Influences of Dynamic Level and Pitch Register on the Vibrato Rates and Widths of Violin and Viola Players

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Abstract:
The purpose of this study was to investigate possible influences of pitch register and dynamic level on vibrato rates and widths of university and high school violin and viola players. Analysis showed that pitch register significantly affected the vibrato rates and widths of the performers. Musicians vibrated 0.32 Hz faster and approximately 26 cents wider during high pitches than during low pitches. Dynamic level also significantly affected vibrato width. Performers increased vibrato width approximately 4 cents in the forte passages when compared to the piano passages. Furthermore, violinists demonstrated a tendency to vibrate slightly faster and wider than violists, and university performers varied their vibrato width to a greater extent between the piano and forte passages than did the high school performers. These results, along with further study, can contribute to the development of a systematic method for teaching vibrato.
Keywords: vibrato; violin; viola; string vibrato

Article:
Vibrato is an essential musical element in string instrument performance that enhances and facilitates expressive performance. Pedagogues and performers agree that a beautiful vibrato is balanced, even, and free of tension (Applebaum, 1986; Fischbach, 1998; Galamian, 1948; Hamann & Gillespie, 2004; Lucktenberg, 1994; Potter, 1980; Rolland, Mutchler, & Hellebrandt, 2000). However, a widely accepted, systematic method for teaching vibrato has not yet been adopted by string performers and pedagogues. Aspects such as appropriate width, rate, and purported pitch center are frequently debated (Fischbach, 1998; Gillespie, 1996), and disagreement precludes a universal method for teaching vibrato. Contextual variables — including pitch register, dynamic level, instrument type, solo versus ensemble performance, level of training, type of vibrato motion, phrase direction, finger employed, musical style, and personal choice — are among the many factors that possibly influence string vibrato. Research that investigates the influence of individual contextual variables is an important step toward establishing a vibrato curriculum that is consistent and concise. This study attempts to investigate the contextual effects of pitch register (range) and dynamic level on the vibrato widths and rates of violin and viola players.

The appropriate vibrato rate suggested by artists and pedagogues ranges from 5.0 Hz to 8.0 Hz: 5.0 Hz (Applebaum, 1986), 5.0 Hz to 7.0 Hz (Potter, 1980), 5.0 Hz to 8.0 Hz (Doschek, 1968), 6.0 Hz to 7.5 Hz (Fischbach, 1998), 6.0 Hz to 7.0 Hz (Joelson, 1964; Kazez, 1984), 6.5 Hz (Rolland et al., 2000), 7.0 Hz (Rolland, 2000). Some pedagogues advocate that artists should be able to control the vibrato rate to create variety (Clark, 1989; Galamian, 1948). However, a more popular belief is that the vibrato width is the characteristic most frequently manipulated by artists to create color and contrast (Clark, 1989; Joelson, 1964; Rolland et al., 2000). Pedagogues generally recommend that the vibrato be approximately a quarter tone (50 cents) in width (Doscheck, 1968; Fischbach, 1998; Lucktenberg, 1994; Rolland, 2000).

Researchers have investigated the vibrato rates of students and artists and found a range of rates similar to those recommended by pedagogues — namely, 4.0 Hz to 10.0 Hz, with mean rates falling between 5.0 Hz and 7.0

Hz: 5.0 Hz to 6.0 Hz (Fletcher & Sanders, 1967), 6.0 Hz to 7.0 Hz (Small, 1936), 6.0 Hz (Fletcher & Sanders, 1967; Seashore, 1967), 5.5 Hz to 7.0 Hz (Cheslock, 1931), 7.0 Hz (Hollinshead, 1932), 5.5 Hz (Geringer & Allen, 2004). Vibrato widths have been found to range from 26 cents to more than 100 cents (52 cents: Hollinshead, 1932; 48 cents: Reger, 1932; 44 cents: Small, 1936; 38 cents: Reger, 1932; 30 cents: Geringer & Allen, 2004), a range both narrower and wider than that recommended by pedagogues.

Many pedagogues and artists have suggested that the rate and width of the vibrato are dependent on the intensity of the tone (Carroll, 1997; Cheslock, 1931; Galamian, 1948; Joelson, 1964; Potter, 1980; Reger, 1932; Rolland, 2000; Rolland et al., 2000). Furthermore, some artists and pedagogues believe that a natural relationship exists in which the vibrato width increases in forte passages and decreases in piano passages (Applebaum, 1986; Bronstein, 1977; Galamian, 1948; Joelson, 1964; Potter, 1980; Rolland, 2000).

