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Expressive gesture in Grieg's recordings of two Op. 43 Lyric Pieces: An exploratory principal components analysis

Georgia Volioti
University of Surrey, UK

ABSTRACT: Historical recordings embody the material traces of legendary performers from the past and can offer an inspirational resource for modern interpreters. Despite their limitations, early recordings can provide a rich and reliable source of information for the performer-scholar. This article reports an empirical investigation of Edvard Grieg's performance style via historical recordings of two of his *Lyric Pieces*: 'Butterfly', Op. 43 No. 1, and 'To the Spring', Op. 43 No. 6. First, taking a bottom-up approach and starting from the composer's recordings, salient gestures in Grieg's performance style are traced using empirical techniques of beat-tempo analysis. Second, exploratory Principal Components Analysis (PCA) is used to compare the composer's timing profiles with those of other pianists in the sample. Results show that Grieg's extreme flexibility in performance tempo distinguishes him from other interpreters. Specifically, the rhythmic pull of the principal motif in 'Butterfly', Op. 43 No. 1, and the rhetorical inflection of the melody in 'To the Spring', Op. 43 No. 6, appear to be idiomatic features of Grieg's style.

KEY WORDS: Grieg; recordings; performance style; expressive gesture; beat-tempo analysis

CONTEXT AND OBJECTIVES

A substantial, yet still increasing, corpus of musicological literature now exists on the importance of recordings as salient historical documents of performance practice (e.g. Philip, 1992; Day, 2000; Leech-Wilkinson, 2009; Fabian, 2003, 2014). Alongside this orientation, empirical methods for analysing musical performance from recordings have also developed

significantly over the past fifteen years, offering musicologists new tools and possibilities. Although such empirical-analytical approaches tend to favour keyboard repertoire, the scope of research is undoubtedly diverse. For example, researchers have focused on extracting and decoding performance gesture from recordings (e.g. Leech-Wilkinson, 2007, 2010; Timmers, 2007), modelling performance strategies in order to extrapolate individual and collective trends (e.g. Repp, 1998, 1999; Spiro, Gold, & Rink, 2010; Cook, 2007, 2009), or investigating the relationship between performance, analysis and music theory (e.g. Gingras, McAdams, & Schubert, 2010; Dodson, 2008, 2011a, 2011b)[1]. Analysis of recorded performances—whether historical ones, recordings produced for the particular aims of a study, or even computer generated ones (i.e. MIDI or algorithmic performances)—has also underpinned the strong research tradition of building generative models of performance behaviour (e.g. Todd, 1985, 1989; Clarke, 1988; Friberg, Bresin, & Sundberg, 2006; Widmer, 2005; Friberg & Bisesi, 2014).

My investigation is more closely aligned with musicological studies of performance analysis from recordings that seek to elucidate historical aspects of style. Such empirical discourses extend beyond a mere preoccupation with performance history and already indicate diverse applications of working closely with recordings. These include the use of recordings for historically-informed performance (e.g. Lawson & Stowell, 1999; Milsom, 2003; Milsom & Da Costa, 2014), the potency of recordings in pedagogical contexts, such as practice-through-imitation approaches (e.g. Lisboa, Williamon, Zicari, & Eiholzer, 2005), and engaging with recordings in fruitful cross-disciplinary research (e.g. Cook, 2013; Fabian, Timmers, & Schubert, 2014).

In this study I use computationally-assisted techniques, including a semi-automatic extraction algorithm, for obtaining and analysing timing data from recordings. Principal components analysis (PCA) is then used as an exploratory method for discerning putative associations between performers' timing profiles. I engage with these analytical tools in a historical investigation of Edvard Grieg's pianism, aiming to advance a better understanding of his style, albeit only from selected recordings of two of his Op. 43 *Lyric Pieces* due to obvious space restrictions.

Despite various challenges posed by historical recordings, these can still provide a rich source of reliable data to work with (e.g. Nettheim, 2013). Findings stemming from empirical approaches, as reported here, can be of value for informing performance interpretation in a number of ways, such as elucidating historical changes in the expressive variability of musical structure (e.g. Cook, 2009; Leech-Wilkinson, 2010; Fabian, 2014), or harnessing the instructive method of guided listening with the aid of visualisation tools and graphs (e.g. Chew, 2012).

THE HISTORICAL RECORDINGS OF EDVARD GRIEG

Considering that Edvard Grieg made nine acoustic recordings in 1903 and a total of twenty-five piano rolls between the years 1904 and 1906 for various commercial companies (Matthew-Walker, 1993, pp. 27-28; Benestad & Halverson, 2001, pp. 116-118, 418), his

[1] The musicological discourse concerning the relationship between analysis and performance has a far longer tradition (e.g. Cook, 2001; Rink 2002) than these selected references which exemplify empirical (quantitative and qualitative) approaches to performance analysis.

recorded legacy is a significant one pointing to his pioneering spirit and the popularity he amassed as a composer-pianist at the time (e.g. Halverson, 1994). Grieg is among the earliest pianists we have on record today and as such, his style is not the easiest to grasp upon first hearing. As Robert Philip astutely observes, "with some of the earliest pianists on record one gets a sense of a lost language that is no longer understood" (Philip, 1992, p. 63). There is a need, therefore, to try to get beneath the surface of historical styles in order to understand their constituent parts better. The present study aimed to fulfil this objective. Despite the relative obscurity of Grieg's historical recordings throughout much of the 20th century, their digital re-mastering and commercial re-circulation on the record label Simax in 1993[2] sparked a resurgence of interest in the composer's recorded legacy, which has had a broader influence on modern interpreters of his piano music (e.g. Siepmann, 2007; Harrison & Slåttebrekk, 2009). The present study makes a contribution to this growing interest.[3]

My investigation sought a relational understanding of Grieg's score and performance style in comparison to other pianists' interpretations. This is underpinned by the notion of a musical work existing in relation to its performances, as theorised by Nicholas Cook's formulation "the horizontal field of performance instantiations" (Cook, 2003, p. 208). In empirical performance research this theoretical tenet has often motivated the comparative analysis of recordings (e.g. Cook, 2007, p. 185). Moreover, listening to recordings relationally is commonly encountered in artistic practice and pedagogical contexts. Performers often listen to recordings of others' interpretations as a source of inspiration, to enrich their stylistic knowledge, to guide problem-solving or to evaluate their own interpretative decisions (e.g. Lisboa *et al*., 2005; Volioti & Williamon, 2017).

METHODS

Data collection

Expressive timing was extracted from recordings using the sound editor Sonic Visualiser (version 1.2),[4] which offers an efficient tap-along method of data collection as other studies that have used this software also demonstrate (e.g. Cook, 2007, 2009; Spiro *et al*., 2010; Dodson, 2011; Chew, 2012; Volioti, 2010, 2012). This freely-available software provides a user-friendly interactive environment for navigating, listening and analysing recordings. Beat onsets were gathered by a process of manual tapping to each sound file, followed by a rigorous data-editing stage using the Sonic Visualiser Attack Detection Function and Power Curve: Smoothed Power Slope plugins to assign the beat onsets accurately.[5] Spectrographic visualisations were also used to help with onset detection (e.g. Leech-Wilkinson, 2007; Cook

[2] *Edvard Grieg: The Piano Music in Historic Interpretations* (Simax PSC 1809, released 1993). A three-CD anthology which was funded by the Norwegian Cultural Council to commemorate the 150th anniversary of the composer's birth.

[3] By contrast, the reconstruction of Grieg's acoustic recordings (Harrison & Slåttebrekk, 2009) sought to reproduce his playing as accurately as possible in a new commercial re-recording (Simax PSC 1299, released 2010).

[4] Freely available at http://www.sonicvisualiser.org (accessed June 18, 2018). Although an upgraded version of Sonic Visualiser is currently available, the features of the earlier version used here are essentially the same.

[5] See http://sv.mazurka.org.uk/MzAttack/ and http://sv.mazurka.org.uk/MzPowerCurve/ (accessed June 18, 2018).

& Leech-Wilkinson, 2009). The combined features of this data extraction method facilitate a process of entrainment and close familiarisation with each performance. This editable tap-along method is adequately reliable for working with beat-level data as the correction steps bring the accuracy of tapped timings within 10 ms of the actual beat locations (e.g. Sapp, 2007, p. 498; Dodson, 2011b, p. 6) and the error is not cumulative (e.g. Dodson, 2011b, p. 6). Beat timings can be exported from Sonic Visualiser as a text file and imported for further data processing into a spread-sheet such as Microsoft Excel. From beat timings, inter-onset intervals (IOI) were calculated by subtraction. IOI values were expressed as beats per minute (bpm) using the simple formula [60/IOI] (see Cook & Leech-Wilkinson, 2009). Beat tempo (shown on the y-axis) is a commonly used representation of performance timing data in the empirical literature, and offers a more easily accessible and convenient reference for musicians than plotting IOI or their reciprocal values (e.g. Clarke, 2004, pp. 82-83).

Expressive timing and performance gesture

Psychological research has demonstrated that musical structure is directly reflected in the timing profile of a performance (e.g. Clarke, 1988; Gabrielsson, 1999; Palmer, 1989, 1997). Many musicological studies have utilised this premise to investigate historical changes in style through measurements of performance tempo (e.g. Epstein, 1995; Philip, 1992; Bowen, 1996; Cook, 1995, 2009; Fink, 1999; Volioti, 2012). The tempo profile of a performance, as defined by changing beat values, offers a convenient representation of the performer's conceptual plan because it delineates both large-scale form and beat-level detail providing cues about a performer's idiosyncratic gestures.

