

Sound Continuity Comparison Study of Nine Tremolo Methods in Francisco Tarrega's Recuerdos De La Alhambra

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บทคัดย่อ

การศึกษาเชิงสถิติของการเล่นเสียงรัว วัตถุประสงค์เพื่อเปรียบเทียบความต่อเนื่องของเสียงรัวจากวิธีเล่นต่างๆ ทำการถ่ายวิดีโอเพื่อเปิดเล่นด้วยความเร็วต่ำ บันทึกเวลาตีคอร์ดของทุกนิ้ว วิเคราะห์ได้ค่าต่างๆ เช่น ระยะเวลาระหว่างนิ้ว ความเร็วรอบ รูปแบบความต่อเนื่อง (DC) เป็นต้น นำข้อมูลที่ได้ประกอบคำสัมภาษณ์เกี่ยวกับวิธีฝึก หลักการเล่นเสียงรัว ลำดับนิ้ว ข้อระวังขณะเล่น และข้อแตกต่างของเสียงรัวกับ ฟริสโตรค มาเปรียบเทียบกัน ได้ศึกษาเพิ่มเติมจากวิดีโอของนักกีตาร์ชั้นนำด้วย เสียงรัวซ้อมได้หลายวิธี การซ้อมโดยใช้นิ้วถัดไปหยุดเสียงและเล่นให้เกือบพร้อมกันอาจช่วยลดช่องว่างระหว่างนิ้วนั้นได้ การฝึกซ้อมโดยเน้นนิ้วอาจช่วยให้เสียงรัวเรียบสม่ำเสมอขึ้น เสียงรัวคืออาร์เปโจบนสายเดี่ยว เลือกลำดับนิ้วที่ตัวเองถนัด โดยอาจใช้ *pima* หรือ *pimi* แทน *pami* เสียงรัวมีคล้ายฟริสโตรคที่ติดตั้งฉากกับสาย การศึกษาครั้งนี้พบว่านักกีตาร์อาชีพมีความเร็วรอบไม่น้อยกว่า 140 รอบต่อนาที และนักกีตาร์ทั่วไปไม่น้อยกว่า 122 รอบต่อนาที

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ABSTRACT

This is statistical approach to guitar performing study with objective to compare continuity of tremolo from different tremolo techniques. Record and played back video in slow speed. Time data was analyzed. Interval times were computed, turned in to Descriptive Continuity (DC) and compared. Interview was made on fingering order, tremolo principle, practicing procedure, playing cautions, and tremolo-free stroke comparison. Moreover, guitar virtuosos were also studied. There are many practice procedures such as staccato practice, 3-finger practice, variable speed practice or accent practice. While staccato practice may reduce gap on specific fingers, accent practice may result in smooth sound. Trying to play a couple of fingers at the same time may improve tremolo continuity. Thinking that tremolo is arpeggio on the same string is a good psychological principle. Guitarists can try *pima* and *pimi* instead of *pami*. Tremolo finger movement is similar to free stroke with hand angle perpendicular to strings. From this study, the minimum cycle speed of professional guitarist is 140 rpm, and, for general guitarist is 122 rpm.

Keywords: Guitar, Tremolo, Method

1 Stories

This study is statistical approach to guitar performing study. Time data of each striking finger will be recorded and analyzed. Interval time between one stroke to another will be computed. Results will be compared. Seven guitar virtuosos and nine guitarists will be studied. While nine guitarists done in detail such as practicing procedure and method of playing, seven virtuoso will use only data from their records to get tremolo standard data.

Seven guitar virtuosos will be studied. Narciso Yepes, John Williams, Andrés Segovia, Ana Vidovic, Sharon Isbin, David Russell and Julian Bream. Furthermore, nine guitarists, agreed not to mention names, seven Thais, one Japanese and one American, will be interviewed and recorded their right hand playing *Recuerdos de la Alhambra* composed by Francisco Tarrega (1852-1909). Nine guitarists are C.T., S.S., E.J., R.V., S.M., S.T., N.K., W.R., and P.C.

Tremolo sound continuity comparison by analyzing time data from different tremolo techniques is the objective of this study. Results can be applied in practicing procedure. This study

is to compare data. Percentage of average cycle time, cycle speed, length and DC (please see 2.6 for definition) will be analyzed and compared. Seven guitar virtuosos and nine guitarists playing *Recuerdos de la Alhambra* composed by Francisco Tarrega (1852-1909) will be used.

2 Definitions

Specific terms are used in this study. Some of them are created just for this study. Numbers in square parentis [] are used as identification of term definition.

