STRUMMING ON AN ACOUSTIC NYLON GUITAR: MICROTIMING, BEAT CONTROL AND RHYTHMIC EXPRESSION IN THREE DIFFERENT ACCOMPANIMENT PATTERNS

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ABSTRACT

The paper presents an exploratory study about the guitar strumming technique, based on three different accompaniment patterns. The experiments were held with an acoustic nylon guitar equipped with hexaphonic pickups, and focused on different features of this technique. It was possible to note a diversity of strategies for beat control and rhythmic expression employed by different musicians, which may be described by technical, perceptive and expressive factors. The results also display preliminary quantitative boundaries for the distinction between block, strummed and arpeggio chords.

1. INTRODUCTION

Playing a guitar depends not only on the instrument's physical features–which varies considerably in the electric, acoustic and nylon versions–but also on right and left-hand techniques developed by different musical styles and genres, in diverse periods and places. Some techniques are well spread among a large number of guitarists, like scales, arpeggios, block chords and slurring, while others are confined to very specific practices and traditions.

The analysis of guitar techniques is an important subject in both theoretical and practical fields. However it can be easily detected that there is a lack of academic literature bearing a quantitative approach on the theme. Besides our own approach [1, 2], we were able to find only one study dedicated to the detection of a strumming action, with participants divided between beginners and experienced guitarists [3]. The current availability of hexaphonic pickups may help to fill this gap, but their most common application is related, up to now, to the augmentation of electric and acoustic guitars for creative purposes [4].

For the present work, we started from the following questions: How is a musician able to express a musical beat, using a chord consisting of multiple attacks? How different are the down and upward movements of the right hand, when it plays a sequence of strummed chords? How are we able to perceive the same basic rhythmic structure from renditions bearing considerable microtiming deviations?

The first section of the paper presents some characteristics of the strummed chord, based on the instrument technique and, also, on psychoacoustic findings. The next section depicts the experiments that were carried out. After that, the results are presented and discussed, from the instrumental, musical and expressive points of view.

2. THE STRUMMED CHORD

Strumming is a quite old guitar technique, presenting a varied nomenclature in different times and cultures. European musicians since, at least, the 16th century have employed it regularly, when it was called *battuto* or *golpeado* [5, 6]. Flamenco music, with roots in Arab and Gypsy musics [7], is almost unimaginable without the rasgueado. From the beginning of the 20th century, popular music began to be widely spread by the new developed means of musical diffusion, and strumming became a ubiquitous sonority, connecting old folk traditions to new song formats. In all instances, the technique is closely related to a vivid rhythmic activity and expression.

In the current stage of our research, it was necessary, for practical reasons, to approach the strumming technique in a narrower perspective, leaving the *rasgueado* out of the scope of the term. In flamenco music, a strummed chord may last for a long time, and may be constructed by a practically uncountable number of strong and weak attacks performed by the five fingers of the right hand. Our object of study is much simpler, consisting of a fast succession of–at most–6 attacks performed on different strings, sequentially, provoked by a single gesture [1]. The three experiments presented in this paper were recorded using a guitar pick, to avoid additional attacks performed by any loose finger.

With these precautions, it is then possible to characterize a strummed chord as a sound entity produced on a guitar, situated somewhere between a block chord and an arpeggio [2]. It is not easy to define clear limits for these categories, since they depend not only upon absolute time spans, but also on register, dynamics, number of notes, resonances, contexts, etc. The results obtained in the current

[1] From the guitar technical point of view, an arpeggio (played with a pick) is still provoked by a single gesture, but the steps between the strings are more controllable by the instrumentalist. For still larger time spans, the individual notes are no more integrated into a single sound object.

[2] In the guitar literature, it is not unusual to find the term arpeggio applied to passages consisting of broken chords in different strings. In the present study, arpeggio refers only to a "stretched" strummed chord.

study, combined with results from a former study, permitted us to propose preliminary empirical limits (microtiming ranges) for these three chord categories, as depicted in section 5.

In psychoacoustics, temporal resolution is “the ability to detect changes in stimuli over time, for example, to detect a brief gap between two stimuli” [8]. Results from diverse experiments indicate a range between 1 and 18 ms for this ability, which presents a good correlation with the values we have found. Another important psychoacoustic feature, with origins in the auditory scene analysis [9], is the coherence of the guitar chords (block, strummed or arpeggiated): we perceive them as a unity, instead of perceiving each note as a segregated stream.

