Expressivity as Time-Dependent Movement for Music Performance: A Statistical Exploration

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Abstract. In performance art, expressivity is a quintessential element in modeling the cognitive and affective interaction between artists and audiences. The expressive body movements of music performers are particularly revealing, due to their continuous, inherent synchrony with the development of the artistic object: the music. We combined functional data analysis of variance and principal component analysis to examine intra-individual consistencies in time and expressive intentions. The bell tip of a clarinet was vertically tracked across 1442 time-points, throughout 13 performances of Stravinsky's *Second Piece for Solo Clarinet*. The clarinetist played the segment in three different performance manners: immobile, standard, and exaggerated. The series of performances was repeated after six months. The statistical exploration revealed performance-gestural consistencies across the half-year interval and comprehensive movement strategies that distinguished expressive intentions. Our method is an important step towards understanding the role of expressive gestures in a multimodal musical framework.

Keywords: performance analysis, music psychology, expressive musical gestures.

1 Introduction

A music performance, when conceptualized as an interaction between performers and audiences, presents with a challenge of communicating both thoughts and emotions between the interlocutors, through the music produced by the instrumentalist. In this multimodal context, the performer necessarily moves to manipulate the musical instrument into producing sound. This provides a continuously changing platform onto which he or she may reflect expressive intent by crafting a *body language* [1] of *ancillary gestures* and *expressive movements* [2].

The visual channel has a significantly impact on the tension conveyed by a performer to an audience, particularly at pivotal points in the score [3]. Although expressive gestures are not essential for playing accurately [4; 5], musicians' movements are common in music performance practices and may form an integral part of highly-skilled musical performances that elicit strong admiration in the audience. This may, in turn, aid in performer's communicating both the conceptual and affective interpretations of the musical score.

Employing analytical tools that avoid the reduction of continuous signals into discrete experimental observations is particularly relevant to music responses, given that structural musical elements are manifested, perceived and integrated over time. In the present study, we focused on movement data in order to discover gesture strategies that are intrinsically continuous. We aimed to develop regression and data reduction techniques to explore the variation of ancillary gestures across expressive intentions and long-term periods of time. We expected that these methods would reveal expressive movement trends that are consistent in time.

2 Method

An expert clarinet performer participated in the study and was compensated for playing Stravinsky's *Second Piece for Solo Clarinet* in three major experimental conditions. The participant thus followed three different instructions, which were aimed at eliciting different expressive intentions through movement gestures: with restrained body movement (the *immobile manner*), in a standard performance style (the *standard manner*), and with intentional expressivity through exaggerated movement (the *exaggerated manner*). Data was collected in two major experimental sessions separated by a six-months interval. In total, 13 performances were recorded in *session A* (immobile 1, standard 1, 2, 3, exaggerated 1 and 2) and session B (immobile 1, standard 1, 2, 3, 4, exaggerated 1 and 2), including an additional warm-up performance in the latter. Optotrak 3020 Motion Capture sensors were placed on the head, shoulder, elbow, hip and knee of the performer body and the mouthpiece and bell of the clarinet. The x, y, and z coordinates for each active, infra-red marker were recorded at a rate of 1 data point per millisecond.

This data was collected as part of a larger project, which included several performers who displayed intra-individual consistencies across performances in one session, and two major trends of associating ancillary gestures with equal-duration note clusters and phrasing, respectively [6]. The current study aimed to focus on consistencies across several months, and expand upon qualitative analyses [7] to statistically explore intrinsic sources of long-term variation in expressive ancillary gestures.

3 Analysis

3.1 Preliminary Data Processing

A total of thirteen performance observations were obtained – 6 in session A (standard 1, 2, 3, immobile, exaggerated 1, and 2) and 7 in session B (standard 1, 2, 3, and 4, immobile, exaggerated 1, and 2). The vertical position of the tip of the clarinet bell was retained for the current analysis, as this is the dimension most indicative of the performer's overall movement pattern. The data was registered with respect to the mean overall center bell position for each recording, to eliminate inter-participant variability on height.