Little empirical research has been conducted investigating the relationship between dynamic level and vibrato rate and width in string players. In two empirical studies from the 1930s, researchers explored the effect of dynamic level on vibrato rate and width in string players and found a slight increase in rate and a marked increase in width during forte passages as compared to piano passages (Cheslock, 1931; Reger, 1932), which is consistent with pedagogical recommendations. However, the relationship between dynamic level and vibrato rate and width has not been sufficiently investigated.

Pitch register (range) may also affect the rate and width of vibrato. As pitches become higher on string instruments, the physical distance between the intervals decrease; therefore, some pedagogues assert that the vibrato should decrease in its width (Applebaum, 1986; Carroll, 1997; Flesch, 1924; Lucktenberg, 1994; Mantel, 1972) and possibly increase in rate (Carroll, 1997; Lucktenberg, 1994; Mantel, 1972). Furthermore, some pedagogues recommend that the vibrato rate is slightly slower and wider for violists when compared to that of violinists (Applebaum, 1986; Primrose, 1976).

Empirical research investigating the effect of pitch register and instrument type on vibrato rate and width has produced a variety of results. Geringer and Allen (2004) studied high school and university string players. They found that vibrato rate was not significantly among between violins and cellos but that vibrato width was wider for violins (34 cents) than cellos (26 cents). Reger (1932) found a difference in vibrato rates between solo artists when comparing solo violinists (6.92 Hz), violists (6.10 Hz), and cellists (6.28 Hz). Papich and Rainbow (1974) found that violinists vibrated wider in the third position than in the first position, but in their 1975 study found that basses vibrated with the same rate and width when in first position compared to fourth position. Further research is necessary to provide more information regarding the inconsistent results of these studies. The possible effects of instrument type and pitch register have not been fully explored, and additional research may shed light on the different widths and rates reported by researchers and pedagogues. It is also important to note that violas have not been included in most studies mentioned above and that little research has investigated the possible differences between violin and viola vibrato.

Two variables — pitch register and dynamic level — were isolated for the purpose of this study, and the vibrato rates and widths of high school and college violin and viola performers were measured. Questions addressed in this study were as follows: Does pitch register affect the rate or width of vibrato? Do vibrato rates and widths of performers vary in accordance with dynamic level? Are there a differences in vibrato width and rate between violinists and violists?

Method

Participants

Participants in this study (N = 58) included 13 high school violin students, 19 high school viola students, 14 university violin students, and 12 university viola students. High school participants were volunteers from one of three Southeastern states who were recommended by their orchestra directors as exceptional players. University volunteers were upper-division undergraduate and graduate music majors from a large comprehensive university in the southern United States. The amount of playing experience of each participant

varied: High school violinists' experience ranged from 4 to 11 years (M = 7 years); high school violists, 6 months to 11 years (M = 5 years); university violins, 5 to 22 years (M = 14 years); and university violists, 6 to 23 years (M= 12 years). Six of the 19 high school violists began string instruction on the violin and then converted to the viola. Seven of the 12 university violas began instruction on the violin and then switched to the viola.

Table 1 Mean Vibrato Rates From Example 1 and Example 2

	Rate (Hz)	
Independent Variable	M	SD
Level of training		
High school	5.49	0.30
University	5.71	0.37
High versus low pitch		
Violin: Low pitch	5.58	0.40
Violin: High pitch	5.85	0.32
Viola: Low pitch	5.36	0.35
Viola: High pitch	5.62	0.27
Instrument by training level		
High school violin	5.53	0.30
High school viola	5.45	0.30
University violin	5.89	0.33
University viola	5.53	0.33

Musical Excerpts

The English horn solo (measures 7-10) in the second movement of Symphony No. 9, New World, by Dvořák provided the musical stimuli for this study. To investigate the influence of pitch register (range) on vibrato rate and width, two passages using the four-measure melody were transposed into a low-pitch register and a high-pitch register for violin and viola (see Figure 1). The example melody was notated in a low pitch register, and Example 2 provided the identical melody in a high-pitch register — specifically, two octaves higher than Example 1. To create consistency in the fingerings and positions between the violin and viola, the passage was transposed to E minor for the violin and A minor for the viola so that performers would play the passage on each instrument's third string with the same fingerings in the first position (Example 1) or on each instrument's first string with the same fingerings in the seventh position (Example 2).

