The Control of Acoustic Intensity During Jazz and Free Improvisation Performance: Possible Transcultural Implications for Social Discourse and Community

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Abstract

This paper demonstrates the predominance of a pattern of acoustic intensity change in recorded improvisations in which intensity rises are shorter than falls and in which the rate of intensity change is greater in the rises than in the falls. A wide range of improvised music from the USA, Europe, and Australasia is studied, and the analyses are conducted by measuring intensity in moving windows across each piece. The windows used are 0.04 sec, 0.5 sec, 5 sec, and 10 sec, chosen to sample a range of important musical structures such as patterns, phrases, and phrase groups. In addition, a comparative analysis uses detected rhythmic beats as the window, with slightly variable lengths. The recurrent pattern is interpreted in terms of a hypothesised Force-Effort-Energy-Loudness-Affect (FEELA) chain, linking improviser with listeners and with other improvisers. Partial experimental investigation of this chain in other work has been consistent with the theory in supporting a major role of acoustic intensity in the perception of both musical change and affect. It seems that improvisers share this patterning of acoustic intensity with interpreters of classical music, and composers of electroacoustic music. Thus we suggest that music made with non-acoustic instruments—that is those for which physical effort of performers does not provide the energy comprised in a sound—has developed the same pattern because composers and improvisers recognise its expressive power as a statistical archetype. Improvisers are particularly salient to this argument because they are not necessarily constrained by any of the prior conventions of music. It remains to be seen whether this statistical feature could have been assimilated from environmental and/or speech sounds. Given that the studied music flows within both the Afro-logic and Euro-logic discourses delineated by George Lewis, we discuss the possible trans-cultural implications of our observations for social discourse and community.

Introduction

In this Introduction, we provide a background to the study of intensity (the measurable acoustic counterpart of perceived loudness) in music. We also elaborate the reasons for obtaining empirical data on intensity patterns in improvised music, particularly in the context of perception. We consider the socio-cultural impacts of this aspect of improvisation in the latter part of the Discussion section.

It was demonstrated in stimulating work by David Huron that loudness patterns represented in the notation of Western classical and romantic music show an archetypal feature in which crescendi (acoustic intensity increases) are more common than decrescendi. Notated crescendi thus seem to occupy a larger part of the duration of the overall piece (Huron "Increment/Decrement Asymmetries in Polyphonic Sonorities"; Huron "Asymmetries in Beethoven's Piano Sonatas"; Huron "The Ramp Archetype: Musical Dynamics in 14 Piano Composers"; Huron "The Ramp Archetype and Auditory Attention"). Huron also suggested, notably in a summary diagram, that each individual crescendo may generally be longer than the subsequent adjacent diminuendo. A possible explanation for this was proposed, that crescendi may maintain attention while it wanes during decrescendi. Thus the notated structure was suggested to achieve a greater maintenance of attention than alternative intensity profiles might, quite possibly an objective shared by many composers. It is worth emphasising that here we are analysing *acoustic intensity* profiles, not those of perceived “tension” or “intenseness of expression.” However, as our argument further develops below, we will return frequently to the possible relationship between acoustic intensity and perception of expression and the impact and importance of sounds, discussing a hypothesised chain of causation between acoustic intensity and such expressive phenomena.

It is known that in some circumstances crescendi produce a greater perception of change in loudness than do the reciprocal diminuendi (e.g. a crescendo from 75-90dB over a few seconds compared with diminuendo from 90-75 in the same length of time). This perceptual asymmetry has been interpreted in terms of object “looming,” in which an object approaches at constant velocity (Neuhoff). If the object is emitting a constant sound, then a rapid crescendo results, and there is clearly some biological benefit in an enhanced attention towards the object as it approaches, possibly presenting some danger, rather than during its departure and diminuendo (Bach et al.). This asymmetry can also involve altered perceptions of stimulus duration for the two phases (Grassi and Darwin). The perceptual asymmetry in change of loudness is strongest when the crescendi are relatively short—between 1 and 10 seconds, which is also the duration range in which the maximal estimations of overall intensity change seem to occur

(Mathews). The perceptual data are complex and context-dependent, so they do not afford a simple prediction as to whether long-short crescendo-diminuendo patterns are likely to attract more attention than short-long patterns, as implied by Huron's work. However, the perceptual data do suggest that relatively short crescendi with relatively high rates of intensity change are likely to be efficient means of gaining attention.

Huron's work was not accompanied by empirical measures of the occurrence of the acoustic patterns that would be predicted by the notational observations. As a step towards this, we made measurements of intensity profiles in a range of Canadian electroacoustic music (Dean and Bailes "Is There a 'Rise-Fall Temporal Archetype' of Intensity in Electroacoustic Music?") and subsequently in a broader range of electroacoustic music, mainly composed, but including two pieces involving improvisation (Dean and Bailes "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music"). These data showed clearly that the acoustic properties of these works did not coincide with the prediction implied by Huron's data. Rather, they revealed a related pattern in which intensity rises are shorter than falls, both overall and when comparisons between successive pairs of such events were made. Correspondingly, the rate of change of intensity during rises was on average greater than during falls. This might be expected if a piece has a constant mean intensity value, and oscillates up and down symmetrically from it, since there are clear limits to the maximum and minimum intensities that can usefully be generated. On the other hand, a piece with a slow trend in overall intensity, or with a small number of such trends, might not necessarily show this related feature of greater rate of change for the short intensity rises than for the longer falls.

Given the occurrence of both temporal and rate of change differences between rises and falls in intensity, we suggested that an alternative interpretation, based both on ideas of attention and of arousal might be that it is rather this rate of change which is important for maintenance of attention and perhaps some broader affective correlates. We have also studied 119 recordings of movements of classical instrumental works, mainly by Haydn but including several others analysed by Huron, confirming our observations (unpublished), and thus showing that the pattern is not specific to electroacoustic music. These data also revealed that superimposed on the recurrent pattern there are inter-individual and inter-work differences in the average lengths of time over which they occur, and this might be expected of a vehicle for expressive output such as music.

Since score notations are at most a guide for interpretation, we envisage that it may be the physical performative aspect of music-making which is responsible for these recurrent patterns in instrumental music that distinguish the acoustic realization from the notation. This argument also suggests that improvisation performance, which is mostly realized with no or very limited notated referent, might involve similar recurrent intensity patterns. On the other hand, improvisers have far greater opportunity to mould their sonic activity and its acoustic intensity than do interpreters, and so if the recurrent rise-fall pattern were primarily a feature of composition, or notation and its interpretation, then improvisers might not display the same pattern. Thus there is particular importance in establishing whether or not improvisers share the pattern of intensity profiling we have described in some other musics. This paper addresses this question in some detail, studying both music entirely produced on acoustic instruments (where physical activity dictates the acoustic intensity produced by providing the energy which constitutes the sound), and some produced by electronic instruments and computers where this is no longer the case, as with some of the electroacoustic music we studied earlier. Specifically, we consider intensity profiles in some key styles of jazz since bebop, in free improvisation within and without the jazz tradition, and in electroacoustic improvisations beyond those studied earlier. While some of the classical works we have studied are quite rhythmic and metrical, with fairly constant pulses, none are truly groove-based (Keil and Feld; Kernfeld), a designation which is less appropriate to classical music apart from some minimal music in the late 20th century. So here we have explicitly included such highly rhythmic music, possibly constituting a quite conservative test of our rise-fall hypothesis, in that with a strong rhythmic groove such recurrent intensity patterns might be subordinated or unnecessary. We also take care to assess the possibility that it might even be the groove per se which generates such intensity patterns in this music.

Consideration of pulse-oriented rhythmicity points to the issue of the time frame on which intensity profiles are studied, as it implies its own time boundaries, even though they are somewhat variable in length as tempo fluctuates in a performance. Previously, we have used a range encompassing all but the largest structural units of music, those far beyond phrases: our windows were 0.04 sec, 0.5 sec, 5 sec, and 10 sec. Here we complement this by including an analysis whose time units are beats (very slightly variable in length, but in this case c. 1 sec) that even in music at large virtually always fall between the 0.04 sec and 5 sec time frames. We compared the analysis based on beats with that based on the surrounding fixed time frames, with the expectation that the features measured at the beat level will be quantitatively intermediate between those of the two surrounding fixed time frames, as is the case for the different time frames in our earlier studies. It is a logical necessity that when intensity is measured at 0.5 sec intervals, rise/fall patterns operating over longer time frames will be reflected in the measurements on the 0.5 sec interval—but there can be some shorter patterns that are not. Thus there was reason to expect that measurements based on beats of c. 1 sec would be a simple intermediate between those for the same piece measured in the 0.5 and 5 sec windows. This expectation was interrogated directly in the case of a Miles Davis piece, with the intention that if it was not upheld, beat analyses would be pursued. The prediction was fulfilled, and beat-based analyses were found to be unnecessary.