The sections selected for analysis spanned the first two staff lines of the Stravinsky score. The observations were time warped, to permit comparisons across performances, as well as analyses of the movement patterns that were not attributable to the performance speed. This was done according to 14 time points which were independently identified in the score, based on their importance in the phrasing structure and their perceptual salience (in essence, these time points were assumed to mark congruent musical events across observations). The final observations measured 1442 time points in length (1 time-point per millisecond) and the index time point was referenced to t = 0 seconds. The data was not scaled, to maximize accuracy in assessing the amplitude variability in movement peaks and troughs.

Using functional data analysis techniques [8], each performance observation was modeled with 150 B-spline functions of order 4. In comparison to the original framework of 1442 points, this model sufficiently accounted for the continuity in the data, rendered the basic units of analysis more computable, allowed for more degrees of freedom in statistical analyses and avoided the stationarity assumption; the framework was thus particularly suited to analyse the sources of variation in gestures that may be an integral part of continuous musical communication. The following analyses were thus employed on these modeled continuous observations.

3.2 Descriptive Analysis

Figure 1 illustrates the thirteen performance observations, their mean and the standard deviation.

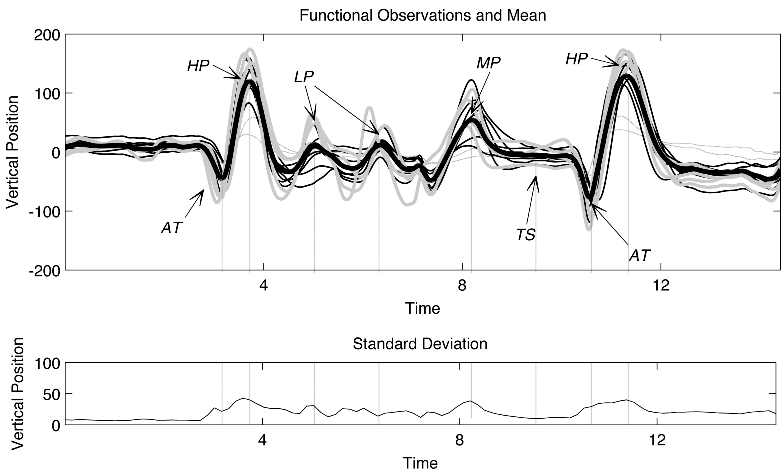

Fig. 1. The 13 performances as a function of time. The grand mean (*thick solid black curve*), the immobile (*dotted thin curve*), the standard (*black solid thin curve*) and the expressive (*solid grey curve, upper*) performance manners (*upper*), and the standard deviation (*lower*). Time (seconds) on the abscissa and the clarinet bell tip height on the coordinate.

We identified five types of movement shapes to index the major gestural structure of the piece and provide a platform for interpreting the main contributors to the variance in the movement. As illustrated in Figure 1, these were *high peaks (HP)* (t = 3.7 s; 11.3 s) preceded by *anticipatory troughs (AT)* (t = 3.2 s; 10.6 s), *medium height peaks (MP)* (t = 8.2 s), *low peaks (LP)* (t = 5 s; 6.4 s) and *transition sections (TS)* (t between 9 and 10 seconds).

Further analyses were concerned with *intentional* movement patterns (e.g. performed beyond those necessary for maneuvering the musical instrument in producing music). Thus, the immobile observation was thereby subtracted from the standard and exaggerated performances for statistical exploration.

3.3 Analysis of Variance

Analysis of variance (ANOVA) was performed on the functional observations, in order to investigate local (short-span) effects of session and performance manner. Based on the computed regression functions, the continuous F-ratio was obtained across the performance time duration (see Figure 2). To avoid capitalization on chance, we considered time regions that spanned at least 500 data points (i.e. milliseconds) and crossed the 5% critical significance level.