2.1 Time [1] is actual playing time in second.

2.2 Cycle Time [2] is duration in second used to play one cycle of tremolo.

2.3 Cycle Speed [3] is number of tremolo cycle in one minute (rpm).

2.4 String Codes [12] are as following:

12 means playing *a m i* on the 1st string and playing *p* on the 2nd string

13 means playing *a m i* on the 1st string and playing *p* on the 3rd string

14 means playing *a m i* on the 1st string and playing *p* on the 4th string

15 means playing *a m i* on the 1st string and playing *p* on the 5th string

16 means playing *a m i* on the 1st string and playing *p* on the 6th string

23 means playing *a m i* on the 2nd string and playing *p* on the 3rd string

24 means playing *a m i* on the 2nd string and playing *p* on the 4th string

25 means playing *a m i* on the 2nd string and playing *p* on the 5th string

26 means playing *a m i* on the 2nd string and playing *p* on the 6th string

34 means playing *a m i* on the 3rd string and playing *p* on the 4th string

35 means playing *a m i* on the 3rd string and playing *p* on the 5th string

36 means playing *a m i* on the 3rd string and playing *p* on the 6th string

2.5 Speed Code [13] is 100 when cycle speed is 100 rpm or less, 120 when cycle speed is 100–120 rpm, 140 when cycle speed is 120–140 rpm, 160 when cycle speed is 140–160 rpm, 180 when cycle speed is 160–180 rpm, 200 when cycle speed is 180–200 rpm, 220 when cycle speed is 200–220 rpm.

2.6 Descriptive Continuity (DC) [25] are letters used to justify length of tremolo. In one tremolo cycle, there are four quarters, 25% + 25% + 25% + 25% = 100%. If some quarter is too much there are gaps. When gap is over 28%, ears can detect. In this study we use letter *pamip* to identify continuity of tremolo. For example, when there is no average length over 28%, *pamip* DC will be used. If average length 1 is over 28%, *p-amip* will be used. If average length 2 is over

28%, *pa-mip* will be used. If average length 3 is over 28%, *pam-ip* will be used. If average length 4 is over 28%, *pami-p* will be used. In general, wherever average length is over 28%, there will be – on the position.

2.7 Length is duration in second used from striking one finger to the next finger. Length is computed by subtract time playing one finger by time playing the previous finger. For *pami* guitarist, Length 1 [4] is for *p* and *a* finger, Length 2 [5] is for *a* and *m* finger, Length 3 [6] is for *m* and *i* finger, and Length 4 [7] is for *i* and *p*. On the other hand, for *pima* guitarist is reverse. For comparison, Lengths are computed in percentage over cycle time [8] to [11]. Average length [14] to [17] is consider from mm. 1-54, 1-20, 21-35 and 38-54. Also, average length is from sorting in speed code and string code. Average cycle time [18] is summation of average length. Average % length [19] to [22] is also used to determine descriptive continuity (DC).

2.8 Finger Notations Right Hand: *p* – pulgar, *i* - indice, *m* - medio, *a* - anular

2.9 Fingering Order in this study are *pami*, *pima*, *pimi*, and *pmim*.

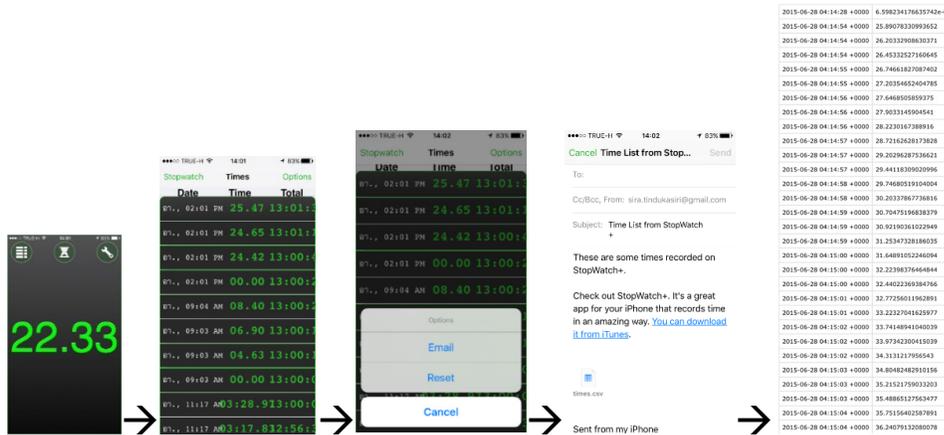
2.10 Good Tremolo should reflect sustained sound, even and pleasant-sounding, smooth uniform, has enough speed that ears neglect gaps. Volume is normally low to medium since fast motion reduces striking power. In this study, good tremolo is defined by length. When length is too much, it is not considered good tremolo. Too much length is defined by length percentage over 28.

