lick by one or more notes off the end produces significantly more results, with a seven-note version returning as many as 206 iterations going back into the early 1940s. Many of these are clearly unrelated, but nonetheless it is fair to say that Dorian and other modal scalar licks are in use early on, but lengthier uses of the scale—more than one octave—are introduced around

⁶ The twenty nearly exact matches, along with those played by Coltrane himself, include as follows: Anthony Braxton, "Giant Steps"; Art Farmer, "Blue Wail"; Bob Berg, "Angles"; Bob Cooper, "Little Pony"; Dave Liebman, "Day and Night"; David Murray, "Chelsea Bridge"; David Newman, "Son of Ice Bag"; Don Landis, "Stella by Starlight"; Eric Alexander, "Some Other Spring"; Freddie Hubbard, "Dolphin Dance" and "Maiden Voyage"; Joe Henderson, "In 'n' Out" and "Johnny Come Lately"; Joe Magnarelli, "Big Sky"; Keith Oxman, "Deep in a Dream"; Kenny Garrett, "Gendai"; Michael Brecker, "Maiden Voyage" and "Peep"; Steve Coleman, "The Oracle"; and Woody Shaw, "Stepping Stone."

the time that Coltrane became a bandleader in his own right. Not surprisingly, this is also supported by Porter. He says:

Coltrane's style was always changing. He moved more and more into developing a self-reliant sound world, a world that by the 1960s had less and less in common with the music that he started with—the music of Lester Young and Charlie Parker. [...] What's more, he developed a vocabulary of licks that are in many cases not traceable to his predecessors. One way that Coltrane developed this unique sound world is by bringing into his music—and through his influence, into all of jazz and beyond—an eclectic collection of method books, exercises and scales from around the world. (Porter 1998: 216)

Jimmy Heath, a contemporary of Coltrane in Philadelphia, confirms in an interview with Porter that the two of them were very interested in learning the various modes and modal scales, and created their own exercises for these concepts in all twelve keys. These two statements confirm two issues from the result—that Coltrane was prone to using interesting scales in his works, and that it shouldn't be surprising to see that this concept would not appear in a fairly wide-ranging dataset of improvisational solos by major performers before 1957.

The canon of jazz is not just the players themselves, but also the particular recordings that have been deemed to be influential or important. One might expect that the more canonical recordings would be the ones that generated patterns found in other players' improvisations. In particular, *Giant Steps*, *Impressions*, *Ascension*, *My Favorite Things*, *Love Supreme*, and so forth would seem to be recordings that have generated significant response. While both “Blue Train” and “Nutty” are well known pieces, they have not warranted extended discussion by jazz historians or critics, which is what makes it surprising to see this apparently influential lick coming from those recordings. Looking back at Porter's biography, for example, “Blue Train” is briefly mentioned, and no musical examples from the entire *Blue Train* album are found in the text; instead, the recordings that receive the most attention from Porter are the previously-mentioned “canonical” works. To test for the relative impact of this lick vs. those in more canonical recordings, we applied the same type of investigation to a number of the recurring patterns from Coltrane's solo in “Giant Steps”—a recording from the same time period in Coltrane's life that has definitely had traction in both musicological jazz scholarship (again, see Porter 1998) and pedagogical/analytical material (Ake 2002). For “Giant Steps” we found two extremes: results that don't clearly point to Coltrane's influence because they have hundreds of hits that span the entire historic timeframe of the database—as far back as the 20s, and results that show Coltrane as the only musician performing the pattern in question. This confirms a reasonable hypothesis that the interesting thing about “Giant Steps” is not the circulation of the patterns Coltrane uses to get through the harmonic structure, but rather the harmonic structure itself. This is what ultimately makes the “Blue Train” Dorian lick an interesting find—it produces results that show a pattern originating with Coltrane and transferring widely. Moreover, it shows an appreciation (consciously adopted or not) for Coltrane's more soulful work.

