Nonlinear Changes in the Rhythm of European Art Music: Quantitative Support for Historical Musicology

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Research has used the normalized pairwise variability index (nPVI) to examine relationships between musical rhythm and durational contrast in composers' native languages. Applying this methodology, linearly increasing nPVI in Austro-German, but not Italian music has recently been ascribed to waning Italian and increasing German influence on Austro-German music after the Baroque Era. The inapplicability of controlled experimental methods to historical data necessitates further replication with more sensitive methods and new repertoire. Using novel polynomial modelling procedures, we demonstrate an initial increase and a subsequent decrease in nPVI in music by 34 French composers. Moreover, previous findings for 21 Austro-German (linear increase) and 15 Italian composers (no change) are replicated. Our results provide promissory quantitative support for accounts from historical musicology of an Italian-dominated Baroque (1600-1750), a Classical Era (1750-1820) with Austro-German centres of gravity (e.g., Mannheim, Vienna), and a Romantic Era (1820-1900) with greater national independence. Future studies should aim to replicate these findings with larger corpora with greater historical representability.

In recent years, research has provided empirical support for the long-held belief among music historians that the prosody of composers' native languages is reflected in the rhythmic and melodic properties of their music. The authors who originated this research endeavor recently presented an approach for quantifying historical developments in musical rhythm and provided novel data testifying a linear increase in durational contrast in music by German and Austrian composers (henceforth referred to as "Austro-German music"), but not in Italian music during 1600-1900 (Daniele & Patel, 2013). In the present paper we replicate, refine, and extend these findings by including composers from France, another highly influential country in Central-European music. Primarily, we demonstrate the importance of applying more complex analytical strategies to pick up nonlinear trends in the historical analysis of musical rhythm. Future studies along these lines may inform the understanding of Western music history. First, however, we review previous literature.

Previous to empirical investigations, the postulated connection between language and music received particular articulation in relation to nationalist composers from the Romantic (and late-Romantic) Era such as Leoš Janáček (Wingfield, 1992), Modest Mussorgsky (Oldani, 2015), Richard Wagner (Trippett, 2012), and Béla Bartók (Fischer, 1995). However, related ideas could be found within the fields of ethnomusicology (Herzog, 1934; Nettl, 1993) and evolutionary biology (Brown, 2000), which suggests that this connection is of a much older date and perhaps even represents a universal trait of human musicality. Neuroscientific studies showing shared neural processing of aspects of language and music are consistent with this idea (Koelsch, 2012; Patel, 2008, 2011).

The English musicologist Gerald Abraham (1974) concluded that "[t]he nature of people's language inevitably affects the nature of its music not only in obvious and superficial ways but fundamentally" (p. 62). In a controversial essay, Jean-Jacques Rousseau (1753/2009) asserted that "every National Music derives its principal character from the language to which it belongs" (p. 145), and continued somewhat less bluntly "that there is neither meter nor melody in French Music, because the language is not susceptible to them" (p. 174). Nevertheless, apart from a few early and exploratory endeavors (Dell, 1989; Hall, 1953; Wenk, 1987), until

TABLE 1. *Vocalic nPVI for spoken German, French and Italian According to the Studies by Ramus (2002), Grabe and Low (2002), Russo and Barry (2008), and Arvaniti (2012)*

	nPVI		
Study	*French*	*German*	*Italian*
Ramus (2002)	49.3	–	46.0
Grabe & Low (2002)	43.5	59.7	–
Russo & Barry (2008)	–	52.5	–
Arvaniti (2012)	–	53.6	48.5
Mean	**46.4**	**55.3**	**47.25**

about a decade ago no empirical support for this assumption existed due to a lack of measures to quantify prosodic structure that were applicable to both music and language.

An empirical tool for tackling the hypothesized connection between language and music first manifested itself in the field of psycholinguistics. Here, the normalized pairwise variability index (nPVI) was invented as a means of classifying languages with different patterns of subsequent vowel durations (see Appendix A for details on computing nPVI in language and music). Generally, "stress-timed" languages such as British English, German, Dutch, and Scandinavian show relatively high durational contrast between successive vowels, which results in high nPVI values whereas "syllable-timed" languages such as Italian, Spanish, and French show lower durational contrast between successive vowels which results in lower nPVI values (Deterding, 1994; Ling, Grabe, & Nolan, 2000; Low, 1994, 1998). This pattern can be seen in Table 1. In critique of this categorical distinction, the use of a continuous nPVI scale in itself testifies to the greater validity resulting from regarding languages as points on a continuum, thus allowing for different degrees of stress- and syllable-timing (Ramus, 2002). Further critics have argued that stress- and syllable-timing represent mutually orthogonal dimensions, but they also admit that this point primarily applies to more ambiguous languages like Estonian and Spanish (Nolan & Asu, 2009), which are not considered in the present study.

In the musical domain, researchers have explored the potential of nPVI as a general tool for musical rhythm analysis (London & Jones, 2011; Toussaint, 2012) and for characterizing compositional styles of individual composers (VanHandel & Song, 2009, 2010). Patel and Daniele (2003a) reported significantly higher degrees of rhythmic variability in music by English than by French composers who were born in the 19th century and died in the 20th century. nPVI values were computed directly from note durations in the scores, and very strict sampling criteria were used excluding themes consisting of less than 12 notes, themes with grace notes, fermatas, internal pauses, and titles referring to song, stylized dances, "exotic" and children's music. Patel and Daniele (2003a) argued that their discovery was a result of English being a stress-timed and French being a syllable-timed language and that "an empirical basis for the claim that spoken prosody leaves an imprint on the music of a culture" (p. B35) had now been established.

This finding has later been replicated. For instance, Hannon (2009) showed a comparable difference between nPVI values in 75 English and 75 French children's songs. Focusing on dialectal units rather than distinct languages, McGowan and Levitt (2011) found correspondences between linguistic nPVI in English dialects spoken in Scotland, Ireland, and Kentucky and musical nPVI measured from expressive performances of reels on the fiddle.

To obtain a larger sample size than the original one used by Patel and Daniele (2003a), Huron and Ollen (2003) applied less stringent sampling criteria and thus expanded their dataset to include the complete first edition of the *Dictionary of Musical Themes* (Barlow, Morgenstern, & Erskine, 1948) comprising melodies by composers of 14 different European nationalities. A slightly less significant difference between French and English musical nPVI values emerged, possibly due to the less stringent inclusion criteria. In this study, Austro-German music was shown to have a lower mean nPVI value than music by Italian and French composers speaking syllable-timed languages. This discovery was highly unexpected given the fact that German and Austro-German are regarded as stress-timed languages.

This apparent paradox instigated a new stream of research into the historical development in musical nPVI, to which the present study contributes. Patel and Daniele (2003b) quickly responded to Huron and Ollen (2003), demonstrating a significant increase over time in nPVI values of 20 German and Austrian composers born between 1637 and 1895. They suggested that this represents a decreasing influence of Italian music on Austro-German music during that period, which has indeed been acknowledged by music historians (Hanning, 2002). This influence was great during the Baroque period, but decreased in the course of the Classical and subsequent Romantic Eras.

This inference, however, is not entirely watertight. First, since historical data cannot be subjected to randomized, experimentally controlled trials, we cannot obtain absolute evidence for the direction of causality,

nor of causality itself. Second, Patel and Daniele's (2003b) "Italian influence hypothesis" is a post hoc hypothesis, proposed during the course of the study to account for unexpected results, rather than being developed *a priori* (VanHandel, 2005, p. 45). Since the hypothesis is based on the data itself, we cannot be sure of its general validity. Third, both linguistic and stylistic influences on musical rhythm may exist simultaneously and sometimes even run counter to one another (Patel & Daniele, 2003b). In these cases it becomes extremely difficult–if not impossible–to disentangle one type from the other.

These limitations are difficult to address methodologically. The best available solution is to attempt to replicate the effects through analysis of musical and linguistic data from other nationalities. Whereas spoken linguistic material is not available from before the emergence of phonographic recordings, historical musical material can more easily be accessed in terms of musical scores. Daniele and Patel (2013) recently did this to show that Italian composers exhibit different historical patterns of nPVI from those of Austro-German composers. Contrary to the findings for Austro-German music, which they replicated with a much larger sample size, nPVI of Italian composers did not increase in the 1600-1900 time window. This was taken as support for the "Italian influence hypothesis."