3. Methodology

3.1 Study from Virtuosos

Video of seven virtuosos form YouTube have been downloaded then played back on VLC media player with 25% of the original speed. While the first note is 0 sec, record time of every stroke with Stop Watch+ application on iPhone. Time is recorded by touching screen of iPhone. Every touch on iPhone inputs time data. Export data to Excel spread sheet. See Figure 1

Figure 1 Stop Watch+ Data Exported to Excel



Since the data was played at 25% speed, 25% means 4 times the original speed, the data must be divided by 4 to get Time [1]. When subtract Time of p finger by Time of p finger from the previous cycle we get Cycle Time [2]. See Figure 2, where Stroke is number of striking finger from the first note, start from Stroke 1. Cycle is number of tremolo play from the beginning, also start from 1. Mm. is measure number.

Figure 2 Calculation of Time [1] and Cycle Time [2]

Tremolo Data by Nacho Yepes (pam)

Stroke	Cycle	mm.	Speed	String	Length 1	Length 2	Length 3	Length 4	Time	Cycle Time	Cycle Speed	Length 1	Length 2	Length 3	Length 4	
			Code	Code	%	%	%	%	(second)	(second)	(rpm)	(second)	(second)	(second)	(second)	
1	1	1	p	200	25				-	0.3037	197.5634	0.0949	0.0550	0.0573	0.0965	
2			a	200	25				0.0949							
3			m	200	25				0.1499							
4			i	200	25				0.2072							
5	2		p	220	24	26%	23%	24%	27%	0.3037	0.2755	217.7858	0.0707	0.0631	0.0667	0.0750
6			a	220	24				0.3744							
7			m	220	24				0.4375							
8			i	220	24				0.5042							
9	3		p	220	23	22%	26%	23%	29%	0.5792	0.2582	232.3780	0.0579	0.0667	0.0586	0.0750
10			a	220	23				0.6571							

$$\text{Time [1]} = \frac{\text{Time Data from Stop Watch+}}{4}$$

$$\text{Cycle Time [2]} = 0.5792 - 0.3037 = 0.2755$$

Cycle time is time in second used in on cycle. To calculate cycle speed which is number of cycle in one minute or 60 seconds (rpm), we take 60 (seconds) divided by Cycle Time (second) we get Cycle Speed [3]. See Figure 3

Figure 3 Calculation of Cycle Speed [3]

Tremolo Data by Nacio Yepes (pami)

			[13]	[12]	[8]	[9]	[10]	[11]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	
Stroke	Cycle	mm.	Speed	String	Length 1	Length 2	Length 3	Length 4	Time	Cycle Time	Cycle Speed	Length 1	Length 2	Length 3	Length 4	
			Code	Code	%	%	%	%	(second)	(second)	(rpm)	(second)	(second)	(second)	(second)	
1	1	1	p	200	25				-	0.3037	197.5634	0.0949	0.0550	0.0573	0.0965	
2			a	200	25				0.0949							
3			m	200	25				0.1499							
4			i	200	25				0.2072							
5	2		p	220	24	26%	23%	24%	27%	0.3037	0.2755	217.7858	0.0707	0.0631	0.0667	0.0750
6			a	220	24				0.3744							
7			m	220	24				0.4375							
8			i	220	24				0.5042							
9	3		p	220	23	22%	26%	23%	29%	0.5792	0.2582	232.3780	0.0579	0.0667	0.0586	0.0750
10			a	220	23				0.6371							

$$\text{Cycle Speed [3]} = \frac{60}{\text{Cycle Time [2]}} = \frac{60}{0.2755} = 217.7858$$

Subtract Time by the previous Time we get Length which is duration from one Time to the next Time. In case of *pami* fingering order, Length between *p* and *a* finger is called Length 1 [4], Length between *a* and *m* finger is called Length 2 [5], Length between *m* and *i* finger is called Length 3 [6], and Length between *i* and *p* finger of the next cycle is called Length 4 [7]. All lengths are computed into percentage of cycle time as shown in [8] to [11]. See Figure 4 and Figure 5.

