# An Empirical Study of Historical Patterns in Musical Rhythm: Analysis of German & Italian Classical Music Using the nPVI Equation

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**This paper introduces a new approach for** the historical study of musical rhythm based on an empirical measure of rhythm known as the nPVI ('normalized pairwise variability index'). The nPVI is an equation that measures the degree of durational contrast between successive events in a sequence. While the nPVI is increasingly used for comparative studies of rhythm in music and language, we show that it can also be used for historical research. A historical analysis of musical nPVI values from German/Austrian and Italian instrumental classical music between ~1600-1900 reveals different patterns in the two cultures: German/Austrian music shows a steady increase in nPVI values over this period, while Italian music shows no salient increase. These patterns are discussed in light of the idea (from historical musicology) that the influence of Italian music on German music began to wane in the second half of the 1700s due to a rise of musical nationalism in Germany. The nPVI data prove to be consistent with this idea, illustrating how nPVI analysis can reveal patterns that enrich and inform historical research.

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**Key words:** musical rhythm, quantitative musicology, nPVI, historical trends, empirical musicology

**The nPVI ('normalized pairwise variability index')** is an equation that measures the average degree of durational contrast between neighboring elements in a sequence, such as successive vowels in a spoken sentence or successive notes in a musical melody. The greater the durational (agogic) contrast between neighboring elements in a sequence, the higher the nPVI value of that sequence (cf. the Appendix for an example nPVI computation, and Figures 4a and 4b for examples of musical themes with contrasting nPVI values). The nPVI was originally developed by phoneticians, who showed that certain "stress-timed" languages (such as British English, German, and Dutch) had higher vocalic nPVI values than certain "syllable-timed" languages (such as French, Spanish, and Italian), meaning that sentences in stress-timed languages showed greater contrast in successive vowel durations (likely due to the strong influence that stress and vowel reduction have on vowel duration in these languages) (Grabe & Low, 2002; Low, Grabe, & Nolan, 2000; Ramus, 2002; for recent data on vocalic nPVI in English, German, Italian, and Spanish, see Arvaniti 2012, Figure 2b).

While the nPVI was developed in the field of linguistics, it has also been used to study relations between linguistic and musical rhythm. Patel & Daniele (2003a) used the nPVI to test a provocative intuition voiced by musicologists and linguists since the mid 1950s: namely, that purely instrumental music can reflect the prosody of a composer's native language. The researchers found support for this idea in turn-of-the-20$^{th}$-century instrumental classical music from England and France: on average, English musical themes had a greater nPVI value than did French musical themes, reflecting the greater vocalic nPVI of British English speech compared to French speech (cf. Huron & Ollen 2003 and London & Jones 2011 for further analysis of Patel & Daniele's musical nPVI data). In a similar vein, McGowan and Levitt (2011) have used the nPVI to demonstrate how speech rhythms can be reflected in instrumental folk music. (For a perceptual study of the nPVI in music, see Hannon, 2009; for a different approach to comparing rhythm in speech and music, see Temperley & Temperley, 2011.)

In their study, Patel and Daniele (2003a) purposely avoided examining vocal music. They felt it would be unsurprising if vocal music bore the stamp of linguistic rhythm, given that such music involves fitting tunes to the words of a language. In fact, subsequent research by VanHandel and Song (2010) on 19$^{th}$ century art song showed that a reflection of linguistic rhythm in vocal music is by no means guaranteed. These researchers found no significant difference in average musical nPVI

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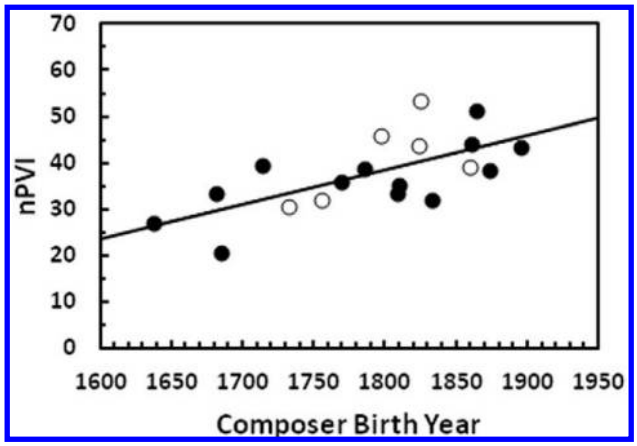


