Dancing Dots - Investigating the Link between Dancer and Musician in Swedish Folk Dance.

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ABSTRACT

The link between musicians and dancers is generally described as strong in many traditional musics and this holds also for Scandinavian Folk Music - *spelmansmusik*. Understanding the interaction of music and dance has potential for developing theories of performance strategies in artistic practice and for developing interactive systems. In this paper we investigate this link by having Swedish folk musicians perform to animations generated from motion capture recordings of dancers. The different stimuli focus on motions of selected body parts as moving white dots on a computer screen with the aim to understand how different movements can provide reliable cues for musicians. Sound recordings of fiddlers playing to the "dancing dot" were analyzed using automatic alignment to the original music performance related to the dance recordings. Interviews were conducted with musicians and comments were collected in order to shed light on strategies when playing for dancing. Results illustrate a reliable alignment to renderings showing full skeletons of dancers, and an advantage of focused displays of movements in the upper back of the dancer.

1. INTRODUCTION

Research on interactions between participants in a music performance can reveal basic strategies and help to develop theories of how performances are shaped in specific performance contexts. In specific here, the focus lies on the interaction between a musician and a dancer and how musicians shape performance when interpreting dance movements. In terms of computational applications, an understanding of how these interactions work is an important basis for the implementation of interactive systems, as for instance the automatic alignment of a music performance recording to the movements of a dancer, or – thought the other way around – the generation of a virtual dancer to the real-time performance of a musician. In terms of artistic research, revealing tacit strategies for how body movement can be interpreted musically has great potential for exploring new artistic concepts that can be used in interaction between between music and dancers.

In this paper, we focus on the specific performance context of Swedish Folk Music, *spelmansmusik* and the music and dance form *polska*. In this musical form, as in many traditional musics, music and dance are usually performed together, which creates strong links between involved performers [1]. Considering the dance and music as complementary elements has been common to the study and understanding of this performance practice [2–5]. The shaping of musical beat in music and in dance has been pointed to as central for this interaction and for how different metrical types, styles and forms are developed. [2, 6, 7].

Research into musicians' movement in classical Eurogenetic [8] music documented cues and gestures in ensemble and solo playing [9–11]. Studies of Scandinavian folk music have begun to explore how embodied meter is expressed in motion patterns of dancers and musicians [5] and in relation to musical beats [12]. It remains an open question what role the visual contact between musicians and dancers plays for this interaction, for instance if a musician's focus on certain body parts of a dancer may facilitate a more stable interaction, or if generally the perspective on the whole body is needed. This can also be related to ways of describing dance heritage documentation and in folk dance didactic practices [13].

In this paper, we explore if the reduction of a dancers' movement obtained through infrared Motion Capture technology (MoCap) still facilitates the performance by a musician when viewing this reduced movement. Although this setup does not include the full interaction between player and dancer the experiment will help the understanding of which aspects of body movements provide reliable cues for players, and how reliable these cues are. To this end, performance recordings were used that had been conducted [12] with an Optitrack MoCap system, with three fiddle-playing musicians and two dancers forming six pairs of musician and dancer, playing two pieces of a local polska tradition. For the experiments in this paper, five different visualizations of the dancers' body movements were generated that visualize movements of various body parts. The three musicians taking part in the initial performances were asked to play the related pieces only to the generated visual cues, without sound cues accompanying the display. The obtained outcomes provide first results of both qualitative and quantitative nature of how the musicians are able to synchronize to the various cues. The results indicate that when viewing a full body rendering of the dancer, the players were able to follow the dance almost perfectly. In cases of more radical reductions of the dance movements - using only one or two markers from the dancers - the task became harder, resulting in increased deviations. However, cases where players were aligned to their original performance demonstrate that the reduced renderings still contain various degrees of information for the player.

The remainder of this paper is structured as follows: Section 2 provides a concise overview of the related literature, including studies of interactions in music performance, and in particular of interactions between dancers and musicians. Section 3 describes the construction of the stimuli, the experimental setup, and the analysis methods. The results are provided in Section 4 and discussed with suggestions for further research in Section 5.