Conclusion and outlook

In the first case study, we traced a typical bebop lick and its variants. The lick seems to have been popularized by Charlie Parker and Dizzy Gillespie, even though they themselves might have taken inspiration from earlier swing players. Many other players from the bebop era, known to be influenced by Parker and Gillespie (Berliner 1994; DeVaux 1991), also used the pattern quite frequently, indicating a direct transmission. Since then it is a stock phrase of jazz improvisation. Modern post-bop players also use it quite often. This is indicative of their mastery of the bebop tradition, though it might also be a direct and deliberate reference to their bebop forebears (e.g., Michael Brecker using it over “Confirmation”, a well-known composition by Charlie Parker). The many pattern variants nearly always appear in specific metrical configurations and harmonic contexts. This indicates that metrical and harmonic aspects might be stored along with the pattern in a player’s memory. However, a pattern can be adapted to different harmonic contexts without losing its musical shape which opens further questions about pattern construction and memorisation.

In the second case study, we treated a rather short but significant cadential formula, which appears to be an embellished descending minor third using a double chromatic approach. It can be found all over jazz history and also appears in typical harmonic contexts, mostly over dominant-seventh chords starting from the fifth or the root of the chord. Furthermore, it could be shown that this formula is itself used to build longer licks that are played rather frequently. Thus, this case study gives some interesting insights into melodic construction principles of jazz solo improvisation.

With the third case study, we show a substantial trajectory of material from Coltrane to later players. Looking at “Blue Train” and exploring a modal lick in a social manner suggests confirmation of the notion that jazz is a social artform. However, there are limitations to the results that ultimately stem from the size of the existing dataset. We believe that a larger dataset would allow for an even more critical exploration of patterns and licks, and that perhaps we could also make claims about the influence of previously unexplored or overlooked material in jazz scholarship. Because the selection of solos currently available in the similarity search tool is extremely canonical (WJD) or representative (DTL1000), we can say with confidence that it is at least representative of the existing history of jazz. However, when we are able to incorporate more examples, we may be able to make larger and more concrete claims.

However, we believe that expanding the dataset will allow for scholars going forward to become even more critical than we are at the present; as a result, the apparatus may be able to contribute to the exploration of influential works and performers and provide closer links to other artists with whom they have interacted and inspired. Even better, with the addition of discographic information and social mapping applications, we should be able to see in detail how performers work in network with each other both in performance and through recorded works, and then to be able to suggest even further examples, hopefully resulting in a more robust, comprehensive, and detailed account of the travels of licks, riffs, and other musical patterns than possible with customary methods. Moreover, our approach offers a critical

reflection on the role of new methodologies—together referred to as “Digital Humanities”—in jazz studies.

Bibliography

Ake, David (2002). *Jazz Cultures*. Berkeley: University of California Press.

Baker, D. J., Rosado, A., Shanahan, E., & Shanahan, D. (2016). *The Role of Idiomaticism and Affordances in Bebop Improvisation*. Proceedings of the 14th International Conference on Music Perception and Cognition, San Francisco, pp. 127-130.

Baraka, Amiri (LeRoi Jones) (1963). *Blues People: Negro Music in White America*. New York: W. Morrow.

Benson, Bruce Ellis (2008). “Stealing Licks: Recording and Identity in Jazz.” In: *Recorded Music: Philosophical and Critical Reflections*. Ed. by Mine-Dogantan-Dack. London: Middlesex University Press, pp.137-152.

Berliner, Paul (1994). *Thinking in Jazz: The Infinite Art of Improvisation*. Chicago: University of Chicago Press.

Coker, Jerry (1970). *Patterns for Jazz*. New York: Alfred.

Hélène Crayencour, Simon Dixon, Klaus Frieler, Lucas Henry, Frank Höger, Geoffroy Peeters, Martin Pfeleiderer, Polina Proutskova, Gabriel Solis, Tillman Weyde, Daniel Wolff (2020). The DTL1000 Jazz Solo Dataset (in preparation).

