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Is there a 'rise-fall temporal archetype' of intensity in the music of Joseph Haydn? The role of the performer

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ABSTRACT: Patterns of acoustic intensity profiles are investigated in recorded performances of the music of Haydn. Consistent with our earlier observations of composed, acousmatic, live-performed, and improvised electroacoustic music, and of jazz improvisations (Dean & Bailes, 2010a, b), we hypothesised that in successive pairs of intensity rises and falls, rises are shorter in duration relative to falls, follow a faster rate of dynamic intensity change (decibel change / time), but are not significantly different in frequency of occurrence. We ask here whether this hypothesis is applicable to interpretations of 119 movements of Haydn's works. We consider a wide range of instrumental groupings, from solo to orchestral, and we also consider multiple performances of single pieces. The hypothesised pattern was routinely observed. We also took note of alternative predictions that might flow from the 'ramp archetype' observed by Huron (1991) in notated scores of the classical and romantic era, notably in the scores of the Beethoven piano sonatas and others. This statistical archetype might suggest, contrary to our hypothesis, that performed crescendi are longer in duration than diminuendi, greater in their frequency of occurrence, and follow a more gradual rate of intensity change. Thus we also investigate our hypothesis in relation to a sample of the Beethoven sonatas included in Huron's (1990) score analysis. The data on Beethoven are again consistent with our hypothesis, and we conclude that it is appropriate to these performances also. The observations can be understood in terms of the psychology of expectation and attention, and we discuss the possibility that they apply to vocal and natural sounds, either of which might allow an explanation for their occurrence in music.

KEY WORDS: acoustic analysis, Beethoven, Haydn, intensity change, musical dynamics, ramp archetype

Dynamic features of music have a profound effect on listeners' perceptual and emotional experience. For example, temporal patterns of acoustic intensity change in both orchestral and electroacoustic music are significantly related to continuous real-time perceptions of loudness and the perceived affective feature, arousal (Dean, Bailes, & Schubert, 2011; Ferguson, Schubert, & Dean, 2011). It has been established that acoustic intensity acts as a reliable cue to music's expressed emotion(s) across cultures (Balkwill, Thompson, & Matsunaga, 2004) and is associated with heightened psychophysiological responses that may underpin emotional experience (Juslin & Västfjäll, 2008; Olsen & Stevens, 2013). Empirical studies have investigated behavioural outcomes in response to acoustic intensity in music, but little research has focused on the characteristics of realised acoustic intensity dynamics in musical performance. The aim of this study therefore was not to investigate human response to intensity dynamics per se, but rather, to conduct a musicological/acoustic investigation of recurrent temporal structures of intensity dynamics in *performed* instrumental music. We present a computational analysis of musical dynamics in recorded performances of works from Haydn, supplementing it with work on Beethoven that builds on the musicological analyses of dynamics as notated in scores, conducted by David Huron over twenty years ago.

Recently we provided computational analyses of acoustic intensity dynamics in a wide range of electroacoustic music (Dean & Bailes, 2010b). In electroacoustic music, intensity profiles are largely unrestricted by the physical activities of performers that directly generate sound on conventional musical instruments. The results showed an asymmetry in acoustic intensity, which is the basis for our main hypothesis here: we found that in electroacoustic music the duration of rising intensity ramps is shorter than their falling intensity counterparts, and correspondingly the rate of intensity change during rising intensity ramps is greater than in falling intensity ramps.

Although this observation applied to studio-composed acousmatic music, it was not necessarily true of improvised electro-acoustic music, where a range of instrumental interfaces can be used. But in our 'FEELA' interpretation (Dean & Bailes, 2010b) we suggested that electroacoustic performers do use sonic counterparts from sculpted electroacoustic sound to invoke notions of force-energy input that are in common with instrumental performances. The FEELA interpretation predicts that listeners are affected by a performer's observed force and energy (FE), and may perceive effort and loudness (EL), which influences perceived affective expression from the music (A). So in accord with this, we analysed a number of performances of improvised music, including both acoustic and digital instruments, with results that were similar to those for acousmatic (pre-composed) music (Dean & Bailes, 2010a). Thus, to date, all our studies of acoustic features of acousmatic and performed electro-acoustic music of the 1950s until the present support our hypothesis: that in performed music, crescendi are shorter and with faster dynamic change than diminuendi, although the frequency of occurrence of the two dynamic features may not differ.

The present study consequently investigates the characteristics of acoustic intensity in performances of the instrumental music of the classical period, with primary reference to the above hypothesis. Particular focus was placed here on the massive canon of works by Joseph Haydn, arguably one of the most unpredictable of the major classical composers in his use of pitch, texture, and rhythmic variation (Margulis & Beatty, 2008). In providing guidance to the Laibach Philharmonic in advance of a performance of his music, Haydn reportedly said: "above all … refrain from all manner of ornamentation … As you well know, the greatest beauty depends only on the right tempo, suitable dynamic shading, and accurate execution" (Jerold, 2008, p. 104). Given that Haydn's scores contain relatively few dynamic markings, especially in comparison with music of later centuries, we should therefore expect performances to represent a rather greater range of dynamic structures than the scores may imply. This makes Haydn's music particularly interesting as examples for our study of the classical canon in performance. Following from the acoustic analysis of Dean and Bailes (2010a, b), we expect that acoustic intensity patterns in performances of music from the works of Haydn will follow the prediction of our hypothesis.

In addition to investigating our hypothesis, we also revisited converse ideas that can be derived from consideration of notated score analyses. Musicological analyses of dynamic markings in piano sonatas of Beethoven (and some other classical and romantic works) have shown that notated musical crescendi – which are associated with increases of acoustic intensity and perceived loudness – are more frequent and cover a greater duration of dynamic change than notated diminuendi (associated with decreases of intensity and loudness) (Huron, 1990). Huron proposed a temporal asymmetry of intensity patterns in music, which he called a 'ramp archetype' (Huron, 1991). He suggested that gradual and extended rises (increasing ramps) of intensity associated with notated crescendi might function to maintain listeners' attention throughout a musical piece (Huron, 1992).

Through association between notated crescendi/diminuendi and rises/falls of intensity ramps, Huron suggested that dynamic markings on a score have both performance and perceptual validity; that is, the markings are correlated with perceptual experiences such as loudness in response to musical dynamics (Huron, 1991). However, he did not conduct acoustic analyses of musical dynamics and their perceptual correlates. In the context of performed musical dynamics, specific predictions from Huron's ramp archetype theory can be made, and these would be the exact converse of our hypothesis. The validity of Huron's notational analyses is in no way doubted; our question here is whether their implications are realised in performances of Beethoven or not. Overall, the main aim of this study was to investigate our hypothesis through computational analyses of a range of recorded musical performances of Haydn. In addition, given the results of this, the secondary aim of the study was to assess whether its predictions are still upheld in performances of selected works of Beethoven included in the score analysis conducted by Huron (1990).

METHOD

Pieces analysed

The corpus for this study contained 119 movements of Haydn's works, including 19 string quartets together with examples of piano trios, piano sonatas, brass concerti, and symphonies, as listed in Table 1. The quartets were wide ranging within Haydn's oeuvre: they included all six of the Opus 20 set, and one example from each of the other major series from Opus 9 to Opus 77. We wanted to assess how widespread the statistical features might be amongst different performers, and different instrumental forces. Thus we also included comparisons between: (1) different performers' renderings of a single work; (2) piano trio performances using modern and period pianos; and (3) symphonies and other chamber/orchestral works. These contrasts were intended to assess whether the results might be indicative of the general way that Haydn's music is performed, or if they might reflect the taste of individual performers.

In addition to the works of Haydn, seven Beethoven piano sonatas were analysed (19 movements). Computational analyses of dynamics in these sonatas form the secondary aim of our study and provide a partial comparison with Huron's (1990) score analysis of Beethoven's entire set of 32 piano sonatas. The selection of 19 movements comprised a portion of the works analysed by Huron (1990) and were chosen to include works from the majority of the period in which Beethoven was writing piano sonatas (1795 to 1822). The sonatas studied were from Opus 31 (1802) to Opus 111 (1822). The pianists were from different periods of 20th century piano performance, and were intended to provide stylistic complements to the often idiosyncratic approach of Glenn Gould (whose recording of Haydn piano music is also studied).

