The reciprocity between ancillary gesture and music structure performed by expert musicians

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ABSTRACT

During the musical performance, expert musicians consciously manipulate acoustical parameters expressing their interpretative choices. Also, players make physical motions and, in many cases, these gestures are related to the musicians' artistic intentions. However, it's not clear if the sound manipulation reflects in physical motions.

The understanding of the musical structure of the work being performed in its many levels may impact the projection of artistic intentions, and performers alter it in micro and macro-sections, such as in musical motifs, phrases and sessions. Therefore, this paper investigates the *timing* manipulation and how such variations may reflect in physical gestures.

The study involved musicians (flute, clarinet, and bassoon players) performing a unison excerpt by G. Rossini. We analyzed the relationship between *timing* variation (the Inter Onsets Interval deviations) and physical motion based on the traveled distance of the flute under different conditions. The flutists were asked to play the musical excerpt in three experimental conditions: (1) playing solo and playing in duets with previous recordings by other instrumentalists, (2) clarinetist and (3) bassoonist.

The finding suggests that: 1) the movements, which seem to be related to the sense of pulse, are recurrent and stable, 2) the *timing* variability in micro or macro sections reflects in gestures' amplitude performed by flutists.

Author Keywords

Music practice, expressive intention, ancillary gestures, timing manipulation, flute.

CCS Concepts

•Information systems → Music retrieval; •Applied computing → *Performing arts;* Sound and music computing;

1. INTRODUCTION

Music performance involves musicians manipulating sound and physical motion aiming at expressing their interpretative intentions. Performance planning and practicing include adjusting acoustic parameters such as duration (rhythmic figurations and groupings), dynamics (changes loudness and softness), intonation, sound color, and note articulation, and consequently, these modifications are methods with which musicians convey their musical intentions [8, 12, 13]. By changing parameters of sound, a performer can completely alter the performance of a musical piece through the way it is expressed [7, 20]. Researchers have tended to focus on methods that describe the expressive intentions in music performance, by analysing the manipulation of sound [19, 7, 21], considering the deviation in sound parameters. A review of the literature on this topic shows that *timing* variation is an useful parameter to approach the music expressiveness [19, 14, 5]. Therefore, we opted to study the *timing* variability due to its notoriety in the overall perception of expressiveness.

According to [23], there are two essential principles for communicating musical structure: (1) differentiation of pitch and duration; (2) grouping of notes in phrasing, metrical units, or harmonic areas. In other words, the author explains that the perception is enhanced by increasing the difference between categories, such as stretching notes or playing short notes even shorter (duration contrast), beyond the variation of the sound's energy as changing dynamics of the sound.

The *timing* deviation includes horizontal and vertical relations between sounds. The vertical *timing* variations affect the degree of synchronization of audio in separated parts within the ensemble texture. Meanwhile, the horizontal connections concern the *timing* of successive sounds within each voice or instrumental part. Both aspects modify the harmonic and melodic music features, but, in this study, we only focused on *timing* deviation in a simple melodic line. A standard mode of horizontal deviation requires intentionally varying the length of metric inter-beat intervals to produce systematic modulations in local tempo [8].

Although the *timing* deviation invariably occurs, it is not produced randomly nor just as a sound effect. The horizontal *timing* variations are exceptionally consistent across performances of a piece by the same musician [22, 28], and performers who interpret music quite differently might produce similar patterns of *timing* and dynamics [19].

In the literature many works [27, 26, 24, 4, 17, 16, 3, 10, 20] have demonstrated that body movements, other than being essential to sound production on the instrument, in many cases, ancillary gestures are also closely related to the performers' artistic intentions. According to [18], the study of gesture in music is an important area of research that raises many issues about perception, performance, and emotional communication. The authors point out that movements are part of performance but not necessarily produce sound. Ancillary gestures have been recognized essential to the instrumentalist's performance, considering that some of them are stable and reproducible, even after extended periods. Therefore, the repeatable movement patterns might

NIME'19, June 3-6, 2019, Federal University of Rio Grande do Sul, Porto Alegre, Brazil.

have a communicative function in enhancing the perceivers' experience of the sound's phrasing [11], being intimately connected to the structure of the music.