DeVeaux, Scott (1997). *The Birth of Bebop: A Social and Musical History*. Berkeley: University of California Press.

Finkelman, Jonathan (1997). “Charlie Christian and the Role of Formulas in Jazz Improvisation.” In: *Jazzforschung/Jazz Research* 29, pp. 159-188.

Frieler, Klaus (2017). Computational melody analysis. In: *Inside the Jazzomat. New Perspectives for Jazz Research*, ed. by Martin Pfeleiderer, Klaus Frieler, Jakob Abeßer, Wolf-Georg Zaddach, and Benjamin Burkhart. Mainz: Schott-Campus, pp. 41-84. <http://schott-campus.com/jazzomat/>

Frieler, K. (2019). [Constructing jazz lines. Taxonomy, Vocabulary, Grammar](#). In: M. Pfeleiderer & W.-G. Zaddach (Eds.), *Jazzforschung heute. Themen, Methoden, Perspektiven*, Berlin: Edition EMVAS.

Frieler, Klaus / Müllensiefen, Daniel (2006). “Evaluation of approaches to measuring melodic similarity.” In: *Data Science and Classification*. Ed. by Vladimir Batagelj, Hans-Hermann Bock, Anuska Freligoj and Ales Ziberna. Berlin: Springer, pp. 299—306.

Frieler, Klaus / Höger, Frank / Pfeleiderer, Martin (2019). „Anatomy of a lick. Structure & variants, history & transmission.” In: *Book of Abstracts of the Digital Humanities Conference, Utrecht, 2019*.

Frieler, K., Başaran, D., Höger, F., Crayencour, H.-C., Peeters, G. (2019). [Don't hide in the frames: Note- and pattern-based evaluation of automated melody extraction algorithms](#). In: Proceedings of the 6th International Conference on Digital Libraries for Musicology (DLfM '19), November 9, 2019, The Hague, Netherlands.

Gioia, Ted (1997). *The History of Jazz*. Oxford: Oxford University Press

- Goldman, Andrew (2012). "What Does One Know When One Knows How to Improvise?" In: *Proceedings of the 12th International Conference on Music Perception and Cognition and the 8th Triennial Conference of the European Society for the Cognitive Sciences of Music. Thessaloniki, Greece.*
- Goldman, Andrew (2013). "Towards a Cognitive-Scientific Research Program for Improvisation: Theory and an Experiment." In: *Psychomusicology: Music, Mind and Brain* 23(4), pp. 210-221.
- Grachten, M., & Arcos, J. L. (2004). "Using the Implication/Realization Model for Measuring Melodic Similarity." In: *Proceedings of the 16th European Conference on Artificial Intelligence, ECAI04.* IOS Press.
- Gross, Austin Andrew (2011). *Bill Evans and the Craft of Improvisation.* PhD Dissertation, Eastman School of Music, University of Rochester.
- Gulati, Sankalp (2016). *Computational Approaches for Melodic Description in Indian Art Music Corpora* (PhD thesis). Universitat Pompeu Fabra, Barcelona.
- Gushee, Lawrence (1977). "Lester Young's 'Shoe Shine Boy'," originally in International Musicological Society, Report of the Twelfth Congress, Berkeley. Excerpted in Lewis Porter, 1991, *A Lester Young Reader*, Washington: Smithsonian Institution Press, pp.225-254.
- Höger, Frank / Frieler, Klaus / Pfeleiderer, Martin (2019). „Digging into pattern usage within jazz improvisation (Pattern History Explorer, Pattern Search and Similarity Search).” In: *Book of Abstracts of the Digital Humanities Conference, Utrecht 2019.*
- Johnson-Laird, Philip N. (2002). "How Jazz Musicians Improvise". In: *Music Perception* 19, pp. 415-442.
- Kernfeld, Barry (1983). "Two Coltranes." In: *Annual Review of Jazz Studies* 2, pp. 7-66.
- Kenny, Barry (1999). "Structure in Jazz Improvisation: A Formulaic Analysis of the Improvisations of Bill Evans." In: *Annual Review of Jazz Studies* 10, pp. 163-194.
- Lord, Albert B. (1960). *The Singer of Tales.* New York: Atheneum.
- Martin, Henry (1996). *Charlie Parker and Thematic Improvisation.* Lanham, Maryland: Scarecrow.
- Martin, Henry / Waters, Keith (2006). *Jazz: The First 100 Years*, 2nd edition. Boston: Schirmer.
- Monson, Ingrid (1996). *Saying Something: Jazz Improvisation and Interaction.* Chicago: University of Chicago Press.
- Norgaard, Martin (2011). "Descriptions of Improvisational Thinking by Artist-Level Jazz Musicians." In: *Journal of Research in Music Education* 59(1), pp. 109-127.
- Norgaard, Martin (2014). "How Jazz Musicians Improvise: The Central Role of Auditory and Motor Patterns." In: *Music Perception* 31(3), pp. 271-287.
- Norgaard, Martin / Spencer, Jonathan / Montiel, Mariana (2013). "Testing Cognitive Theories by Creating a Pattern-Based Probabilistic Algorithm for Melody and Rhythm in Jazz Improvisation." In: *Psychomusicology* 23(4), pp. 243-254.
- Owens, Thomas (1974). *Charlie Parker: Techniques of Improvisation.* PhD Dissertation, University of California, Los Angeles.
- Pfeleiderer, Martin (2017). "The Weimar Jazz Database." In: *Inside the Jazzomat. New Perspectives for Jazz Research*, ed. by Martin Pfeleiderer, Klaus Frieler, Jakob Abeßer, Wolf-