Figure 4 Calculation of Length 1 [4], Length 2 [5], Length 3 [6], Length 4 [7]

Tremolo Data by Nacio Yepes (pami)

			[13]	[12]	[8]	[9]	[10]	[11]	[1]	[2]	[3]	[4]	[5]	[6]	[7]	
Stroke	Cycle	mm.	Speed	String	Length 1	Length 2	Length 3	Length 4	Time	Cycle Time	Cycle Speed	Length 1	Length 2	Length 3	Length 4	
			Code	Code	%	%	%	%	(second)	(second)	(rpm)	(second)	(second)	(second)	(second)	
1	1	1	p	200	25				-	0.3037	197.5634	0.0949	0.0550	0.0573	0.0965	
2			a	200	25				0.0949							
3			m	200	25				0.1499							
4			i	200	25				0.2072							
5	2		p	220	24	26%	23%	24%	27%	0.3037	0.2755	217.7858	0.0707	0.0631	0.0667	0.0750
6			a	220	24				0.3744							
7			m	220	24				0.4375							
8			i	220	24				0.5042							
9	3		p	220	23	22%	26%	23%	29%	0.5792	0.2582	232.3780	0.0579	0.0667	0.0586	0.0750
10			a	220	23				0.6371							

$$\text{Length 1 [4]} = 0.3744 - 0.3037 = 0.0707$$

$$\text{Length 2 [5]} = 0.4375 - 0.3744 = 0.0631$$

$$\text{Length 3 [6]} = 0.5042 - 0.4375 = 0.0667$$

$$\text{Length 4 [7]} = 0.5792 - 0.5042 = 0.0750$$

Figure 5 Calculation of % Length over Cycle Time

Tremolo Data by Naciso Yepes (pam)

Stroke	Cycle	mm.	Speed	String	Length 1	Length 2	Length 3	Length 4	Time	Cycle Time	Cycle Speed	Length 1	Length 2	Length 3	Length 4
			Code	Code	%	%	%	%	(second)	(second)	(rpm)	(second)	(second)	(second)	(second)
1	1	i	p	200	25				-	0.3037	197.5634	0.0949	0.0550	0.0573	0.0965
2		a	200	25					0.0949						
3		m	200	25					0.1499						
4		i	200	25					0.2072						
5	2	p	220	24	26%	23%	24%	27%	0.3037	0.2755	217.7858	0.0707	0.0631	0.0667	0.0750
6		a	220	24					0.3744						
7		m	220	24					0.4375						
8		i	220	24					0.5042						
9	3	p	220	23	22%	26%	23%	29%	0.5792	0.2582	232.3780	0.0579	0.0667	0.0586	0.0750
10		a	220	23					0.6371						

$\text{Length 2 \% [9]} = \frac{0.0631}{0.2755} = 23\%$ $\text{Length 4 \% [11]} = \frac{0.0750}{0.2755} = 27\%$
 $\text{Length 1 \% [8]} = \frac{0.0707}{0.2755} = 26\%$ $\text{Length 3 \% [10]} = \frac{0.0667}{0.2755} = 24\%$

Length 1 % [8], Length 2 % [9], Length 3 % [10], Length 4 % [11]

String used in playing can be determined by watching and listening to video. String Codes are specified in column [12]. Speed Code [13] (see definition in 1.5.5) can be specified using Excel formula. See Figure 6

Figure 6 Speed Code [13]

Tremolo Data by Naciso Yepes (pam)

Stroke	Cycle	mm.	Speed	String	Length 1	Length 2	Length 3	Length 4	Time	Cycle Time	Cycle Speed	Length 1	Length 2	Length 3	Length 4
			Code	Code	%	%	%	%	(second)	(second)	(rpm)	(second)	(second)	(second)	(second)
1	1	i	p	200	25				-	0.3037	197.5634	0.0949	0.0550	0.0573	0.0965
2		a	200	25					0.0949						
3		m	200	25					0.1499						
4		i	200	25					0.2072						
5	2	p	220	24	26%	23%	24%	27%	0.3037	0.2755	217.7858	0.0707	0.0631	0.0667	0.0750
6		a	220	24					0.3744						
7		m	220	24					0.4375						
8		i	220	24					0.5042						
9	3	p	220	23	22%	26%	23%	29%	0.5792	0.2582	232.3780	0.0579	0.0667	0.0586	0.0750
10		a	220	23					0.6371						
11		m	220	23					0.7038						
12		i	220	23					0.7621						

Logic :

- If cycle speed is less than 100, string code is 100, or go to next step.
- If cycle speed is less than 120, string code is 120, or go to next step.
- If cycle speed is less than 140, string code is 140, or go to next step.
- If cycle speed is less than 160, string code is 160, or go to next step.
- If cycle speed is less than 180, string code is 180, or go to next step.
- If cycle speed is less than 200, string code is 200, or go to next step.
- String code is 220.

Formula :

=IF(Cycle Speed<100,100,IF(Cycle Speed <120,120,IF(Cycle Speed <140,140,IF(Cycle Speed <160,160,IF(Cycle Speed <180,180,IF(Cycle Speed <200,200,220))))))

Substitute Cycle Speed by cell coordinate. Copy the formula throughout every row we get Speed Code of every cycle. While data is grouped in three categories, by measures, by string code, and, by speed code, calculate average data.