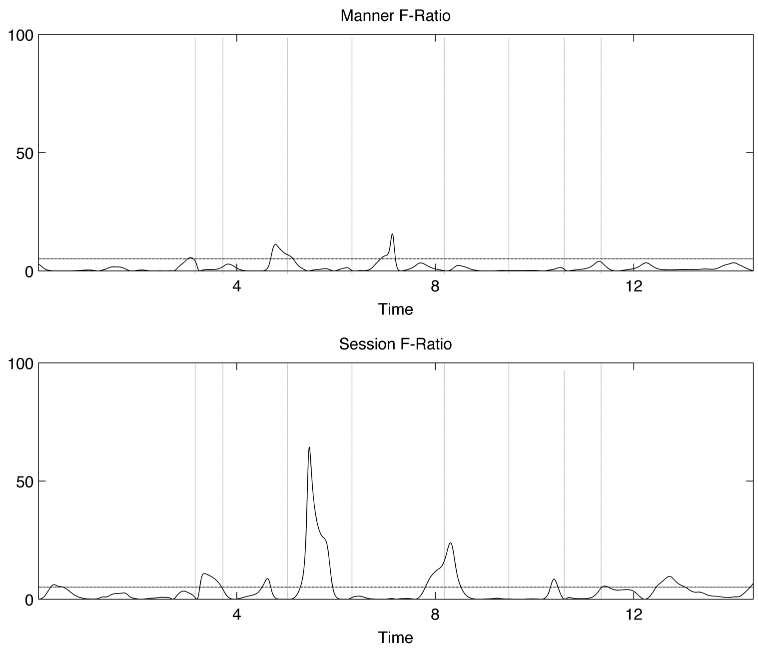

Fig. 2. The main effect F-ratio for the manner (upper) and session (lower) in the analysis of variance. The critical significance is indexed horizontally at the 5% significance level.

Session effects were observed at the time sections centered at around t=3.5, 5.5, 8.3 and 10.4 seconds. These mark a change in the phase of both trough-peak cycles and end of the section of low peaks. Main effects of manner were centered at t=3, 5, and 7 seconds. These marked amplitude changes (lowering) of the first trough, as well as amplitude changes at low peaks, enhancing position fluctuations between the major peaks. In a two-way ANOVA, these main effects were replicated, in addition to an interaction effect showing a marked F-ratio peak centered at t=7.4, which indexes the end of the first trough-high peak cycle and beginning of the low peak fluctuations. This indicated a difference in the relative height of finishing the first high peak and starting the section of low peaks.

3.4 Principal Components Analysis

3.4.1 Sessions A and B

Principal components analysis was performed on the spline function coefficients of the functional observations, separated by manner of performance and by session.

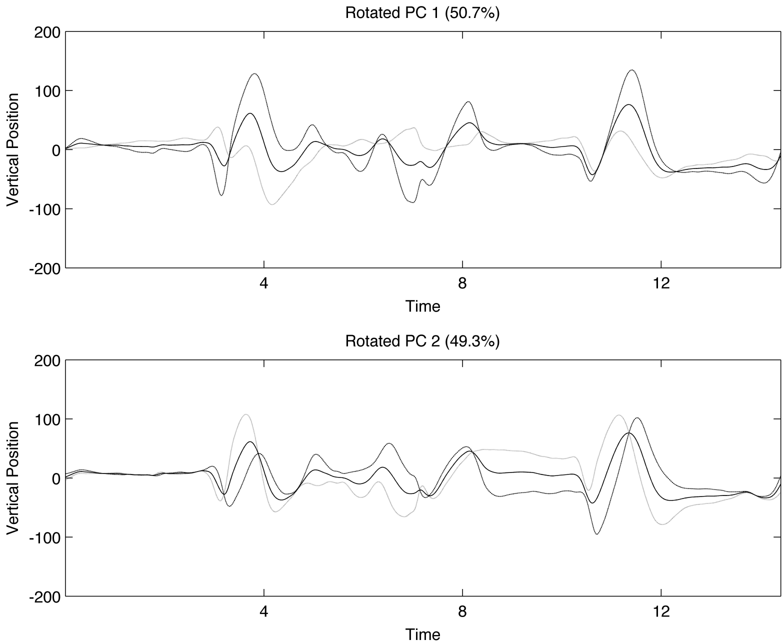

Fig. 3. The results of the PCA performed on the Session A functional observations for the first harmonic (*upper plot*) and the second harmonic (*lower plot*), after Varimax rotation. The effects of adding (*broken curve*) or subtracting (*dotted curve*) each PC to the mean.