My working definition of gesture draws from Leech-Wilkinson's research: "a gesture can be defined as an irregularity in one or more of the principal acoustic dimensions (frequency, loudness, timing), introduced in order to give expressive emphasis to an individual note, chord or longer passage" (Leech-Wilkinson, 2010, p. 58). Performance style is a collection of expressive gestures that characterise how musical sound is made meaningful by performers across different historical contexts. As a type of perturbation of temporally defined phenomena (e.g. tempo, dynamics, timbre etc.), gesture refers to the kinaesthetic shape of musical sound that denotes expressive information (Leech-Wilkinson, 2009, 2010; Windsor, 2011). Performed gestures, whether apparent or implied, convey and complement other gestures, or shapes of embodied movement, such as those perceived and interpreted by listeners as well as those a music analyst or performer may extrapolate from a score. Since, "in phenomenological terms gestures are communicated through the traces they leave in the environment whether immediately on their production or preserved over time as in a sound recording" (Windsor, 2011, p. 60), the study of performance gesture from recordings is an ecologically valid and culturally viable method of analysis.

Semi-automatic extraction procedure

Although working with beat-tempo data has many advantages, beat timings can subsume sub-beat rhythmic information that may contain vital expressive differences between performers. The piece 'To the Spring', Op. 43 No. 6, has a lyrical melody and an almost continuous crotchet accompaniment. The melody is invariably performed with more flexibility than the accompaniment. Separating the melody from its accompaniment can reveal the unique attributes of a performer's style and help explain how these two expressive

components contribute to performance variability. A semi-automatic extraction procedure was used to obtain and separate melody and accompaniment timings for Op. 43 No. 6. (This method was not applied to the other piece, 'Butterfly' Op. 43 No. 1, because this comprises continuous semiquaver movement and is performed, on average, at a faster tempo than 'To the Spring', thus making the separation and manual correction of semiquaver onsets after extraction less accurate.) The algorithm used here was created principally by Andrew Earis (2007) and developed further in collaboration with Craig Sapp under the auspices of the UK AHRC funded Centre for the History and Analysis of Recorded Music (CHARM). The programme was downloaded and run according to the instructions available online.[6] The steps for generating the input data, pre-processing the audio files and running the semi-automatic extraction algorithm are provided in the Appendix.

Exploratory principal components analysis

Principal components analysis (PCA) was used as a dimension reduction method (e.g. Field, 2000; Costello & Osborne, 2005) for exploring how performers' timing profiles relate to one another and which performance strategies are most representative within the sample. Applications of PCA have been documented in studies of expressive variability patterns in timing and dynamics from recorded performances (e.g. Repp, 1998, 1999) or MIDI generated performances (e.g. Madison, 2000). PCA is a data reduction technique which induces an orthogonal linear transformation in a large and complex data set and transforms the data into a new co-ordinate system so that the sample variance is expressed in terms of a smaller number of principal components (PCs). The explanatory power of PCs is indicated by the factor loadings (i.e. correlations) of each variable. The first (unrotated) PC extracted during PCA accounts for the largest amount of variance and is equivalent to the average of all the timing profiles in standardised form.[7] The second PC accounts for the largest amount of the remaining variance and is equivalent to the average of the residuals after the first PC has been subtracted from the data. The number of significant PCs selected was determined by the size of their eigenvalue, which should be greater than one (Kaiser, 1960), and by a visual inspection of the scree plots (Cattell, 1966). Although the timing strategy represented by a PC can be expressed as a statistical category in terms of standard scores, it is more meaningful for a sample of real performances to interpret a PC according to those timing profiles that load most strongly onto it (e.g. Repp, 1998). PCA was carried out in SPSS (version 21) specifying varimax rotation as the orthogonal transformation, since this is the most commonly used rotation method. PCA was initially run to determine the number of PCs (eigenvalue > 1) and then re-run by indicating the exact number of PCs and specifying rotation. Given the relatively modest sample size in this study, small factor loadings have not been suppressed (Field, 2000, p. 440), and all the values are reported in the results. Beat-tempo profiles representative of each PC are also displayed and discussed.

[6] Freely available at http://mazurka.org.uk/software/earis/v100 (accessed June 18, 2018).

[7] During PCA the procedure converts timing durations (i.e. beat tempo in this case) into standard scores (mean of zero and standard deviation of one). PCA deals with differences in the profile shape of timing durations and is, therefore, insensitive to differences in basic tempo or the within-performance tempo variability as measured by standard deviation (see Repp, 1998, p. 1088).

RESULTS AND DISCUSSION

Selected observations from Grieg's interpretation of Butterfly Op. 43 No.1

The rhythmic pull

A salient feature of Grieg's playing is that he elongates the first beat of the opening bar by emphasising the dotted F sharp quaver with an agogic accent and then accelerating freely over the semiquavers (Figure 1). I have termed this feature the 'rhythmic pull' because in qualitative terms the notated rhythm feels stretched, creating a local expansion of the beat pulse.

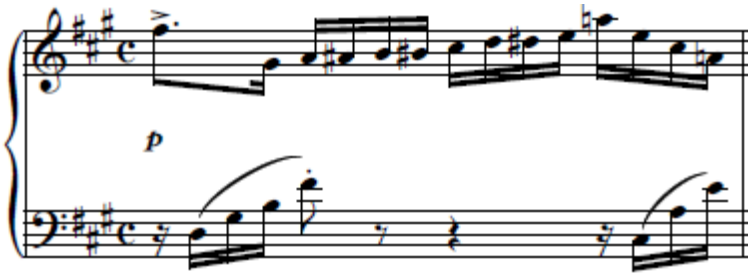


Figure 1. The Butterfly motif (score reproduced from 1902 C. F. Peter's Edition, public domain).

In simple quantitative terms, this expanded pulse gesture is made apparent by the surge in beat tempo at the start of the profile (Figure 2). Between the first two beat inter-onsets the tempo increases from 47 bpm to 101 bpm. The rhythmic pull is clearly audible in the recording and becomes a distinctive feature of thematic-motivic characterisation throughout the performance whenever the opening motif reappears in the ternary design of the piece (e.g. bars 3, 4, 7, 9, 10, 23, 25, 26, 27, 40, 42, 43 and 44).[8] The Butterfly motif is, thus, consistently demarcated by an elastic temporal gesture comprising an expansion phase—the deliberate elongation of the first beat—and a contraction phase—the rushing of the chromatic semiquavers.

[8] References to bar numbers, here and throughout, include the repetition of the first six bars. The score of Op. 43 No. 1 used is the 1902 C. F. Peter's Edition, available in the public domain at: http://ks.imslp.info/files/imglnks/usimg/7/75/IMSLP28165-PMLP01778-Grieg-KlavierwerkeBand1-Op43-Peters.pdf (accessed June 18, 2018).

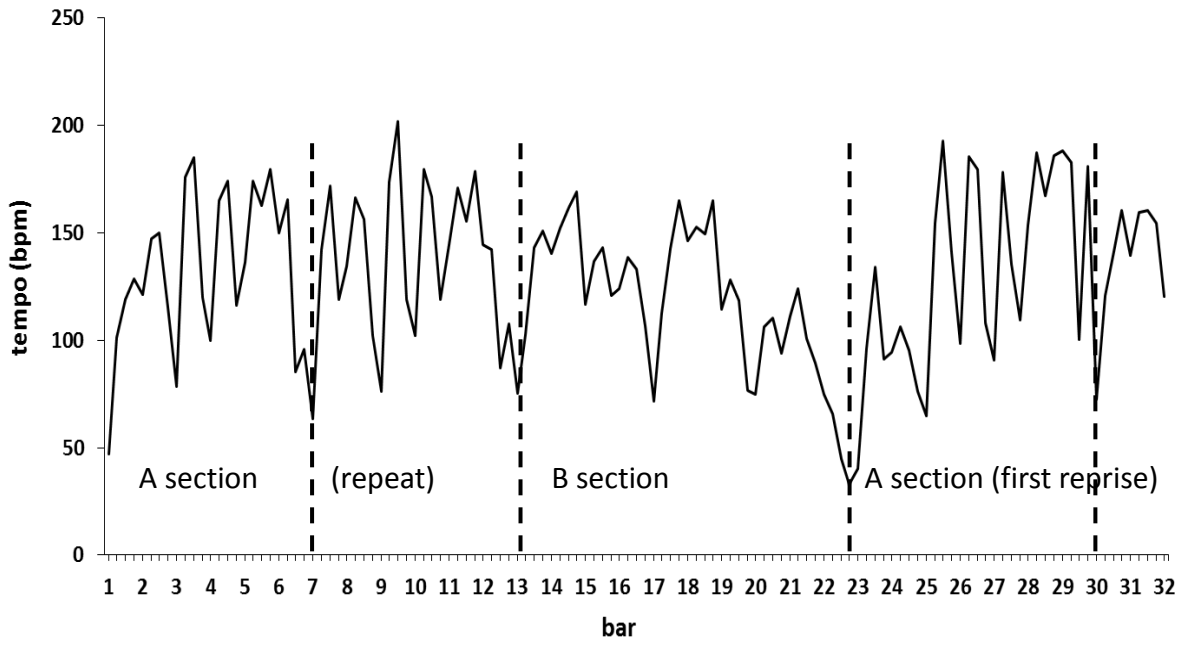


Figure 2. Expressive timing in Grieg's performance of Op. 43 No. 1 (bars 1-32 only). Graph showing beat tempo profile obtained from 1903 acoustic recording (Simax PSC 1809, re-issued 1993).

Phrasing and delineation of musical structure in performance

Another distinctive feature of Grieg's playing is the forward-moving tempo. Although the troughs in the tempo curve denote a clear sectional plan (Figure 2), the music is through-performed by Grieg with almost unbroken continuity. For example, the A section (bars 1-6 and 7-12) is executed in a single breath by a progressive acceleration in tempo, which heightens certain harmonic features such as the reappearance of the dominant in bar 4 (now in first inversion) and the anticipation of the modulation to the dominant in bars 5 and 6. In the first return of the A section (bars 23-30), the increasing temporal momentum, again, heightens the cadential progression at bars 28 and 29 (I^6_4 – V – I in the tonic key of A major).

