The Shape of Swing: How Timing Outlines Form in Jazz Solos

Analyzing Beat-Upbeat Ratio (BUR) Structures in the Weimar Jazz Database

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Outline

Do changes in swing timing within jazz improvisational solos have structure, or do they reflect random variation?

- Swing, or the expressive shaping of timing, is challenging to quantify since it uses both uneven subdivision of eight notes and articulations to create a groove.
- We investigate whether jazz musicians systematically structure swing rate within phrases, suggesting swing as a deliberate expressive device within jazz improvisational solos.
- At what scale does swing shaping operate at: phrase boundaries vs form boundaries (32-bar song forms, 12-bar blues).

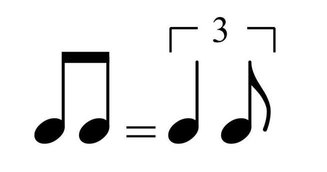

Figure 1: Example of swinging triplet (BUR = 2)

- The **Beat-Upbeat Ratio (BUR)** is often used to quantify swing by measuring the durational ratio between successive eighth notes.
- A BUR of 1.0 indicates "straight" eighths; a BUR of 2.0 represents a swung triplet feel for eighth notes (see figure above).
- Scholarship has shown that soloists rarely use the 2:1 triplet (BUR $\approx$ 2.0), instead clustering around 1.3 to 1.4 (Corcoran and Frieler 2021).

- Benadon suggested that varying BUR could be used by improvisers as an expressive device (Benadon 2006).
- BUR variation can articulate phrase/form structure.
- An increase in BUR can mark phrase boundaries such as onset or offset.
- High BURs often mark phrase and form boundaries.
- Serves to:
    1. Signal phrase onset and closure.
    2. Re-sync with rhythm section, which tends to play with higher BUR.
    3. Highlight tactus pulse and interact with underlying groove.
    4. Outline form and provide shape to solos.

The Weimar Jazz Database (Pfleiderer 2017)

- The Weimar Jazz Database (WJazzD) contains transcriptions of 456 monophonic solos by 78 different performers, across 9 instruments and various jazz styles from 1925 to 2009.
- Annotations in WJazzD include pitches, onsets, offsets, dynamics, chord sequences, beat, phrase grouping, and measure numbers, aligned with the original audio.
- The WJazzD was developed by the Jazzomat Research Project, which also created MeloSpyLib — a Python library for encoding, analyzing, visualizing, and converting monophonic jazz solos, including the calculation of BURs.

- Analyzed overall BUR (Beat-Upbeat Ratio) distributions across hundreds of jazz solos using the Weimar Jazz Database (WJazzD).
- Corcoran and Frieler's Key Findings:
  - Tempo relation: BUR slightly decreases as tempo increases — swing feel becomes more even at fast tempos.
  - Different genres swing differently:
    - "Soft" swing styles (e.g., Traditional, Swing, Bebop, Cool, and Free) have around 1.3–1.5 BUR.
    - Only Hardbop and Postbop average ∼2:1 ratios, classified as "hard" swinging.
  - Performer variation: Most soloists use slightly uneven eighths; a few use strong swing contrast more consistently.
  - Rhythmic feel: Even non-swing grooves (e.g., Latin, Funk) feature substantial uneven BURs in solos — suggesting solo and rhythm section swing may operate independently.

- We build on the work of Corcoran & Frieler (2021), who used the Weimar Jazz Database (WJazzD) to analyze global trends in swing (BUR) across styles, tempos, and performers.
- Unlike past studies using this jazz corpus, we focus on BUR variation within phrases and across formal structures, testing Benadon's theory that swing timing is used as an expressive, form-bearing gesture.
- We identify statistically significant swing variation patterns that suggest deliberate intra-phrase expressive structures.
- We determine if BUR increases during phrase onset and closure, and examine form-level effects in 32-bar song forms and 12-bar blues.
- Our analysis reveals hierarchical timing patterns operating from phrase level up to complete musical forms.

- Phrases (BUR > 6) divided into 3 sections to measure the change in BUR near phrase onset and closure.
- When the number of BUR values in a phrase was not divisible by three, the middle section was made longer to ensure that the phrase edges were not over-averaged.
- We compute mean BUR per section and find the standard deviation of each section within the phrase.
- We use Cohen's $|d| \geq 0.2$ to detect increasing or decreasing sections. This is considered the threshold for a medium effect size where the difference between the two distribution means is clearly above variation within both distributions.

Shape Classification: Defining the Patterns

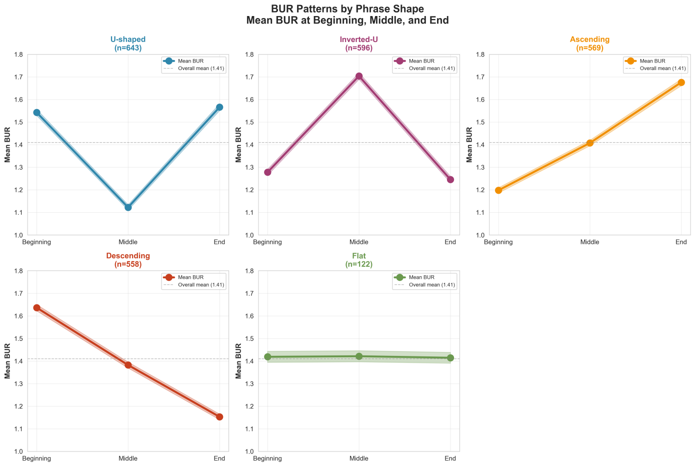

Figure 2: BUR patterns found in phrases.