**FIGURE 1.** Musical nPVI values for 13 German composers (closed dots) and 6 Austrian composers (open dots) as a function of composer birth year, from Patel and Daniele (2003b). Each dot represents the mean nPVI value for one composer, based on themes from Barlow and Morgenstern (1983). For details on composers and on how themes were selected, see Daniele and Patel (2004).

values of Greman and French art songs, despite the fact that German speech is known to have a higher nPVI than French speech. This demonstrates an important point, namely that the reflection of linguistic rhythm in musical rhythm is not inevitable. Rather, language is but one possible influence on musical rhythm, and at certain points in history its influence may be outweighed by other cultural forces. Indeed, this observation is the stepping-off point for the current study, which examines the nPVI in historical perspective.

Our study has its roots in Huron and Ollen's (2003) finding that the average nPVI of German and Austrian instrumental classical music between ∼1600 and 1900 is rather low, and thus is not reflective of the high nPVI of spoken German. This discrepancy motivated Patel and Daniele (2003b) and Daniele and Patel (2004) to examine historical trends in the musical nPVI values of German-speaking composers during this era, which spans the Baroque, Classical, and Romantic eras in concert music. When examining the nPVI values of instrumental musical themes from 20 composers from this era, a striking pattern emerged: a salient increase in nPVI values over historical time. These data are reproduced in Figure 1, with one minor change (the composer G. F. Handel, who was included as a German composer in the original studies, is now excluded due to his prolonged residence in England). The best-fitting regression line in Figure 1 is highly significant (nPVI = .0742 * Birth Year − 95.1, $df = 17$, $r^2 = .45$, $p = .002$), indicating an increasing degree of agogic contrast in German/Austrian instrumental classical music over this time period. (Since the current paper deals entirely with instrumental classical music, henceforth 'music' refers to this type of music).

What accounts for this pattern? Huron and Ollen (2003) reported that the average nPVI of Italian musical themes between ∼1600-1900 was relatively low (reflecting the "syllable-timed" rhythm of the Italian language), inspiring Patel and Daniele (2003b) and Daniele and Patel (2004) to suggest that the pattern in Figure 1 could be due to the well-known influence of Italian music on German/Austrian music during the Baroque (1600-1750) and into the Classical (1750-1825) eras (Kmetz, Finscher, Schubert, Schepping, & Bohlman, 2001). According to this view, it was in the Romantic era (1825-1900) that German music broke free of this influence and began to show relatively high nPVI values, reflective of the German language. More recently, we have found some support for this "Italian hypothesis" from historical musicology. Specifically, Morrow (1997) argues that during the four decades spanning 1760 to 1798, German musical taste changed dramatically. According to Morrow, before this movement there was little value placed on instrumental music as a fine art in Germany. It received less attention and funding than vocal music and was unambiguously "Italian" in style and form. Not until the 1760s did German music critics and the listening public begin to lend more significance to instrumental music and its ability to both express "the unique essence of music" and emotionally sway decidedly German listening tastes. Indeed, "In the 1760s and early 1770s, this assumption took the form of labeling the Italianate style as 'comic' and opposing it with the Germanic adjective of 'serious'" (Morrow 1997, p. 53). According to Morrow, what followed was a striking rise in German nationalism that would shape German music for the next forty years. It is worth noting that Morrow often includes Austrian composers (e.g., Haydn, Mozart) in her discussion of "German" music since Austria had not yet gained independence from the Holy Roman Empire of the German Nation when this shift in musical taste occurred (Johnson, 1989). (Thus, for the remainder of this paper, references to 'German music' should be taken as shorthand for 'German/Austrian music.')