Table 1: List of Haydn and Beethoven performances used in analyses (136 movements in total)

Performer	Numbering	Instrumentation
Works of Haydn		
Angeles Quartet	Opus 9, 17, 20 (No. 1-6), 33, 42,	String Quartet
	50, 54, 55, 64, 71, 74, 76, 77	
Amadeus Quartet	Opus 64, 74	String Quartet
Gould	Opus 51, 52	Piano Sonata
Ranki	Opus 54, 55	Piano Sonata
Cohen Piano Trio	Number 39	Piano Trio
Schiff Piano Trio	Number 12, 14, 31	Piano Trio
Wallace	Hob. Vlle/1	Trumpet Concerto
Thompson	Hob. Vlld/3	Horn Concerto No. 1 in D
Queyras	Hob. Vllb/1	Cello Concerto in C
Philharmonia Hungarica	Number 103, 104	Symphony
Works of Beethoven		
Backhaus	Opus 31 (No. 2), 57, 78, 79, 81	Piano Sonata
Brendel	Opus 109, 111	Piano Sonata

Data analysis

Data analysis followed the detailed protocol described by Dean and Bailes (2010b), a summary of which is presented here.

Data reduction

The duration, frequency, magnitude, and rate of intensity change for successive pairs of rises and falls in each piece were analysed using Praat (Version 5.3.23). Intensity is measured using the 'energy averaging' option within Praat, and a pitch range for the analysis from 20Hz upwards, which provides intensity as Sound Pressure Level (SPL) in decibels (dB). Stereo sound files are averaged in this process. Summary statistics representing the intensity temporal profiles are determined from the 0.04 s window analyses described below.[1]

The 'all-peaks' and 'significant-peaks' measures

First, the mean intensity (SPL) over time frames of 0.04 s, 0.5 s (the approximate duration of a beat), 5 s (the approximate duration of a bar of music in the slow movements, and two bars in fast movements), and 10 s was measured. For each temporal window of analysis, each successive (paired) peak and trough was identified. By definition, every intensity peak is followed by a trough (the 'all-peaks' measure). A maximum temporal window of 10 s was chosen because data points available for meaningful statistical comparisons decrease as the temporal window increases. The 10 s window was deemed a suitable maximum that was sensitive to performed dynamics while also allowing a suitable number of data observations for analysis.

Second, 'significant-peaks' and troughs were measured for the 40 ms data using a 1/5 dynamic step criterion. Here only peaks/troughs that differ from the immediately preceding peak/trough by >=1/5 (the 'dynamic step') of the range between 10%-90% quantiles of mean intensity are recorded. A 1/7 dynamic step criterion has also been used in similar analyses of dynamics in electroacoustic music (Dean & Bailes, 2010b) and parallels dynamic ranges used in contemporary notated music and the notational score analyses of Huron (1990); for example, *ppp* (representing a range up to the 10% quantile), *pp*, *p*, *mp*, *mf*, *f*, *ff*, and *fff* (representing the range beyond the 90% quantile). However, there are few dynamic markings and even fewer systematised ranges defined in Haydn's notation of his music, even though complex dynamic nuancing is introduced in most (if not all) performances, and also encouraged by the composer. In light of this fact, the analysis here will report data using the 1/5 quantile range dynamic step (corresponding to *pp*, *p*, *mp*, *mf*, *f*, *ff*)[2]. Most of the Haydn performances have dynamic ranges of between 20 and 30 dB; thus in general the 1/5 criterion corresponds to 4-6 dB. Beethoven was renowned for a more comprehensive use of dynamic markings than other composers of his period. Therefore, we also analysed these data using the 7-step criteria, and results (not shown) are consistent with the overall conclusions of the study. Rise times and corresponding rates of intensity increase are measured by cumulating the parameters of each immediate succession of peaks, and fall parameters for each succession of troughs. In all-peaks and significant-peaks analyses, the whole duration of the piece is attributed either to intensity rises or intensity falls. Note that rise-fall patterns can only be determined when they are at least twice the window length in duration, but the 40 ms window permits determining rise-falls of any greater length, and can do so with greater precision than permitted by a longer window. In previous papers we have fully detailed the technical issues of window size, and confirmed that our measures do not reflect simple note attacks.

[1] The first window in a Praat intensity analysis is set by the software, and is usually longer (~170 ms) than the minimum (40 ms), and so this is measured and accounted for in the analyses. Occasional artefactual calculated window intensity values below zero, and 'undefined' values, are set to zero during the analysis (these occur at less than 0.5% of data points).

[2] An analysis using the 1/7 dynamic step criterion was conducted on the present set of performance recordings, and results concur with the 1/5 dynamic step criterion and support all conclusions of the study.

Frequency of dynamics

In a third analysis, we tested whether rises of acoustic intensity are more common than intensity falls. We used the significant-peaks and the 0.5 s window, since: (1) musically significant crescendi and diminuendi (as normally conceived) operate over at least this time frame; and (2) significant-peaks and the 0.5 s window permit the detection of any longer patterns. An intensity rise in this analysis is an increase in intensity of >(1/2 x dynamic step) from the reference value at any particular time (the most recent peak or trough); an intensity fall is a comparable decrease. This ensures that the difference is generally well above the just noticeable difference for sound intensities (of the order of 1 dB) (Johnson, Turner, Zwislocki, & Margolis, 1993). Successive values that oscillate within ±(1/2 x dynamic step) from the reference value at any particular time are labelled 'plateau'. Here, as in musical notation and in contrast to the all-peaks and significant-peaks analyses just described, if an intensity rise precedes and succeeds a plateau, this is counted as two rises and one plateau, and similarly for intensity falls. Thus, in contrast to the all-peaks and significant-peaks measures, here the total piece duration is apportioned among unpaired rises, falls, and plateaux. The main parameters from the three types of analyses used to test the hypotheses were: (1) duration of each pair of rises and falls in the all-peaks and significant-peaks analyses, from which we measured the difference between fall and rise time; (2) the log-ratio of the rate of intensity change between rises and falls, so that values above 0 indicate that intensity change is faster in rises than falls; and (3) the total count of rises and falls. In addition to these three parameters used to explicitly test hypotheses, a number of additional parameters were recorded. An example of the parameters calculated from each performance of music can be seen in Table 2, where data are presented specific to Haydn's string quartet, Opus 20, No 5.

Statistical approach

In relation to the three categories of analysis, three statistical parameters were extracted to investigate the hypotheses: (1) frequency of intensity rises and falls; (2) difference between intensity fall and rise durations (i.e., difference = fall-time – rise-time); and (3) ratio between rise – fall rates of intensity change. We first analyse whether the difference in successively paired rise and fall times (specifically, difference = fall-time – rise-time) is on average positive (in accord with the hypothesis). These tests are conducted using one-tailed *t*-tests, although it must be noted that the use of multiple *t*-tests does increase the possibility of Type I errors. Secondly, we analyse whether the ratio of rate of intensity change, log(rise-rate/fall-rate), differs from zero (i.e., the rates are different). With ratio determinations it is desirable to use a geometric mean, and this is done here by taking the arithmetic mean of the log(ratio) values, and expressed still as log(ratio). This was tested using a two-tailed *t*-test. Again, the hypothesis predicts that these values will be positive (above zero). Thirdly, we test whether the frequency of observed intensity rises and falls differs significantly from one another. This was tested for each sound file using chi-square analyses. The hypothesis that individual rises are on average shorter than falls (i.e., not considering them as contiguous pairs) was tested using a one-tailed *t*-test. All three analyses were conducted at each temporal window; that is, using 0.04 s, 0.5 s, 5 s, and 10 s dynamic window criteria. Alpha level was set at 0.05.

