Swing Once More: Relating Timing and Tempo in Expert Jazz Drumming

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swing refers to a characteristic long-short subdivision of the beat that is generally considered a crucial aspect that contributes to the quality of a jazz or pop performance. The current study measures this pattern (referred to as the 'swing ratio') at different tempi in jazz drumming. The experimental setup differs from earlier studies in a number of ways. First, swing ratios were systematically measured at different beat durations in a musically realistic range. Second, repeated performances were collected to check for consistency. Third, drummers were asked to perform on a full MIDI drum kit. The results show that professional jazz drummers have enormous control over their timing. Nevertheless, the swing ratio is not kept constant, but it is systematically adapted to a global tempo. As such, this study provides further support for the hypothesis that expressive timing generally does not scale with tempo.

“Swing,” “groove,” “drive,” and “shuffle” are just a few of the many terms that are used by musicians to describe the timing patterns that are common to jazz and pop music. Groove and swing are generally considered crucial aspects that contribute to the quality of a jazz performance, as well as listeners' appreciation of it (Iyer, 2002; Madison, 2001). Swing, the topic of this study, refers to the structural property that the beat (usually the quarter note pulse) is subdivided into unequal units, a characteristic long-short pattern that effectively changes the ratio between pairs of notes from 1:1 to 2:1 or even higher ratios (see Figure 1a) to give a sense of groove or swing. Swing rhythm has a rich cultural background (Gridley, 1985) and forms the basis of many grooves in modern music,

ranging from rumba and jazz to funk and hip hop (Butler, 2006; Butterfield, 2006). Swing also denotes a jazz style, originating in the 1930s, in which this subdivision is a prominent feature (Schuller, 1989).

Jazz swing has been a topic of several empirical studies (for a review see Friberg & Sundström, 2002). We will review those that focus on jazz drumming, swing, and the role of tempo, the topic of this research report.

Collier and Collier (1996) presented analyses of drummers' swing ratio as a function of tempo. They asked three drummers to perform a swing pattern (see cymbal pattern in Figure 1b) on a single MIDI drum pad with a cymbal sound in two conditions: one with a natural swing feel, the other in strict triple time. The swing ratios were measured at a wide range of different tempi, from extremely slow (a beat duration of 2400 ms) to relatively fast (a beat duration of 214 ms). In the swing condition one drummer performed with a clear increase in swing ratio with decreasing tempo (see AKC, the raising line in Figure 2a in color plate section). The other drummers showed quite a different pattern, both of them with a slight peak in the swing ratio in the intermediate tempo range (EWP and RAP in Figure 2a in color plate section). However, since only mean swing ratios were reported, it is unclear how much control these drummers had over their performances. Furthermore, there was no control for tempo drift, which might have influenced the measurements.

Friberg and Sundström (2002) analyzed audio recordings of four internationally known jazz drummers, measuring the ride cymbal pattern in the audio signal. They found quite some variability in the performances. Participant AN had the smallest variation within each excerpt, and TW showed the largest variation, especially at slow tempi (see Figure 2b in color plate section).[1] The tempo range of the recordings used was between approximately 110-330 bpm. The authors concluded that swing ratio decreased with increasing tempo, suggesting the relation between swing ratio and

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[1]It is unclear whether tempo drift played a role in this study.

FIGURE 1. Swing and music notation. (A) Though commonly written as eighth notes (1:1), swing eighth notes are typically performed somewhere between triple (2:1) or dotted (3:1) eighths. (B) The swing excerpt as used in this study. The ride cymbal pattern was used for measuring the swing ratio.

tempo to be linear. Furthermore, they found the absolute duration of the short note in the long-short pattern of the swing rhythm to be constant at about 100 ms for the medium to short beat durations (see Figure 3a in color plate section), suggesting a threshold on note duration that was argued to be due to perceptual factors. However, the systematic probing of the effect of tempo was constrained by the relatively small set of available recordings.