Contributing to this forward-moving feeling in performance is Grieg's economical phrase-final rubato. For example, the *poco rit.* indicated at the beginning of bar 6 is in fact delayed until the end of that bar. The pacing of the third and fourth beats in bar 6 is rather uneven, blurring any impression of a deliberate *ritenuto*: the fourth beat, the E in the bass, is a little rushed as it is played quickly after the third beat (Figure 3a). There is no lingering at the double bar; Grieg moves straight on to the repetition. Grieg's interpretation of these opening six bars, and their repetition, articulates the absence of a root position tonic in the music through a continuous phrase gesture which is driven by unbroken rhythmic movement. By contrast, other pianists such as Hofmann (1916), Ganz (1916), Johansen (1940) and Bauer (1942) anticipate the ending, in their early recordings, by slowing down in the last two bars (5-6 and 11-12). The lack of any rubato in Grieg's recording is again very striking at the end of bar 29 (Figure 3b), which marks the first appearance of a root position tonic in the piece. Grieg's tendency to move straight on at this point, masking this structural cadence with his untiring

semiquaver movement, highlights his conception of the ternary design of this miniature piece in terms of a more continuous and overarching musical narrative. Only one other recording from this sample, Joyce (1939), exemplifies a similar rhythmic elision across bars 29-30.

Grieg's very economical rubato can also be heard in the B sections of the piece (bars 13-22 and 30-39), where the phrasing strategy, again, closely reflects the underlying harmonic rhythm: the first four-bar unit (bars 13-16) highlights the shift to F sharp minor (V-i cadence at bars 15-16); the second three-bar segment (bars 17-19) marks the transition to B major (V-I cadence across bars 19-20); and the final three-bar gesture (bars 20-22) anticipates the return to A major at the start of bar 23. These transitions are subtle, because Grieg's constantly forward-moving fast tempo binds the musical structure together into a longer ten-bar gesture.

Besides observations pertaining to performance beat tempo, spectrographic visualisations can aid the listening experience by revealing additional historical signifiers, such as minute sub-beat-level gestures. As can be heard in the recording, Grieg dislocates the left- and right-hand parts at the cadential bars of the A sections (e.g. bars 5, 6, 11, 12, 28, 29, 45, 46, 47, 48) and in some bars containing the Butterfly motif where the interpolated rhythms can again be heard (Figure 4). These expressive asynchronies add to the improvisatory character of this performance and bear testament to remnants of contrametric rubato in Grieg's style: the 18th-century tradition of playing with one hand before the other, which was still being practised in the 19th century (Rosenblum, 1994).

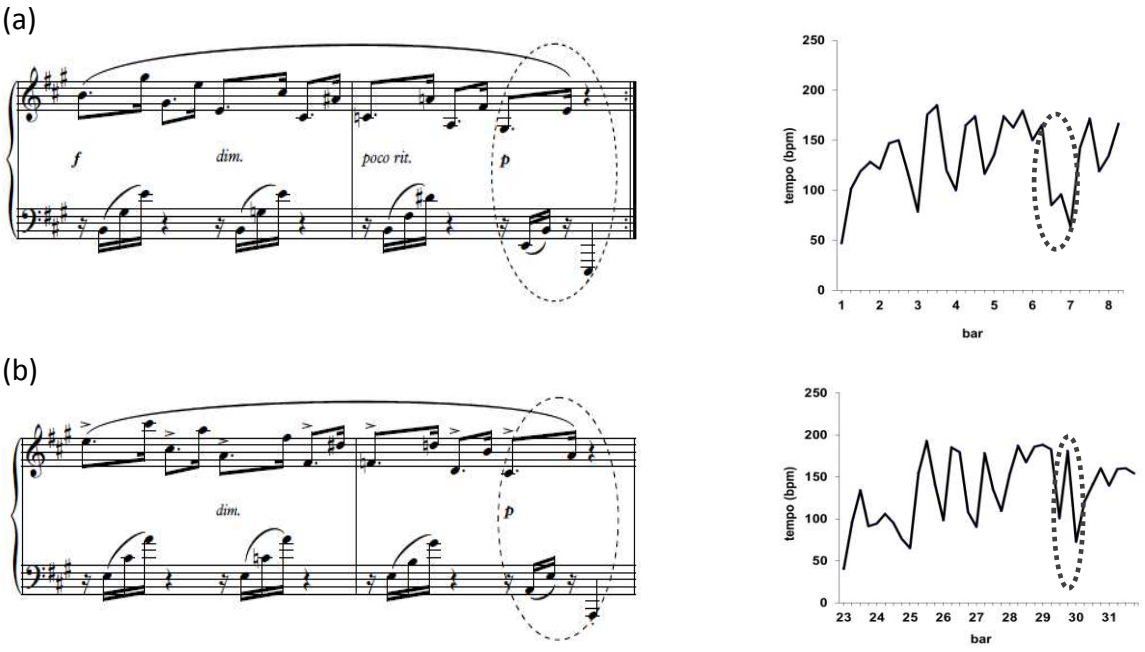
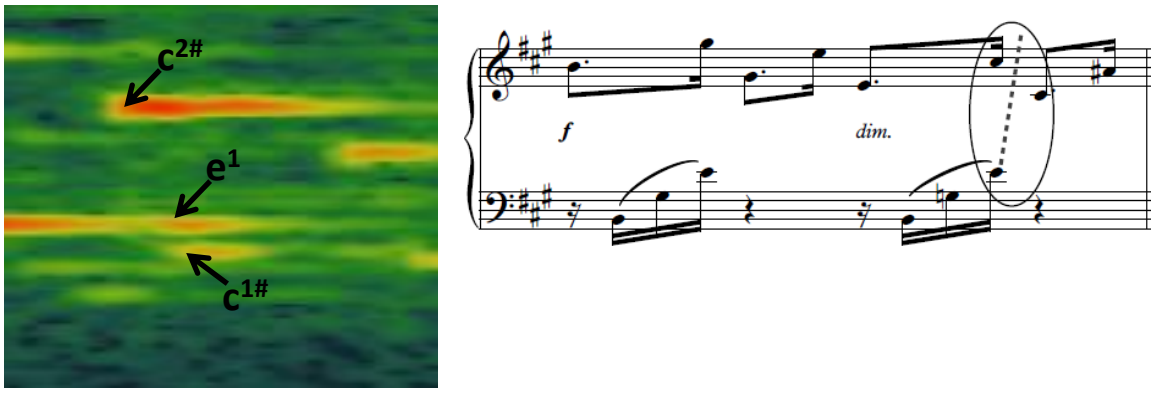


Figure 3. Beat-tempo profiles showing Grieg's cadential gestures in Op. 43 No. 1.
(a) Cadence at bar 6 (dotted area highlights rushing of last crotchet beat in bar 6).
(b) Cadence at bar 29 (dotted area highlights rushing of last crotchet beat in bar 29).

(a)



(b)

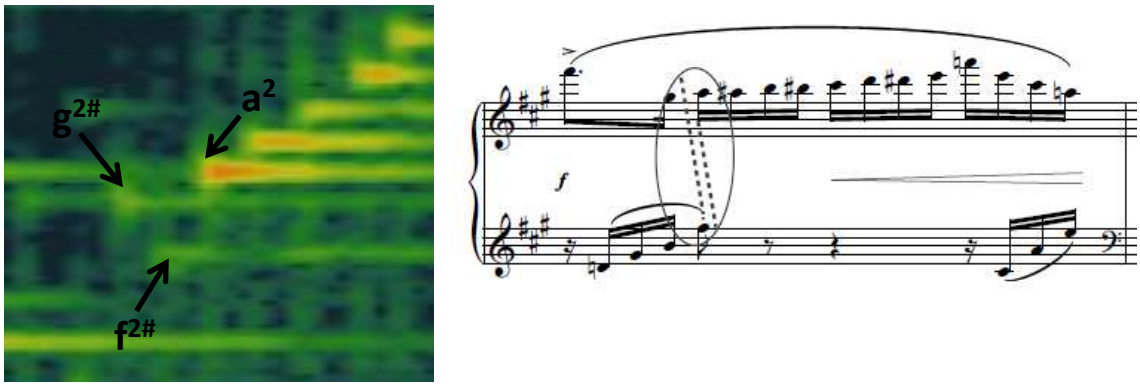


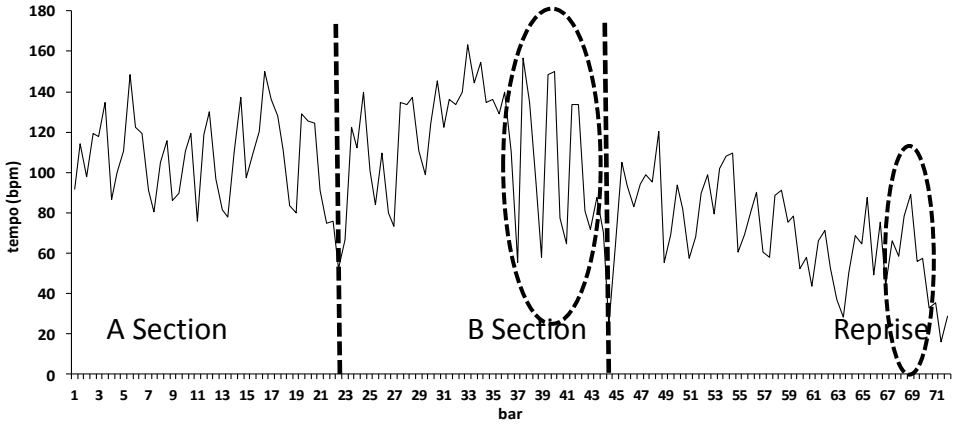
Figure 4. Selected spectrographs showing the interpolation of left- and right-hand parts in Grieg's playing of Op. 43 No 1 at: (a) bar 5, and (b) bar 44. Pitch frequencies do not align vertically but are in succession. Highlighted areas of the score indicate the pitches shown in the spectrographs. These specimens are taken from the 1906 piano roll (Simax PSC 1809, re-issued 1993), which has clearer spectra. These gestures are also audible in the 1903 acoustic recording.