Georg Zaddach, and Benjamin Burkhart. Mainz: Schott-Campus, pp. 19-40. <http://schott-campus.com/jazzomat/>

Pfleiderer, Martin / Frieler, Klaus / Abesser, Jakob / Zaddach, Wolf-Georg / Burkhart, Benjamin (Eds.) (2017). *Inside the Jazzomat: New Perspectives for Jazz Research*. Mainz: Schott. <http://schott-campus.com/jazzomat/>

Porter, Lewis (1997). *Jazz: A Century of Change*. New York: Schirmer.

Pressing, Jeff (1988). "Improvisation: Methods and Model." In: *Generative Processes in Music*, ed. by John A. Sloboda. Oxford: Oxford University Press.

Sawyer, Keith (1992). "Improvisational Creativity: An Analysis of Jazz Performance." In: *Creativity Research Journal* 5(3), pp. 253-63.

Schaffrath, Helmut (1995). The Essen folksong collection. In D. Huron (Ed.), *Database containing 6,255 folksong transcriptions in the Kern format and a 34-page research guide*. CCARH.

Schuller, Gunther (1958). "Sonny Rollins and the Challenge of Thematic Improvisation." In: *Keeping Time: Readings in Jazz History*, ed. by Robert Walser. Oxford/New York: Oxford University Press, pp. 212-222.

Shipton, Alyn (2007). *A New History of Jazz*. New York: Continuum.

Smith, Greg (1983). *Homer, Gregory, and Bill Evans? The Theory of Formulaic Composition in the Context of Jazz Piano Improvisation*. PhD. Dissertation, Harvard University.

Stewart, Milton (1973). *Structural Development in the Jazz Improvisational Technique of Clifford Brown*. PhD Dissertation, University of Michigan. (Also, in: *Jazzforschung/Jazz Research* 6/7 (1974/75), pp. 141-273.

Terefenko, Dariusz (2004). *Keith Jarrett's Transformation of Standard Tunes*. PhD Dissertation, Eastman School of Music, University of Rochester.

Treitler, Leo (1974). "Homer and Gregory: The Transmission of Epic Poetry and Plainchant." In: *Musical Quarterly* 60, pp. 333-372.

Tucker, Mark / Jackson, Travis A. (2001). "Jazz." In: *New Grove Dictionary of Music and Musicians*, 2nd edition, London : Macmillan, Vol. 12, pp. 903-926.