In summary, both studies showed a tempo-dependent swing ratio. Swing performance is not invariant under tempo transposition, that is, it cannot be transposed in tempo by multiplying all durations with a constant factor (if swing would be tempo-independent, it would match a straight horizontal line in Figure 2). This is in line with the more general hypothesis that expressive timing in music performance does not scale proportionally with tempo. This hypothesis—referred to as the *tempo-specific timing hypothesis*—was tested in a series of perceptual studies (Honing, 2006; Honing & Ladinig, 2006, 2008) using commercial recordings from the classical, jazz, and rock repertoire. These web-based listening experiments showed that listeners are able, on the basis of expressive timing judgments, to decide whether an audio recording is real or tempo-transformed (i.e., originally performed at another tempo, but made similar in overall tempo to the real recording). In summary, both in perception and performance, timing appears to be tempo-dependent.

In the current study we try to replicate the findings in music performance, using an experimental setup in which three professional jazz drummers perform a swing fragment on a full MIDI drum kit. This experiment differs from the earlier studies in a number of

ways. First, we systematically probed the swing ratio at different beat durations in a musically realistic range (between approximately 100-240 bpm). This was done to complement the earlier studies that presented fewer measurements at larger beat durations (slower tempi). Second, we collected repeated performances to check for consistency, given the within excerpt variability for different drummers reported in Friberg and Sundström (2002) (N.B. Collier & Collier, 1996 does not report on a measure of variability). Third, we asked drummers to perform on a full MIDI drum kit, which was conceived as a trade-off between a real concert situation (like some of the recordings used in Friberg and Sundström) and a single drum pad lab setup (like Collier & Collier), balancing experimental control with the ecological validity of the measurements obtained.

We will focus here on three questions: How much control do drummers actually have over their swing ratio? Does swing ratio indeed scale linearly with tempo (as suggested by Friberg and Sundström, 2002, but not by Collier & Collier, 1996)? And is there indeed a threshold in note duration around 100 ms (as suggested by Friberg and Sundström)?

Method

Participants

Three professional drummers participated in the experiment. JK, JL, and MS are well-known Dutch jazz musicians, each professionally active between fifteen (JK) and thirty (MS) years and formally trained between ten (MS)

and sixteen (JL) years at established conservatories, in styles ranging from bebop and cool to more recent genres.

Materials

The musical material consisted of a typical jazz swing excerpt (see Figure 1b). The ride cymbal pattern was used for extracting the swing ratios. An audio example of the excerpt was presented once at the beginning of the experiment (with metronomic 2:1 eighth note ratios at tempo 174 bpm), as part of a briefing on what to expect, and with a 5-10 minute interval before the first recording was made. The musical score (see Figure 1b) was available throughout the recording session.

Equipment

The participants performed on a Yamaha DTXpress III MIDI drum kit. The MIDI output was recorded using Steinberg Nuendo (Version 3.2) with a typical MIDI delay of 3-10 ms (Loy, 1985). The drum sounds of the drum kit (sample set 'funky sound'), along with a metronome, were presented over headphones (Behringer HPS3000). All three participants were used to studio recording and familiar with performing in such a semi-artificial setup.

Procedure

The participants performed the swing excerpt (see Figure 1b) at nine different beat durations: 250, 300, 340, 380, 420, 460, 500, 540, and 580 ms. They were instructed to play naturally, yet only the notated notes. A trial started with a metronome indicating the desired tempo (a randomized selection of the nine beat durations), after which 16 repetitions were performed. A metronome was presented along with each repetition to control for tempo drift. Each participant performed two trials, resulting in 64 measures ($16 \times 2 \times 2$) per tempo per drummer.

Analysis

The data were preprocessed and restructured using custom made software in Common Lisp (Steele, 1990), removing, e.g., spurious notes and occasional double onsets. The statistical analyses were done using SPSS (Version 15.0). Inter-onset intervals (IOIs) were calculated by taking the difference of two subsequent eighth note onsets in the cymbal pattern (see Figure 1b).