The above-mentioned features in Grieg's playing of Op. 43 No. 1 create a vitalist performance aesthetic. Vitalism, as manifested through the expressive bending of time, was a key attribute of 19th-century performance styles (e.g. Taruskin, 1995; Hamilton, 2008). Beneath the surface of Grieg's fast and undulating performance tempo frequent changes in direction are audible, due to the subtle lengthening or shortening of certain beats, which blur any sense of a predictable pulse. By inflecting the notated rhythms, Grieg essentially shapes the music on the go, or 'on the fly', lending it a speech-like naturalness whereby certain beats in the music, such as the rhythmic pull of the Butterfly motif, are given heightened rhetorical expression. The music breathes in performance, and Grieg's playing is not strictly 'in time' but creates its own sense of time. In 19th-century piano practice, the performed inflection of the music was closely identified with a rhetorical, singing-like style of delivery that dates back to the 17th and 18th centuries (Milsom & Da Costa, 2014; Hamilton, 2008, pp. 139-78).

Selected observations from Grieg's interpretation of To the Spring Op. 43 No.6

Features similar to those noted in Grieg's performance of 'Butterfly', Op. 43 No. 1, abound in his interpretation of 'To the Spring', Op. 43 No. 6. While the ternary design of this *Lyric Piece* is easily discernible from the beat-tempo profile (Figure 5a), Grieg's playing, on the recording, projects an organic conception of the music as he develops the melody from a wistful opening to a more triumphant return in the barcarolle-like reprise. Grieg's economical rubato is, again, prominent in this performance. A prime example can be heard in the closing bars. Despite the *ritardando* indication at bar 69 (Figure 5b, right), Grieg pushes the tempo onwards and executes the arpeggio figure in bar 69 with a seamless glissando (Figure 5a). In a sense, by going against his written score, Grieg's performance reveals an alternative, more buoyant, coda for the piece. An example of Grieg's elastic performance tempo, another hallmark of his style, is the steep surges in intra-bar tempo that can be observed across the *agitato* passage of bars 37-43 in the B section (Figure 5a). The repeated crotchets in the accompaniment (Figure 5b, left) are executed progressively more hurriedly within each bar, producing a tumultuous rippling musical gesture.

(a)



(b)

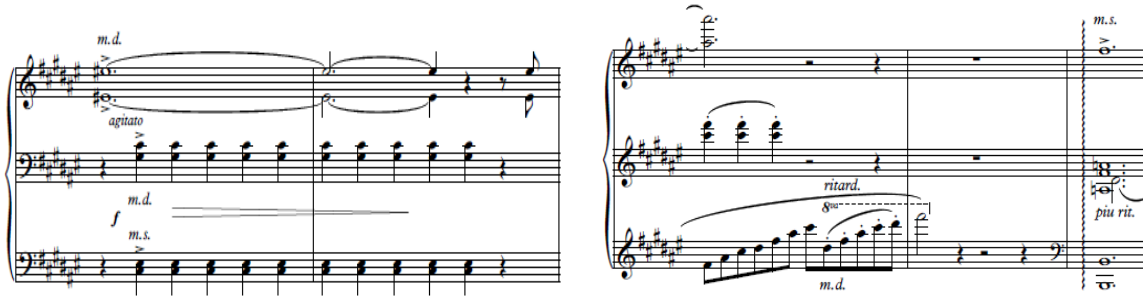


Figure 5. Expressive timing in Grieg's performance of Op. 43 No. 6 (bars 1-72).
(a) Graph showing beat-tempo profile obtained from 1903 acoustic recording (Simax PSC 1809, re-issued 1993). Dotted circles highlight the surges in intra-bar tempo at bars 37-43 and the delayed *rit.* across bars 69-70.
(b) Score of Op. 43 No. 6 corresponding to opening of *agitato* at bars 37-38 (left), and final *rit.* at bars 69-71 (right). Score reproduced from 1902 C. F. Peter's Edition, public domain.

The opening section of 'To the Spring' (bars 1-22) accommodates more beat-tempo variability in Grieg's than in others' performances. A comparison of how Grieg's sectional profiles correlate with those of the other pianists in the sample confirms that the values for the first A section (excluding the two-bar introduction) are, on the whole, lower than for the middle section or the reprise (Figure 6). A number of musical-structural features could explain this trend. The middle section is more temporally driven towards the *agitato* climax (bars 37-43) and the phrasing follows a regular pattern of four- and two-bar gestures, thus potentially forcing more commonality in interpretation. The reprise, too, could encourage more commonality in performance due to the physical constraints it presents: wider registral spans and a three-stave texture potentially hinder liberties with tempo. Like Grieg, most pianists take the reprise at a slower tempo (refer to tempo graph in Figure 5). The opening A section, however, comprises two expressive components—melody and accompaniment—which appear to behave more freely here than elsewhere in the piece. The *cantabile* melody undoubtedly requires a lingering, supple tempo, while the recurring three-against-two coupling of melody and accompaniment creates opportunity for rhythmic flexibility and, thus, more variability between pianists. The repeated crotchets in the accompaniment also attract a flexible rather than rigid rhythmic execution, through the localised bending of beat tempo. Separating the melody from the accompaniment, using the semi-automatic extraction procedure, can reveal how these two expressive elements contribute to variability in historical performance. This is explored in the PCA results in the next section, but first I will discuss briefly Grieg's execution of the melody and crotchet accompaniment.

	Section A (bars 3-22)	Section B (bars 23-44)	Reprise (bars 45-72)
	Grieg 1903	Grieg 1903	Grieg 1903
Ganz 1917	.557**	.893**	.567**
Grainger 1921	.706**	.827**	.728**
DeGreef 1929	.783**	.853**	.758**
Gieseking 1931	.433**	.700**	.614**
Grøndahl 1937	.593**	.893**	.615**
Joyce 1939	.580**	.807**	.705**
Bauer 1942	.642**	.858**	.727**
Gieseking 1948	.522**	.742**	.638**
Mourao 1970	.606**	.845**	.645**
Knardahl 1977	.462**	.894**	.740**
Kocsis 1981	.375*	.898**	.719**
Oppitz 1993	.449**	.693**	.669**
Gavrilov 1993	.374*	.836**	.646**
Richter 1993	.441**	.797**	.634**
Braaten 1993	.584**	.897**	.592**
Andsnes 1993	.191	.731**	.523**
Nøkleberg 1993	.259	.743**	.499**
Pletnev 2000	.118	.747**	.643**
Austbø 2001	.477**	.782**	.654**

** correlation is significant at the 0.01 level (2-tailed)

Figure 6. Pearson correlations for 'To the Spring', Op. 43 No. 6. Comparison between Grieg and all other pianists in the sample.

A distinctive feature of Grieg's interpretation of the opening melody in Op. 43 No. 6 is the execution of the duple-time crotchets in bars 3, 11, 15 and 17 (for musical score, see Figure 7). The last crotchet in each pair is audibly shortened in duration, thus giving the melodic note that follows a heightened expressive quality. This gesture corresponds to the second timing principle from the generative rules of musical performance: "a note may be lengthened to heighten the impact of the note that follows by delaying its occurrence, the delayed note usually being at the beginning of a structural group" (Clarke 1988, pp. 17-21). Grieg's rhythmic execution, which produces unequal durations or stresses, articulates a declamatory style whereby certain notes in the melody are given greater rhetorical emphasis. In the opening pentatonic melodic fragment (bars 3-6), the emphasis on the dotted minim D sharp in bar 4 (the sixth degree of the scale) marks the anticipation of the relative minor (D sharp minor), which is affirmed in bar 14. The emphasis on the melodic A sharp in bar 12, via the preceding

augmented F sharp triad (a chromatically altered dominant in bar 11), highlights the move towards the relative minor. Finally the emphasis on G sharp in bar 18 via the preceding modally-inflected sharpened fourth, which is also the leading note in C sharp major (B sharp in bar 17), heralds the arrival of the dominant (Figure 7).

Another aspect of Grieg's playing that brings out the declamatory character of the melody is the execution of the second beat crotchets in bars 7, 9, 13, 18 and 21. Grieg pushes the tempo across this motif (which is often a descending line and often marked *tenuto*) producing another rhetorical rhythmic gesture: instead of articulating three more-or-less equal crotchet durations, the first note is placed with an agogic accent while the other two follow in quick succession. Similar supple, rippling gestures can be heard in the execution of the crotchet accompaniment, especially where this is more exposed due to lack of melodic movement underneath, such as in bars 6, 10 and 14 (Figure 7).