Table 2: Detailed results from the analyses of Haydn Quartet Op 20 No 5, performed by the Angeles Quartet

	Cresc.	Dim.	Plateau	Rise/Falls	Crescendo duration			Diminuendo duration			Fall - rise duration		Crescendo change rate		Diminuendo change rate		Cres./Dim. log Ratio	
	N	*N*	*N*	*N*	*M*	*SD*	Total	*M*	*SD*	Total	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Haydn-20-5-1	120	118	178															
0.04 s HA20-5-1-allpeaks				1439	0.13	0.09	194.24	0.16	0.14	226.80	0.02	0.16	19.99	16.39	-17.83	10.99	0.00	0.48
0.04 s HA20-5-1-sigpeaks				481	0.40	0.40	190.44	0.47	0.37	227.08	0.08	0.51	27.79	19.09	-20.81	12.32	0.11	0.39
0.5 s HA20-5-1-allpeaks				219	0.93	0.57	203.50	0.99	0.59	217.50	0.06	0.82	6.11	5.09	-5.55	4.64	0.06	0.52
0.5 s HA20-5-1-sigpeaks				88	2.07	1.80	182.00	2.68	2.35	236.00	0.61	2.57	8.00	6.66	-6.11	5.59	0.12	0.43
5 s HA20-5-1-allpeaks				24	8.11	3.84	194.64	9.58	5.69	230.00	1.47	7.28	1.15	1.04	-1.04	0.89	0.09	0.56
5 s HA20-5-1-sigpeaks				15	11.31	7.67	169.64	16.67	11.75	250.00	5.36	12.00	1.54	1.32	-1.00	0.63	0.20	0.35
10 s HA20-5-1-allpeaks				11	21.79	7.52	239.64	17.27	6.47	190.00	-4.51	9.32	0.58	0.67	-0.78	0.90	-0.15	0.68
10 s HA20-5-1-sigpeaks				8	27.45	11.73	219.64	33.75	19.96	270.00	6.29	18.48	0.98	1.54	-0.41	0.26	0.18	0.65
Haydn-20-5-2	75	77	141															
0.04 s HA20-5-2-allpeaks				1096	0.14	0.09	150.32	0.16	0.16	178.20	0.03	0.18	18.34	17.83	-15.90	10.47	0.00	0.54
0.04 s HA20-5-2-sigpeaks				263	0.53	0.63	138.68	0.71	0.66	185.44	0.18	0.84	30.65	23.43	-19.09	11.89	0.16	0.44
0.5 s HA20-5-2-allpeaks				159	0.95	0.55	151.00	1.14	0.73	180.50	0.19	0.95	7.04	7.19	-5.83	4.90	0.04	0.57
0.5 s HA20-5-2-sigpeaks				56	2.42	1.59	135.50	3.38	2.24	189.00	0.96	2.56	10.04	11.52	-5.62	4.32	0.15	0.48
5 s HA20-5-2-allpeaks				22	7.71	3.71	169.64	7.27	4.56	160.00	-0.44	4.86	1.35	2.04	-1.08	0.73	0.02	0.57
5 s HA20-5-2-sigpeaks				11	9.06	7.71	99.64	21.36	19.12	235.00	12.31	22.21	2.07	2.69	-0.90	0.59	0.24	0.65
10 s HA20-5-2-allpeaks				12	14.14	7.91	169.64	13.33	4.92	160.00	-0.80	8.97	0.56	0.62	-0.47	0.54	0.36	0.94
10 s HA20-5-2-sigpeaks				4	37.41	20.48	149.64	22.50	9.57	90.00	-14.91	23.73	0.41	0.33	-0.43	0.25	-0.06	0.64
Haydn-20-5-3	111	111	148															
0.04 s HA20-5-3-allpeaks				951	0.16	0.13	152.96	0.19	0.18	179.68	0.03	0.21	18.33	16.77	-16.53	10.57	-0.01	0.53
0.04 s HA20-5-3-sigpeaks				343	0.43	0.32	148.72	0.53	0.41	181.36	0.10	0.50	26.15	20.08	-19.39	9.52	0.06	0.35
0.5 s HA20-5-3-allpeaks				192	0.90	0.53	173.50	0.83	0.44	160.00	-0.07	0.68	6.91	6.92	-7.19	5.29	-0.04	0.53
0.5 s HA20-5-3-sigpeaks				86	1.81	1.41	156.00	2.02	1.59	173.50	0.20	1.89	8.98	9.71	-7.25	5.29	0.03	0.45
5 s HA20-5-3-allpeaks				17	10.27	4.81	174.64	9.41	5.27	160.00	-0.86	6.89	0.84	0.68	-1.00	0.97	0.09	0.45
5 s HA20-5-3-sigpeaks				11	18.60	15.99	204.64	11.36	10.27	125.00	-7.24	21.38	0.80	0.77	-1.00	0.57	-0.22	0.38
10 s HA20-5-3-allpeaks				10	17.96	6.31	179.64	16.00	9.66	160.00	-1.96	12.30	0.46	0.56	-0.43	0.41	0.07	0.47
10 s HA20-5-3-sigpeaks				5	47.93	22.72	239.64	18.00	17.89	90.00	-29.93	19.87	0.27	0.21	-0.59	0.27	-0.37	0.34

Table 2 cont'd	Cresc.	Dim.	Plateau	Rise/Falls	Crescendo duration			Diminuendo duration			Fall - rise duration		Crescendo change rate		Diminuendo change rate		Cres./Dim. log Ratio	
	N	*N*	*N*	*N*	*M*	*SD*	Total	*M*	*SD*	Total	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Haydn-20-5-4	37	36	67															
0.04 s HA20-5-4-allpeaks				646	0.12	0.07	75.96	0.15	0.11	98.32	0.03	0.13	21.80	19.63	-18.60	10.62	-0.01	0.48
0.04 s HA20-5-4-sigpeaks				232	0.28	0.21	64.88	0.44	0.40	102.52	0.16	0.41	30.67	19.06	-19.54	10.15	0.17	0.37
0.5 s HA20-5-4-allpeaks				107	0.75	0.39	80.50	0.86	0.62	92.00	0.11	0.70	5.60	6.58	-4.32	3.53	0.02	0.58
0.5 s HA20-5-4-sigpeaks				31	3.13	4.08	97.00	2.31	1.82	71.50	-0.82	4.40	6.94	8.72	-5.46	4.58	0.01	0.55
5 s HA20-5-4-allpeaks				10	8.96	6.58	89.64	9.00	3.94	90.00	0.04	6.64	1.15	1.61	-0.91	1.46	0.05	0.78
5 s HA20-5-4-sigpeaks				3	31.55	25.00	94.64	26.67	17.56	80.00	-4.88	8.56	1.74	1.96	-2.22	3.16	0.16	0.75
10 s HA20-5-4-allpeaks				4	27.41	9.67	109.64	17.50	15.00	70.00	-9.91	8.17	0.65	1.00	-0.47	0.73	0.26	0.70
10 s HA20-5-4-sigpeaks				0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Each piece is labelled as: Composer-Opus-Number-Movement; All durations are reported as seconds; *M* = Mean; *SD* = Standard Deviation

RESULTS

Across all movements analysed from the works of Haydn and Beethoven (*n* = 136), there were no significant differences in the frequency of occurrence between rises and falls of intensity. In regards to ramp duration and rate of change, Figure 1 and Figure 2 represent significant observations for each temporal window of analysis in performances of Haydn. As can be seen from the distribution of data around the x-axis of each figure, almost all (96.7%) of the significant results followed the direction predicted: the durations of intensity falls are significantly longer than intensity rises in the majority of significant cases, and intensity rises also undergo a faster rate of intensity change.