Please note that No. [25] is number of tremolo cycle counting on the measure shown on the second column. Descriptive Continuity (DC) [25] is determined using the percentage (please see definition). In this study, good tremolo is defined by length.

3.1.1 Analyze by Measure

Recuerdos de la Alhambra, as mentioned, has three parts, A, B and C. A is mm. 1-20. B is mm. 21-35. C is mm. 38-54. To calculate average value of length using equations:

3.1.2 Analyze by String Code

Sort data by string code. Calculate all value in the same procedure as described in 3.1.1 Analyze by Measure. Please note that the first column on the left shows No. [25] is number of tremolo cycle counting on the string code shown on the second column. String code is determined by watching video.

Figure 7 Length Equation

$$\text{Avg. Length 1 [14]} = \frac{\text{Sum. of all Length 1 [4]}}{\text{No. [25]}}$$

$$\text{Avg. Length 2 [15]} = \frac{\text{Sum. of all Length 2 [5]}}{\text{No. [25]}}$$

$$\text{Avg. Length 3 [16]} = \frac{\text{Sum. of all Length 3 [6]}}{\text{No. [25]}}$$

$$\text{Avg. Length 4 [17]} = \frac{\text{Sum. of all Length 4 [7]}}{\text{No. [25]}}$$

$$\text{Avg. Cycle Time [18]} = [14]+[15]+[16]+[17]$$

$$\text{Avg. Length 1 \% [19]} = \frac{[14]}{[18]}$$

$$\text{Avg. Length 2 \% [20]} = \frac{[15]}{[18]}$$

$$\text{Avg. Length 3 \% [21]} = \frac{[16]}{[18]}$$

$$\text{Avg. Length 4 \% [22]} = \frac{[17]}{[18]}$$

$$\text{Avg. Length [23]} = \frac{[14]+[15]+[16]+[17]}{4}$$

$$\text{Avg. Cycle Speed [24]} = \frac{60}{[18]}$$

3.1.3 Analyze by Speed Code

Sort data by speed code. Calculate all value in the same procedure as described in 3.1.1 Analyze by Measure. Please note that the first column on the left shows No. [25] is number of tremolo cycle counting on the speed code shown on the second column. Speed code determination were explained in Figure 5.

3.2 Study from Nine Guitarists

Due to present of 9 guitarists, recording and interview will be done without identifying their names.

3.2.1 Interview Players

All 9 players will be interviewed on fingering order, principle in playing tremolo, practice procedure, cautions while playing tremolo, and tremolo and free stroke comparison.

3.2.2 Video Recording Analysis

Make video recording of the nine players playing *Recuerdos de la Alhambra* without repeat. Play back on VLC media player with 25% of the original speed. While the first note is 0 sec, record time of every stroke with Stop Watch+ application on iPhone. Export data to Excel spread sheet. Divided all data by 4 to get real time data. Analyze data on Excel spread sheet in the same procedure as in 3.1. Compare every methods and make conclusion.

4 Data Analysis

There are two parts of analysis, 3.1 Study from Virtuosos and 3.2 Study from Nine Guitarists. Tremolo played by guitar virtuosos consists of only data while Tremolo from nine guitarists consists of data and interview. Average data and DC are classified by speed code. To see overall performance of players, average lengths, using average data of the whole piece, are shown in figure with right hand picture. Furthermore, in order to see how number of each DC distribute on speed code and string code, figures are shown. Interview were made in five categories, fingering order, principle in playing tremolo, practice procedure, caution while playing tremolo and tremolo and free stroke comparison.

Fingering order interview will ask for their order of tremolo finger. Principle in playing tremolo is about idea of tremolo. In this study we founded many different practice procedures. For readers, it may be very useful to try, but be careful. One practice procedure may work well for a guitarist, in contrast, may not work at all for another. Caution while playing tremolo interview

results in both physical and psychological technique. Tremolo and free stroke comparison interview gives additional point of view on how guitarists play tremolo.

5 Conclusion

From interviews, results are concluded and compared in Table 1 Tremolo Interview Comparison. DC, practice procedure, tremolo principle and free stroke comparison are used to compare. Table 2 Tremolo Speed and Length comparison shows result comparison of seven virtuoso and nine guitarists from this study.

6 Discussion

Narciso Yepes has mostly *pami-p* DC. His tremolo is considered as cycle by cycle style. *pami* is played right after the previous *pami* and so on. This results in a little gap between each cycle. Furthermore, *pamip* DC occurs when he increase cycle speed to 200-220 rpm. Here the little gap becomes littler that he gets *pamip* DC. *p-ami-p* DC occurs when Yepes does rubato.