In the Discussion section of the paper, we consider the relationships between the acoustic and perceptual correlates of the intensity profiles we describe, and socio-cultural interaction. In essence, we argue that perceived loudness patterns flowing from those of intensity may be harnessed trans-culturally, and in both speech and music, to influence inter-personal and group interactions. Speech involves many processes in common with those of musical improvising, particularly in relation to loudness: this may be particularly important because speech rhythms do not use consistent rhythmic pulses to anywhere near the degree that music does. This possible confluence of features of acoustic intensity in speech and music may point to an important role for acoustic intensity and perceived loudness in affect generation during conversation, and in socio-cultural affiliation and empathy. These influences may perhaps be consciously controlled within interactions designed to generate effective social policy as well as social cohesion.

Music chosen for study

It is difficult if not impossible to devise a representative sampling strategy for the recorded literature of improvised music (all such recordings are not universally available in any one place—even the web), let alone to fulfil it. So we chose to include some key stylistic movements with music from the USA, Europe, and Australia (and their confluences), representing both the Afro-logic and Euro-logic streams in improvisation—as deeply categorised by George Lewis (Lewis), and discussed in our earlier work (Smith and Dean).[i] From sonic and musical viewpoints, we included both acoustic and electroacoustic improvisations, some works as recorded by two different artists (Coltrane's "Resolution"), two performances by one individual in a single context (Merzbow), and two by another individual (Evan Parker) in contrasted settings (solo; group acoustic and electronic improvisation). The recordings range from solo instruments (Evan Parker, Cecil Taylor), to classic jazz piano trio and quintet formations, to irregular large groups, to solo electronics and group electronics. We also include an analysis of one piece recorded as part of a laboratory experiment, described more fully below. We chose amongst the longer of the pieces available in each case, to increase statistical power. In the case of the particularly long improvisation by the Necks, we chose to use the first 30 minutes of a piece which lasts 53'20", so as to maintain a fairly even spread of durations amongst our sample. This decision is also consistent with there being relatively few pieces in the recorded literature of improvised music from the Afro- and Euro-logic traditions that are longer than 30 min (unless multi-movement). The pieces studied are summarised in Table 1.

Table 1. Music Studied.

Artist/ (Primary Country of Origin)	Forces used; Live vs Studio	Purely Acoustic (A); or Electroacoustic (including electronic or processed sounds: E)	Pulsed (groove based): Y/ N/ Mixed	Duration	Piece/Recording details (CD release)
Charlie Parker (USA)	Quintet; Live	A	Y	7'31"	"Night in Tunisia" from *The Massey Hall Concert* (Saga EC 3320-2). Recorded 1953.
Miles Davis (USA)	Quintet; Live	A	Mixed	14'55"	"My Funny Valentine" from *The Complete Concert 1964:My Funny Valentine and Four & More* (CBS 471246 2). Recorded 1964.
John Coltrane (USA)	Quartet; Studio	A	Y	7'24"	"Resolution" from *A Love Supreme* (Impulse DMCL 1648). Recorded 1964.
Ornette Coleman (USA)	Trio; Live	A	Mixed	9'54"	"The Riddle" from *At the Golden Circle, Vol. Two* (Blue Note 7243 35519 2 6). Recorded 1965.
Sun Ra and his Astro-Infinity Arkestra (USA)	Big band, with 'solar sound organ (Gibson Kalamazoo organ), clavioline,	E	N	21'51"	"Atlantis" from *Atlantis*, (Evidence ECD 22067). Recorded 1967.

	assorted percussion, and ensemble; Studio.				
Spontaneous Music Ensemble (UK)	Ensemble; Studio	A	N	7’23”	“Seeing Sounds & Hearing Colours-Movement 3” from *Withdrawal (1966-7)* (Emanem 4020). Recorded 1967.
Bill Evans (USA)	Piano trio; Live	A	Y	8’22”	“Nardis” from *At the Montreux Jazz Festival* (Verve 539 758-2). Recorded 1968.
Herbie Hancock (USA)	Sextet; Studio.	A & E	Mixed	21’25”	“Wandering Spirit Song” from *Mwandishi* (Warner Brothers 2-45732). Recorded 1970.
Globe Unity Orchestra (Germany)	Improvisers’ Orchestra; Live	A	Mixed	8’39”	“Alexanders Marschbefehl” by Misha Mengelberg from *Rumbling* (FMP CD40). Recorded 1975.
Graham Collier Music (UK)	Big band; Studio.	A	Mixed	8’54”	“New Conditions Part 1 and 2” from *Darius/Midnight Blue/New Conditions*, (BG0CD895). Recorded 1976.
Cecil Taylor (USA)	Solo piano; Live	A	N	33’15”	“Erzulie Maketh Scent Part 1” from the album of the same name (FMP CD 18). Recorded 1988.
Derek Bailey (UK)	Solo guitar; studio	A	N	17’08”	“Ten 10” from *Solo Guitar Vol 2* (Incus CD 11). Recorded 1991.
Evan Parker (UK)	Solo saxophone; Concert Hall used as Studio	A	N	17’20”	“Conic Section 3” from *Conic Sections* (ah um 015). Recorded 1993.
The Necks (Australia)	Piano trio: studio.	A	Y	30’00”	“White” from *Silent Night*, (Fish of Milk CD FOM 0004); the opening part. Recorded 1995.
austraLYSIS Electroband (Australia)	Electroacoustic trio (saxophone and digital sound); broadcasting corporation studio	AE	Mixed	7’31”	“Ostinato” from *Present Tense* (Tall Poppies TP 109). Recorded 1996.
Brad Mehldau (USA)	Piano trio; studio	A	Y	6’30”	“I didn’t know what time it was,” from *The Art of The Trio Vol 1* (Warner Bros. 9362 46260 – 2). Released 1997.
Fennesz (Austria)	Electronics; studio	E	N	2’48”	Excerpt from *Plus Forty Seven Degrees 56’ 37” Minus 16 degrees 51’08”* (Touch CD, as released on Rough Trade Shopes Electronic 01 cdstumm203 in 2002). Recorded 1999 or earlier.
Merzbow 1 (Japan)	Analogue electronics & instrument; Live	E	N	3’25”	This is the audio from a performance video (“merzbow.mov”) released on the “*Merzrom*” CD-Rom published with *Merzbook: The Pleasuredome of Noise*, by Brett Woodward (Extreme,

					1999; Preston, Vic, Australia. Recording date unspecified. 22.05kHz sample rate.
Merzbow 2 (Japan)	Digital electronics; Live	E	N	2'12"	The audio from "opera2.mov" from the same CD-Rom as above. Recording date unspecified. 22.05kHz sampling.
pxp ("a farmersmanual subunit") (Austria)	Group electronics; not specified	E	Mixed	4'41"	"pxp — while(p)print … #5." *Prix Ars Electronic 2002 Digital Music* CD. Released 2002.
Kurt Elling (USA)	Vocal and trio; studio.	A	Y	6'51"	"Resolution" from *Man in the Air* (Blue Note 7243 5 90948 2). Recorded 2003.
Antony Pateras/Robin Fox/Martin Ng (Australia)	Electronics; live	E	N	4'24"	Untitled from the *Now now. Excerpts 2003* (now now cd004). Recorded 2003.
Evan Parker Electro-Acoustic Ensemble (UK)	Ensemble; live	AE	N	17'29"	Shadow Play from *The Eleventh Hour* (ECM 1924). Recorded 2004.
Fritz Hauser (Switzerland)	Solo untuned percussion; studio	A	N	6'53"	"Puzzle" from *Flip* (Celestial Harmonies 13275-2). Released 2007.
Matt McMahon* (Australia)	Solo piano; *recorded in a laboratory experiment (see legend).	A	Mixed	2'42"	Unreleased purely research-related performance. Recorded 2010.