These were related to the score duration, effectively transforming the data to a l/tempo measurement, and then log-transformed. These measurements are referred to as a *log-transformed normalized IOI profile* (Desain & Honing, 1994).[2]

Results

The overall results are shown in Figures 2c and 3b (see color plate section). We will discuss these below in more detail.

Consistency

With regard to the question of control we looked at two measures. First, standard deviations of swing ratios showed that all three drummers had a similarly low variability in producing the swing ratios (see error bars in Figure 2c in color plate section), especially when compared to those reported in the Friberg and Sund- ström (2002) study (see Figure 2b in color plate section). Second, we looked at correlations within tempi as a measure of consistency between the two trials. Aver- age correlations within tempi of the log-transformed normalized IOI profile[3] revealed that each drummer performed relatively consistently (JK: $r(162) = .49$, $p < .0001$; JL: $r(162) = .60$, $p < .0001$; MS: $r(162) = .66$, $p < .0001$).[4]

While the drummers showed a highly consistent swing ratio and performed with little variability, there were considerable differences between their individual drumming styles. This difference was confirmed by an

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[2]A simple duration scale (consisting of raw IOIs) cannot be used to calculate correlations between timing profiles because different note durations in the score would swamp any timing effects and sim- ply result in high correlations. A beat duration scale, the inverse of a tempo scale, does not suffer from that difficulty. In addition, these 1/tempo measurements are log-transformed arguing that consistency in performances measured by correlation of log duration (or log tempo) would theoretically coincide better with perceived similarity of timing patterns. Repp (1994) acknowledged this issue and consequently adapted the use of log-transformed IOIs. In fact, log-transformed IOIs make it more difficult to show nonproportional scaling.

[3]See Footnote 2 and Desain and Honing (1994, p. 288) for a dis- cussion on this particular transformation. IOIs are normalized with respect to a triplet interpretation of the score (see Figure 1b), i.e., using the ratio 2:1 as the norm, instead of 1:1 (as notated).

[4]Normalization has a large effect on these correlations. When the reference is taken to be a notation in eighth notes (i.e., 1:1 instead 2:1) the correlations of log-transformed IOIs become .99, .98, and .99 respectively. These correlations should hence be interpreted in relative terms, not their absolute value.

TABLE 1. Average Correlations Between Tempi.

Drummer	Beat Duration	Beat Duration								
		580	540	500	460	420	380	340	300	250
JK	580	1								
	540	.24	1							
	500	.46	.33	1						
	462	.04	.44	.22	1					
	420	.11	.39	.25	.58	1				
	380	.27	.35	.36	.33	.32	1			
	340	.50	.18	.41	.14	.15	.38	1		
	300	.52	.23	.41	.17	.29	.41	.44	1	
	250	.43	−.29	.13	−.43	−.33	−.03	.26	.28	1
Average									.25	
JL	580	1								
	540	.35	1							
	500	.25	.51	1						
	462	.39	.47	.72	1					
	420	.35	.57	.76	.73	1				
	380	.35	.54	.78	.74	.79	1			
	340	.21	.38	.47	.44	.50	.50	1		
	300	−.40	−.46	−.44	−.57	−.53	−.48	−.30	1	
	250	−.43	−.58	−.72	−.77	−.81	−.75	−.55	.63	1
Average									.10	
MS	580	1								
	540	.75	1							
	500	.75	.71	1						
	462	.71	.71	.76	1					
	420	.67	.77	.72	.74	1				
	380	.78	.80	.70	.72	.72	1			
	340	.38	.51	.50	.53	.51	.49	1		
	300	−.23	−.28	−.18	−.19	−.32	−.23	.08	1	
	250	−.51	−.61	−.54	−.62	−.74	−.49	−.41	.32	1
Average									.25	
Grand Average									.20	

ANOVA with drummer and tempo as factors (3 and 9 levels, respectively), and with swing ratio as the dependent variable. As was already suggested by Figure 2c, the influence of tempo was highly significant, $F(8,3419) = 1113.82$, $p < .0001$, $\eta_p^2 = .72$, as was the effect of drummer, $F(2,3419) = 376.94$, $p < .0001$, $\eta_p^2 = .18$, and the interaction of tempo and drummer, $F(16,3419) = 177.65$, $p < .0001$, $\eta_p^2 = .45$.[5] In short, each drummer had a significantly different swing ratio for each tempo.