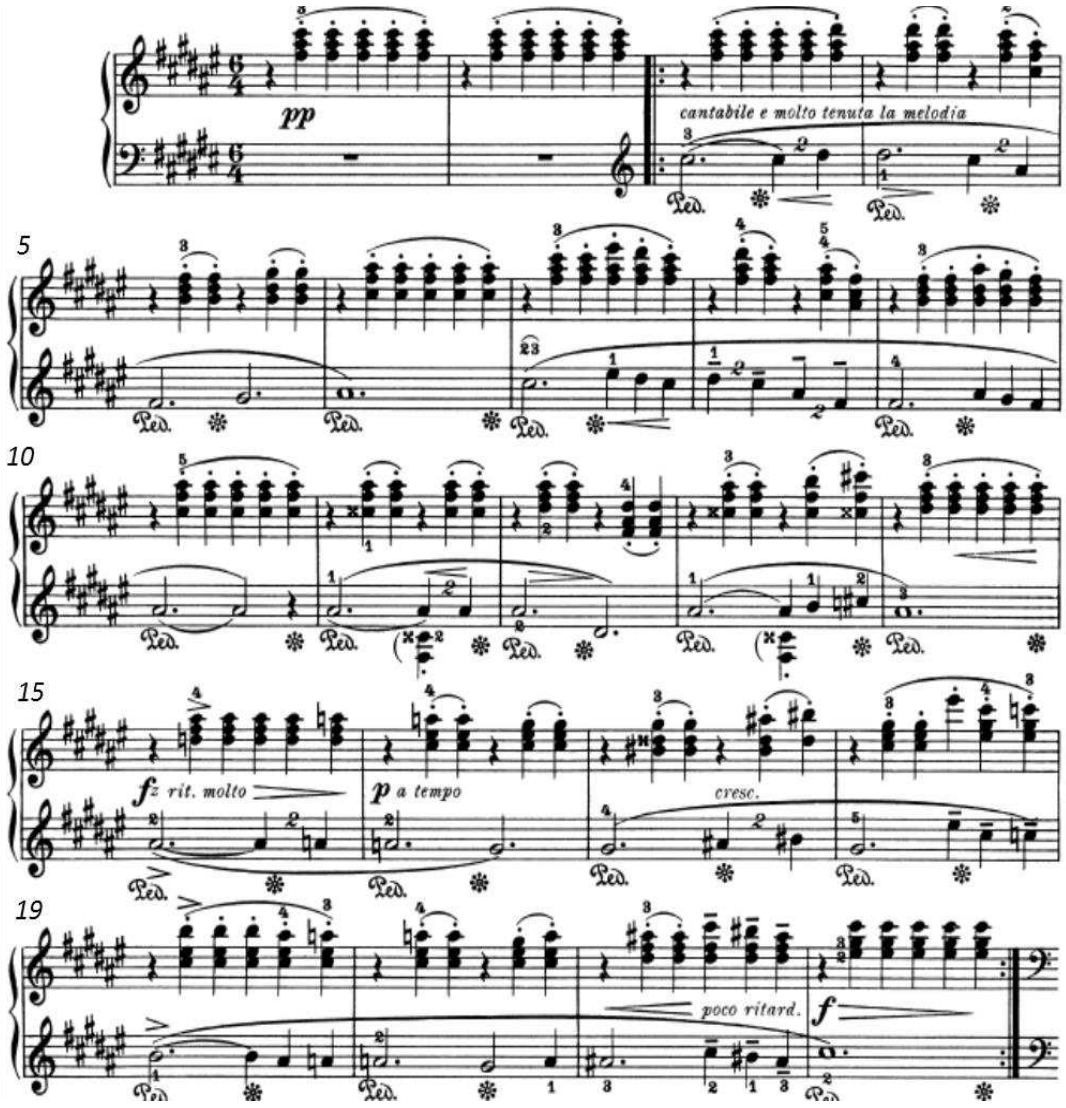


Figure 7. 'To the Spring', Op. 43 No. 6, bars 1-22 (1902 C. F. Peter's Edition).

In the next section I will consider how Grieg's style fares in the broader context of the performance history of these two Op. 43 *Lyric Pieces*. I have used PCA as an exploratory method to decipher putative clusters of association from representative samples of recordings spanning the 20th century (26 recordings for 'Butterfly' and 20 for 'To the Spring').[9]

Suitability of PCA

PCA works optimally on short fragments of music. If the entire beat-tempo profiles containing repeated sections of music are analysed, the underlying assumption of independence in the variables is implicitly violated since the longer the musical sequence the more commonalities it will contain, such as at structural boundaries (Repp, 1992, 1997). For each piece, only applications of PCA on short sections of music are discussed below. To determine the suitability of PCA for each sample, the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) and Bartlett's test of sphericity were inspected (Costello & Osborne, 2005). For every instance of PCA reported below, the KMO value was higher than 0.7 (a value above 0.5 is considered adequate) and Bartlett's test was significant ($p<0.0005$).

PCA results for Butterfly Op. 43 No. 1

When PCA was applied to the opening A section of Op. 43 No. 1 (bars 1-6), a clearly discernible structure for the rotated variables emerged. Grieg had the highest loading (0.96) on PC 2, which accounts for 5.65% of the variance (Figure 8a and b). The rest of the pianists' recordings are more strongly associated with PC 1 (80.53% of variance), and, on the whole, exemplify loadings higher than 0.5 (Figure 8a and b). According to Knardahl's (1977) and Hofmann's (1916) timing profiles, which yielded the highest correlations for PC 1, performances that load more strongly onto PC 1 will exemplify less temporal fluctuation for the Butterfly motif, especially in bars 3 and 4, and a more progressive *ritenuto* across bars 5 and 6 for the articulation of closure (Figure 8c). By contrast, performances loading higher on PC 2 exemplify a more pronounced rhythmic pull and the lack of a two-bar *ritenuto*, reserving phrase-final rubato for the very last beat. Besides Grieg (1903), Reynolds (1999) has the second highest loading on PC 2. While the within-bar tempo fluctuation for the Butterfly motif is not as exaggerated as Grieg's, her articulation of closure is very similar, as can be seen in the graph (Figure 8c) and heard in the recording. In terms of these performance features—the extent of the rhythmic pull, as indicated by the intra-bar surge in beat tempo, and the type of cadential *ritenuto*—the two PCs represent observably (and audibly) different interpretative strategies for the A section of Op. 43 No. 1.

[9] Although popular among amateurs, Grieg's *Lyric Pieces* are not often performed or recorded by concert pianists. This is reflected in the recording history of this repertoire, which amounts to recordings in the tens rather than hundreds. While much larger samples of recordings have been reported in applications of PCA (e.g. Repp, 1998), it is assumed that even the smaller samples used here contain sufficiently different performance strategies to render the exploratory use of PCA suitable.

(a)

Performer	Component	
	1	2
Knardahl 1977	0.93	0.26
Hofmann 1916	0.92	0.31
Mourao 1970	0.90	0.26
Grøndahl 1937	0.88	0.36
Richter 1993	0.86	0.43
Johansen 1940	0.85	0.38
Joyce 1939	0.85	0.41
Rubinstein 1953	0.84	0.44
Gieseking 1948	0.83	0.45
Gilels 1974	0.81	0.52
Austbø 2001	0.80	0.51
Gavrilov 1993	0.80	0.50
Kocsis 1981	0.78	0.57

Performer	Component	
	1	2
Ganz 1916	0.78	0.53
Bauer 1942	0.73	0.51
O'Hora 1995	0.71	0.63
Braaten 1993	0.70	0.67
Ciccolini 1964	0.68	0.39
De Greef 1929	0.66	0.63
Nøkleberg 1993	0.61	0.56
Gieseking 1931	0.60	0.58
Grieg 1903	0.07	0.96
Reynolds 1999	0.42	0.81
Andsnes 1993	0.51	0.76
Oppitz 1993	0.60	0.71
Pletnev 2000	0.54	0.71

(b)

Component	Initial eigenvalues		
	Total	% of Variance	Cumulative %
1	20.94	80.53	80.53
2	1.47	5.65	86.18

(c)

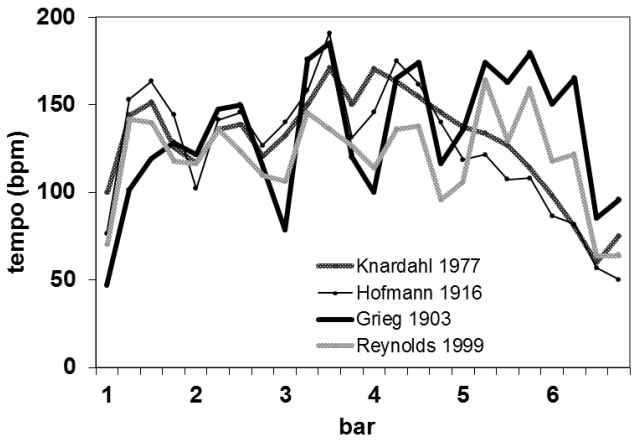


Figure 8. PCA for Section A of Op. 43 No. 1 (bars 1-6), all 26 recordings.
(a) Component loadings after rotation.
(b) Percentage of variance covered by eigenvalues of the two PCs.
(c) Performance strategies exemplified by PC 1 and PC 2 (bars 1-6).

The application of PCA on the first return of the A section of Op. 43 No. 1 (bars 23-30) yielded three PCs with eigenvalues greater than one (Figure 9a and b). PC 1, as represented by the timing profiles of Grøndahl (1937) and Mourao (1970), exemplifies a performance strategy whereby the beat tempo relaxes or levels off, momentarily, across the dotted

rhythms of the second bar (bar 24), and the phrasing ends with a two-bar *ritenuto* across bars 28-29 (Figure 9c). PC 2, according to the beat-tempo profiles of Gavrilov (1993) and Oppitz (1993), also exhibits a *ritenuto* (although this is only initiated from bar 29), but not the levelling off across the second bar in this phrase (Figure 9d). A distinctive timing feature of PC 3, as represented by the profiles of Grieg (1903) and Joyce (1939), is the abrupt rhythmic elision at the end of the phrase (indicated by a surge in beat tempo at bar 30), due to the lack of any phrase-final rubato (Figure 9e). Notwithstanding the observable differences between (and within) PCs 1 and 2, it is PC 3 that highlights a distinct structure in the rotated variables. Grieg's and Joyce's profiles are the principal outliers, and, hence, more distant from the rest of the group.

Analysis of the B section of Op. 43 No. 1 (bars 13-23), reveals a clearly discernible structure of the variables after rotation. Due to limitations of space the full results are not reported here.[10] The key finding was that Grieg's timing profile was no longer the main outlier in the sample, but tended to cluster closer to other pianists. There were more commonalities between Grieg's and the other performers' interpretation of the B section than the A sections of the piece.