Studies in psycholinguists point to gestures in speakers come about as a by-product of changes in speech [9], and we hypothesise that gestures can express the way which performers understand and convey the musical structure. According to [15], the concept of music *embodiment* is a process in which the human body is a mediator between the musical mind and the physical environment, and the gestures would be the way in which the body extends itself in space and time. The researcher explains that gestures are part of synchronisation and entrainment of the body and the meaning of the emotional engagement as well as deliberate actions.

More recently, scholars have been researching the relationship between physical motion and interpretation choices of music's structure [24, 20], aiming at investigating the ancillary gestures and musical phrase organisation. In [10], cellists were asked to play two versions of a musical excerpt, with shorts and long melodic groupings specified, and although the performer's heads move more frequently when they play shorts groupings compared to long units grouping, the motion modified across different sections of the excerpt.

Here we want to examine the connection between ancillary motion and interpretative choices, during a musical performance. Importantly, our approach considers the artistic choices by musicians and how instrumentalists adapt a musical situation as ensemble practice. Therefore, we designed an experiment in which involved expert flutists playing a musical excerpt in three different conditions: (1) playing solo and playing in duets with previous recordings by other instrumentalists, (2) clarinetist and (3) bassoonist. These recordings were performed by musicians who manipulated the *timing* by their own interpretative choices, and consequently, each one expressed his/her musical idea organisation. Importantly, our work focus on how flute players performed the musical excerpt while they were asked to play in different *timing* variation. In other words, we analysed the physical motion and *timing* deviations interpreted by flutists during three experimental conditions. It is important to note that these are data from an earlier study developed in my Ph.D. dissertation, but this paper only focuses on a part of the study with an incremental discussion.

We believe that analysing modifications in the musical phrases and physical gestures can be a strategy to understand how performers communicate the musical structure.

2. DATA COLLECTION

We collected the acoustical and physical data as part of this study intending at investigating the relation between sound manipulation and bodily/instrumentally motion, during a music performance. In this section, we will provide comprehensive details about the experimental methodology.

2.1 Participants, Material and Equipment

We recruited six expert musicians, four flutists, one clarinetist, and one bassoonist, all of them having at least 30 years of musical training. Other observations indicate that experienced performers acquire ability throughout the years to achieve high goals without the need for spurious gestures. Also, the level of difficulty and demands for a certain level of excellence usually creates a need for more movement from the performer, especially for beginners.

The design of the experiment was based on sound and motion manipulation performed by musicians in a musical interpretation. Therefore, instrumentalists were asked to play four times the excerpt in solo condition, and after that, just flutists were invited to perform in duets with the previous recordings of clarinet and bassoon. For reference, a metronome produced a steady tempo at 67 bpm (beats per minute) before each take. The resulting included a total of 48 takes: 16 solo takes, and 32 takes in duet.

We used a musical excerpt which was extracted from the second movement of Wind Quartet No. 2, in G Major for flute, clarinet, bassoon, and horn by Gioachino Rossini. For our experiment, we adapted the score to two duets, flute with clarinet and flute with bassoon (figure 1). Having a unison performance enabled us to present a real performance situation that requires musicians to adjust to the partner at each note.

Figure 1: Excerpt for flute, clarinet and bassoon parts extracted from the second movement of Wind Quartet No. 2, in G Major by G. Rossini.

The audio was captured by an omnidirectional microphone (M-Audio Solaris) at a sampling rate of 44.1 kHz. The microphone was located approximately 1 to 1.5 meters from the source, given that musicians could move during their performances. The physical motion was recorded with the NDI Optotrak Certus motion capture device, at a sampling rate of 100 frames per second. Markers were positioned on musicians' body and instrument. The cameras were placed vertically, 3 meters away from the musicians. Figure 2 shows the data acquisition setup and the adopted coordinate system: x-axis as lateral displacement, y-axis as height, and z-axis as depth. A clapper-board was used in order to synchronize audio and movement data.

2.2 Procedure

The study procedure had two main sessions: the solo session and the duets session. At the beginning of the study, all of the participants were asked to play the excerpt with his/her interpretative intentions, four times. That is, musicians performed as if in a real practice situation, in which they should play their artistic choices featuring the solo session.