Example 3 was designed to investigate the influence of dynamic level on vibrato rate and width. This passage was transposed to B minor for the violin and E minor for the viola so that the melody would be performed on the second and third strings of the respective instrument in first position. Dynamic markings in Example 3 indicated four measures of piano followed by four measures of forte, then four measures of forte followed by four measures of piano. Therefore, the identical four bars were performed in a forte dynamic level and a piano dynamic level, for comparison purposes.

In all examples, bow direction, fingerings, and dynamics were labeled clearly to help control for additional contextual variables. Four string pedagogy experts — two violinists (one university professor and one high school teacher) and two violists (one university professor and one high school teacher) — were contacted and subsequently agreed to review the fingerings and bowings labeled in the examples. Suggested bowing and fingering revisions from the panel of experts were incorporated into the examples.

Procedure

All participants were recorded using a Sony ECM-M5907 stereo condenser microphone and a Sony WM-D6C Professional Cassette Tape Recorder. University volunteers were recorded in a small recording studio. To record the high school participants (in three states), it was necessary to record in a number of locations at the high schools where students volunteered. In all instances, students were recorded individually in a quiet environment. To ensure that the instruments were tuned to the same approximate pitch levels, a visual tuning meter calibrated to A 440 was provided, to which participants tuned their own instruments. Performers were permitted to practice each example until they felt comfortable with the notated bowings, fingerings, and dynamics. A metronome marking of 80 was provided as the recommended tempo for a quarter note in all examples and was turned off before recording.

The recorded audio files were transferred to a computer hard disk using an A/D converter (Audiophile 2496; M-Audio, Irwindale, California) at a sampling rate of 48 kHz with 24-bit resolution. The resulting sound files were analyzed using the computer software program Praat 4.3 (University of Amsterdam, Institute of Phonetic Sciences, Netherlands). Praat is a software program designed to analyze frequency and other sound parameters with high accuracy (Boersma, 1993). A sampling rate of 100 samples per second was used for the analysis of vibrato. Praat has been used in several recent investigations of pitch performance in music (Geringer & Allen, 2004; Geringer, Allen, & MacLeod, 2005; Kopiez, 2003).

Forty-eight recordings were analyzed following selection criteria regarding vibrato performance. The presence of a minimum of three vibrato cycles was required in 90% of the sustained pitches in each example for inclusion in the final data set. The first 12 participants who met the criteria were selected from each group for further analysis for a total of 48 participants (university violin, n = 12; high school violin, n = 12; university viola, n = 12; high school viola, n = 12). The first 12 university violins, university violas, and high school violins recorded met the minimum criteria for inclusion in the study. It was necessary to record 19 high school violists before 12 participants were found who were able to vibrate during 90% of the sustained pitches.

Measurement Procedure

From recordings of the 48 string players' performances, 44 pitches were isolated, and the vibrato rate and width were measured. The vibrato rate for each pitch was calculated by dividing the number of complete cycles per second selected during the middle portion of tones (a minimum of three cycles to a maximum of six cycles) by the duration of those cycles in milliseconds. To measure the vibrato width, the highest and lowest frequencies (Hertz) of the vibrato cycle were measured that appeared to best represent the width of all of the cycles in the selected pitch. The minimum and maximum frequencies were then converted to cents, and the width of the representative vibrato was determined. Analysis of variance (ANOVA) was used for all statistical tests, with a significance level of .01.

Reliability and Implementation

Two independent observers measured the vibrato rates and widths of 10% of the pitches, for a total of 20% of the pitches. Those vibrato rates were then compared to the vibrato rates measured by the experimenter. Reliability for rate was calculated using the Pearson correlation coefficient (r = .76 and .79). The vibrato widths measured by the two observers were also compared to the vibrato widths measured by the experimenter (r = .99 for both). The intensity levels of the forte and piano passages were measured for 50% of the pitches. The mean difference in intensity between the piano and forte pitches of Example 3 was 5.4 dB.