The Italian hypothesis for the pattern seen in Figure 1 leads to the idea of examining Italian musical nPVI from a historical perspective. In particular, based on Morrow's idea of a late 18$^{th}$-century transition in German music away from an Italian influence, one might expect to see some divergence between German and Italian composer nPVI values during this time. Motivated by this idea, the

current study compares historical patterns in German and Italian nPVI values in the ∼1600-1900 time frame. The basic approach is similar to that used in Patel and Daniele (2003b) and Daniele and Patel (2004) (henceforth, these two papers are referred to as the DP studies). In the DP studies, each composer was assigned a mean nPVI value and that value was plotted as a function of composer birth year. The resulting data were analyzed with linear regression to determine if there was a predictive relationship between birth year and nPVI value. The current study follows the same approach except that birth year is replaced by midpoint year (i.e., the year midway between birth and death years, see Method for details). Furthermore, the current study analyzes two cultures in historical perspective, not just one. Of particular interest to the current work is the behavior of the best-fitting regression lines for German and Italian music around the transition period mentioned by Morrow (1997) (i.e., from ∼1760-1800).

## Method

As in the DP studies, the musical materials for the current work were drawn from *A Dictionary of Musical Themes, Revised Edition* (Barlow & Morgenstern, 1983). This book contains music notation for ∼10,000 themes from Western European instrumental classical music. German, Austrian, and Italian composers were identified based on country of birth, native language, and language of the country where they spent the bulk of their careers. Thus, as noted above, G.F. Handel was excluded due to his prolonged residence in England. Similarly, the following composers were excluded for prolonged residence abroad (> 15 years in a foreign country whose predominant language differed from their native language): J. C. Bach (England), Boccherini (Austria & Spain), Cherubini (France), Locatelli (The Netherlands), Loeffler (France and the United States), Lully (France), Moszkowski (France), Platti (Germany), Scarlatti (Portugal and Spain), and Wolf-Ferrari (Switzerland and Germany).

nPVI values of musical themes for German, Austrian, and Italian composers in Barlow & Morgenstern (1983) were kindly provided by David Huron based on his digital encodings of note durations in these themes (Huron, 1995). In this encoding, notes are assigned relative duration values based on the conventions of Western music notation (e.g., a quarter note = 1, half note = 2, eighth note = 1/2, etc.). For the purpose of computing nPVI values for this study, any sequence of notes joined by a tie was assigned a single duration equal to the summed durations of the constituent notes, and if any rests occurred in a theme, the duration of each rest was added to the duration of the preceding sounded note.[1] As a result, the sequence of durations for each theme represented the duration of its interonset intervals or IOIs. (IOIs have often been used in empirical studies of musical rhythm.) Based on this encoding, one nPVI value was computed for each theme. (See the Appendix for the nPVI equation, an example of duration coding and nPVI calculation for musical themes, and a link to an online nPVI calculator.)

We applied one exclusion criterion in our selection of themes: any theme with grace notes (acciaccaturas) and/or appoggiaturas was excluded from the analysis. This decision was made for two reasons. First, there is considerable uncertainty about what duration should be assigned to such notes (these durations would depend on performance practice at the time the themes were composed). Second, and of more theoretical significance, we wanted to rule out the possibility that the rising nPVI pattern seen in German/Austrian music was simply due to an increasing tendency to notate ornamental figurations in this musical tradition. That is, if German/Austrian composers became more explicit about notating ornamentation between ∼1600-1900, and such ornaments tend to drive up the nPVI of musical themes (due to their short duration, which contrasts sharply with adjacent longer notes), then this could generate a rising nPVI pattern for purely 'notational' reasons.[2]

To qualify for inclusion in the current work, a composer had to have at least 15 musical themes available for analysis (the same cutoff as used in the DP studies). Each composer's mean nPVI value was computed from the nPVI of his individual themes, and this mean value and the composer's midpoint year were used as a data point in a historical nPVI graph.[3] (Midpoint year was defined as the mathematical average of the birth year and death year, and was chosen instead of birth year because it better represents when a composer was

[1] There are other possible ways of handling rests. For example, one could simply omit them from the sequence of durations used for nPVI computation. That approach was used in Daniele and Patel (2004), in which themes with internal rests were permitted as long as at there was at least one continuous sequence of seven or more notes without a rest. For such themes, the nPVI was computed for each continuous sequence of seven or more notes and the mean of these nPVI values was taken as the nPVI of the theme. Given the similarity of Daniele and Patel's (2004) results to the current results, we expect that redoing the current nPVI analysis with rests omitted would not impact our findings in a significant way.