(a)

Performer	Component			Performer	Component		
	1	2	3		1	2	3
Grøndahl 1937	0.90	0.20	0.13	O'Hora 1995	0.75	0.51	0.29
Mourao 1970	0.90	0.29	0.20	Braaten 1993	0.73	0.53	0.27
Johansen 1940	0.90	0.29	0.01	Gilels 1974	0.73	0.62	-0.01
Hofmann 1916	0.87	0.41	-0.01	De Greef 1929	0.72	0.57	0.03
Austbø 2001	0.85	0.35	0.26	Gieseking 1931	0.72	0.51	0.06
Bauer 1942	0.84	0.45	-0.06	Gavrilov 1993	0.48	0.76	0.09
Ganz 1916	0.84	0.41	0.17	Oppitz 1993	0.48	0.74	0.25
Knardahl 1977	0.83	0.44	0.07	Pletnev 2000	0.38	0.72	0.31
Gieseking 1948	0.80	0.44	0.10	Ciccolini 1964	0.58	0.68	-0.08
Rubinstein 1953	0.80	0.56	0.07	Reynolds 1999	0.52	0.63	0.20
Richter 1993	0.79	0.49	0.28	Andsnes 1993	0.57	0.59	0.40
Nøkleberg 1993	0.76	0.34	0.27	Joyce 1939	0.26	-0.02	0.88
Kocsis 1981	0.76	0.46	0.32	Grieg 1903	-0.23	0.54	0.75

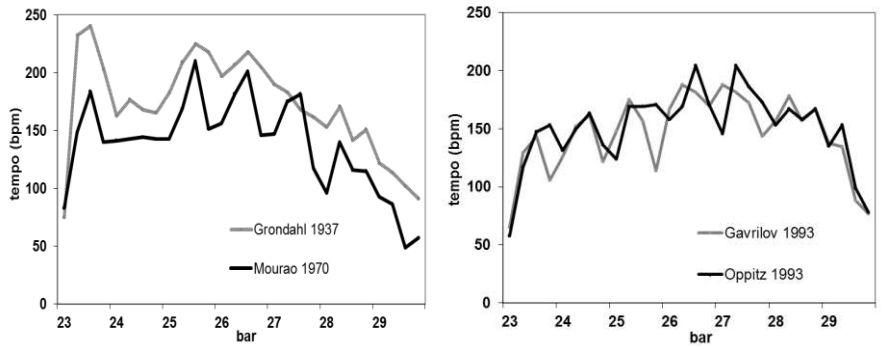
(b)

Component	Initial eigenvalues		
	Total	% of Variance	Cumulative %
1	19.55	75.18	75.18
2	1.90	7.29	82.48
3	1.03	3.96	86.44

Figure 9. PCA for first return of A section of Op. 43 No. 1 (bars 23-30), all 26 recordings.
(a) Component loadings after rotation.
(b) Percentage of variance covered by eigenvalues of the three PCs.

[10] See Volioti, 2011, pp. 154-156.

(c) (d)



(e)

Figure 9. (continued) PCA for first return of A section of Op. 43 No. 1 (bars 23-30).
(c) Performance strategies exemplified by PC 1.
(d) Performance strategies exemplified by PC 2.
(e) Performance strategies exemplified by PC 3.

PCA results for To the Spring Op. 43 No. 6

When PCA of the beat-tempo data of the first eight-bar phrase of the A section of Op. 43 No. 6 (bars 3-10, i.e. excluding the two-bar introduction) was carried out, six PCs were extracted (full results not reported here). This finding suggests that when comparing beat-tempo profiles there is heterogeneity in this sample that is not easily reducible to a few significant PCs.

PCA using the melody timings only (bars 3-10), yielded a reduction to four PCs and the structure of the rotated variables revealed clearer chronological groups in the sample (Figure 10a). The largest variance (40.66%) is explained by PC 1, which represents early pianists such as Grieg (1903) and Grainger (1921). PC 3 (11.97% of variance) also accounts mainly for styles from the first half of the 20th century, such as Gieseking (1931 and 1948) and Joyce (1939). PCs 2 and 4 (explaining collectively 24.77% of variance) exemplify later pianists' styles, such as Gavrilov (1993) and Pletnev (2000) respectively. I will deal only with PCs 1 and 4, which represent audibly distinct performance strategies and account for the largest and smallest sample variances respectively.

As can be seen in Figure 10c, and heard in the recordings, Grainger's (1921) and Grieg's (1903) melody profiles share various similarities.[11] Both pianists bring out the second melody note in bars 4, 7 and 9 with an expressive *tenuto* stress, producing a dip in the melody tempo. (This gesture is also present at bars 7 and 9 in Pletnev's profile, but not in bar 4.) Similar *tenuto* accents characterise the first and third melody notes in bar 8 in both Grieg and Grainger's performances. Grieg, however, exemplifies a more poignant declamatory melodic gesture across bars 3-4, due to the extreme shortening of the duration of the second duple-time crotchet in bar 3 (reflected by the sharp peak in the melody profile). Another point of difference is that Grieg demonstrates a more liberal rushing of the last three melody crotchets in bars 7 and 9 than Grainger (reflected by a notable rise in Grieg's beat tempo). By contrast, Grainger creates an additional declamatory inflection of the melody by shortening the second duple-time crotchet in bar 4, hence the peak in tempo on the third inter-onset of bar 4 (Figure 10c).

The above-mentioned declamatory-like rhythmic elisions in the melody at bar 3 (Grieg and Grainger) and bar 4 (Grainger) cannot be seen in Pletnev's profile (PC 4). For instance, Pletnev's opening four-bar phrase (bars 3-6) is at a slower tempo than the PC 1 profiles and exemplifies more even rhythmic sub-divisions. Listening to early pianists' recordings, especially those representing PC 1 (e.g. Grieg, Grainger, De Greef, Bauer and Grøndahl), confirms their tendency towards more idiomatic rhythmic execution. PC 1, therefore, accounts for the largest variance due to the early pianists' faster tempi and rhythmic elisions that produce a more exaggerated rhetorical inflection of the *cantabile* melody.

[11] Any stylistic similarity between these two pianists might not be so surprising given that Percy Grainger was Grieg's favourite interpreter of his piano music. The close association between these two individuals, and Grieg's influence upon Grainger as performer and composer, is well documented in the literature (e.g. Grimley, 2006, pp. 192-220; Tan, 2000; Volioti, 2010).

(a)

Performer	Component			
	1	2	3	4
Grieg 1903	0.86	-0.11	0.10	0.27
Ganz 1917	0.54	-0.19	0.56	0.33
Grainger 1921	0.90	0.13	0.28	0.02
DeGreef 1929	0.75	0.11	0.47	0.10
Gieseking 1931	0.32	-0.03	0.89	0.01
Grøndahl 1937	0.51	0.13	-0.01	0.66
Joyce 1939	0.13	0.24	0.74	0.35
Bauer 1942	0.73	0.29	0.34	0.16
Gieseking 1948	0.25	0.09	0.85	0.04
Mourao 1970	0.49	0.80	-0.08	-0.13
Knardahl 1977	0.44	0.74	0.04	-0.03
Kocsis 1981	0.36	-0.04	-0.03	0.83
Oppitz 1993	-0.03	0.13	0.32	0.74
Gavrilov 1993	-0.28	0.85	0.10	-0.03
Richter 1993	-0.05	0.65	-0.04	0.43
Braaten 1993	0.25	0.61	0.51	0.22
Andsnes 1993	-0.28	0.55	0.47	0.20
Nøkleberg 1993	0.20	0.53	0.15	0.56
Pletnev 2000	-0.02	0.03	0.18	0.89
Austbo 2001	0.46	0.52	0.39	0.44

(b)

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	8.13	40.66	40.66
2	3.02	15.11	55.77
3	2.39	11.97	67.74
4	1.93	9.66	77.40

Figure 10. PCA for melody line extracted from Op. 43 No 6 (bars 3-10), all 20 recordings.
(a) Component loadings after rotation.
(b) Percentage of variance covered by eigenvalues of the four PCs.

(c)

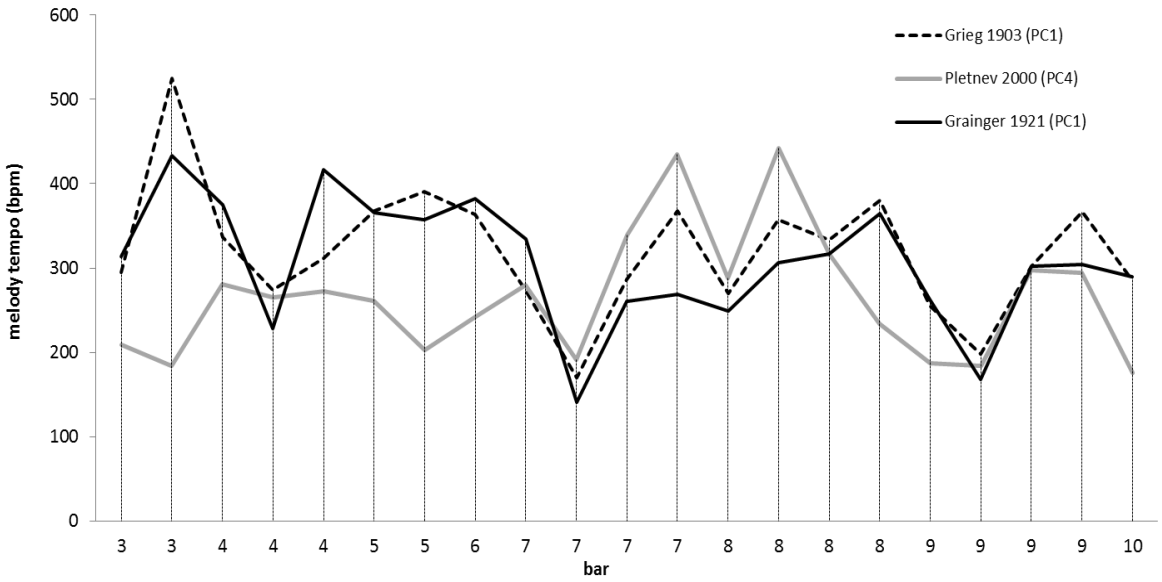


Figure 10. (continued) PCA for melody line of Op. 43 No. 6 (bars 3-10).
(c) Comparison of timing profiles representing PC 1 (largest variance) and PC 4 (smallest variance). The x-axis markings indicate the number of melodic inter-onsets within the bar. There are two melodic inter-onsets in bar 3, three events in bar 4, two events in bar 5, one in bar 6, four events in bar 7 and so on (for a score of Op. 43 No. 6, see Figure 7).

