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Respiration as a Tool for Nonverbal Communication in Accompanied Vocal Performance

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ABSTRACT

In this paper, the effects of nonverbal communication involving respiration during collaborative vocal performance are investigated. In addition to its importance for effective vocal technique, respiration in music performance also functions as an anticipatory signal that allows for perceptual matching, i.e. in terms of expressivity and phrasing, and effective decision-making between two performers. Noninvasive sensors measured respiration during individual music rehearsal and collaborative music practice. The purpose of the research project was to analyze the effects of nonverbal communication that occur between singers and accompanists during a performance. The efficient nonverbal cooperation between singers and accompanists is an important factor in vocal performance. The analysis of the specific skill sets involved is an important area of this research study, as it may contribute to the understanding of embodied music cognition and the action-reaction cycle in the context of vocal performance. The data collected in terms of performance strategies may provide a significant insight into the effects of supportive musical gestures on a vocal performance. Respiration values did seem to be impacted as a result of musical collaboration. Mean differences in the timing of respiration was predominantly lower for unrehearsed over rehearsed performances.

I. INTRODUCTION

Collaborative vocal performance requires specific skill sets between a singer and a piano accompanist. Pianists assist in the dramatic expression and communication of the text and musical intentions of a vocalist. In collaborative singing performance, the pianist's role is to guide and support the singer's performance. Thus, the accompanist should not only work to deliver the musical accompaniment correctly and expressively, but also to enhance the expressive information conveyed. In order to enhance a vocal performance, both musicians are required to interact continuously. They are responsible not only for the production of their own music, but also for any structural information and "connective tissue" (Katz, 2009) of the composition to preserve musical, textual and dramatic integrity. When the singer enters, the pianist must be synchronized, even if starting from silence. This is a dynamic communicative exchange, involving complex nonverbal interaction and collaborative decision-making. An action perception coupling must be created between performers, through the use of sensory performance cues in order to successfully negotiate in a live musical performance.

Respiration is one of the primary components of effective musical collaboration between singers and piano accompanists, as well as a means of physical identification. From a pedagogical and collaborative performance perspective, respiration is a necessary support mechanism for the ongoing processes of musical alignment and synchronization. The pianist is not required to breath with the singer to perform on their instrument. However, these support gestures may allow for better phrase initiation and matching of expressive intent before the musicians begin the phrase. Respiration is one of the tools used to preserve the flow and progress of the musical performance, resulting in a better match of musical intention in artistic collaboration (Katz, 2009). However, a more comprehensive understanding of these strategies is still possible through empirical analysis, both pedagogically and for performance practice.

II. BACKGROUND

A. Previous Research in Performance

Extensive research has been conducted on the timing and dynamics in piano performance. For example, Repp (1998) conducted a quantitative analysis of pianists timing strategies in solo piano performance. Through principle component analysis (PCA), he identifies several timing strategies commonly utilized by pianists during performances of Chopin's Etude in E major. These timing strategies included 1) major ritards at the ends of melodic gestures; 2) acceleration within some of these gestures without final ritards; 3) extreme lengthening of the initial downbeat; and 4) ritards between as well as within melodic gestures.

In respiration in piano performance, King (2006) has studied the role of respiration as a supporting gesture in solo piano performance. Video analysis of the performances of three pianists was conducted. According to King, breathing and other motor processes could be seen to support the physical – musical continuum at different hierarchical levels in performance of the same piece. The preliminary findings of this research study demonstrated consistent breathing patterns of the pianists throughout the performances of the selected compositions. However, there were differences found in the breathing techniques of the participants, particularly, at the start and end of vocal phrases. King postulates that breathing had an important role at the start of the

performance, as the breath cycle seemed to preempt action. Breathing points were also consistently made during rests that separated sections, phrases or statements. Physical movements were also examined and were found to convey information about tempo and phrasing of the melodic lines when looking at features such as body movements, elbow circling, wrist pushing, and head tilting in accordance with the main beats of the bar.

These studies provide support for the hypothesis that the performance and timing may be affected by expressivity and play a part in the action- reaction cycle (Leman, 2008). The study presented in this paper contributes to this research by examining the role of interaction and intentional matching between singers and pianists.

B. Theoretical Model

According to the theory of embodied music cognition (Leman, 2008), mutual understanding, intentional matching and signaling in music performance occurs largely through bodily action. Respiration functions within accompanied vocal performance as a tool for corporeal articulation and intentionality. Within the context of collaborative music performance, respiration is a form of synchronization and embodied attuning that not only facilitates coordination, but also for engages of higher-level intentional processes, such as expressive affect and dramatic articulation of the music.

In the following sections, the research method used to examine the role of respiration and embodied attunement will be discussed. This is followed by a presentation of the results regarding the impact of collaboration on respiration of accompanied vocal performance, as well a discussion of the broader implication of these finding.