Given the accumulating evidence that durational contrast in music depends on stylistic as well as linguistic influences, historical nPVI analyses should be able to demonstrate transitions between the stylistic periods such as the Baroque, Classical, and Romantic Eras. Daniele and Patel (2013) have already found a general distinction between Austro-German and Italian music, which could be taken as an indicator of the transition from the Italian-dominated Baroque to the Classical Era with more Central-European centres of gravity like Mannheim (Würtz & Wolf, 2015, section 2) and Vienna. However, the subsequent transition to Romanticism with its increasing focus on national identities, which was inherent to the 19th century, has yet to be studied quantitatively in terms of nPVI.

The present study aims to address this gap in previous research by studying the historical development in nPVI in music by French composers. Like Italy, Austria, and Germany, France is a large European country with considerable linguistic and cultural influence, which is often associated with a particularly strong national identity and which must be included in a full historical account of Western music history in the period 1600-1900. At times during this period, the French capital Paris was one of the leading centres of European musical life

(Anderson et al., 2015). But what would we expect from the development in nPVI in French instrumental music during this period?

The article on "France" in *Oxford Companion to Music* suggests possible hypotheses (Arnold & Langham Smith, 2015). First, France is described as being host to a continuous, stubborn nationalism throughout all three relevant centuries. In summary, "France has resisted foreign intrusions, be they Italian or German—and when they have been too strong to discount entirely, they have been influenced considerably by French taste" (Arnold & Langham Smith, section 10). This suggests that we should expect historical stability in musical nPVI, just as Daniele and Patel (2013) reported for Italian music.

Second, while subscribing to the notion of a general pattern of stubborn, French nationalism, the very same article describes a "new wave of internationalism" starting from around 1770 (Arnold & Langham Smith, 2015). Furthermore, it is mentioned that especially piano music, symphonies, and chamber music by German and Austrian composers were performed increasingly often in public concert houses and private salons in Paris during the subsequent century. Accordingly, Mongrédien and Pauly (1996, p. 315) emphasize that the "[r]elations between France and Germany in the area of music [. . .] were probably closer than one has been led to believe." In this light, an alternative hypothesis would be that nPVI in French music would follow the historical increase characteristic of Austro-German music during this period–not due to waning Italian influence, but rather due to increasing Austro-German dominance.

Third, if we continue into the second half of the 19th century, VanHandel (2005, 2006) has already found a significant decrease in durational contrast for French vocal music grouped in decades of composition from 1840 to 1900.[1] A third alternative hypothesis would thus be that this historical development would extend further back into history, manifesting itself as a general decrease in French musical nPVI over time.

Fourth, a more convincing possibility would be a combination of the two previous hypotheses such that durational contrast in French music diverted stylistically from Italian music in the Classical Era following the

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[1] Note that VanHandel uses weighted phrase-nPVI (pnPVI) where nPVIs for different phrases are weighted by the number of events, justified by observation that the unit of isochrony in language is reset for each phrase. Since, however, the current themes were very short, the counting beat was not expected to change, thus making pnPVI and nPVI values comparable as substantiated by VanHandel (2006) herself.

Austro-German increase, and subsequently decreased again as an effect of budding nationalism during the Romantic Era. Importantly, this prediction of an initial increase and a subsequent decrease necessitates a methodological improvement in terms of polynomial modelling where previous studies have only used linear modelling procedures.

In addition to testing the four hypotheses stated above regarding historical developments in French musical nPVI, we will attempt to reproduce Daniele and Patel's (2013) findings relating to Austro-German and Italian music. We will do so using more sophisticated techniques that enable us to identify troughs and peaks in musical nPVI in Europe during 1600-1900, which previous studies could potentially have missed. The testing of the third and the fourth hypothesis will, moreover, investigate whether the decreasing tendency in nPVI observed by VanHandel (2005, 2006) for the vocal repertoire generalizes to instrumental themes, thus making it a candidate for a general stylistic trait of French music.

In sum, the present research constitutes a replication, extension, and methodological refinement following closely in a line of previous research. Consequently, we use a dataset that is directly comparable to that used in previous research, Barlow, Morgenstern, and Erskine's (1983) *A Dictionary of Musical Themes*. This choice of corpus has advantages and disadvantages which will be addressed in the discussion.

Materials and Methods

CHOICE OF INCLUSION CRITERIA

Considerable attention was paid to the process of selecting composers and sampling amongst their themes. Since Daniele and Patel (2013) was published after this work had been conducted, we use the criteria from the earlier study by Patel and Daniele (2003b) for the selection process; future work should confirm that the results generalize to the less stringent inclusion criteria of Daniele and Patel (2013). However, for the subsequent analysis of the data, we have attempted to follow Daniele and Patel (2013) as closely as possible. We did have to adjust these criteria slightly for three reasons: first, the inclusion of music from all stylistic periods focusing on a country with a somewhat different ornamental practice from the one in Germany and Austria (Kreitner, Ng, & Schulenberg, 2015, sections 7-8); second, due to certain ambiguities as regards methodology in the previous articles; and finally, in a few cases we had to decide upon and specify even clearer criteria. All selections of composers and themes used the 1983-edition of *A Dictionary of Musical Themes* (Barlow et al., 1983).

INCLUSION CRITERIA FOR COMPOSERS

Eligible composers were defined as native speakers of French who lived and worked in France.[2] Hence, Belgian composers who were native speakers of French, but did not live and work in France (Théophile Ysaÿe, Joseph Jongen, and Henri François Joseph Vieuxtemps) were excluded from this study whereas André Grétry (who was born in Liège, but studied in France and took French nationality), Guillaume Lekeu (who was born in Belgium, but studied in France), César Franck (who was born in The Netherlands, but soon moved to Paris and took French nationality), and Arthur Honegger (who had Swiss nationality, but was born and lived most of his life in France) were included. We focused on composers whose "midpoint year," corresponding to the mathematical average of a composer's birth year and death year, was 1600-1950. Because, unlike Austro-German composers, many French composers were only represented by a few themes in the musical dictionary, the less stringent inclusion criterion of five eligible themes was used here (cf. Patel and Daniele, 2003a; unlike Patel & Daniele, 2003b, who used a criterion of 15).

Regarding our attempt to replicate VanHandel's (2005) findings in the instrumental repertoire relating to decreasing durational contrast over time in the French vocal repertoire composed from 1840-1900, it is important to note that VanHandel used the year of composition, which we did not have access to here. Thus, we included composers born in 1820-1900, motivated by our expectation that major instrumental works tend to occur after the composer's 20th birthday and because there is no theoretical reason to assume that the trend identified by VanHandel would not continue beyond the specific range investigated.

INCLUSION CRITERIA FOR MUSICAL THEMES

We define restrictive criteria for the selection of musical themes to avoid possible bias caused by explicit stylistic factors unrelated to linguistic influences. Accordingly, themes that referred to works and styles of other composers, were inspired by foreign influence, or were based on an external rhythmic agenda such as marches, rag-times or stylized dances (e.g., sarabande, courante, minuet, allemande, rigaudon, forlana, gavotte, passepied, passacaglia, siciliano/sicilienne, contredance, carmagnole, valse, czardas, farandole, bolero, pavane, gigue,

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[2] Despite lack of complete and unambiguous knowledge of native speaker status for all composers, we consider our approach both reliable and consistent with previous procedures (e.g., Patel and Daniele, 2003a; 2003b).

mazurka) were excluded (for an overview of these exclusion criteria, see Table 2 in Daniele and Patel, 2004). Also, since nPVI is a normalized mean of variability in musical themes, nPVI values risk becoming distorted if there are too few notes in a theme. Consequently, themes with less than 12 notes were excluded.

In acknowledgment of inconclusive findings relating to the possible influence of linguistic nPVI on durational contrast in music with lyrics (Sadakata, 2006; Sadakata, Desain, Honing, Patel, & Iversen, 2004; VanHandel, 2006; VanHandel & Song, 2009, 2010), themes whose title referred to kinds of song were initially excluded from the present study (e.g., serenades, chorales, arias, barcarolles, berceuses, alboradas, tunes, chants, and songs). However, due to the dominance of the operatic genre in French music around the early 19th century, a total exclusion of opera themes even when performed instrumentally would yield no data from composers with midpoint years between 1733 (Louis-Claude d'Aquin) and 1836 (Hector Berlioz). Therefore, nPVI values for these operatic composers were computed in cases where they were represented in Barlow et al. (1983) by at least five eligible themes after inclusion of instrumental themes from their operas.[3] Analyses were conducted for French composers both excluding and including the instrumental opera corpus.