[2] We are grateful to John Halle for this idea.

[3] A complete list of themes analyzed in the current work is available from the first author upon request.

active.) The resulting scatterplots—one for German/Austrian composers, one for Italian composers—were analyzed with linear regression to determine if any significant relationship existed between midpoint year and mean nPVI values. Since using a cutoff of 15 musical themes resulted in 21 German/Austrian and 9 Italian composers, we also conducted a subsidiary regression analysis of the Italian data after including 6 more Italian composers (achieved by lowering the cutoff for Italian composers from 15 to 5 themes), in order to determine if the Italian regression finding was robust when 15 composers were analyzed (rather than 9).

While the basic methods of the current work are based on the DP studies, the specifics differ in several ways, aimed at testing the robustness of the original DP results. First, the DP studies used numerous exclusion criteria in selecting themes for nPVI analysis. For example, marches were excluded due to their external rhythmic agenda, as were any themes from pieces that may have been vocally conceived (e.g., pieces with 'song' in their title; see Daniele & Patel 2004, Table 2, for a full list of exclusion criteria). In contrast, the only exclusion criterion in the current work concerns themes with grace notes/acciaccaturas/appoggiaturas, as noted above. Second, in the current work certain composers were excluded for 'migrational' reasons (as discussed above). Third, more German-speaking composers are included in the current analysis than in the DP studies (21 German and Austrian composers vs. 19 in the original DP studies). Fourth, in the DP studies, if a composer had more than 40 usable themes (i.e., themes that passed the exclusion criteria), 40 were randomly selected for nPVI analysis. In the current work, no upper limit is enforced: if a composer had more than 40 themes available, all were analyzed.

## Results

The historical nPVI data for German and Austrian composers are plotted in Figure 2, and Table 1 shows the corresponding list of individual composers and their nPVI values.[4]

Linear regression revealed a highly significant relationship between midpoint year and nPVI value (nPVI = 0.0974 * Midpoint Year – 132.4; $df = 19$; $r^2 = .52$, $p < .001$). This replicates the basic DP finding: nPVI showed a steady increase over time in German/Austrian music between the Baroque and Romantic eras. The slope of the best fitting regression line was a bit steeper than that of the original DP studies (.097 vs. .074), and the amount of variance explained is a bit higher ($r^2 = .52$ vs. .45). For the current purposes, the important point is that the basic pattern was replicated, despite a different sampling procedure.

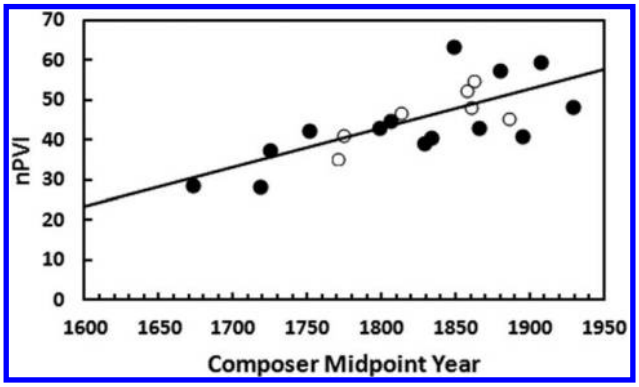


**FIGURE 2.** Musical nPVI of 14 German composers (closed dots) and 7 Austrian composers (open dots) as a function of composer midpoint year, based on the current analysis. Each dot represents the mean nPVI value for one composer (minimum number of themes per composer = 15).

The data for Italian composers are plotted in Figure 3a, and Table 2 shows the corresponding list of individual composers and their nPVI values. Unlike for German/Austrian music, linear regression indicated no significant predictive relationship between composer midpoint year and nPVI value (Italian nPVI = .0076 * Midpoint Year + 27.737; $df = 7$; $r^2 = .02$; $p = .72$). Since this finding was based on just 9 Italian composers (due to the 15-theme cutoff) we checked the robustness of the finding by lowering the theme cutoff to 5, which increased the number of Italian composers to 15. Once again, the linear regression of nPVI on midpoint year remained nonsignificant (Figure 3b, nPVI = 0.0248 * Midpoint Year − 3.4255; $df = 13$; $r^2 = .12$; $p = .21$).