Witmer, Robert (2001). "Lick." In: *New Grove Dictionary of Music and Musicians*, 2nd edition, London : Macmillan, Vol. 14, p. 655.

Abstract:

The importance of musical patterns to jazz is well established in the scholarly literature, in musicians' discourse and in fan lore. However, research into pattern usage has so far mostly been based on manual analyses of jazz recordings and transcriptions. The paper reports on some findings of a collaborative project on pattern usage in jazz improvisation that uses computational methods for transcription and analysis of recordings and a large database. After outlining the concept and existing research on patterns and licks in jazz improvisation the paper introduces the approach of the project, the interactive analysis webtools and the database that covers one hundred years of US jazz history. Then, the paper focuses on three case studies: firstly, the transmission of a particular epitomic bebop lick is traced. This lick

originated with the main bebop musicians (Charlie Parker, Dizzy Gillespie), but is still used by modern post-bop players (Michael Brecker, Chris Potter). Secondly, a short cadential formula is investigated that is used frequently in all of jazz history and is a common building-block for longer patterns. Thirdly, the concept of “post-Coltrane” improvisation is scrutinized by looking at an extended ascending diatonic scale, which was played by Coltrane in his solo on “Blue Trane” (1957) and later by other soloists, which are often described as “post-Coltrane” or Coltrane-influenced.

Biographies:

Hélène-Camille Crayencour is a researcher at Centre national de la recherche scientifique in Paris. Along with computer sciences, she has studied musicology and French literature at Sorbonne Université. Her research is focused on Statistical Relational Artificial Intelligence and Data Science for the Arts.

Simon Dixon is Professor of Computer Science, Director of the UKRI Centre for Doctoral Training in Music and Artificial Intelligence, and Deputy Director of the Centre for Digital Music at Queen Mary University of London. His research focus is music informatics, in particular the use of artificial intelligence and digital signal processing for the analysis and computational modelling of musical knowledge and performance.

Klaus Frieler is a post-doc researcher with the Dig That Lick project at the University of Music FRANZ LISZT Weimar and holds a PhD in Systematic Musicology from the University of Hamburg. His main research interests are computational musicology and music psychology with a special focus on creativity, particularly, jazz improvisation, and melody perception.

Lucas Henry is a PhD candidate in ethnomusicology at the University of Illinois. He holds a MA in jazz studies from Rutgers University, Newark. He also works as the Coordinator of Academic Programs at the European Union Center at the University of Illinois, and has previously taught courses in Music Studies at Temple University.

Frank Höger studied Systematic Musicology and Computer Science at the University of Hamburg. After graduating in 2010 he developed web applications for the private sector. He found his way back into academics in 2017 as Research Fellow within the project "Melodic Patterns in Jazz Performances" at the University of Music FRANZ LISZT Weimar.

Martin Pfeiderer is professor for the history of jazz and popular music at University of Music FRANZ LISZT Weimar since 2009. He studied musicology, philosophy and sociology at Giessen University (1988-93) and was assistant professor for systematic musicology at Hamburg University (1999-2005). His research is dedicated to rhythm, singing, and improvisation in jazz and popular music, sociology of music, aesthetics and computational musicology.

Gabriel Solis is professor of music, African American studies, and anthropology at the University of Illinois. He is the author of books on the performance and reception of jazz in the later 20th century with the University of California and Oxford University Presses, and

co-editor with Bruno Nettl of a book on musical improvisation published by the University of Illinois press.

Tillman Weyde is Senior Lecturer in Computer Science at City University of London. He is a member of the Research Centre for Machine Learning and the Data Science Institute. He leads the Music Informatics and Machine Intelligence Research Group and has worked on Music Computing projects for 20 years in symbolic music analysis and audio processing. He has led research projects in EU i-Maestro and the EPSRC projects Digital Music Lab among developing methods for interactive music learning and large-scale music data analysis.