In Session A, the PCA was performed on a total of five functional observations (standard 1, 2, 3, exaggerated 1 and 2). The procedure revealed four prominent eigenvectors, their corresponding harmonics accounting for 48.2%, 30.2%, 13.1%, and 8.5% of variance, respectively.

The fPCA on the six observations in Session B (standard 1, 2, 3, 4, exaggerated 1 and 2) revealed five major harmonics, accounting for 37.2%, 26.2%, 20.5%, and

9.5%, respectively. To maximize both data reduction and exploratory interpretability, the first two principal components (PC) were retained from both session groups and subjected to Varimax rotation procedures. The effect of adding and subtracting each rotated component from the mean was analysed at main position indexes with respect to amplitude and phase variation not taken out by the time-warp registration process.

Thus, as illustrated in Figure 3, in Session A, the first rotated PC accounted for 50.7% of the variance, reflecting changes in the amplitude at *LP and HP*, the amplitude at the first *AT* and the phase at *MP*. The second rotated PC accounted for 49.3% and revealed changes in phase at *HP*, amplitude at *LP* and TS.

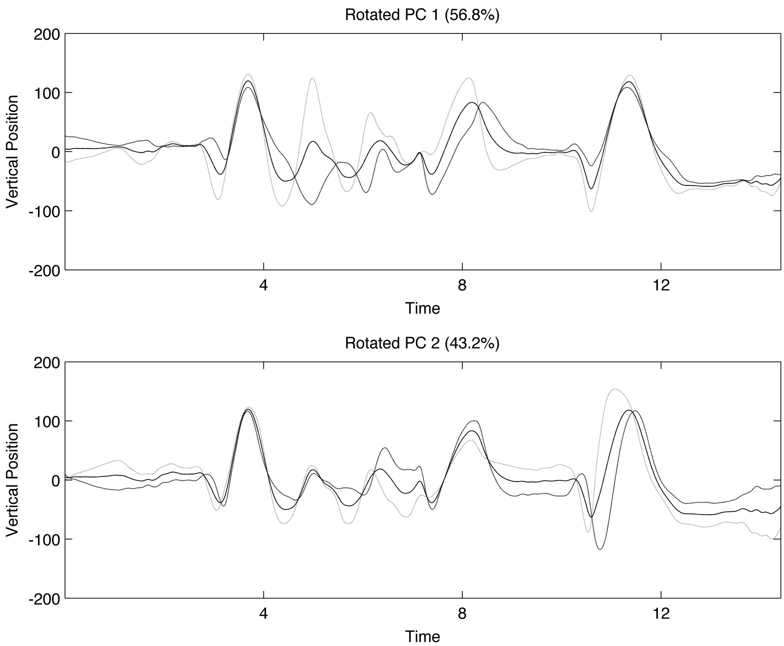

Fig. 4. The results of the PCA performed on the Session B for the first harmonic (*upper plot*) and the second harmonic (*lower plot*), after Varimax rotation. The effects of adding (*broken curve*) or subtracting (*dotted curve*) each PC to the mean.

In session B (see Figure 4), the first rotated PC accounted for 56.8% of the variance and reflected influences in amplitude at *LP*, and both *AT*, and phase at *MP*. The second PC (43.2%) marked phasing at second HP, amplitude at LP and TS.