Thus the current analysis shows that German and Italian music show different historical patterns of nPVI values in the ~1600-1900 time period. While German music shows a salient increase in nPVI during this period, Italian music does not show this pattern.

## Discussion

The current work introduces a new approach for the historical study of musical rhythm based on a recently developed tool for the empirical analysis of rhythm: the

[4] Regression equations reported in the text were computed using mean nPVI values with greater than four digits after the decimal point. For the purposes of presentation, mean nPVI values reported in the tables have been rounded to one digit after the decimal point.

**TABLE 1.** *German/Austrian Composer List.*

| Composer | Birth Year | Death Year | Midpoint Year | Mean nPVI | # themes | Nationality |
|---|---|---|---|---|---|---|
| Buxtehude | 1637 | 1707 | 1672 | 29.0 | 16 | German |
| Bach, J. S. | 1685 | 1750 | 1717.5 | 28.6 | 357 | German |
| Telemann | 1681 | 1767 | 1724 | 37.9 | 32 | German |
| Bach, C. P. E. | 1714 | 1788 | 1751 | 42.6 | 18 | German |
| Haydn | 1732 | 1809 | 1770.5 | 35.7 | 278 | Austrian |
| Mozart | 1756 | 1791 | 1773.5 | 41.7 | 460 | Austrian |
| Beethoven | 1770 | 1827 | 1798.5 | 43.4 | 490 | German |
| Weber | 1786 | 1826 | 1806 | 45.1 | 48 | German |
| Schubert | 1797 | 1828 | 1812.5 | 47.2 | 232 | Austrian |
| Mendelssohn | 1809 | 1847 | 1828 | 39.6 | 146 | German |
| Schumann | 1810 | 1856 | 1833 | 40.8 | 218 | German |
| Wagner | 1813 | 1883 | 1848 | 64.0 | 82 | German |
| Suppé | 1819 | 1895 | 1857 | 52.7 | 30 | Austrian |
| Bruckner | 1824 | 1896 | 1860 | 48.7 | 60 | Austrian |
| Strauss Jr., J. | 1825 | 1899 | 1862 | 55.1 | 95 | Austrian |
| Brahms | 1833 | 1897 | 1865 | 43.5 | 362 | German |
| Bruch | 1838 | 1920 | 1879 | 58.0 | 15 | German |
| Mahler | 1860 | 1911 | 1888.5 | 45.7 | 57 | Austrian |
| Reger | 1873 | 1916 | 1894.5 | 41.3 | 23 | German |
| Strauss, R. | 1864 | 1949 | 1906.5 | 60.0 | 111 | German |
| Hindemith | 1895 | 1963 | 1929 | 48.6 | 65 | German |

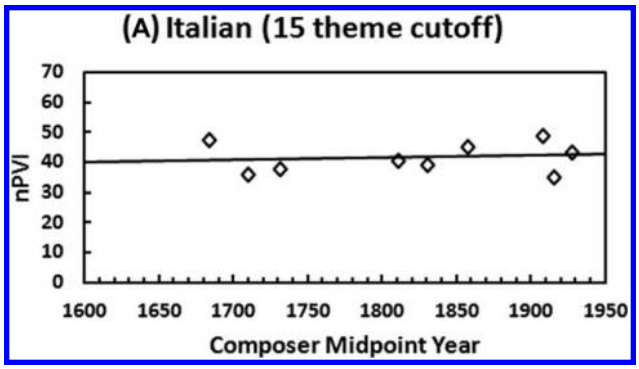


**FIGURE 3A.** Musical nPVI of 9 Italian composers as a function of composer midpoint year. Each dot represents the mean nPVI value for one composer (minimum number of themes per composer = 15).