A strummed chord may be reasonable described by the number of notes (or strings) in use, the direction (up or downward), and the intertone and global spread intervals. A last qualification may be given by the global duration, varying between the short/dry and the long/resonant poles. The main difference between block and strummed chords lays on the attack phase. Applying Schaeffer’s typological concepts [10], it is possible to say that with block chords the attack occurs at once, while in strummed chords it happens iteratively, as well as in arpeggios. From a guitarist’s point of view, the performance of rhythmic patterns with such chords (presenting an enlarged attack phase), using not rarely down and upward movements, may pose technical and musical challenges. The present study aimed to understand some strategies used by different musicians for playing strummed chords, and how they might be related to our perception [3] .

We display the strummed chords in two ways, depending on which features are to be underlined. In the first option, the attacks of each string (vertical axis) are plotted against the total duration (horizontal axis), as in Figure 6. The second display depicts the normalized IOIs–intertone onset intervals–of each string in the vertical axis, and it is applied to excerpts that exhibit considerable regularity in the rhythmic values, as well as in the set of strings in use. In the following experiments, the reference rhythmic figure used for the IOI normalization was the 16th note. This display uses a smoothed line (without interpolation) to connect the individual values, as in Figures 4, 5 and 7.

In this study, the use of the term beat has a somewhat biased musical meaning. Here, beat is to be understood as the momentary contribution of a strummed chord to a rhythmic structure, perceived as a single musicalo object. It is also important to say that the beat control analysis will be restricted to the technical/artistic choices made by a guitarist during a performance.

3. DESCRIPTION OF THE EXPERIMENTS

3.1 Setup

The hardware consisted of a Yamaha nylon acoustic guitar (model CG182S), equipped with RMC hexaphonic pickups. The pickup signals were impedance-matched through

[3] The excerpts used in the present study can be found at http://www.musica.ufmg.br/sfreire/wordpress/?page_id=12.

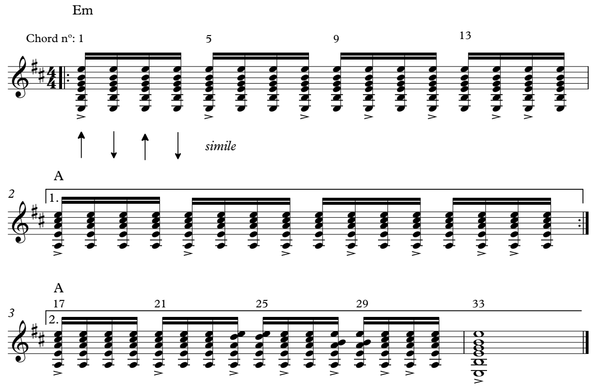

Figure 1. Excerpt 1: an arrangement for the accompaniment of a section from *Breathe*.

Behringer Di20 direct boxes, and then digitally converted by a Focusrite Saffire Pro 40 interface. An iMac 2.9 GHz Intel Core i5, and a set of pedals (for realtime commands) completed the setup. All audio processing algorithms were programmed in Max/MSP (version 6). The setup is dedicated to realtime extraction of a series of low-level descriptors, such as moment of attack, duration, amplitude, fundamental frequency, spectral centroid, slurring, etc. It was recently named *GuiaRT* [4], and it is used for both performance analysis and the interactive re-creation of textures.

The amplitude estimation is done as follows: after an attack is detected on a selected string, we search for the peak value of its RMS signal (calculated over 1024 samples, with a hop size of 256, and 48 KHz as the sampling frequency) in the next 60 ms. In the case of a chord, we add the peak values detected for each string, before the conversion to a dBFS value. This procedure takes in account neither the precedence [8] or the masking [11] effects, nor the loudness curves [8]; hence, the calculus points to the energy spent by the guitarist during the performance of a chord. Nevertheless, we believe that there is a considerable correlation between the perceived loudness and the estimated value. The algorithms extract the attack information within a margin of error of 10 ms; as the present study deals with information in this order of magnitude, we had afterwards to make fine adjustments by hand, visually inspecting the waveforms [4] .

3.2 Participants and Excerpts

The excerpts chosen for the three experiments present study are the following: (a) Excerpt 1: an arrangement for the accompaniment of a section from *Breathe*, by Pink Floyd (see Figure 1); (b) Excerpt 2: a simple Guarania accompaniment pattern (Figure 3); (c) Excerpt 3: the introduction of *Wonderwall*, by Oasis (Figure 3).