Table legend.
All recordings above were obtained at 44.1 kHz sampling, 16 bit, stereo unless specified otherwise. Where on the original there was a spoken introduction, or applause before or after the music, this has been removed. The times noted are those stated on the CDs, for identification purposes. Electric piano and Sun Ra's organs are classified as electroacoustic for the purposes above, since the performer's energy is not directly transmitted into the sound.

* The recording by Matt McMahon was made within an ongoing experimental research project on the psychology of improvisation and required the pianist to fulfill a simple descriptive referent in realizing the piece. The referent instructions were to perform an improvisation of about 3 minutes, in which there are three successive sections, the first rhythmically "pulsed" in character, the second "unpulsed," and the third again "pulsed." There were no instructions as to material, loudness, or relative duration and no definition of "pulse" was offered.

We note that audio 'compression' may be applied to some recordings during mixing, mastering, or even as a result of some denoising processes: such compression may result in a limitation of the extreme values of intensity in a sound file, and at least in contemporary pop music is often used to boost the overall apparent dynamic level. We consider that the present recordings use relatively few of such processes (in comparison, say, with a highly produced studio album such as Miles Davis's *Tutu*). But in any case, these techniques do not much alter the *patterns of acoustic intensity change* within the 10-90% quantile range we study (summarised below), and are not likely to have a significant effect on most of the statistical parameters we determine.

Analytical Methods

We have previously detailed our computational methods for analysing intensity (Dean and Bailes "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music") and hence provide only a brief summary here. We use the software Praat 5 to run scripts that produce our measures and some statistical assessments. Intensity was analysed in successive frames separated by a hop of 40 msec, and considering the frequency range (20-22050Hz). These data were either used directly or aggregated to provide averages over "windows" of 0.5 sec (round about or less than most pulse rates), 5 sec (a common phrase length), and 10 sec (some long phrases, multiple phrases, continua). The issue of choice of window length is elaborated later. For each duration 0.04, 0.5, 5, and 10 sec, we determined every successive peak and trough (the "all peaks" measure), and every successive peak and trough which met the criterion to be a "dynamic step" (the 'dynamic steps' measure). A peak occurs each time a locally maximum intensity value is reached (relative to surrounding values), however small the difference between that peak and the surrounding values may be; and similarly for troughs, which are local minimum values. In contrast, a "dynamic step" peak is one that, additionally, exceeds a certain minimum "step" in intensity from the immediately preceding trough (i.e. usually constitutes a larger jump than a simple peak amongst the "all peaks" series, fulfilling a more stringent criterion). The "dynamic step" is that minimum difference, and for each particular piece it was set at 1/5 of the intensity difference between the intensities observed at the 10% and 90% quantiles of intensity values, judged using the 0.04 sec window. The 10% quantile, for example, is the intensity below which 10% of the observed intensity values fall. The 10-90% range was chosen to correspond to previous analyses and to provide 5 steps which equate roughly to the intention of the notations pp, p, mp, mf, f, and ff: where pp corresponds to the 10% and ff to the 90% quantile. Thus there are always far fewer dynamic steps than there are peaks and troughs in the all peaks series. The coefficient of variation (CV = standard deviation/mean) of the (0.04 sec) intensity profile provides a relative comparison of the variability of intensity of the different pieces. Data are only presented when there are at least 5 rise-fall pairs (since it is virtually impossible for smaller numbers to provide statistically significant and meaningful data).

The main parameters determined in "all peaks" and "dynamic steps" analyses were the duration of the components of each pair of rises and falls. For each pair we measure the difference between fall and rise time: according to our hypothesis, on average this difference should be positive (fall time > rise time). Similarly, we measure the rate of intensity change during the two phases, predicting that the absolute rate of change will be greater during the crescendi than the decrescendi. Note that the windowed search for paired rise/falls can result in the loss of data from the analysis at the beginning and end: a decrescendo at the very start is lost, and in a 10 second window analysis up to 20 seconds can be lost at the end of the file (a rise followed by an incomplete fall). The total time for which data is presented therefore varies slightly from analysis to analysis.

Since Huron counted the notated crescendi and diminuendi (and related notations such as sforzando and accent), we also undertook the nearest equivalent acoustic analysis. In the absence of any principled argument to the contrary, our hypothesis was the null hypothesis: that crescendi and diminuendi are indistinguishable in number. For this, we used the 0.5 sec window, a time window that permits identifying virtually all crescendi and diminuendi that would be notated in classical music, of any length equal to or greater than 0.5 sec. We defined a "crescendo" as an increase in intensity greater than 1/4 of the "dynamic step" from the reference value current at any particular time (the most recent dynamic step peak or trough) and a diminuendo as a comparable decrease. Oscillations of intensity within the ±1/4 range do not qualify and are counted as "other" events (plateaux). This means that unlike the "all peaks" and "dynamic steps" analyses, this approach permits there to be multiple successive crescendi not broken by a dinimuendo, but just by plateaux. Similarly, there may be multiple diminuendi separated only by plateaux. Note again that these crescendi and diminuendi are expected to be far less numerous than the all peaks rise-falls measured in the same 0.5 sec time window.

One piece (Miles Davis's *My Funny Valentine*) was analysed not only in terms of the fixed time windows described already, but also in terms of beats. After an opening melismatic section that is free of tempo, the slow pulse rendering of the theme begins at 59.4 sec and the 4/4 metre is increasingly clear and precise. The tempo is relatively constant in this section, and just before 2'37" the group move into a "double tempo" in which there are twice as many accented pulses per bar as before. The analysis continues to use the original 4 beats per bar, each now comprising two pulses; the beat tempo becomes abruptly very slightly slower than in the preceding section (as judged by comparing the 8 bars before and after the start of the double tempo section). In later sections corresponding to the tenor saxophone solo and the piano solo there are substantial gradual decelerandi, and by the time Miles Davis's trumpet rejoins (at 13'20" but heralded by applause, presumably as he re-entered the visible stage area) the original 4 pulses per bar are clearly re-established. From 14'34" until the end of the piece there is another, shorter, tempo-free melismatic section. To conduct a beat-level analysis, beats were marked manually in Sonic Visualiser and checked aurally. In a few cases, there is apparent disparity amongst the musicians as to beat placement. At such moments, evidence from the bass line is used. In one sequence of 6 beats, there is a substantial group rubato, and the appropriate number of subdivisions has been placed roughly equally in time, since there was no dominant interpretation. In total, these “deviant” cases numbered only 8 beat positions, out of a total of 825 (including the position of the first beat of the bar beginning the final free tempo section). These beats represent 206 complete bars, but parts of the repeating song bar structure, the “chorus,” are taken into the melismatic sections, so that the pulsed section does not correspond to an integral number of choruses. The intensity profile of the pulsed section was analysed separately, both in terms of beats and in terms of all the defined time windows.

Results

Table 2. Summary Intensity Statistics for the Studied Recordings.

Creator (and piece number for Merzbow)	Mean Intensity (SPL in dB)	Coefficient of Variation of Intensity
Charlie Parker	73.77	0.06
Bill Evans	64.58	0.11
John Coltrane	72.08	0.07
Ornette Coleman	76.78	0.06
Sun Ra and his Astro-Infinity Arkestra	70.24	0.13
Spontaneous Music Ensemble	66.72	0.15
Herbie Hancock	68.69	0.09
Bill Evans	64.58	0.11
Globe Unity Orchestra	64.53	0.15
Graham Collier Music	71.76	0.11
Cecil Taylor	65.11	0.15
Derek Bailey	60.81	0.14
Evan Parker Solo	73.35	0.05
The Necks	77.34	0.06
austraLYSIS Electroband	68.76	0.09
Brad Mehldau	72.88	0.08
Fennesz	79.66	0.07
Merzbow 1	83.50	0.02
Merzbow 2	77.73	0.03
pxp (“a farmersmanual subunit”)	75.56	0.07
Kurt Elling	77.06	0.08
Antony Pateras/Robin Fox/Martin Ng	79.42	0.09
Evan Parker Electro-Acoustic Ensemble	59.04	0.13
Fritz Hauser	53.23	0.29
Matt McMahon	59.93	0.09

Table Legend.
SPL refers to sound pressure level, measured in the unit of decibels (dB). Mean intensities and their coefficients of variation were measured using the 40 msec window, taken as being the most representative of the overall sound file. Coefficient of variation of intensity was inversely correlated with mean intensity ($r = -0.81$, $p<0.001$), while mean intensity showed no relation to date of recording: these two general features of the Table are considered below in the Discussion section.

