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Performing in concert and in rehearsal: a comparison using audio, video and movement data

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ABSTRACT

As a musician it is clear that a concert performance involves a specific engagement. Both the physical attitude and the musical expression change through the interaction with the public. However, the mechanisms involved in this interaction are not well documented.
To study the influence of the public on performance, a concert with a singer and a viola da gamba player was recorded using audio, video and acceleration sensors (invisibly) attached to wrists and back of the performers. These data were compared to the general rehearsal, recorded in identical settings. This enables a scientifically valid comparison, without challenging the ecological validity.
General rehearsal and concert performance are relatively similar, which shows that performers are able to reproduce their interpretation. Still, the comparison reveals some interesting differences. Analysis of the tempo shows that the pieces in a slower, rather free tempo are performed slower in concert, while the faster, more dance-like tempi are performed slightly faster. The gesture analysis shows a tendency for the singer to use more open, communicative postures during the concert. The movement analysis shows an overall increase in intensity for the singer while the player roughly follows the pattern of the timing. In summary we could say that the different analyses show an intensification of the performance while interacting with the public.

I. INTRODUCTION

The empirical study of expressivity in music performance has gained increased interest during the last decades (cf. Palmer, 1997, Gabrielsson, 2003, Camurri et al., 2005). Most studies have been based on experiments in laboratory conditions. Interest in concert conditions can be noticed in ethnomusicology (e.g. Clayton, 2007), and in studies dealing with communication (e.g. Williamon & Davidson, 2002), health issues such as performance anxiety (e.g. Yoshie, Shigemasu, Kudo & Ohtsuki, 2009), or some acoustical issues (e.g. Ternstrom, Cabrera & Davis, 2005).

One of the aspects that make a concert performance unique is the interaction between musicians and public. This interaction gives the concert performance a flavor that is experienced as an added value in comparison to recordings. Interestingly, performing musicians usually acknowledge that the interaction with the public affects their performance, but very little is known about what is actually changing and how. Intuitively one could say that musical elements like the timing and dynamics change, but also the gestural communication is changing, using e.g. movements or eye contact.

In this paper we develop a methodology that allows measuring these elements in an ecologically valid context. The goal is to study what actually happens in a concert, by doing measurements on performers. The public should be unaware of the fact that measurements are going on. In addition, the performers should be free to interact with the public, not hindered by the technical setup.

In order to be able to measure the effect of the interaction with the public, data from the concert recording are compared with data from the general rehearsal. In this general rehearsal, the whole program was performed as if it were a concert (same lighting, staging, dressing, …), with the only important difference that there was no public, except for two people handling the recordings, seated on a balcony in the back of the hall without direct contact with the performers.

The structure of the paper is as follows. In the first part, the general setup of the experiment is described. In the second part, an analysis of the audio, video and movement data is given. The final part contains the discussion and conclusion.

II. SETUP

The recordings were made at the concert hall of the Orpheus institute in Ghent (Belgium). The concert was the final presentation of the annual chamber music seminar organized by the Orpheus Institute and was given by the first two authors, Chia-Fen Wu (soprano voice) and Dirk Moelants (viola da gamba). During the seminar they worked on the performance of vocal music with accompaniment of the viola da gamba, a practice of which only a few specific scores survive, but which clearly did exist in the 16th and 17th centuries, particularly in Italy and England.

The concert program is given in table 1. Three pieces (05, 11 & 12) are short pieces for solo viola da gamba. All the other pieces are performed by a (soprano) voice with viola da gamba accompaniment. In seven of the pieces (01-04 & 13-15) the accompaniment is a realization of a basso continuo, in four pieces (06-08 & 10) it is an adaptation of a lute tablature, while the piece by Hume (09) was the only one originally written for voice with viola da gamba accompaniment. The last piece (18) is a traditional Chinese song, brought in a tango-style arrangement, the viola da gamba playing pizzicato. In the concert performance it was brought as an encore. The two pieces before (16 & 17) are Taiwanese art songs, originally with piano accompaniment, in which melodies in traditional style are combined with jazzy arrangements.