John Williams has mostly *pamip* DC. Only when 1st beat bass accent is required, he creates *p-amip* DC especially in major part (mm. 21-35). Also at the beginning of phrase where he does rubato on measure 26 and at the end of the piece, he made *p-amip* DC.

Table 1 Tremolo Interview Comparison

Guitarist	Practice Procedure	Principle	Free Stroke Comparison
C.T.	4-finger practice, focus on finger preparation.	Each finger has the same length.	Tremolo is faster than free stroke, same angle.
S.S.	4-finger practice, increase speed up and down, also volume up and down	Each finger has the same length.	Tremolo angle must be square, but, free stroke has many angles.
E.J.	3-finger practice in many combinations, Staccato practice, focus on finger preparation.	Each finger has the same length.	Same as free stroke.
R.V.	2-finger practice in many combinations.	Each finger has the same length.	Tremolo uses only nail.

S.M.	Staccato practice, focus on finger preparation.	Similar to <i>pima</i> arpeggio, try to play <i>p</i> and <i>i</i> almost at the same time.	Same as free stroke.
S.T.	Divided piece into phrases according to chords, focus on only <i>p</i> and <i>i</i> preparation.	Similar to <i>pimi</i> arpeggio.	Free stroke is freer on changing angle and position.
N.K.	Accent practice on one finger at a time.	Each finger has the same length.	Same as free stroke.
W.R.	Practice only melody by <i>ami</i> then add <i>p</i> .	Play <i>p</i> and <i>a</i> almost at the same time.	Tremolo angle is square.
P.C.	Many combinations practice on each finger, make rubato to create finger connection on a couple of finger.	Focus on connection from <i>i</i> to <i>p</i> .	Tremolo use more on the middle finger joint.

Andres Segovia has mostly *p-amip* DC because he always accent on *p* finger especially on the first bass of new chord. At the middle of phrase, he increases speed to 160-220 rpm result in reducing gap and get *pamip* DC.

Ana Vidovic does not have specific DC. Note that string code affects her tremolo continuity. While playing closed strings such as 12, 13, 14, 23, 24, 34, tremolo seems to be smooth. Gap at *pm* reduces. Explanation to this is when finger *p* and *m* are close to each other, it is easier finger preparation than when *p* and *m* are far apart.

Sharon Isbin has *p-ami-p* DC in average. Note is made that while playing she always has accent on *p* finger; results in gaps on both *pa* and *ip*. These gaps reduce only at cycle speed over 160 rpm.

Table 2 Tremolo Speed and Length comparison

	Avg. Cycle Speed (rpm)	Avg. Length 1 (second)	Avg. Length 2 (second)	Avg. Length 3 (second)	Avg. Length 4 (second)	DC
Yepes	201.0010	0.0778	0.0685	0.0686	0.0905	pami-p
Williams	166.3459	0.0987	0.0895	0.0799	0.0937	pamip
Segovia	155.4279	0.1170	0.0885	0.0833	0.1055	p-amip
Vidovic	146.9841	0.1153	0.0939	0.0935	0.1230	pmim-p
Isbin	146.1671	0.1218	0.0948	0.0883	0.1203	p-ami-p
Russell	158.9556	0.1040	0.0874	0.0854	0.1071	pamip
Bream	149.1071	0.1010	0.0939	0.0994	0.1093	pamip
C.T.	155.5025	0.0971	0.0946	0.0938	0.1047	pamip
S.S.	134.5427	0.1058	0.1082	0.1110	0.1241	pamip
E.J.	163.2167	0.0953	0.0890	0.0883	0.1016	pimap
R.V.	162.4502	0.0938	0.0903	0.0896	0.0959	pamip
S.M.	150.4381	0.1008	0.0967	0.0968	0.1114	pimap
S.T.	122.2776	0.1187	0.1141	0.1202	0.1388	p-imip
N.K.	146.2976	0.0879	0.1007	0.1022	0.1205	pami-p
W.R.	138.3424	0.1080	0.0998	0.1018	0.1294	pami-p
P.C.	162.5628	0.0964	0.0746	0.0877	0.1125	pami-p

Tremolo played by David Russell is pamip DC in average. Only pami-p happens when cycle speed is less than 160 rpm in mm. 38-54.

Tremolo played by Julian Bream is pamip DC in average. Only pami-p happens when cycle speed is less than 140 rpm.

C.T. has mostly pamip DC. Also, it has pamip DC when string code and speed code are considered. Only at the beginning and a point where it make rubato with speed under 120 rpm, it makes pam-ip. In general, C.T. is pamip tremolo which focus on finger preparation and consider each finger has the same length.