Results

Influence of Pitch Register on Vibrato Rates and Widths

Vibrato rates from Example 1 (low-pitch register) and Example 2 (high pitch register) were analyzed using a three-way ANOVA with two between-subjects factors (training level and instrument type) and one within-subjects factor (pitch register). A significant difference was found for the main effect of pitch register, $F(1,44) = 62.87$, p .. .01, partial $\eta^2 = .59$. The performers vibrated at a faster rate during the high excerpt (M = 5.74 Hz, SD = 0.35 Hz) than during the low excerpt (M = 5.47 Hz, SD = 0.28 Hz). No significant differences were found

for the between-subjects variables or the interactions between any of the other factors. There was a tendency for violinists to vibrate at a rate slightly faster than that of the violists, 5.71 Hz and 5.49 Hz, respectively. The university instrumentalists displayed a general tendency to vibrate at a faster rate (5.71 Hz) than that of the high school players (5.49 Hz; see Table 1).

Vibrato widths from Example 1 (low-pitch register) and Example 2 (high-pitch register) provided data for a three-way ANOVA with two between-subjects factors (training level and instrument type) and one within-subjects factor (pitch register). Significant differences were found for pitch register, F(l, 44) = 481.9, p.. .01, partial T|2 = .92, and instrument type, F(1,44) = 24.03, p .. .01, partial η^2 = .35. A significant interaction was also found between pitch register and instrument type, F(l, 44) = 21.3, p .. .01, partial η^2 = .33 (see Figure 2).

A comparison of mean vibrato widths between the two instruments revealed that violinists utilized a wider vibrato (M = 51 cents, SD = 8 cents) than did violists (M = 41, SD = 8). The lower register was performed with a narrower vibrato (M = 34, SD = 8) than was the higher register (M = 58, SD = 12). In the low excerpt, violists vibrated a mean width of 32 cents (SD = 7), whereas the violinists vibrated 37 cents (SD = 7). In the high excerpt, violists vibrated 50 cents (SD = 8), and violinists vibrated 65 cents (SD = 9). Overall, the violinists' vibrato had a greater increase in vibrato width in the upper register than did the viola players (see Figure 2).

Influence of Dynamic Level on Vibrato Rates and Widths

The vibrato rates from the piano and forte pitches in Example 3 were analyzed using a three-way ANOVA with two between-subjects factors (training level and instrument type) and one within-subjects factor (dynamic level). There was a slight tendency for university players to vibrate at a faster rate (M = 5.63 Hz, SD = 0.42 Hz) than that of the high school players (M = 5.41 Hz, SD = 0.30 Hz) and for violinists (M = 5.64 Hz, SD = 0.37 Hz) to vibrate at a slightly faster rate than that of the violists {M = 5.39 Hz, SD - 0.36 Hz); however, effects of dynamic level on rate were not signficant.

Vibrato widths from the piano and forte pitches in Example 3 were analyzed using a three-way ANOVA with two between-subjects factors (training level and instrument type) and one within-subjects factor (dynamic level). Significant differences were found for the main effects of dynamic level, F(l, 44) = 14.08, p .. .01, partial ^{2} = .24, and instrument type, F(l, 44) = 14.93, p .01, partial η^2 = .25. Overall, musicians vibrated wider during the forte portion of the excerpt (M = 39.4 cents, SD = 8.0 cents) than during the piano portion of the excerpt (M = 36.5, SD = 6.0). The violin players produced a wider vibrato overall (M = 42, SD = 8) than did the viola players (M = 34, SD = 6), and university performers varied their vibrato width to a greater extent between the piano and forte passages (5 cents) than did the high school performers (2 cents). No significant interactions were found.

Vibrato Rates and Widths of Violinists Compared to Violists

Violinists demonstrated a tendency to vibrate at a slightly faster rate than that of violists. In all passages, violinists vibrated at a faster rate than that of the violists. However, differences in mean rates were not significant. A significant difference was found for vibrato width between the two instruments in all three musical examples. Violinists performed with a vibrato that was significantly wider than the violists' vibrato (see Table 2).

Discussion

Vibrato is one of the most difficult technical and musical skills to teach, and relatively little is known about the fundamental elements of its production. For example, what are the appropriate rates and widths of a musical vibrato, and to what degree should the vibrato vary to support the musical intentions of the performer? It seems likely that teachers may recommend an increase in vibrato rate when they really mean an increase in vibrato width, or vice versa. Clarity in music instruction will benefit students and potentially facilitate the learning process. Furthermore, contextual variables such as pitch register, dynamic level, and instrument type all appear to affect vibrato rate and width in a number of ways. To teach vibrato effectively as concisely and accurately as possible, it seems prudent to understand as many of these variables and their contextual influences as possible.