ENCODING OF MUSICAL THEMES

Now we turn to the encoding of the selected musical themes. First, internal pauses were counted as part of the previous note (cf. Daniele & Patel, 2013; unlike Patel & Daniele, 2003a). Since the use of pauses in Western art music is influenced by musical style and by individual notational practice, this allows us to analyze themes over a wide historical period.

Second, all themes containing grace notes (i.e., notes in smaller print whose duration is unmeasured and does not count towards the bar length as specified in the time signature) were omitted because the execution of these is difficult to define precisely (Seletsky, 2015)[4] and because previous studies have shown that grace notes

are unlikely to have any effects on the relationship with language (VanHandel, 2005). However, themes containing ornament signs (e.g., trills, mordents) were included so as not to omit large quantities of themes from the Baroque Era where notation and execution of such embellishments was rather arbitrary; i.e. some composers chose to notate many such ornaments explicitly, and others supposed that the performer would add ornaments intuitively when reading the score (Kreitner et al., 2015, section 7). Thus, in the current study ornament signs were simply ignored by counting principal notes in terms of their nominal value when calculating nPVI values of these themes (by comparison, Daniele & Patel, 2013, ignored such themes altogether).

Third, because the significance of fermatas is somewhat ambiguous, we excluded the relatively few themes containing internal or initial fermatas. In cases where the fermata was on the last note, the themes were included using the notated value for the final note.

Fourth, in themes with repeat signs (i.e., double bars with dots), the complete sounding theme was entered into the nPVI calculation regardless of the manner of notation. That is to say, if a single bar was repeated, the notes of this bar were included twice.

The sampling criteria described above resulted in a sample of 649 themes by 34 French composers including the instrumental opera corpus and 576 themes by 27 French composers excluding the instrumental opera corpus. The exact names and midpoint years of composers as well as their average nPVI values are shown in Table 2. *A Dictionary of Musical Themes* (Barlow et al., 1983) did not provide data for any French composers with midpoint years prior to 1700, but otherwise our sample spanned the full range of midpoint years from 1600 to 1950 that was also used by Daniele and Patel (2013). For the re-analysis of data from other nationalities, nPVI values for 21 German/Austrian composers (3195 themes) and 15 Italian composers (293 themes) were taken from Daniele and Patel (2013).

Results

FRENCH MUSIC

Table 2 shows the results from the nPVI calculations. Composers have been sorted chronologically according to midpoint year. Sample sizes, mean nPVI, and standard errors are shown both excluding and including the instrumental opera corpus.

Before proceeding to test our main hypotheses, we assess whether to include the instrumental opera corpus in the subsequent analysis. As is evident from Table 2, for the composers who have separate nPVI values excluding

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[3] Huron and Ollen (2003) used the complete dictionary, thus similarly including instrumental opera themes. Unlike previous studies of nPVI in French and German vocal music (VanHandel, 2005; VanHandel & Song, 2009; 2010), we did, however, not assess whether librettists shared the native language of their associated composer.

[4] Cf. Seletsky (2005) on grace notes: "Speed of execution depends on the nature of the ornament they represent and to some extent on the tempo of the music but, except in the case of appoggiaturas, grace notes are usually performed lightly and very quickly". This practice was consistent with Daniele and Patel (2013).

TABLE 2. *Mean nPVI for French Composers*

Composer	Years	Midpoint year	Excluding instrumental opera corpus			Including instrumental opera corpus		
			No. themes	Mean nPVI	SE	No. themes	Mean nPVI	SE
Couperin, François	1668-1733	1700.5	42	31.37	3.75	42	31.37	3.75
Rameau, Jean-P.	1683-1764	1723.5	12	20.36	4.50	13	20.45	4.50
Leclair, Jean-Marie	1697-1764	1730.5	5	28.44	13.53	5	28.44	13.53
d'Aquin, Louis-Claude	1694-1772	1733	6	28.21	10.17	6	28.21	10.17
Grétry, André	1741-1813	1777	0	N/A	N/A	5	35.07	7.20
Boieldieu, François-A.	1775-1834	1804.5	0	N/A	N/A	5	30.37	10.53
Auber, Daniel	1782-1871	1826.5	0	N/A	N/A	11	49.97	9.08
Adam, Adolphe	1803-1856	1829.5	0	N/A	N/A	6	36.61	5.66
Berlioz, Hector	1803-1869	1836	23	51.92	5.47	37	51.89	4.57
Thomas, Ambroise	1811-1896	1853.5	0	N/A	N/A	14	39.32	6.75
Gounod, Charles-F.	1818-1893	1855.5	0	N/A	N/A	7	39.22	6.98
Franck, César	1822-1890	1856	60	54.54	4.06	60	54.54	4.06
Bizet, Georges	1838-1875	1856.5	14	39.47	6.28	18	38.02	5.30
Lalo, Édouard	1823-1892	1857.5	9	63.17	8.85	12	64.37	6.69
Delibes, Léo	1836-1891	1863.5	8	46.63	11.29	10	40.13	10.13
Chabrier, Emmanuel	1841-1894	1867.5	0	N/A	N/A	10	41.28	6.98
Massenet, Jules	1842-1912	1877	14	44.68	4.62	18	46.49	4.85
Chausson, Ernest	1855-1899	1877	22	47.39	3.52	22	47.39	3.52
Saint-Saëns, Camille	1835-1921	1878	85	37.73	2.32	85	37.73	2.32
Lekeu, Guillaume	1870-1894	1882	11	51.56	4.15	11	51.56	4.15
Fauré, Gabriel	1845-1924	1884.5	41	47.16	4.08	41	47.16	4.08
Debussy, Claude	1862-1918	1890	61	43.80	3.33	61	43.80	3.33
d'Indy, Vincent	1851-1931	1891	21	53.77	7.27	21	53.77	7.27
Satie, Éric	1866-1925	1895.5	7	32.54	2.18	7	32.54	2.18
Pierné, Henri	1863-1937	1900	6	39.60	6.12	6	39.60	6.12
Dukas, Paul	1865-1935	1900	6	64.91	19.60	6	64.91	19.60
Roussel, Albert	1869-1937	1903	21	43.41	4.57	21	43.41	4.57
Ravel, Maurice	1875-1937	1906	45	43.17	4.36	45	43.17	4.36
Inghelbrecht, D.-É.	1880-1965	1922.5	10	41.95	6.06	10	41.95	6.06
Honegger, Arthur	1892-1955	1923.5	11	40.46	6.08	12	39.22	5.68
Ibert, Jacques	1890-1962	1926	14	36.34	5.38	14	36.34	5.38
Poulenc, Francis	1899-1963	1931	7	27.92	4.43	7	27.92	4.43
Milhaud, Darius	1892-1974	1933	11	35.06	5.26	11	35.06	5.26
Auric, Georges	1899-1983	1941	7	51.97	6.80	7	51.97	6.80

Note. For composers with no eligible instrumental opera themes, the results excluding the opera corpus have been copied to the rightmost columns.

and including the instrumental opera corpus, the mean nPVI values are rather similar (i.e., Rameau, Berlioz, Lalo, Delibes, Massenet, Honegger). To assess these differences, we regressed *corpus* (two levels: instrumental, operatic) and *birth year* on mean nPVI for composers with either only instrumental or only operatic themes (using a backward stepwise procedure with a removal criterion corresponding to the probability of $F \geq 0.10$).

Whereas the full model, including both corpus and birth year as predictors, did not account for a significant proportion of the variance in mean nPVI, $R^2 = .17$, $R^2_{adj.} = .10$, $F(2, 25) = 2.49$, $p = .10$, a reduced model was preferred, including only birth year, $R^2 = .16$, $R^2_{adj.} = .13$, $F(1, 26) = 5.05$, $p = .03$. Therefore, we increase

our sample size by including the instrumental opera corpus in subsequent analyses. It is worth noting, however, that the low R^2 values, even in the latter case, suggest that linear modelling may not be the optimal way of capturing the historical development in musical nPVI.