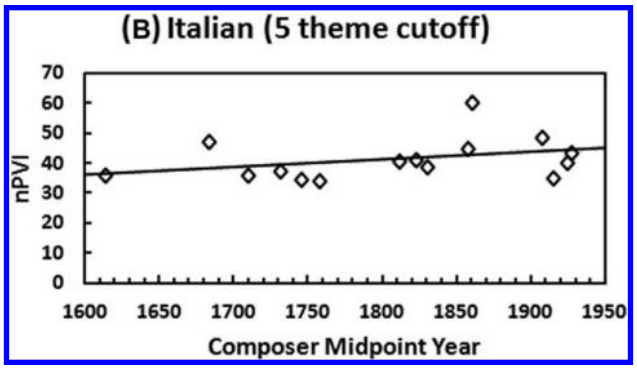


**FIGURE 3B.** Musical nPVI of 15 Italian composers as a function of composer midpoint year. Each dot represents the mean nPVI value for one composer (minimum number of themes per composer = 5).

nPVI equation. Using the nPVI to quantify the average degree of durational (agogic) contrast in a composer's work, a notable difference between German/Austrian and Italian instrumental classical music is revealed in the ~1600-1900 time frame: during this period, agogic contrast shows a salient increase in the former music but not in the latter. In more musical terms, this means that as time passed from the Baroque to Classical to Romantic eras, German and Austrian composers increasingly shifted toward themes with a greater degree of durational contrast between notes, while Italian composers did not show this pattern.

Figure 4 provides an illustration of these patterns, using themes analyzed in our study. Panel 4a shows a theme by Bach (composed in 1736), which has an nPVI value of 29.5, near the average nPVI value of all themes combined from the earliest three German/Austrian composers in our study (29.3). Panel 4b shows a theme from about 175 years later by Richard Strauss (composed in 1909-1910), with an nPVI value of 53.5, near the average nPVI value of all themes combined from the latest three German/Austrian composers in our study (54.1). The higher nPVI of the Strauss theme reflects the greater average durational contrast between adjacent

**TABLE 2.** *Italian Composer List.*

| Composer | Birth Year | Death Year | Midpoint Year | Mean nPVI | # themes |
|---|---|---|---|---|---|
| Frescobaldi | 1583 | 1643 | 1613 | 36.0 | 7 |
| Corelli | 1653 | 1713 | 1683 | 47.4 | 30 |
| Vivaldi | 1678 | 1741 | 1709.5 | 36.2 | 51 |
| Tartini | 1692 | 1770 | 1731 | 37.8 | 22 |
| Galuppi | 1706 | 1785 | 1745.5 | 34.8 | 8 |
| Nardini | 1722 | 1793 | 1757.5 | 34.4 | 5 |
| Paganini | 1782 | 1840 | 1811 | 40.6 | 26 |
| Donizetti | 1797 | 1848 | 1822.5 | 41.2 | 6 |
| Rossini | 1792 | 1868 | 1830 | 39.1 | 24 |
| Verdi | 1813 | 1901 | 1857 | 45.2 | 22 |
| Ponchielli | 1834 | 1886 | 1860 | 60.5 | 5 |
| Respighi | 1879 | 1936 | 1907.5 | 49.0 | 47 |
| Casella | 1883 | 1947 | 1915 | 35.3 | 17 |
| Pizzetti | 1880 | 1968 | 1924 | 40.6 | 8 |
| Malipiero | 1882 | 1973 | 1927.5 | 43.6 | 15 |

notes in this theme. Consider next panels 4c and 4d, which show themes by Vivaldi (published between 1720-1740) and Casella (composed in 1924), separated by about 190 years. The Vivaldi theme has an nPVI of 43.5, near the nPVI value of all themes combined from the earliest three Italian composers in our study (42.5); the Casella theme has an nPVI of 38.4, near the nPVI value of all themes combined from the last three Italian composers in our study (39.5). The two Italian themes have much more comparable nPVI values than do the two German themes. This result is observed despite the two themes having distinct rhythmic patterns, because the nPVI is only sensitive to the average degree of duration contrast between adjacent notes, and it is this feature that shows little historical change in Italian music. (The themes in Figure 4 were chosen to illustrate nPVI trends over time; it should be remembered that every composer in our study exhibits a range of nPVI values in his themes.)