In this study, pitch register affected the vibrato rates and widths of university and high school performers in a way inconsistent with pedagogical suggestions. Some pedagogues assert that the vibrato should decrease in width in the upper register to accommodate the decrease in physical distance between intervals (Applebaum, 1986; Carroll, 1997; Flesch, 1924). When the instrumentalists in this study performed in a higher register, the vibrato width was wider. Mean vibrato width in the lower register was 34 cents, as compared to 58 cents in the upper register. Consistent with pedagogical suggestion, the vibrato rate was faster in the upper register (Carroll, 1997; Lucktenberg, 1994; Mantel, 1972), although this change was slight.

Table 2 Mean Rates and Widths of Violinists and Violists

	Rate (Hz)		Width (Cents)	
Example	M	SD	M	SD
Examples 1 and 2				
Violin	5.71	0.36	51	8
Viola	5.49	0.31	41	8
Example 3				
Violin	5.64	0.37	42	8
Viola	5.37	0.36	34	6

Note: Pairs of italicized means are significantly different from each other (p .. .01).

The participants in this study were not professional performers; therefore, it is not possible to conclude on the basis of this study that changing width in different registers is desirable, but it does point to an issue that should be resolved. The questions then become: Is the increase in vibrato width and rate found in the higher register of this study intentional? Does the increase in rate and width contribute to a musically pleasing sound? Should the vibrato motion be altered to maintain a vibrato oscillation similar to that found in the lower register? What do professional ensemble and solo performers do in higher registers versus lower registers?

The vibrato rates and widths of the musicians in this study also varied with the dynamic level. Participant vibratos were wider when performing forte passages compared to piano passages. The rate also varied slightly between the two dynamic levels. Forte passages were accompanied by a slightly faster in rate, although this difference was not significant. This information may be helpful when describing the function of the left hand in forte versus piano passages. Teachers may suggest that the vibrato motion correspond to the dynamic level, using less motion in piano passages and more motion in forte passages. Width appears to be the element that varies the most; therefore, a teacher may describe the motion using the terms wider and narrower rather than faster and slower.

The differences found between violin and viola vibrato rates and widths are of interest to teachers and performers. In this study, the violinists were found to vibrate to a wider extent than that of the violists, contrary to pedagogical suggestions (Applebaum, 1986; Primrose, 1976). Violinists also exhibited a slightly faster vibrato rate than that of violists, consistent with pedagogical advice. Again, this research cannot determine whether this difference is desirable. It seems likely that the vibrato motion feels wider on the viola than on the violin because of size, but the distance traveled on the fingerboard by the finger actually spans a narrower frequency range. Further research is needed to determine whether professional violists exhibit a wider or faster vibrato than that of the students in this study.

It is important to note that the high school violists struggled to perform the examples with the same proficiency as the high school violinists. Nineteen high school viola students were recorded before 12 students were found

who executed the examples to criteria. This gap in technical ability was not present at the university level and so indicates a need for violists to gain additional technical skills to continue musical study after high school. Teachers might consider giving viola players additional exercises as well as challenging music that will increase their proficiency with both vibrato and passages in higher positions so that their technical skill level becomes comparable to that of the violins.

The difference between violin and viola vibrato is of utmost importance pedagogically because the two instruments are frequently treated the same, when they may in fact need to utilize slightly different techniques. It is also possible that the vibrato is identical but that it sounds and feels different because of instrument size. If the latter is true, violinists and violists may be taught to vibrate in the same fashion, and few adjustments will need to be made in vibrato if a performer converts from one instrument to the other. Furthermore, in group lessons, violinists and violists may be given the same instruction.

Finally, further research is necessary to clarify the elements of a beautiful vibrato. Some aspects of music cannot be perceived by the human ear alone and must be examined in more detail so that the components can be explained clearly and accurately to students. Perhaps such procedures can facilitate learning to vibrate with a beautiful sound. Further research examining other contextual factors will help shed light on this musical and technical challenge. Carefully designed research that provides additional information is needed to accurately describe and guide future teaching practices.

PHOTO (COLOR): Figure 1 Violin and Viola Examples

GRAPH: Figure 2 Mean Vibrato Widths of Violinists and Violists During the Low — Versus High-Pitch Registers in the Musical Excerpts (Example 1 and Example 2)

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