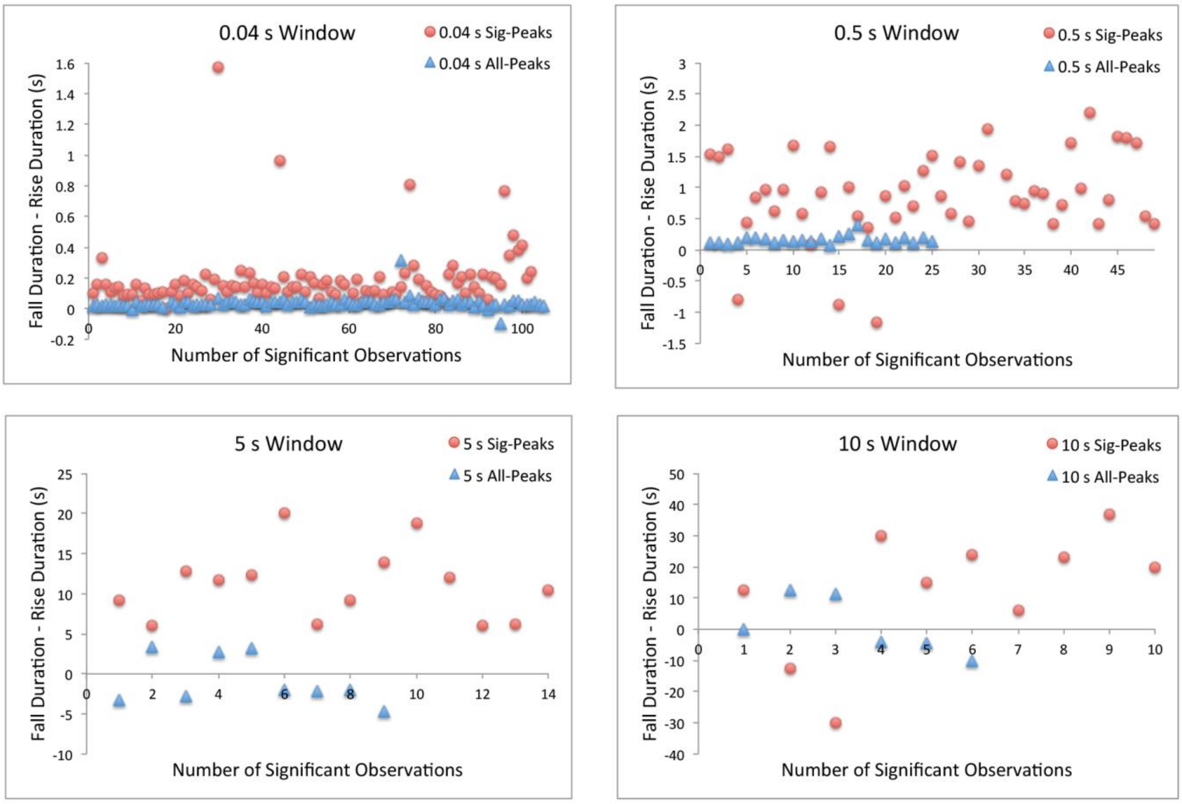

Figure 1. Significant values for the parameter intensity fall-durations minus rise-durations (seconds) in all Haydn pieces at 0.04 s, 0.5 s, 5 s, and 10 s windows of analysis. Positive numbers indicate a significantly longer duration of intensity change for intensity falls, relative to intensity rises. The horizontal axis refers to the number of observations where a significant difference was found between rises and falls of intensity.

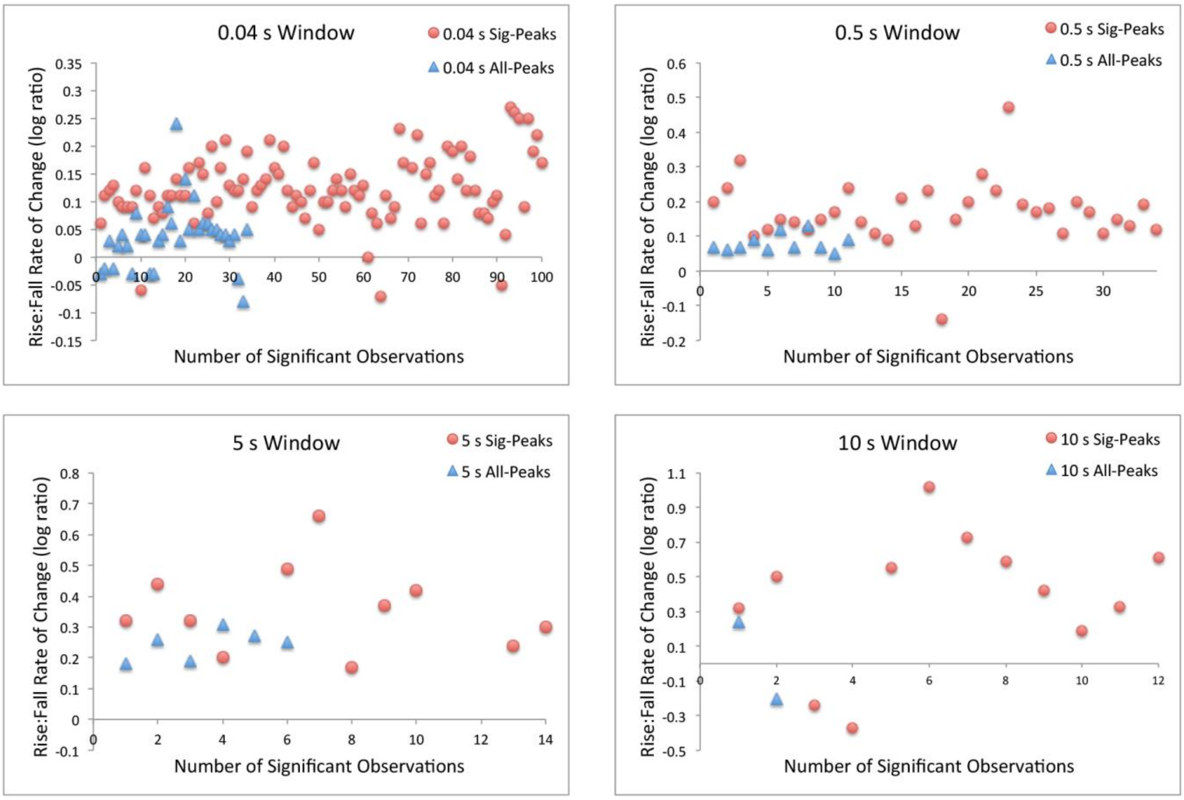

Figure 2. Significant values of the rise:fall intensity rate of change log ratios in all Haydn pieces at 0.04 s, 0.5 s, 5 s, and 10 s windows of analysis. Positive numbers indicate a significantly faster rate of intensity change (log ratio) for intensity rises, relative to intensity falls. The horizontal axis refers to the number of observations where a significant difference was found between rises and falls of intensity.

Acoustic analyses were implemented here on seven Beethoven piano sonatas found in Huron (1990), the results of which are presented in Table 3. The same trend of results can be seen in the Beethoven performances as in the Haydn performances. Results support the hypothesis that performed crescendi are shorter than diminuendi and comprise greater rates of intensity change. Finally, the acoustic analyses presented here enable a direct comparison between identical pieces performed by different ensembles. Table 4 presents results of two Haydn quartets (Opus 61, Opus 76) performed by the Amadeus Quartet and the Angeles Quartet. The overall trend of results observed in the complete data set is replicated here (except for the '5-all peaks', Opus 61-1-2, Angeles Quartet, where rise time is greater than fall time). For a complete data set of each individual performance analysed in this study, see Appendix A and Appendix B.