3.4.2 Performance Manners Standard and Exaggerated

In the Standard Manner group, the fPCA was performed on a total of seven functional observations (standard 1, 2, 3 in session A and standard 1, 2, 3, 4 in session B). Six prominent eigenvectors were elicited, their corresponding harmonics accounting for

47.2%, 25.8%, 10.9%, 7.8%, 4.7% and 3.6%, respectively. The four observations in the Exaggerated Manner group (exaggerated 1, 2 in both sessions) were reduced to three major harmonics, which accounted for 47.8%, 38.3% and 13.8%, respectively. Varimax rotation was applied to the first two principal components in both performance manner groups. The effect of these components was explored in terms of the amplitude and phase influences at the main position indexes (see Figures 5 and 6).

Among the Exaggerated performance observations (see Figure 5), the first rotated principal component accounted for marked phase changes at *high peaks* (*HP)* and *anticipatory troughs (AT)*, phase and amplitude influences at *low peaks* (*LP*) effectively increasing the frequency of oscillating movement patterns, and amplitude changes at the *transition section* (*TS*). The second principal component represented variability with respect to the amplitude of all peak types, both troughs and the end section (*HP, MP, LP, AT*), as well as a marked trend in multiplying the low and medium position oscillations to obtain highly fluctuating movements.

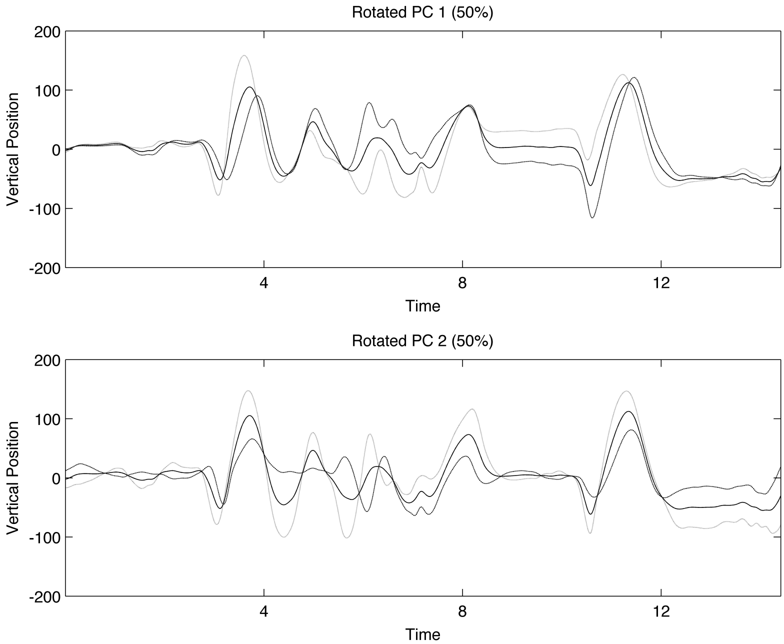

Fig. 5. The results of the PCA performed on the exaggerated manner for the first harmonic (*upper plot*) and the second harmonic (*lower plot*), after Varimax rotation. The effects of adding (*broken curve*) or subtracting (*dotted curve*) each PC to the mean.

In the Standard performances (see Figure 6), the first rotated PC encompassed an emphasis on the amplitude of all peaks and end section. The second PC accounted for the phasing of HP and AT, the amplitude of both medium and low peaks (MP, LP) and TS.