To test our main hypotheses, we fitted four polynomial models to our data. Table 3 shows a model comparison for these functions ranging from a simple 1st-order polynomial (i.e., linear function) to a more complex 4th-order polynomial. All these models explained a significant proportion of the variance in mean nPVI over time. Nevertheless, the adjusted R^2 figures showed that the variance accounted for did not increase when adding

TABLE 3. *Polynomial Functions Fitted to Mean nPVI for French Composers Including the Instrumental Opera Corpus*

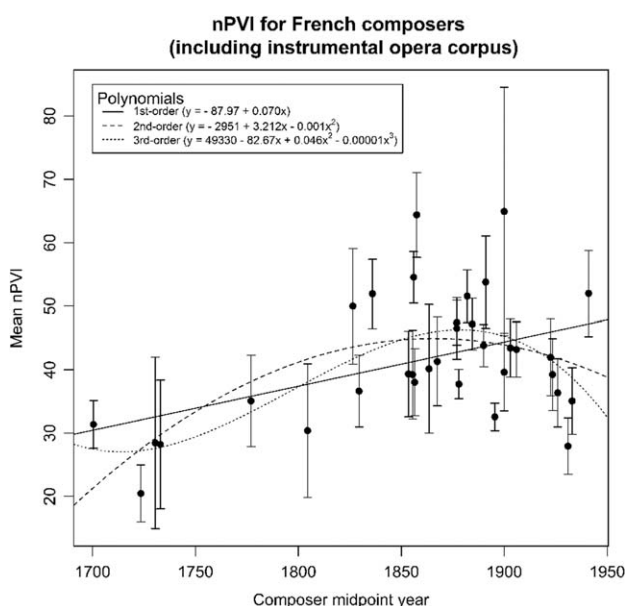| Polynomial	Adj. R^2	F	p	AIC	BIC
1st-order[a]	.17	7.51	.01	251.37	255.95
2nd-order[a]	.28	7.56	.002	247.03	253.14
3rd-order[a]	.31	5.88	.003	246.83	254.46
4th-order	.31	4.62	.005	247.78	256.94

[a]Plotted in Figure 1.

FIGURE 1. Scatterplot of mean nPVI plotted against composers' midpoint years (including the instrumental opera corpus). A first-order (i.e., linear) polynomial, a second-order polynomial, and a third-order polynomial were fitted to the data. Error bars represent standard errors for the individual composers.

more parameters beyond the 3rd-order polynomial. Consequently, the 4th-order polynomial was not included in the plot of the functions in Figure 1.

Hence, in support of our hypothesis, there was a clear advantage of fitting higher-order polynomials rather than a linear function corresponding to nearly a twofold increase in variance accounted for. Comparing the 2nd- or 3rd-order polynomial, the adjusted R^2 and *Akaike's Information Criterion* (AIC) figures suggested a preference for the more complex model, whereas the more conservative *Bayesian Information Criterion* (BIC), which entails a larger penalty term to avoid over-fitting, suggested a preference for the simpler 2nd-order polynomial.

This question was resolved by running two ANOVAs to test for significant changes as an effect of adding more parameters. These analyses showed that the step

from a 1st-order (i.e., linear) to a 2nd-order polynomial did indeed increase the fit significantly, $F(1, 31) = 6.35$, $p = .02$, whereas this was not the case for the next step from a 2nd-order to a 3rd-order polynomial, $F(1, 30) = 2.01$, $p = .17$. Therefore, we prefer the more parsimonious 2nd-order polynomial, which was also consistent with the notion of a single transition from increasing to decreasing mean nPVI.

Strictly speaking, the multiple regression analysis reported in section *Austro-German Music* did not test whether the exclusion of the instrumental opera corpus would change our preference for the 2nd-order polynomial. Therefore, similar polynomial fitting was performed for the dataset excluding the instrumental opera corpus (see Table 4). Once again, the step from 1st-order to 2nd-order polynomial resulted in a significant increase in the proportion of variance explained, $F(1, 24) = 10.24$, $p < .01$. Because, in this case, the 2nd-order polynomial outperformed the 3rd-order polynomial both in terms of adjusted R^2, p value, and the information criteria (AIC and BIC), there was no apparent reason to test this model. However, the 4th-order polynomial exceeded the 2nd-order polynomial in terms of variance explained and AIC so we confirmed that adding two further parameters to the latter did not increase the fit significantly, $F(2, 22) = 1.79$, $p = .19$. This supports our conclusion concerning a single point of deflection in nPVI values for instrumental music by French composers with midpoint years ranging from 1700 to 1941.

In addition to the polynomial fitting reported above, we proceeded to perform traditional linear modelling on specific ranges of composer birth years. These analyses served the purpose of replicating findings from earlier studies, where similar techniques were used, thus allowing direct comparison of effect sizes. First, the significant 1st-order polynomial reported above for French composers for the full range of midpoint years from 1700 to 1941 (see Table 3) is comparable to the linearly increasing musical nPVI previously reported by Daniele and Patel (2013) for Austro-German composers born in 1637-1895. Patel and Daniele's effect size for Austro-German music, $r^2(18) = .49$, $p < .01$, was indeed notably greater than that for French music, but this is unsurprising given the late decrease in French musical nPVI evident from the analysis above.

Second, we tested whether VanHandel's (2005, 2006) finding of a decrease in musical nPVI in French vocal music composed from 1840-1900 could be replicated for the instrumental repertoire with a sample extending into the 20th century. In this analysis we used birth years from 1820-1899 as an approximation of the composition years from 1840-1900 originally used by

TABLE 4. *Polynomial Functions Fitted to Mean nPVI for French Composers Excluding the Instrumental Opera Corpus*

Polynomial	Formula	Adj. R^2	F	p	AIC	BIC
1st-order	$y = -84.22 + 0.068x$	.15	5.51	.03	204.41	208.30
2nd-order	$y = -4281 + 4.686x - 0.001x^2$	.38	8.89	.001	196.82	202.00
3rd-order	$y = 29284 - 50.314x + 0.029x^2 - 0.000005x^3$	.36	5.94	.004	198.30	204.78
4th-order	$y = 1901765 - 4169x + 3.424x^2 - 0.0012x^3 + 0.0000002x^4$	.42	5.64	.003	196.74	204.52

VanHandel. There was indeed a negative correlation between birth year and mean nPVI, but it did not reach significance, $r(21) = -.34$, $p = .11$. This effect was also considerably smaller than that reported by VanHandel, $r^2 = .68$, $p = .02$. Thus, although polynomial modelling indicates a late divergence from a monotonic linear increase in French nPVI over time, this linear analysis shows that the late development cannot be characterized as a simple linear decrease.

Finally, to confirm that the effect size for the general historical increase in nPVI was diminished in comparison with that previously reported for Austro-German music, due to the subsequent decrease for birth years after 1820, a separate follow-up analysis was conducted for birth years preceding 1820. This analysis showed a strong positive correlation between birth year and mean nPVI, $r(9) = .73$, $p = .01$, the size of which was identical to that reported by Daniele and Patel (2013) for Austro-German music. The two resulting linear functions are shown in Figure 2.[5]
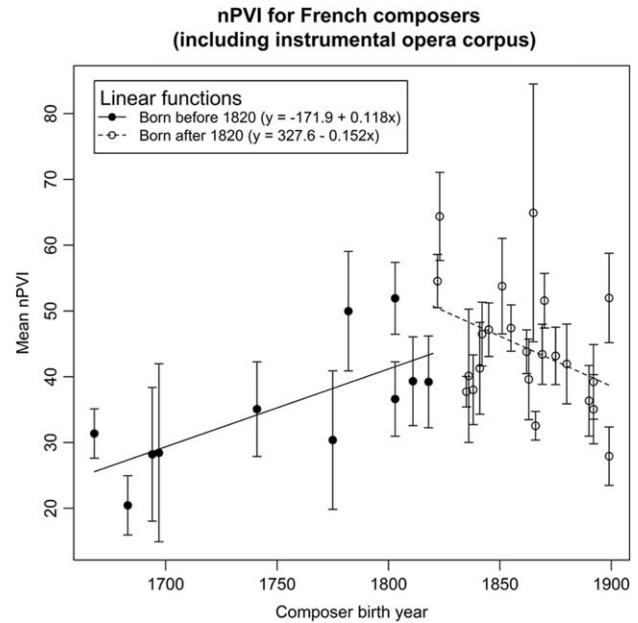
AUSTRO-GERMAN MUSIC

In the last two results sections we report re-analyses of Daniele and Patel's (2013) data for Austro-German and Italian composers to test the validity of previous findings in light of the availability of the polynomial modelling procedures introduced here. Table 5 and Figure 3 show the outcome of this analysis for Austro-German music. Although all polynomials explained a significant proportion of the variance in musical nPVI, the adjusted R^2 values did not increase beyond the simple linear model. Moreover, an ANOVA showed no significant improvement when adding a second parameter to the 1st-order model, $F(1, 18) = 1.01$, $p = .33$. Thus, we replicate and confirm Daniele and Patel's (2013) finding of a linear increase in nPVI for Austro-German music.