Table 3: Overview of results for Beethoven piano sonatas

Piece	Analysis Type							
	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
Fall Duration Minus Rise Duration (s)								
Backhaus Piano Sonatas								
LVB-Bk31-2-1	0.08**			4.02**				
LVB-Bk31-2-2	0.17**	0.27**		0.40*				
LVB-Bk31-2-3	0.03**	0.06**						
LVB-Bk57-1	0.07**	0.15*				6.83*		18.96*
LVB-Bk57-2	0.16**	0.30**				-1.98*		
LVB-Bk57-3	0.05**		0.14*	1.95*				
LVB-Bk78-1	0.09**	0.18**						
LVB-Bk78-2	0.07**	0.27*		4.26**	4.58*			
LVB-Bk79-1	0.04**	0.06**		0.96*				
LVB-Bk79-2	0.19**	0.24**	0.15*					
LVB-Bk79-3	0.04**							
LVB-Bk-81a-1	0.11**	0.29**	0.10*			9.66*		
LVB-Bk-81a-2	0.12**	0.18**						
LVB-Bk-81a-3	0.05**	0.23**		1.18*				
Brendel Piano Sonatas								
LVB-Bre-109-1	0.08**	0.37**				6.16*		
LVB-Bre-109-2		0.17*						
LVB-Bre-109-3	0.09**	0.32**		0.89*	3.10**	16.49**	5.47*	
LVB-Bre-111-1	0.12**	0.44**	0.19**	2.42**				40.05**
LVB-Bre-111-2	0.12**	0.22**	0.08**				-4.11*	
Rise:Fall Rate of Change (log Ratio)								
Backhaus Piano Sonatas								
LVB-Bk31-2-1	0.07**	0.21**		0.30**		0.35**		
LVB-Bk31-2-2	0.13**	0.27**		0.09**				
LVB-Bk31-2-3	0.08**	0.08**						
LVB-Bk57-1	0.06**	0.13**						
LVB-Bk57-2	0.10**	0.28**		0.09*				

Table 3 Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
LVB-Bk57-3	0.06**		0.08*	0.20**				
LVB-Bk78-1	0.13**	0.23**						
LVB-Bk78-2	0.09**	0.21**	0.35**			0.40*		
LVB-Bk79-1	0.06**	0.10**		0.24**				
LVB-Bk79-2	0.21**	0.30**						
LVB-Bk79-3	0.06**			0.55*				
LVB-Bk-81a-1	0.11**	0.24**				0.28*		0.18*
LVB-Bk-81a-2	0.12**	0.25**		0.09*	0.23*			
LVB-Bk-81a-3	0.23**	0.07**		0.15*				
Brendel Piano Sonatas								
LVB-Bre-109-1	0.09**	0.28**						
LVB-Bre-109-2		0.22**						
LVB-Bre-109-3	0.09**	0.23**		0.09*		0.29**		
LVB-Bre-111-1	0.10**	0.34**	0.07*	0.27**				0.59**
LVB-Bre-111-2	0.13**	0.22**	0.06**	0.07*				

Note: $*p<.05$; $**p<.01$; Table reports values resulting from statistically significant observations only.

Table 4: Multi-performer comparisons from two Haydn quartets (Opus 61 & 76)

Performance	Analysis Type	Fall Minus Rise Duration (s)	Rise:Fall Rate of Change (log ratio)	Performance	Analysis Type	Fall Minus Rise Duration (s)	Rise:Fall Rate of Change (log ratio)
Amadeus Quartet				*Angeles Quartet*			
Opus 61-1-1	0.04-all peaks	0.04**		Opus 61-1-1	0.04-all peaks	0.04**	0.04**
	0.04-sig. peaks	0.11**	0.11**		0.04-sig. peaks	0.14**	0.16**
	0.5-all peaks		0.07*				
Opus 61-1-2	0.04-all peaks	0.05**		Opus 61-1-2	0.04-all peaks	0.04**	
	0.04-sig. peaks	0.12**	0.13**		0.04-sig. peaks	0.14**	0.15**
					5-all peaks	-2.79*	
Opus 61-1-3	0.04-all peaks	0.05**		Opus 61-1-3	0.04-all peaks	.06**	
	0.04-sig. peaks	0.21**			0.04-sig. peaks	0.22**	0.20**
	0.5-sig. peaks	0.47*			0.5-all peaks	0.13*	
	5-all peaks	3.23*					
	5-sig. peaks	13.95**					
	10-sig. peaks	36.73*					
Opus 61-1-4	0.04-all peaks	0.03**		Opus 61-1-4	0.04-all peaks	0.04**	
	0.04-sig. peaks	0.09**	0.08**		0.04-sig. peaks	0.11**	0.12**
	5-sig. peaks	18.84*			10-sig. peaks	24.07**	0.59*
	10-all peaks	12.59*					
Opus 76-1-1	0.04-all peaks	0.03**		Opus 76-1-1	0.04-all peaks	0.03**	-0.03*
	0.04-sig. peaks	0.04*	0.06**		0.04-sig. peaks	0.09**	0.10**
Opus 76-1-2	0.04-sig. peaks		-0.07*	Opus 76-1-2	0.04-sig. peaks	0.18**	0.10**
Opus 76-1-3	0.04-sig. peaks	0.11**	0.11**	Opus 76-1-3	0.04-all peaks	0.06**	
	0.5-all peaks	0.26*			0.04-sig. peaks	0.16**	0.12**
					0.5-sig. peaks	0.87**	
Opus 76-1-4	0.04-all peaks	0.04**		Opus 76-1-4	0.04-sig. peaks	0.04**	0.14**
	0.04-sig. peaks		0.07**				

*Note: *p<.05; **p<.01; Fall Minus Rise Duration*: Positive numbers indicate a significantly longer duration of intensity change for diminuendi, relative to crescendi; *Rise:Fall Rate of Change*: Positive numbers indicate a significantly faster intensity rate of change (log ratio) for crescendi, relative to decrescendi.

DISCUSSION

We assessed here a hypothesis concerning intensity profiles in performances of classical instrumental scores that was developed from our previous analyses of dynamics in electroacoustic music (Dean & Bailes, 2010a, b). Those analyses suggest that rises of intensity are shorter in duration than falls, follow a faster rate of dynamic intensity change, and are not significantly different in frequency of occurrence. From the results presented here analysing works from Haydn and Beethoven, there is strong evidence consistent with the hypothesis. No significant difference in the frequency of occurrence between rises and falls of intensity was observed, and furthermore, the duration of intensity falls was significantly longer than rises. It was interesting that the patterns we observed were maintained across many different genres, instrumental groupings and performers. These include the piano sonata, string quartet, brass and string concerto, symphony, and performances of piano trios with period and contemporary instruments. Performances of the same works by different performers (most notably, the Angeles and Amadeus String Quartets) also recovered the overall pattern of results. Given the diversity of performers studied in this paper as a whole, it is quite likely that our observations are general.

The Beethoven piano sonatas analysed here were also considered by Huron (1990), but our results were again consistent with our hypothesis and confirm a distinction between performance and notation, which is therefore not solely due to our choice of composer to study. We argue that the dynamic markings are realised in performance and contribute to the patterns observed. Moreover, we suggest that additional performed intensity gradations also contribute to the patterns of intensity rises and falls reported in this study, and plateaux of intensity accompany these.

From a methodological perspective, one might imagine that the analysis of notation is essentially bound up with the beat and metrical structure of the music in question, since more markings occur on accented beats than elsewhere, and most occur at rhythmically defined positions. We did not undertake an analysis based on beats because this has previously been accomplished with instrumental jazz performance and shown that if, for example, a beat occurs roughly every second, the intensity patterns revealed by analysing beat windows are intermediate between those observed with fixed duration windows (such as our 0.5 s and 5 s windows) that surround the beat duration. This may well be a statistical necessity given that a reasonably large number of events are analysed, but in any case has been empirically established by previous data (Dean & Bailes, 2010a).