Three different measurements were made of the performances, namely, an audio recording, a measurement of the movement and a video recording. The audio was recorded using a mobile recorder with a built-in microphone (Zoom H2) positioned at the side of the stage. The movement of both performers was measured using wireless accelerometers with a range of +-3g and with 2 or 3 sensitive axes. Two of these sensors were attached to the gamba player namely on the right wrist and at the back of the neck. The singer had a sensor on each wrist and one sensor on her back. The sensors were

attached to the skin with medical bandage tape underneath the clothes in such a way that they did not hamper the movements of the performers and that they were not visible for the audience. The accelerometers were connected to a standalone, battery powered, wireless ADC module (Wi-microDig, Infusion Systems) that digitizes the analogue sensor data and transmits this data wireless via Bluetooth. A Bluetooth class 1 interface was used enabling a range of 100m making it possible to collect the data from the balcony in the back of the concert hall. The sensor data was recorded at a sampling rate of 100Hz using a Max/MSP patch. Furthermore, the entire concert and rehearsal was videotaped using a Canon HV30 camera.

Table 1: Overview of the concert program analyzed in this paper. The pieces will henceforth be referred to by the numbers at the left.

01: Giulio Caccini: Dolcissimo Sospiri
02: Giulio Caccini: Movetevi a pieta
03: Barbara Strozzi: Moralità amorosa
04: Barbara Strozzi: Non occore
05: Richard Sumarte: Daphne
06: John Dowland: Come Again
07: John Dowland: Flow my tears
08: Robert Johnson: Hark, hark, the lark
09: Tobias Hume: Tobacco
10: Thomas Morley: It was a lover and his lass
11: Richard Sumarte: What if a day
12: Richard Sumarte: Whoope doe me no harme
13: Henry Purcell: How sweet it is to love
14: Henry Purcell: Music for a while
15: Henry Purcell: If music be the food of love
16: Teng Yu-Hsien: Bang Chun Hong
17: Yang San-Lang: Go Luan Hue
18: traditional Chinese: Ye Lai Shiang

III. ANALYSIS AND RESULTS

As we want to give a more or less complete view of the changes that occur between the dress rehearsal and the concert performance, a multimodal analysis method was used based on the three different types of recordings: audio, video and movement.

A. Audio analysis: timing

Audio recordings from the concert and the rehearsal of all 18 pieces performed were analyzed using Praat (Boersma & Weenink, 2004). The metric structure was manually annotated by indicating the start of every beat, half-bar or bar, depending on the tempo and rhythmic structure of the music. This gives us between 51 and 328 marked time intervals per piece with means between 716 and 1648 ms.

These annotations allow us to compare the tempo profiles of the concert and rehearsal performance for each individual piece. The lowest correlation between the time intervals of the rehearsal and the concert timing was 0.476 and the average correlation over the 18 pieces 0.853, with 15 pieces having a correlation over 0.83. Three pieces (13, 17 and 18) correlate clearly less than average. These are also the pieces with the lowest variance. This means that the variations in tempo are much smaller so the influence of local, random variance becomes relatively more important. The high positive correlations show that the musicians are capable of reproducing the timing very well (cf. Clynes & Walker, 1986). This is illustrated in figure 1, where we see that, despite the large variance and sudden tempo changes, the timing curves almost coincide.

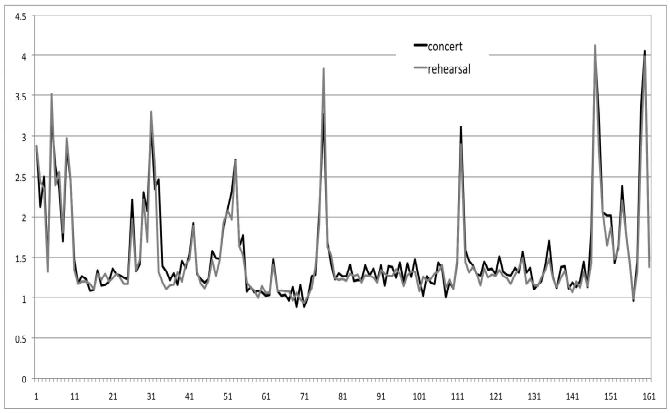

Figure 1. Comparison of the timing in Strozzi's Moralità Amorosa (03), the y-axis represents the length of the annotated intervals (r = .962).

The distribution of the intervals in each of the performances can be compared for each piece. The results are shown in figure 2. In order to be able to compare the data from different pieces, the intervals were normalized by dividing each interval by the mean over the two performances and multiplying this value with 100 for convenience. An analysis of variance shows a significant effect of the mean (normalized) interval ($F(1,34) = 5.145$, $p < 0.05$), with the concert performance being slower than the rehearsal performance. However, the results don't show a uniform effect. In half of the pieces (N = 9), the intervals of the concert performance are clearly longer than those of the rehearsal. Yet, in four other pieces (10, 12, 16, 17) the concert performance is clearly faster, while in the other five (4, 6, 8, 13, 14) there is hardly any difference. How can we understand these differences?