ITALIAN MUSIC

For the Italian composers, none of the polynomial functions significantly predicted mean nPVI (Table 6). The

FIGURE 2. Scatterplot of mean nPVI for music by French composers plotted against composers' birth years (including the instrumental opera corpus). To replicate previous findings for Austro-German instrumental music (Daniele & Patel, 2013; Patel & Daniele, 2003b) and for French vocal music (VanHandel, 2005, 2006), respectively, two linear functions were fitted to the two ranges of composer birth years 1668-1820 and 1820-1899.

TABLE 5. *Polynomial Functions Fitted to Mean nPVI for Austro-German Composers*

Polynomial	Adj. R^2	F	p	AIC	BIC
1st-order[a]	.49	20.14	.0003	142.58	145.72
2nd-order[a]	.49	10.58	.0009	143.43	147.61
3rd-order[a]	.48	7.02	.003	144.83	150.05
4th-order	.44	4.98	.008	146.77	153.04

[a]Plotted in Figure 3.

very low or, in the case of second- and third-order polynomials, negative adjusted R^2 values indicate that the average of the outcome variable provides a better fit to the data than any of the fitted polynomial functions. Based on the higher adjusted R^2 and lower information

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[5] Note that fitting two separate linear functions to birth year ranges before and after 1820 is suboptimal because transitions in historical nPVI are likely to be more gradual.
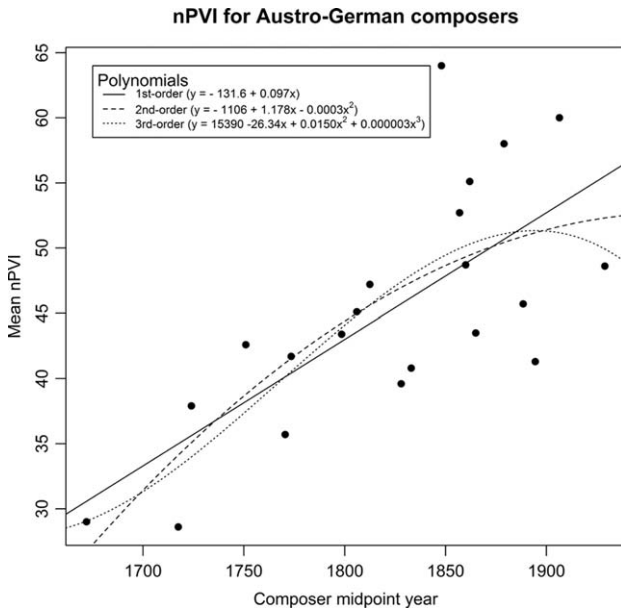
FIGURE 3. Scatterplot of mean nPVI for music by Austro-German composers plotted against midpoint years. A first-order (i.e., linear) polynomial, a second-order polynomial, and a third-order polynomial were fitted to the data.
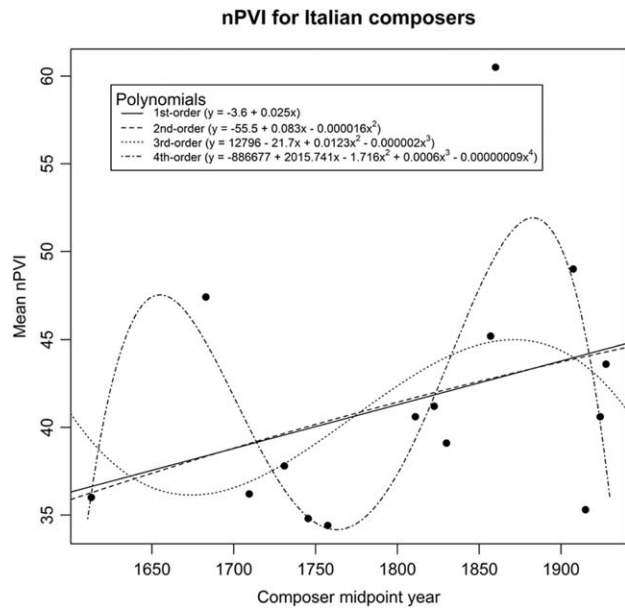

FIGURE 4. Scatterplot of mean nPVI for music by Italian composers plotted against midpoint years. A first-order (i.e., linear) polynomial, a second-order polynomial, a third-order polynomial, and a fourth-order polynomial were fitted to the data.

TABLE 6. *Polynomial Functions Fitted to Mean nPVI for Italian Composers*

Polynomial	Adj. R^2	F	p	AIC	BIC
1st-order[a]	.05	1.75	.21	103.95	106.08
2nd-order[a]	−.03	0.81	.47	105.95	108.78
3rd-order[a]	−.04	0.84	.50	106.76	110.30
4th-order[a]	.37	3.04	.07	99.92	104.16
5th-order	.33	2.39	.12	101.18	106.14

[a]Plotted in Figure 4.

criteria values for the fourth-order polynomial, one might be tempted to prefer this function; however, as is also evident from Figure 4, this would be a case of severe over-fitting given the very limited number of data points (15 in total). An ANOVA only showed marginally nonsignificant improvement of adding three more parameters to the 1st-order model, $F(3, 10) = 3.18$, $p = .07$. Thus, we assess the simple linear function and conclude that nPVI in music by Italian composers did not change in any systematic way over time.

Discussion

MAIN FINDINGS

The present study investigated the historical development in durational contrast in French music composed approximately during the 1650-1950 time period. Following up on previous studies, most notably of Italian and Austro-German music, we aimed to relate durational contrast in music to durational contrast in the native languages of its composers by applying the normalized pairwise variability index (nPVI) to both of these domains. Given our hypothesis of an initial increase and a subsequent decrease of nPVI in French music, we adopted a novel approach fitting polynomial functions to the data in addition to the simpler linear functions used exclusively to date.

As hypothesized, we found that a second-order polynomial provided the best fit to the data. The previous literature contains controversy regarding potential differences, in the effect of linguistic influences on rhythm, between vocal and nonvocal music (Patel & Daniele, 2003a; VanHandel, 2006; VanHandel & Song, 2009). To accommodate this lack of consensus, we performed separate analyses excluding and including instrumental themes from the opera genre, which was especially prominent in late-18th and early 19th-century French music. Our findings remained consistent and robust in both cases. Based on previous findings, linear functions were fitted separately to nPVI values for composers with birth years before and after 1820. This analysis only partly supported our hypothesis, showing a significant initial increase and a subsequent nonsignificant

decrease. Thus, the development in French musical nPVI after birth year 1820 cannot simply be characterized in terms of a linear decrease; rather, visual inspection of the data (Figures 1–2) suggests the possibility of a stylistic division amongst French composers working around this time. We will discuss this possibility in greater detail below.

Since French is a syllable-timed language with similar linguistic nPVI values to spoken Italian, the initial increase in French nPVI until birth year 1820 cannot be explained as a sign of gradually decreasing influence from Italian music. Conversely, it may reflect an increasing influence from Austro-German music culture on French music. Thus, in addition to Daniele and Patel's (2013) "Italian Influence Hypothesis" which applies to Austro-German music, we propose the introduction of an "Austro-German Influence Hypothesis," which accounts for the historical development in French music. Together, these two hypotheses provide a more complete explanatory framework with reference to European art music as a whole. Interestingly, the references by Arnold and Langham Smith (2015) and others to an alleged French resistance to foreign influences give the impression that the novel "Austro-German Influence Hypothesis" is more at odds with mainstream musicology than the original "Italian Influence Hypothesis." The effect size of the initial linear increase that we obtained for French music was practically identical to that previously observed for Austro-German composers throughout the complete range of birth years from 1637 to 1895 (Daniele & Patel, 2013; Patel & Daniele, 2003b). This supports the notion of a historically parallel development in French and Austro-German music up until the birth year 1820, after which a stylistic divergence between these countries may have occurred.