Our results extend those of Patel and Daniele (2003b) and Daniele and Patel (2004) in two ways. First, we find that the rising nPVI pattern for German/Austrian instrumental classical music is robust. This is notable since the current work used different criteria for selecting composers and themes and also had a much larger sample of themes (nearly 3,200 German/Austrian themes, almost five times as many as the earlier studies). Second, we now show that this rising nPVI pattern is not a pan-European phenomenon, since it is absent in Italian music. Rather, it reflects something more specific in German music. It is also worth noting that within German music the rising nPVI pattern cannot be attributed to an increasing tendency to notate ornamental tones (such as grace notes) over historical time, as themes with such ornaments were excluded from the current analysis (as discussed in the Method section).

These findings raise interesting questions for musicology. For example, which type of historical pattern is more common in the classical instrumental music of Europe between ~1600-1900: an increasing degree of agogic contrast or a stable degree of agogic contrast? This question could be addressed by historical analysis of musical nPVI values from other cultures (e.g., French, English, Spanish, Russian), using the *Dictionary of Musical Themes* or other sources. It will be of particular interest to know if German music is unusual (or even unique) among European musical traditions in showing a salient increase in the average amount of agogic contrast from the Baroque to the Romantic eras. If this is true, why would it be the case?

Of particular interest for the current work is how our results relate to writings from historical musicology about the influence of Italian music on German music. Recall that Morrow (1997) argued that the late 1700s was an important transition period in German music, during which the influence of Italian music began to wane and a more specifically German aesthetic began

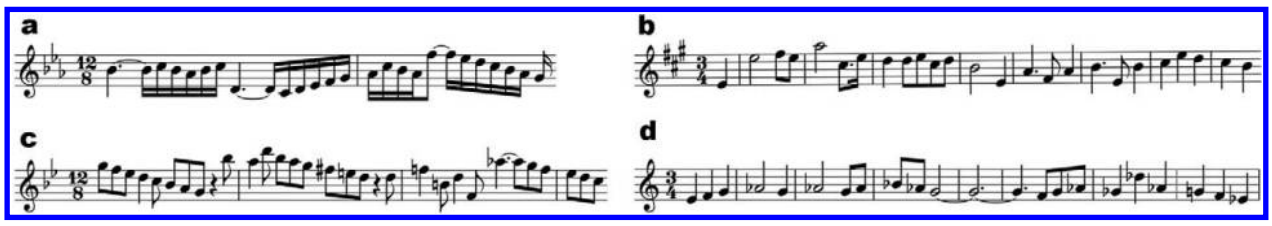


**FIGURE 4.** Four musical themes that illustrate historical trends in German/Austrian vs. Italian musical rhythm in terms of nPVI values. The themes by J. S. Bach (panel A, from Concerto #1 in C minor) and Richard Strauss (panel B, from Der Rosenkavalier) are separated by about 175 years, and the Strauss theme has a much higher nPVI value. The themes by Vivaldi (panel C, from Concerto Grosso in G minor) and Casella (panel D, from La Giara) are separated by about 190 years, but have similar nPVI values. See the text for details. (The Barlow & Morgenstern, 1983, codes for themes a-d are B69, S1443, V150, and C49, respectively.)

to emerge. More broadly, the late 1700s is recognized as a time when ideas of nationalism and cultural identity became more prominent in German thought; for example, in the philosophical writings of Herder (Barnard, 2003). If reflection of native language is one component of musical nationalism (Abraham, 1974), then one might expect German music during and after this transition period to increasingly reflect the high-nPVI, stress-timed German language. From this standpoint, it is interesting to note that the point at which the German nPVI regression line (shown in Figure 2) intersects with the Italian nPVI regression line (in Figure 3a) is the year 1783 (this date is determined by finding the points at which German and Italian regression line equations have an equal nPVI value). If the Italian regression line in Figure 3b is used, the German-Italian intersection point is a bit earlier, at year 1777. In both cases, the regression analyses suggest that German nPVI values rise above Italian nPVI values precisely during the period identified by Morrow as a period of dramatic change in German musical taste (1760-1798). Thus our finding supports Morrow's claim for a noticeable waning of Italian influence on German music in the later part of the 18th century.