Swing Ratio as a Function of Tempo

Next we looked at how the swing ratio was adapted to the overall tempo. As a measure of the relation between expressive timing and tempo, for each drummer correlations of log-transformed normalized IOI profiles were calculated between tempi. Table 1 shows the average correlations between tempi. Overall these correlations were very low, $r(321) = .20$, $p < .0001$, indicating

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[5]These results are different from those reported in Friberg and Sundström (2002, p. 338).

that swing timing did not scale proportionally with tempo. However, no evidence was found for a linear interpretation.[6] Apparently, swing ratio does not simply scale linearly with tempo.

Absolute Duration as a Function of Tempo

Finally, we looked at the absolute duration of the second note as a function of tempo. Friberg and Sundström (2002) suggested that there was a lower limit to the duration of the second note (see dotted line in Figure 3 in color plate section). In this study however, we found the second note duration to be linear in beat duration, $r(3446) = .94$, $p < .0001$, without support for a lower limit around 100 ms. (There is one peculiar difference: JL's performance at a beat duration of 250 ms.)

Discussion

The results show that professional jazz drummers have enormous control over their timing. They are able to time their performance with a precision of milliseconds over a considerable amount of repetitions (see Figure 3b in color plate section). Similar levels of control have been reported in the expressive timing literature (Clarke, 1999; Palmer, 1999) mainly focusing on classical piano music. Interestingly, even when drummers are in complete control (i.e., not dependent on interaction with other musicians, such as the data presented in Friberg & Sundström, 2002), the swing ratio is not kept constant, but is systematically adapted to the overall tempo. While the results presented in Friberg and Sundström are based on a small and relatively arbitrary set of recordings, the approach of analyzing real recordings is an attractive alternative to the method used in the current study. However, the challenge is to find recordings of the same pieces in a variety of tempi, which is not always easy (cf. Honing & Ladinig, 2008).

Furthermore, we found no evidence for the swing ratio to scale linearly with tempo, as was suggested in Friberg and Sundström (2002). While there is some evidence for linearity between beat durations of 250 ms and 350 ms (see Figure 2c in color plate section), at longer beat durations the swing ratio seems to stabilize around a swing ratio close to 2.2:1. Clearly, a more complex model is needed to capture the scaling of swing ratio with tempo in jazz drumming. In Haas and Honing (2007) some alternatives are explored. However, the purpose of the current study was not to model swing, but to see whether we could find evidence for tempo-specific timing in jazz drumming. In accordance with some earlier studies (e.g., Desain & Honing, 1994; Friberg & Sundström, 2002), and contrasting other studies suggesting proportional scaling (e.g., MacKenzie & Van Eerd, 1990; Repp, 1994), this study provides further support for the *tempo-specific timing hypothesis* (Honing, 2006)—jazz experts adapt their timing to the tempo of their performance to obtain (or sustain) the effect of swing.

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[6]Due to space restrictions we refer the reader to Haas and Honing (2007) and Haas (2007) for alternative interpretations and a preliminary model.