In previous work (Dean and Bailes "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music") we have illustrated the typical properties of the data obtained in these analyses, and pointed out that the longer the time window under study, the fewer rise-falls will be observed in a given piece, and hence the less likely there will be any statistically significant differences between the parameters. In Table 3, we present just the analyses in which there are measurements that achieve statistical significance, selected from the complete set. We note however, that those analyses that do not reach significance are mostly concordant with the patterns found for the significant data we present here.

Table 3. Statistically Significant Fall-Rise Differences for the Pieces Studied.

Composer/ Ensemble (crescendo count, diminuendo count; statistical significance of difference, if any) Analysis Window (sec)/ Peak Type	Fall-time ([F]: Mean, seconds)	(Fall-time mean - Rise- time [R] mean) difference, seconds (significance)	Mean Intensity Rise rate (dB/sec)	Intensity Rate difference ($R_{rate}+F_{rate}$)$^{\#}$ (significance)
Charlie Parker (154 crescendi, 162 diminuendi, 282 other)				
0.04/All peaks	0.15	0.03****	33.53	5.45****
0.04/Dynamic steps	0.26	0.08****	41.89	9.65****
0.5/All peaks	0.94	0.14****	5.09	0.77
0.5/Dynamic steps	1.84	0.32	5.93	1.57*
5.0/Dynamic steps	17.14	-25.67**	0.23	-0.10
Miles Davis (283 crescendi, 312 diminuendi, 547 other.)				
0.04/All peaks	0.22	0.09****	33.06	8.20****
0.04/Dynamic steps	0.59	0.29****	49.79	23.10****
0.5/All peaks	1.00	0.17****	7.70	1.01*
0.5/ Dynamic steps	2.22	0.76****	9.55	2.75****
John Coltrane (138 crescendi, 144 diminuendi, 310 other)				
0.04/All peaks	0.16	0.04****	27.04	6.27****
0.04/Dynamic steps	0.31	0.08****	34.82	10.12****
0.5/All peaks	2.42	1.02****	5.50	1.86****
Ornette Coleman(195 crescendi, 198 diminuendi, 398 other)				
0.04/All peaks	0.14	0.02****	29.10	3.76****
0.04/Dynamic steps	0.25	0.03****	36.63	5.79****
Sun Ra and his Astro-Infinity Arkestra (139 crescendi, 140 diminuendi, 577 other)				
0.04/All peaks	0.14	0.02****	14.24	1.23
0.04/Dynamic steps	1.85	0.90****	30.58	9.76****
0.5/All peaks	0.91	0.07**	4.29	0.81
0.5/Dynamic steps	7.06	3.71*	12.57	4.11****
10/Dynamic steps	108.33	-1.59	0.37	0.21*
Spontaneous Music Ensemble (92 crescendi, 100 diminuendi, 294 other)				
0.04/All peaks	0.15	0.02****	27.39	4.02
0.04/Dynamic steps	0.57	0.02	42.82	10.30***
10/All peaks	18.33	-0.79	0.50	-0.01*
Bill Evans (154 crescendi, 161 diminuendi, 300 other)				
0.04/All peaks	0.16	0.04****	39.13	8.97****
0.04/Dynamic steps	0.35	0.07****	49.04	12.98****

Herbie Hancock (295 crescendi, 298 diminuendi, 894 other)				
0.04/All peaks	0.17	0.04****	20.82	3.93****
0.04/Dynamic steps	0.60	0.14****	30.23	8.40****
Globe Unity Orchestra (112 crescendi, 118 diminuendi, 289 other)				
0.04/All peaks	0.14	0.03****	34.66	6.46
0.04/Dynamic steps	0.62	0.24****	65.98	26.47****
0.5/All peaks	0.85	0.08*	7.53	0.55
0.5/Dynamic steps	3.39	1.38*	14.19	4.42****
Graham Collier Music (88 crescendi, 90 diminuendi, 329 other)				
0.04/All peaks	0.16	0.03****	18.68	3.05
0.04/Dynamic steps	0.91	0.26***	28.46	8.82****
0.5/All peaks	1.00	0.14**	4.66	0.63
5.0/All peaks	8.64	1.08	0.59	0.08*
Cecil Taylor (403 crescendi, 414 diminuendi, 1217 other)				
0.04/All peaks	0.17	0.05****	32.97	7.14****
0.04/Dynamic steps	0.58	0.12****	47.16	13.93****
0.5/All peaks	0.87	0.06**	7.52	0.90
0.5/Dynamic steps	3.30	0.80*	13.39	3.94****
5.0/All peaks	8.63	-1.51*	0.96	0.34
Derek Bailey (315 crescendi, 364 diminuendi, 648 other; *)				
0.04/All peaks	0.26	0.13****	45.98	16.42****
0.04/Dynamic steps	0.53	0.25****	60.49	25.68****
0.5/All peaks	0.98	0.18****	9.75	1.79
0.5/Dynamic steps	2.12	0.69****	12.97	4.78****
10/Dynamic steps	56.00	9.16	0.34	0.16*
Evan Parker Solo (328 crescendi, 328 diminuendi, 1099 other)				
0.04/All peaks	0.12	0.004****	18.25	0.18
0.5 /All peaks	0.83	0.04*	2.47	0.21
5/All peaks	7.56	-2.35***	0.18	-0.15
5/Dynamic steps	26.32	-27.09*	0.18	-0.19
10/ All peaks	15.12	-6.82*	0.09	-0.10
The Necks (526 crescendi, 567 diminuendi, 1256 other)				
0.04/All peaks	0.22	0.11****	36.06	13.22
0.04/Dynamic steps	0.44	0.20****	49.99	25.64****
0.5/All peaks	0.90	0.11****	5.81	1.00****
0.5/Dynamic steps	1.97	0.34	712.	1.55****
5/Dynamic steps	74.00	-1.95	0.33	0.19****
10/All peaks	17.17	-4.34*	0.07	-0.01

austraLYSIS Electroband (155 crescendi, 157 diminuendi, 305 other)				
0.04/All peaks	0.18	0.05***	28.35	6.71****
0.04/Dynamic steps	0.41	0.09****	38.83	1.08****
0.5/Dynamic steps	1.95	0.46*	8.16	2.25***
Brad Mehldau (142 crescendi, 149 diminuendi, 278 other)				
0.04/All peaks	0.16	0.04****	34.08	7.89****
0.04/Dynamic steps	0.27	0.08****	41.91	12.68****
10/Dynamic steps	56.67	-15.54	0.18	-0.01****
Fennesz (56 crescendi, 54 diminuendi, 86 other)				
0.04/All peaks	0.12	0.01**	34.60	3.34
0.04/Dynamic steps	0.16	-0.01	50.03	6.41***
Merzbow 1 (46 crescendi, 47 diminuendi, 121 other)				
No significant differences found.		All but one observation have rise time shorter than the following fall.		Most observations have rise rate greater than fall.
Merzbow 2 (15 crescendi, 17 diminuendi, 85 other)				
No significant differences found.		Most observations have rise time shorter than the following fall.		Most observations have rise rate greater than fall.
pxp (“a farmersmanual subunit”) : (82 crescendi, 85 diminuendi, 182 other)				
No significant differences.		Most observations have rise time shorter than the following fall.		Most observations have rise rate greater than fall.
Kurt Elling (128 crescendi, 135 diminuendi, 256 other)				
0.04/All peaks	0.16	0.05****	33.61	6.89****
0.04/Dynamic steps	0.31	0.10****	43.62	11.84****
0.5/Dynamic steps	2.29	0.98****	7.43	2.59****
Antony Pateras/Robin Fox/Martin Ng (11 crescendi, 6 diminuendi, 59 other)				
0.04/All Peaks	0.15	-0.03****	1.98	-0.02
0.5/All peaks	0.98	-0.39*	0.55	-0.15**
Evan Parker Electro-Acoustic Ensemble (170 crescendi, 193 diminuendi, 642 other)				
0.04/All peaks	0.13	0.01****	20.20	0.48
0.04/Dynamic steps	0.71	0.12*	28.02	2.19
0.5/All peaks	1.05	0.12****	4.44	0.46
10/Dynamic steps	53.64	10.76	0.39	0.18*
Fritz Hauser (75 crescendi, 85 diminuendi, 251 other)				
0.04/All peaks	0.15	0.04****	52.20	8.05**
0.5/ All peaks	1.00	0.17***	12.34	2.34
0.5/Dynamic steps	3.22	0.27	16.61	5.57*

10/Dynamic steps	53.33	-6.67	0.61	0.12***
Matt McMahon (48 crescendi, 51 diminuendi, 123 other)				
0.04/All peaks	0.18	0.07****	28.08	8.80****
0.04/Dynamic steps	0.41	0.10****	32.03	11.26****
Analysis Window (sec)/ Peak Type	Fall-time ([F]: Mean, seconds)	([F] Fall-time mean - Rise- time [R] mean) difference, seconds (significance)	Intensity Rise rate (dB/sec, Mean)	Intensity Rate difference $(R_{rate}+F_{rate})^{\#}$ (significance)

Table Legend.
The counts of crescendi, diminuendi and “other features” were made using the 0.5 sec window. Note that these counts are much smaller than the number of peaks detected with the “all peaks” algorithm, because of the rigorous definition of crescendo and diminuendo (Methods). Statistical significance is shown as follows: not significant, no asterisk; p<0.05, *; p<0.01, **; p<0.005, ***; p<0.001, ****.