We next present a non-exhaustive discussion of the possible explanations for our observations, together with indications as to how these explanations could be investigated further. Taking the data in this paper alone, an obvious possible explanation might be that intensity profiles in performed music are tightly coupled to performer action. In accordance with our FEELA interpretation (force → effort → energy → loudness → affect), it might be that performers often attempt to produce enhanced affect, and they do so by superimposing increases of energy (thus creating both higher acoustic intensity and perceived loudness) on top of the loudness profiles suggested by the notation. Specifically, there could be a tendency for the performer primarily to seek short moments of enhanced affect, succeeded by longer periods of relaxation, which would correspond to short crescendi and longer diminuendi and/or stasis (plateaux). It is worth noting at this point that one of the difficulties of interpreting sparse notation is to decide when a crescendo (or diminuendo) is expected to finish. There are rarely score markings to indicate a period of static maintenance of a given dynamic (our plateaux), so judging what we call above a 'plateau' in the intensity profile is virtually impossible from a classical score. This may be an additional reason for the difference between our analysis of performed music and Huron's analysis of notations. We note that the attack profiles of many instrumental sounds show very rapid increases in dynamics, then either a period of sustain followed by a slower decay (say for a wind instrument) or immediately by a rapid decay (say for a percussion instrument, or the piano). These are not important factors in either our or Huron's analysis. This is because in our case, the smallest time window of analysis is 40 ms, longer than the attack time of most sounds. Furthermore, all the data presented here are aggregations of several 40 ms units (the smallest mean rise-fall time using this window and the all peaks measure is about 300 ms). It is also clear from data in Figure 1 and Figure 2 that as the temporal window of analysis increases, the number of statistically significant results decreases. This is most likely due to the lower number of data points available for analysis from relatively long temporal windows. Future research can gauge whether the trend in our results continues over longer temporal windows (e.g., 20-30 s) by using musical stimuli with relatively long durations (e.g., 20-30 min). In previous cases of electroacoustic works of this length, we again found the hypothesised patterns over such longer time frames.

The differences between rises and falls of intensity presented here for classical music are similar to those in electroacoustic music reported in Dean and Bailes (2010a). Why should this asymmetry in acoustic intensity dynamics be carried beyond instrumental music, into previously published data using electroacoustic music, where no musical instruments are used to perform? Possibly it is again the FEELA processes, and the experience of music (and perhaps speech) which embodies the asymmetry, leading electro-acoustic performers to create music that reflects the same pattern with most likely implicit or non-conscious awareness of doing so. As a result of this process, a listener can be influenced by the observed force and effort (FE) of a live performer and experience a similar impact from instrumental music and sculpted electroacoustic sound. In each case, listeners may perceive effort and loudness (EL) from the acoustic signal. Loudness (closely related to measures of acoustic intensity) is a proposed correlate of the real-time affective (A) responses to certain classical music (Schubert, 2004), and this relationship is probably more general. Perceptual evidence linking segmentation and affect in electroacoustic and instrumental music has also been reported; segments that may be constituted by rises and falls of intensity (Dean et al., 2011). As a result, we expect that many musical pieces of various genres that aim for affective expression will use the intensity structures we describe (i.e., parallel with the live performer's FEELA process).

It is worth considering the fact that the works studied here are all polyphonic, at least in the simple sense of involving either multiple performers, and/or the two hands of the piano. It might be argued that the important intensity/loudness profiles, especially from the point of view of FEELA, are those of the melodic line(s), rather than those of accompaniment parts. Dissecting this directly would require both a separation of the recorded parts, and direct perceptual analysis, both large tasks beyond the scope of this paper. However, it is a rare event that the intensity profiles of accompaniments countermand those of melodic foregrounds; rather, normally both move in parallel, and this is certainly the case with the notation of the works at hand. It may occasionally be the case that the melodic lines have greater notated intensity detail, especially in more recent music, but it remains relatively rare that parts of an ensemble change their intensities in opposite senses. Thus it is highly likely that our conclusions would be unaffected by separation of the intensity profiles of melodic lines from those of accompaniment.

Can an explanation of these results be framed in perceptual terms? The first factor that might influence such an explanation is statistical learning of the patterns heard in the everyday environment (e.g., the intensity profiles of rain, wind, friction, engines). Do these show the intensity profile patterns we have described? If so, composers and performers may have learnt – either implicitly or explicitly – to exploit them simply through mere exposure. To our knowledge, the appropriate analyses of environmental sounds are yet to be completed.

An alternative perceptual hypothesis flows from psychoacoustic investigations of continuous increases and decreases of intensity in relation to judgements of loudness and subjective duration. These studies have used both musical stimuli of varied complexity (Ferguson, et al., 2011; Olsen, Stevens, & Tardieu, 2010) and non-musical but complex auditory stimuli (DiGiovanni & Schlauch, 2007; Grassi & Darwin, 2006; Stecker & Hafter, 2000). Specifically, there is psychoacoustic evidence that continuous decreases of intensity (diminuendi) are perceived to be shorter in duration than equivalent increases (Grassi & Darwin, 2006; Grassi & Pavan, 2012). The final decay of a decrease in intensity may be erroneously treated by the perceptual system as an echo from prolonged environmental reverberation (Stecker & Hafter, 2000). As a result, the final portion of the decreasing intensity decay may be perceptually irrelevant and eliminated from perceptual experience. Such a mechanism would enable cognitive resources to be retained for potentially significant future events, such as an approaching sound source requiring an immediate adaptive response – avoidance or retreat for example (DiGiovanni & Schlauch, 2007; Grassi & Darwin, 2006; Neuhoff, 2001).

These psychoacoustic data offer a clue as to why musical dynamics are structured as longer decreases and shorter increases in intensity. If the final portion of a continuous decrease of intensity is not perceptually processed to the same degree as a continuous increase, then a performance of a diminuendo may need to be longer than a crescendo to elicit the same perceptual impact. Shorter crescendi may well be perceived as equivalent in duration to longer diminuendi but with a perceived and real faster rate of change. This line of argument raises the issue of the perception of crescendi and diminuendi durations within music, as opposed to the non-musical experimental stimuli used previously (e.g., Grassi & Darwin, 2006). This remains to be investigated.

Although this study shows that the notated ramp archetype is not often realised in performance, the results may still be interpreted in light of maintained attention, as rate of intensity change is a key feature affecting arousal and emotional response to music (Dean, et al., 2011; Olsen & Stevens, 2013; Scherer & Oshinsky, 1977; Schubert & Dunsmuir, 1999). For example, continuous time-series analyses reveal that the more sudden a change in intensity/loudness (e.g., 1-2 s compared to 2-3 s), the faster the change in self-reported arousal often associated with emotional response (Schubert & Dunsmuir, 1999). Furthermore, fast rates of intensity change in crescendi of the music of Brahms and Scriabin are significantly correlated with self-reported increases of arousal and shivers down the spine (Yasuda, 2009).

In conclusion, the study presented here has shown that performed dynamics in a large selection of string quartets, piano sonatas, concertos, and symphonic works from Haydn and Beethoven show rises shorter in duration than falls, and following a faster rate of dynamic intensity change. Furthermore, rises and falls are statistically indistinguishable in frequency of occurrence. Future studies of this nature will investigate recurrent statistical regularities of dynamic intensity change in a range of alternative musical genres (e.g., ambient music) and environmental domains (e.g., bird song, environmental sounds).