2. BACKGROUND

Various studies have documented the human ability to recognize and relate to human motions from highly reduced representations. Research with point-lights by Johansson [14] and Cutting et al [15] showed perception of human walking and recognition of individual walking styles from a small set of moving dots. Point-lights were also used by Pollick et al [16] to study the perception of gender and affect from isolated hand movements and by Petrini et al [17] to study the effect of musical expertise on the sensitivity to asynchrony of drummers.

Synchronization in music ensembles was studied, for instance, by Hofmann et al [18], who analyzed how the timing of an individual performer influences ensemble synchronization in Jazz trio performances. In different musical context, Bishop et al [10] studied the synchronization of classical duo players (violin and piano) using only visual or only audio signals. MoCap was used by Keller et al [11] when examining the effect of anticipatory auditory imagery - described as the skill of planning and predicting actions during a musical performance - on the temporal coordination of body movement and sound in classical piano duos.

Toivianinen et al [19] used MoCap to study dance movements in relation to musical structure - how different metrical levels were manifested in different parts of human bodies moving to music. Naveda et al [20] suggested a model of topological gesture analysis that related dancers' motions to musical and metrical patterns in a spatiotemporal representation. Scandinavian Folk dance styles have been characterized by the vertical motion patterns of the center of gravity (libration curve/sviktkurva) by Blom [2] which influenced research and didactic practise of Scandinavian folk dance. This synchronization between dance and music has been further explored using MoCap in settings with interacting dancers and musicians [5, 12]. To the best of our knowledge, synchronization of instrument playing to reduced renderings of dance movement have not been studied before.

In the context of sound and music computing, systems for tracking periodic movements have been developed and implemented for sports and wellbeing [21, 22], and motion sonification systems have been developed for applications within circus, dance and opera [23]. A categorization of musical gestures into sound-producing (by musicians) and sound-perceiving (*e.g.* by dancers) was suggested by Jensenius et al. [24]. However, such a division between gestures can be blurred in situations where dancers may influence the playing of a musical instrument by means of their movement. Our study will therefore contribute to investigations of the rhythmic gestures that emerge from the periodic movements of dancers.

3. METHOD

3.1 Material

In an earlier study [12], three musicians playing for two dancers were recorded in an Optitrack MoCap System. The recordings included settings with each musician playing the same two pieces to each of the dancers dancing alone or together in a couple. 41 markers were placed on each dancers to facilitate a close rendering of the dancers full body movements. Musical beats were manually annotated from the audio of the recordings to allow comparisons with the movement data.

For the present study recordings from this material were selected in settings where each of the two dancers were dancing alone to each of the three players. Each of these settings had recordings with the same two music pieces resulting in a total number of 12 recordings (2 pieces $\times$ 2 dancers $\times$ 3 players). The pieces used in the study were two *polska* tunes referred to as *Lorikspolskan* and *Polska efter Pellar Anna* related to the influential fiddler Gössa Anders Andersson (1878-1962) from Orsa in Dalarna, Sweden [25]. These tunes are quite complicated in terms of rhythmic and metrical structure, with varying beat duration, obscured beat onsets and varying rhythmic figures [7]. Five different types of stimuli were generated from each recording using the MoCapToolBox [26]. These stimuli consisted of videos showing five different renderings of the MoCap data with markers moving as white dots on a black background.

The five renderings were chosen to reflect two strategies when watching the dance: focusing on the feet and steps, or focusing on the general movement of the center of the body. The first type of stimuli videos (labeled BT) included one single marker placed on the spine below the neck, and included both y-axis (vertical), and a projection of x- and z-axis on a plane, transforming the circular movement of the dancer into a horizontal movement on the screen. The second video showed the same marker moving only vertically, as this rendering only included movement data from the y-axis (labeled BTY). The third and fourth videos showed two markers placed on the dancers feet, close to the joint of the little toe, in similar renderings to the first and second stimuli. These stimuli will be labeled RLT, for those animations including y-axis and the projection of x- and z-axis of left and right foot, and RLTY, for those animations including y-axis only. The fifth video showed all 41 mark-