The first experiment, using Excerpt 1, aimed to understand the basic down and upward movement of the guitar pick in a completely regular rhythm (excluding the accents), performed without metronome. We also expected to detect some influence of left hand movements in the

[4] This fact limits the processing of larger data sets. For analyses where the intertone intervals are not essential, it is possible to adjust only the first and last note of each chord.

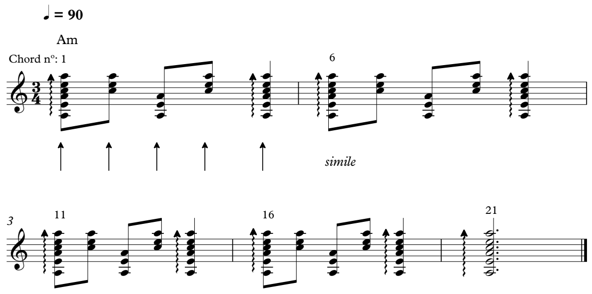

Figure 2. Excerpt 2: a simple Guarania accompaniment pattern.

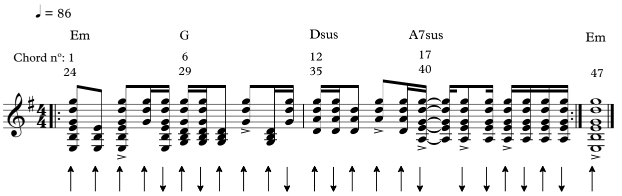

Figure 3. Excerpt 3: introduction of *Wonderwall*.

next to the last measure. (The guitarists played the whole excerpt, although our analyses focused only on the second ending.) The second experiment, which explored Excerpt 2, focused on beat control with different chord types: arpeggios, and strummed chords in the low and high registers, without left fingers movements. It was recorded with a metronome click. Finally, Excerpt 3 was used to compare different performances of a varied rhythmic (and harmonic) structure, also played with a metronome. Each excerpt was recorded once by three different musicians.

The participants are undergraduate students of our School of Music, attending either Popular Music or Composition courses. In total, five different musicians played the nine renditions. The renditions will be referred to as B1, B2 and B3 for the *Breathe* arrangement; G1, G2 and G3 for the Guarania patterns; and WW1, WW2 and WW3 for the introduction of *Wonderwall*. The same musician played the renditions B1, G1 and WW1. Another musician played the G2 and WW2 renditions, while a third musician played G3 and WW3. The two remaining guitarists played one rendition each: B2 and B3.

Number of Attacks						
	String					
Rendition	1	2	3	4	5	6
B1	27	31	32	31	25	13
B2	26	28	29	29	26	14
B3	30	33	33	33	31	31

Table 1. Number of attacks per string, in each rendition of Experiment 1.

Normalized IOIs mean values			
String	Rendition		
	B1	B2	B3
1	233 ± 29	231 ± 32	232 ± 37
2	233 ± 11	230 ± 15	232 ± 26
3	233 ± 14	230 ± 16	231 ± 12
4	233 ± 25	230 ± 32	231 ± 12
5	232 ± 37	229 ± 50	232 ± 26
6	229 ± 41	240 ± 60	231 ± 41
Mean BPM (quarter note)	64.4	65.2	64.9

Table 2. Normalized IOIs mean values (and standard deviation) for each string in each rendition of Experiment 1.

4. RESULTS AND INDIVIDUAL DISCUSSION

4.1 *Breathe* arrangement

The three renditions produced almost the same value for BPM (beats per minute), despite the absence of a metronome during the performance. For the estimation of the BPMs, we started from this assumption: the player must aim a string (or a region comprising 2 or 3 strings) for the beat reference [5]. Hence, this aim must be encountered among the most played strings, and present the lowest standard deviation values for the individual (normalized) IOIs. Table 1 presents the global number of attacks, and Table 2 the average and standard deviation IOI values, for each string in each rendition. The total number of chords is 33. From this data, we may infer that the beat control–or, at least, the regularity of up and down movements–of renditions B1 and B2 was based on strings 2 and 3, and that rendition B3 elected strings 3 and 4 for the same purpose.