There were hints of this divergence in findings of decreasing phrase-based nPVI in French vocal music composed 1840-1900 (VanHandel, 2005). Our results for French composers born in 1820-1899 partly generalize this historical development to the instrumental repertoire. However, the effect size that we obtained did not reach significance and was somewhat smaller than that originally reported for French vocal music (VanHandel, 2005). This could be due to greater noise in the data when plotting according to birth years for each composer instead of composition years for each musical theme, an approach adopted deliberately here so as to replicate Patel and Daniele's (2003b) methods and facilitate comparison of the results. Furthermore, VanHandel's procedure would take the error of each mean value into account, resulting in substantially increased degrees of freedom. This would, however, necessitate much more

similar sample sizes across composers, again reducing the overall sample size and the number of composers fulfilling the inclusion criteria. In the next section (*Interpretation of Findings in the Context of Historical Musicology*) we will discuss an alternative possibility that the lower effect size reflects a stylistic two-fold split in French music around this time. In any case, the overall observation of regression back towards the low linguistic nPVI equilibrium of the French language remains informative at least as a stylistic trait of vocal music by French composers working specifically within this repertoire at the time.

Finally, in addition to our analysis of French music, further re-analyses successfully replicated Daniele and Patel's (2013) earlier reports of historically increasing nPVI in Austro-German music and historically stable nPVI in Italian music. Taken together, these findings confirm the linear effects for Austro-German and Italian music from the 17th century and beyond; higher-order models failed to fit the data better. Since linear models failed to account for trends in French music, however, we recommend that future research examines the possibility of nonlinear trends through time.

Before we discuss the contribution of our findings to historical musicology, a few methodological caveats need to be considered. First, it is worth keeping in mind the limitations resulting from the fact that our present operationalization of the relationship between music and language does not allow a direct one-to-one comparison. Specifically, music is represented by standardized written scores from a range of historical periods, whereas language is represented by a cross-section of colloquial oral speech data from a single contemporary context. Also, we need to assume that, during our period of interest (i.e., 1600-1950), durational contrast in the European languages has remained largely static and comparable to the present-day situation, where the syllable-timed languages Italian and French have low linguistic nPVI and German and Austro-German have relatively high linguistic nPVI. Given the lack of historical speech data from before the emergence of phonographic recording, this is a limitation that our work shares with all other studies of historical developments in nPVI (Daniele & Patel, 2013; Patel & Daniele, 2003b; VanHandel, 2005, 2006).

Second, it remains an open question whether nPVI is indeed the most suitable measure of musical rhythm (London & Jones, 2011; Toussaint, 2012). For instance, nPVI considers rhythm as a purely sequential phenomenon; it only takes the duration of subsequent note values into account, thus disregarding musical meter alongside other aspects of the intrinsically hierarchical

structure of music (Lerdahl & Jackendoff, 1983). Interestingly, a related, albeit not identical, criticism applies to the use of nPVI in psycholinguistics.

Other ways of quantifying musical style have been developed and tested. Margulis and Beatty (2008) used durational entropy as a way of characterizing musical style, and found a historical increase taken as evidence "that rhythmic freedom might be a key indicator of stylistic evolution" (p. 76). Further studies have shown that listeners are capable of picking up these probabilistic cues through long-term statistical learning (Hansen & Pearce, 2014). How these cues relate to linguistic parameters is pending further research. In the meantime, computational procedures have emerged for studying intrinsic connections between music and language (e.g., Patel, 2006; Patel, Iversen, & Rosenberg, 2006).

Third, the choice of encoding scheme for musical themes is likely to influence the results of nPVI computations in systematic ways. For instance, VanHandel (2005, pp. 63-64) found that the inclusion of pauses in the note value of the preceding note rather than excluding pauses altogether produced higher nPVI values on average. Future studies should aim to replicate findings relating to historical changes in musical nPVI with different encoding schemes.

Fourth, and most crucially, the interpretation of our findings in the context of historical musicology relies on the assumption that the sample used is historically representative of French music during this period. Although this limitation applies to all previous studies who have used this and similar samples for historical analysis (Patel & Daniele, 2003a; Daniele & Patel, 2004, 2013; VanHandel, 2005, 2006), it is still worth bringing to the fore. In addition to its obvious bias towards instrumental rather than vocal repertoire, Barlow et al.'s (1983) *A Dictionary of Musical Themes* suffers from a general bias towards the musical taste and trends of mid-20th-century North America. For instance, works in the Austro-Germanic tradition are emphasized, and particularly symphonies and solo keyboard pieces are overrepresented while church music, certain types of chamber music, and occasional pieces may be underrepresented (London, 2013). This leads to uneven sampling within composers which, in turn, results in corpora that might not be wholly representative of a given composer's complete artistic output. In contrast, an ideal corpus for answering research questions derived from historical musicology would strive to have (a) equal numbers of composers from each historical era and linguistic tradition, (b) equal sample sizes for all composers, and (c) involve representative samples for each composer that accurately reflect the range of their

output, including the genres in which they worked. London (2013) provides useful guidelines in this regard. Hence, the hypotheses presented in the subsequent discussion should be tested on musical samples with greater historical representability.

INTERPRETATION OF FINDINGS IN THE CONTEXT OF HISTORICAL MUSICOLOGY

Subject to the methodological limitations outlined above, we will now discuss our findings in the context of historical musicology. When teaching Western music history, it is common practice to divide the years 1600-1900 into three stylistic epochs: specifically, the Baroque Era ($\sim$1600-1750), Classical Era ($\sim$1750-1820), and Romantic Era ($\sim$1820-1900). For sake of clarity, we will also refer to this standard division. Stylistically, each of the three historical epochs was characterized by distinct compositional conventions which, in turn, emerged from different centres of gravity across the European continent. Occasional changes in the distribution of power and influence between musical metropolises lie at the core of what defined the transitions from one historical era to the next.

Our findings reveal interesting perspectives on the possible nature and direction of the changing stylistic influences. To reiterate, we demonstrated that during 1600-1950 musical nPVI increased in Austro-German music, remained relatively constant in Italian music, and increased until the birth year 1820 in French music after which it decreased. Because French and Italian composers spoke syllable-timed languages with relatively similar linguistic nPVI values (see Table 1), it is not possible to draw any strong conclusions about the mutual influences between musical cultures in these countries simply from the musical nPVI values. However, historical fluctuations in French and Italian nPVI can be interpreted as indicative of possible influences on and from Austro-German music culture.

Hence, as shown in Figure 5, we interpret these results as suggesting that in the Baroque Era ($\sim$1600-1750) Italian music influenced Austro-German music, in the Classical Era ($\sim$1750-1820) Austro-German music influenced French music, and in the Romantic Era ($\sim$1820-1900) there was little mutual influence between Austro-German musical cultures and French and Italian composers. Broadly speaking, this is supported by the observation that North- and Central-Italian cities were key centres of gravity during the Baroque, Austro-German cities such as Mannheim and Vienna became increasingly important during the Classical Era until the National-Romantic Era resulted in stylistic decentralisation represented by a greater
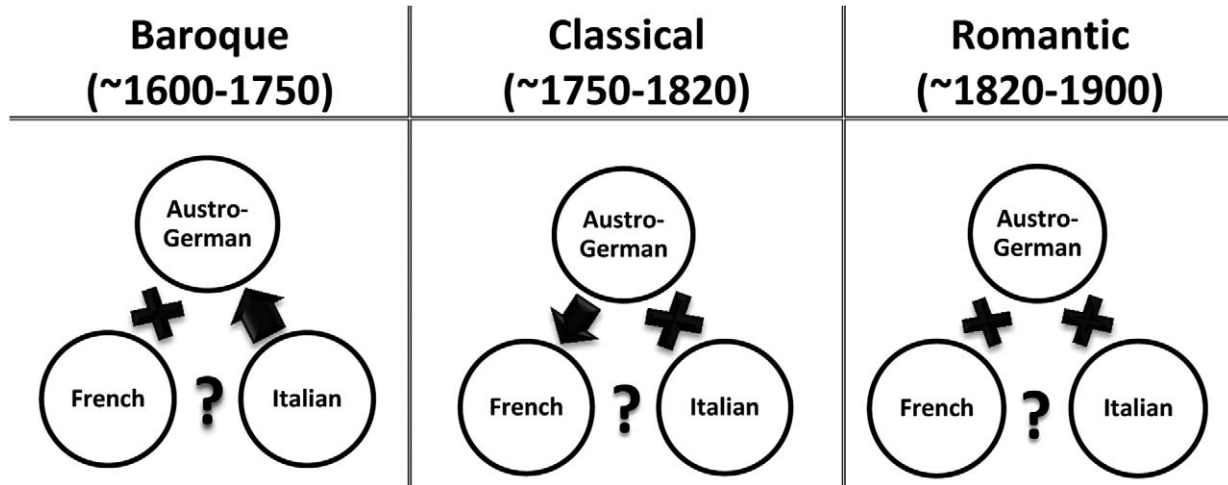
FIGURE 5. Patterns of typical stylistic influences during the Baroque, Classical and Romantic Eras. An arrow indicates the presence and direction of stylistic influence, a cross indicates the absence of notable stylistic influence, and a question mark indicates that no conclusion about stylistic influence can be drawn from the nPVI data because the two countries both speak syllable-timed languages. These relationships are directly supported by our quantitative analyses of the historical development in nPVI in music by French, Italian and Austro-German composers.

number of national musical capitals within and beyond Central Europe.