It is striking that those pieces in which a slow, rather free rhythm is predominant, the concert performance is always slower. In the more regularly metrical pieces we don't see this effect, and exactly in those pieces which have a swift metric movement we see that the effect is reversed. The only exception is piece 18, which is metrically regular (though with a rather laidback metric feeling). However, this piece was performed as an encore in the concert, which give a different atmosphere and is thus difficult to compare with the performance of the other pieces.

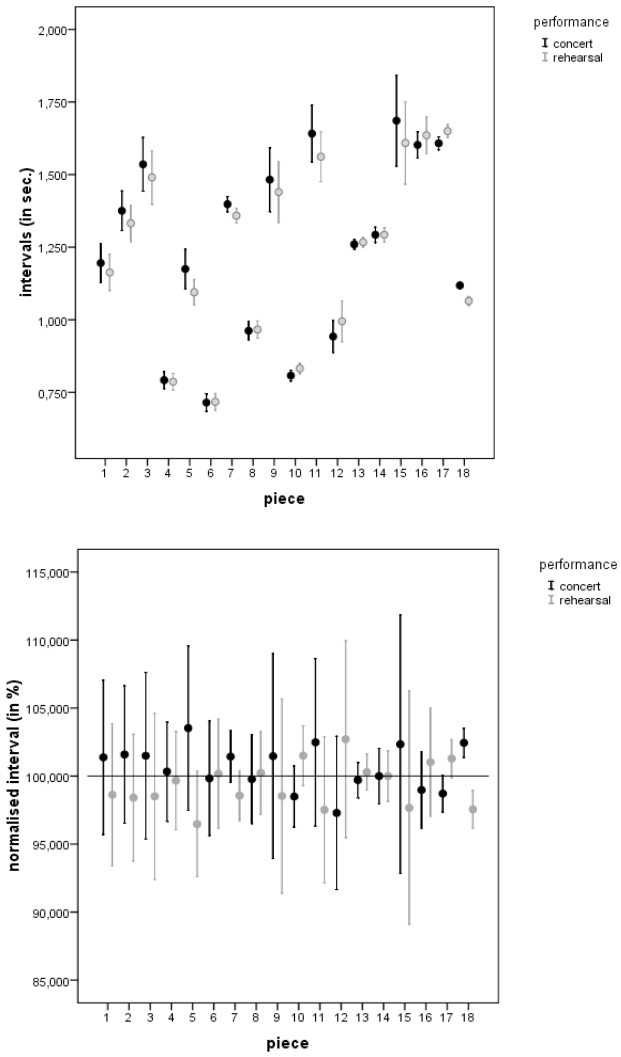

Figure 2. Comparison of the time intervals from concert (black) and rehearsal (grey), for each of the 18 pieces in the concert. Error bars represent the 95% confidence interval of the mean. The upper graph shows the absolute values (in seconds), the lower the normalized data.

B. Video Analysis: gestures

To enable a quantification of the singers' gestures, a global analysis of the basic postures used during the performance was made. On the basis of this, a system of categorization was designed, which allows an analysis using eight categories. A symbolic representation of these basic postures is given in figure 3. The postures are classified one a scale from 'closed' to 'open', with 0. hands behind the back, 1. hands joined in front of the body, 2. both arms slightly spread in front of the body, 3. both arms in front of the body, one above the other, 4. one arm next to the body, the other in front, 5. two arms next to the body, 6. one arm next to the body, the other spread open and 7. two arms spread out.

Postures 1 to 5 account for 98,7% of the singing positions, so the analysis will be restricted to these 5 types. Examples of the five most common postures are depicted in figure 4. Posture 0 occurs only once, posture 6 six times and posture 7 three times. It is however interesting to note that all the occurrences of these three 'exceptional' postures are seen in the concert performance, except for one occurrence of posture 7 during the rehearsal.

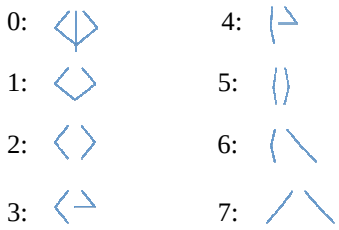

Figure 3. Graphic representation of the eight basic postures found in the singer's gestures.

Figure 4. Illustration of the five main gestural prototypes found in the singer's performance.