Observing the graphs that plot the IOIs against the global time, it is possible to conclude that there is no unique strategy for beat setting (or for the regularity of up and down movements), even inside a single performance. We can notice moments when the minimal IOI variations are alternated between two neighboring strings (following the up and down movements), and others when the minimal variations are located on just one string. Between chords 11 and 22 of rendition B3 (see Figure 4), it is possible to observe these changes in the performance strategy. Initially, the minimal IOI variations are located on the fourth string; then, around the chord change (that takes place between chords 16 and 17), the minimal variations alternate between strings 3 and 4; afterwards, it is the third string that presents a (quasi) straight line pattern. Another situation is depicted in Figure 5. IOIs values for strings 2 and 3, from chords 23–30 in rendition B1, show a similar change of rhythmic control. In the 24th chord, a melody is initiated at the second string. After that, the second string's IOI curve resembles a horizontal line. In the same figure, it is possible to see a single attack on the second string, just after 14000 ms. This is a 32th note anticipation made by a left finger just before the next strum, and its IOI value was

[5] We presume that a standard performance of this excerpt should have equally spaced quarter-note beats within each measure, and that these beats should be coincident with the attack phase of the respective chords.

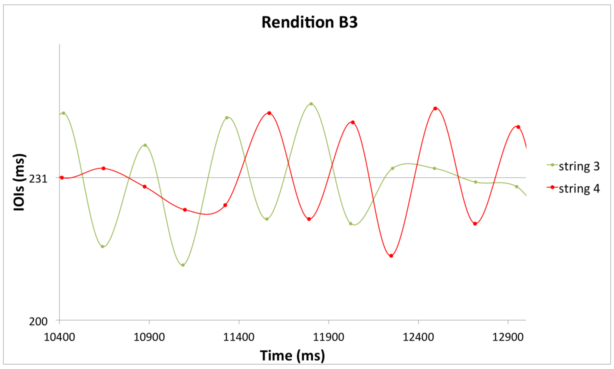

Figure 4. Normalized IOIs x global time graph for chords 11–22, strings 3 and 4, in rendition B3.

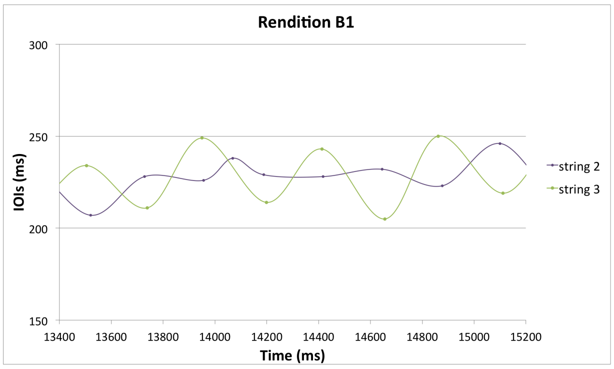

Figure 5. Normalized IOIs x global time graph for chords 23–30, strings 2 and 3, in rendition B1.

multiplied by 2, as well as the IOI of the precedent event on the second string, also a 32th note.

4.2 Guarania accompaniment pattern

With this quite simple excerpt, we wanted to infer how a performer integrates a long arpeggio into a rhythmic structure, using a metronomic reference. We expected the chords to be divided into two categories, with regard to the spread interval: either 6-note arpeggios or 3-note strummed chords. But, in fact, the arpeggios were further divided into two subsets, which are related to their position in the pattern. The downbeat chords (nos. 1, 6, 11, 16 and 21) presented a spread interval considerably larger than the arpeggios in the third beat (nos. 5, 10, 15 and 20). Table 3 depicts the mean intertone spread interval for the three chord types, for each rendition. Note that rendition G2 has, on the whole, larger values than the remaining renditions, and its strummed chords tend to short arpeggios.

The immediate explanation for the subdivision of the arpeggio chords lies on their position in the rhythmic structure: the downbeat arpeggios have more time for preparation, since they are preceded by quarter note durations, while the third beat arpeggios come after eighth note chords. However, from the point of view of its total duration, the situation becomes the opposite: the downbeat arpeggios last only one eighth note, while the third beat arpeggios last one quarter note. Hence, a more satisfactory explanation must include another musical feature: all chords in the excerpt

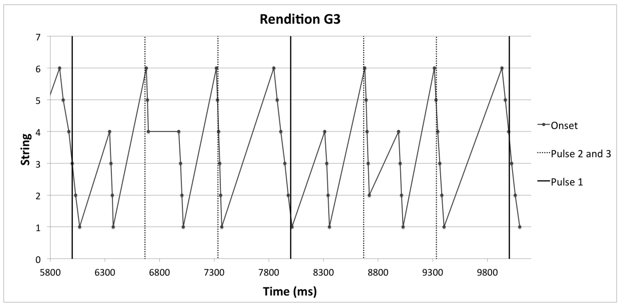

Figure 6. Measures 3 and 4 from rendition G3 of Excerpt 2, with lines indicating the metronome clicks.