We will now take a closer look at the historical contexts underlying our interpretation of three periods with distinct patterns of influence between French, Austro-German, and Italian music. Our main source will be the article on "France" from *Oxford Companion to Music* (Arnold & Langham Smith, 2015) with occasional references to other works indicated when relevant. Starting from the end of the 16th century and onwards, French culture was strongly influenced by novel humanistic thinking. The *Académie de Poésie et de Musique* was founded to promote the practice of setting words to music following the metrical patterns of classical Roman and Greek verse. Numerous migrant musicians from Northern Italy worked at the royal court during this time, the most prominent being Jean-Baptiste Lully (1632-1987) who, as director of state music from 1661, laid a solid Italian-derived foundation for the French overture style that became a hallmark of French Baroque music. Outside the performance domain, the Italian *partimento* tradition became the pedagogical foundation for the teaching of most Central-European composers during this period; in fact, this practice remained dominant far into the 19th century (Gjerdingen, 2007).

In contrast, during the subsequent Classical Era, public and private performances of Austro-German music became increasingly customary in France where, in the meantime, Louis XVI and his Viennese wife Marie Antoinette had inherited the throne. The Bohemian-born composers Christoph Willibald Gluck and Anton

Reicha moved permanently to Paris after several years in Vienna in 1773 and 1808, respectively, and the former became immensely influential on subsequent generations of French opera composers. Meanwhile, symphonies by Mozart and Haydn were performed by the orchestras (Mongrédien & Pauly, 1996), piano manufacturers like *Pleyel* and *Érard* hosted concerts with foreign piano music, and nobility and wealthy art protégés like the Rothschild family organized private chamber music concerts featuring quartets by Beethoven, Haydn, Mozart and others (Lesure, 2015). In the composer and theorist Jérôme-Joseph de Momigny's words, the composer, publisher and piano builder Ignaz Pleyel — another Austrian-born immigrant — was a key figure responsible for teaching the public to appreciate Haydn and Mozart's quartets in the years up to 1808 (Mongrédien & Pauly, 1996, p. 295). Publication of Mozart biographies and the opening of a German-language theatre named after him in Paris in 1801 (albeit only for a short period) also contributed to the awareness of Austro-German music culture, although the reception was not always warm and welcoming (Mongrédien & Pauly, 1996, pp. 325-331).

Then, in 1870-1871, France suffered defeat in the Franco-Prussian War, which evidently spurred a new national sentiment; it is not unlikely that this was, in some cases, accompanied by an aversion towards Austro-German culture. The *Société Nationale de Musique* was established in 1871 specifically to serve the purpose of nourishing an autonomous, French musical style. Events like the *Exposition Universelle* in Paris in
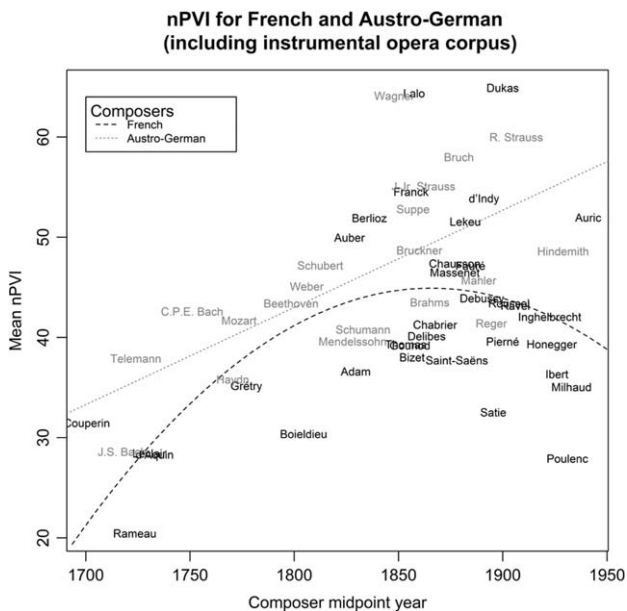
FIGURE 6. Mean nPVI values of French and Austro-German composers including the instrumental opera corpus plotted with lines of best fit as in Figures 3 and 5. The centre of the text string corresponds to the position of the associated data point.

1889, where, amongst other things, a Javanese gamelan ensemble was presented, contributed to increasing national pride while promoting an open mindset to non-Western music that inspired subsequent generations of French composers.

The stylistic divergence between Austro-German and French music around the birth year 1820 (or midpoint year ~1850), where the former continued its increase whereas the latter started to decrease, or rather split into two, is highly interesting from a musicological perspective. In Figure 6 we have plotted the names of French and Austro-German composers corresponding to their mean nPVI values with lines of best fit as in Figures 1 and 3. These lines reveal a pattern that is reminiscent of the convergence between French and German nPVI that VanHandel (2005, p. 77) previously reported for vocal music around the time period 1860-1870. The names, on the other hand, show which French composers deviate most significantly from the general pattern of historical decline in terms of exceptionally high nPVI values (e.g., Franck, Lalo, d'Indy, Dukas, Auric). Yet other composers appear to have been leading figures in this decline by showing remarkably low nPVI values (e.g., Satie, Poulenc). We will now discuss aspects of these composers' biographies that may explain these divergences. Note, however, that for some of these composers, only 6 or 7 eligible themes were available (see

Table 2), sometimes with considerable dispersion in nPVI for the individual themes. Needless to say, this calls for replication with larger corpora.

César Franck (1822-1890), Édouard Lalo (1823-1892), Vincent d'Indy (1851-1931), Paul Dukas (1865-1935), and Georges Auric (1899-1983) did most notably not follow the historical decline in musical nPVI. Being himself partly of German origin due to his mother, Franck gained a certain affinity with Austro-German music characterized as a "double allegiance to the Viennese tradition [represented by Beethovenian idealism] on the one hand, and to Liszt and Wagner on the other" (Trevitt & Fauquet, 2015). He studied counterpoint with the Bohemian-born Anton Reicha, and some of his compositions were privately premiered for Meyerbeer and Liszt (Davies, 1977, p. 60), the latter of which gave constructive advice and subsequently promoted his organ pieces. Franck's music is characterized by the use of iambic rhythm (likely to result in high nPVI) and cyclic form, possibly inspired by Beethoven and Liszt (Trevitt & Fauquet, 2015).

Edouard Lalo also composed in the Austro-German symphonic style with a certain predilection for rhythmically vivid, Brahmsian scherzo movements. He contributed to the piano trio genre that had been neglected in France until then and also founded the Armingaud Quartet in 1855 "with the aim of making better known the quartets of Haydn, Mozart, Beethoven, and also of Mendelssohn and Schuman" (MacDonald, 2015). His music was accused of being "Wagnerian" (e.g., Cooper, 1951, p. 37).

Vincent d'Indy studied composition with Franck and came to admire Austro-German symphonic music, drawing direct inspiration in his own music from Wagner, Weber, Meyerbeer, Liszt, and Beethoven as well as from Franck and Berlioz (Thomson & Orledge, 2015), who were both French composers with relatively high nPVIs (see Figure 6). He also travelled to Germany where he played for Liszt and attended the first production of Wagner's *Ring Cycle* in Bayreuth. In his later years after he was appointed director of the *Schola Cantorum* in 1904, however, he became increasingly nationalistic and also openly opposed German dominance after the outbreak of World War I in 1914 (Thomson & Orledge, 2015).

Paul Dukas was another occasional student of Franck (Trevitt & Fauquet, 2015) who travelled to Bayreuth (1886, 1889), as well as to London (1892), solely to attend performances of Wagner's *Ring* and wrote numerous articles on foreign composers like Mozart, Beethoven, and Wagner (Schwartz & Hopkins, 2015). His life-long friend Debussy asserted that Dukas music was not French enough (Walsh, 1997, p. 111).