Afterward, the clarinetist and bassoonist were requested to indicate the preferred recordings to be followed by flutists in duets session. In this session, the flute players were asked to accompany both tapes in the best way they could, adjusting their playing to the ensemble partner's interpretation. In addition, flutists performed with a headphone in one ear listening to, separately, the clarinet and the bassoon performances, more four times each. Audio-Technica ATH-M50 headphones were used in only one ear, leaving the other

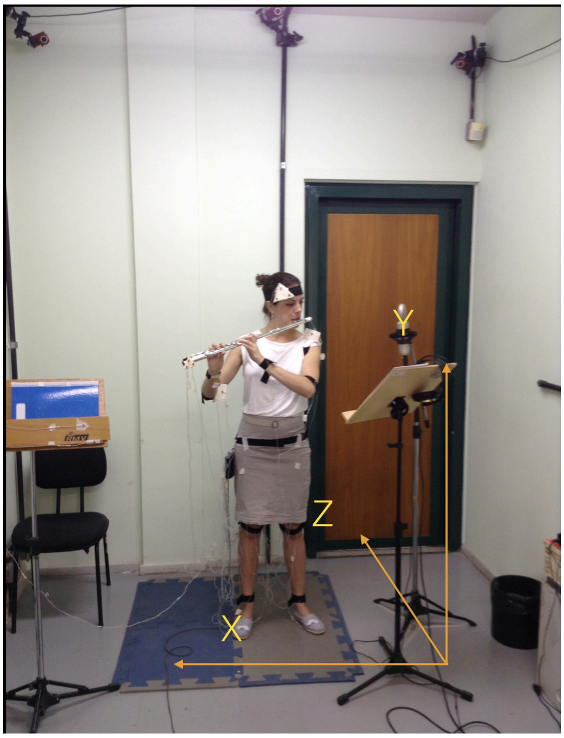

Figure 2: Data acquisition setup, from the motion capture tracker viewpoint.

ear free for the flutist to listen to his/her sound, creating a semi-closed situation. Through the use of headphone, we were able to record each instrument independently.

Finally, additional self-reports were performed on with flutists about his/her phrase grouping and sound manipulation during their performance. The interviews aiming at supporting possible correspondence between the interpretative choices identified during the analysis.

3. ANALYSIS

We were interested in assessing the flutists' interpretative choices playing in solo and duets condition, especially the *timing* variability and how such variations may reflect in physical movement. From the data collected, we analysed the relation between *timing* manipulation and motion, comparing the traveled distance of the foot joints flute and the Inter Onsets Intervals (IOI) deviations during the three experimental conditions.

In order to analyse the audio data, we segmented it into musical notes, and this process was accomplished semi- automatically with the use of EXPAN. This tool was developed at CEGeME (Center for Research on Gesture, Music & Expression) for musical expressiveness analysis [1], which combines pitch and amplitude values to detect note onset/offset, end of attack, and beginning of release. A Sonic Visualizer plugin [2] developed within the EXPAN toolbox was also used for possible inspection and adjustment of the segmentation parameters.

To assess the *timing* variation, the sound descriptor IOI (Inter-Onsets-Intervals) was used. This method measures the variation of the length of metric inter-beat intervals and features systematic modulations in local tempo. Therefore, one possible way to analyse the *timing* variability is to investigate the change of IOI.

The inter-onsets-intervals are based on the note onsets obtained from the audio signals, and in this study, the IOI's are normalised to the quarter-note. The *timing* variability feature, by flutist 1 as example, can be seen in the figures 3, in which the deviation from the line indicates the note duration manipulated by musician. In order to inspect the differences in participants, we also measured the time duration as well as the *timing* variation in clarinetist and bassoonist performances.

To investigate the physical motion, we analysed the movement from markers positioned on the flute. Previous studies have shown that the instrument's motion is a meaningful indicator of artistic gestures performed by musicians [26, **?**, 4, 24]. Therefore, in this study, flute's markers are used as input data of mapping the ancillary gestures.