[#] Since F_{rate} (the rate of intensity change during a fall) is negative, this calculation gives the signed difference between the two rates, with a positive value indicating a faster change during a rise.

The results in Table 3 were resoundingly consistent with our two inter-related hypotheses of shorter rises with more rapid intensity change than the corresponding falls. Of the rise-fall duration differences that achieved statistical significance, there were 56 observations consistent with the hypothesis that rises occupy shorter times than corresponding falls, and only 7 that were not. In terms of the improvisations involved, 22 showed a significant duration effect as hypothesised at some time window of analysis, while only 5 showed any converse observations. There were no pieces lacking the hypothesized effects and only showing significant contrary effects, though the case of Evan Parker's solo piece does seem to be an exception to the hypothesised duration pattern (see below). Similarly, with respect to the predicted faster intensity change during rises than falls, there were 49 observations consistent with the hypothesis and only 3 contrary, of which two had a trivial magnitude (0.01 dB/sec). Thus, in sum, our twin hypotheses were strongly supported.

When we counted crescendi and diminuendi with consistent acoustic criteria, we found only one significant difference: the piece by Bailey had more diminuendi than crescendi, while others showed no difference in the frequency of the two intensity change types. While Huron showed that there are more score markings related to crescendi than diminuendi in the classical and romantic music examples he studied, our hypothesis based on our previous acoustic data and our theoretical explanation was that there would be no significant difference in the frequency of the two events. This was also therefore strongly supported.

It is worth considering the analyses that are counter to our hypotheses in a little more detail: Mehldau, 10sec/Dynamic steps; Evan Parker solo, 5 sec/both analyses; Evan Parker 10 sec/All peaks; Pateras et al. 0.04/ and 0.5 sec/All peaks; Taylor 5 sec/ Dynamic steps; Spontaneous Music Ensemble 10 sec/ All peaks; The Necks, 10 sec/All peaks. In the cases of Mehldau and the Spontaneous Music Ensemble, the contrary difference was acoustically insignificant (0.01 dB/sec), and at other time windows of analysis (e.g. 0.04 sec) the hypothesised pattern was observed. With the Evan Parker solo, again the short window revealed the expected duration pattern, but three longer windows revealed the contrary. It does seem that Parker is unusual in his handling of these duration issues when performing solo. The piece studied is adequately long for statistical purposes, and the only caveat that should be borne in mind is that his CV of intensity (Table 2) is the third smallest (0.05), indicating that the relative importance of dynamic intensity change in his piece might be low compared with most under study. The analyses of Parker in the electroacoustic ensemble are in contrast to these solo data, and are consistent with both our hypotheses. During his solo performances Parker makes almost continuous sound, often using circular breathing techniques: it is possibly this feature which helps to distinguish this performance from others, and also from his work in his Electroacoustic Ensemble. In the Ensemble, there are not only several performers and sound sources, but Parker's playing is also a little more intermittent, and may be technically distinct from the point of view of breathing. The Pateras recording also shows some contrary results, even though the piece is quite short: one analysis involves significant contrary differences in the intensity rate of change and the duration, while the other shows a significant but minute difference in duration with a longer rise than fall. The two longest pieces also present some counter-examples: Taylor's solo piano piece gives one datum contrary to our hypothesis, amongst a plethora which are consistent with it, as does the piece by the Necks. It should be noted that at the significance level of $p<0.05$, one in twenty analyses will usually show a spurious significant result.

We noted above that the statistical power of an analysis is generally enhanced the larger the number of pieces of data that replicate a given condition, and thus the longer pieces provide more opportunity to detect patterns in longer rise-falls than do the shorter pieces. The observations presented are consistent with this, as is the observation that maximum lengths for the statistically significant falls in Table 3 correlate with the length of the piece analysed ($r=0.55$, $p=0.004$). This issue of statistical power needs to be borne in mind in considering the interpretation of our data.

Our range of musical materials was intended to be diverse in many respects, one aspect being the degree of emphasis on groove and pulse, as summarised in Table 1. It is noteworthy that our twin hypotheses are supported just as strongly by the data from the freely improvised unpulsed pieces, as by the data from the groove music. Clearly, groove is not a prerequisite for the occurrence of the rise-fall acoustic intensity pattern we define. It might be, though, that groove is in itself sufficient to drive waves of attention, and thus that recurrent intensity patterns would be less necessary. On the other hand, it remains possible that in the groove pieces the intensity pattern is directly related to the groove and might be particularly emphasised if analyses were made on the basis of windows each comprising one or more pulses. We indicated in the introduction our musical, acoustic, and statistical reasons for not anticipating any such special relationship, but we next describe our direct assessment of the issue. In the final discussion, we return to the question of the impact of groove and intensity on social interaction.

Comparison of measurements based on fixed time windows with those based on beats: Miles Davis's "My Funny Valentine."

Table 4 summarises the results of both fixed-window and beat-based analyses (from the long pulsed section) of this piece. The beat-based analysis can be compared both with the fixed window analyses of the whole piece and with the additional fixed window analyses of the pulsed section only. It is very clear that while the beat-based analysis does not highlight significant differences between rises and falls, the results it shows are always intermediate between those of the 0.5 sec and 5 sec fixed windows, consistent with the fact that the average beat occupies 1.06 sec. This is particularly obvious and precise when the balanced comparison is made with the fixed window analysis of the pulsed section alone, but clear-cut also for the comparison with the whole piece. The similarity in determined number of rise-fall events for the 0.5/Steps analyses and the "beats" analysis also confirms that the aggregation of the smaller time windows is producing results predictive of those using the beat windows. The additional data support the conclusion above that where there are sufficient crescendi and diminuendi for differences to reach statistical significance, it is (in this piece—always) the crescendi which are shorter and show more rapid intensity changes than the diminuendi. We conclude that, as anticipated, results at the beat level can be predicted from the pair of fixed-window datasets whose window lengths are respectively a little greater and a little smaller than the beat duration. Thus repeated analyses based on the variable length beat windows of pieces are not required. Even when compared with the use of a range of automated beat detectors, the manual approach to accurately placing beats was the most time-efficient, and thus the process is slow. So it is convenient that our evidence confirms this is unnecessary. Table 4 also serves to illustrate again the complete range of data we obtained in these analyses, from which salient extracts are made in Table 3.