It is important to note that our findings concern instrumental music. This choice is based on the research that gave rise to the current work (e.g., Daniele & Patel, 2004; Huron & Ollen, 2003; Patel & Daniele, 2003b), and from an interest in whether (and how) purely instrumental music reflects language patterns. The current findings naturally raise the question of whether similar patterns would be seen in vocal music. Given the findings of VanHandel and Song (2010), discussed in the introduction, it is by no means guaranteed that German/Austrian vs. Italian vocal music (e.g., art song, opera, or folk music) would show the same historical patterns as instrumental music. (For researchers interested in pursuing this question, Barlow & Morgenstern's, 1983, *Dictionary of Vocal Themes* and *Dictionary of Opera and Song Themes* may be of interest). Indeed, finding separate historical trajectories of nPVI over time between ~1600-1900 for instrumental and vocal music would raise further interesting questions for historical musicology. (It should be noted in passing that in the current work, unlike in the DP studies, all instrumental themes with vocal connotations, e.g., baracole, chanson, serenade, etc., were included in the analysis, as were themes from the instrumental parts of operas, e.g., *Don Giovanni*).

Another interesting issue for future research concerns the analysis of nPVI in actual musical performances (vs. in music notation). Would the patterns we report here be replicated if duration measurements were made on recorded performances? Addressing this question would require facing a number of complex issues. Since many of the pieces analyzed here have been recorded multiple times, which performance of each piece should be analyzed? How might recorded performances differ in rhythmic characteristics from performances that took place during the composer's lifetime (to which we typically have no access)? Despite these questions, we feel that historical nPVI studies of performance are worth pursuing in future research,

We believe that this study illustrates how the nPVI can be a useful tool in historical studies of music. In particular, the nPVI can reveal historical patterns in musical rhythm that can inform, refine, or test existing ideas in historical musicology. In the future, it may be possible to use historical nPVI analysis to examine other cases where musical and linguistic nPVI values seem to diverge. For example, Russian is considered a stress-timed language (Roach, 1982), but has a low average musical nPVI value in the ~1600-1900 time frame (Patel, 2008). This may suggest an influence from the music of other cultures with low-nPVI music. A historical explanation for this anomaly could be that the reign of Catherine the Great (1762-1796) motivated the Russian gentry to learn (and predominantly speak) French (Shlapentokh, 2008), a language (and music) with relatively low nPVI values (Patel & Daniele, 2003a). Further research with the nPVI on this topic and others will likely uncover historical patterns that might have otherwise escaped detection. We hope the current work helps foster these kinds of studies.

## Author Note

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## Appendix

This appendix shows the nPVI equation, provides examples of duration coding of two musical themes, and shows an example of nPVI computation for one of these themes.

### THE NPVI EQUATION

$$\mathrm{nPVI} = \frac{100}{m-1} \times \sum_{k=1}^{m-1} \left| \frac{d_k - d_{k+1}}{\frac{d_k + d_{k+1}}{2}} \right|$$

where m is the number of elements and $d_k$ is the duration of the kth element.

### EXAMPLES OF DURATION CODING AND NPVI COMPUTATION

The two themes below are reproduced from Patel and Daniele (2003a) and are meant to illustrate how duration values are coded from musical notation, and how the nPVI is computed from these values. The themes were not part of the current study, but come from the same source book as used in the current work, *A Dictionary of Musical Themes* (Barlow & Morgenstern, 1983).

The first theme is D122 in the Dictionary, from Debussy's Quartet in G minor for Strings (1st movement, 2nd theme) and the second theme is E72 in the Dictionary, from Elgar's Symphony No. 1, in A Flat, Opus 55 (4th movement, 2nd theme). For each theme, the relative duration of each note is shown below the musical staff. The first note is assigned a duration of 1, and the durations of the remaining notes are expressed as multiples or fractions of this value. These numbers are then used in the nPVI equation, as illustrated below the Elgar theme. The resulting nPVI value for the Elgar theme is 57.1, and for the Debussy theme, 42.2. If the reader wishes to replicate these results, or conduct original nPVI analyses of other musical material, enter the relative duration values of notes into the online nPVI calculator at: www.nsi.edu/~ani/npvi_calculator.html.

In the example below, the higher nPVI value of the Elgar theme compared to the Debussy theme reflects the greater degree of agogic contrast between successive notes in the Elgar theme (e.g., the contrast between dotted quarter-notes and following eighth notes).