To analyse the evolution of the flute tridimensional motion, we measured the traveled distance by foot joint's flute across four takes in each experimental conditions. First, we estimated the value of Euclidean distance, given that it measures the positions of the markers in two subsequent samples. Following this, we sum the total amount of range. We opted for this unidimensional parameter because it captures a significant amount of information from the musicians' movement.

Further, we examined the vertical motion of the flute during the musicians' performance. Having the vertical gesture allowed us to investigate the possible relationship between movement and tempo, given that we can determine the note onsets of the acoustical signal.

4. RESULTS

In this section, we point to the profile of *timing* manipulation and physical motion performed by flute players. To do so, we inspected the possible patterns during three experimental conditions which flutists were asked to perform: (1) playing solo, (2) performing in duet with a previous recording of the clarinet, (3) playing, also in duet with the bassoon's recording.

Our data suggest that the local tempo is unique, given that musicians, invariably, adjust it during their performances. In other words, the tempo is continuously modulated given the asymmetric distribution of IOI durations caused by *accelerandi* and *ritardandi* at musical structural boundaries. However, the stability of *timing* profile could be assessed across the repeated performances, as well as the mean global tempo performed by musicians may characterize the individual *timing* manipulation.

Comparing instrumentalists performances based on duration in seconds, we assess a difference between clarinetist and bassoonist performances. Changes in time duration were identified pointing to 14.12 seconds and 13.12 seconds in which the clarinet and bassoon players, respectively. However, the *timing* profile shows a significant manipulation over the note duration, indicating that bassoonist and clarinetist intentionally alter the *timing* in 1) macro-sections and 2) micro-sections, respectively.

These results showed that the clarinetist played a *ritardandi* at the last bar (micro-section) while bassoonist manipulated the *timing* deviation during the excerpt (macro-section).

In other words, the performance by clarinet player is extreme enough to sound like real tempo changes between bars 3 and 4, featuring a final *cadential.* In opposition, the bassoonist tends to respond to this musical structure by distributing the *cadential ritardandi* over the entire phrase, taking progressively more time for each bar.

We now consider the motion features and generally speaking, the results showed there are more movement when the flutists played in duet with the clarinet than when they were playing in solo condition. Also, the numbers point to the decreasing or maintaining of movement's amount when flute players are playing in duet with the bassoon, table 1. Importantly, the flutist 3 was the only exception, and we used her self-report to discuss this finding. More details in the next section.

The relationship between physical motion and sense of tempo maintaining was analysed by using the vertical movement. The flute's gestures highlighted the impact of rhythm patterns based on motion features and the pulse of notes.

5. DISCUSSION

We know from previous works that performance planning and practicing includes musicians, consciously, manipulating acoustical parameters and making decisions for grouping notes into phrases and emphasizing harmonic and rhythmic features [6, 8]. Both principles are not necessarily independent, and these changes influence how the musical structure is intentionally expressed. As far as we are aware that players make physical gestures during their performances [4, 24, 28], and ancillary gestures are associated with the musicians' interpretative intentions [26, 20].

Our study with flute players shows that the motion's quantity, performed by them, varies when they were submitted to play in different *timing* variation: (1) playing in duet with an instrumentalist performing a *timing* manipulation in a short time interval, featuring a tempo changes and (2) performing in duet with a musician, who tends to distribute the *timing* variation in an extended time period.

We hypothesize that when flutists were asked to play a *ritardandi* in a micro-section, the instrument's motion increased indicating the decrease in the tempo. It may be assumed that flutists tended to adjust the apparent tempo changes and it was reflected in gestures. In addition, there is evidence to suggest that musicians tended to make continual gestures when they played with stable *timing* variation duet. In other words, flute players decreased or maintained motion when they were compared between playing solo and playing in duet with the bassoonist, considering that both interpretations show similarities in performed *timing* intentions profile.

According to [14], phrase entries and endings present distinct challenges for ensemble coordination. The synchronisation at phrase endings is a hard task because tempo may decrease, depending on the performers' artistic intentions, once phrase boundaries are approached [19]. Phrase boundaries often coincide with structural boundaries that refer to "points of change". These points are characterised by intense communicative interaction to produce a qualitative change in the "feel" of the music, reflecting in hierarchical relations and the boundaries of musical ideas [25].