Mean values for internote spread intervals inside a chord (ms)			
Rendition	Downbeat Arpeggios	Third beat Arpeggios	Strummed Chords
G1	32	17	13
G2	40	31	23
G3	33	16	11

Table 3. Mean values for intertone spread intervals inside a chord in each rendition of Experiment 2.

are to be played downwards–from low to high strings–, and the three musicians reportedly expressed the rhythmic pattern aiming at the first string in each arpeggio. A more elongated arpeggio in the third beat would break this expectation, possibly changing the perception of the accent to the low register.

The arpeggios of each rendition presented an individualized relation to the metronome. In rendition G1, the last notes of the arpeggios (on first string) tended to coincide with the click. On the contrary, in rendition G2 (with the highest spread intervals) these coincidences occured in the middle strings. In G3, the coincidences are more varied, as can be seen in Figure 6.

4.3 Introduction of *Wonderwall*

This excerpt is the most complex in the current study, and widens the options for varied performances. It requires considerably faster right hand movements, and also fast chord changes made by the left fingers. Table 4 depicts the differences found in the number of notes played in each chord, compared to a reference score (Figure 3). The three renditions present very dissimilar mean values for the global spread intervals, as depicted in Table 5. It is possible to associate the higher spread values of rendition WW3 with the fact that, in general, its chords are being played after the metronome click. Rendition WW2 showed the highest agreement with the metronome, and intermediate spread values.

In this excerpt, the rhythmic structure presents sequences of 16th notes, in different positions with regard to the pulse. We have chosen one of these sequences (chords 19–24) for an analysis of its regularity (such as the one applied to Excerpt 1), but this time with the presence of a metronome. Figure 7 depicts the IOIs x global time graph for chords

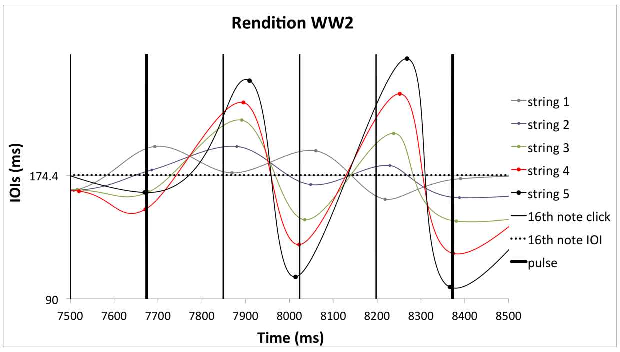

Figure 7. Normalized IOIs x total time graph for chords 19–24 from rendition WW2 of Excerpt 3, with lines indicating the metronome clicks. The dotted horizontal line represents the IOIs between metronomic 16th notes.

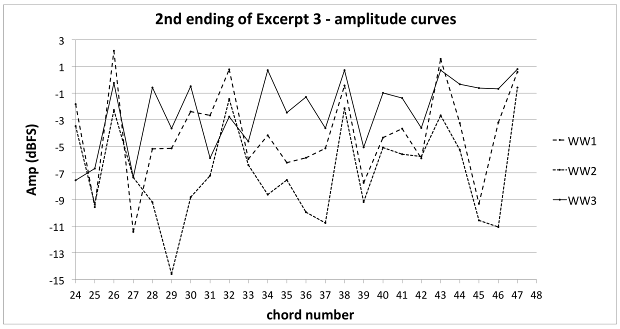

Figure 8. Amplitude curves of the second ending from the three renditions.

19–24 from rendition WW2. It can be seen that strings 2 and 3 are responsible for the beat control, alternating around a mean value. Yet, this beat control is performed with a slight accelerando during this sequence of five 16th-note chords, its start and end points coinciding with the metronome click.

The dynamics analysis also reveals interesting interpretative features. Figure 8 depicts the amplitude curves from the second ending in each rendition (chords 24–47). It is easy to see a coincidence in five (out of seven) prescribed accents, in chords 26, 32, 38, 43 and 47. Rendition WW3 presents more prominent accents in chords 40 and 41, but also in chords 28, 30, 34, 36, 44 and 46. A common characteristic of these chords is that they are to be played upwards (from high to low strings), and the results show that a very different strategy was used in WW3, compared to the other two. In fact, this musician used all six strings to play these chords, while the others used much fewer. This technical/esthetical choice made the rendition more compressed, with less salient accents and a darker timbre. On the other hand, rendition WW2 clearly explores three dynamic levels: accentuated, mid-level and background chords. A decrescendo before an accented chord is also typical for this rendition, while in rendition WW1 it is more likely to find a crescendo leading to an accented chord.