Like some of his colleagues from *Les Six,* Auric studied composition with Vincent d'Indy, which could potentially have been a source of Austro-German influence. In fact, Auric's nPVI is much higher than that of other members of *Les Six* who similarly received tuition from d'Indy, namely Milhaud (35.06) and Honegger (39.22). It is unclear why Auric's use of musical rhythm differed from that of his closest colleagues from *Les Six.* However, musicologists assert that "[r]ather than a shared aesthetic, these composers were united by strong friendship" (Chimènes & Nichols, 2015); moreover, "[m]uch has still to be discovered about Auric" (Drake, 2015).

Based on these account, it is evident that Franck, Lalo, d'Indy, Dukas, and Auric all in different ways oriented themselves towards Austro-German music. Specifically, they took part in greater travel activities than the average French composer at the time, and they showed particular interest in symphonic music, chamber music, and in the operas of Richard Wagner. Amongst the Austro-German composers in Daniele and Patel's (2013) study, Wagner is indeed the one with the highest mean nPVI.

We will now turn to two French composers who contributed most notably to the historical decline in musical nPVI, Erik Satie (1866-1925) and Francis Poulenc (1899-1963). Satie's music is characterized by the "cardinal French virtues of simplicity, brevity and precision," and he emphasized the importance of melody whereas, "[c]uriously, rhythmic originality never seemed to concern him" (Orledge, 2015). At times opposing the concept of musical development, Satie became an early precursor of minimalism and repetitive music (Orledge, 2015). He was a friend of Debussy and enrolled as a mature student in d'Indy's *Schola Cantorum.* However, at that point Satie was 39 years old and had already consolidated his personal style. Turning to Poulenc, there is no evidence of any particular Austro-German influence on his compositions, although he did travel to Vienna in 1922 to meet with Schoenberg. Chimènes and Nichols (2015, section 8) write: "Chromaticism in his music is never more than passing [. . .] Texturally, rhythmically, harmonically, he was not particularly inventive. For him the most important element of all was melody."

In summary, French composers who showed declining nPVI were generally more preoccupied with melody and homophonic texture than with denser textures characterized by counterpoint, rhythmic complexity and late-Romantic chromaticism. Whereas simpler textures with rhythmic homogeneity are conducive to fusion of auditory streams, high nPVI values in individual parts can be used as a means of differentiating the voices in comparatively denser textures. One could consider these

French traits as representative of stylistic innovations in French music around this time that later on became hallmarks of Impressionism. Further examples would be the use of ostinati and repetitions (Pasler, 2015). The apparent turning point around birth year 1820 precedes the typical delimitation of musical impressionism used by historical musicologists, of which some have promoted Chabrier (born in 1841) as the "first to translate the Impressionist theories into music" (Pasler, 2015). The apparent stylistic divergence demonstrated here may thus represent novel precursors of musical impressionism preceding those that historical musicologists have previously pointed out. VanHandel's (2005, 2006) findings of historically decreasing nPVI in French vocal music from 1840 to 1900 may thus reflect a nationalist rather than a Wagnerian bias of these particular composers as well as a tendency for nationalistically oriented composers to express themselves through vocal rather than instrumental repertoire.

Assuming that linguistic nPVI remains constant, this interpretation strongly suggests that patterns of musical nPVI over time reflect stylistic trends and developments within and between musical cultures. Nonetheless, it remains difficult to disentangle potential influences of language and cultural styles, which may run counter to one another (Patel & Daniele, 2003b). It is still possible to associate the decreasing nPVI in late 19th century French music with a rising nationalism in France, associated with an increasing preoccupation with expressive qualities of French language (as did VanHandel, 2005, p. 114). However, a recent study has demonstrated stylistic influences on nPVI. Specifically, Raju, Asu, and Ross (2010) found decreasing nPVI in vocal music by Estonian composers during the 20th century and related this to the New Simplicity movement. This confirms that nPVI represents a powerful tool for musical rhythm analysis–even without reference to linguistic origins (London & Jones, 2011; Toussaint, 2012).

Furthermore, the biographies of the two Austro-German composers with the last midpoint years already hint towards a stylistic explanation. Specifically, Richard Strauss (1864-1949), who was associated with late-Romantic chromaticism, has a high nPVI (60.0), whereas Paul Hindemith (1895-1963), who was associated with stylistic movements such as Neue Sachlichkeit and Neo-Classicism, has a much lower nPVI (48.6). Thus, could the divergence of musical nPVI in late-Romantic music simply be due to general stylistic trends in European art music rather than having anything to do with the composer's native language? And might it be the case that there simply happened to be an Austro-German bias towards Wagnerian late-Romanticism and

a French bias towards Neoclassicism? Further data on the development in nPVI over the lifespan of individual composers (see e.g., Daniele & Patel, 2015; VanHandel, 2005, pp. 78-81, 2006), covering a greater range of European countries, language, cultures, and time periods, will be necessary to throw further light upon these questions.

In conclusion, the interpretation of our findings in context of historical musicology suggests novel quantitative correlates of the historical shift towards the National-Romantic Era. Around this time, a stylistic divergence seems to have occurred in French music in particular, and in Central-European music in general, that came to influence much of the stylistic development during the first half of the 20th century. This work provides a more complete picture of mutual influences between the Central-European musical cultures. Notably, our preliminary historical data provided no empirical support for a general stubborn French nationalism throughout the period, as Arnold and Langham-Smith (2015) alluded to in their statement that "France has resisted foreign intrusions, be they Italian or German." Rather, French musical culture appears to have remained in close dialogue with its European neighbors drawing inspiration both from Italian and later on Austro-German music culture. Our work thus clarifies some of the ambiguities present in Arnold and Langham-Smith's (2015) account. Generally, our findings align better with musicological work by Mongrédien and Pauly (1996), who emphasize that relations between French and German music have been understudied

hitherto (p. 315) and, specifically, that Beethoven's music actually crossed the border to France much earlier than previously thought, being widely available from Parisian publishers by 1810 (p. 319). Furthermore, we have demonstrated the importance of applying polynomial modelling to historical nPVI data. Specifically, if we had restricted ourselves to the linear modelling procedures used in previous research, we would not have discovered the nonlinear development over time of nPVI in French music. As discussed above, this has both methodological and theoretical implications for future work investigating nPVI as a measure of linguistic influence on rhythm in music.

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Appendix A

nPVI IN LANGUAGE:

Here, we introduce the normalized pairwise variability index (nPVI) as a linguistic measure of durational contrast and demonstrate in practice how it can be applied to musical scores.

nPVI is defined as:

$$nPVI = 100 \times \left[\sum_{k=1}^{m-1} \left| \frac{d_k - d_{k+1}}{(d_k - d_{k+1})/2} \right| / (m-1) \right], \quad (1)$$

where m is the number of vocalic intervals in an utterance, and d_k is the duration of the kth interval. In contrast to the raw pairwise variability index (rPVI), which was used in earlier research on durational contrast in speech (Ramus, 2002; Ramus, Nespor, & Mehler, 2000), the nPVI measure has been optimized by normalizing for variations in speech-rate by dividing each difference between two successive vocalic durations by the mean duration of that pair (Grabe & Low, 2002). The grand mean is then finally multiplied by 100 simply to obtain an easily manageable number.

nPVI IN MUSIC:

When calculating the nPVI of a musical theme, a number representing the relative duration is simply assigned to each note appearing in the musical score. In most cases the shortest note could be assigned the value "1" and so forth. Importantly, since nPVI is a relative measure of variability, the choice of denominator is arbitrary and has no impact on the final nPVI value. Figure A below shows the initial phrase from *La Marsellaise* with relative durations notated above the score.

The nPVI scale ranges from 0 to 200. The lowest value is represented by a succession of notes of equal durations (i.e., isochronous) whereas, for instance, a single-dotted rhythm will result in an nPVI value of 100. As evident from Figure B below, further dotting will only result in the nPVI asymptotically approaching (but never reaching) the theoretical maximum of 200.

APPENDIX FIGURE A. The initial phrase from *La Marsellaise* with relative durations of each note indicated above the staff. These numbers are inserted as *d* into the nPVI formula (Equation 1 above) in order to calculate the nPVI value. In this case the result is 78.42.

APPENDIX FIGURE B. Four rhythmic motifs approaching, but never reaching, the theoretical maximum nPVI of 200.