S.S. has mostly pamip DC. There is pami-p only in the minor part (mm. 1-20), at cycle speed 100-120 rpm when he play on 13, 14 and 24 string code. This can be explained that the slow and calm motion of the minor part required rubato while playing. Gaps occur when doing rubato. Playing strings are not the cause. In general, S.S. is pamip tremolo which practice by changing volume and speed up and down.

Figure 7 DC Comparison

mm.	Ycpes	Williams	Segovia	Vidovic	Isbin	Russell	Bream	C.T.	S.S	E.J.	R.V.	S.M.	S.T.	N.K.	W.R.	P.C.
1-54	pami-p	pamip	p-amip	pmim-p	p-ami-p	pamip	pamip	pamip	pamip	pimap	pamip	pimap	p-imip	pami-p	pami-p	pami-p
1-20	pami-p	pamip	p-amip	pmim-p	p-ami-p	pamip	pamip	pamip	pami-p	pimap	pamip	pimap	pimi-p	pamip	pami-p	pami-p
21-35	pami-p	p-amip	p-amip	p-mim-p	p-ami-p	pamip	pamip	pamip	pamip	pimap	pamip	pimap	pimi-p	pami-p	pami-p	pami-p
38-54	pami-p	pamip	p-amip	p-mimp	p-ami-p	pami-p	pamip	pamip	pamip	pimap	pamip	pima-p	p-imip	pami-p	pami-p	pami-p
String Code																
12	pami-p	p-amip	pamip	pmimp	p-ami-p	pamip	pamip	pamip	pamip	pimap	pamip	pimap	pimip	pamip	pami-p	pami-p
13	pami-p	pamip	p-amip	pmim-p	pamip	pami-p	pamip	pamip	pami-p	pimap	pamip	pimap	pimi-p	pami-p	pami-p	pami-p
14	pami-p	pamip	p-amip	pmim-p	pami-p	pamip	pamip	pamip	pami-p	pimap	pamip	pimap	pimip	pami-p	pami-p	pami-p
15	pamip	p-amip	p-amip	p-mimp	p-ami-p	p-amip	pamip	pamip	pamip	p-imap	pamip	p-imap	pimip	pami-p	pamip	p-ami-p
16	pamip	p-amip	p-amip	p-mimp	p-ami-p	p-amip	p-amip	pamip	pamip	pimap	pamip	p-imap	p-imip	pami-p	pami-p	p-amip
23	pami-p	pamip	pamip	pmim-p	pamip	pami-p	pamip	pamip	pamip	pimap	pamip	pimap	pimi-p	pami-p	pami-p	pami-p
24	pami-p	pamip	pami-p	pmim-p	pami-p	pami-p	pamip	pamip	pami-p	pima-p	pamip	pima-p	pimi-p	pami-p	pami-p	pami-p
25	pami-p	p-amip	p-amip	p-mimp	p-ami-p	p-amip	pamip	pamip	pamip	pima-p	pamip	pima-p	pimip	pami-p	pami-p	pami-p
26	pamip	pamip	p-amip	p-mimp	p-ami-p	pamip	pamip	pamip	pamip	p-imap	pamip	p-imap	pimip	pamip	pami-p	pami-p
34	pami-p	pamip	p-amip	pmim-p	pami-p	pami-p	pamip	pamip	pamip	pimap	pamip	pima-p	pimip	pami-p	pami-p	pami-p
35	pamip	pamip	pamip	p-mimp	p-ami-p	p-amip	pami-p	pamip	pamip	pimap	pamip	p-imap	p-imip	pami-p	pamip	pami-p
36																
Speed Code																
100	pami-p		p-amip	p-mim-p	pami-p	p-ami-p	pami-p	pam-ip	pa-mip	p-ima-p		pima-p	p-imip		pami-p	pam-i-p
120	pami-p	p-amip	p-amip	p-mim-p	p-ami-p	p-ami-p	p-ami-p	pam-ip	pami-p	p-ima-p		pima-p	pimi-p	pami-p	pami-p	
140	p-ami-p	p-amip	p-ami-p	pmim-p	p-ami-p	pami-p	pami-p	pami-p	pamip	pima-p	p-amip	pimap	pimi-p	pami-p	pami-p	pami-p
160	pami-p	pamip	pamip	pmimp	pamip	pami-p	pamip	pamip	pamip	pimap	pamip	pimap	pimi-p	pami-p	pami-p	pami-p
180	pami-p	pamip	pamip	pmimp	pamip	pamip	pamip	pamip	pamip	pimap	pamip	pimap		pami-p	pami-p	pami-p
200	pami-p	pamip	pamip	pmimp	pamip	pamip	pamip	pamip		pimap	pamip	pimap			pamip	pami-p
220	pami-p	pamip	pamip	pmimp	pami-p	pamip				pima-p	pami-p	pima-p			pami-p	