Table 4. Comparisons of Intensity Data Between Fixed Windows and Beats. Miles Davis's *My Funny Valentine*: the Complete Dataset

Analysis Type (crescendi count, diminuendi count, other event count; statistical significance of difference between cresc. and dim. counts) Analysis Window (sec)/ Peak Type	Number of Rise-fall Events	Rise-time (R: Mean, seconds)	Fall-time (F: Mean, seconds)	Fall-time Mean minus Rise-time Mean (difference, seconds, significance)	Total Intensity Rise Time, seconds	Total Intensity Fall Time, seconds	Rise Rate of Intensity Change (dB/sec, Mean)	Fall rate of Intensity Change (dB/sec, mean)	Significance of Absolute Rate Difference (F_{rate}-R_{rate}; p value)
Fixed Time Windows; whole piece (283 cres; 312 dim; 547 others; n.s.)									
0.04/All peaks	2552	0.13	0.22	0.09****	331.4	549.9	33.06	-21.86	<0.001
0.04/Dynamic steps	993	0.30	0.59	0.29****	302.0	580.9	49.79	-26.69	<0.001
0.5/All peaks	483	0.83	1.00	0.17****	401.5	483.0	7.70	-6.69	<0.05
0.5/Dynamic steps	240	1.46	2.22	0.76****	350.0	532.5	9.55	-6.80	<0.001
5/All peaks	56	8.56	7.23	-1.33	479.6	405.0	0.76	-0.76	n.s.
5/Dynamic steps	27	18.69	12.22	-6.47	504.6	330.0	0.93	-1.03	n.s.
10/All peaks	28	16.77	15.71	1.06	469.6	440.0	0.32	-0.35	n.s.
10/Dynamic steps	12	26.64	43.33	16.69	319.6	520.0	0.45	-0.38	n.s.
Beats: pulsed portion of the piece (188 cresc; 213 dim; 188 others; n.s.)									
Beats	248	1.61	1.66	0.05	399.7	412.0	4.11	-4.12	n.s.
Fixed Time Windows: pulsed portion of the piece (260 cres; 293 dim; 524 others; n.s.)									
0.04/All peaks	2357	0.13	0.21	0.08****	306.9	502.4	34.03	-22.49	<0.001
0.04/Dynamic steps	995	0.28	0.54	0.26****	275.2	537.8	50.20	-27.05	<0.001
0.5/All peaks	450	0.83	0.98	0.15****	371.5	440.5	7.57	-6.73	n.s.
0.5/Dynamic steps	218	1.47	2.25	0.78****	320.0	491.0	9.28	-6.35	<0.001
5/All peaks	52	8.27	7.50	-0.77	430.0	390.0	0.70	-0.69	n.s.
5/Dynamic steps	27	13.89	15.56	1.67	375.0	420.0	0.75	-0.81	n.s.
10/All peaks	25	17.60	15.20	-2.4	440.0	380.0	0.26	-0.34	n.s.
10/Dynamic steps	11	38.18	30.91	-7.27	420.0	340.0	0.28	-0.30	n.s.

Table Legend. Conservative two-tailed t tests were applied to the duration and intensity change rate values to test whether the observed paired differences between fall-rise duration and rise-fall intensity change rate were significant. The chi-square test was used for the comparison of counts of crescendi and diminuendi. Note again that as described in Methods these counts are not the same as rise or fall in either the "All Peaks" or "Dynamic Steps" analyses. "Others" covers all varieties of plateaux: n.s. = not significant. Statistical significance is shown as follows: not significant, no asterisk; p<0.001, ****.

General Discussion

The discussion has two parts: in the first we consider the data and their musical and perceptual interpretation; and in the second we ask how these identified musical phenomena may relate to culture and community and add a new suggestion that may have practical application in productive social discourse.

Consideration of our findings from the perspective of music perception and cognition.

Overall our results are clearly in support of our hypothesis that rising intensity segments are shorter and show greater rates of intensity change than their falling counterparts. One might question the assumption that five gradations of intensity, linear in measured intensity (which is itself a logarithmic scale, accounting somewhat for human perceptual characteristics) are appropriate for the analyses. In the European notated traditions, however, even since the time of Haydn, a range of dynamic notations corresponding to this or a greater number of levels has been routine, and thus is amongst the objectives sought by professional performers. It is clear that such a use of dynamic levels may not characterize improvisers' purposes in all the conditions we have studied here. In particular, it seems that the pieces with the higher average dynamic level also exploit lower degrees of variation in dynamics (as reflected by the present coefficients of variation: Table 1), and two things may flow from this. First, the use of dynamic level changes may be less systematic and/or extensive in pieces with higher acoustic intensity; and second, the overall importance attached to such control as a contribution to musical expression may be lower, from the performer's and/or the listener's perspective. But it is notable that, unlike extremely high intensity levels, strong groove does not seem to be a substitute for intensity patterning: it does not replace it, and thus presumably does not make it redundant. More generally, it remains to be investigated whether performing improvisers and interpreters of notation vary in their conception of musical dynamic levels. Introspection suggests that dynamic contrasts are important to improvisers, but especially as they may not even be familiar with or supportive of musical notation. They are likely to conceptualise it rather differently from interpreters who are largely bound to notation. For example, improvisers may view dynamics as nothing beyond a continuum, in which there are no subdivisions such as p or mp would imply. What is clear is that if any performer intends to initiate a crescendo, the dynamic increase has to take as its reference the ongoing general (average) level, which is also what we have done in our analyses. Even a marking such as ff is likely to be interpreted with reference to current audible sonic levels as well as the current notated level (if any), and this interpretation is probably intertwined with a more continuing conception of what constitutes ff with a given instrumental ensemble in a given physical environment.

The mean intensity of pieces (Table 2) showed no relation to date of recording, or to recording environment or instrumentation. In contrast, in a series of measurements on popular music of the last twenty years, it has been observed that intensity levels had been progressively increasing (Lamere). In agreement with our observations, those data also suggest that their coefficients of variation decrease with average intensity. Thus it is fair to conclude that most of our performers, with the notable exception of Evan Parker in his solo saxophone guise, share on one or more time frames the temporal patterns of intensity rise and fall we have described, mostly regardless of how loud they choose to make and record their music. As we have noted, studio audio techniques (which would have applied to only a modest degree in the pieces studied here) would not be expected to disturb most of the patterning, even though they may lead to adjustments in level ranges, particularly those at the extremes.

It is notable that the longer the time window studied, the fewer the significant observations we obtain: this is immediately understandable from a statistical perspective, as mentioned already, since the longer the time window the fewer individual data points for a given piece. However, the fact that the length of the longest significant duration pattern detected with our fixed range of time windows increases with piece length suggests that in very long pieces there may indeed be repeating dynamic patterns operating over longer time frames than the 10 sec maximum we studied. Regrettably, proper analysis of these patterns using our approach would require many long pieces (to provide statistically sufficient data), and this would be a highly unrepresentative sample of improvised music from the continents under study—thus we have not attempted it. In the future, we will develop alternative approaches to this question.

Could it be that the intensity patterns we observe are simply a reflection of the brief attack period at the beginning of each sound from an acoustic instrument? For most instruments there is indeed a rapid attack (rise in energy) and then, whether or not there is a sustained phase of unchanging intensity, the decay is a little slower than the attack, with the occasional exception of some percussion instrument sounds. It could be argued that this pattern describes the same feature we have observed: short rise, long fall. However, the time scale on which acoustic instrument attack time operates is much shorter (usually much less than 50 msec) than even the shortest significant rise patterns we observed. In earlier work (Dean and Bailes "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music"), we have also shown that in monophonic or biphonic minimal music with average intensity c. 70 dB, each successive note (or paired note) attack disturbs the ongoing dynamic measured in the shortest appropriate window by only c. 1 dB. One decibel is close to the threshold of detection, and far smaller than would constitute a "step" in the present analyses. Furthermore, we are dealing usually with the attack of multiple instruments, which are blurred with respect to each other. It is unlikely that any of our shortest rise structures simply reflect acoustic instrument attack, and impossible that the longer ones do. In addition, this "attack" pattern is altered in real-time computer generated or manipulated sounds, which contribute to some of the electroacoustic improvisations we have studied, and so the attack pattern could again not explain our data on them. We have therefore not investigated this issue further.

Our data mostly involve acoustic instruments, in which the sound generated is a direct result of physical energy supplied by the performers. Thus unlike our earlier similar data on electroacoustic music, where this was not the case, we can here directly interpret the results in terms of our Force-Effort-Energy-Loudness-Affect (FEELA) hypothesis (Dean and Bailes "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music"). This hypothesis proposes that it is the physical effort of the performer which is not only expressed as the energy level (i.e. acoustic intensity) of the resultant sound, but also perceived as such, and that affect is expressed and perceived by performers and listeners through the directly correlated loudness (which increases with the energy of the sound). Here, we also impinge on the issue raised at the very outset of the paper: that we are dealing with measures of *acoustic intensity* that may yet have substantial bearing on the perception of affect, including tension or intenseness, by both performer and listener.