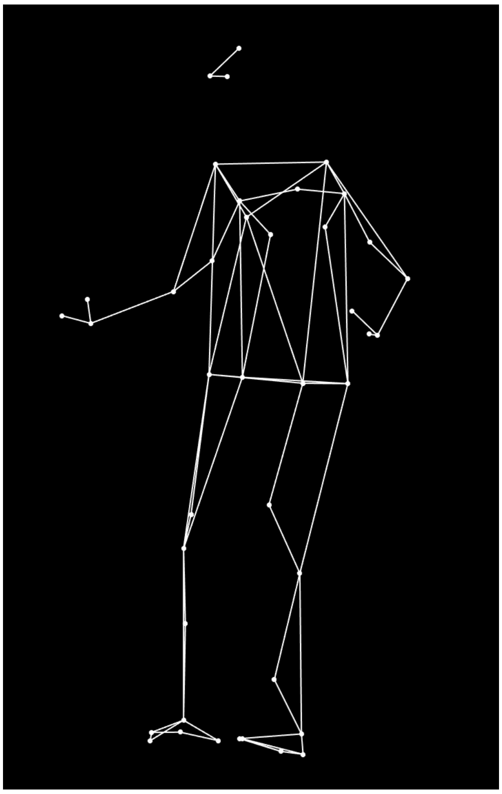

Figure 1. The dancer projected in the FULL stimuli.

ers of the dancer connected with thin white lines in order to form a skeleton of the dancers body was labeled FULL and is displayed in Figure 1. This full marker setup was included to investigate the impact of the reduction present in the transformation of the whole body to a set of limited interconnected points. The stimuli were generated using a frame rate of 30 frames per second. [1]

To facilitate comparison of the audio recordings of the players performing to the animation (referred to as *secondary* recordings in the remainder of the text) to the original audio (*i.e.* performing with the dancing as recorded in the context of [12]), a reference was provided to inform players where to start playing. This was achieved by including a small part of the sound from the original recording as a cue in the beginning of the videos. The included part consisted of two measures of the original recorded tune. Initial clap sounds where added to the animation videos to allow for precise synchronization of the performance beginnings, and the investigation of the alignment of the original and secondary recordings.

3.2 Participants

Participating as performers in the present study were musicians Sven Ahlbäck, Ellika Frisell and Olof Misgeld. All three participating musicians have 25-45 years experience as performers within this style, and 15-25 years as teachers of Folk Music within higher performance education at the Royal College of Music in Stockholm (KMH). They are identical with the players who recorded the original performances [12], and they were asked to perform to the five types of animations emerging from the four performances of themselves playing two tunes to two dancers in the original recordings (2 pieces $\times$ 2 dancers $\times$ 5 animation types = 20 stimuli per player). The dancers in the original recordings (Ami Dregelid and Andreas Berchthold) have a high level of experience as performers and dance pedagogues.

3.3 Experimental setup

The experimental setup had each musician performing seated in front of a computer screen showing the animations. The performances were recorded using two microphones, one directed towards the violin, and one towards the feet in order to obtain clear sound recordings of the foot tapping. All session were recorded on video to capture the players' comments between performing to the stimuli. Before each stimulus, the player was provided with the information which of the two polskas was used in the video they were watching. The players were instructed to play the same piece by trying to synchronize their playing using the information from the stimuli. Both tunes consisted of two repeated parts forming a complete round (AABB), and each round was repeated two or three times. The players were informed that they will be playing to stimulus that emerged from a dance performance they were originally involved in as musicians, but they were not told which of the dancers was dancing in each stimulus. In the experiment all five animation types related to one recorded piece were presented before moving on to the next piece. This was done in the order of starting from the four more reduced renderings and finishing each take with the full skeleton. No written music was used at any point as pieces were all played from memory.

3.4 Analysis

For the analysis, the beginning of each secondary recording was manually aligned to the beginning of the original recording using the recorded clap sounds. The recordings were then compared by listening simultaneously to the two files, playing one file in each ear while making annotations on how recordings diverged, noting stable or diverging sections. Where a diversion was noted sample measurements in seconds were estimated from corresponding beats in the two recordings.