Random Model: Phrase BUR Permutation

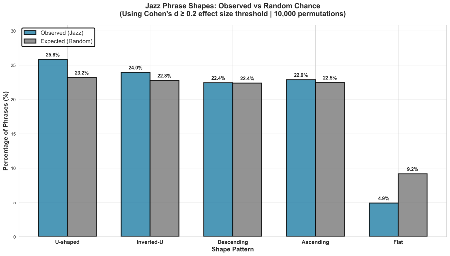

Figure 3: BUR Phrases

- The random model uses a permutation test where BUR values within each phrase were shuffled randomly in that phrase.
- The resulting phrase shape was calculated over 10,000 phrase permutations using the same phrase shape test.
- This validates whether observed patterns differ from random variation, while still using original data.

Table 1: U-Shaped Pattern Frequencies

Shape Pattern	Observed Frequency	Expected (Random)
U-shaped	25.84% (643 phrases)	23.20% (577 phrases)
Z-score $= +3.14$ **Significance:** $p < 0.01$		

- BURs accentuate beginning and end of phrases.
- Confirms Benadon's BUR theory about higher BUR values at the onset and closure of phrases.

Table 2: Flat Pattern Frequencies

Shape Pattern	Observed Frequency	Expected (Random)
Flat	4.90% (122 phrases)	9.16% (228 phrases)
Z-score = -7.65 **Significance:** $p < 0.01$		

- The random model predicts more unstructured/ambiguous phrasing.
- This implies a deliberate push for expressive contour.
- Another way to view it is through entropy: by increasing entropy in our phrase shapes, a random model should produce more flat shapes as inherent phrase shapes will get randomized and averaged out.

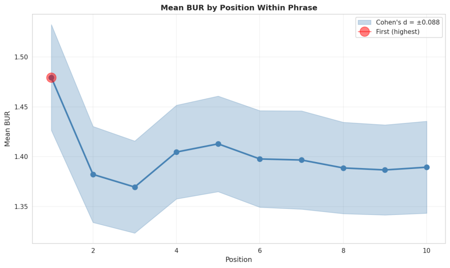

Figure 4: Mean BUR by Position Within Phrase

- The first BUR value in a phrase is significantly higher than all subsequent BUR values.
- This was calculated by averaging BURs at each position across all phrases.
- This reinforces the view that BUR is used not just for feel, but to structure phrases expressively.

Table 3: 32-Bar Song Form: End vs Beginning Swing (Non-Blues Only)

Location	BUR	Comment
Bar 32 Beat 4 (form ending)	1.230	Played straighter
Phrase average	1.34	Baseline comparison
Bar 33 Beat 1 (form beginning)	1.37	Return to normal swing
$p = 0.009$, Cohen's $d = -0.25$ (medium effect)		

- At the end of 32-bar song forms (AABA, etc.), swing becomes straighter (reduced BUR).
- At the start of the next form cycle, swing returns to typical levels.
- The effect is statistically significant ($p = 0.009$) with a medium effect size ($d = -0.25$).
- Analysis excludes blues tunes, which follow 12-bar rather than 32-bar structure.

Table 4: 12-Bar Blues: Turnaround vs Chorus Swing

Location	BUR	Comment
Bar 12 Beat 4 (form ending)	1.38	Reduced swing
Blues average	1.47	Baseline comparison
Bar 13 Beat 1 (form beginning)	1.46	Normal swing level
$p = 0.019$, Cohen's $d = -0.16$ (small effect)		

- In 12-bar blues, turnarounds show reduced swing relative to the tune's average.
- At the start of each new form, swing returns to typical levels.
- Both 32-bar and 12-bar forms show systematic timing modifications at structural boundaries.

Conclusion: Hierarchical Swing Structure is Deliberate

- Swing rate (BUR) changes are **measurable and systematic at multiple structural levels**.
- **Phrase level:** U-shaped BUR contours confirm expressive structuring of phrases.
- **Phrase level:** Flat contours are avoided, reinforcing structural intent.
- **Phrase level:** First BUR is elevated, suggesting strong expressive entry into each phrase.
- **Form level:** BUR systematically decreases at form endings and increase at form beginnings (32-bar and 12-bar blues forms).
- Swing microrhythm acts as a **hierarchical form-bearing gesture**, operating from phrase boundaries up to complete musical forms.

References

- Benadon, Fernando. 2006. "Slicing the Beat: Jazz Eighth-Notes as Expressive Microrhythm." Ethnomusicology 50 (1): 73–98. JSTOR.
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