The FEELA hypothesis has yet to be fully tested experimentally, but it emphasises the role of acoustic intensity (perceived as loudness) in the communication of affect in music, and there are some data in relation to certain steps or relationships within the process. For example, there is mounting evidence in support of a role of acoustic intensity in affect generation. Schubert demonstrated the important correlations between loudness (the perception of acoustic intensity per se) and real-time affective responses, particularly perceived arousal, in classical works (Schubert); subsequently, we have extended this data to encompass electroacoustic music, with in-depth time series analysis of acoustic and perceptual streams (Dean and Bailes "Time series analysis"). Furthermore, in very recent work we have shown that the alteration of intensity profiles in otherwise unchanged music creates a parallel alteration of perceived arousal: for example, inverting the intensity profile inverts the arousal profile. Thus intensity is an important component of this perceptual chain, and at least the latter steps of the FEELA hypothesis have experimental support.

Our ideas on the FEELA hypothesis flow directly from a consideration of Huron's original ideas on the patterning of intensity profiles as observed in notated scores. He suggested that the rise portions of the pieces (which from notation he judged to be dominant over the falls in terms of duration) attract attention in the listener. He therefore suggested that compositions might structure their dynamics so as to exploit the pattern to maintain attention. While our observations suggest that rises are shorter than falls, in contrast to his original evidence, they also show that intensity rate changes are higher in the rises, and it may be this feature which still underpins the generation of heightened attention. By "attention," we here refer to the biological phenomenon in which the approach of a dangerous object (bus, lion) captures our awareness, such that we can quickly prepare for appropriate avoidance or other actions. During such an approach, an object or organism gets apparently bigger, and usually louder, as indicated in the concept of looming (Bach et al.; Neuhoff).

We were also influenced by the fact that in many classical composers' music the extent of dynamic markings (those referring to intensity) is quite slight. Indeed, Haydn is recorded as telling an orchestra preparing a performance of one of his pieces that ornamentation was unacceptable, but dynamic shading was everything (Jerold). Thus we realize that classical music interpreters provide extensive dynamic contrasts beyond those notated, and it was this view that also conditions and supports the FEELA hypothesis. It was on the basis that such performance traditions have become so familiar that any composer would intuitively exploit them that we proposed that even in electroacoustic music, where there need be no physical energy to generate the acoustic sound, the archetypal short rise-long fall pattern would be found, as we indeed confirmed (Dean and Bailes, "Is There a 'Rise-Fall Temporal Archetype' of Intensity in Electroacoustic Music?"; "A Rise-Fall Temporal Asymmetry of Intensity in Electroacoustic Music").

In the present paper, we return largely to performers who use their own physical effort to generate sonic energy—and without any or much guidance from notation, least of all in notated dynamics. The results are strongly supportive of our hypothesis, and yet still reveal how an individual, such as Evan Parker, can perturb the norm with what for many people are powerful results. While we are emphasising the shared generalities of the rise-fall patterns in what we present, it is also worth noting that there are many features of our data that show the complementary feature of inter-individual and inter-piece difference. For example, in Table 2 there are large differences in coefficient of variation of intensity (from 0.02 for Merzbow to 0.29 for Hauser): while these are partly explicable in terms of the inverse correlation of CV with mean intensity which we describe, there are clearly other inter-individual factors at work. Similarly, even in the selected data shown in Table 3, if we focus on the 0.5 sec/Dynamic Steps Fall time parameter, we find a wide range—from 1.84 s (Charlie Parker) to 7.06 s (Sun Ra)—and when all data are considered this is even increased slightly. Similar major differences between pieces distinguish the other features we have studied: they may reflect different intuitive or consciously strategic approaches by different musicians. It is notable that the two performances of "*Resolution*", by the two quartets of saxophonist Coltrane and vocalist Elling have closely similar parameter values, suggesting that particular referent compositions may nevertheless induce certain shared intensity features. To establish this would of course require more extensive investigation, using larger numbers of multi-performed themes. Such shared intensity patterns have been observed in our other work on Haydn and other classical music, where we have compared performances of the same piece by different ensembles from different periods, but this is more expected in that they are each realizing the same complete event sequence embodied by the score.

An objective of our future work is to see whether dynamic cues could lead a group of improvisers to segment during performance: where a 'leader' might condition a change in overall group musical direction in part through a change in dynamic intensity (Pressing; Sawyer; Smith and Dean). We expect this will be the case, and we aim to investigate other aspects of the early chains in the FEELA process through such performance studies. An awareness of the patterns we describe may not be necessary for improvisers; but it is unlikely that they escape the influence of these patterns, and unlikely that such awareness would be disadvantageous. We suspect that these patterns may also be intrinsic to environmental and speech sounds, which are important contributors to the statistical features of sound that we all experience and assimilate. We consider the implications of this possibility further in the final section.

Some implications of intensity patterning in improvisation for social interaction

"[Composition is] to exchange the noises of bodies, to hear the noises of others in exchange for one's own, to create, in common, the code within which communication will take place." (Attali 143).

Our emphasis above on affect as a cognitive variable points to the fact that in the broadest sense affect influences individual and collective comprehension and cohesion. As we noted (Dean, "Noisespeech"), free improvisation was a key exemplar put forward in "Attali's almost utopian concept of 'Composition', a kind of music which largely evades commodification and 'announces' the spectra of future social interactions: it invents its language as well as its message." It would be fair to exchange "improvisation" for "composition" in the quotation heading this section, given Attali's very special usage of the word "composition." As noise constitutes both the disordering and the ordering of the world, so Deleuze and Guattari also conceive that "to improvise is to join with the World, or to meld with it. One ventures from home on the thread of a tune. Along sonorous, gestural, motor lines" (Deleuze and Guattari 311). Deleuze and Guattari are clearly thinking particularly of "motor" generated sound, directly apposite to our FEELA hypothesis, but their more general reference to the "sonorous" and "gestural" also encompasses electroacoustic composition and improvisation. There is a commonality of view amongst these authors that improvisation can be a form of real-time semiotic generation: an expression that establishes its own "codes," symbols, and sometimes even lexicon and syntax afresh as it proceeds, but within its own culture, its world.

Yet our evidence above is that in addition to such real-time semiosis, in the wide range of cultural contexts from which our musical examples have been taken, there is maintained a continuing core semiotic structure of intensity and loudness. Widespread assertions of the universality of pitch structures such as the octave can readily be undermined (Dean, Bailes, and Brennan), as by Xenakis' emphasis on the fourth as a crucial pitch interval from ancient Greek music onwards and the much-promoted octave as a later culture-specific enthusiasm. Xenakis discusses this repeatedly in his book of conversations (Varga). Similarly, repetitive rhythmic pulse is not universal in music. Thus it is particularly interesting that musical improvisation, which can in principle break any universal convention, instead seems not to do so in relation to patterning of intensity, and furthermore maintains these patterns even in highly rhythmic, groove-oriented music. It is also worth bearing in mind that a listener confronted with a new piece of music, or even one within an established genre with which they have no familiarity, thus has little or no prior cultural fluency (Bradley and Lang), and so like the improviser has to construct their own semiotic field as the piece progresses; shared intensity profiles may form the familiar basis on which such field(s) can be superimposed and facilitate their formation equally for improviser and for listener.

We want to argue that this facilitation of semiosis may have even broader applications in the improvisation of linguistic discourse: that speech prosody may embody the same intensity patterns as we have described, and that the patterns may be harnessed towards effective discussion and community interaction, perhaps going beyond the power of simple dialogue into an even more equitable improvised communication. Given this optimistic purpose, we need first to make a cautionary juxtaposition of the sometimes idealistic published views of improvisation as pure and novel individual or group communication with some more sceptical viewpoints before we assess further the likely contribution of intensity profiles to discourse and social interaction. We will urge caution by contrasting some recent assessments of relationships between improvisation and the law, and improvisation and the unnameable, presented in this journal and editorialised respectively by Piper and Fischlin; some commentaries from Lewis, Mazzola, and ourselves; and the somewhat more cynical recent approach of Gary Peters, a cultural theorist committed to improvisation.

At one extreme, Mazzola and Cherlin suggest that “free jazz [. . .] allows the individual to optimise creative potential, but it also optimises the dialectic amongst individuals to create a higher synthesis, an infinite denouement” (135). Referring to the work of Fischlin and Heble, Piper also suggests that “group improvisation encourages a widening of community, individual and group responsibility, and negotiation of difference. Its practice cultivates [. . .] a withholding of judgement.” For Piper, improvisation “represents identity and social practices.” On the other hand, we have also noted another, perhaps less socially desirable form of non-judgementality: that improvisers may well choose to be “non-sensory,” by which we mean they might “make no response to external material, but [. . .] attempt to avoid even perceiving it. [. . .] The sensory vs non-sensory axis is [. . .] continuous” (Smith and Dean 32). But, as Piper points out, “improvisation creates [. . .] scripts which cannot help but be normative at times,” and the shared intensity profiles we have described can be seen to exemplify this, and might be a partial antidote to such a “non-sensory,” seemingly non-mutable, improvisatory stance.