An analysis was made of the number of times the singer moved to one of these basic postures, counting the number of times they occurred, regardless of the length and disregarding transitory states. The results of this analysis are shown in figures 5 and 6.

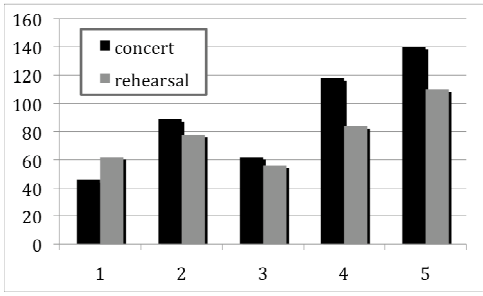

Figure 5. Comparison of the occurrence of the five basic postures in the concert (black) and rehearsal (grey).

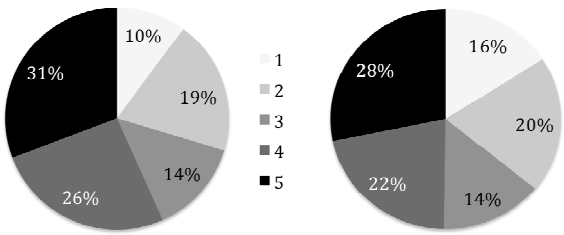

Figure 6. Relative distribution of the five basic postures in the concert (left) and rehearsal (right).

This analysis shows that there is a global increase in the number of changes if we compare the concert with the rehearsal. The total number of stable positions increases from 391 in the rehearsal to 456 in the concert. The increase is seen for four of the five postures, only for posture 1, there is a decrease. This evolution is also reflected in the relative share of the 5 postures within each of the performances. Postures 4 and 5 take occur relatively more often during the concert, while during the rehearsal, posture 1 takes a larger share. If we add to this the occurrence of postures 6 and 7 during the concert, we clearly see an evolution from a more 'closed', introverted attitude in the rehearsal, to a more 'open', communicative attitude during the concert.

C. Movement analysis

The analysis of the movement of the performers was done on the data collected with the accelerometers described above. The singer was equipped with 3D accelerometers on both wrists and a 2D accelerometer on the back of the torso. The viola da gamba player was monitored using 2D accelerometers on his right wrist and at the back of his neck. The digitized signal is used for the analysis described here. Since there is no need for an absolute calibration in a comparative study all values are ADC values.

A common way of quantifying movement measured by an accelerometer is the calculation of the intensity of movement (cf. De Bruyn, Moelants & Leman, 2008). This intensity of movement is the norm of the difference of two consecutive samples in acceleration, measured in the different directions, also called the size of the total jerk. This quantity is summed for the duration of each piece and normalized to the number of samples in that piece. The result of this calculation is an average intensity of movement for each sensor and each musical piece making a comparison possible.

The results of this analysis are shown in figure 7. We see a strong overall tendency for the singer to move more intensively with her left hand as compared to her right hand. For both hands, the intensity of movement lies significantly higher in the concert performance with $F(1,28) = 11.486$, $p < 0.01$ for the left and $F(1,28) = 11.185$, $p < 0.01$ for the right hand. The results for the back are rather enigmatic. There seems to be a consistently lower intensity of movement in the beginning of the concert as compared to the rehearsal, but this effect is gradually reversed towards the middle of the concert to come back towards the end. Interestingly we see a similar effect in the back of the viola da gamba player, with a stronger intensity of movement only in the middle part of the concert. One possible explanation is the fact that exactly in the middle part we find the more rhythmically intensive pieces with a regular meter, possibly, the performers use their body to help to convey this meter to the audience. Next to this it is striking that the right hand of the viola da gamba player shows a high intensity of movement and a large variability. This is due to the direct connection between the rhythmic content of the music and the right hand movement, with pieces containing many fast notes showing a higher intensity of movement (18 is again an exception as it is played pizzicato, which involves a completely different movement of the right hand). Also here we see an intensification of the movements in the concert for those lively pieces, whereas there is rather a tendency to reduce the intensity of movement for the slower pieces.