E.J. has mostly pimap DC. Due to his practicing which is staccato making, length *im* and *ma* are small. In the same manner, when striking *pima* is the same playing mechanic as when striking arpeggio on bass, 1st, 2nd and 3rd string. Both are reasons why length *im* and *ma* are small. When melodies are on the 2nd string, both length *ap* and *pi* increase. Explanation is that to play melodies on the 2nd string requires extra fingers preparation. Since E.J. fingering order is *pima*, *p* and *i* have to get prepare first. Right palm has to expand more comparing to *pami* fingering order which *p* and *a* prepare first. Result is tension on right hand which causes more length on *ap* and *pi*. In general, E.J. is pimap tremolo that practice by doing staccato.

R.V. has mostly pamip DC Only in the first measure has pami-p at cycle speed 140 rpm. This is how he start the piece by increasing speed from slow to normal. Also in the first and second measures of major part, he has pami-p. He does rubato. In general, R.V. is pamip tremolo that play with nail only.

S.M., the *pima* fingering order requires extra palm expansion for finger preparation especially for *p* and *i* when playing strings which are far apart such as 1st and 6th strings. Data show that there are more gaps when playing far apart strings than when playing strings that close to each other. At the same manner, when melodies are on 2nd and 3rd string which require extra finger preparation. Furthermore, palm expansion may create more hand tension. Her idea that try to play *p* and *i* at almost the same time creates more chance to have pima-p DC. Furthermore, pima is similar to playing arpeggio on bass and 3rd, 2nd and 1st strings. pima-p DC has more chance to happen. In general, S.M. is *pima* tremolo that *p* and *i* are played almost at the same time.

Mostly, S.T. has p-imip and pimi-p DC. Since *p* and *i* are next to each other but totally different in structure and bending direction, it is difficult to play *p* and *i* in connection. Furthermore, pimip fingering order requires *i* to play two times in a cycle, so, it need to get prepared all the time and can easily get fatigued. Cycle speed is low in average because of too much work on *i* finger. Same manner as *pima*, right palm expansion may create more hand tension. By the way, 3-finger tremolo has more freedom in changing striking angle. No worry on *a* finger which can easily create noise. In general, S.T. is *pimi* tremolo that focus on *p* and *i* preparation.

Tremolo by N.K. is mostly pami-p. The technique is to finish one cycle then play the next cycle, and so on. Tremolo tends to have a little gap between *i* and *p* of the next cycle. In minor part (mm. 1-20), DC are mix between pami-p and p-amip because the part has a lot of rubato and

melodies are mostly on 2nd string, so she makes those two DC. In general, N.K. is *pami* tremolo that practice by making accent on each finger.

W.R. technique is to finish one cycle of tremolo then start the next cycle, and so on. Result is potential to have gap between *i* and *p* and having mostly *pami-p* as DC. In general, W.R is *pami* tremolo that consider only *ami* has the same timing. *p* is added between *i* and *a*.

P.C. has mostly *pami-p*. The technique is to finish one cycle of tremolo, get finger prepared then start the next cycle, and so on. Result is potential to have gap between *i* and *p* and having mostly *pami-p* as DC. Exception are at the beginning of the piece where he makes *p-ami-p* and *p-amip* for rubato as he starts a phrase. He ends the piece with *pam-i-p*. In general, P.C. is *pami* tremolo that practice by doing many combinations of finger order. This use more on the middle finger joint while playing.

Sound continuity of tremolo are different as shown in Table 5.1 and 5.2. Although most fingering order is *pami*, guitarists can try and choose their most favorite fingering order that work best for them. Modern guitarists has more freedom to try *pima* and *pmim* which, for some reason, work well for them. Practice procedure such as staccato practice, 3-finger practice, variable speed practice or accent practice may work well for guitarist. While staccato practice may reduce gap for student with too much gap on specific fingers, accent practice may result in smooth and balance sound. With caution assistance from teacher, choose practice procedure that suitable to your physical and level. Although majority guitarists in this study consider one cycle of tremolo has four sounds which are equal in length, trying to play a couple of fingers at the same time may improve tremolo continuity. Thinking that tremolo is arpeggio on the same string is a good psychological principle. Tremolo and free stroke are same. Little difference is striking angle. Tremolo striking angle is always more perpendicular to strings comparing to free stroke.

From Table 2, minimum cycle speed of seven virtuoso is 149.1071 rpm, while minimum cycle speed of nine guitarist is 122.2776 rpm. To be concluded, from this study, the minimum cycle speed to be professional guitarist is 140 rpm, and, for general guitarist is 122 rpm.

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