An automatic alignment of the secondary recordings to the original recordings was created using an audio matching algorithm [27]. The outputs of the automatic alignment were compared to the manual annotations, with the automatic alignment being consistent with manual annotations in all cases. Based on the reliability of the automatic alignment, alignment curves were computed for all pairs of original and secondary sound recordings. The curves specify the temporal shift in seconds of each point in the original recording compared to the secondary recording (see Figure 2). The mean beat duration obtained from beat annotations of the original recordings enable us to relate this temporal shift in seconds to beats. Using the alignment curves, the recordings were divided into segments belonging to one of three categories:

[1] Examples of stimuli videos are provided in https://bit.ly/2E8jxte

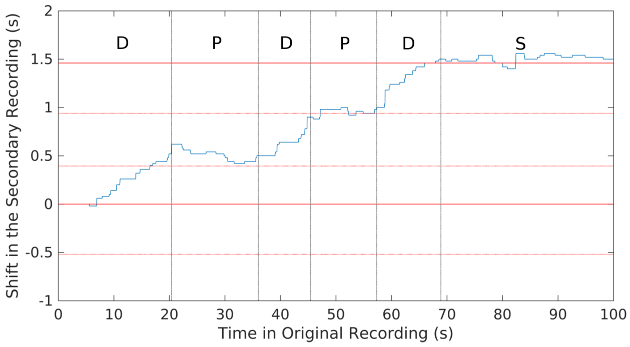

Figure 2. Example of an alignment curve (BT stimulus), showing a stable alignment after 68s (S), and changes between drift (D) and alignment to other metrical levels (P) before. The bold horizontal lines mark measure positions, whereas dotted horizontal lines mark the second and third beats of the three-beat cycle, as obtained from the manual beat annotations.

1. STABLE: segments where the alignment curve stays within the area of ± one beat to the 0-line, without moving monotonously to a neighboring beat annotation and crossing it. Also included into this category were segments where the alignments curves shifted by a multiple of a measure, which occur after a player had been drifting in tempo in a previous segment or if the player changed the form of the piece. STABLE segments were taken as indication that the player relates in a stable way to the dance animation. For example, the segment between 68s and 100s in Figure 2 was marked as STABLE, since it is shifted by one complete measure.

2. DRIFT: segments where the alignment curve moves monotonously across beat annotations. These phases are seen as an indication that the player was not able to synchronize her/his playing to the stimulus in a stable way, which resulted in slowing or speeding up.

3. PHASE-SHIFTED: segments where the alignment curve stays within the area of ± one beat to a non-measure line (dotted horizontal lines in Figure 2), without monotonous drift to a neighboring beat annotation and crossing it. This case is related to shifting one or two beats to the original. This was interpreted as the player adhering to a different interpretation of the three-beat cycle of the *polska*, something unlikely to occur in real performance settings.

The sessions were video recorded, and semi-structured interviews were conducted with the performers between the experiment tasks. Statements of the players of the qualitative experiences will be used in addition to the quantitative measures obtained from annotating the alignment curves. This helps to identify the strategies that were applied by the three performers in following the visualizations.

Stimulus type	RLT	RLTY	BT	BTY	FULL
Stable (%)	49.7	46.9	72.3	73.1	98.4
Drift (%)	34.4	36.7	19.2	23.5	1.6

Table 1. Share of the segments annotated as either stable or drifting, as percentages of the whole duration of recorded secondary performances (about 1h22min, equally divided among the five stimulus types).

4. RESULTS

4.1 Automatic alignments

Following the annotations of STABLE segments, and to DRIFT and PHASE-SHIFT segments as described in Section 3.4, the percentage of STABLE and DRIFT phases occurring in all secondary recordings was calculated (Table 1). High shares of STABLE phases indicate that performers synchronized well to a particular stimulus type, whereas high shares of DRIFT phases indicate that the performers were not able to extract reliable tempo-related information from the stimulus type.

Stable-aligned segments cover almost the complete duration (98.4%) of recorded secondary performances for the FULL setup. This demonstrates that when seeing the full skeleton, the players were almost perfectly capable to align their performance with the stimulus. This extends previous results of movement interpretation [14, 15] to the task of performance synchronization, and provides a proof of concept for the validity of the motion capture data. Performers were able to synchronize to a lesser degree to the markers on the neck (BT, BTY), and even less to the visualizations obtained from the feet (RLT, RLTY). Overall, however, performers could synchronize in a stable way in at least 46.9% of the recordings (RLTY), which indicates that all visualizations provide important information on the dancers' movement. The quality of the alignment in the stable phases, computed as the average area under the alignment curve, is quite high, with the performers synchronizing with an average deviation of about 80ms, independent from the visualization type.