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Appendix A: Complete Haydn and Beethoven analyses of individual performances: Fall duration minus rise duration (s)

	Analysis Type							
Piece	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
Works of Haydn								
Angeles Quartet								
HA-9-1-1	0.02**	0.10**	0.13*	0.55**				
HA-9-1-2	0.03**	0.16**		1.54**				
HA-9-1-3	0.02**	0.33**		1.49**		9.12*		
HA-9-1-4	0.03**	0.16**	0.12*	1.61**				
HA-17-1-1	0.03**	0.11**						
HA-17-1-2	0.02**	0.13**	0.12*			6.02*		
HA-17-1-3	0.14**					12.76**		12.55*
HA-17-1-4	0.03**	0.08**						
HA-20-1-1	0.02**	0.09**	0.10*					
HA-20-1-2	0.02**	0.09**						
HA-20-1-3	-0.01**			-0.80*				
HA-20-1-4	0.04**	0.16**						
HA-20-2-1	0.02**	0.05*		0.45*				
HA-20-2-2	0.03**	0.13*						-12.46*
HA-20-2-3	0.03**	0.09**						
HA-20-2-4	0.03**	0.09**						
HA-20-3-1	0.03**	0.10**						
HA-20-3-2	0.01**							
HA-20-3-3					-3.23*			
HA-20-3-4	0.04**	0.11**						
HA-20-4-1	0.03**	0.15**		0.85**				
HA-20-4-2	0.01*							
HA-20-4-3	0.04**	0.11**						
HA-20-4-4	0.04**	0.16**	0.11*	0.96*		11.70*		
HA-20-5-1	0.02**	0.08**		0.62*				
HA-20-5-2	0.03**	0.18**	0.19**	0.96**		12.31*		
HA-20-5-3	0.03**	0.10**						-29.93*
HA-20-5-4	0.03**	0.16**						

Appendix A Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HA-20-6-1	0.03**	0.14**						
HA-20-6-2		0.12**						30.04*
HA-20-6-3	0.07**	0.22**	0.20*	1.67**	3.37*			
HA-20-6-4	0.03**	0.06**						
HA-33-1-1	0.04**	0.19**						
HA-33-1-2	0.05**	1.57**		0.59*				
HA-33-1-3	0.04**	0.15**		0.10*				
HA-33-1-4	0.03**	0.11**		0.92*				
HA-42-1-1	0.03**	0.15**	0.18*	1.65**				
HA-42-1-2	0.06**	0.14**		-0.87*				
HA-42-1-3	0.25*			1.00*				
HA-42-1-4		0.14**						
HA-50-1-1				0.54*				
HA-50-1-2		0.23**	0.11*					
HA-50-1-3	0.05*	0.17**						
HA-50-1-4	0.04**	0.1**						
HA-54-1-1	0.04**	0.16**		0.36*				
HA-54-1-2	0.02**	0.10*						
HA-54-1-3	0.04**	0.14**		-1.15*				
HA-54-1-4	0.04**		0.16*			20.06*		
HA-55-1-1	0.04**	0.13**						
HA-55-1-2		0.96*						15.06*
HA-55-1-3	0.06**	0.21**						
HA-55-1-4	0.03**	0.11*						
HA-64-1-1	0.04**	0.14**						
HA-64-1-2	0.04**	0.14**			-2.79*			
HA-64-1-3	.06**	0.22**	0.13*					
HA-64-1-4	0.04**	0.11**						24.07**
HA-71-1-1				0.87*		6.25*		
HA-71-1-2	0.01**	0.21**	0.15*	0.52*				
HA-71-1-3	0.03**	0.17**		1.03**				
HA-71-1-4	0.03**	0.07**						
HA-74-1-1	0.02**							6.29*
HA-74-1-2	0.03**	0.16**	0.14**	0.70*				

Appendix A Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HA-74-1-3	0.04**	0.18**	0.17**	1.27**	2.65**			
HA-74-1-4	0.03**	0.11**		1.52*				
HA-76-1-1	0.03**	0.09**						
HA-76-1-2		0.18**						
HA-76-1-3	0.06**	0.16**		0.87**				
HA-76-1-4		0.04**						
HA-77-1-1	0.04**	0.10**	0.07*	0.59*				0.17*
HA-77-1-2	0.03**	0.19**						22.91*
HA-77-1-3		0.04**	0.22**	1.41*		9.12*		
HA-77-1-4	0.03**	0.12**						
Amadeus Quartet								
HAmQ64-1-1	0.04**	0.11**						
HAmQ64-1-2	0.05**	0.12**						
HAmQ64-1-3	0.05**	0.21**		0.47*	3.23*	13.95**		36.73*
HAmQ64-1-4	0.03**	0.09**				18.84*		12.59*
HAmQ76-1-1	0.03**	0.04*						
HAmQ76-1-2								
HAmQ76-1-3		0.11**	0.26*					
HAmQ76-1-4	0.04**							
Gould Piano Sonatas								
HGould51-1	0.04**	0.09**						
HGould51-2	0.06**	0.14**		1.35**				
HGould52-1	0.06**	0.23**		1.94**				11.41*
HGould52-2	0.31**	0.81**	0.40**	0.41**				
HGould52-3	0.04**	0.28**	0.16*	3.03**				
Ranki Piano Sonatas								
Hranki-54-1	0.08**	0.19**			-1.92**			
Hranki-54-2	0.03**	0.05*						
Hranki-55-1	0.07**	0.15**	0.11*	1.21**		12.08**		
Hranki-55-2	0.04**	0.11**						

Appendix A Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
Cohen Piano Trio								
Hcohen-39-1	0.04**	0.09**						
Hcohen-39-2	0.04**	0.08**						
Hcohen-39-3	0.03**	0.05**	0.18**	0.78**				
Schiff Piano Trio								
Hschiff-12-1	0.06**	0.22**		0.12**				
Hschiff-12-2	0.07**	0.28**	0.19**	0.74*		-2.23*		
Hschiff-12-3	0.03**							
Hschiff-14-1	0.05**	0.17**		0.94**				
Hschiff-14-2	0.06*	0.21**		0.91**				20.05*
Hschiff-14-3	0.03*	0.10**					-4.14**	
Hschiff-31-1	0.04**	0.22**		0.43*				
Hschiff-31-2	0.04**	0.14**		0.72*				
Wallace Concerto								
HWlceTptC-1	0.02**	0.10**					-4.51*	
HWlceTptC-2	0.01*	0.22*		1.72**		6.04*		
HWlceTptC-3	0.05**							
Thompson Concerto								
Hthompson-1	0.02**	0.06*		0.99**	-1.99*			
Hthompson-2	-0.01*	0.21*						
Hthompson-3	0.02**	0.20*		2.21*			-9.94*	
Queyras Cello Concerto								
Hqueyras-8b-1	0.03**	0.16**						
Hqueyras-8b-2	-0.1*		0.12*	0.41*				
Hqueyras-8b-3	0.03**							
Philharmonia Hungarica Symphonies								
HHunS103-1	0.02**	0.77**						
HHunS103-2	0.05**	0.35**						
HHunS103-3	0.05**	0.48**		0.81*				

Appendix A Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HHunS103-4	0.03**				-4.66*			
HHunS104-1	0.03**	0.38*		1.82*				
HHunS104-2	0.03**	0.41**	0.20**	1.79**				
HHunS104-3	0.04**	0.20*		1.71*		6.18*		
HHunS104-4	0.03**	0.24**				10.45**		
Works of Beethoven								
Backhaus Piano Sonatas								
LVB-Bk31-2-1	0.08**			4.02**				
LVB-Bk31-2-2	0.17**	0.27**		0.40*				
LVB-Bk31-2-3	0.03**	0.06**						
LVB-Bk57-1	0.07**	0.15*				6.83*		18.96*
LVB-Bk57-2	0.16**	0.30**				-1.98*		
LVB-Bk57-3	0.05**		0.14*	1.95*				
LVB-Bk78-1	0.09**	0.18**						
LVB-Bk78-2	0.07**	0.27*		4.26**	4.58*			
LVB-Bk79-1	0.04**	0.06**		0.96*				
LVB-Bk79-2	0.19**	0.24**	0.15*					
LVB-Bk79-3	0.04**							
LVB-Bk-81a-1	0.11**	0.29**	0.10*			9.66*		
LVB-Bk-81a-2	0.12**	0.18**						
LVB-Bk-81a-3	0.05**	0.23**		1.18*				
Brendel Piano Sonatas								
LVB-Bre-109-1	0.08**	0.37**				6.16*		
LVB-Bre-109-2		0.17*						
LVB-Bre-109-3	0.09**	0.32**		0.89*	3.10**	16.49**	5.47*	
LVB-Bre-111-1	0.12**	0.44**	0.19**	2.42**				40.05**
LVB-Bre-111-2	0.12**	0.22**	0.08**				-4.11*	

Note: **p*<.05; ***p*<.01; Table reports values resulting from statistically significant observations only.