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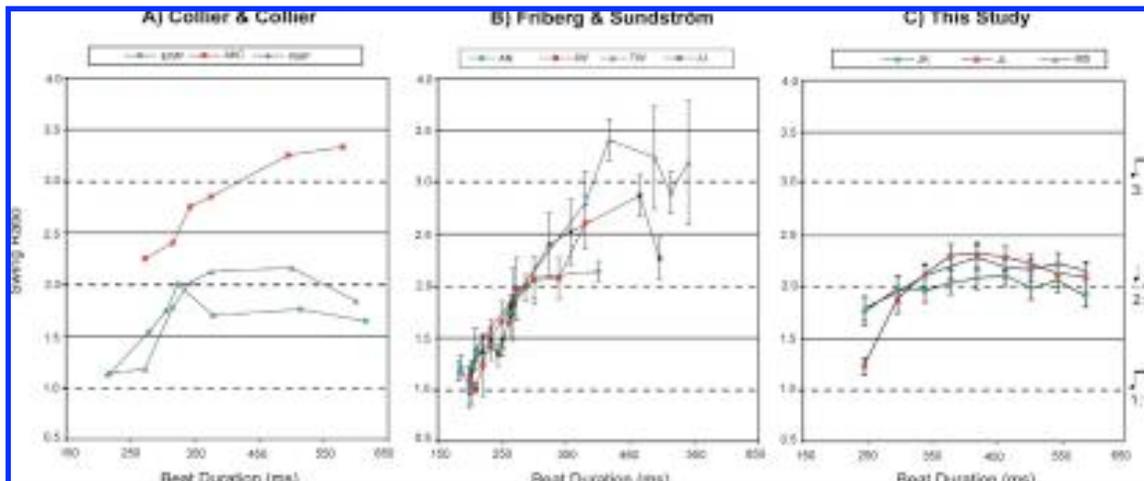
HENKJAN HONING & W. BAS DE HAAS, FIGURE 2.
Swing ratio as a function of beat duration, as measured by (A) Collier and Collier (1996) (N.B. Showing only the measurements in the range faster than 650 ms), (B) Friberg and Sundström (2002), and (C) the current study. Error bars show the standard deviation. (N.B. Collier & Collier reported only means).
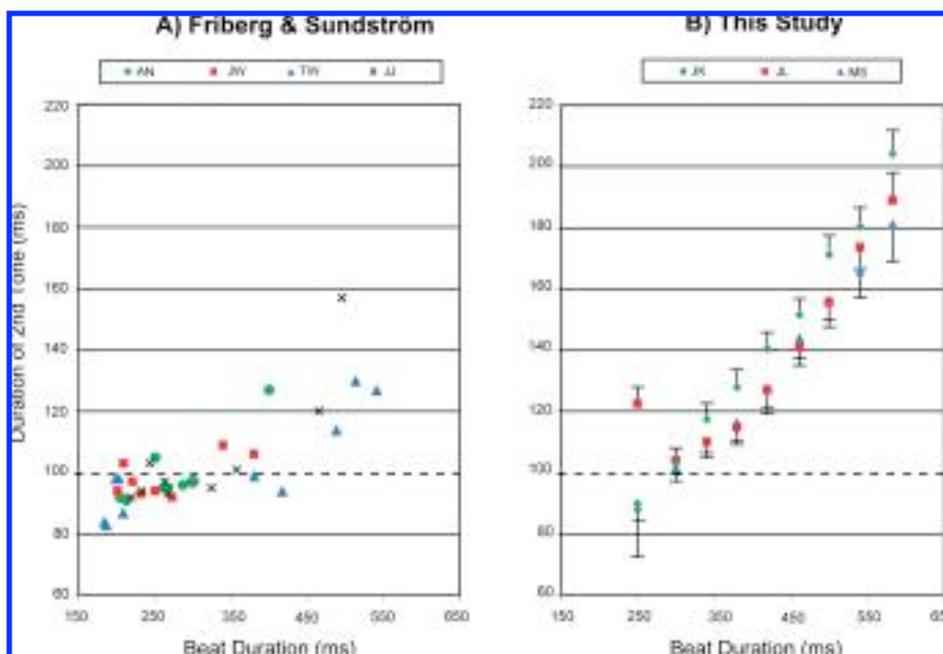
HENKJAN HONING & W. BAS DE HAAS, FIGURE 3.
Absolute duration of the second note of the swing rhythm as a function of beat duration, as measured by (A) Friberg and Sundström (2002) and in (B) the current study. The dotted line marks the 100 ms threshold as suggested by Friberg and Sundström. Error bars show the standard deviation (N.B. Friberg & Sundström reported only means).