III. METHOD

The method used to analyze data between performers is similar to that utilized by Buonaccorsi et al. (2001) for the measurement of spatial synchrony. This method involved the measurement of synchrony according to the concordance of peak in paired time series.

A. Participants

Twelve subjects (consisting of six piano-singer duos) participated in the study. Gender was balanced with six female (three singers, three pianists) and six male subjects (three singers, three pianists). Participants were aged 21-53 (*M*=33, *SD*=11.36). Subject population was drawn from singers and pianists that had performed previously together. The background information regarding participants musical and performance experience was collected with the use of questionnaires.

B. Tools and materials

Respiration was monitored via *Plux* respiration sensors. The sensor consisted of a monolithic silicon pressure sensor encapsulated in an air membrane. This is then sewn into a band, which can be placed around the ribs to measure intercostal expansion. Air temperature variations have been tested between 0 to 85°C to vary a maximum offset of ±2.5 Volts per full-scale span. This range was adjusted from the original sensor parameters of 5.0 Volts. The sensors transmitted data via a Bluetooth Arduino coordinate by a patch programmed in MAX/ MSP.

C. Procedure

Singer-pianist pairs were asked to perform four pieces in an individual condition followed by a collaborative condition. In the individual condition, musicians performed their pieces alone, similarly to when they practice at home. In the collaborative condition, performers were asked to perform the pieces together, similar to musical rehearsal. Tasks consisted of the performance of four pieces, two that were selected by the participants based on the repertoire they had previously practiced together, and two additional pieces, which had not been rehearsed collaboratively (*Songs my Mother Taught Me* by A. Dvořák and *Drink to Me Only with Thine Eyes* which is anonymous). These pieces were provided to the participants individually in advance to avoid confounding factors associated with sight singing or reading. However, subjects were asked not to perform the pieces together or practice them with recordings. Audio and video of experimental sessions were recorded. Pianists were asked to use a Yamaha P-60 midi keyboard (with weighted keys and pedal) during monitoring to more accurately determine note onsets and offsets.

D. Signal Processing

As described in the previous section, the signal from the respiration sensor is digitized with a Bluetooth Arduino and sent wirelessly to the computer. This digitization returns the raw sensor signal with values between 0 and 1023 at a sampling rate of 200Hz which are analyzed offline. To reduce the sensor noise on the raw signal the data is filtered using a Savitzky-Golay filter (Schafer, 2011) with order 3 and a frame size of 51 samples. The filter operates by obtaining the coefficients a_k of a polynomial:

$$p(n) = \sum_{k=0}^{N} a_k n^k$$

Which then minimizes the mean-squared approximation error ε for the signal x(n) around the zero point.

$$\mathcal{E}_N = \sum_{n=-M}^{M} (p(n) - x[n])^2$$
$$= \sum_{n=-M}^{M} \left(\sum_{k=0}^{N} a_k n^k - x[n] \right)^2.$$

This filter has the advantage that it preserves sharp peaks without introducing any time delay.

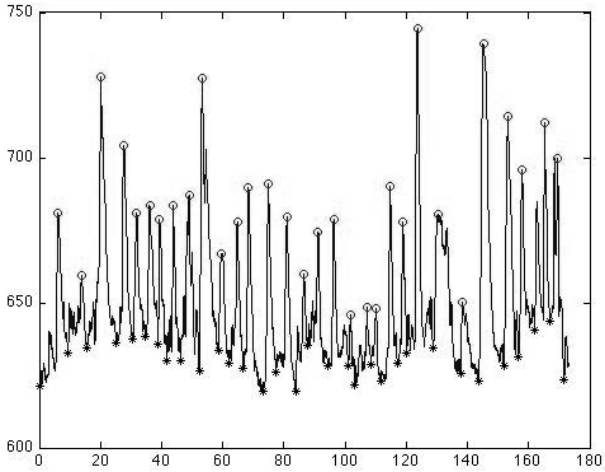

Figure 1. Respiratory signal with peak and minima detection.

The resulting signal is displayed in Figure 2. Lower values correspond to a low-pressure readout during exhalation, while higher values correspond to a high pressure due to the expansion of the ribcage against the sensor. The points of inhalation are represented by peaks of the signal before the beginning of a musical phrase. It was necessary to determine the points of inhalation for quantification of the respiratory data from the sensor signal. These are located by applying a peak detection algorithm. The peaks found are indicated with a circular marker in Figure 1. The timing of the remaining peaks is analyzed by calculating the difference in time between the peaks in the two recordings for the four musical pieces.