Appendix B: Complete Haydn and Beethoven analyses of individual performances: Rise: Fall rate of change (log ratio)

	Analysis Type							
Piece	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
Works of Haydn								
Angeles Quartet								
HA-9-1-1	-0.03*	0.06**		0.13**				
HA-9-1-2		0.11**		0.20**				
HA-9-1-3		0.12**		0.24**		0.32**		
HA-9-1-4		0.13**		0.32**				
HA-17-1-1		0.10**						
HA-17-1-2		0.09**						
HA-17-1-3						0.44**		0.32**
HA-17-1-4	-0.02*	0.09**						
HA-20-1-1		0.09**						
HA-20-1-2		0.12**						0.50*
HA-20-1-3	0.03*	-0.06*						
HA-20-1-4		0.16**						
HA-20-2-1				0.10*				
HA-20-2-2		0.11**	0.07*	0.12*	0.18*			
HA-20-2-3		0.07**						
HA-20-2-4		0.09**			0.26*			
HA-20-3-1		0.08**	0.06*	0.15*				
HA-20-3-2								
HA-20-3-3	-0.02*							-0.24*
HA-20-3-4		0.11**			0.19*			
HA-20-4-1	0.02*	0.11**		0.14**				
HA-20-4-2			0.07*					
HA-20-4-3	0.04*	0.14**						
HA-20-4-4		0.11**	0.09*			0.32**		
HA-20-5-1		0.11**	0.06*	0.12**		0.20*		
HA-20-5-2		0.16**		0.15*				
HA-20-5-3		0.06**				-0.22*		-0.37*
HA-20-5-4		0.17**						

Appendix B Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HA-20-6-1	0.02*	0.15**						
HA-20-6-2	-0.03*	0.08**						0.55**
HA-20-6-3	0.08**	0.20**		0.17*	0.31*			
HA-20-6-4	0.04**	0.10**						
HA-33-1-1		0.16**						
HA-33-1-2		0.21**						
HA-33-1-3		0.13**						
HA-33-1-4		0.12**						
HA-42-1-1				0.24**	0.27*			
HA-42-1-2						0.49*		
HA-42-1-3								
HA-42-1-4		0.12**						
HA-50-1-1				0.14**				
HA-50-1-2		0.14**						
HA-50-1-3		0.19**						
HA-50-1-4		0.09**						
HA-54-1-1		0.12**		0.11*				
HA-54-1-2				0.09*				
HA-54-1-3		0.13**						1.02*
HA-54-1-4						0.66**		
HA-55-1-1		0.14**						
HA-55-1-2								0.73**
HA-55-1-3		0.21**						
HA-55-1-4								
HA-64-1-1	0.04**	0.16**						
HA-64-1-2		0.15**						
HA-64-1-3		0.20**						
HA-64-1-4		0.12**						0.59*
HA-71-1-1				0.21**		0.17*	0.24**	
HA-71-1-2	-0.03*	0.09**		0.13*				
HA-71-1-3		0.11**		0.23**				
HA-71-1-4		0.10**		-0.14**				
HA-74-1-1		0.07**	0.12*					
HA-74-1-2		0.12**		0.15**				

Appendix B Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HA-74-1-3		0.17**		0.20**	0.25**			
HA-74-1-4		0.05*						
HA-76-1-1	-0.03*	0.10**						
HA-76-1-2		0.10**						
HA-76-1-3		0.12**						
HA-76-1-4		0.14**						
HA-77-1-1	0.03*	0.12**						
HA-77-1-2		0.09**						0.42*
HA-77-1-3		0.15**		0.37*				
HA-77-1-4		0.12**						
Amadeus Quartet								
HAmQ64-1-1		0.11**	0.07*					
HAmQ64-1-2		0.13**						
HAmQ64-1-3								
HAmQ64-1-4		0.08**						
HAmQ76-1-1		0.06**						
HAmQ76-1-2		-0.07*						
HAmQ76-1-3		0.11**						
HAmQ76-1-4		0.07**						
Gould Piano Sonatas								
HGould51-1	0.04**	0.09**						
HGould51-2	0.09**	0.23**		0.28**				
HGould52-1	0.06**	0.17**		0.23**				
HGould52-2	0.24**	0.47**	0.13**	0.12**				
HGould52-3	0.03*	0.16**		0.47**				
Ranki Piano Sonatas								
Hranki-54-1	0.14**	0.22**		0.19**				
Hranki-54-2	0.05**	0.06**						
Hranki-55-1	0.11**	0.15**		0.17**		0.42*		
Hranki-55-2	0.05*	0.17**						

Appendix B Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
Cohen Piano Trio								
Hcohen-39-1	0.06**	0.11**						
Hcohen-39-2	0.06**	0.12**						
Hcohen-39-3	0.05**	0.06**		0.18**				
Schiff Piano Trio								
Hschiff-12-1	0.05**	0.20**		0.11*				
Hschiff-12-2	0.04*	0.19**						
Hschiff-12-3								0.19*
Hschiff-14-1	0.04**	0.14**		0.20**				
Hschiff-14-2		0.20**		0.17**				0.33**
Hschiff-14-3		0.12**						
Hschiff-31-1	0.03*	0.18**		0.11**				
Hschiff-31-2	0.04*	0.12**		0.15*				
Wallace Concerto								
HWlceTptC-1		0.08**		0.13*				0.61*
HWlceTptC-2				0.19**				
HWlceTptC-3		0.08*					-0.20*	
Thompson Concerto								
Hthompson-1		0.07**		0.12*				
Hthompson-2	-0.04*			0.14*				
Hthompson-3		0.10*		0.25*				
Queyras Cello Concerto								
Hqueyras-8b-1		0.11**		0.11*				
Hqueyras-8b-2	-0.08**	-0.05*	0.07*	0.10*				
Hqueyras-8b-3		0.04*						
Philharmonia Hungarica Symphonies								
HHunS103-1		0.27**		0.16*				
HHunS103-2		0.26**	0.05*					
HHunS103-3		0.25**						

Appendix B Cont'd	0.04 s All-Peaks	0.04 s Sig. Peaks	0.5 s - All-Peaks	0.5 s - Sig. Peaks	5 s - All-Peaks	5 s - Sig. Peaks	10 s - All-Peaks	10 s - Sig. Peaks
HHunS103-4		0.09*				-0.33*		
HHunS104-1		0.25**	0.09*	0.18*				
HHunS104-2		0.19**		0.17**		-0.27*		
HHunS104-3	0.05**	0.22**		0.19*		0.24*		
HHunS104-4		0.17**				0.30**		
Works of Beethoven								
Backhaus Piano Sonatas								
LVB-Bk31-2-1	0.07**	0.21**		0.30**		0.35**		
LVB-Bk31-2-2	0.13**	0.27**		0.09**				
LVB-Bk31-2-3	0.08**	0.08**						
LVB-Bk57-1	0.06**	0.13**						
LVB-Bk57-2	0.10**	0.28**		0.09*				
LVB-Bk57-3	0.06**		0.08*	0.20**				
LVB-Bk78-1	0.13**	0.23**						
LVB-Bk78-2	0.09**	0.21**	0.35**			0.40*		
LVB-Bk79-1	0.06**	0.10**		0.24**				
LVB-Bk79-2	0.21**	0.30**						
LVB-Bk79-3	0.06**			0.55*				
LVB-Bk-81a-1	0.11**	0.24**				0.28*		0.18*
LVB-Bk-81a-2	0.12**	0.25**		0.09*	0.23*			
LVB-Bk-81a-3	0.23**	0.07**		0.15*				
Brendel Piano Sonatas								
LVB-Bre-109-1	0.09**	0.28**						
LVB-Bre-109-2		0.22**						
LVB-Bre-109-3	0.09**	0.23**		0.09*		0.29**		
LVB-Bre-111-1	0.10**	0.34**	0.07*	0.27**				0.59**
LVB-Bre-111-2	0.13**	0.22**	0.06**	0.07*				

Note: *p<.05; **p<.01; Table reports values resulting from statistically significant observations only.