Interestingly, previous works have shown that the vertical movement may help the musician to keep track of the tempo, and serve as a signal to other performers, dancers, or listeners [11]. Also, the continual movement might be necessary to keep rhythmical features related to both performances and perception intact, and a common manifestation of constant motion occurs when a person taps his foot or move his instrument. In other words, it makes sense that motion is the maintainer and the communicator of the pulse. Although such gestures vary considerably between instrumentalists and performance styles, they may be thought of as necessary for the *timing* in performance [28].

The resulting vertical movement is able to indicate the relationship between physical motion and sense of tempo maintaining. The flute's gestures highlighted the impact of tempo, considering that the figure 4 points to motion features based on the onsets of notes. It reveals that the rhythm feature has a significant effect on musicians gestures.

As reported in the *Results*, the flutist 3 was an exception, considering that she made large gestures in duet conditions, independently which was the instrumentalist. When questioned during self-report, she related about her principal flute position in the orchestra and revealed that she is directly affected by the conductor requiring "precision" during the performance. In her opinion, the term is reflected in physical gestures which conduct the tempo "in an ensemble performance, I need to move myself to express the tempo for others". This factor may be responsible for the flute player 3 has performed distinctive gestures in both duets than in solo interpretations, making sense with her report about motion as the transmitter of tempo.

6. CONCLUSIONS

We addressed whether the *timing* manipulation performed by musicians may reflect in physical gestures during their interpretations. The fact that we used an experiment involving musicians performing solo and in different duets reinforces the argument that the sound manipulation communicates the individual interpretative intention. The results of *timing* deviation show that each performer emerges an important idiosyncratic ability. Also, the variability of *timing* seems reflected in the continual motion of the pulse and gesture's amplitude, considering that these movements are recurrent in all experimental conditions, inferring the singularity in each interpretation.

Although there is a limitation due to the small population observed, we examined each flutist separately as an essential factor in determining individual sound and gesture manipulation. Furthermore, we compared the three conditions (playing solo, playing in duet with clarinet, and with bassoon) and verified how each flute player adjusted their sound and motion.

Our findings so far have been very encouraging to show that ancillary gestures can facilitate the expression of music corroborating with previous results. Also, our study is in line with the idea that physical motions can be so-called phrasing gestures since it is closely connected to musical phrasing [11]. Besides, ancillary gestures are an integral part of the musicians' performance as well as they are stable and reproducible in various performances. Our work has led us to conclude that these motions have a communicative function in enhancing the perceivers' experience of musical phrasing.

In summary, our work points to an interrelationship between sound and gesture manipulation related to interpretative intentions. Finally, we did not intend to conclude that *timing* variation increase or decrease motion amount, but that sound manipulation may reflect in physical motion. Therefore, future works will concentrate on gestures as a method to study human cognition as well as to investigate the process of musical thinking.

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Table 1: The measurement of the distance of foot joint's flute performed by flutists

Players	Experimental Conditions	Average travel distance of foot joint's flute [m]	difference
Flutist 1	Playing solo	2.010	
	Playing in duet with clarinet	2.290	+14%
	Playing in duet with bassoon	2.068	+3%
Flutist 2	Playing solo	1.367	
	Playing in duet with clarinet	1.615	+18%
	Playing in duet with bassoon	1.119	-18%
Flutist 3	Playing solo	1.093	
	Playing in duet with clarinet	1.201	+10%
	Playing in duet with bassoon	1.270	+16%
Flutist 4	Playing solo	1.116	
	Playing in duet with clarinet	1.273	+14%
	Playing in duet with bassoon	810	-27%