Analysis of the extracted crotchet accompaniment (bars 3-10), yielded four PCs with eigenvalues greater than one (Figure 11a). Early pianists, such as Grieg (1903) and Grainger (1921), load more strongly onto PC 1 (42.36% variance). The crotchet profiles of some later pianists (e.g. Mourao and Kocsis) are also embedded in PC 1. Profiles from the first half of the century are associated more strongly with PC 2 (12.27% variance), while profiles from the second half of the century tend to load onto PC 3 (10.04% variance). PC 4 (7.45% variance) exemplifies mainly later pianists' strategies, such as those of Pletnev (2000).

Figure 11c shows interpretative differences in the execution of the crotchet accompaniment for profiles that load higher on PCs 1 and 4. Only these two PCs are considered here since they represent audibly distinct strategies. Early pianists such as Grieg (1903) execute the crotchet accompaniment more flexibly than those using the strategies embedded in PC 4, and produce an undulating crotchet pulse making piquant rhythmic gestures including the rushing of the last beat in bars 3, 4 and 8 (Figure 11c). Grieg's recording reveals that these irregularities in tempo are the result of interpolating three-against-two rhythms between the crotchet accompaniment and the melody. PC 1 also contains the profiles of some later pianists, such as Kocsis (1981), who exhibit rhythmic flexibility in the three-against-two couplings. For example, Kocsis makes an additional, and rather extreme, rhythmic interpolation in the first part of bar 8 (see Figure 11c). As observed in the PCA results of the melody timings, however, Kocsis' melody profile was strongly correlated with PC 4 (see Figure 10a), which was representative of the tendency towards less melodic inflection. Given the combined PCA results for melody and crotchet accompaniment, it appears that although the exaggerated rhetorical inflection of the melody is a property of earlier performing styles,

the rhythmic flexibility in the crotchet accompaniment is not. Historical variability in this sample arises from how performers 'mix-and-match' the expressive handling of these two elements. However, the idiomatic inflection of both melody and accompaniment, which is indicative of 19th-century rhetorical performance practices, is clearly evident in the early 20th-century recordings of pianists such as Grieg and Grainger.

(a)

	Component			
Performer	**1**	**2**	**3**	**4**
Grieg 1903	0.89	0.11	0.02	0.08
Ganz 1917	0.24	0.80	0.00	0.33
Grainger 1921	0.88	0.25	0.11	-0.02
DeGreef 1929	0.58	0.69	0.09	0.07
Gieseking 1931	-0.19	0.88	0.10	0.03
Grøndahl 1937	0.35	0.43	-0.08	0.55
Joyce 1939	0.57	0.39	0.31	0.30
Bauer 1942	0.76	0.16	0.09	0.22
Gieseking 1948	0.23	0.69	0.30	-0.15
Mourao 1970	0.80	0.14	0.32	0.03
Knardahl 1977	0.49	0.50	0.28	0.20
Kocsis 1981	0.81	-0.16	-0.09	0.35
Oppitz 1993	0.17	-0.01	0.32	0.71
Gavrilov 1993	-0.14	0.19	0.82	0.18
Richter 1993	0.31	0.29	0.50	0.41
Braaten 1993	0.37	0.41	0.60	0.28
Andsnes 1993	0.08	-0.02	0.88	0.06
Nøkleberg 1993	0.54	0.14	0.17	0.49
Pletnev 2000	0.03	0.05	0.14	0.83
Austbø 2001	0.50	0.08	0.67	0.14

Figure 11. PCA for crotchet accompaniment of Op. 43 No. 6 (bars 3-10), all 20 recordings.
(a) Component loadings after rotation.

(b)

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	8.47	42.36	42.36
2	2.45	12.27	54.62
3	2.01	10.04	64.67
4	1.49	7.45	72.12

(c)

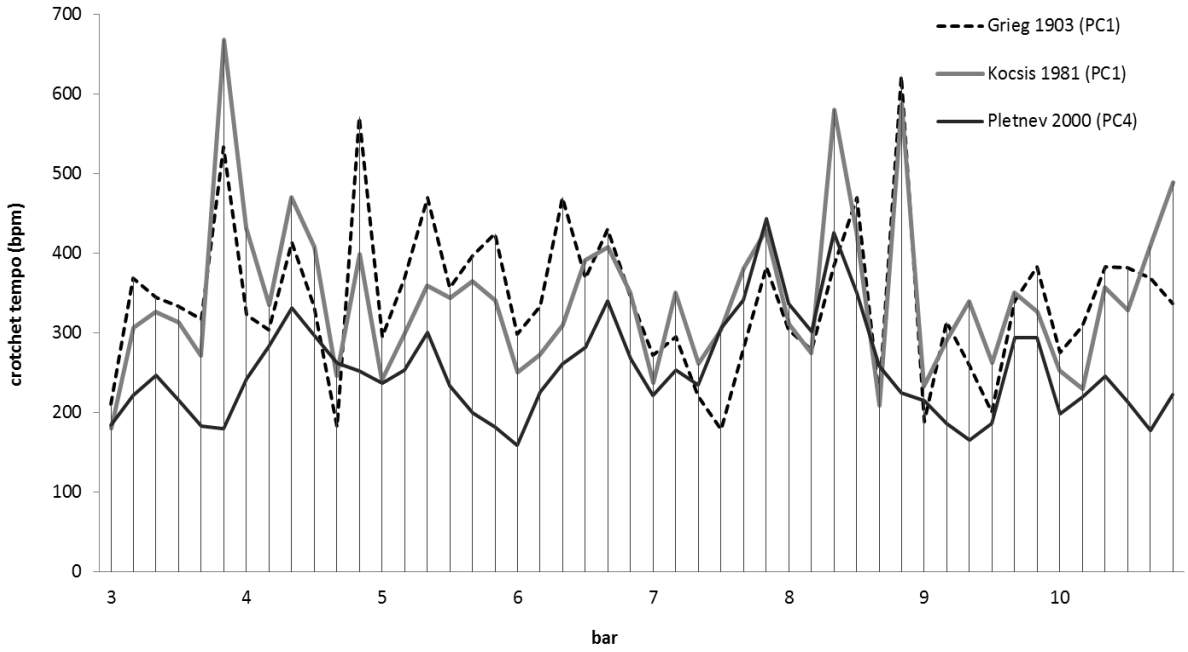


Figure 11. (continued) PCA for crotchet accompaniment of Op. 43 No. 6 (bars 3-10).
(b) Percentage of variance covered by eigenvalues of the four PCs.
(c) Comparison of timing profiles representing PC 1 and PC 4 only.

CONCLUSIONS

In this article I have presented an empirical characterisation of Edvard Grieg's pianism via historical recordings of two of his Op. 43 *Lyric Pieces* using techniques of beat-tempo analysis. From the exploratory PCA, results show that Grieg's performance strategies for the A sections of 'Butterfly', Op. 43 No. 1, set him apart from other pianists in the sample. This is attributed to two interpretative features: the exaggerated rhythmic pull of the first beat of the Butterfly motif and the lack of a progressive *ritenuto* at the cadence. The lack of phrase-final rubato potentially indicates Grieg's restrained romantic performance aesthetic. Grieg had openly expressed his "mistrust of the rubato influenza" (e.g. Halverson, 1994, pp. 21-22 and 34). His performance style is permeated by a predilection for fast tempi and an overall rhetorical flair for always pushing the rhythmic momentum forwards and articulating the large-scale narrative of the music.

The elastic potential scripted in the intervallic make-up of the Butterfly motif potentially permits greater interpretative freedom for a 19th-century pianist such as Grieg, prompting more rhetorical inflection in performance. Such expressive lengthening of a single beat becomes an ostensible demonstration of what the 19th-century piano pedagogue and theorist Adolph Kullak designates: "the [single] tone held back becomes more suggestive, more pregnant; it more strongly impresses itself upon the ear, […] it symbolizes the intensity, the impressiveness, the warmth of declamation" (Kullak, [1861] 1893, p. 282).

Following the extraction of separate melody and accompaniment timings for the opening section of 'To the Spring', Op. 43 No. 6, the results of exploratory PCA showed that early pianists' styles, including that of Grieg, contribute to the largest expressive variability in the sample due to more exaggerated rhetorical inflection of both the melody and crotchet accompaniment at faster tempi. Grieg's playing of 'To the Spring', Op. 43 No. 6, was found to be imbued with a similar vitalist aesthetic as 'Butterfly', Op 43. No. 1. The performance of 'To the Spring' is adorned with expressive declamatory melodic accents and supple rippling gestures in the execution of the crotchet rhythms. As Mathis Lussy, another 19th-century performance theorist, asserted: performance expression is not simply the ability to abide by tonality, metre and rhythm, but stems from the performer's ability to create "irregularities that can affect the sentiments" (Lussy, [1874] 1892, p. 163). Grieg's performance style, as this empirical investigation of recordings of two *Lyric Pieces* has shown, displays his tendency to favour such irregular, yet highly expressive, gestures that tease the listener's ear.

From the methodological standpoint, complementary statistical analyses besides exploratory PCA, such as multi-dimensional scaling or clustering analysis, could also be useful in discerning the differences between Grieg's interpretations and those of other pianists. Concerning the semi-automatic extraction method used here, further evaluation would be desirable for establishing its relative strengths.