IV. RESULTS

A. *Questionnaire*

All participants had performed as a soloist in the past year and there was an average of six years of professional experience. Five participants (three pianists, two singers) had more than ten years of experience. Seventy-five percent of participants had been trained to some extent in the opposite instrument. Participants were asked if the measurement instruments interfered with their performance and 66% (evenly distributed with singers and pianist) reported some impact. The major reason was increased awareness of respiration, due to the fact that this part of the performance was obviously monitored.

Participants were asked how their performance changed from individual music performance to collaborative performance. With singers responses were highly varied. Most responded that there was a feeling of increased musicality and expressiveness. With pianists a common theme was the need to follow and adapt. Therefore, respiration was an important signaling tool, especially in terms of communication of musical intention, i.e. through pauses and word painting. This was described as a "clear and natural sign" assisting in musical coordination and creation of musical meaning.

B. Analysis of the Effect of Collaboration

In examining the collaborative condition, across groups pianists demonstrated the tendency to breath according to the phrasing of the musical piece. In the collaborative condition, pianists generally inhaled with the singer at the beginnings of the phrases 98 percent of the time (*M* =. 975, *SD*=4.2). The average difference in time between singers and pianist during the collaborative condition was 0.89 ms (*SD*= 1.27).

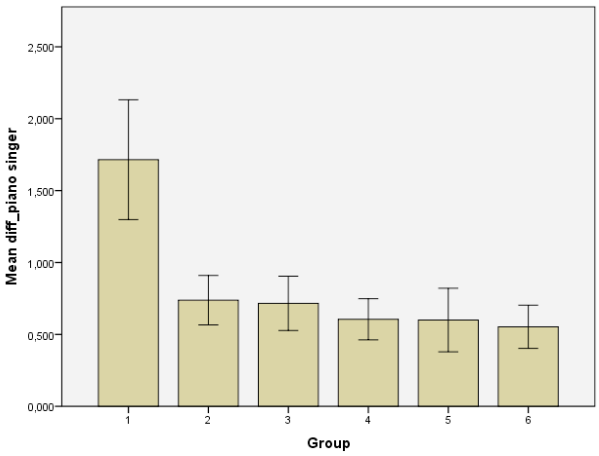

Figure 2. Mean and standard deviation of difference in timing between singers and pianists

Only Group 1 demonstrated a mean inhalation values that were higher than the other participants, also with a much broader standard deviation. (see Fig. 2) Generally, the difference in mean respiration values between singers and pianists was higher for unrehearsed than for rehearsed pieces (see Fig. 3). Although, only for Group 1, can we be 95% confident in these results.

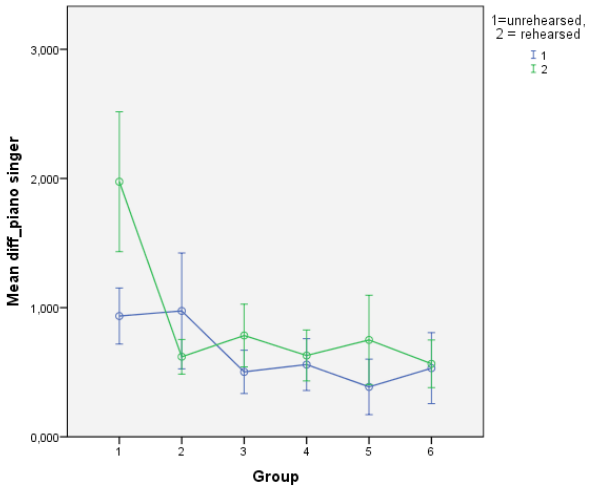

Figure 3. Mean respiration values between rehearsed and unrehearsed performance in collaborative condition. In all cases Songs 1 and 2 were previously unrehearsed by participants.

V. DISCUSSION

Results indicate that respiration between singers and pianists is indeed impacted through musical collaboration. Respiration functions as a multi-sensory tool for dynamic temporal coordination. It may be concluded that respiration, as an anticipatory gesture before the start of a phrase, is one tool that supports cognitive evaluation and reasoning allowing both performers to effectively coordinate their performance. Once an effective action patterns are established, they seem to be maintained, even if unnecessary for the playing of the instrument. Respiration is a communicative device allowing for coordination of musical meaning before the beginning of the phrase. Respiration between musician impacts phrasing, musical line, and the matching of musical intentions.

VI. CONCLUSION

The study presents some preliminary results regarding the impact of respiration as a perceptual matching between singers and pianists. These results provide a foundation for further investigation into the role of respiration in the action perception cycle occurring continuously between individuals in a musical performance. Respiratory coordination provides a basis for multisensory and multimodal interaction between performers. Respiratory patterns were not only impacted through collaboration, but also seemed to be maintained as ancillary performance patterns.

VII. ACKNOWLEDGMENTS

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