In contrast, Fischlin, alluding perhaps to Deleuze, suggests that “The nomadic nature of improvised discourses, their ability to travel, to be transposed in and across cultures as they travel, is a key to their authenticity, their ability to retain what makes them both distinct and able to mutate in new contexts.” Without delving into the contested nature and relevance of authenticity in improvised music, we can nevertheless again see intensity profiles as potentially a key to the portability of improvisation. In the present study, we have travelled from music which formed part of the discourse of anti-racism and the legal and social emancipation of African-Americans (e.g. Parker, Davis, Coltrane, Coleman), through the music of Whiteness (e.g. Evans, Mehldau; see discussion of Whiteness in Brewster), to music particularly informed by meditative thought (Elling, The Necks, Hauser); and from the USA to Europe and Australia, intensity patterns have travelled with us. They too are nomadic. It would seem that intensity is one of the shared features that can underpin George Lewis’s dichotomous distinction between Afro- and Euro-logic amongst improvisers.

But in improvisation at large, within and outside music, not everything is quite an “infinite denouement,” as Mazzola (135) would have it. As we have argued previously,

> An important element in improvising is the balance between using procedural formulae and pre-existent material, and creating new material, new combinations of material, and new procedures. Improvisations are not entirely self-generating and most improvisers have a bank of “personal clichés” to which they resort. The newness of the improvisation depends on how wide a range of personal clichés the improvisor has, and the extent to which (s)he can recombine and transform these in performance. On the other hand, the improvisor is usually willing to use whatever materials are available: for example, environmental improvisors might use any aspect of the environment in which they work, and do not necessarily depend on prior knowledge or expectation of it. (Smith and Dean 29)

This is perhaps what Fischlin implies by nomadic mutation, and intensity patterns are one of the “procedural formulae” which underpin it in a seemingly transcultural way.

Thus we need to repeatedly query the meaning and status of individuality in improvisation, as in social interaction more broadly. As Fischlin says, “the individual exists not so much as a marker of domination and elevated status in musical improvisation but as a generator of new ideas in concert with others.” Peters goes further in querying the status of the individual, and of interaction and novelty, arguing that “the fundamental relationship is [. . .] between improvisor and improvisation, not between improvisor and improvisor” (3), an argument complementary to ideas raised by Dean in discussing formalist and structural aspects of improvised music in the context of its relative non-referentiality (*New Structures in Jazz and Improvised Music since 1960*, appendix). “At its best [improvisation] is by no means participatory but exclusive and excluding – collective, yes, communal, no” (Peters 58). Presenting analogies with scrap yard games, Peters also suggests that what is important is a “productive interpenetration of origination and re-novation as the new and the old are engaged with simultaneously” (2), concepts again highly consonant with the continuing re-novation of intensity profiles we have described. As he says, “the improvisatory exigency is no longer to outstrip the dead weight of what is there but to give it again [. . .] as if for the first time,” which can permit “the discovery of difference within the same” (5). For him “the ambivalence of improvisation *itself* [constitutes an] aesthetic space wherein the aporia of liberty is enacted and re-enacted.” Not only is liberty a logically impossible aporia, but for Derrida so is improvisation itself: “I believe in improvisation, and I fight for improvisation, but with the belief that it is impossible” (Dick and Kofman). In sum, the concept of improvisation and the role of individuality and interaction in it must always be queried and reconsidered, and nuanced to the events under discussion.

With this attempt at a balanced snapshot of the conflicted nature of improvisatory processes and their reception, we can return to our suggestion that improvisatory intensity profiles might contribute to social discourse. The most obvious aspect of such a contribution has been identified already: by providing a significant shared feature, acoustic intensity patterns may facilitate interaction between improvisors of otherwise non-congruent enthusiasms and equally their interaction in turn with their audience, involving the reception of some familiar structures, re-novated for this purpose. The theories of cross-cultural musical affect (e.g. Balkwill and Thompson; Balkwill, Thompson, and Matsunaga) make considerable play on the feature of intensity and its consistent use across cultures in affect generation, and this points to the fact that there is a future need for an investigation of intensity profiles in improvised musics other than those of the cultures we have studied here, diverse though they are. The expectation might reasonably be that such musics, for example, Indian classical music, will be found to share the patterning we describe; and so may performances in the Iranian story-improvising tradition, and other verbally-oriented improvisations (Smith and Dean 84-105). The logical projection here is that shared intensity profiles might enhance interpersonal interaction not only within communities that interact with Afro- and Euro-logic improvisation, but transculturally in an even broader way.

Besides providing a familiar if “re-novated” platform on which producers and listeners can construct their interpretation of improvised music, intensity profiles can clearly influence whether the music is perceived as arousing or disengaging, and this may influence the degree and way in which social exchange and effect is created by performance. It may be that the “collective ideation” of a performance “cannot be a product that remains alive after flow is gone” (where flow is a metaphorical description of some of the psychological states of improvisers during performance), as Mazzola and Cherlin argue (110). There may, however, be continuing impacts, at least in the short term. There are indeed empirical indications that performing together, particularly in synchrony, can enhance the social affiliation of individuals (Hove and Risen), and that aspects of a group performance can influence the degree to which group cohesion is perceived by others (Hagen and Bryant), both likely “glues” in the construction of community. Intensity patterns may act in part in a biological manner, perhaps even through the hormone oxytocin (Kosfeld et al.), memetically reflecting a confluence of evolutionary biology (the assessment of sonic information and its potential impact on the organism), cultural discourse, and social change. Paul Gilroy’s “intercultural and transnational formation that [he] call[s] the black Atlantic” (ix) can be seen as one axis of such processes, which operate at least to some degree trans-culturally. As he argues, “the black Atlantic [reveals] the instability and mutability of identities which are always unfinished, always being remade” (xi), and it is to this process which improvisation can contribute.

We want finally to suggest some ways that improvisatory discourse in social policy generation may operate with greater interpersonal equity than solely dialogic discourse. It is commonly conceived that dialogue involves all parties respecting and attending to the views of all others as well as their own (i.e. adopting a “sensory” stance); but improvised construction of policy could additionally commit all parties to developing the ideas of others in an equitable balance with their own, thus doing more than simply deferring their judgementality with respect to others’ ideas. This can be seen as an application of some of the more idealistic conceptions of improvisation discussed above, in which openness, equality, and innovation are stressed. While retaining a necessary critical distance from these ideals, we can nevertheless consider whether the intensity profiles we have been defining may have a bearing on these improvisatory policy generation processes. We suggest that the intensity patterns described above may well characterize prosody in routine as well as affective and performance speech processes, and this may be a transcultural phenomenon. If so, the use of prosodic intensity variation (probably of the kind we have described here) could contribute to the effectiveness of improvisatory argumentation and idea development during policy discourse. We know already that prosody can be used to convey affect with a fair degree of reliability, even when the spoken “words” or “sentences” do not make sense in any known language (Banse and Scherer). Thus it is plausible that intensity profiles in the performance of speech can also be glues that assist the transcultural transmission of verbal ideas, and hence social discourse at large. This proposal may provide an empirical opening into the assessment of the efficiency of communal idea development and social policy formation, akin to some of the implications of Jean-Luc Nancy’s concept of “listening” in discourse: “What secret is at stake when one truly *listens*, that is, when one tries to capture or surprise the sonority rather than the message? [. . .] If ‘to hear’ is to understand the sense, [. . .] to listen is to be straining towards a possible meaning, and consequently one that is not immediately accessible” (5-6). To listen and hear in this improviser’s way could also encourage the equitable development of ideas, whatever their provenance.

Notes

[i] Lewis indicates that these terms refer to "complementary" kinds of musical "logic." We can give here but a flavour of the subtle distinctions and fundamental issues he raises. A key feature of Afro-logic Lewis enunciates is "telling your own story," which in turn creates musical structure. In contrast, Euro-logic is suggested to prioritise "autonomous, often culturally ad hoc systems of specified musical behavior options," even when inviting improvisation. We refer to these characterisations in this paper primarily to suggest that the range of musical performances we have studied is quite broad, especially from a cultural perspective.

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