For the DRIFT phases, an opposite tend emerges from the second line of Table 1. Full body skeleton visualizations lead to almost no drift phases (1.6%), and RLT/RLTY have the highest amount of phases in which players are not able to synchronize to the tempo of the initial performance. Even though statistical significance could not be reached in the given amount of performances, the visualization of the marker on the neck (BT, BTY) enables for a more stable alignment than the visualization of the feet. This finding corroborates the approach of using the center of gravity for analysis of Nordic folk dance [2, 5].

4.2 Comments on playing with dots

After completing each set of five stimuli, musicians were asked to compare the task of playing to the different stimuli videos. Players generally commented that watching and having to follow the dance this closely was unusual as in normal situations they would rely on interacting with the dancer, as one player said similar to being in a conversation with the dancer. The FULL stimuli were commented on as easiest and most similar to a real situation, and players were also able to quickly identify which dancer were dancing when watching the full-body skeleton.

After the FULL stimuli, the BTY stimuli were generally commented as second-easiest. This was explained by being able to focus on only one dot moving in the vertical direction. Also mentioned was the accelerating movements to and from the beats as the dot was in constant motion. These accelerations were also included in the BT stimuli, but then players stated that it was easier to lose track as the dot was moving horizontally as well.

The RLT and RLTY stimuli were commented on as more difficult, and players reported being confused and losing track. Players expressed a drifting out of phase when dancers changed steps between the walking and turning sections of the polska dance. RLT and RLTY were also commented as more static, showing more interrupted movements, and not consistently relating to tempo, phase and period.

These qualitative outcomes are consistent with the quantitative findings summarized in Table 1. In addition, players commented that it generally became easier to play to the stimuli as they got more used to them and learned to interpret them. One player commented he/she thought all renderings had the potential to work after a certain amount of practice.

4.3 Strategies when playing for dancing

Strategies when playing for dancing can include what aspect of the dancer's motion the player is focusing on when watching the dance. Players commented on this in relation to the FULL video saying they were considering the interaction between different body parts taking into account changes in inclination, acceleration and balance of the body. One player commented on this as how the dancer is dealing with gravitation. Hand movements were also commented on as having a relation to the played tune: as if the dancers were playing the melody.

When trying to recognize the two dancers from more reduced renderings, the players commented on individual differences in dancing styles. They also related such differences to dancers typically dancing on either the left or the right side when dancing in pairs. Strategies included identifying a certain beat in the three-beat polska cycle. This was recurrently commented on in relation to playing to reduced renderings, i. e. finding the second beat in a lifting motion or the first beat in a more concise marked motion. Focusing on a certain beat in the animation was commented on as affecting the performance, inspiring players to emphasize a certain beat or choose a certain interpretation of asymmetric beat patterns [12].

Another strategy concerned the foot-tapping. A player commented that he/she refrained from tapping strongly in order to be more receptive when watching the stimuli. Normally he/she would think of the tapping as a kind of motor for the music.

Players commented that when playing for groups in more diverse real-life settings they take into account that steps are not always synchronized with all beats in the music. Players stated that they would often benefit from watching the feet/steps, however not in isolation but with attention to the whole dancer and the transfer of weight when moving. Subsequently the renderings of RLT and RLTY do not compare entirely to a situation when watching the feet of a real dancer.

5. CONCLUSIONS

The results of this experiments demonstrate that musicians are able to interpret and synchronize to dancers movements also from reduced renderings. Both qualitative and quantitative results emphasize – on the one hand – the importance of having information from the whole body, but – on the other hand – demonstrate the large amount of information still present in a very radical reduction, especially for the BLT and BLTY stimuli. Previous studies of movement interpretations from point-lights did to our knowledge not include these kind of settings.

The question remains to what extent this is an effect of expertise within the specific performance context, which could be tested by extending experiments to performers with less experience in accompanying Swedish folk dance. The experiments provided a challenge since players rarely play to pre-recorded dancing without the possibility to interact. Visualizations with only one or two markers added to the challenge as musicians had to interpret a very limited information from a dancer.

The study suggests that music-dance interaction is far from trivial to the performers in this context, and that the required embodied knowledge should be further explored in combined scientific and artistic research settings. Further insights can pave the way to facilitate applications that allow dancers to interact with pre-recorded music, or musicians with a virtual dancer. The goal of such applications is seen in the extension of current performance possibilities, not in the replacement of the interaction between musicians and dancers.

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