% of Chord Types				
		Rendition		
Type	Score	WW1	WW2	WW3
6-note	23	31	21	51
5-note	30	14	40	26
4-note	13	29	26	17
3-note	34	22	13	4
2-note	–	4	–	2
Total of chords (n)	47	49	47	47

Table 4. Percentage of chord types prescribed in the score, and percentage of chords actually played in each rendition of Excerpt 3.

Global Spread Intervals (ms)			
	Rendition		
Type	WW1	WW2	WW3
6-note	26	39	62
5-note	36	40	60
4-note	23	26	42
3-note	16	21	23

Table 5. Mean values for global spread intervals in each rendition of Excerpt 3.

5. GENERAL DISCUSSION: MICROTIMING, BEAT CONTROL AND RHYTHMIC EXPRESSION

5.1 Chords microtiming

Combining the current results with the empirical data provided by a former study [2], it is possible to propose some quantitative boundaries for the different types of guitar chords: block chords, strummed chords, arpeggios. Table 6 depicts the mean values for global spread intervals –time spans between the first and last attack on a chord– and the intertone spread intervals–time spans between two adjacent tones in a chord–yielded by these studies.

It is difficult to perceive such tiny time differences among chords, specially within block and strummed chords. Nevertheless, it is clear for the performers that "something"

Chords (notes/type)	Tempo	Intertone spread int. (ms)	Global spread int. (ms)
4-note / block	very fast [2]	0–6	5–18
3-note / block	very slow [2]	0–5.5	5–11
6-note / strummed	adagio (Excerpt 1)	8–11	37–46
6-note / strummed	moderate (Excerpt 3)	5–12.5	26–62
6-note / arpeggio	moderate (Excerpt 2)	16–40	64–202

Table 6. Mean values for intertone and global spread intervals, in different chord types.

changes, this term substituting timbre or sound color. We can explain these changes by dissimilar energy distribution among the strings, by mutual comb-filtering and sympathetic resonances, and also the already mentioned precedence and masking effects.

5.2 Categorical performance / perception of rhythm

Two complementary facets of the human perception/action loop, linked to the musical experience, are given by Honing [12] and Lehmann et al. [13]. Honing states that "some rhythms allow for a considerable timing variation, without the risk of being perceived as another rhythm". According to him, one of the components of the rhythmic experience is the perception of a "rhythmic category, referred to as a *rhythmic pattern*". This categorization occurs at a "discrete, symbolic scale", and is built from a continuous scale related to performance and expressivity. On the other side, Lehmann et al. expresses that "even the most highly trained performers are incapable of playing a sequence of notes that have exactly the same sound characteristics (timing, loudness, timbre) from note to note." It is also important to take in account a second rhythmic component introduced by Honing: a *metrical structure*. As he says, "a rhythm is often interpreted in a metric framework, be it a regular pulse (or beat) or a hierarchically organized interpretation of two or more levels of beats."

When someone plays (and/or listens to) a rhythmic structure played with strummed and arpeggiated chords, he or she is probably taking advantage of all these cognitive features. The iterative attack that characterizes these chord types may not only lighten the performance of a–categorical–rhythmic pattern, but also contribute to a wider expressive palette. In metaphorical terms, we could say: the task is no more the insertion of points in a timeline, but the drawing of small segments with varied sizes, slopes and thicknesses, and nuanced colors.

5.3 Rhythmic expression

In this pilot study, we could show the influences of microtiming on the timbre of a chord, and also its relation with the left fingers movements. We have also described how rhythmic patterns and metrical structures may influence the spread intervals in a chord. Additionally, we pointed out dissimilar technical resources and diverse interpretative intentions in the analysis of amplitude curves in a larger sequence. The experiments showed that the use of strummed chords influenced different components of the musical rhythm, from the single beat to the shaping of a metrical structure.

6. FINAL REMARKS

The study presented in this paper covered important topics concerning the guitar strumming technique: a quantitative account of the microtiming present in the different guitar chord types, the description of different strategies for beat control, and an initial appreciation of the expressive rhythmic potential mediated by such a technique. Future work will focus on expert strumming performances with metronomic reference.

These efforts may contribute to a deeper understanding of technical and musical issues raised by the guitar strumming, as well as to studies dedicated to similar rhythmic accompaniments on the harp, percussion, and other string instruments.

Acknowledgments

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