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GEORGIA VOLIOTI is a lecturer in Music at the University of Surrey. Her interests, which are inter-disciplinary in orientation, lie in historical and cultural musicology, music performance studies, and empirical musicology. Research topics include analysis of performance, historical recordings, cultural responses to recordings, listening practices, musicians' self-regulated learning, expressive gesture, and visual culture and music. Her work has been published in *The Musical Quarterly, Music & Letters, The Journal of Musicological Research*, and *Musicae Scientiae*. She has also contributed essays to edited collections, and scholarly review articles have appeared in *Nineteenth-Century Music Review and Empirical Musicology Review*, among others.

APPENDIX

A 1.1 Generating the input data for the semi-automatic extraction algorithm

The semi-automatic extraction algorithm requires input data in the file format [.notes]. This is similar to a MIDI file but in a more readable text format. First, the musical score was converted into digital notation as follows:

a) The score was scanned as a black and white image at 300 dots per inch resolution and saved as a TIFF file.

b) The scanned image was converted into symbolic data using the music recognition software SharpEye.[12]

c) Music data from SharpEye were saved in MusicXML format and converted into Humdrum.[13] This step creates the source for the pitches in the score.

Second, the tapped beat timings obtained from each recording in Sonic Visualiser and exported in text format were merged with the digitised score data as follows:

d) The beat-tempo data from each recording were first aligned with the beat locations according to the digitised score. The timings of notes which were not on the beats were linearly interpolated to create a file that contains all the estimated note locations in a recording. These data were saved in the [.notes] format and provided the input for the extraction algorithm. A [.notes] file of a recording is an approximate performance score and contains only the estimated note onset timings. The algorithm uses these to find their sonic realisation in the actual performance. The more accurate the beat timings the more accurate the search and identification of the inter-onsets by the algorithm.[14]

[12] Available at http://www.visiv.co.uk (accessed June 18, 2018).
[13] Available at http://extras.humdrum.org/man/xml2hum (accessed June 18, 2018).
[14] Steps a) to c) have to be performed only once per score. Steps b) to d) were completed with the assistance of Craig Sapp using the beat-tempo data I obtained with Sonic Visualiser for all twenty recordings of 'To the Spring', Op. 43 No. 6. I subsequently put each one of the twenty [.notes] files through the semi-automatic extraction algorithm.

A 1.2 Pre-processing of audio files

The algorithm requires the input audio files to be at a sampling rate of 16kHz. These were generated in Audacity (version 1.3).[15] Each audio file was imported and the stereo track was split into mono. With both waveform panels selected, 'Amplify' was chosen from the 'Effect' option and the amplification value was set at –6dB. From the 'Project Rate' option the sampling value was set at 16,000 Hz. From the 'Tracks' option, 'Mix and Render' was chosen. Finally, the modified file was exported as WAV.

A 1.3 Running the semi-automatic extraction algorithm

For each sound recording processed with the extraction algorithm, the output file labelled 'algorithm-subbeats.dat-individualnotes.dat' was imported into Microsoft Excel. Using the information contained in the third column (pitches in MIDI notation) and the fifth column (individual timings for each note in the recording), the timings corresponding to those pitches of interest, such as the melody line of 'To the Spring', Op. 43 No. 6, were manually selected. Where a rhythmic event comprises multiple notes, such as a chord, the algorithm will generate timings for both the collective event (recognising all notes in the chord as one event) and the separate timings for each note. The accompaniment crotchet chords were selected according to the timing value corresponding to the top note, since the top note doubles the melody and is clearly audible in all the recordings.

These selected timing values (in seconds) were saved in text format and imported back into Sonic Visualiser so that their locations could be checked. Any errors were manually corrected in Sonic Visualiser by moving any displaced time instant and aligning it onto its corresponding note onset. The corrected annotation layer was saved in text format and exported to Excel in the usual manner. From the corrected timings, the melody line and the crotchet accompaniment were expressed in beats per minute. To convert the melody line into beats per minute, each [60/IOI] value was multiplied by the number of crotchet beats corresponding to that notated rhythm. For example, in 6/4 time a dotted minim is equivalent to three crotchets (therefore multiply [60/IOI] by three), a dotted crotchet in duple metre is equivalent to one and a half crotchet beats (therefore multiply [60/IOI] by one and a half) and so on.

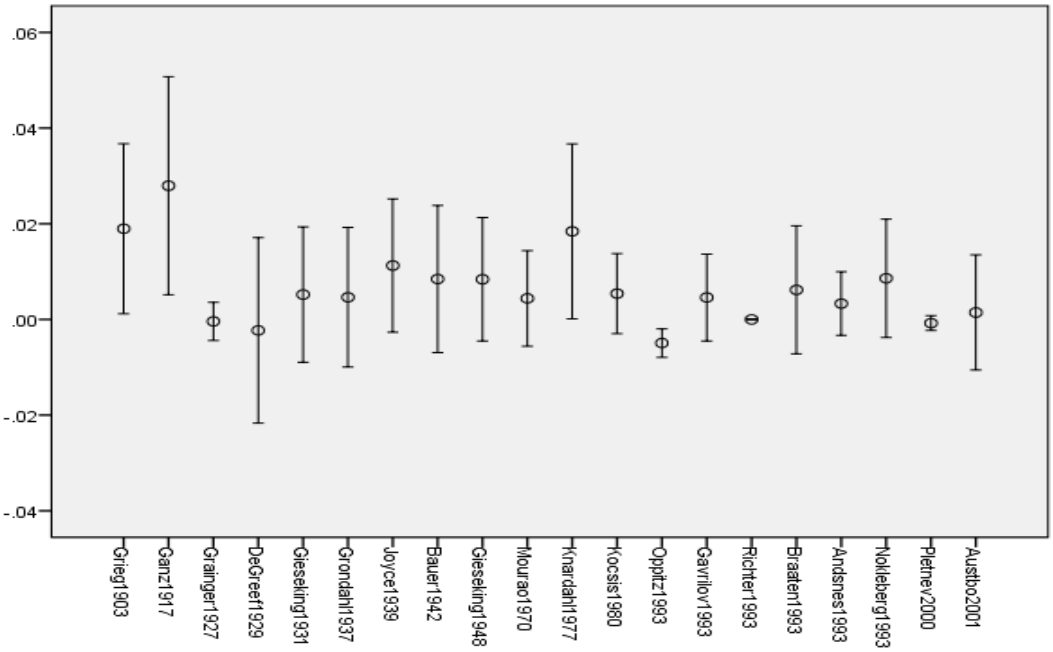
A 1.4 Error estimation after extraction

A quick and convenient evaluation of the extraction method was done by comparing the timing values before and after correction. Figures A 1.4 (a) and (b) below show the error bar plots (mean and associated 95% confidence interval) of the difference in before and after timings for each recording. (An extensive evaluation of the algorithm lies beyond the current scope.) The extraction method tends to work better for cleaner recordings dating from more recent decades. As my listening experience revealed during manual correction, early recordings by Grieg (1903), Ganz (1917) or De Greef (1929), which exhibit faster tempi and a more idiomatic execution of the score rhythms, contained several extracted time instants that did not always align onto the correct note onset. For the melody line of Op. 43 No. 6, these

[15] Available at http://audacity.sourceforge.net/download/ (accessed June 18, 2018). More recent versions of Audacity are currently available but the features are essentially the same.

misaligned events tended to occur where two notes of the same pitch are repeated in quick succession, most notably in bars 3-4, 11-12 or 15-16 (for a score of Op. 43 No. 6, refer to Figure 7).

(a)



(b)

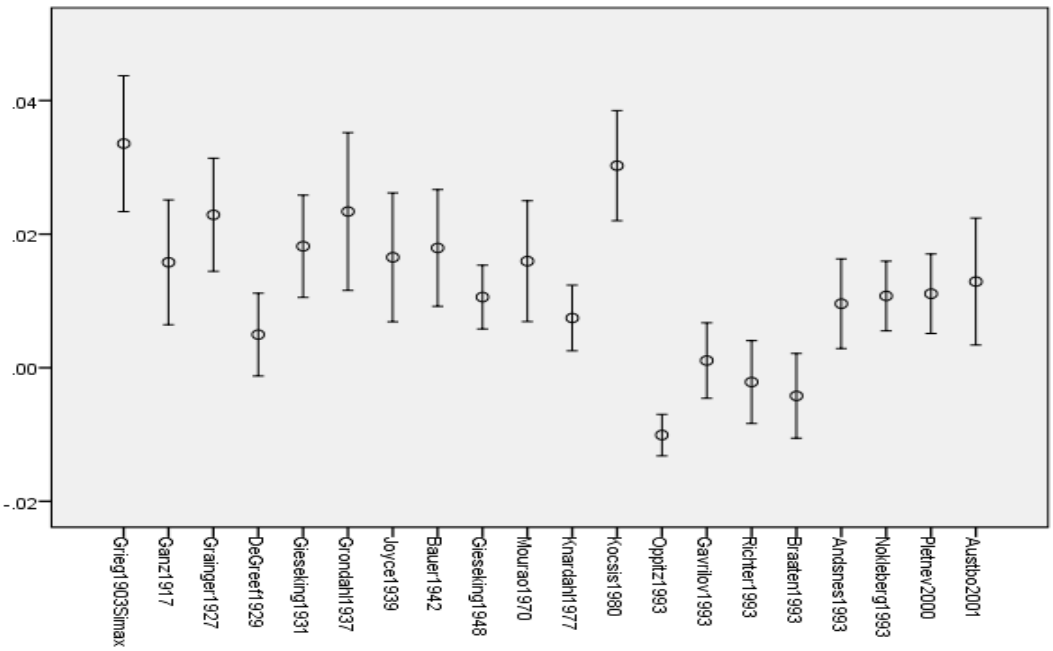


Figure A 1.4 Error bar chart (mean with associated 95% confidence interval) for the difference in before/after correction timings for:
(a) extracted melody; and (b) extracted crotchet accompaniment of Op. 43 No. 6.