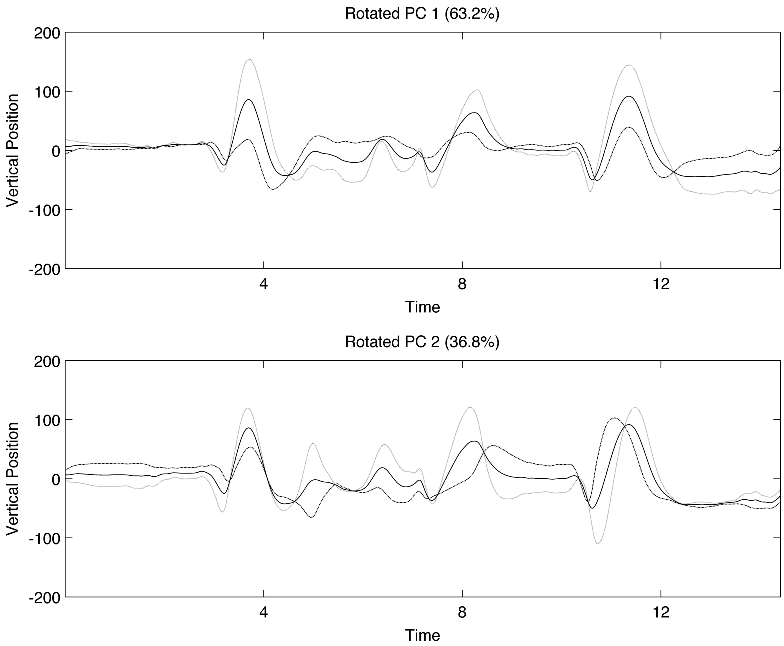

Fig. 6. The results of the PCA performed on the standard manner for the first harmonic (*upper plot*) and the second harmonic (*lower plot*), after Varimax rotation. The effects of adding (*broken curve*) or subtracting (*dotted curve*) each PC to the mean.

4 Discussion and Conclusion

The present analysis aimed at faithfully modeling the continuity of movements across time and revealed interesting short-span and global differences in the role of expressive intentions and session. The analysis of variance revealed short-span, local differences in the gestural movement of the clarinetist. The session differences were mainly related to phasing differences across performances, implying possible refinement of the performer's ability to closely associate his expressive movements to the music. On the other hand, the manner effects showed marked amplitude differences across peaks and troughs, resulting in an overall increase in the height fluctuation across performances. This was mirrored in increasing the height differences between low and high trough and peaks, as well as doubling of troughs (e.g. at t=14.5 and 15 seconds). This suggests stylistic differences between performance manners, characterized by enhancing movement throughout successive musical events in the service of gestural expressivity.

Marked differences in global movement strategies were revealed by the functional principal components analysis. After Varimax rotation, 70% to 80% of the total movement variance was described by two principal components that accounted for similar patterns of variability across the two sessions. The similarity was exemplified by a gestural approach of emphasizing low-to-high fluctuations and phasing medium peaks. The second consistent movement trend concerned the phasing of highest movement peaks joined by an amplitude modulation of medium-height gestures. This suggests a consistent trend to maintain a balance by complementing phase with amplitude variation across different gestures.

When comparing the two performance manners, however, their variance was accounted by two principal components characterizing global patterns that were markedly different between standard and exaggerated condition groups. One of the marked dissimilarities was the increase in the frequency of oscillations in the exaggerated manner, that were achieved at different gesture patterns by both of the two gestural component patterns. These were also combined, in the first and second component, with an attenuation and an increase, respectively, of the medium peak amplitude, thereby achieving higher consistency phasing consistency. These patterns were thus complex, showing combinations of phase and amplitude variability patterns at different sections of the piece.

This suggests that, in comparison with the differences across performance sessions separated by several months, the expressivity intentions are more revealing of the complex movement architecture that are continuously crafted by the music performer. Expressive musical gestures are, thus, a durable indicator of the performer's stylistic intentions (reflecting his or her cognitive and affective interpretation of the score) and are an integral element of the ongoing music, rather than a parallel, complementary behaviour reflecting additional cues of momentary disposition, or embellishments to performance demands.

In our aim to understand the sources of variation in ancillary gestures, we have shown that they remain ingrained in the performance, even after several months. To our knowledge, this is the first investigation of music performance gestures that is focused on modeling the functional continuity of the movement to reveal both local and global strategies under the influence of temporal, session effects and expressive intentions. This work is important for supporting the essential role of performance gesture as indicative of expressed emotion in music, representing an inherent structural element in the music production.

5 References

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