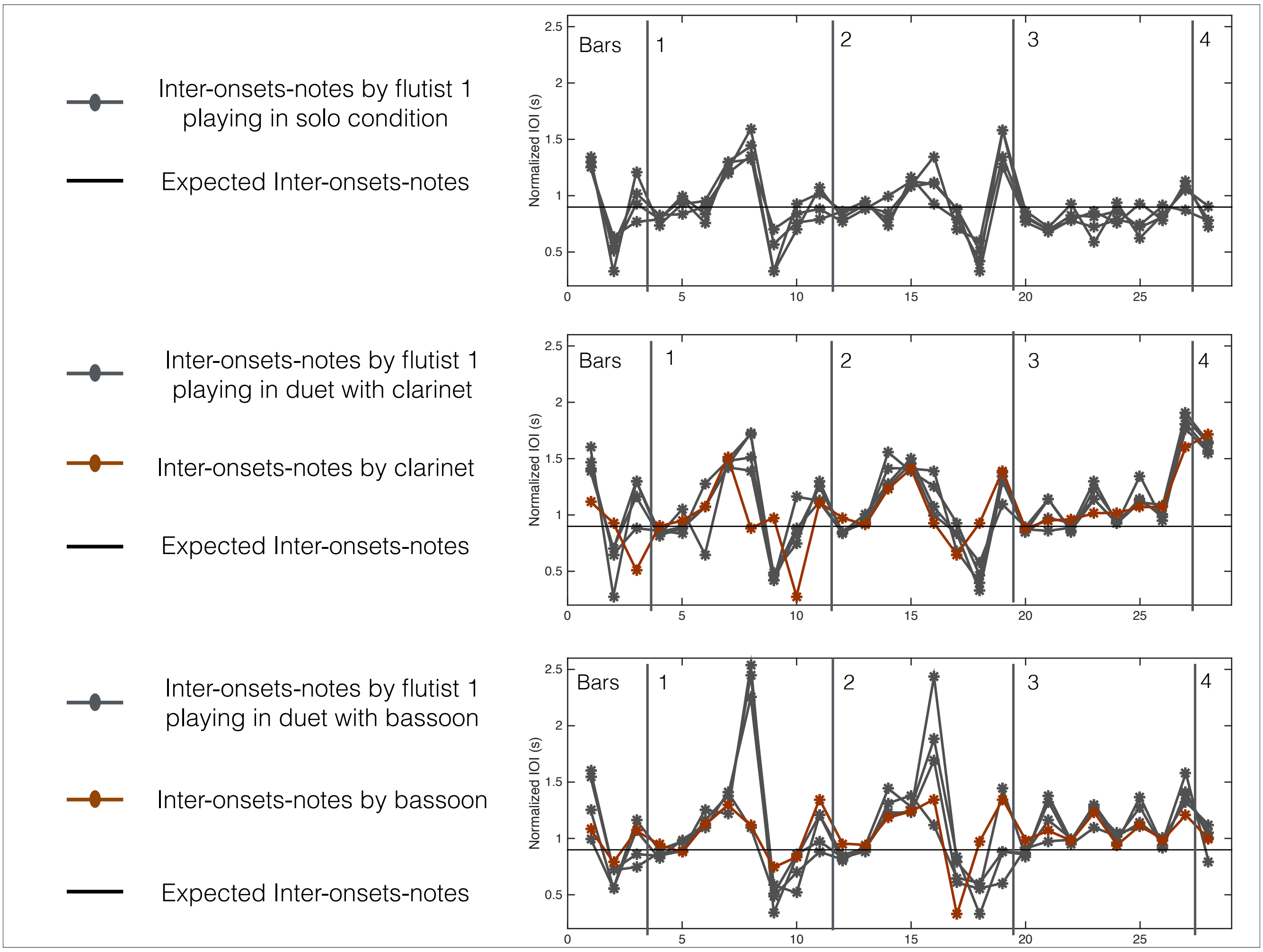

Figure 3: ***Timing*** **deviation features. The panels show the IOI values performed by flutist 1 during different experimental conditions.In all panels, the solid lines show the expected IOI**

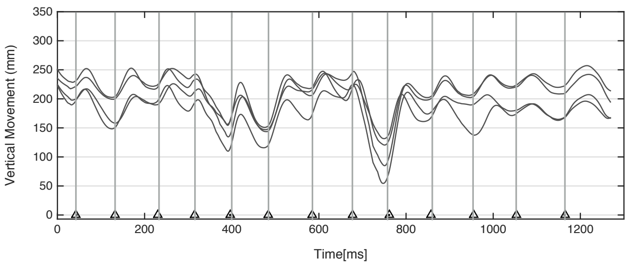

Figure 4: Time warped comparison of vertical movement of the flute for four performances by flutist 4.

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