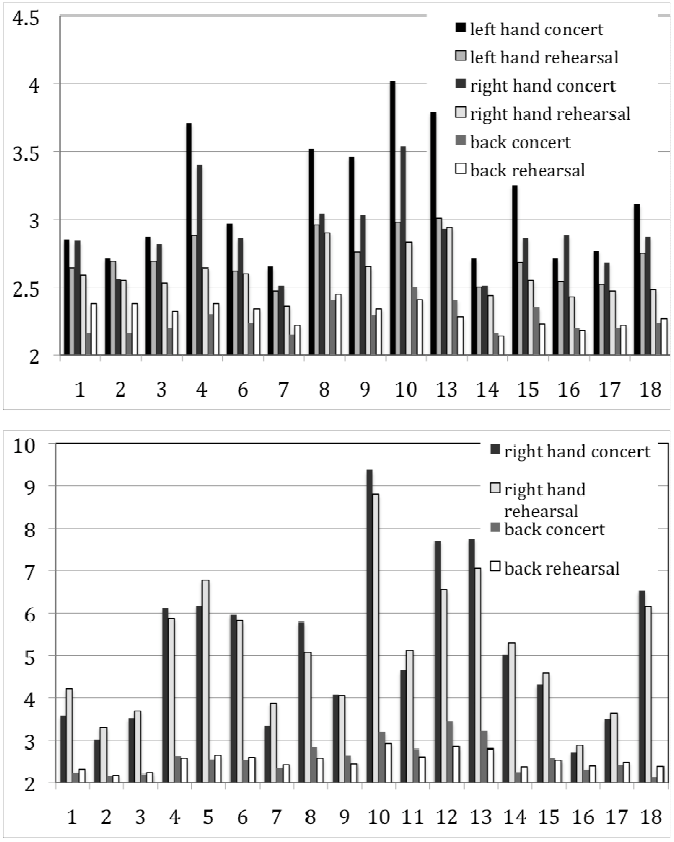

Figure 7. Comparison of the movement analysis data. Above both hands and back of the singer, below right hand and back of the viola da gamba player. Results are shown for each piece (numbers 05, 11 and 12 are omitted in the upper graph, as they are solo pieces for viola da gamba).

IV. DISCUSSION AND CONCLUSIONS

The comparison of a general rehearsal performance and a concert performance using multi-modal measurements has given us interesting insights in the effect of the presence of the public on a musical performance. We don't see many uniform effects, except for the increase in movement in the hands of the singer, which is clearly used as a means to communicate with the public. An effect that is also illustrated by the increase of posture changes and a tendency to use open, more communicative postures in the concert as compared to the bigger share of closed, introverted postures in the rehearsal. The timing intensity and the movement analysis further show that the musical content has a large influence. Pieces with a slow, free rhythm are played slower in the concert, while the livelier, metrically regular pieces are played faster and with a larger intensity of movement.

Besides the issue of comparability, working with a 'dress rehearsal' has two other advantages. First, there should not be an influence of technical problems or uncertainty about the interpretation. In this case, the musicians did perform all the pieces in concert already several times (although not exactly in the same concert program), so they technically mastered the music and had a common vision on the interpretation. As a general research strategy it is important to make sure that we

don't compare a proper concert performance with one in which the musicians are still struggling with technical issues or still have to develop a common vision on the interpretation. Next to this, a second advantage lies in the attitude of the performers. The musicians are motivated to consider the performance as a kind of try-out concert. It allows them to test the acoustics of the hall, the stage and lighting, the order of the program. This is very different from just a 'normal' rehearsal, where they would still disrupt the normal course of the concert program. For musicians a rehearsal is actually quite a different task than a concert. They would normally give comments on each other's performance, do suggestions on interpretation and, importantly, have a much more relaxed attitude. If we want to do research on the effect of the interaction with the public, this is an important factor. Using data from a 'normal' rehearsal, we cannot distinguish between effects due to this basic difference in attitude and the influence of the public.

Finally, it is important to note that, although the performers were clearly aware that measurements were going on, there was no hypothesis set forward. If there would be, we could assume that the performers would - consciously or unconsciously - be inclined to confirm these hypotheses.

Additional research on these data could include more aspects of video analysis, such as the timing of the stable postures and the transitions, eye contact, facial expression and the rhythmic movements of the head of the viola da gamba player. The movement analysis could be expanded with a periodicity analysis. Measuring changes in dynamics or timbre is a bit more difficult in this case, as the presence of a public changes the acoustic properties of the room. Nevertheless some effects that cannot be attributed to this effect could be traced. Next to this, also a study of the appreciation by listeners/viewers can be added, using subjective judgments of audio or video fragments. As the performances are rather similar, this is however a difficult task, which can only be done by experts.

In the future this type of set-up can be used to test performances in different contexts. How does e.g. the acoustics of a hall affect the performance, or what is the influence of different types of audiences (e.g. children, adolescents, blind people, a professional jury, non-western audiences,…).

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